

Analyses of Pulse Farmers' Production Efficiency Considering Climate Effect and Willingness to Pay for Weather Index-Based Crop Insurance in Myanmar

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**ANALYSES OF PULSE FARMERS' PRODUCTION
EFFICIENCY CONSIDERING CLIMATE EFFECT AND
WILLINGNESS TO PAY FOR WEATHER INDEX-BASED
CROP INSURANCE IN MYANMAR**

SEIN MAR

2018



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CROP INSURANCE IN MYANMAR**

by

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Abstract

Pulses are the second most important crop after rice, contributing the great share of foreign exchange earnings for the Myanmar economy as they have the highest potential for export and foreign income earning. Myanmar stands out as a leading country in pulse production among the ASEAN member countries and as the fifth major exporting country after Canada, Australia, the United States and Russia.

Although pulses are very promising crops for export, pulse farmers are facing various problems and constraints, especially uncertain and sudden changes in weather conditions during the crop season, which subsequently cause serious pests and disease infestation and crop damage. Among the problems faced by pulse farmers, uncertain and erratic rain occurred during the growing season is the major constraint for farmers as it is out of human control and makes farmer difficult in managing the farm practices. Therefore, this study focuses on investigating the current production efficiencies of farmers under consideration of climate change for both heavy rain areas, Lower Myanmar and dry zone areas, Central Dry Zone (CDZ) of Myanmar. Moreover, the research also touches the introduction of a hypothetical crop insurance program to farmers as a possible remedial measure for the mitigation of the climate change risk for farmers to protect loss from weather risk. And the study elicits the potential demand of farmers and its determining factors on farmers' WTP of the weather index-based crop insurance program in both of study areas. A field survey was conducted two times: first in July-August, 2016 to collect the data for efficiency analyses and second in August-September, 2017 for gathering farmers' willingness to pay (WTP) for hypothetical crop insurance program.

Firstly, technical efficiency analysis of pulses farmers incorporating the quantity of rainfall received during the specific growth stages for both Lower and CDZ of Myanmar was estimated by applying stochastic frontier production (SFP) function using Frontier 4.1 software. The results of the data from Lower Myanmar indicate that rainfall at the flowering time can reduce the technical efficiency, and, hence, productivity. Replanting of the crop after crop damage by heavy rain can ensure to achieve high productivity and technical efficiency. In CDZ results, rainfall received at the flowering stage can induce more fruit setting, consequently improve productivity. Although the result contradicted the first result of Lower Myanmar, it is worthy to note that the study area is a drought-prone area and water scarcity is the most serious problem. The study suggests incorporating weather-related variables in the stochastic frontier function can get more precise results and encourage to avoid the under/overestimation of

technical efficiency. Also, the negative and positive relationship of rainfall in two areas with technical efficiency and productivity points out a need for a safety net like weather index-based crop insurance program to help farmers' income stability.

Secondly, the profit efficiency of individual farmers was estimated using stochastic frontier profit function utilizing Frontier 4.1 software for both of study areas. The results of analysis from the Lower Myanmar, loss group of farmers due to crop damage by rain are less efficient in profit and hence low profitability. Replanting of pulses after damage by heavy rain can enhance the profit of the farmers. Moreover, rainfall at the flowering stage again has a negative significant effect on profit efficiency. The results of the profit efficiency study in CDZ depicts that loss group of farmers are lower in profit efficiency compared to no loss group.

Moreover, low rainfall at the early vegetative growth stage can reduce the profitability by mean of delay crop growth while increased rainfall in the flowering stage is undesirable for the achievement of high profit due to detrimental to flowering and pollination, but not fruit setting. The results of both study areas also prove a necessity for the development of the weather index-based crop insurance program, accompanying with the provision of drought-resistant seed for CDZ, effective techniques for chemicals and fertilizer application in conducting training, and focusing on small-scale, less-experienced and low-educated farmers. In Lower Myanmar encouragement on setting up of farmer organization, farmers' participation in an organization is the feasible ways to improve profit efficiency.

Last, using double-bounded dichotomous choice contingent valuation method (DB DC CVM), factors affecting willingness to join the hypothetical weather index-based crop insurance program utilizing logit model was first investigated, and then farmers' WTP for the insurance product was analyzed by applying double bounded (DB) logit model. Over 80% of farmers in both study areas are willing to join the program. Its determining factors positively related to willingness to join (WTJ) are family labor involvement in farming activities, agricultural income and crop loss due to rain last year for Lower Myanmar, while for CDZ, high education level, agricultural income and encountering crop loss due to heavy or less rainfall during the last growing season have positive effect on WTJ, and gender and age are negatively related to WTJ. Regarding factors affecting farmers' willingness to pay (WTP) for crop insurance, WTP is positively dependent on farmers' experience and off-farm income and negatively relies on gender and age. In addition, bid offered is the most important factor influencing farmers' WTP with a negative effect in both study areas. For CDZ, farmers who are male, less-experienced, landowner, small-scale, access to government credit and have off-farm income are more willing to pay the crop insurance.

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Chapter 1

Introduction

1.1 Role of pulses in Myanmar

As an agronomic country, the agriculture sector is vital to increasing Myanmar's rural population's income, alleviating widespread poverty and enhancing the living standards of the Myanmar people. The role of agriculture in economic development is central because 71% of the total population lives in rural areas, with most of them engaging in agriculture and making their living from the land (MoALI, 2015).

Among the crops mostly grown in Myanmar, pulses are the second most important crop after rice and have the highest potential for export and foreign income. Presently, Myanmar stands out as a leading country in pulse production among the ASEAN (Association of Southeast Asian Nations) member countries and as the fifth major exporting country after Canada, Australia, the United States and Russia (APEDA, 2015). Production, consumption and surplus of pulses in Myanmar are depicted in [Figure 1.1](#).

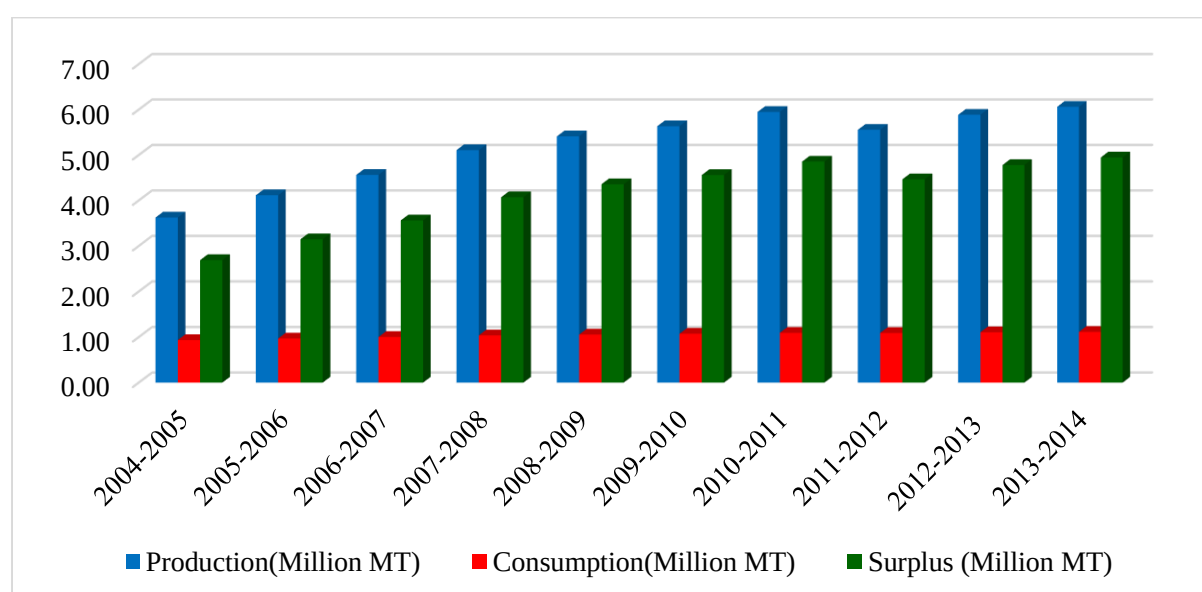
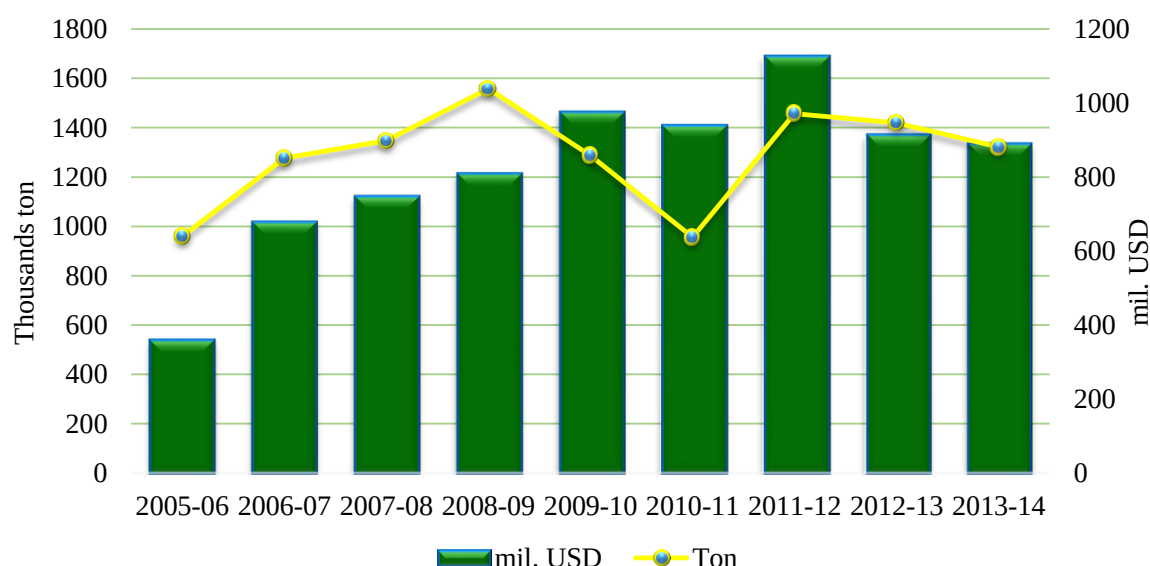


Figure 1. 1 Production, consumption and surplus of pulses in Myanmar

Source: Department of Agriculture (DOA), 2016

The total export of pulses from Fiscal Year 2005-2006 to 2013-2014 is illustrated in [Figure 1.2](#). From 2014-2015, the export of pulses generated about 1205 million US\$, which is about 48% of the total crop export and 41% of the agricultural product export value (Myanmar Agriculture at a Glance, 2015). The export-oriented production of pulses in Myanmar has contributed to the modest increase in global pulse production.



[Figure 1. 2](#) Total pulses export of Myanmar (2005-2006 to 2013-2014)

Source: DOA, 2016

1.1.1 Pulse production in Lower Myanmar

Pulses are grown all over the country in Myanmar, but the cultivated varieties of pulses are different depending on location. In Lower Myanmar, green gram, black gram, and cowpea are the major widely grown pulses. Survey area map is illustrated in [Figure 1.3](#). In some parts of the Bago Region, pulses are grown in winter after a prolonged monsoon flooding period that usually takes about four and a half months. In these areas, pulse crops are a major source of annual household income for farmers. Therefore, if pulse crops fail, the farmers in the Bago Region will face greater losses than farmers in the Yangon Region, where pulses are grown as a winter cash crop after monsoon rice. Therefore, pulses are the most important crop for the economic stability of the farmers in the Bago Region. [Figure 1.4](#) depicts the generalized

cropping calendar of pulses in Lower Myanmar. Generally, the pulses begin to grow in early November and begin to be harvested at the beginning of February. If the rain is heavy, however, during the seedling stage or early vegetative stage, some farmers have to replant an entire plot again, or some have to do patch replanting, causing late sowing, which causes poor performance in crop growth.

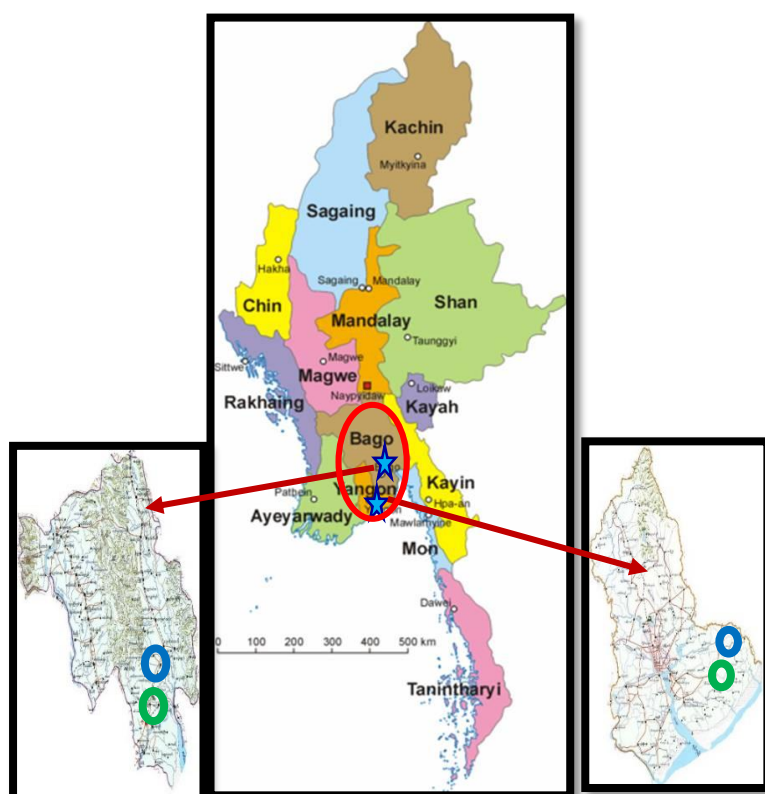


Figure 1. 3 Survey area map of Lower Myanmar

Nov (Weeks)				Dec (Weeks)				Jan (Weeks)				Feb (Weeks)				Mar (Weeks)				Apr (Weeks)			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Land Preparation, Sowing				Vegetative Stages				Flowering & Fruit Setting Stages				Maturity Stages, Start Harvesting				Second and Third Times of Flowering & Fruit Setting, Maturity Stages Simultaneously							

Figure 1. 4 Generalized cropping calendar of pulses in Lower Myanmar

Source: Personal communication, 2016

1.1.2 Historical rainfall incidence during pulses season in Lower Myanmar

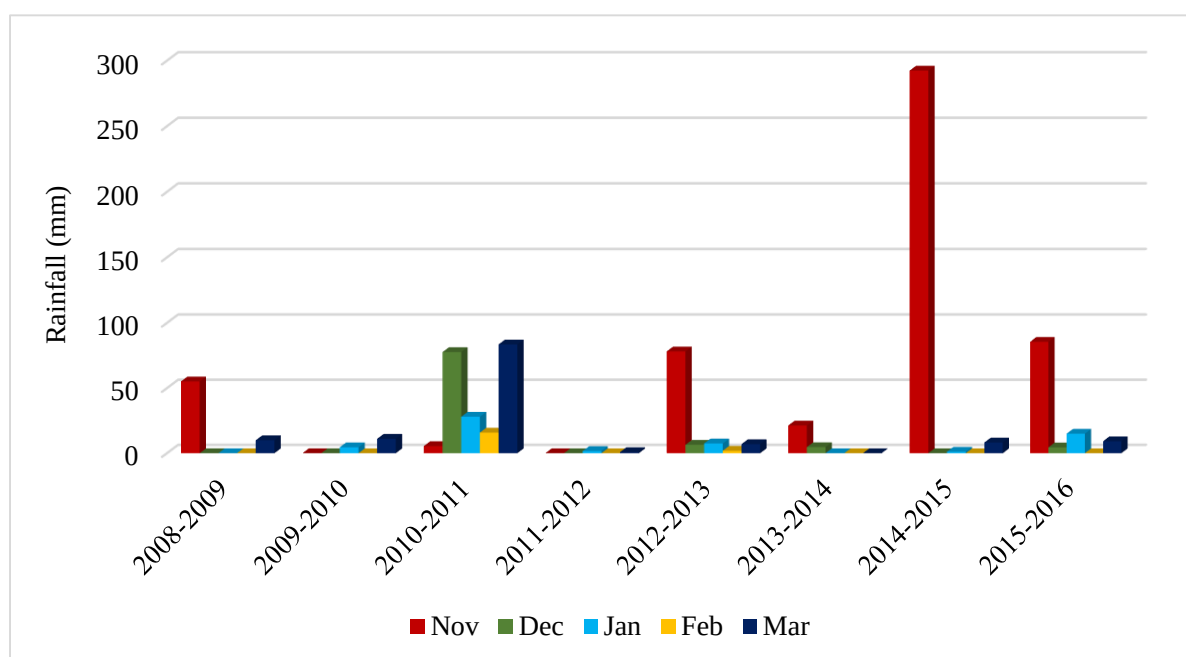


Figure 1. 5 Rainfall received during pulse growing season in Lower Myanmar from 2008-2009 to 2015-2016

Source: DOA, 2016

Historical rainfall received during the pulses growing season in the study areas of Lower Myanmar is displayed in [Figure 1.5](#). In this area, pulses are started to grow at the end of the monsoon season (usually in November) with the residual moisture, the vegetative and reproductive stage usually encounters in the winter season, and ripening stage is in late winter and early summer. Normally, the growing season starts at November when the monsoon season terminates and ends at March when it is summer season. If the rain incidence occurs during the sowing early vegetative stage, which is in November, and destroy the crops, farmers sometimes have to grow the crops again which makes farmers more cost of production, and if it occurs during the flowering stage, which is in January, it makes the flowers shed and hinders fruit setting causing the farmers significant yield loss. So, rainfall received during these growth stages is very important in determining crop success. According to the evidence shown in

Figure 1.5, severe rainfall at the growing season is the highest (292.42 millimeters (mm)) in 2004-2015 growing season followed by 2015-2016 (85.53 mm), 2012-2013 (78.17 mm) and 2008-2009 (55.12 mm). In 2014 DOA annual report, the record of pulse crop damage due to heavy rain is 32,677 hectares. Moreover, in 2010-2011 growing season, rain incidence also occurs during late vegetative stage and harvesting stage. Rain also happened at the flowering stage in 2010-2011 and 2015-2016 growing season.

1.1.3 Pulses production in Central Dry Zone of Myanmar

In Central Dry Zone (CDZ) of Myanmar, pigeon pea, chickpea and green gram are widely grown in Mandalay, Magwe and Sagaing Regions. Pigeon pea is the third most important pulse after green gram and black gram. Map of survey areas in CDZ is illustrated in Figure 1.6. In CDZ, most farmers mainly cultivate it by intercropping or mixed cropping with some crops such as sesame, groundnut, sorghum, cotton, green gram, cowpea and chickpea. Traditionally it is mainly grown under rain-fed condition by using traditional long-duration (>200 days) varieties (Kyu et al., 2016). As it is a rain-fed crop, it normally grows at the beginning of May along with the first rain occurrence and harvests in December. Therefore, the crop has to face the serious drought of June-July in the early vegetative stage, and terminal drought in the reproductive stage as Magwe and Mandalay Regions are the drought-prone areas. As a result, it is common for crop failure problem which causes a significant reduction in yield loss and consequently leads to farmers' economic loss (Kyu et al., 2016). Most of the farmers in the survey area grow pigeon pea as a main standing crop and green gram, chickpea and cowpea are grown as a sole or mixed or intercropped with pigeon pea, sesame and groundnut. Only some or few farmers cultivate green gram, chickpea and cowpea as a pre-monsoon crop from May to August and as a winter crop from October to January (Figure 1.7).

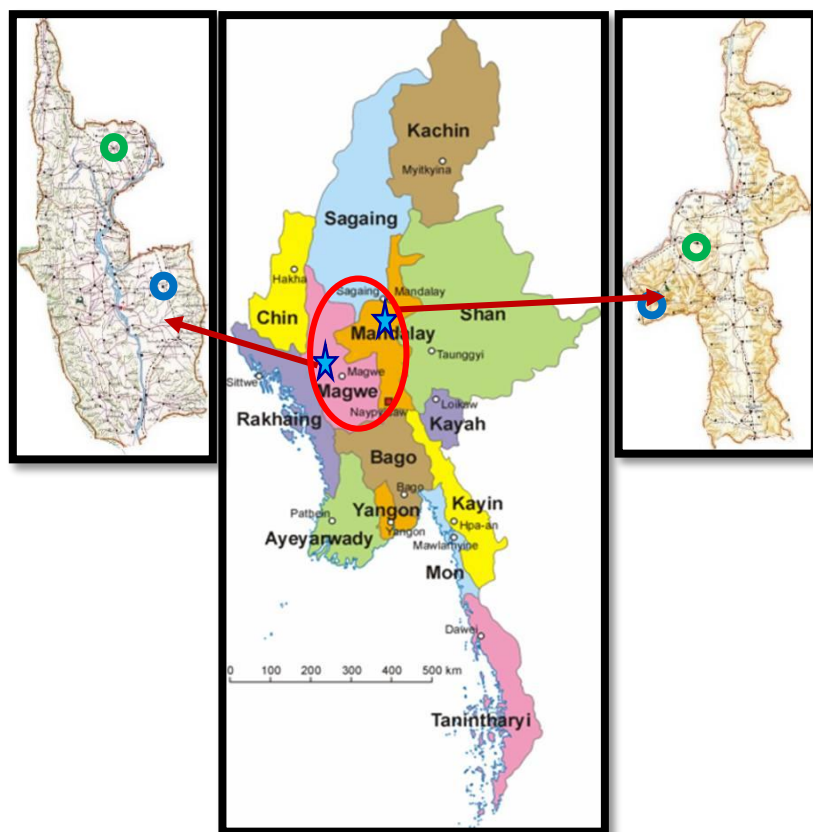


Figure 1. 6 Survey area map of CDZ

April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
Land Preparation	Pigeon pea cropping calendar (intercropped or mix-cropped with green gram, chick pea, cowpea, sesame, groundnut)								
	Sow	Early vegetative growth stage	Vegetative growth stage			Flowering	Seed set & Maturity	Harvest	
	Pre-monsoon Green gram, chick pea and cowpea cropping calendar				Green gram, chick pea and cowpea cropping calendar				
	Sow	Vegetative stage	Flowering	Harvest	Sow	Vegetative stage	Flowering	Harvest	
	Green gram, chick pea and cowpea has the same growing period and they are grown as pre-monsoon crops and as sole or intercropped or mixed cropping with pigeon pea, sesame, and groundnut.				Green gram, chick pea and cowpea are grown as winter crops and as sole or intercropped or mixed cropping with pigeon pea, sesame, and groundnut.				

Figure 1. 7 Generalized cropping calendar of Central Dry Zone of Myanmar

Source: Personal communication, 2016

1.1.4 Historical rainfall incidence during pulse growing season in Central Dry Zone (CDZ) of Myanmar

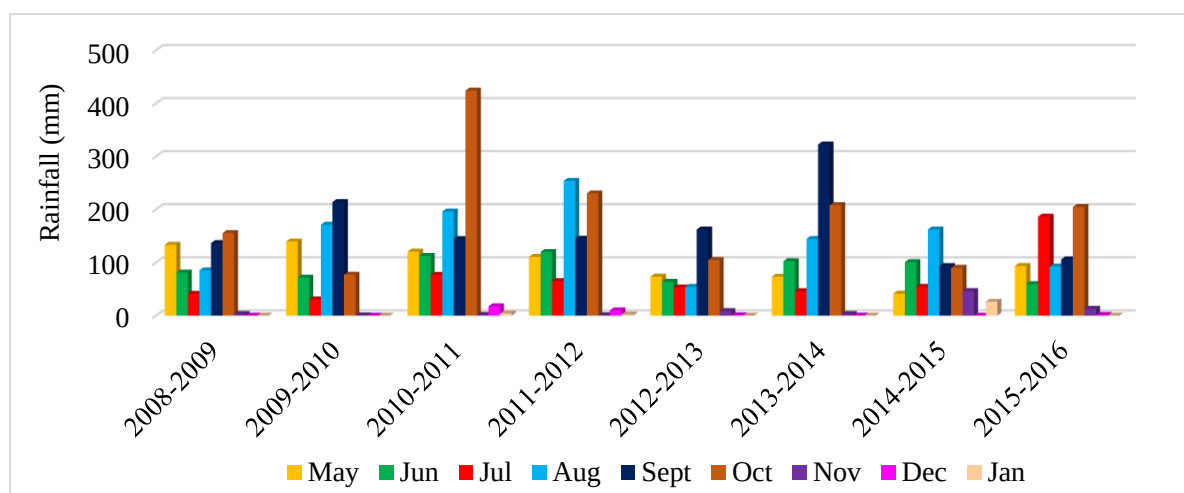


Figure 1. 8 Rainfall received during pulse growing season in CDZ from 2008-2009 to 2015-2016

Source: DOA, 2016

Figure 1.8 shows the historical rainfall received during the pulse growing season of the Central Dry Zone (CDZ) of Myanmar. As a drought-prone areas, rainfall magnitude received along the growing season is quite low in almost every year except in 2010-2011 and 2013-2014 growing season. Rainfall in May-June of early growth stage is less than 150 mm in every year and rainfall received during this period is important for the plant growth. The minimum rainfall is received in July in every year except in 2015-2016 growing season. Except in 2009-2010 and 2014-2015 growing season, October rainfall is relatively high in a flowering season of pigeon pea.

1.2 Problem statement

Although pulses are very promising crops for export, pulse farmers are facing various problems and constraints, such as uncertain and sudden changes in weather conditions during the crop season, which subsequently cause serious pests and disease infestation, low-quality seed for cultivation, unstable domestic and export markets and sudden price fluctuations.

Among the problems faced by pulse farmers, uncertain and erratic rain occurred during the growing season is the major constraint for farmers as it is out of human control and makes farmer difficult in managing the farm practices. At present, optimum pulse yields targeted by the Ministry of Agriculture, Livestock and Irrigation (MoALI) are 1.6-2.5 tons per hectare, dependent on the kinds of pulse varieties, whereas the average actual yield, which farmers obtain at the farm level, is about 1.3 tons per hectare (DOA, MoALI, 2015). Therefore, a yield gap exists between actual and targeted yields; thus, considerable improvements are needed in the productivity of pulse farming to achieve target yields.

The farmers from the survey areas of both regions encountered erratic rain during the crop growing season, especially rain at flowering stage, which can damage and shed pulse flowers, and it will directly affect the fruit setting and consequently lead to yield losses. Crop sensitivity to different stresses varies greatly, depending on the different growth stages of the crop such as the vegetative, reproductive, flowering and maturity stages (Sherlund et al., 2002). Moreover, Sardana et al. (2010) observed that cloudy weather or rain at flowering and fruiting resulted in poor pod setting and seed filling and may lead to increased damage from pod borers.

There are two ways to increase pulse yield to achieve targets among all farmers: one is to introduce new technologies, which are costly, and another is to improve the technical efficiency of farmers, considering their input use in response to climate change during the crop growing season, especially under erratic rain occurrences. This situation calls for empirically assessing the present technical and profit efficiencies of pulse farmers and the determining factors to explore the effective tactics and policy recommendation that will improve technical and profit efficiency and consequently productivity of pulse cultivation.

Currently, when the farmers face crop damage caused by weather-related risks such as erratic and uncertain rain incidence, the government provides the victim farmers with the kinds of seed distribution for replanting and capital for buying agricultural inputs and cost after field

evaluation and receiving damage report. Here, the main problems in conducting these activities are delaying in the delivery of these provisions making replanting the crops late in seasonality, and the provision sometimes does not cover for all the victim farmers. One of the important measures for development of Myanmar pulses farmers' economy is to plan for weather-related risk mitigation through a crop insurance program to protect farmers from losses due to erratic and uncertain rainfall.

Therefore, there should be introduced a secure network like weather index-based crop insurance program for farmers, and consequently, it also demands to assess the farmers' interest and willingness to pay for weather index-based crop insurance for the establishment of the potential market of weather index-based crop insurance program.

The present status of the development of weather index-based crop insurance program in Myanmar is underdeveloped and in a very initial stage. Foreign insurance companies who are interested in investing the weather index-based crop insurance program in Myanmar are conducting feasibility study by collaboration of some interested local insurance companies to understand the demand for agricultural risk mitigation products in Myanmar, to find the most effective ways to distribute them to smallholder farmers, and to verify whether there is a market potential or not.

To our knowledge, there are no previous studies on the technical and profit efficiencies of pulse production in Myanmar considering erratic and uncertain rainfall of climate effect on crop yield. Moreover, weather index-based crop insurance program is under the initial step to develop in Myanmar, and no one has not yet touched the field of farmers' willingness to participate and to pay for this program. The findings from the research will be a supportive corner of the program initiative and be in need of current attempt to the development of agricultural insurance scheme in Myanmar as a safety net for farmers.

To fill this gap, the research has been conducted addressing all these issues, and the result of this researches hope to fulfill the current need of the policy implications. Accordingly, the following research questions have come up:

1. What is the current technical efficiency levels of pulses farmers under erratic rainfall effect and which determinants are they facing?
2. What is the current profit efficiency levels of pulses farmers considering erratic rainfall effect and its determinants?
3. Is there any potential market for the establishment of weather index-based crop insurance program in Myanmar?
4. How many pulse farmers are willing to participate in the weather based crop insurance program?
5. How much do farmers willing to pay for hypothetical weather index-based crop insurance for pulse crops?
6. Which factors are determining for their willing to participate in and pay?

1.3 Research objectives

The main aim of the study is to explore some policy recommendations for the improvement of pulses industry in Myanmar based on evaluating the present production performance of pulses farmers and on providing the prerequisite information necessary for the development of crop insurance program. The detail objectives are:

1. to analyze the current technical and profit efficiency levels of pulses farmers and its influencing factors incorporating weather effect,
2. to analyze the present profit efficiency levels of pulses farmers and its influencing factors incorporating weather effect,

3. to estimate the farmers' willingness to join (WTJ) and willingness to pay (WTP) for hypothetical premium levels of weather index-based crop insurance program, and
4. to identify the factors affecting the farmers' WTJ and WTP for weather index-based crop insurance program.

1.4 Significance of the study

This study contributes the current literature of efficiency analysis by considering the effect of erratic and uncertain rainfall on the specific growth stages of the pulse crops. It also provides the empirical evidence on the current status of pulse production efficiency and its determinants which need to improve for the sustainable development of the pulse industry in Myanmar. Moreover, it points out the potential market for the establishment of the weather index-based crop insurance program in Myanmar and elicits the actual farmers' interest in this program and willingness to pay for it. In addition to, it also highlights the factors affecting on the farmers' willingness to participate and to pay for the program to be considered for the investors and policymakers when for the development of an insurance program as well as its effective implementation.

1.5 Outline of the dissertation

In this study, the assessment of the rainfall effect on the technical and profit efficiencies of the pulse farmers and their willingness to participate and to pay for weather index-based crop insurance for the protection of farmers from losses due to weather-related risks are organized in seven chapters as follows: this chapter firstly introduced the role of pulses and problem statement, research objectives, and significance of the research. The preceding chapter, Chapter 2, discusses technical efficiency and its determinants in Lower Myanmar. Chapter 3 expresses technical efficiency and its influencing factors in CDZ of Myanmar. Chapter 4

examines profit efficiency and factors determining the efficiency in Lower Myanmar. Chapter 5 assesses profit efficiency and its determinants in the CDZ of Myanmar. Chapter 6 exhibits the farmers' WTP for weather index-based crop insurance using CVM and its determining factors in both Lower Myanmar and CDZ. In Chapter 7, main findings and policy recommendations on the rainfall effects on the efficiencies of pulse farmers, and farmers' demand of a hypothetical weather index-based crop insurance program and factors affecting their willingness to participate in the program, as well as farmers' willingness to pay and its influencing factors on the hypothetical insurance program. In the last section of the chapter, research contributions and suggestion for the further studies are discussed.

Chapter 2

Impact of Erratic Rainfall from Climate Change on Pulse Production Efficiency in Lower Myanmar

2.1 Introduction

Agriculture can be viewed in three dimensions of environment, behavior, and policy (Clapham, 1980); it is a risky business, as environmental factors interact in a complicated way with farmer behavior (Stener and Coria, 2011). This factor is especially relevant in developing countries, where farm infrastructure and policy environments for farming activities have not yet been well developed. Rahman and Hasan (2008) affirmed that farmer production performance is greatly influenced not only by the availability of physical resources and farming technologies but also by environmental conditions that affect production. In resource-poor areas, soil degradation, biocide resistance in pests and adverse weather are some of the most prominent environmental problems that can directly affect agricultural production systems (Clapham, 1980; Rahman and Hasan, 2008). With projected increases from 3% to 15% in global mean precipitation, regional rainfall distribution is uncertain, as are related impacts to agriculture (Stener and Coria, 2011). Along with the potential increase in global temperature, rainfall has already become increasingly variable and unpredictable and has demonstrated uneven distribution (Lal et al., 2011; Sarker et al., 2012; Selvaraju et al., 2006; Yu et al., 2010), causing extreme events such as floods and droughts. Previous studies by Easterling et al. (2007) and Gitay et al. (2001) have revealed that such climate changes will significantly impact crop yields.

In their seminal work, Battese et al. (1996) described how excluding a weather-related variable in a stochastic frontier model may result in production variability, as weather influenced the estimation of technical efficiencies and suggested incorporating risk issues in frontier analyses. Ali and Byerlee (1991) also found that in agriculture, omitting environmental

variables such as soil type, rainfall and pest problems can lead to overestimation of farm technical inefficiency. Hasan et al. (2008) and Sherlund et al. (2002) acknowledged that the prevalence of inefficiency on small farms might partly be due to the lack of environmental production conditions in the estimation of the technical efficiency of farms during the previous three decades. Moreover, extreme weather events during growing and harvesting seasons can cause serious damage to agriculture and can influence farmers' production decisions regarding the allocation of farm inputs, resulting in lower output and higher inefficiency (Ali et al., 1994). Therefore, concerned with short-term climate, the adoption of efficiency analysis can measure and help examine the variations in the physical and financial performance of farmers operating under the same environmental and economic constraints (Wilson et al., 2001).

Under unfavorable environmental conditions, farmers will allocate more inputs to obtain maximum yields (Sherlund et al., 2002), and thus, the productivity and efficiency of agricultural production are affected by the environmental factors (Hoang and Yabe, 2012). Furthermore, Sherlund et al. (2002) also mentioned that traditional agriculture greatly relies on environmental production conditions, which influence farmer decision-making about the application and management of farm inputs used. Hoang (2013) found that weather conditions are one of the growth-defining factors that determine the potential growth of crops. Moreover, the presence of excessive moisture due to unnecessary and erratic heavy rain during the critical period of flowering time can also induce crop failure through the failure of pollination and fruit setting.

Most of the input-output relationship studies did not incorporate changes in climate conditions (Chavas and Cox, 1995; Hoang, 2013; Koeijer et al., 1999). Furthermore, previous predictions of production efficiency have often been derived from an economic production function without consideration of changes in crop science and climate conditions, which leads to undesirable estimation results (Coelli et al., 2005; Hoang, 2013).

In a production efficiency study, failing to take into account environmental production conditions such as rainfall, pest infestation, and plant disease in the production function induces significantly inflated and biased estimates of the parameters in the production function and overestimates the technical inefficiency (Rahman and Hasan, 2008; Sherlund et al., 2002).

Rahman and Rahman (2013) observed the impacts of rainfall on the energy productivity of maize in Bangladesh and found that seasonal rainfall variability reduced summer maize productivity due to unpredictable rainfall patterns in the summer season in Bangladesh. They also found that rainfall has a significant influence on crop productivity, showing the flaw in not incorporating its contribution to productivity in many previous studies.

Introducing pulse crops that are climate smart and simultaneously adapt to climate change and contribute to mitigating its effects can be key to increase resilience to climate change in farming (FAO, 2016). Pulses themselves are, however, very sensitive to torrential rain, especially in the early vegetative stage and at flowering (Majumdar, 2011), and a high quantity of rainfall can cause disease infestation in crops (Rosenzweig and Liverman, 1992).

Therefore, considering the dependence of crop yields on climatic conditions and the frequent incidence of erratic rainfall during the crop growing season of pulses, there is a vital need to assess the potential effects of rainfall during the crop growing season to ensure the economic viability of pulse farmers and to find a suitable policy approach that can reduce the potential impacts of climate change on crop productivity.

To our knowledge, there is no research emphasizing rainfall effects during the flowering stage, which is vital for pulse crops to assess their potential impact on technical efficiency.

2.1.1 Rain incidence during the pulse growing season

The farmers from the survey areas of both regions encountered erratic rain during the crop growing season, especially rain at flowering, which can damage and shed pulse flowers, and it will directly affect the fruit setting and consequently lead to yield losses. Crop sensitivity to different stresses varies greatly, depending on the different growth stages of the crop such as the vegetative, reproductive, flowering and maturity stages (Sherlund et al., 2002). Moreover, Sardana et al. (2010) observed that cloudy weather or rain at flowering and fruiting resulted in poor pod setting and seed filling and may lead to increased damage from pod borers.

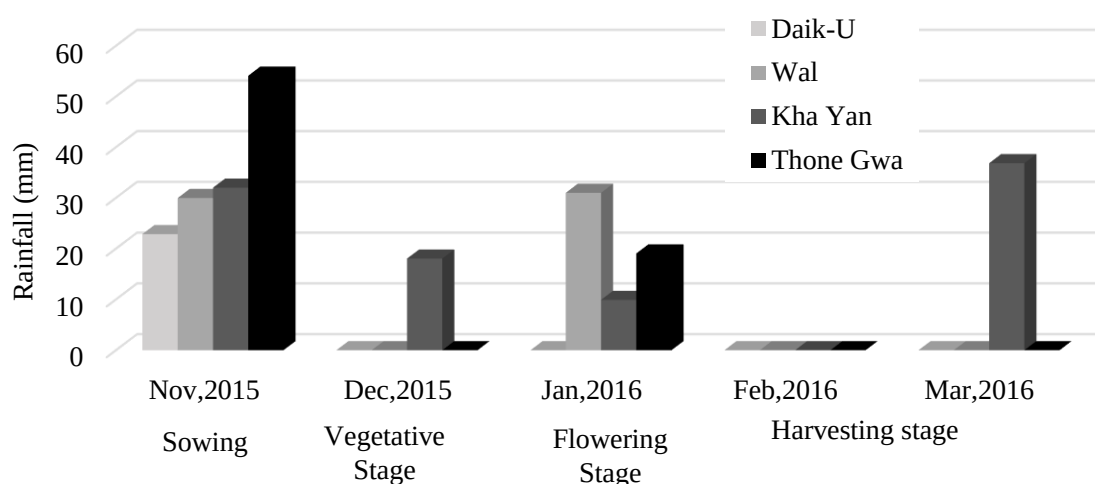


Figure 2. 1 Rainfall (mm) during the 2015-2016 growing season of pulses

Source: DOA, 2016

Figure 2.1 shows the monthly rain incidence throughout the 2015-2016 winter crop-growing season. Last growing season, the rain incidence occurred in November during sowing time and the early vegetative stage and in January during flowering. In practice, Daik-U township in the Bago Region did not record rainfall magnitude during the flowering season in January 2016, meaning that there was no rain incidence, while the other three townships did. The actual rainfall of each township in the flowering season was 30.99 mm in Waw township, 9.91 mm in Kha Yan township, and 19.50 mm in Thone Gwa township.

The response of farmers to heavy rain during the early vegetative stage is mentioned in Figure 2.2 in which 11% of sampled farmers replanted the entire damaged plot of pulses, 10% undertook partial replanting, 13% faced growth retardation due to heavy rains, and 66% did not face any crop damage.

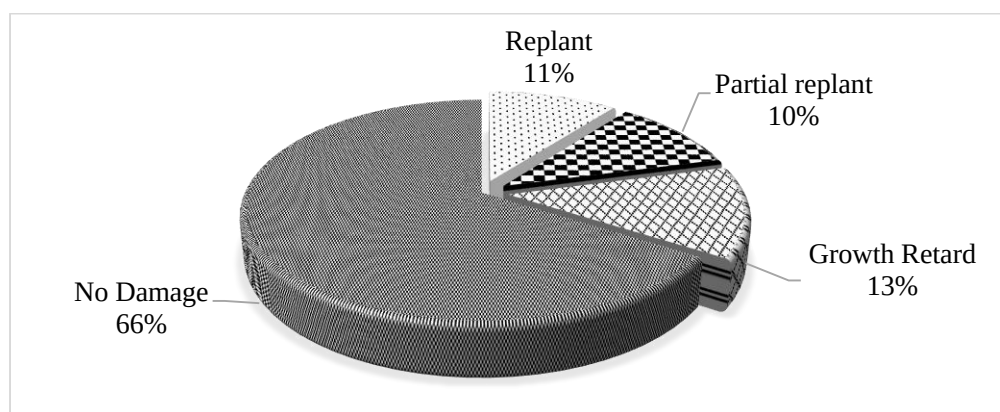


Figure 2.2 Response activities of pulse farmers when faced with heavy rain in the early growth stage in the 2015-2016 growing season

Source: Field Survey, 2016

In Figure 2.3, the response of sample farmers to the damage levels of rain incidence during the flowering stage is illustrated, where about 40% of the respondents answered that they encountered different levels of yield loss, including extreme losses (8% of farmers), high losses (8%), moderate losses (10%) and slight losses (14%) due to rain, whereas 60% of farmers experienced no damage. A total of 73 farmers on 182 sampled farmers reported that they failed to achieve the highest yield potential from pulse production due to rain incidence during the flowering season.

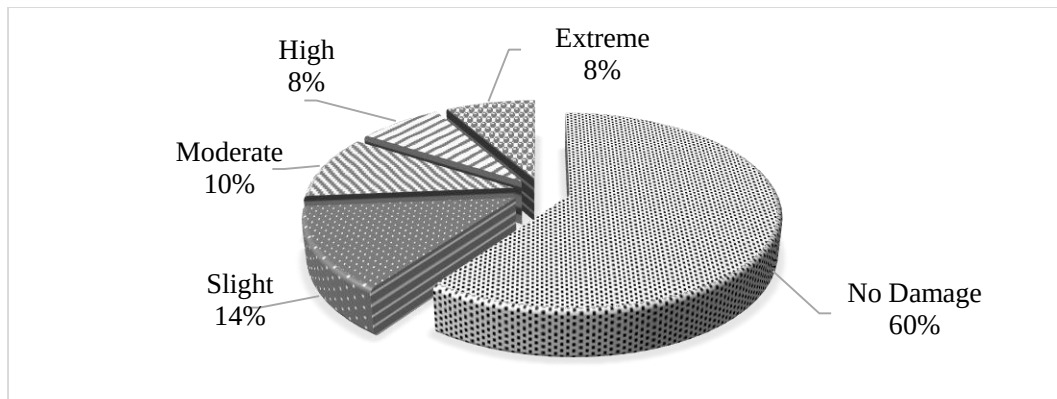


Figure 2. 3 Percentage of farmers who faced different levels of damage among the respondents due to rain incidence in the flowering stage

Source: Field Survey, 2016

Although pulses are important and very promising potential export crops in Myanmar, not only for farmer income but also for the national economy, there has been no obvious study of the productive efficiency of pulse production. Although many scholars have focused on estimating the technical efficiency of many crops such as rice (Kyi and Oppen, 1999; Myint and Kyi, 2005), cotton (Win, 2004), sesame (Latt et al., 2011) and mango (Mar et al., 2013) in Myanmar, no one has yet researched the technical efficiency of pulse farmers until now.

So far, to my knowledge, only the seminal works of Hasan et al. (2008), Sherlund et al. (2002) and Ogada et al. (2014) considered environmental production conditions including the rainfall index and overall rainfall magnitude received during the entire growing season in an analysis of technical efficiency. However, in our study, we focused only on specific rainfall during the flowering time and the additional cost of replanting as a proxy of environmental production conditions.

In this study, the quantity of rainfall (mm) received during flowering among pulses was incorporated into the production function to empirically investigate the effect of rain incidence during the flowering stage of pulses on crop yields. This point is the main and original idea of this research. Rainfall data were collected from respective survey areas of the township office

of the Department of Agriculture (DOA), where the rainfall data were collected on a daily basis at the township level. We expected a negative relationship between rainfall incidence during the flowering time and pulse yield.

The main aim of this research was to explore some policy recommendations for the improvement of the pulse industry in Myanmar based on evaluating the present production performance of pulse farmers. The detailed objectives were to estimate the technical efficiency of pulse farmers during rain occurrences during the flowering of pulses and to analyze the influencing factors with and without rainfall as a climate change proxy.

Therefore, this study will focus on answering the following research questions: (1) Does the impact of rain during the flowering season of pulses have a positive or negative influence on productivity? (2) Are pulse farmers using their inputs efficiently? (3) What factors are affecting the technical efficiency of the pulse production?

This paper will be organized as follows. The next section describes the analytical framework, study areas, and data, followed by the empirical model. The proceeding section presents the results and discussion, and the final section provides conclusions, policy recommendation, and implications.

2.2 Research methodology

2.2.1 Analytical framework

In this study, the stochastic production frontier approach, introduced by Aigner et al. (1977) and Meeusen and van Den Broeck (1977), was applied. In addition to the physical inputs used in production, the quantity of rainfall (mm) that occurred during the flowering time of pulses and additional costs incurred from replanting pulses (hereinafter, referred to as ‘replanting cost’) if the farmers encountered heavy rain that caused total pulse damage during sowing and in the early stage of vegetative growth were included in the model to examine farmer production performance under climate change. The analytical framework and

incorporation of two extra variables, rainfall and replanting costs, in this analysis was based on descriptions of Rahman and Hasan (2008) and Sherlund et al. (2002). The stochastic production frontier for the i^{th} farmer is written as follows:

$$Y_i = f(X_i, R_i) - u_i + v_i, \quad (2.1)$$

where Y_i is the output, X_i is the vector of physical inputs, R_i is the vector of rainfall variable and the variable for the replanting cost, and v_i is assumed to be an independently and identically distributed $N(0, \sigma_v^2)$ two-sided random error, independent of the u_i , which is a non-negative random variable ($u_i \geq 0$) that accounts for technical inefficiency in production and is assumed to be independently distributed as truncations at zero in the normal distribution with a mean $-Z_i\delta$, and variance σ_u^2 ($|N(-Z_i\delta, \sigma_u^2)|$). In most studies in the literature, it is typically estimated by

$$Y_i = g(X_i, R_i^*) - u_i^* + v_i^*, \quad (2.2)$$

where $R_i^* \subseteq R_i$, which ignores R_i variables, resulting in biased estimates of the parameters of the production function, overstatement of technical inefficiency, as well as biased correlates of inefficiency (Rahman and Hasan, 2008; Sherlund et al., 2002).

Wang (2002) provided some theoretical insights into the bias problem in estimating the stochastic frontier function and farm-specific technical efficiency separately using a two-step approach. In the estimation of the technological parameters of the production function, the ignorance of the dependence of inefficiency on its sources can produce biased estimates of these parameters if the explanatory variables in the production function and those in the technical efficiency model were correlated.

To avoid this kind of correlation, the single stage approach proposed by Battese and Coelli (1995) was utilized to determine the influencing factors of production efficiency in which the technical efficiency of the farms is associated with farmer socio-economic conditions and managerial skills and with the demographic characteristics of the farms. Following Battese

and Coelli (1995), the technical efficiency of the stochastic frontier production function of the i^{th} farm is defined as follows:

$$TE_i = E[\exp(-u_i) | \xi_i] = E[\exp(-\delta_0 - \sum Z_i \delta | \xi_i)], \quad (2.3)$$

where $\xi_i = v_i - u_i$ and E is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation u_i for the observed value of ξ_i .

In this analysis, we extend the technical efficiency model by incorporating dummy variables indicating the levels of yield loss due to rain incidence¹. So, the simplified specification of technical efficiency effect model including these dummies is described as follows:

$$u_i = Z_i \delta + D_i \tau + \zeta_i \geq 0, \quad (2.4)$$

where δ and τ are vectors of the parameters to be estimated, Z_i are the farm-specific demographics, managerial and household characteristics, D_i is the dummy variable indicating the levels of yield loss due to the rain incidence, and the error ζ_i is a random variable distributed with zero mean and variance, σ^2 . Since $u_i \geq 0$, $\zeta_i \geq -Z_i \delta$ so that the distribution of ζ_i is assumed as a truncation from below at the variable truncation point, $-Z_i \delta$.

The maximum likelihood method is used to estimate the unknown parameters, with the stochastic frontier and inefficiency effect functions estimated simultaneously. The likelihood function is expressed in terms of the variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ (Battese and Coelli, 1995).

2.2.2 Study area and data information

Of the approximately 4,655,981 hectares of total pulse area in Myanmar, the Bago and Yangon Regions contributed to 1,010,894 hectares (21.7%) (DOA, MoALI, 2016).

¹ A description of these variables is provided in Table 1.

The survey was conducted from July-August 2016 using structured questionnaires and face-to-face interviews. The study area focused on Lower Myanmar, specifically the Bago and Yangon Regions, which were selected depending on the prevalence of the pulse growing areas and farmers. Then, two townships from each Region were selected based on the above categories, and finally, two villages from each township were chosen at random for conducting primary data collection from farm households. A simple random sampling technique was used to select 182 farmers to interview. All of the information collected from pulse farmers was based on pulse production activities operated in the growing season from November 2015 to March 2016, as in the study area pulses, which are grown only in the winter season. The units of all dependent and independent variables appeared in the analysis and were weighted to be a reasonable estimation, as almost all of the sample farmers in this study cultivated different kinds of pulse varieties such as green gram, black gram and/or cowpea on their farms.

2.2.3 The empirical model

In this study, the data obtained from 182 farmers were analyzed using a stochastic production function (SPF), applying a Cobb-Douglas production frontier function with maximum likelihood techniques, which examined the factors influencing the productivity of the pulse production that had a direct impact on farmer income and profits from pulse production. Besides observing the consequences of rainfall incidence during the flowering time of pulses, the frontier was estimated ‘with’ and ‘without’ rainfall and replanting cost variables. Thus, the traditional specification of the production frontier, which omits the two weather impact variables, is given as follows:

$$\ln Y_i = \alpha'_0 + \sum_{j=1}^5 \alpha'_j \ln X_{ij} + v'_i - u'_i \quad (2.5)$$

and

$$u'_i = \delta'_0 + \sum_{d=1}^9 \delta'_d Z_{id} + \zeta'_i \quad (2.6)$$

where $\ln$ is a natural logarithm; Y_i is the weighted amount of pulse yield for the i^{th} farm measured in tons per hectare; X_i is the j^{th} input, such as the *seed rate* (kg), *fertilizer* (kg), *chemicals* (kg) applied to control weeds, pests and diseases, *human labor* (man-day) and *land preparation cost* (Ks) expended by the i^{th} farmer (all of the inputs used were weighted values on a per hectare basis); v_i is the two-sided normally distributed random error; and u_i is the one-sided half normal error. Z_{id} is the variable representing the farm-specific managerial and demographic and household characteristics to explain the inefficiency of the farm, ζ_i is the truncated random variable, and α_0 , α_j , δ_0 and δ_d are the parameters to be estimated. The symbol “’” denotes the model without *rainfall* and *replanting cost* variables.

Similarly, the full model specification including the variables representing *rainfall* and *replanting cost* incurred due to rain incidence in the production function is written as follows:

$$\ln Y_i = \alpha_0 + \sum_{j=1}^5 \alpha_j \ln X_{ij} + \sum_{m=1}^2 \beta_m \ln R_{im} + v_i - u_i \quad (2.7)$$

and

$$u_i = \delta_0 + \sum_{l=1}^4 \tau_l D_{il} + \sum_{d=1}^9 \delta_d Z_{id} + \zeta_i \quad (2.8)$$

where R_{im} is the variable representing the amount of *rainfall* incidence during flowering time in each township in millimeters (mm) and the *replanting cost* incurred for growing pulses again after full damage by rain in Kyats, D_{il} depicts the dummy variables for the different levels of yield losses (100%, 75%, 50%, 25% loss compared to no loss), which were opined by the sample farmers based on the impact of rain incidence during flowering. β_m and τ_l are parameters to be estimated. All other variables are the same as previously defined.

In the stochastic frontier model, a total of five input variables and two variables related to rain impact are used, and a total of nine farm-specific, demographic and household socio-economic characteristics and four dummy variables representing different levels of yield loss were incorporated into the technical inefficiency effect model. We illustrate these variables in the descriptive summary, namely, in the following results section.

2.3 Results

2.3.1 Descriptive summary of production inputs and rain incidence

Table 2.1 depicts the definition, units of measurement and summary statistics of all the dependent and independent variables in the models. All of the units of production inputs were calculated on a per hectare (ha) basis. The results indicate that the average *yield* of pulses is 1.19 tons, with a wide range from 0.32 tons to 2.19 tons. The *seed rate* used also ranged widely, from 41.56 kilograms (kg) to 145.27 kg, with an average of 78.64 kg.

The mean quantity of *fertilizers* applied, including nitrogenous, phosphate, potash, compound and other foliar fertilizers, measured in kilograms, was about 61 kg with 0 kg minimum and about 259 kg maximum.

The quantity of *chemicals* used, consisting of weedicide and pesticides, widely ranged from 0.3 kg to 32.95 kg with an average amount of 9.98 kg, showing a wide variation in chemical use.

The average utilization of *human labor*, comprising hired (permanent and casual) and family labor, measured in man-days, counted in 8 hrs/day, was about 88 man-days, with a minimum of 29.65 man-days and a maximum of 221.15 man-days, indicating that pulse cultivation was highly labor intensive in the study areas. It accounted for all of the farm activities, such as plowing, sowing, fertilization, chemical spraying, weeding, harvesting, and threshing.

The average *land preparation cost* using animal labor and machinery power was about 128,000 Kyats (Ks), with a wide variation in the cost of the minimum 43,000 Ks and the maximum 296,520 Ks.

This trend of wide ranges between the minimum and maximum amount of inputs also follows the same trend for other inputs, such as *seed rate*, *fertilizer*, *chemicals* and *human labor*. From these results, pulse farmers can be understood to use production inputs according to their

Table 2. 1 Descriptive statistics of output and the independent variables used in the models

Sample size = 182

Variables	Unit	Mean	Standard Deviation	Minimum	Maximum
<i>Yield</i>	Tons per hectare	1.19	0.34	0.32	2.19
<i>Rainfall at flowering time</i>	Millimeters	14.64	11.81	0.00	30.99
<i>Replanting cost^a</i>	'000 Kyats per hectare	21.30	66.75	0.00	453.96
<i>Seed rate</i>	Kilograms per hectare	78.64	17.40	41.56	145.27
<i>Fertilizer</i>	Kilograms per hectare	61.24	57.59	0.00	258.93
<i>Chemicals</i>	Kilograms per hectare	9.98	6.39	0.30	32.95
<i>Human Labor</i>	Man-days per hectare	88.35	34.11	29.65	221.15
<i>Land preparation cost^b</i>	'000 kyats per hectare	128.04	40.86	43.00	296.52
<i>100% yield loss by rain^c</i>	1=Yes, 0=No	0.08	0.28	0.00	1.00
<i>75% yield loss by rain^c</i>	1=Yes, 0=No	0.08	0.27	0.00	1.00
<i>50% yield loss by rain^c</i>	1=Yes, 0=No	0.10	0.31	0.00	1.00
<i>25% yield loss by rain^c</i>	1=Yes, 0=No	0.14	0.35	0.00	1.00
<i>No loss by rain</i>	1=Yes, 0=No	0.60	0.49	0.00	1.00
<i>Gender of household head</i>	Male=1, Female=0	0.96	0.19	0.00	1.00
<i>Age of household head</i>	Years	50.92	11.54	23.00	82.00
<i>Experience of household head</i>	Years	21.84	9.78	2.00	50.00
<i>Education of household head</i>	Years	7.30	3.73	3.00	16.00
<i>Credit Access</i>	1=Yes, 0=No	0.88	0.33	0.00	1.00
<i>Participation in farmer organization</i>	1=Yes, 0=No	0.05	0.23	0.00	1.00
<i>Training Access</i>	1=Yes, 0=No	0.32	0.47	0.00	1.00
<i>Location</i>	1=Bago, 0=Yangon	0.54	0.50	0.00	1.00
<i>Pulses Area</i>	Hectare	7.26	7.00	0.40	52.61

^a *Replanting cost* is a cost incurred from replanting the pulses after complete damage of the pulses by rain in the early vegetative stage. About 10.4% of farmers replanted their crops during the 2015-2016 growing season.

^b Only 29 farmers used animal power for land preparation, whereas the other farmers used machinery services. Animal power is counted in workdays. However, in machinery service, farmers used different kinds of tractors with different engine powers, which makes it difficult to get a precise average working hour for one hectare of land across the survey area. Moreover, machinery services were generally paid for on a per hectare basis but not on a working hour basis. Therefore, we used the cost (Kyats/hectare) of combining animal and machinery service costs.

^c Figures based on farmer response about the level of yield loss due to rain. About 40% of farmers faced a different level of losses, as shown in the above table during the 2015-2016 pulse-growing season. A *100% yield loss from rain* indicates that farmers lost about 100% of the first flowers and thus completely lost the output of the first harvest. A *75% yield loss from rain* represents a loss of about 75% of the flowers, which highly reduced the output of the first harvest. A *50% yield loss from rain* indicates a loss of about 50% of the flowers and in the output of the first harvest. A *25% yield loss from rain* represents a loss of only about 25% of the flowers, as well as the output of the first harvest after rain incidence. 1 US\$ = 1,362 Kyats (as of 29 December 2017). Source: Field survey data, 2016.

knowledge, preferences, available capital and the weather situation they faced. For example, if the weather is cloudy, they use more chemicals to protect the plants from pests and disease infestation.

About 4% of pulse farmers were female heads of households; the average *age* of the farmers was about 51 years old, and they had about 22 years of pulse cultivation *experience* and accomplished 7 years of *education*, on average. About 88% of them accessed government *credit*, whereas only 5% participated in *farmer organizations*, such as the village land management organization and the Saemual Undong village development program²; however, there is no farm cooperative, particularly for pulse farmers, in the study area. Only 32% of farmers received *training*³ from the Department of Agriculture (DOA), whereas others had not received any technical assistance in pulse production from the DOA extension workers. Among a total of 182 sample farmers, 54% of the farmers were from the Bago Region. The average *pulse area* in the study area was 7.26 hectares in which most of the farmers are large-scale farmers over a range of 0.40 ha to 52.61 ha farms.

2.3.2 Description of specific rainfall effects on productivity

The recorded amount of average *rainfall during the flowering season* was 14.64 mm, with a minimum of 0.00 mm and a maximum of about 30.99 mm. Approximately 11% of

² Saemual Undong village development program is a project conducted by a collaboration of the Korea International Cooperation Agency (KOICA) and the Ministry of Agriculture, Livestock and Irrigation (MoALI). The farmers who participated in that project can access training arranged by the program and hence improve their technical knowledge about farming and other village development schemes.

³ *Training* conducted by the Department of Agriculture consists of cultural practices, plant protection technologies, fertilizer application techniques, good agricultural practices, postharvest technology and organic farming technology.

farmers had to replant their crop again due to serious damage to the plant from heavy rain. The average *replanting cost* in which the pulses were sown again when rain completely damaged the crop accounted for 21,300 Ks with a maximum of 453,960 Ks. About 14%, 10%, 8% and 8% of them faced 100%, 75%, 50% and 25% *yield losses from rain* during the flowering season, respectively.

In estimating the parameters of the production function, the weather information (*rainfall* in the flowering stage and *replanting cost*) were assumed to be true exogenous variables, which should be considered for inclusion in full specification (hereinafter, the term specification or model will be used interchangeably), as the omission of these variables would lead to upward bias in estimating firm-specific technical efficiency (Sherlund et al., 2002). Table 2.2 describes the results of correlations between production inputs and *rainfall* and *replanting cost*. The strength of the correlation between *rainfall* and production inputs of *seed rate*, *chemicals*, and *human labor* was moderately strong, whereas the other production variables had a weak but non-zero correlation with both *rainfall* and *replanting cost*. This strong correlation between the production inputs and environmental production conditions including rainfall was also reported by Sherlund et al. (2002), while Hasan et al. (2008) and Rahman and Hasan (2008) found weak but non-zero correlations between them. These findings indicated the need to control for environmental conditions in estimating firm-specific technical efficiency. *Seed rate*, *fertilizer*, and *labor* have a positively significant relationship with *rainfall*, whereas *chemicals* is negatively related, which supports the general idea of a plant and weather relationship when rain occurs, during which pest and disease infection become severe; consequently, more pesticides are used. The *replanting cost* is positively correlated with the *seed rate* and *human labor*; this finding also indicates a reasonable relationship among these variables.

Table 2. 2 Correlation among production inputs and rainfall and replanting costs

	<i>Seed rate</i>	<i>Fertilizer</i>	<i>Chemicals</i>	<i>Land preparation cost</i>	<i>Human labor</i>
<i>Rainfall at flowering (mm)</i>	0.443***	0.124*	-0.439***	0.020	0.305***
<i>Replanting cost</i>	0.129*	-0.122	0.119	0.067	0.246***

Note: ***, ** and * represent significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) levels, respectively.

Source: Own estimates

2.3.3 Parameter estimates of the stochastic frontier production function

The maximum-likelihood estimates for the parameters in the frontier function and inefficiency model, using Frontier 4.1 software by Coelli (1996), are given in [Table 2.3](#) for both the short (without *rainfall* and *replanting cost*) and the full (with *rainfall* and *replanting cost*) specifications. The results of the hypothesis testing are presented in [Table 4](#). First, to test the statistical superiority of the full specification, a log-likelihood ratio (LR) test was performed using the log-likelihood values of both short and full specifications reported in [Table 2.3](#)⁴. The test result of the one-sided error 25.79 ($p < 0.000$) rejected the null hypothesis and strongly supported the appearance of the full specification against the χ^2 (6, 0.99) value of 16.81. Similarly, the null hypothesis where *rainfall* and *replanting cost* were jointly zero in full specification was also rejected, indicating that *rainfall* and *replanting cost* affected the productivity of pulses significantly at 1% and 10% level, respectively, and it is worth including these in the full specification.

The null hypothesis of no inefficiency effect was strongly rejected in both models by the LR tests, which are depicted in [Table 2.4](#). The γ values of both specifications shown in [Table 3](#) also support the rejection of the previous null hypothesis test, as these γ values are statistically

⁴ $LR = -2[\ln L(H_0) - \ln L(H_1)] \sim \chi^2(J)$, where $\ln L(H_0)$ and $\ln L(H_1)$ are log-likelihood functions of restricted and unrestricted frontier models and J is the number of restrictions (Coelli et al., 2005).

Table 2. 3 Maximum likelihood estimates for parameters of the Cobb-Douglas production function

Variables	Without rainfall impact variables			With rainfall impact variables		
	Coefficients	Std. Error	t-ratio	Coefficients	Std. Error	t-ratio
Production function						
Constant	1.253	0.791	1.584	0.978	0.971	1.007
<i>Rainfall at flowering time</i>	-	-	-	-0.071***	0.017	-4.139
<i>Replanting cost</i>	-	-	-	0.011*	0.006	1.903
<i>Seed rate</i>	0.187*	0.104	1.805	0.345***	0.099	3.475
<i>Fertilizer</i>	-0.020	0.015	-1.298	-0.005	0.015	-0.371
<i>Chemicals</i>	0.101***	0.031	3.209	0.027	0.035	0.766
<i>Human labor</i>	0.147**	0.059	2.517	0.206***	0.061	3.371
<i>Land preparation cost</i>	-0.219***	0.070	-3.153	-0.256***	0.071	-3.626
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.304	0.106	2.880	0.164	0.047	3.479
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.877	0.053	16.417	0.787	0.064	12.211
Log-likelihood function	-5.381			7.479		
Technical Inefficiency Effects Function						
Constant	-0.114	1.155	-0.099	0.543	1.085	0.500
<i>100% yield loss from rain</i>	-	-	-	0.818**	0.377	2.170
<i>75% yield loss from rain</i>	-	-	-	0.883**	0.384	2.297
<i>50% yield loss from rain</i>	-	-	-	0.346	0.264	1.309
<i>25% yield loss from rain</i>	-	-	-	0.627**	0.252	2.492
<i>Gender of household head</i>	-1.173**	0.515	-2.277	-0.798**	0.359	-2.221
<i>Age of household head</i>	0.614	0.430	1.429	0.286	0.332	0.862
<i>Experience of household head</i>	-0.157	0.191	-0.818	-0.094	0.174	-0.537
<i>Education of household head</i>	0.143	0.179	0.800	0.038	0.177	0.212
<i>Credit access</i>	-0.830**	0.355	-2.341	-0.623**	0.232	-2.687
<i>Participation in farmer organization</i>	-0.758*	0.442	-1.716	-0.546	0.394	-1.385
<i>Training access</i>	-0.711*	0.403	-1.763	-0.531*	0.309	-1.717
<i>Location</i>	-0.735**	0.367	-2.000	-0.601*	0.308	-1.954
<i>Pulse area</i>	-0.682**	0.296	-2.303	-0.399**	0.179	-2.229
Total number of observations	182			182		

Note: ***, ** and * represent significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) levels, respectively. Std. Error means standard error.

Source: Own estimates

significant at the 1% level of significance in a t-test, meaning that about 88% and 79% (Table 2.3) of the variation in pulse yields in both models, respectively, is due to technical inefficiency rather than random variability among farmers and that the majority of farms in the sample operate below a technically efficient threshold. Moreover, it can be concluded that a traditional least square production function is not adequate and that the Cobb-Douglas production function is an appropriate representation of the data.

Table 2. 4 Hypothesis testing

Hypothesis	Critical Value of χ^2 (d.f, 0.99)	Without rainfall effects		With rainfall effects	
		LR statistic	Decision	LR statistic	Decision
Short specification without rainfall variables is enough (to test the statistical superiority of the full specification)	16.81	0	0	25.72***	reject
No effect of rainfall on productivity ($H_0: \beta_1 = \beta_2 = 0$)	9.21	0	0	15.26***	reject
No presence of technical inefficiency ($H_0: \gamma = 0$)	6.64	19.80***	reject	14.12***	reject
Constant return to scale in production ($H_0: \alpha_1 + \alpha_2 + \dots + \alpha_5 = 1$)	15.09	38.18***	reject	53.52***	reject
No effect of managerial variables on efficiency ($H_0: \delta_5 = \delta_6 = \dots = \delta_{13} = 0$)	21.67	25.10***	reject	28.10***	reject

Note: *** represents significance at the 1% ($p < 0.01$) level.

Source: Own estimates

As the output of pulses was expressed as the Cobb-Douglas production function, the estimated coefficient values of the variables can be directly read as the elasticities of the function. The total elasticity of the stochastic frontier function represents the proportionate changes in productivity if the inputs change during the production process. A restricted frontier regression was performed for both models with the null hypotheses of a constant return to scale. The LR test statistic reported in Table 2.4 rejected the hypothesis, indicating that pulse production is running under decreasing returns to scale, which is more serious under *rainfall*

and *replanting cost* controls in the full model. The result implied that an increase in one unit of input used would be an increase in the output of pulses in the decreased proportion. It also implies that pulse farmers are operating farming activities below the optimal rate and also proved that the rainfall and replanting costs affect the estimates of the production function itself.

In the full model, as expected, *rainfall* has a negatively significant effect on productivity at the 1% level of significance, implying that the higher the *rainfall*, the more crop damage and the lower the productivity that occurred. However, *replanting cost* is positive and significant at the 10% level, indicating that the replanting practice of pulse farmers after heavy rain incidence and damage to the crop can obviously improve the pulse yields compared to doing nothing. It may be because the affected farmers can replant the pulses without a delay in the suitable sowing time.

In both specifications, the *seed rate* and *human labor* coefficients are positive, whereas the coefficient value of *land preparation cost* is negative, and these estimated coefficients have a significant impact on productivity.

However, in the short specification, the *chemicals* coefficient has a positively significant impact on yield at the 1% level, whereas it is positive but not significant in the full specification. When the rainfall factors are accounted for in the model, the *chemicals* variable becomes insignificant, implying additional chemicals does not improve productivity, however sign is positive. The *seed rate* is the most dominant input on productivity, followed by *land preparation cost* and *human labor* in the full model. However, in the short model, the *land preparation cost* variable is the most dominant factor on pulse yields, followed by the *seed rate*, *human labor* and *chemicals*.

The positively significant result of *seed rate* also falls within the results of Rahman and Hasan (2008) in a wheat farmer technical efficiency analysis in Bangladesh. The result of the positive impact of *human labor* on productivity is in line with the findings of Kyi and Oppen

(1999), Latt et al. (2011) and Mar et al. (2013); in these studies, the authors estimated the technical efficiency in rice, sesame, and mango in the same country, Myanmar. The negative effect of *land preparation cost* on productivity confirmed the findings of Mar et al. (2013) in a technical efficiency analysis of mango farmers in central Myanmar and of Hasan et al. (2008) for efficiency estimations of pulse farmers in Bangladesh. Effective land preparation techniques should be conveyed to farmers.

2.3.4 Frequency distribution of technical efficiencies in both specifications

The frequency distribution of the technical efficiency indices of pulse farmers is illustrated in [Figure 2.4](#) in which the prominent feature of incorporating *rainfall* and *replanting cost* variables in the full specification can be virtually seen, indicating a wider distribution of the technical efficiency through each level of efficiency scores than in the short specification. The mean, minimum and maximum technical efficiency levels of both specifications are presented in [Table 2.5](#). Incorporating the effect of *rainfall* and *replanting cost*, the mean and maximum technical efficiency levels of the full specification will become slightly increased, whereas the minimum technical efficiency level decreases, creating wide variation in technical efficiency scores and indicating that the omission of *rainfall* and *replanting cost* can lead to overestimating the inefficiency of farmers.

Moreover, with the *rainfall* and *replanting cost* variables, the majority of pulse farmers (83.51%) fall into the highest level (above 0.80-1.00), whereas the short specification resulted in 81.32%, which is less than the full specification. In both specifications, a minimum technical efficiency score of less than 50% included only about 3%, indicating that almost all pulse farmers are achieving relatively high technical efficiency in production. In the short specification, 18.69% of farmers were operating with an efficiency score under 0.80, whereas under the full specification, only 16.49% were in that range. The mean technical efficiency scores of 0.857 in the short specification and 0.862 in the full specification suggested that there

was obvious technical inefficiency among the pulse farmers for both specifications and indicating that the inputs used could be reduced by approximately 14% without decreasing the current output level if a farmer's technical efficiency improved to a fully efficient level so as to increase the gross margin of pulse farmers.

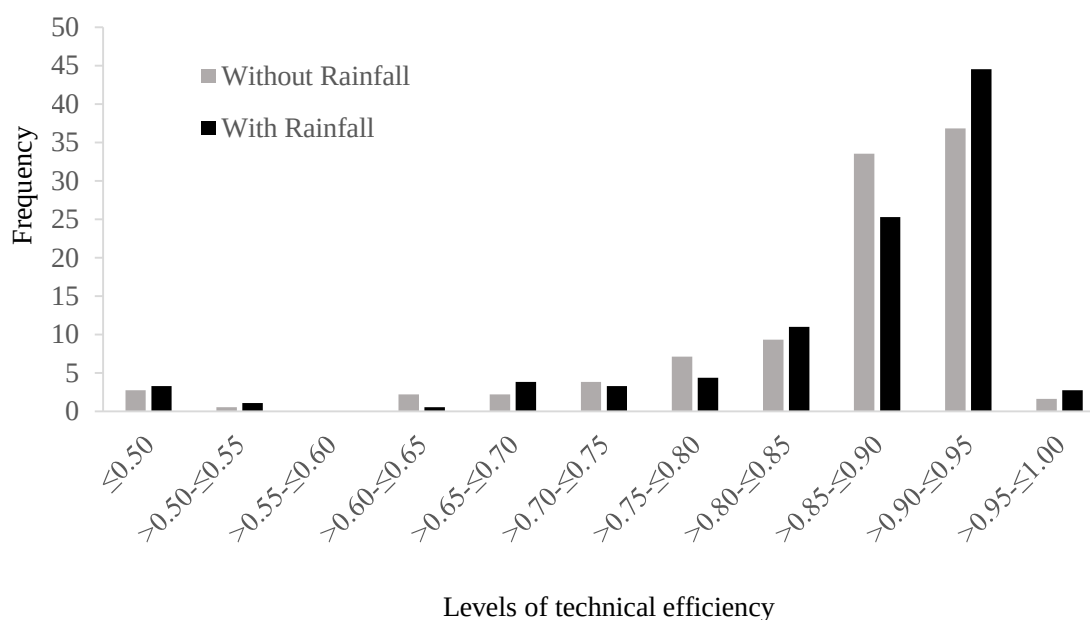


Figure 2. 4 Technical efficiency scores with and without rainfall effects

Source: Own estimates

Table 2. 5 Technical efficiency estimates with and without rainfall effects

Items	Without rainfall	With rainfall
Mean efficiency score	0.857	0.862
Minimum	0.350	0.314
Maximum	0.957	0.964

Source: Own estimates

Furthermore, this estimated mean technical efficiency in the full specification also implies that productivity could be increased by 16.00% [$\{(0.862-1.00)/0.862\} \times 100$] (Rahman and Hasan, 2008) with full efficiency improvement. Moreover, the average technically efficient farmers could reduce their cost by 10.58% (i.e., $[1-\{0.862/0.964\}] \times 100$) (Bravo-Ureta and

Pinheiro, 1997; Khai and Yabe, 2011; Obare et al., 2010), and the most technically inefficient farmers could save costs of 67.43% (i.e., $[1 - \{0.314/0.964\}] * 100$) if they achieved the maximum technical efficiency level of their counterparts.

2.3.5 Factors associated with sources of technical efficiency

The estimated results of inefficiency models for both specifications are depicted in the lower panel of Table 2.3. The results indicate a significant effect of omitting *rainfall* and *replanting cost* variables on the correlates of inefficiency in the model. The coefficients representing the different 100%, 75% and 25% *levels of yield loss* due to rain incidence during the cropping season have, as expected, a negative significant effect on the technical efficiency of the farmers, except the 50% *yield loss* variable, explaining that the rain incidence is one of the determinants used to achieve higher technical efficiency among farmers. However, determining why the 50% *yield loss* variable is insignificant requires further investigation.

The hypotheses testing the zero joint effect of the managerial factors of the farmers was rejected for both specifications at the 1% level of significance, indicating that the technical efficiency level of pulse production mainly relies on managerial factors among farmers. As shown in the lower part of Table 3, the *gender of household head*, *access to government credit*, and *access to training* on pulse production practices, *location* where the farms are located, and *pulse area* have a positive and significant effect on technical efficiency in both specifications, although *participation in a farmer organization* was positively significant only in the short specification. The results shows that the impact of rainfall incidence has a stronger effect on technical efficiency compared to *participation in a farmer organization*, as the result of that variable becomes insignificant in the full specification. The positive effect of male household heads on technical efficiency may be due to higher motivation, farming knowledge and management skills, and the decision-making behavior of a male head on the farming activities compared to a female head.

The result of the dummy variable for *location* explains that farmers in the Bago Region have higher technical efficiency than those in the Yangon Region. The likely reason is that in the Bago Region, pulses are cultivated with more intensive care because they are the main income-generating crop because most of the sample farmers can grow only pulses in winter due to prolonged flooding during the monsoon season, and/or in the Yangon Region, when pulses are grown only after the harvesting of monsoon rice, resulting in a deficit of moisture content during the sowing time or delays in sowing or more rain incidence during the flowering time.

The positive significance of *pulse area* on technical efficiency may be due to the large-scale farmers obtaining the benefit of training or extension networks for cultural practices as a key informant, and who easily access loans for production costs from private money lenders, as the government credit for winter crops is only about 50,000 Ks per hectare, which is insufficient for even the initial production cost such as land preparation, and who easily buy agro-chemicals on credit whenever needed from pesticide companies/dealers, which is a significant difficulty for small farmers.

2.4 Discussion

The strong correlation between the production inputs and environmental production conditions, including rainfall, was also reported by Sherlund et al. (2002), while Rahman and Hasan (2008) and Hasan et al. (2008) found weak, but non-zero, correlations between them. These findings indicated the need to control for environmental conditions in estimating firm-specific technical efficiency. *Seed rate*, *fertilizer*, and *labor* have a positively significant relationship with *rainfall*, whereas *chemicals* is negatively related, meaning when rain occurs more, less chemicals are used. The *replanting cost* is positively correlated with the *seed rate* and *human labor*; this finding also indicates a reasonable relationship among these variables.

According to the results of the production frontier function, there is ample opportunity to improve technical efficiency (14%) to achieve fully-efficient utilization of farm inputs under the current situation. Rain incidence during the pulse flowering season will decrease pulse productivity and cause farmer losses, consequently resulting in low economic standards among farmers. Therefore, to generate security in the face of such climate-related disasters, which are out of human control, the government should introduce a safety network, such as a weather index-based crop insurance program for farmers to protect family farms from unexpected weather risks and economic losses. Moreover, the results revealed that farmers who faced 100%, 75%, and 25% *yield losses* due to rain have low technical efficiency, which made them experience a low yield from pulse production.

Replanting the crop will significantly increase pulse productivity. Thus, farmers should undertake replanting practices after damage from rain during the early growth stage. However, to follow the seasonality of pulses, farmers should urgently replant the crop, which demands government support. Therefore, the government should encourage faster decisions during field assessment about the damage level and should quickly provide farmer victims with the emergency support of seed and capital for planting costs; often, the compensation from the government is quite late, delaying replanting and resulting in poor crop performance.

The results revealed that seed is one of the most important factors for increasing productivity. The result of *seed rate* falls within the findings of Rahman and Hasan (2008) in a wheat farmer technical efficiency analysis in Bangladesh. More seed rate use per ha increases the output. The research on improved and locally-adaptable variety development of pulse seeds, which are also preferably adaptive to climate change conditions, should be geared toward making more effective use of seeds and driving productivity improvement through dissemination of quality seeds throughout the pulse growing regions. On the other hand, to avoid the overuse of seeds, research should also focus on area-specific recommendations of

seed rate for individual kinds of pulses, which should be developed and suggested to farmers through effective demonstration plots. Moreover, seed storage technologies should be shared with farmers to prevent seed waste. The increased use of *human labor* would cause pulse yields to increase with a positive impact of the variable on productivity.

The result of *chemicals* in the short model depicted that the more chemicals used, the higher the productivity, implying pest and disease control practices are very important for obtaining high yields; however, the excessive use of chemicals can be harmful to human and environment so that they should be used with careful attention to the residual effects on crops. Moreover, in the full model, incorporating *rainfall* and *replanting cost* variables, *chemicals* has no significant effect on pulse productivity. The reason might be the mistiming of pesticide application, which decreases the effectiveness of applied chemicals on plants. Therefore, this could be an important consideration for future research.

The negative effect of *land preparation cost* on productivity alarms the need of effective land preparation techniques should be conveyed to farmers. The positive significance of *pulse area* on technical efficiency is in line with the previous results of Rahman and Hasan (2008), and contradicts the findings of Sherlund et al. (2002) and Battese et al. (2014), who found that smallholder rice farmers are more technically efficient under controlled environmental production conditions. Furthermore, the obtained results may be due to the large-scale farmers obtaining the benefit of training or extension networks for cultural practices as a key informant, and who easily access loans for production costs from private money lenders, as the government credit for winter crops is only about 50,000 Ks per hectare, which is insufficient for even the initial production cost, such as land preparation, and who easily buy agro-chemicals on credit whenever needed from pesticide companies/dealers, which is a significant difficulty for small farmers.

2.5 Conclusion and policy recommendations

This research was motivated by the concern that most farmers face heavy rains during the growing season and that crop damage and yield losses due to heavy rains cause extensive losses among farmers. Therefore, the situation calls for an empirical analysis of the technical efficiency of pulse farmers that considers the climate effect. The result may help to draw true inferences, without any unnecessary consequences, toward designing policies that could help to improve pulse productivity while considering the climate effect, which has never been done in the case of Myanmar.

Based on the results of the study, encouraging female and small-scale farmers to participate in training programs would be beneficial for improving the performance of farming practices resulting in higher technical efficiency and, hence, productivity. Furthermore, if farmer organizations can introduce a safety network, such as a crop insurance program for farmers, the efficiency of a cooperative may become significant. The results indicate that conducting practical, effective, and efficient training programs that educate pulse farmers can increase the technical efficiency among pulse farmers and can increase productivity. Moreover, building a persistent bond between farmers and extension staff through effective extension activities is necessary for expanding the use of farming technologies. Promoting extension services should also be accelerated with the encouragement of the respective policy-makers for improving farmers' technical know-how and their motivation to accept new or existing technologies.

The provision of credit to farmers should increase, at least to meet the initial cost of production, to improve technical efficiency and the consequent productivity of pulses; furthermore, credit should be provided to farmers in time for the planting season. This finding greatly supports the current plan of increasing agricultural credit for upland crops to 125,000 Ks per ha, which should also be extended to winter crops, like pulses, in Lower Myanmar.

These policy recommendations will fulfill the current needs of farmers and help policy-makers recognize the effectiveness of these recommendations, as pulses are one of the most important crops contributing to the economic development of Myanmar.

Chapter 3

Evaluation of Climate Effects on Technical Efficiency of Pulse Farms in Central Dry Zone of Myanmar

3.1 Introduction

In this Chapter, technical efficiency considering climate effects for the pulse farmers in Central Dry Zone (CDZ) of Myanmar will be empirically estimated.

Sherlund et al. (2002) revealed that traditional agriculture greatly relies on the environmental production conditions and under unfavorable conditions, farmers will allocate more production inputs to achieve high yield. Battese et al. (1996) noted the influences of weather variables on the technical efficiency estimation process and suggested to include these variables in the stochastic frontier model. In production efficiency analysis negligence of taking into account, the environmental production conditions such as rainfall, temperature, pest infestation and plant disease result in biased estimates of the parameters and overestimate of the technical inefficiency (Ali and Byerlee, 1991; Hasan et al., 2008; Sherlund et al., 2002). The most production efficiency analysis did not consider the effect of changes in climate conditions (Chavas and Cox, 1995; Hoang, 2013; Koeijer et al., 1999).

Therefore, in this analysis, weather variables such as rainfall and temperature will be incorporated into the stochastic frontier model to avoid biased estimates of the parameters and overestimation of the technical inefficiency.

3.1.1 Pulses in Central Dry Zone of Myanmar

In Myanmar, pulses are the second most important crops after rice and a major source of export earning among agricultural crop products. Depended on the location of pulses grown, different kinds of pulses are grown over the country. Pigeon pea, chickpea and green gram are

widely grown in Mandalay, Magwe and Sagaing Regions of CDZ of Myanmar while the mainly cultivated pulses in Lower Myanmar are green gram, black gram and cowpea.

In Myanmar, pigeon pea is the third most important pulse after green gram and black gram. In CDZ, most farmers mainly cultivate it by intercropping or mixed cropping with some crops such as sesame, groundnut, sorghum, cotton, green gram, cowpea and chickpea. Traditionally it is mainly grown under rain-fed condition by using traditional long-duration (>200 days) varieties (Kyu et al., 2016). As it is a rain-fed crop, it normally sows at the beginning of May along with the first rain occurrence and harvests in December. Therefore, the crop has to face the serious drought of June-July in the early vegetative stage, and terminal drought in the reproductive stage as Magwe and Mandalay Regions are the drought-prone areas. As a result, it is common for crop failure problem which causes a significant reduction in yield loss and consequently leads to farmers' economic loss (Kyu et al., 2016). Most of the farmers in the survey area grow pigeon pea as a main standing crop and green gram, chickpea and cowpea are grown as a sole or mixed or intercropped with pigeon pea, sesame and groundnut. Only some or few farmers cultivate green gram, chickpea and cowpea as a pre-monsoon crop from May to August and as a winter crop from October to January (Figure 1.6).

3.1.2 Rainfall pattern during the pulse growing season

As a drought-prone area, CDZ has less rainfall with the average annual rainfall of 750 millimeters (mm) being high variability throughout the year, high temperature and shifting monsoon onset.

Monthly rainfall received during the growing season of 2015-2016 in the survey areas of Mandalay and Magwe Regions was illustrated in Figure 3.1. It can be seen that rainfall received during the growing season of pulses among the study townships highly fluctuates. In May-June, at the early vegetative growth stage of pulses, Myaing and Kyauk Pa Daung townships have minimum rainfall (128 mm and 142 mm) and the maximum rainfall of 196 mm

is, however, received in Magway township. In October when it is the flowering stage of pulses, rainfall received is quite high and is about 300mm in Nwar Htoe Gyi township and rainfalls of other three townships, Myaing, Kyauk Pa Daung and Magway, are about 150, 178, and 179 mm, respectively. Although pigeon pea is a drought tolerant crop, if severe water stress due to less rainfall occurs during the early vegetative growth stage and reproductive stage, plant growth and crop yield will decline significantly (Majumdar, 2011, pg- 64). Drought stress can result in 50% decrease in seed yield of pulses in the tropics (Kumar and Bourai, 2012).

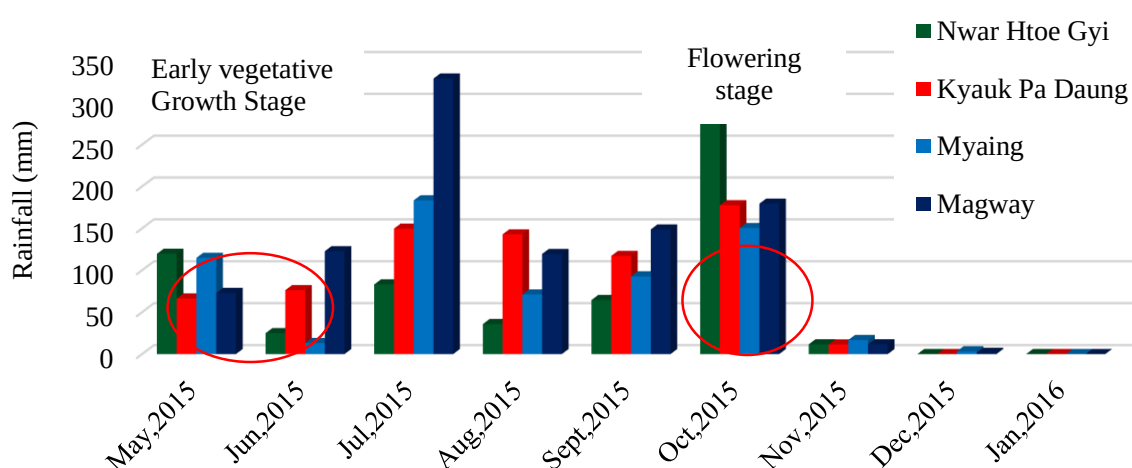


Figure 3. 1 Rainfall (mm) during the 2015 growing season of pulses

Source: DOA, 2016

Figure 3.2 depicted the monthly maximum temperature of the survey areas during the 2015-2016 growing season of pulses. May has the maximum temperature of about 40 degree Celsius, June temperature is about 37 degree Celsius, and in January the maximum temperature is about 30 degree Celsius. All study townships have almost the same temperature along the crop growing season. Rain scarcity along with high temperature causes the plant severe water stress and delay plant growth.

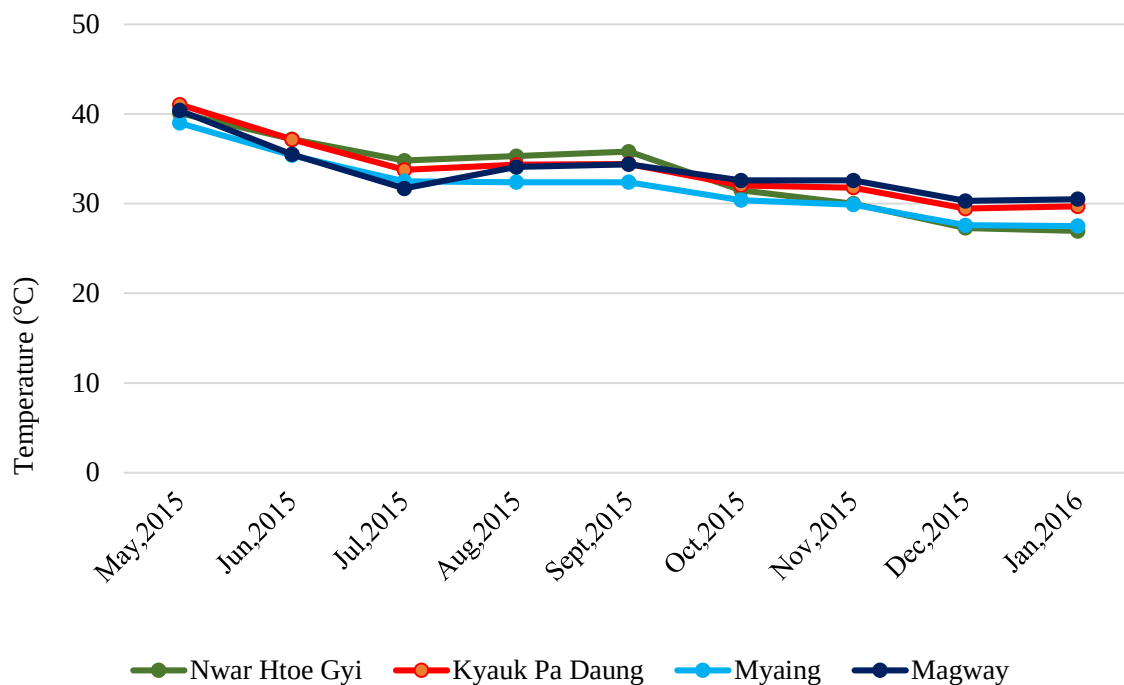


Figure 3. 2 Monthly maximum temperature (°C) during the 2015 growing season of pulses

Source: Department of Meteorology, 2016

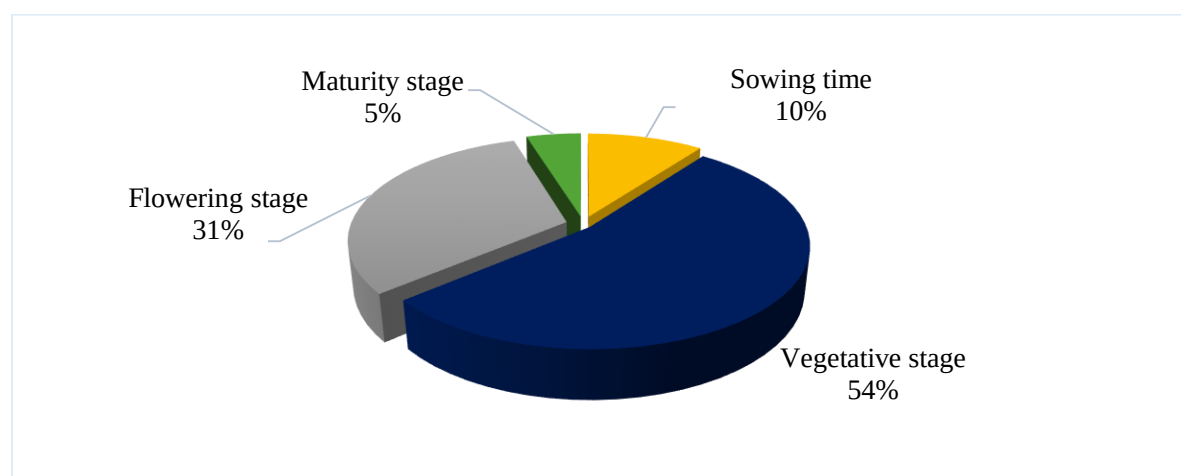
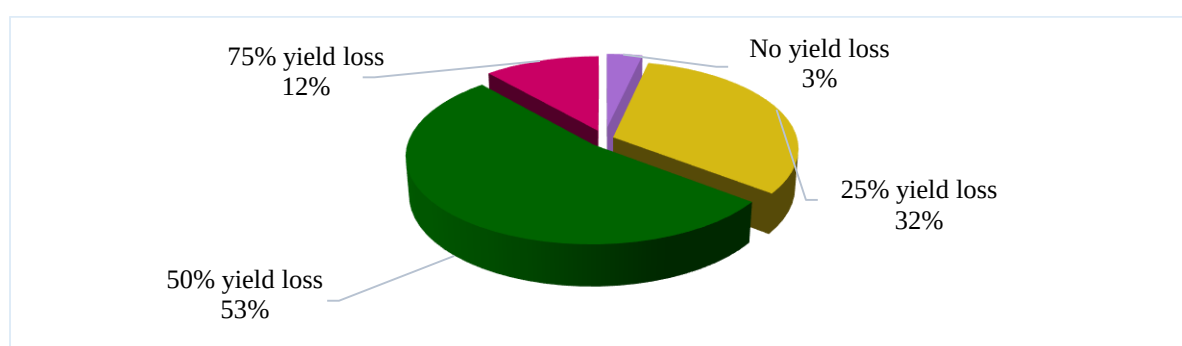


Figure 3. 3 Farmers' response to the stages of pulses encountering rain scarcity during 2015-2016 growing season

Source: Field Survey, 2016

The responded perception of farmers, who encountered rain scarcity during the crop growing season, to different stages of pulses is stated in [Figure 3.3](#). Among 166 farmers interviewed, 17 (about 10%) farmers answered that they faced rain scarcity at the sowing time, while 90 (about 54%) farmers faced at the vegetative stage, 52 (about 31%) farmers at the flowering stage and 8 (about 5%) farmers at the maturity stage.

In [Figure 3.4](#), farmers' evaluation of the yield losses due to rain scarcity is depicted. Of the 166 sample farmers, 111 farmers responded that they encountered the scarcity of rain along the growing season and expressed their perception on yield loss. Among them, 13 farmers (12%) faced 75% yield loss, 59 farmers (53%) reduced yield due to 50% yield loss and 36 farmers (32%) was for 25% yield loss, and only 3 farmers (3%) answered that they did not have any crop loss and got normal yield.



[Figure 3. 4](#) Response of farmers on the different levels of damage due to the scarcity of rain

Source: Field Survey, 2016

Presently the average yield of pulses in CDZ was about 0.99 ton per hectare, while the target and potential yield for pulses is about 0.70 ton per hectare. To find the yield improvement strategies of pulses for protecting farmers from economic loss due to rain scarcity, the first important priority is to assess the current technical efficiency of those farmers and its influencing factors. There are many studies concerned CDZ on climate adaptation strategies overall crops, but no one has not yet touched the technical efficiency analysis of pulses for that area focusing on the climate effects such as rainfall and temperature. Moreover, there are many

technical efficiency studies incorporating annual rainfall and temperature in various countries focusing on various crops. However, to our knowledge, there is no research emphasizing climate effects for the specific growth stages of the crop. This paper will fulfill this research gap.

In this study, the quantity of rainfall (mm) and maximum temperature received during early vegetative and flowering stage of the pulses were included in the production function to empirically estimate the effect of climate on the technical efficiency of pulses in CDZ. This point is the main and original idea of this research. Rainfall data were collected from township office of the Department of Agriculture in the respective townships in the survey area, where the township level rainfall data are recorded on a daily basis. Maximum temperature data were collected from the nearest weather station of the Department of Meteorology in the survey areas. Rainfall has a positive relationship with yield as the study areas are dry zone areas while temperature effect on crop yield cannot be defined early as the effect of temperature on crop yield has sometimes positive or negative.

The main purpose of this research is to explore some policy recommendations for the improvement of the pulse industry along with climate change issue based on evaluating the present performance of pulse farmers. The ultimate objectives were to estimate the technical efficiency of pulse farmers considering with or without rainfall and temperature effects on it as a climate change proxy.

3.2 Research methodology

3.2.1 Analytical framework

The analytical framework for the stochastic frontier production function is the same as in Chapter 2.

3.2.2 Study area and data information

The study was focused on Mandalay and Magwe Regions of Central Dry Zone (CDZ) of Myanmar. These regions contributed to about 1,443,420 hectares (31.0%) of the approximately 4,655,981 hectares of total pulse area in Myanmar. (DOA, MoALI, 2016).

The field survey was carried out from July-August 2016 using structured questionnaires and face-to-face interviews. The multistage sampling method was applied to the selection of the survey area. First, two regions were selected depending on the prevalence of the pulse growing areas and farmers after discussing with the respective regional, district and township managers from the Department of Agriculture. Then, two townships from each Region were selected based on the above categories, and finally, two villages from each township were selected at random for conducting primary data collection from farm households. A simple random sampling technique was used to select 166 farmers to interview. All of the information collected from pulse farmers was based on pulse production activities operated in the growing season from May 2015 to January 2016, as in the study area pulses are grown along with the onset of the monsoon season. The units of all dependent and independent variables appeared in the analysis were weighted to be a reasonable estimation, as almost all of the sample farmers in this study cultivated different kinds of pulse varieties such as pigeon pea, chickpea, green gram, black gram and cowpea on their farms with the cropping pattern of sole or mixed or intercropped cropping with sesame and groundnut.

3.2.3. The empirical model

Stochastic production function (SPF), applying a Cobb-Douglas production frontier function with maximum likelihood techniques, was applied to analyze the data obtained from 166 farmers and simultaneously examined the factors influencing the productivity of the pulse production with a one stage procedure. The analysis was done separately ‘with’ and ‘without’ rainfall and temperature variables during the early growth stage and flowering stage to observe

the consequences of these variables on the production efficiency. The simple specification of the production frontier, which omits the two weather variables, is given as follows:

$$\ln Y_i = \alpha'_0 + \sum_{j=1}^5 \alpha'_j \ln X_{ij} + v'_i - u'_i \quad (3.1)$$

and

$$u'_i = \delta'_0 + \sum_{d=1}^7 \delta'_d Z_{id} + \zeta'_i \quad (3.2)$$

where $\ln$ is a natural logarithm; Y_i is the weighted amount of pulse *yield* for the i^{th} farm measured in tons ha⁻¹; X_i is the j^{th} input, such as the *seed rate* (kilogram (kg)), *fertilizer cost* (Kyats (Ks)), *chemicals* (kg) applied to control pests and diseases, *human labor* (man-day) and *land preparation cost* (Ks) expended by the i^{th} farmer (all of the inputs used were weighted values on a per hectare basis); v_i is the two-sided normally distributed random error; and u_i is the one-sided half normal error. Z_{id} is the variable representing the farm-specific managerial and demographic and household characteristics to explain the inefficiency of the farm, ζ_i is the truncated random variable, and α_0 , α_j , δ_0 and δ_d are the parameters to be estimated. The symbol “'” denotes the model without *rainfall* and *temperature* variables.

Similarly, the full model specification including the variables representing *rainfall* and *temperature* in the production function is written as follows:

$$\ln Y_i = \alpha_0 + \sum_{j=1}^5 \alpha_j \ln X_{ij} + \sum_{m=1}^2 \beta_m \ln R_{im} + v_i - u_i \quad (3.3)$$

and

$$u_i = \delta_0 + \sum_{l=1}^3 \tau_l D_{il} + \sum_{d=1}^7 \delta_d Z_{id} + \zeta_i \quad (3.4)$$

where R_{im} is the variable representing the amount of *rainfall* incidence in millimeters (mm) and *temperature* (°C) during the early growth stage and flowering stage in each township, D_{il} depicts the dummy variables for the different levels of yield losses (75%, 50% and 25% loss compared to no loss), which were reflected the perception of the sample farmers based on the scarcity of rain during the growing season. β_m and τ_l are parameters to be estimated. All other variables are the same as previously defined.

In the stochastic frontier model, a total of five input variables and two variables related to weather proxy are used, and a total of seven farm-specific, demographic and household socio-economic characteristics and three dummy variables representing different levels of yield loss were incorporated into the technical inefficiency effect model. (See Table 1 in the result section for a detail description).

3.3 Results

3.3.1 Summary statistics for the variables used in the models

The definition, units of measurement and detailed descriptive statistics of the dependent and independent variables used in the models are presented in [Table 3.1](#). During 2015-2016 growing season of pulses in the survey areas, the average *rainfall* received at the early vegetative growth (May-June, 2015) and flowering stages (October 2015) was about 152.79 mm and 205.60 mm while the mean of the sum of the maximum *temperatures* was about 76.43 °C and 31.62 °C, respectively.

The results show that the mean *yield* of pulses was about 0.52 ton per ha with a range of 0.60 ton per ha to 3.27 tons per ha. The standard deviation among the yield level was 0.48. The *seed rate* averaged at 16.63 kilograms per ha with a wide variation of 3.06 kilograms per ha to 144.93 kilograms per ha due to different spacing in growing pulses. The wider the spacing between the plants of the pigeon pea, the less the seed rate. The result showed that the *fertilizer cost* also ranged widely from the minimum of 2,900 Kyats (Ks) per ha to the maximum of 327,140 Ks per ha with an average cost of 49,190 Ks per ha. This may be due to the reason that some farmers applied only organic fertilizer which has a cheap price compared to other chemical fertilizers. *Chemicals* applied is less use of averagely only 0.67 kilograms per ha with the minimum amount of 0.00 and maximum 6.50 kilograms per ha. The mean utilization of *human labor* is about 64.15 man-days per ha, showing the wide range of 7.75 man-days per ha minimum and 308.13 man-days per ha maximum. The average *land preparation cost* is about

Table 3. 1 Summary statistics of the output and inputs used in the stochastic frontier production function

Variables	Unit	Mean	Std. Dev.	Min	Max
<i>Yield</i>	Tons per hectare	0.57	0.48	0.06	3.27
<i>Rainfall at early vegetative growth stage ^a</i>	Millimeters	152.79	25.79	128.02	195.58
<i>Maximum temperature at early vegetative growth stage ^a</i>	Degrees Celsius	76.43	1.44	74.40	78.21
<i>Rainfall at flowering time ^b</i>	Millimeters	205.60	63.35	150.37	310.64
<i>Maximum temperature at flowering time ^b</i>	Degrees Celsius	31.62	0.81	30.40	32.60
<i>Seed rate</i>	Kilograms per hectare	16.63	14.83	3.06	144.93
<i>Fertilizer cost ^c</i>	000 Kyats* per hectare	49.19	45.86	2.90	327.14
<i>Chemicals</i>	Kilograms per hectare	0.67	1.01	0.00	6.50
<i>Human labor</i>	Man-days per hectare	64.15	48.78	7.75	308.13
<i>Land preparation cost</i>	000 Kyats* per hectare	56.06	43.71	3.33	261.76
<i>75% yield loss by scarcity of rain ^d</i>	Yes=1,No=0	0.08	0.27	0.00	1.00
<i>50% yield loss by scarcity of rain ^d</i>	Yes=1,No=0	0.36	0.48	0.00	1.00
<i>25% yield loss by scarcity of rain ^d</i>	Yes=1,No=0	0.22	0.41	0.00	1.00
<i>Gender of household head</i>	Yes=1,No=0	0.96	0.19	0.00	1.00
<i>Experience of household head</i>	Years	26.61	12.92	5.00	60.00
<i>Education of household head</i>	Years	6.28	3.51	2.00	16.00
<i>Participation in farmer organization</i>	Yes=1,No=0	0.05	0.23	0.00	1.00
<i>Training access</i>	Yes=1,No=0	0.52	0.50	0.00	1.00
<i>Pulses area</i>	Hectare	2.99	3.09	0.20	23.00
<i>Location</i>	1=Mandalay, 0= Magwe	0.49	0.50	0.00	1.00

^a The amount of May-June rainfall occurred and the maximum temperature received at the early vegetative growth stage during the 2015–2016 growing season in each survey areas. The maximum temperature is summed up for the two months of the early vegetative growth stage of pulses.

^b The amount of October rainfall occurred and the maximum temperature received at the flowering stage during the 2015–2016 growing season in each survey areas.

^c Fertilizer cost composited of the cost of organic manures such as cow dung, chicken dung and goat dung and chemical fertilizers including nitrogenous, phosphate, potash and compound fertilizers and other foliar fertilizers as it is very difficult to calculate the applied quantity of organic manures which are used in various unit measures such as in cart, in bag, in basket.

^d Totally reflects the perception of farmers on the level of yield loss due to rain incidence. 75% loss of yield represents that third-fourth of pulse yield was decreased by low rain, while 50 % and 25% yield losses mean half and one-fourth of reduction of yield due to rain scarcity during the 2015-2016 pulse growing season.

* 1 US\$ = 1342 Kyats (as of 17 May 2018).

Source: Own estimates

64,150 Ks per ha ranging from 3,333 Ks per ha to 26,1760 Ks per ha depending on times of harrowing which is highly relied on rain incidence as farmers often harrowed their farm, again and again, to keep the soil loose before first rain occurrence. In the survey areas, as soon as the first rain started, the farmers immediately starts sowing the crops.

Among sample farmers, 8% of them responded that they faced *75% yield loss due to the scarcity of rain* consequently crop growth retard and failure while 36 % and 22% answered that they got 50% and 25% reduction of yield.

96 % of farm household head are male with about averagely 27 years of experience and the average educational level is about six years meaning most of them are at the secondary school level. Only 5% of farmers participated in a farmer organization, and 52% of farmers received the training conducted by the Department of Agriculture (DOA) for the cultural practices, pest and disease management and fertilizer application of pulse cultivation. Compared to farmers in Lower Myanmar, farmers in CDZ have more training access due to many international projects in CDZ collaborating with DOA. The mean pulse sown area is about 3 hectares with 0.20 hectare minimum and 23 hectares maximum.

3.3.2 Description of specific rainfall and temperature effects on productivity

In the production function analysis, the omission of the weather variables which were assumed to be truly exogenous would lead to an upward bias of the firm-specific technical efficiency (Sherlund, 2002). Therefore, in this study, the weather information such as *rainfalls* and *maximum temperatures at the early growth and flowering stages* would be incorporated in the full specification of the model to avoid the bias estimation. Table 3.2 shows the results of the correlation of the inputs used in the production and *rainfalls* and *maximum temperatures*. *Rainfall at the early growth stage* has a negative significant correlation with *seed rate*, indicating that if the rain was scarce at the early growth stage, the use of seed rate has to be high to keep enough plant population. Moreover, *fertilizer cost* and *land preparation cost* also

negatively and significantly correlated with the *rainfall at the early growth stage*, meaning the fertilizer application and land preparation would be more effective with the access of rain. The correlation of *maximum temperature at the early growth stage* with *fertilizer cost*, *chemicals* and *human labor* was positively significant at 1% and 5% levels. It highlights that the higher the temperature, the less efficient in the use of fertilizer, chemicals and land preparation for the farmers. Furthermore, the *maximum temperature at the flowering time* also has a positive significant correlation with the *human labor* at 5% level while it is negatively correlated with *land preparation cost*. The other input variables and weather variables have an insignificant and weak relation but non-zero correlation. This kind of weak and strong correlation between the production inputs and weather variables was also presented by other studies such as Sherlund et al. (2002), Mar et al. (2018), Rahman and Hasan (2008) and Hasan et al. (2008).

Table 3. 2 Correlation among inputs and rainfall and temperature effects

	<i>Seed rate</i>	<i>Fertilizer cost</i>	<i>Chemicals</i>	<i>Human labor</i>	<i>Land Preparation cost</i>
<i>Rainfall at early vegetative growth stage</i>	-0.189**	-0.169**	-0.078	-0.074	-0.205***
<i>Maximum temperature at early vegetative growth stage</i>	0.116	0.268***	0.168**	0.402***	-0.019
<i>Rainfall at flowering time</i>	0.030	-0.071	0.033	0.119	0.032
<i>Maximum temperature at flowering time</i>	-0.092	0.029	0.031	0.159**	-0.185**

Note: *** and ** represent significance at the 1% ($p < 0.01$) and 5% ($p < 0.05$) levels, respectively.

Source: Own estimates

3.3.3 Parameter estimates of the stochastic frontier production function

Table 3.3 depicted the results of the hypothesis testing. First, a log-likelihood ratio (LR) test was conducted using the log-likelihood values of the both short (without weather variables) and full (with weather variables) specification to test the hypothesis that the short specification of the model is enough. $LR = -2[\ln L(H_0) - \ln L(H_1)] \sim \chi^2(J)$ where $\ln L(H_0)$ and $\ln L(H_1)$ are log-likelihood functions of restricted and unrestricted frontier models and J is the

number of restrictions (Coelli et al., 2005). The LR test result of one-sided error was 11.8 and the critical value of χ^2 (5, 0.95) was 11.07, rejecting the null hypothesis at 5% level of significance and explaining the full specification is necessary.

Secondly, the null hypothesis of no effect of weather variables on productivity was also rejected at 1% level of significance, indicating these *rainfall* and *temperature* encountered at specific growth stages of pulses affected the yield of the pulses, and the full specification is worth to be done.

Table 3. 3 Tests of hypothesis

Hypothesis	Critical Value of χ^2 (d.f,0.99)	Without rainfall effects		With rainfall effects	
		LR statistic	Decision	LR statistic	Decision
1 to test the statistical superiority of the full specification (Short specification without weather variables is enough)	χ^2 (5, 0.95) = 11.07	-	-	11.80**	reject
2 No effect of weather variables on productivity (H0: $\beta_1=\beta_2=\beta_3=\beta_4=0$)	χ^2 (4, 0.99) = 13.28	-	-	28.16***	reject
3 Constant return to scale in production (H0: $\alpha_1+\alpha_2+\dots+\alpha_5=1$)	χ^2 (5, 0.90) = 9.24	0.32	accept	0.002	accept
4 Absence of technical inefficiency (H0: $\gamma=0$)	χ^2 (1, 0.90) = 2.71	3.94*	reject	3.72*	reject
5 No effect of managerial variables on efficiency (H0: $\delta_5=\delta_6=\dots=\delta_{13}=0$)	χ^2 (7, 0.90) = 12.02	32.06*	reject	14.04*	reject

Note: ***, ** and * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level.
Source: Own estimates

Third, to test the null hypothesis of constant return to scale of the functions, the restricted frontier analysis was performed for both specifications. As a Cob-Douglas production function was applied to estimate the technical efficiency of pulse farmers, the coefficient values of the variables can be interpreted as direct elasticities of the function. The total elasticity of the stochastic frontier production function can explain how the proportionate

changes in the yield of pulses when the change in inputs used during the production process. The LR test statistics for the null hypothesis of the constant return to scale in Table 3 were reported that it was accepted in both model, especially in full specification, indicating that the production function is under constant to scale indicating that one percent increase in inputs used would constantly increase the yield of pulse, *ceteris paribus*.

Then, the null hypothesis of the presence of the technical inefficiency in both specification was rejected by the results of LR tests shown in Table 3.3 at 10% level of significance. The results were also strongly supported by the γ values of both specifications in Table 3.4 where γ values were statistically significant at 10% level in the short model and 1% level in the full model. Moreover, the results explained that 61.40% of the variation in a composite error term is due to technical inefficiency in the short specification and 99.99% of the variation in the full specification, and farmers are operating pulse production below technical efficiency threshold.

The hypothesis tests of no effect of managerial variables on efficiency were rejected at 10% level in both specifications, revealing that pulse farmers' managerial factors are also important indicators for the improvement of the technical efficiency of the farmers.

Moreover, the null hypothesis of no effect of level of yield loss due to rainfall and temperature on technical efficiency was also tested and accepted although the farmers' perception on levels of yield loss was expected the negatively significant effect on the technical efficiency level. The result is totally reflected the farmer' perception on yield.

The maximum likelihood estimation of the Cob-Douglas stochastic frontier production function and inefficiency model are performed by using Frontier 4.1 software by Coelli (1996) for both short (without weather variables, *rainfall and temperature at the early vegetative growth and flowering stages*) and full specifications (with weather variables). The results are described in Table 3.4. Although the sign of the *rainfall at the early vegetative growth stage*

and *temperature at the flowering stage variables* are positive as expected, they are not significant. The *temperature at the early vegetative growth stage* has a positive significant effect on pulse yield at 1% level, revealing that high temperature can encourage the vegetative growth of the pulse. However, *rainfall at the flowering stage* is positively significant at 1% level indicating that rainfall can encourage the reproductive growth of the pulses through the provision of the required moisture for flowering.

In both specifications, the estimated coefficients of *seed rate*, *fertilizer cost*, *chemicals* and *human labor* were statistically significant at 1%, 5% and 10% level, respectively, with a positive relationship with the yield of the pulses. However, the significant effects are stronger in full specification incorporating weather variables. In full specification, *land preparation* variable was positive and significant at 1% level, indicating that *land preparation* is an important activity for the achievement of the high yield through keeping high soil moisture content in the CDZ. This result contradicts the result of Mar et al. (2018) in which *land preparation* of the pulses in Lower Myanmar has a negative significant effect. This contradiction may be due to the different purpose of farmers' practice on land preparation dependent on the location of the study area even in the same country as in Lower Myanmar it was done for replanting again after damage of crop by rain and, but in CDZ it was done for retaining enough required soil moisture for the crop growing.

. The positive relation of *seed rate* with increase productivity is consistent with the findings of Kyi and Oppen (1999) for rice in Myanmar, Haque et al. (2014) for mung bean in Bangladesh, Sibiko et al. (2013) for common bean in Uganda and Mar et al. (2018) for pulses in Lower Myanmar. Moreover, the positive result of *human labor* in this study is also in conformity with the studies of Haque et al. (2014), Latt et al. (2011) for sesame in Myanmar and Mar et al. (2018).

3.3.4 Factors influencing the technical efficiency of the farmers

In the lower part of Table 3.4, the results of technical inefficiency estimation for both models are presented. In full model, the coefficients of the farmers' perception on the different level of yield loss due to the scarcity of rain were positively but not significantly affected on technical efficiency although these variables were expected to have a positive significant relation on technical inefficiency. The only feasible reason for these unexpected result may be due to the weak correlation of these yield loss variables with other managerial variables as these yield loss variables totally represent only for the farmers' perception.

In inefficiency analysis for both models, the coefficients results of *gender* and *pulse area* have a positive and significant effect on technical inefficiency at 10% and 1% level, respectively, indicating the performance of female household head and small-scale farmers are more efficient than the male head and large-scale farmers. This result that female farmers are more efficient than male farmers is also in conformity with the result of Hasan et al., (2008) for pulse farmers in Bangladesh. These results are, however, opposite to the finding of Mar et al. (2018) in their study of Lower Myanmar. This may be because of the different nature of the location, production pattern and weather effect. In addition, female empowerment in the study areas will be more important compared to Lower Myanmar.

The finding that small-scale farmers are more efficient than large-scale farmers is also in line with the results of Bravo-Ureta and Pinheiro (1997) for peasant farming in the Dominican Republic, Latt et al. (2011) for sesame farmers in Myanmar, Ogada et al. (2014) for food crop farmers in Kenya, Sherlund et al. (2002) for rice farmers in Africa. The result, however, contradicts the findings of Mar et al. (2018) for pulse farmers in Lower Myanmar, Rahman and Hasan (2008) for wheat farmers in Bangladesh. Besides, the previous research of (Coelli and Battese, 1996) mentioned that smaller farmers tend to be more efficient in production than larger farmers with the intensive management.

Table 3. 4 Maximum likelihood estimates for parameters of the Cobb-Douglas production function

Variables	Without weather variables			With weather variables		
	Coefficients	Std. Error	t-ratio	Coefficients	Std. Error	t-ratio
Production function						
Constant	-3.413***	0.944	-3.616	-25.259***	3.577	-7.062
<i>Rainfall at early vegetative growth stage</i>	-	-	-	0.080	0.173	0.462
<i>Temperature at early vegetative growth stage</i>	-	-	-	3.362***	0.341	9.850
<i>Rainfall at flowering time</i>	-	-	-	0.517***	0.186	2.776
<i>Temperature at flowering time</i>	-	-	-	1.062	2.020	0.526
<i>Seed rate</i>	0.227***	0.082	2.785	0.244***	0.072	3.402
<i>Fertilizer cost</i>	0.147**	0.063	2.321	0.200***	0.062	3.218
<i>Chemicals</i>	0.071*	0.043	1.665	0.076*	0.042	1.811
<i>Human labor</i>	0.197**	0.088	2.242	0.181***	0.063	2.873
<i>Land Preparation cost</i>	0.070	0.065	1.077	0.100***	0.025	3.914
Variance Parameter						
$\sigma^2=\sigma_u^2+\sigma_v^2$	0.290	0.041	7.143	0.258	0.028	9.136
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	0.614	0.352	1.743	0.99	0.029	34.716
Log Likelihood Function	-126.975			-121.067		
Technical Inefficiency Effects Function						
Constant	1.291**	0.633	2.040	1.388***	0.239	5.801
<i>High yield loss by scarcity of rain</i>	-	-	-	0.178	0.175	1.020
<i>Moderate yield loss by scarcity of rain</i>	-	-	-	0.022	0.100	0.220
<i>Slight yield loss by scarcity of rain</i>	-	-	-	0.032	0.123	0.260
<i>Gender of household head</i>	0.555*	0.322	1.727	0.550***	0.167	3.284
<i>Experience of household head</i>	-0.119	0.097	-1.221	-0.102	0.081	-1.263
<i>Education of household head</i>	-0.177*	0.100	-1.769	-0.121	0.091	-1.329
<i>Participation in farmer organization</i>	-0.181	0.213	-0.849	-0.193	0.173	-1.117
<i>Training access</i>	-0.156	0.098	-1.588	-0.144*	0.087	-1.651
<i>Pulses area</i>	0.200***	0.067	2.958	0.163***	0.050	3.266
<i>Location</i>	-0.340***	0.131	-2.593	0.002	0.135	0.017
Total Number of Observations				166		

Note: ***, ** and * represent significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) levels, respectively. Std. Error means standard error.

Source: Own estimates

The estimated coefficient of *education* is negatively and statistically significant at 10% level on technical inefficiency in the short model, showing that the higher education level of the farmers, the higher the technical efficiency, it was, however, not significant in the full model.

The result of *location* variable was also positively significant at 1% level in the short model, but it was not an important variable for the full model. This result indicated that under consideration of the weather variables, both of the regions of the study area has the same weather pattern as these regions are located in CDZ. In full specification, farmers' *access to training* of the farming practices is positively and statistically significant on technical inefficiency at 10% level, indicating the more *training access* by farmers, the lower the technical inefficiency.

3.3.5 Frequency distribution of the technical efficiency in both models

The frequency distribution of the technical efficiency indices of the pulse farmers in both specification is shown in [Figure 3.6](#) in which incorporating the weather variables in the full specification of the production function can be obviously proved the wider distribution of the technical efficiency than in the short specification. In [Table 3.6](#), the mean, minimum and maximum technical efficiency level of both specifications are depicted. In this study, the mean technical efficiency was quite low, and it is about 40% under the short specification and about 27% in the full specification. The results indicate the omission of weather variables can be overestimated technical efficiency of about 13% than under the full specification. This result contradicts with the findings of Rahman and Hasan (2008), Sherlund et al. (2002), Hasan et al. (2008) and Mar et al. (2018) in their studies under incorporating weather and environmental conditions variables; the technical efficiency level is understated. Moreover, about 87% of the farmers are operating below 40% of efficiency level under full specification while it is about 56% under the short specification. Compared to Lower Myanmar in which the mean technical

efficiency level of pulse farmers was about 86% in both specifications, the result of the technical efficiency level in CDZ was lower than 46% in the short specification and 59 % in the full specification. This difference might be mainly due to the difference in climate condition.

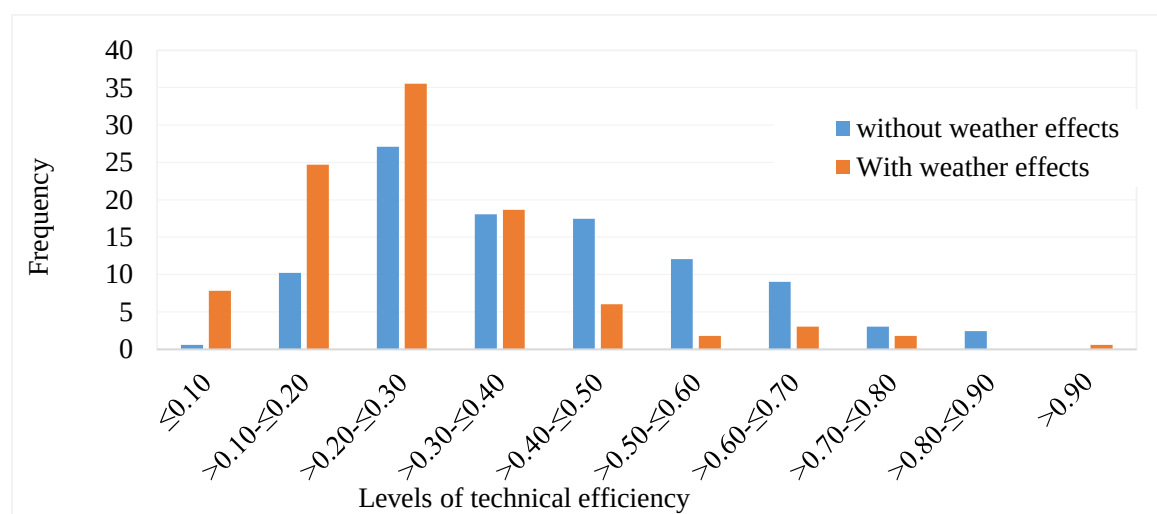


Figure 3. 5 Frequency distribution of technical efficiency of pulse farmers

Source: Own estimates

Table 3. 5 Mean, minimum and maximum technical efficiency of pulse farmers

Items	Without rainfall and temperature	With rainfall and temperature
Mean	0.40	0.27
Minimum	0.09	0.04
Maximum	0.82	0.99
Standard Deviation	0.17	0.15
t-test for difference in mean efficiency score between alternative models	7.03 ***	(2.576)

Figure in parenthesis is the t-ratio.

***significant at 1%level ($p < 0.01$).

Source: Own estimates

3.4 Conclusion and policy recommendations

In correlation analysis, there is a negatively strong correlation between the production inputs such as *seed rate*, *fertilizer*, *chemicals* and *land preparation*, and *rainfall at the early vegetative growth stage*. However, *maximum temperature at the early vegetative growth stage* is positively and strongly correlated with *fertilizer cost* and *human labor* and moderately related

to *chemicals*. Moreover, *maximum temperature at the flowering stage* has a positive and moderately strong correlation with human labor and land preparation.

There is a high opportunity for the farmers to improve technical efficiency. The present result highlights the need for improvement in the technical efficiency of about 60% under the short specification and 73% under the full specification without changing the current level of input used. *Rain and temperature received at the early growth stage and flowering stage* can increase the productivity of pulse. However, the study areas are dry zone area and the feasible and possible ways to help farmers from loss by drought are to provide drought resistant varieties, adaptation measures for drought and establishment of weather index-based crop insurance policy and program for farmers as a safety tool from the loss of the drought.

In the production function results, the strong and positive significant effect of *seed rate*, *fertilizer* and *human labor* in weather variables incorporated model revealed that the effectiveness in use of these input factors is highly depended on the availability of enough soil moisture by mean of rainfall, and then temperature for photosynthesis. The results also indicate that availability of rainfall and temperature at the specific growth stages of the pulses would be affected not only the productivity of pulses but also the effectiveness of the application of these variables.

In efficiency estimation results, under consideration of weather variables in the full specification, *gender*, *training* and *pulse area* are important variables. Male farmers are less efficient than female farmers suggesting that in conducting the improvement program of technical efficiency of the farmers, male farmers' participation should be more emphasis. Performing training is also a crucial activity for the increase of the farmers' technical efficiency, especially paying more attention to the participation of large-scale farmers in the study areas.

The coefficient of *pulse area* variable had a positive and significant relationship with inefficiency. The result can be interpreted that if large-scale farmers have many field plots

which make them difficult to manage intensively as large farms need higher managerial skill than small farms so as to pay more attention in conducting training and field visit programs for farming technology distribution to farmers.

Chapter 4

Evaluation of erratic rainfall effect on profit efficiency of pulses farmers in Lower Myanmar

4.1 Introduction

Although pulses are very important crops for not only domestic consumption but also the export potential for foreign exchange earning contributing to the economic development of Myanmar, pulse farmers are facing economic loss due to unpredictable and erratic weather conditions. In the previous literature, climate change can have serious impacts for economic development, especially in the agricultural sector, due to its direct exposure to and dependence on the weather and other natural conditions (Yu et al., 2010). Studies for the Southeast Asian region show that climate change could lower agricultural productivity by 15–26 % in Thailand, 2–15 % in Vietnam, 12–23 % in the Philippines, and 6–18 % in Indonesia (Yu et al., 2010; Yu et al., 2009). But it has not yet studied for Myanmar. This study will help evaluate the economic impact of climate variability through the consideration of erratic rainfall effects on the profit efficiency of the pulse farmers in Lower Myanmar.

Analyzing profit efficiency provides a more valuable source of information for policymakers than the partial vision offered by computing cost efficiency (Maudos et al., 2002). Estimating a frontier profit function seizes the firm level production specified factors, thus allowing the higher revenues reserved by the firms that produce differentiated or higher quality output to compensate for the higher cost incurred (Kolawole, 2006).

Although there are considerable efforts on the estimation of technical efficiency of farmers in Myanmar (Aung, 2011; Kyi and Oppen, 1999; Latt et al., 2011; Mar et al., 2013; Myint and Kyi, 2005; Win, 2004), profit efficiency analysis has been paid little attention, especially on the focus of incorporating weather variable to assess the erratic rainfall effects. This study aims to assess the effects of impact of rain incidence on the profit efficiency level

of the pulse farmers by separating two groups in which the loss group included the farmers who faced yield loss due to erratic rain incidence during the flowering stage of the pulses and the other is no loss group with the farmers who did not face any yield loss due to rain with the following detail objectives:

1. to estimate the benefit-cost of pulse production under consideration of yield loss which is perceived by farmers during the survey,
2. to analyze the profit efficiency of pulse farmers under consideration of rainfall effects,
3. to assess the difference in profit efficiency levels between farmers who faced yield loss and no yield loss by rain incidence during the growing season of pulses, and
4. to determine the factors affecting the efficiency levels of the farmers.

4.2 Research methodology

4.2.1 Analytical framework

Following Farrell's (1957) seminar work, efficiency studies have been proliferated in all fields. However, the original proposed works of (Aigner et al., 1977; Meeusen and van Den Broeck, 1977) in modeling and estimating of stochastic frontier function has been valuable proved in measuring efficiency in the field of agriculture. As defined by Farrell, efficiency is the ability of a farm to produce a given level of output at the lowest cost. In estimating efficiency, the stochastic frontier function is the most popular approach used by many scholars (Coelli et al., 2005; Rahman, 2003). When estimating economic efficiency of individual farms, a production function approach may not be suitable as the farms may face different prices and have different endowments. Therefore, farm-specific prices of the inputs used should be incorporated into the analysis in the estimation of efficiency as argued by (Yotopoulos and Lau, 1973). In the context of profit function, profit efficiency is the ability of the farm to achieve the maximum possible profit, given the prices and levels of the current inputs used (Ali and Flinn,

1989). In this study, to estimate the farm-specific profit efficiency of the pulse farmers under consideration of yield loss by rain incidence incorporating rainfall and replanting variables in the model and to identify the factors affecting the efficiency level, the stochastic frontier profit function is applied as in Battese and Coelli (1995). The stochastic frontier profit function with weather-related variables, rainfall and dummy for replanting, is specified as follow:

$$\pi_i = f(P_{ij}, X_{ij}, W_{ij}) + \varepsilon_j \quad (4.1)$$

and the specification of the model without weather-related variables is defined as;

$$\pi_i^* = f(P_{ij}^*, X_{ij}^*) + \varepsilon_j^* \quad (4.2)$$

where π_i in the model with rainfall and dummy for replanting and π_i^* in the model without rainfall and dummy for replanting are normalized profits of the i th farmer defined as gross revenue less variable cost divided by the farm-specific price of output; P_{ij} and P_{ij}^* are the vectors of j th variable input prices paid by the i th farm divided by output price; X_{ij} and X_{ij}^* are the vectors of j th variable inputs used by the i th farm divided by output price; W_{ij} is the vector of weather related variables, rainfall (millimeter, mm) and a dummy for replanting which was practiced by farmers when they encountered crop damage by heavy rain at the sowing time of pulses; ε_i and ε_i^* in each model is a composed error term (Aigner et al., 1977; Meeusen and van Den Broeck, 1977). The error term is defined as:

$$\varepsilon_i = v_i - u_i \quad (4.3)$$

The two error components v_i and u_i are assumed to be independent of each other. The v_i represents a random error or variations in output that are assumed to be independent and identically distributed as $N(0, \sigma_v^2)$ due to factors outside the control of farmers as well as the effects of measurement errors in the output variable and stochastic noise.

The u_i is a non-negative random variable, associated with inefficiencies of production, which are assumed to be independently distributed such that u_i is obtained by truncation (at zero) of the half- normal distribution ($u \sim |N(0, \sigma_u^2)|$) with mean δZ_i , and variance, σ^2 (Battese

and Coelli, 1995; Coelli et al., 2002). Z_i is a vector of explanatory variables associated with profit inefficiency of pulse farmers over time and δ is a vector of unknown parameters to be estimated. In other words, the term u_i measures the profit shortfall from its maximum possible value given by the stochastic frontier (Ali and Flinn, 1989). The inefficiency effect, u_i , in the stochastic profit frontier model could be specified as below;

$$u_i = \delta Z_i + \xi_i \quad (4.4)$$

where ξ_i is defined by the truncation of the normal distribution with zero mean and variance, σ^2 , such that the point of truncation is $-\delta Z_i$ i.e., $\xi_i \geq -\delta Z_i$. These assumptions are consistent with u_i being a non - negative truncation of the $N(\delta Z_i, \sigma^2)$ distribution.

The maximum likelihood method is used to estimate the unknown parameters, with the stochastic frontier and inefficiency effect functions estimated simultaneously. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ (Battese and Coelli, 1995). So that $0 \leq \gamma \leq 1$. Therefore, the profit efficiency (PE) of the j th farm is specified as:

$$PE_j = \exp(-\hat{u}_i) = \exp\{-E(u_i|\varepsilon_i)\} \quad (4.5)$$

The assumptions of the statistical distributions of v_i and u_i , making it possible to calculate the conditional mean of u_i given ε_i is shown in the study of Jondrow et al. (1982) as;

$$E(u_i|\varepsilon_i) = \sigma * \left[\frac{\left\{ f^*\left(\frac{\varepsilon_i \lambda}{\sigma_i} \right) \right\}}{\left\{ 1 - F^*\left(\frac{\varepsilon_i \lambda}{\sigma_i} \right) \right\}} \right] - \left(\frac{\varepsilon_i \lambda}{\sigma_i} \right) \quad (4.6)$$

where f^* and F^* are the standard normal density and distribution functions respectively, evaluated at $\varepsilon_i \lambda / \sigma_i$, and $\sigma_i = \sigma_v^2 + \sigma_u^2 / \sigma^2$.

The level of profit efficiency lies between 0 and 1, indicating if $u_i = 1$, the farmer is efficient in profit and if $u_i < 1$, the farmer is inefficient in profit. The profit efficiency of the farmers are estimated by using the Frontier 4.1 software developed by Coelli (1996).

4.2.2 Study area and data collection

The study area, sample size and data collection technique are the same as in Chapter 2.

In this Chapter, the information of the input prices is used from the collected data in Chapter 2. According to the perception and response of farmers on yield loss due to rain incidence, they are separated into two groups: (1) loss group: the farmers faced yield loss due to rain incidence in the growing season of the survey year, and (2) no loss group: the farmers who did not face yield loss by rain incidence. Among the 182 sample farmers, 73 farmers responded that they faced yield loss so that they will be put under loss group, while 109 farmers replied that they did not face any yield loss and thus they will be under no loss group.

4.2.3 Empirical model

In analyzing the data of each group, to observe the consequences of rainfall incidence during the flowering stage of pulses on the profit efficiency, there two models: Model (1): the profit function with incorporating *rainfall* and dummy variable for *replanting*, and Model (2): the profit function without incorporating *rainfall* and dummy variable for *replanting*. In loss group, the total sample farmers who faced yield loss by rain is 73 farmers, and in no loss group, the total respondents who did not face any yield loss by rain are 109 farmers. The reason to incorporate rainfall variable and a dummy variable for replanting is by assuming that if the farmers encountered erratic rainfall during the growing season, this rain can not only damage the growth of the pulses but also make farmers busier for the resilience of the damage which causes farmers to use more inputs and need more managerial skill.

In this study, the data were analyzed using a stochastic production function (SPF), applying a Cobb-Douglas production frontier function with maximum likelihood techniques, which examined the factors influencing the productivity of the pulse production that had a direct impact on farmer income and profits from pulse production.

Thus, the traditional specification of the profit frontier model (1), which incorporates the two weather-related variables in the loss group and no loss group, is given as follows:

$$\ln \pi_i = \alpha'_0 + \sum_{j=1}^5 \alpha'_j \ln P_{ij} + \sum_{j=1}^4 \beta'_j \ln X_{ij} + \tau'_{i1} \ln W_{i1} + \tau'_{i2} D_{i2} + v'_i - u'_i \quad (4.7)$$

and

$$u'_i = \delta'_0 + \sum_{d=1}^9 \delta'_d Z_{id} + \xi'_i \quad (4.8)$$

where $\ln$ is a natural logarithm; π_i is the normalized profit (total revenue less the total cost of variable inputs) normalized by the price of the output of pulses for the i th farm; P_{ij} is the price of j th input normalized by the output price, where P_S is the price of seed, P_F is the price of fertilizer, P_C is the price of chemicals, P_L is the price of human labor, P_{LP} is the price of animal and machinery power per hectare of pulses; X_i is the quantity of j^{th} input, such as the *seed rate* (kg), *fertilizer* (kg), *chemicals* (kg) applied to control weeds, pests and diseases, *human labor* (man-day) (all of the inputs used were weighted values on a per hectare basis); W_i is the magnitude of rainfall (mm) received by i th farm; D_i is a dummy variable for replanting, in which, if farmers who encountered rain incidence at the sowing time replanted the pulses again, it is 1, and if no replanted, it is 0; v_i is the two-sided normally-distributed random error; and u_i is the one-sided half normal error. Z_{id} is the variable representing the farm-specific managerial, demographic and household characteristics such as dummy variable for *gender* (male = 1, female = 0), *age* of household head (years), *farming experience* of the household head, *education* level (years) of the household head, dummy variables for *access to government credit* (yes = 1, no = 0), *participation in farmer organization* (yes = 1, no = 0), *access to training* (yes = 1, no = 0) conducted by the Department of Agriculture, *location* dummy (Bago Region = 1, Yangon Region = 0), and *pulses area* (hectares), to explain the inefficiency of the farm, ξ_i is the truncated random variable, and α_0 , α_j , δ_0 , and δ_d are the parameters to be estimated. The symbol “’” denotes the model with *rainfall* and dummy variables for *replanting*.

For model (2) of both groups, the profit frontier without rainfall and dummy variable for replanting is as:

$$\ln \pi_i = \alpha_0 + \sum_{j=1}^5 \alpha_j \ln P_{ij} + \sum_{j=1}^4 \beta_j X_{ij} + v_i - u_i \quad (4.9)$$

and

$$u_i = \delta_0 + \sum_{d=1}^9 \delta_d Z_{id} + \xi_i \quad (4.10)$$

where all variables are the same as previously defined.

4.3 Results

4.3.1 Comparison of the benefit-cost of the pulse production between loss and no loss groups

The benefit-cost analysis of the pulse farmers who faced yield loss (hereinafter, loss group) and no yield loss (hereinafter, no loss group) was calculated separately. Table 4.1 shows the information of the cost and benefit of per hectare pulse production. The profit the farmers attained was calculated by subtracting total costs from total revenue.

In Table 4.1, the average yield and weighted price per ton of pulse are almost the same between the groups. The total revenue of loss group was about 1,276,921 Ks per ha, and in no loss group, it was about 1,252,770 Ks per ha. The total revenue of the two groups is not much different. However, the cost of seed price, chemicals and land preparation is much higher in loss group compared to no loss group. The main reason of the difference between the two groups was if the farmers from loss group faced rain incidence and crop damage by rain during the growing season, some farmers have to replant, consequently, have to use more seed and do more land preparation, and some have to use more chemicals for pest and disease protection. Moreover, about 25% of farmers from loss group replanted their pulses while in no loss group no farmer replanted.

As a result, the total variable cost (TVC) of farmers from loss group was about 1,063,390 Ks per ha while in no loss group it was about 888,335 Ks per ha. The cost difference

was about 175,055 Ks per ha. Therefore, the net profit of the groups was about 213,530 Ks per ha in loss group and 364,435 Ks per ha in no loss group with a difference of 150,905 Ks per ha which is superior by no loss group. It can be concluded that the difference is due to crop damage by rain incidence and that the farmers who faced loss need to invest more capital for pulse production than no loss farmers, proving that rain incidence during the growing season of pulses can reduce the profitability of the farmers.

Table 4. 1 Benefit-cost analysis of loss farmers and no loss farmers

	Theme	Loss group	No loss group
1	Yield(ton per hectare (ha))	1.21	1.17
2	Output price (Kyats per ton)	1051121.39	1075335.36
	T-Revenue/ha (A = 1*2)	1276920.82	1252770.25
3	Seed cost per ha (B)	136259.23	122621.23
4	Organic fertilizer cost per ha	315.93	328.71
5	Chemical fertilizer cost per ha	26034.06	34069.19
6	Foliar cost per ha	65872.84	61938.01
	Total fertilizer cost per ha (C = 4+5+6)	92222.83	96335.91
7	Herbicide cost per ha	20713.84	13645.55
8	Pesticide cost per ha	176151.69	139540.76
	Total chemicals cost per ha (D = 7+8)	196865.53	153186.31
9	Human labor cost per ha (E)	371742.50	315598.72
10	Animal power cost per ha	7111.16	2836.05
11	Machinery power cost per ha	133041.62	117087.16
	Total land preparation cost per ha (F = 10+11)	140152.79	119923.21
12	Replanting cost per ha (G)	50786.48	0.00
13	Threshing cost per ha (H)	14458.44	9938.81
14	Fuel cost per ha (I)	2338.89	3792.72
15	Marketing cost per ha (J)	13051.74	8759.56
16	Accessory cost per ha (K)	10050.03	8999.54
17	Interest for the loan per ha (L)	35462.03	49179.40
	Total variable cost (TVC = B+C+D+E+F+G+H+I+J+K+L)	1063390.42	888335.39
	Net Profit (A-TVC)	213530.40	364434.86

Source: Field survey data, 2016

4.3.2 Summary statistics of the variables for the farmers who faced yield loss and no yield loss by rain incidence

It should explain the detailed summary statistics of the output and input variables used in the stochastic profit frontier in two groups first.

From Table 4.2, it is obvious that the average *rainfall* received is not much different among the two groups. However, in loss group, 25% of farmers practiced *replanting* the pulses due to rain incidence while in no loss group, it did not practice. The average *seed rate* used is about 82.28 kg per ha in loss group and 76.21 kg per ha in no loss group with a higher amount of about 6 kg per ha of used seed in loss group. Average *fertilizer* used is about 51.61 kg per ha in loss group and about 67.68 kg per ha in no loss group, meaning no loss group applied more fertilizer with the amount of about 16 kg per ha. The mean *chemicals* applied is about 11.87 kg per ha in loss group and 5.71 kg per ha in no loss group with a difference of about 3 kg per ha which is more used by loss group. Moreover, the average *human labor* utilization for pulse production in loss group is about 96.88 man-days per ha while in no loss group it is about 82.61 man-days per ha, indicating loss group used more labor for production. As mentioned in the above section, the higher utilization of the *seed*, *chemicals*, *human labor* by loss group may be due to rain incidence.

In the summary statistics of socio-economic, demographic and farmers' managerial characteristics, the average ratio of *gender*, mean *age*, mean *experience*, average *education* level is almost the same among the two groups. However, about 3% of farmers from no loss group gets more *access to credit*, and 2% of them more participate in *training* program.

Regarding *location* dummy, about 71% of farmers from loss group is from Bago Region, and 42% of them in no loss group are from that Region, revealing that farmers from Bago Region suffered from more loss by rain than from Yangon Region. The average *pulses area*

from loss group is about 7.56 ha, and it is about 7.05 ha in no loss group, only 0.5 ha difference among the groups.

Table 4. 2 Summary statistics of the variables used in the models for loss group and no loss group

Variables	Loss group				No loss group			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Rainfall (mm)	14.97	13.38	0	30.99	14.41	10.69	0	30.99
Replanting (Yes=1, No=0)	0.25	0.43	0	1.00	-	-	-	-
Seed rate (Kg)	82.28	20.27	55.48	145.27	76.21	14.79	41.56	141.23
Fertilizer (Kg)	51.61	59.49	1.73	258.93	67.68	55.63	0	255.34
Chemicals (Kg)	11.87	6.99	3.02	32.95	8.71	5.64	0.30	28.13
Human labor (Man-day)	96.88	37.60	30.00	202.00	82.61	30.40	31.00	221.00
Gender (Yes=1, No=0)	0.96	0.20	0	1.00	0.96	0.19	0	1.00
Age (Years)	49.33	11.66	23.00	76.00	51.99	11.38	26.00	82.00
Experience (Years)	21.75	10.94	2.00	50.00	21.89	8.98	5.00	42.00
Education (Years)	7.29	3.80	3.00	16.00	7.31	3.70	3.00	16.00
Access to credit (Yes=1, No=0)	0.86	0.35	0	1.00	0.89	0.31	0	1.00
Participation in farmer organization (Yes=1, No=0)	0.04	0.20	0	1.00	0.06	0.25	0	1.00
Access to training (Yes=1, No=0)	0.27	0.45	0	1.00	0.36	0.48	0	1.00
Location (Bago=1, Yangon=0)	0.71	0.46	0	1.00	0.42	0.50	0	1.00
Pulses area (Ha)	7.56	6.32	0.81	32.38	7.05	7.44	0.40	52.61

Std. Dev. is an abbreviation of standard deviation.

Source: Own estimates

4.3.3 Estimation of profit frontier function

The estimated results of maximum-likelihood of the stochastic frontier profit function with the separate analyses for the Model (1) with weather-related variables and Model (2) without weather-related variables in each group is presented in Appendix A. Firstly, hypothesis testing was performed to check whether weather-related variables should be included into the

model or not, and whether technical inefficiency effect is present or not. The results are depicted in Table 4.3 for both loss group and Table 4.4 for no loss group.

In Table 4.3 of loss group, the null hypothesis test of no effect of weather-related variables on profitability, which were jointly zero in full specification, is rejected at 10% significant level with the χ^2 value 5.88 of the test, meaning rainfall and dummy for replanting can affect the farmers' profit efficiency so as to be worth to incorporate for these variables in the model. The second hypothesis testing is the null hypothesis of no profit inefficiency effect in both models, which is also rejected at 1% level of significance with the χ^2 values of 38.62 and 45.27 in respective models. The results indicate that the profit efficiency level of farmers is also influenced by the socio-economic, demographic and managerial factors of the farmers.

The γ values of both specifications shown in Table 4. 5 means that almost 100% of the variation in pulse yields in both models is due to profit inefficiency rather than random variability among farmers and that the majority of farms in the sample is operating below a profitably efficient threshold. Moreover, it can be concluded that a traditional least square production function is not adequate and that the Cobb-Douglas production function is an appropriate representation of the data.

Table 4. 3 Hypothesis testing for loss group with the farmers who faced yield loss by rain incidence

Hypothesis	Critical Value of χ^2	With rainfall effects		Without rainfall effects	
		LR statistic	Decision	LR statistic	Decision
No effect of rainfall on productivity ($H_0: \beta_1 = \beta_2 = 0$)	$\chi^2 (2, 0.90) = 4.61$	5.88*	reject	-	-
No presence of technical inefficiency ($H_0: \gamma = 0$)	$\chi^2 (1, 0.99) = 6.63$	38.62***	reject	45.27***	reject

Note: ***, * represents significance at the 1% ($p < 0.01$) and 10% ($p < 0.10$) level.

Source: Own estimates

In no loss group (Table 4.4), the hypothesis test results also go into the same categories. In this group, the weather-related variable is incorporated only rainfall but no dummy for

replanting as there is no practice of farmers for replanting when they faced rain during the sowing time. The null hypothesis of no weather-related variable effect on the profitability of the farmers is tested by the LR tests and is rejected with the χ^2 value 3.82 of the test at 10% level of significance. Moreover, another null hypothesis of which there is no inefficiency effect in both models is calculated by the LR tests and is also rejected at 1% significant level with the test result of χ^2 value of 46.01 and 45.27 in the respective models. Both of the results of loss group and no loss group can be concluded that weather-related variables should be incorporated in the models. Therefore, the results of the models included weather-related variables would be mainly focused on the preceding result and discussion sections.

Table 4. 4 Hypothesis testing for no loss group with the farmers who faced no yield loss by rain incidence

Hypothesis	Critical Value of χ^2	With rainfall effects		Without rainfall effects	
		LR statistic	Decision	LR statistic	Decision
No effect of rainfall on productivity ($H_0: \beta_1=0$)	$\chi^2 (1,0.90)=2.71$	3.82*	reject	-	-
No presence of technical inefficiency ($H_0: \gamma=0$)	$\chi^2 (1,0.99)=6.63$	46.01***	reject	45.27***	reject

Note: ***, * represents significance at the 1% ($p<0.01$) and 10% ($p<0.10$) level.

Source: Own estimates

4.3.4 Maximum-likelihood estimates of the stochastic frontier profit functions for loss and no loss groups

In this section, only the results of the profit function models incorporating weather-related variables were discussed according to the result of rejecting the hypothesis testing of no effect of weather-related variables. Maximum-likelihood estimates of the stochastic frontier profit functions of loss group and no loss group are presented in [Table 4.5](#).

The coefficients results of the profit function in both loss group and no loss group reveal that the variables for *normalized prices of human labor* and *land preparation* are negatively and highly significant, explaining the higher the prices of these inputs, the lower the

Table 4. 5 Maximum-likelihood estimates of the stochastic frontier profit functions of loss group and no loss group

Variables	Loss group			No loss group		
	Coefficient	Std. Err	t-ratio	Coefficient	Std. Err.	t-ratio
Profit function						
Constant	23.10***	1.44	16.08	6.80***	0.52	12.99
<i>Rainfall</i>	-0.30***	0.00	-115.46	-0.11***	0.02	-5.38
<i>Dummy for replanting</i>	0.69***	0.06	11.50	-	-	-
P_S	-1.54***	0.10	-14.72	0.07	0.07	0.98
P_F	-0.32***	0.03	-10.65	0.11***	0.02	6.42
P_C	-0.97***	0.09	-10.92	0.09***	0.03	2.91
P_L	-1.16***	0.07	-17.55	-0.28**	0.11	-2.53
P_{LP}	-0.20***	0.03	-6.56	-0.47***	0.15	-3.21
<i>Seed rate</i>	0.54***	0.13	4.07	0.34***	0.08	4.43
<i>Fertilizer</i>	-0.57***	0.03	-18.45	0.10***	0.01	10.63
<i>Chemicals</i>	-1.01***	0.07	-13.66	0.11***	0.03	3.92
<i>Human labor</i>	-1.84***	0.08	-21.92	0.09	0.05	1.60
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	17.76	1.10	16.15	23.01	2.03	11.33
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99***	0.00000003	37116718	0.99***	0.00000011	8621144
Log likelihood function	-137.77			-159.79		
Profit inefficiency effect function						
Constant	-0.99	1.03	-0.96	-2.71**	1.00	-2.72
<i>Gender</i>	-4.73**	1.68	-2.81	2.78**	0.99	2.81
<i>Age</i>	3.79***	1.27	2.98	-10.16***	0.92	-11.06
<i>Experience</i>	-0.04	0.84	-0.05	8.63***	1.13	7.61
<i>Education</i>	-0.77	1.25	-0.62	4.17***	0.92	4.55
<i>Credit access</i>	-6.86***	1.43	-4.80	-2.86***	1.02	-2.81
<i>Participation in farmer organization</i>	-1.26	1.06	-1.19	-19.72***	1.56	-12.65
<i>Training access</i>	-5.12***	1.36	-3.76	3.56***	0.99	3.60
<i>Location</i>	-0.21	1.20	-0.17	12.07***	1.00	12.04
<i>Pulse area</i>	-1.79**	0.81	-2.21	-5.37***	0.78	-6.91
Total number of observations	73			109		

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level.
Source: Own estimates

profitability of the farmers. The negative significant effect of *normalized wage rate of human labor* is stronger in loss group than no loss group, pointing out that increase in wage rate of *human labor* will have more impact on the profitability of pulse farmers in loss group by reducing net return from pulse production.

In loss group, the coefficient values of *normalized prices of fertilizer* and *chemicals*, and of used quantity of *fertilizer* and *chemicals* are negatively significant at 1% level, respectively, while the results of those variables in no loss group has a positive significant impact on profitability at 1% level and are opposite to the results of loss group. The results can be interpreted that when yield loss due to rain incidence occurred, the more utilization of these inputs would hinder to achieve the maximum profitability and indicated that the efficient and effective application of these inputs is necessary for the farmers.

In loss group, the coefficient values of *normalized prices of fertilizer* and *chemicals*, and of the used quantity of *fertilizer* and *chemicals* are negatively significant at 1% level, respectively, while the results of those variables in no loss group are opposite to those of loss group and have a positive significant impact on profitability. The results can be interpreted that when yield loss due to rain incidence occurred, the more utilization of these inputs would hinder to achieve the maximum profitability and indicated that the efficient and effective application of these inputs is necessary for the farmers.

The coefficient value of *normalized prices of seed* is negative and significant at 1% level and *seed rate* is positively significant at 1% level, denoting that the increased use of *seed rate* can improve profitability as the more use of seed can ensure for the profit of the farmers in the mean of replanting, while the increase in price of seed can decrease profit of the farmers for loss group. On the other hand, the coefficient of *seed rate* in no loss group also results in a positive significance at 1% level, and the interpretation for this result can be gone the same trend as in loss group. Moreover, in loss group, the result of *human labor* is also negatively

significant impact on profitability at 1% level, inferring that excessive use of *human labor* would reduce the profit from pulse production, while it is positive and not significant in no loss group, meaning that this variable are more responsive to yield loss due to rain incidence.

The results of the estimation of profit inefficiency effect function are illustrated in the lower part of Table 4.5.

In loss group, the dummy variable for *gender* is negatively significant on profit inefficiency at 5% level, implying that the male farmers, as expected, are more efficient in profit than female farmers. It may be because of the definitive decision of the male farmers regarding farm management under crop yield loss condition due to rain incidence. But, in no loss group, *gender* has a positive significant effect on profit inefficiency at 5% level, inferring that female farmers are more efficient than male farmers under no loss condition because of no necessity of any special management for production processes.

The *age* of the farmers is positively significant at 1% level on profit inefficiency in loss group, indicating that the older farmers are less efficient than the younger farmers due to the less motivation and enthusiasm on adopting updated modern farming technology as well as explaining that the younger farmers are more active in handling the adapted measures of encountering erratic rain incidence during the crop season. However, the coefficient result of *age* in no loss group is negatively significant at 1% level, indicating that older farmers are more efficient than younger farmers under no yield loss effect due to rain incidence.

In both groups, the coefficient values of *credit access* variable are negatively significant at 1% level on profit inefficiency, directing *credit access* from government can encourage farmers for more capital investment and thus enabling farmers for using farm inputs in time, consequently enhancing productivity and hence profitability for both groups.

In addition, the results of *pulses area* have a negative significant impact on inefficiency at 5% level in loss group and 1% level in no loss group. The results depict that large-scale

farmers are more efficient than small-scale farmers. The reason may be due to the vulnerability of small-scale farmers in encountering crop damage and yield loss by rain incidence is larger than large-scale farmers in term of capital and management skill. Moreover, the effect is stronger in no loss group, mentioning that the impact of yield loss by rain incidence can decrease profit efficiency for loss group compared to no loss group even the farmers are large-scale farmers.

Training access variable in loss group also has a negative significance at 1% level on inefficiency, implying the more access to training for farmers, the more efficient in profit. On the other hand, in no loss group, the result of *training access* variable is positively significant at 1% level, which is opposite to the loss group. The result directs that *training access* is more important and makes more efficient for the farmers in loss group than those in no loss group as the effectiveness training access is lower in no loss group than loss group.

In no loss group, the estimated results of *experience*, *education* and *location* have a positive significant effect on profit inefficiency, while those variables in loss group are negative but not significant. The results can be interpreted that the farmers with more experience, higher education level and farmers from Bago Region are less profitably efficient than those with less experience, low education level and from Yangon Region. The possible reason may be that experience is regardless for the profit efficiency improvement, farmers with higher education level may have another job other than farming making less attention on production activities, and farmers from Bago Region are more affected by crop damage due to rain incidence than those from Yangon Region.

The result of *participation in farmer organization* variable in no loss group has a negative and significant relationship with inefficiency while it is negative but not significant in loss group. The result reveals that farmers who participate in farmer organization can achieve

higher profit efficiency for no loss group, *participation in farmer organization* is one of a key factor for the profit efficiency improvement of the farmers.

4.3.5 Frequency distribution of the profit efficiency for loss and no loss groups

The frequency distributions of the profit efficiency indices are illustrated for the loss and no loss groups (Figure 4.1). When the profit efficiency level of the two groups are compared, the results obviously shows that the most of the farmers (about 44% of loss group farmers) in loss group are located in under profit efficiency level of less than 0.1 (10%), while in no loss group, it is only about 18% of no loss group farmers under this category. This result proved the impact of yield loss on the profit efficiency as empirical evidence. According to the result, about 72.6% of farmers equivalent to 53 farmers of the total 73 farmers from loss group is under the profit efficiency level of 0.5 (50%) while in no loss group, it is about 57.80% (63 farmers) of the total 109 farmers. This result is also another evidence of yield loss impact by rain incidence on efficiency. The results can be summarized that farmers from loss group are profitably less efficient than those from no loss group.

Table 4.6 reveals the mean, minimum and maximum profit efficiency levels for loss and no loss group. In loss group, the estimated mean profit efficiency is about 33% with a large variation of minimum 0.02% to maximum 99% of efficiency level. In no loss group, the mean efficiency is about 43% with the similar wide range of the lowest level 0.07% and highest level 99%. In a comparison of the efficiency level between two groups, the results prominently show that the efficiency level is lower about 10% in loss group than in no loss group. It can be concluded from the above results that yield loss by rain is the main determining factors for the profit efficiency of the farmers in Lower Myanmar.

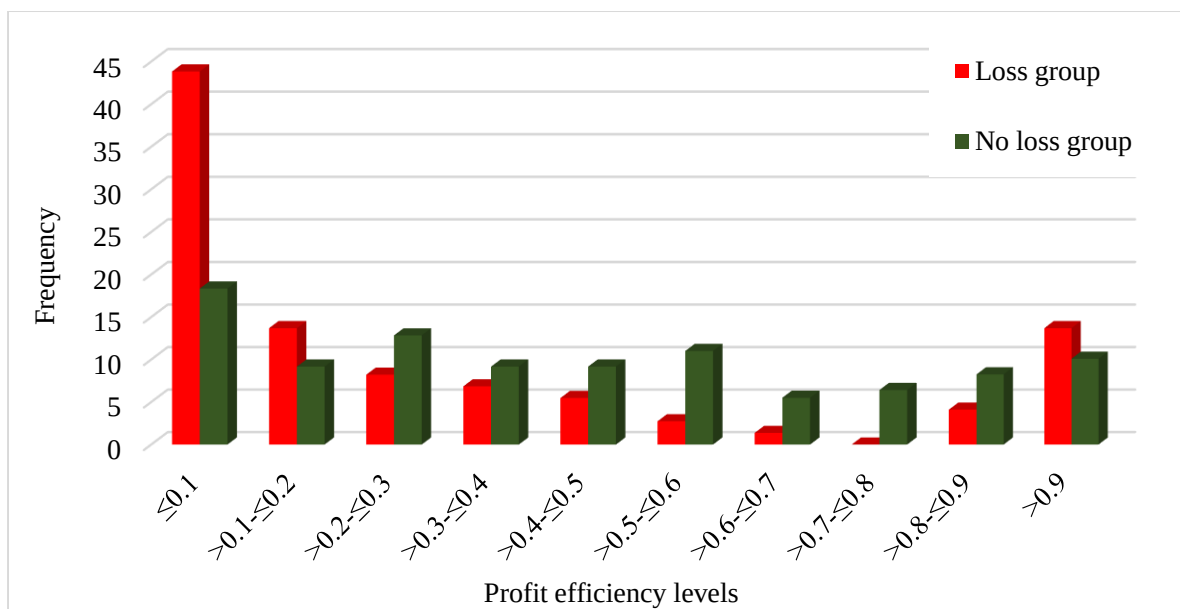


Figure 4. 1 Frequency distribution of profit efficiency of the farmers in loss and no loss groups

Source: Own estimates

Table 4. 6 Mean, minimum and maximum profit efficiency levels for loss and no loss groups

Categories	Loss group	No loss group
Mean	0.3322	0.4337
Minimum	0.0002	0.0007
Maximum	0.9992	0.9990

Source: Own estimates

4.4 Conclusion and policy recommendations

This chapter focuses on the investigation of the erratic rain impact on the profit efficiency of the pulse farmers dividing two groups with and without yield loss due to rain at the flowering stage by applying stochastic frontier profit function.

From the result of the benefit-cost analysis, the net profit loss of farmers due to rain is about 150,905 Ks per ha, practically proving that farmers are facing a loss because of erratic rain during the growing season in Lower Myanmar.

The estimated results of the stochastic frontier profit function also provide that the weather-related variables, the *rainfall* and dummy for *replanting*, should be incorporated in the

model and *rainfall* variable has a negatively significant effect on the profitability of the farmers within each group.

For both groups, *seed rate* has a positive significant relationship with the profitability, suggesting that the more use of seed can increase the productivity and consequently profitability. Therefore, the improved varieties of pulse seed with the reasonable price and recommended seed rate for a specific location is needed to distribute to farmers for the effective use of seed under prevalent condition. Moreover, the efficient and effective application of fertilizer, chemicals and human labor should be provided for farmers to reduce the overuse of these inputs as these inputs variables have a negatively significant impact on profitability.

Also, the *price of seed, fertilizer and chemicals* has a negative relationship with the profitability of farmers from loss group, indicating that the price control policy for these inputs or other relevant actions such as providing of seed, quality assurance of the fertilizer and chemicals should be implemented for the profit certainty of farmers.

Besides, in both groups, *price of human labor* and *land preparation* has a negative and significant effect on profitability, demanding that a need to attempt the reduction of reliance on human labor in pulse production by the substitution of machinery services for some farming activities such as land preparation, spraying fertilizer and chemicals and harvesting. Therefore, the government should support to farmers for easier access to these kinds of machinery.

On the other hand, the farmers' socio-economic, managerial and demographic characteristics also determine the profit efficiency levels of farmers. Specifically, in loss group, providing more access to credit, conducting more training program focusing on pulse production practices adapted to seasonal climate change with the target farmers who are female farmers, old household head and small-scale farmers for the improvement of the profit efficiency of the farmers.

For no loss group, the difference from loss group is the negative significant effect of *gender* and *participation in farmer organization*, and the positive significant relation of farmers' *experience*, *education* and *location* on profit inefficiency. Therefore, for the efficiency improvement of pulse farmers for this group, the policymakers should emphasize on the establishment of farmer organization and encouragement of active participation in this organization. Also, when conducting efficiency improvement program, it should be focused more on farmers who are young, more experience, higher education mainly focused on those who have another job, and those who are from Bago Region.

The results of the frequency distribution of efficiency levels point out that greater effort need to be improved the efficiency level with the wide space of about 67% for loss group and about 57% for no loss group. According to the analysis results, there are farmers who have almost zero efficient in profit in both groups, while some farmers are fully efficient.

To sum up the above results, it is obvious that yield loss due to rain incidence can make farmers' profit return reduce. Although some policy recommendations mentioned above is important, rain incidence is out of farmers' control and thus another important suggestion is the establishment and development of the safety net for farmers like weather index-based crop insurance program to help farmers' income ensure when they face profit and income loss due to erratic rain during the growing season.

Chapter 5

Evaluation of uncertain rainfall effect on profit efficiency of pulses farmers in CDZ of Myanmar

5.1 Introduction

Drought is a common and recurring phenomenon for agriculture sector (Heim, 2002), it may be exactly pointed to CDZ of Myanmar, as seasonal drought is a common problem that farmers usually face during the growing season of almost every year in this area. It makes worse with the climate changes along with uneven and delay onset of rain and high temperature. With this permanent problem, farmers in CDZ usually try to grow the crops with mixed or intercropped cropping system, mostly with pigeon pea as a standing crop to diversify the income sources from agriculture. Other major crops which are mixed or intercropped with pigeon pea are green gram, black gram, chickpea, sesame and groundnut. (For cropping pattern of CDZ, see the introduction of Chapter 3.)

The annual rainfall of CDZ is on average less than 750 mm, with marked variation occurring between and within townships: 803 mm in Kyauk Pa Daung, 783 mm in Nwar Htoe Gyi and 759 mm in Myaing and 954 mm in Magway townships. Rainfall tends to be higher in Magway, with a more even distribution than in the other townships. The meteorological records of Department of Agriculture indicate that over the last decade the severe drought happened four times in Nwar Htoe Gyi, two times in Kyauk Pa Daung, three times in Myaing townships attaining less than 600 mm of annual rainfall (DOA, 2017). Temperatures in the study areas range from a minimum of 10 °C (degree Celsius) to a maximum of 43 °C over the hottest period of the year (March-April). The average rainfall received during the crop growing season in the study areas is about 782 mm from 2008 to 2015 which is 32mm higher than the average rainfall of the CDZ, and this may be due to variation in regions. Low and uncertain rainfall received during crop growing season may retard crop growth and consequently crop productivity.

In rain-fed agriculture, a decrease in rainfall will aggravate the loss through the reduction of crop yield (Liu et al., 2010). It can reduce plant growth, the crop biomass and yield, which can be sensitive to the variable susceptibility of crops during different stages of crop development (Esfahanian et al., 2017; Heim, 2002). Powell and Reinhard (2015) also revealed that it is important to specify the uncertain rainfall and uncommon temperature events of short duration on crop yield over the time in which the events occurred and measured.

In CDZ, pulses are one of the major income sources for farm household economy. Despite many studies focused on the agricultural production of CDZ (Kahan, 2001; Matsuda, 2013; Rao et al., 2011; Susanne Kempel, 2013), there has not been studied about profit efficiency of pulse farmers in CDZ. This study intends to fill the gap and try to evaluate the effect of rainfall and temperature occurred during the early vegetative growth stage and flowering stage, as these stages are sensitive to low rainfall or drought for growth and flowering (Majumdar, 2011, pg- 64). The detail objectives are as same as Chapter 4 as follow:

1. to estimate the benefit-cost of pulse production under consideration of yield loss which is perceived by farmers during the survey,
2. to analyze the profit efficiency of pulse farmers with rainfall effects,
3. to assess the difference in profit efficiency levels between farmers who faced yield loss and no yield loss by rain incidence during the growing season of pulses, and
4. to determine the factors affecting the efficiency levels of the farmers.

5.2 Research methodology

5.2.1 Analytical framework

Analytical framework and software used for analysis follow as the Chapter 4.

5.2.2 Study area and data collection

The study area, sample size and data collection technique are the same as in Chapter 3. In this Chapter, the information of the input prices is used from the collected data in Chapter 3.

5.2.3 Empirical model

The idea of the empirical model is the same as in Chapter 4. However, in this Chapter, *rainfall received at the flowering time*, instead of replanting dummy in Chapter 4, and land preparation cost, which is not used in Chapter 4 due to correlation, is included in the profit frontier function model and profit inefficiency model, *share of pulses* representing the area occupied by pulses in the mixed and intercropped system is incorporated in this Chapter.

5.3 Results

5.3.1 Comparison of the benefit-cost of the pulse production between loss and no loss groups

To assess the effect of low rainfall on the profitability of the pulses farmers in CDZ, the benefit-cost analysis was performed, and the results are presented in Table 5.1. In this analysis, farmers are separated into two groups: (1) loss group, which includes farmers responded that they faced yield loss due to uncertain and erratic rainfall during the crop growing season, and no loss group, in which farmers who did not perceive that they did not face any yield reduction. Table 5.1 presented the information of the cost and benefit of per hectare pulse production. The profit the farmers attained was calculated by subtracting total costs from total revenue.

As depicted in Table 5.1, the average output (ton per ha) is 3.6 ton per ha for both groups and the average price of pulses per ton is about 2,111,842 Ks received by in loss group while 2,056,960 Ks attained by no loss group. The price difference might be due to a different location and different market. Farmers in loss group expensed more cost as the cost of seed, fertilizer, chemicals, human labor and land preparation are higher than in no loss group. The

total variable cost is greater in loss group than in no loss group, highlighting that farmers from loss group are spending more investment for adaptation measures of pulse production under low rainfall situation than no loss group. The result depicted that the net profit of pulse production is about 414,339 Ks per ha for loss group and about 358,668 Ks per ha, with the total variable cost (TVC) of 342,425 Ks per ha and 303,597 Ks per ha, and with the total revenue of 756,765 Ks per ha and 662,266 Ks per ha, respectively. The total revenue and net profit of loss group is greater than no loss group due to higher price received by loss group than

Table 5. 1 Benefit-cost analysis of loss farmers and no loss farmers

Theme		Loss group	No loss group
1	Yield(ton per hectare (ha))	0.36	0.36
2	Output price (Kyats per ton)	2111842.05	2056960.24
T-Revenue/ha(A=1*2)		756765.30	662266.13
3	Seed cost per ha (B)	32374.92	24694.59
4	Organic fertilizer cost per ha	21024.79	14548.64
5	Chemical fertilizer cost per ha	17243.46	13276.58
6	Foliar cost per ha	3262.07	2557.41
Total fertilizer cost per ha (C=4+5+6)		41530.32	30382.63
7	Herbicide cost per ha	609.56	218.73
8	Pesticide cost per ha	7380.33	7750.78
Total chemicals cost per ha (D=7+8)		7989.89	7969.51
9	Human labor cost per ha (E)	202013.88	174110.16
10	Animal power cost per ha	32342.27	29042.07
11	Machinery power cost per ha	9307.84	7756.88
Total land preparation cost per ha (F=10+11)		41650.11	36798.95
12	Threshing cost per ha (G)	3475.65	2661.86
13	Fuel cost per ha (H)	1777.03	869.08
14	Marketing cost per ha (I)	2614.85	3094.11
15	Accessory cost per ha (J)	3099.19	4280.00
16	Interest for the loan per ha (K)	5899.97	18736.73
Total variable cost (TVC=B+C+D+E+F+G+H+I+J+K)		342425.82	303597.64
Net Profit (A-TVC)		414339.48	436581.23

Source: Own estimates

no loss group. According to the result, the net profit loss due to yield loss by rain scarcity is about 22,242 Ks per ha.

5.3.2 Summary statistics of the variables for the farmers who face yield loss and no loss by rain

The summary statistics of weather-related variables (*rainfall at the early growth stage and flowering stage*), inputs, and socio-economic, demographic and institutional characteristics of the two group is revealed in Table 5.2.

The total rainfall received for loss group is about 148 mm during the early vegetative stage and 204 mm during the flowering stage, while it is about 162 mm and 208 mm in no loss group.

The average *seed rate* in loss group is about 12.63 kg per ha with a range of 1.66 kg per ha to 179.06 kg per ha and 76.21 kg per ha while the mean *seed rate* is about 10.48 kg per ha in no loss group with a minimum 1.01 kg per ha and maximum 29.25 kg per ha. The loss group utilized a higher amount of about 2.15 kg per ha in seed used. The average utilization of *fertilizer* is about 29.05 kg per ha in loss group and about 26.03 kg per ha in no loss group. *Fertilizer* application is also a wide variation with a minimum of 0 kg per ha (no use) in both groups and with a maximum of 185.33 kg per ha and 148 kg per ha, respectively. On average, loss group used 3.2 kg per ha of *fertilizer* more than no loss group. The *chemicals* utilization, on average, is about 0.50 kg per ha in loss group and about 0.45 kg per ha in no loss group. Some farmers in both groups do not completely use *chemicals* for pest and disease management and their maximum use of chemicals is about 3.29 kg per ha and 3.71 kg per ha. The average quantity of *human labor* for pulse production in loss group is about 47.26 man-day per ha with a minimum of 8.01 man-day per ha and a maximum of 186.15 kg per ha, while in no loss group, it is about 37.36 man-day per ha with a range of 10.23 man-day per ha to 90.81 man-days per ha. The result indicates that the average use of *human labor* is not much difference between two groups, but the maximum is two times higher in loss group than in no loss group, implying

human labor is more intensively used in loss group. *Land preparation cost* is, on average, about 41.65 thousand Ks per ha in loss group and 23.64 thousand Ks per ha in no loss group, meaning that loss group utilizes more animal and machinery power for ploughing and harrowing to keep soil moisture content as a usual practice in CDZ. The average *share area of pulses* in per unit area of land for average, minimum and maximum value is almost the same in both groups with an average of 0.38 and 0.36, respectively.

The wide variation in use of *seed rate*, *fertilizer*, and *chemicals* in each group should be different in *share area of pulses* among farmers in the same group. Moreover, the similar utilization of these inputs in two groups may be because of same *share area of pulses*.

Table 5. 2 Summary statistics of the variables for the farmers who face yield loss and no loss by rain

Variable	Loss group				No loss group			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
<i>Rainfall at early vegetative growth stage</i>	148.07	23.08	128.02	195.58	161.57	28.36	128.02	195.58
<i>Rainfall at flowering stage</i>	204.31	64.30	150.37	310.64	207.98	62.05	150.37	310.64
<i>Seed rate</i>	12.63	17.53	1.66	179.06	10.48	5.43	1.01	29.25
<i>Fertilizer</i>	29.05	31.75	0.00	185.33	26.59	26.03	0	148.26
<i>Chemicals</i>	0.50	0.67	0.00	3.29	0.45	0.69	0	3.71
<i>Human labor</i>	47.26	33.40	8.01	186.15	37.36	19.47	10.23	90.81
<i>Land preparation cost</i>	41.65	31.21	49.42	14.83	36.79	23.64	32.43	10.99
<i>Share area of pulses</i>	0.38	0.28	0.06	1.00	0.36	0.27	0.06	1
<i>Age</i>	53.75	11.30	29.00	81.00	52.05	11.51	28	75
<i>Experience</i>	6.32	3.58	3.00	16.00	6.21	3.41	2	16
<i>Education</i>	26.83	13.07	5.00	60.00	26.21	12.75	5	50
<i>Credit access</i>	0.84	0.37	0.00	1.00	0.89	0.31	0	1
<i>Participation in farmer organization</i>	0.06	0.23	0.00	1.00	0.05	0.22	0	1
<i>Training access</i>	0.51	0.50	0.00	1.00	0.55	0.50	0	1
<i>Location</i>	0.53	0.50	0.00	1.00	0.43	0.50	0	1
<i>Pulse area</i>	3.61	3.19	0.40	18.21	3.56	2.14	0.51	11.33

Source: Own estimates

The average *age* of farmers is about 54 years and 52 years, respectively, with a range of 29 years and 81 years in loss group, and with 28 years minimum and 75 years maximum in no loss group. The average years of farming *experience* of farmers are six years in both group, and minimum and maximum *experience* of them are almost the same between groups. It can be seen that the average, minimum and maximum results of the dummy variables for access to credit, participation in farmer organization and access to training are almost identical in both groups. The 53% of farmers are located in Mandalay Region in loss group and 43% in no loss group. The average actual *pulses sown area* is averagely about 3.61 ha in loss group with a 0.40 ha minimum and 18.21 ha maximum area, and 3.56 ha in no loss group with a range of 0.51 ha to 11.33 ha.

5.3.3 Estimation of profit frontier function

When estimating the maximum-likelihood of the stochastic frontier profit function, each group is analyzed with two models. Model (1), with rainfall effect model, included two *rainfall variables for the early vegetative growth stage and flowering stage* in addition to the normalized price and quantity of input variables and *share area of pulses* in per unit area of land. In Model (2), without rainfall effect model, *rainfall* variables are dropped and applied only the normalized input price, quantity of inputs used and *share area of pulses*. The detail results of the analysis of two models for loss group is presented in Appendix B.

Firstly, hypothesis tests were conducted, and the results are presented in Table 5.3 for loss group and in Table 5.4 for no loss group. To test the need of incorporating specific *rainfall* variables in the frontier profit function applied for both groups, the null hypothesis test of no rainfall effect on profit efficiency was performed by using likelihood ratio (LR) test. The result of LR test statistic was 13.14 for loss group, and 21.70 for no loss group, which were highly significant at 1% level of critical χ^2 value of 9.21 with 2 degrees of freedom and 0.99 level and the null hypothesis of no rainfall effect on profit efficiency is rejected. The result concluded

that it is worth to incorporate *rainfall* variables in the frontier profit model. Therefore, in the result and discussion sections, the estimated results of the profit frontier functions incorporating rainfall variables for both groups are mainly discussed.

Table 5. 3 Hypothesis testing for loss group with the farmers who faced yield loss by low rainfall

Hypothesis	Critical value of χ^2	Model (1) with weather-related variables		Model (2) without weather-related variables	
		LR statistic	Decision	LR statistic	Decision
No effect of rainfall on productivity ($H_0: \beta_1 = \beta_2 = 0$)	$\chi^2 (2, 0.99) = 9.21$	13.14***	reject	-	-
No presence of technical inefficiency ($H_0: \gamma = 0$)	$\chi^2 (1, 0.99) = 6.63$	39.28***	reject	31.21***	reject

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level.
Source: Own estimates

Table 5. 4 Hypothesis testing for no loss group with the farmers who faced no yield loss by low rainfall

Hypothesis	Critical Value of χ^2	Model (1) with weather-related variables		Model (2) without weather-related variables	
		LR statistic	Decision	LR statistic	Decision
No effect of rainfall on productivity ($H_0: \beta_1 = \beta_2 = 0$)	$\chi^2 (2, 0.99) = 9.21$	21.70***	reject	-	-
No presence of technical inefficiency ($H_0: \gamma = 0$)	$\chi^2 (1, 0.99) = 6.63$	33.34***	reject	20.45***	reject

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level.
Source: Own estimates

Then, to test the adequacy of the frontier profit function applied, the null hypothesis of no presence of profit inefficiency was performed and is rejected at 1% level of significance with LR test statistic of 39.28 in loss group with the critical $\chi^2 (1, 0.99)$ value of 6.63. In no

loss group, the null hypothesis was also rejected at 1% level of significance as the LR test statistic is 33.34 with the same critical χ^2 value as in loss group. The γ values (Table 5.5) of the models in each group also support the rejection of the above null hypothesis, implying that almost 100% of the variation of the values in the models are due to inefficiency effects rather than other measurement error. The results pointed out that the ordinary least square (OLS) production function is not enough for both groups and the Cobb-Douglas production function is an appropriate representation of the data.

The result of maximum likelihood analysis of stochastic frontier profit function is shown in Table 5.5 for both loss and no loss groups.

Actually the expected signs for the variables of *rainfall at early vegetative stage and flowering stage* were positive for both groups as the study area is dry zone area and rainfall is essential for crop growth and productivity. In Table 5.5, the coefficient result of *rainfall at the early vegetative growth stage* in loss group was positively significant at 1% level, while the result of the variable in no loss group is contradicted to loss group, having a negative significant effect at 1% level. The feasible explanation might be that rainfall received during the early vegetative growth stage for loss group can enhance plant growth and thus ensure high productivity, consequently high income as the farmers from the group faced low rainfall and yield loss, whereas farmers in no loss group might receive enough rainfall and no more need to get *rainfall at the early vegetative stage* so that rainfall for the group has a negative impact.

In addition, the result of *rainfall at the flowering stage* is also opposite between two groups. It has a negatively significant effect on net profit return in loss group and a positive significant impact in no loss group which is consistent with the finding of Chapter 3, technical efficiency analysis of pulses in CDZ. The feasible explanation may be that if rainfall is received during the flowering time for dry zone area, it can help develop flower formation and fruit set, however, if rainfall intensity is high, it can be detrimental to the flower pollination and, hence

reduce yield. Therefore, it can be concluded that rainfall intensity should be considered for more precise estimation of the effect of rainfall in CDZ. This negative significant result of *rainfall at the flowering stage* is in line with the finding of the study of Mar et al. (2018) in which rainfall at the flowering time negatively effect on the technical efficiency of farmers.

In both groups, *normalized price of seed* is negatively and significantly related to profitability, while *normalized price of chemicals* has a positive significant effect. However, the positive and significant coefficient of the quantity of *seed rate* explains that the more the use of the seed rate, the higher profitability. The results indicate that although *seed rate* should be used more for the sufficiency of plant population under low rainfall condition, the higher price of seed may reduce the net profit. While the coefficient of *normalized price of chemicals* is positively significant at 10% level, the coefficient of a quantity of *chemicals* input is also positively significant at 1% level. The result implies that the more utilization of *chemicals* can increase the profitability even if the price of chemicals become higher. *Chemicals* should be, however, applied efficiently and effectively under low rainfall condition. The negative coefficient result of *fertilizer* is significant at 1% level, meaning that the higher *fertilizer* uses, the lower the profit of farmers indicating the farmers applied *fertilizer* overdose beyond the profit efficiency level.

As expected, in loss group, the *shared area of pulses* has a positive significance at 5% level, revealing that the more pulses occupied in the per unit area of land, the higher the profit under a scarcity of rainfall condition. However, the result of *share area of pulses* in no loss group is contradicted to loss group and is negative and significant at 1% level, implying the increase of more line of pulses may decrease the profitability under normal weather condition.

Notwithstanding, the significant levels of the negative coefficient of *normalized price of seed* and the positive coefficient of *normalized price of chemicals* become weaker in loss group than no loss group, evidencing under yield loss condition with low rainfall, decrease or

increase of these input price might have less effectiveness on profitability. The interpretation may go the same trend for *share area of pulses*.

Furthermore, in no loss group, the coefficient of the *normalized prize of fertilizer* has a negative and significant relation with profitability, revealing that the higher the price of fertilizer, the lower the profitability. The results of *normalized prices of human labor* and *land preparation cost* are positively significant at 1% level while the coefficients of the quantity of *human labor* and *land preparation cost* are negative and significant at 1% level, respectively. The results pinpoint that even the high price of human labor and land preparation can increase the profit of farmers, the utilization of these inputs should be reduced to ensure maximum profit achievement for farmers from no loss group.

The results related to the factors affecting profit efficiency in both groups are presented in the lower part of Table 5.5. In loss group, the positive significant effect of *age* and *credit access*, and the negative significant relation of *experience*, *education*, *location* and *pulses area* to the inefficiency revealed that farmers who are older, less-experienced and low-educated, access to credit, from Magwe Region and small-scale has lower efficiency level compared to young, well-experienced, educated, large-scale and Mandalay Region farmers who may be higher motivation and interest to innovative farming techniques which are well adapted to the erratic and low rainfall weather condition in CDZ. Moreover, large-scale farmers are more persistent to yield loss and hence achieve high efficiency. In addition, the result shows that *credit access*, which is opposite to expected result, cannot increase the profit efficiency of farmers, leading the interpretation of misuse of credit accessed by farmers for other expense than farming purposes and demanding the directions of effective distribution of credit for farmers in term of material supports other than cash.

Table 5. 4 Maximum-likelihood estimates of the stochastic frontier profit functions of loss group and no loss group

Variables	Loss group			No loss group		
	Coefficient	Std. Err.	t-ratio	Coefficient	Std. Err.	t-ratio
Profit function						
Constant	-3.60**	1.62	-2.22	16.55***	0.14	114.33
<i>Rainfall at early vegetative stage</i>	2.39***	0.69	3.48	-4.66***	0.02	-227.28
<i>Rainfall at flowering stage</i>	-0.66***	0.22	-2.98	2.24***	0.02	112.71
P_S	-0.64**	0.26	-2.48	-1.69***	0.03	-51.65
P_F	0.07	0.15	0.49	-1.02***	0.02	-46.02
P_C	0.19*	0.10	1.94	0.59***	0.01	110.36
P_L	-0.41	0.52	-0.78	1.01***	0.03	37.61
P_{LP}	0.01	0.47	0.01	0.16***	0.01	16.40
<i>Seed rate</i>	0.34***	0.08	4.38	1.10***	0.02	68.44
<i>Fertilizer</i>	-0.14***	0.04	-3.45	-0.47***	0.01	-59.40
<i>Chemicals</i>	0.19***	0.04	4.49	0.86***	0.00	187.48
<i>Human labor</i>	-0.08	0.09	-0.92	-0.46***	0.01	-48.13
<i>Land preparation cost</i>	0.18	0.47	0.38	-0.17***	0.01	-18.49
<i>Share area of pulses</i>	0.27**	0.12	2.20	-0.36***	0.02	-23.53
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	12.90	1.27	10.19	22.49	12.04	1.87
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99***	0.00	340677.73	0.99***	0.00	5452273.60
Log likelihood function	-189.55			-91.62		
Profit inefficiency effect function						
Constant	0.28	0.99	0.28	-12.42	11.51	-1.08
<i>Age</i>	3.16***	0.75	4.20	-2.83***	0.98	-2.89
<i>Experience</i>	-2.54***	0.84	-3.02	3.30**	1.49	2.22
<i>Education</i>	-2.05**	0.96	-2.13	1.08	0.92	1.17
<i>Credit access</i>	1.75*	0.99	1.77	8.21**	4.19	1.96
<i>Participation in farmer organization</i>	0.71	1.06	0.67	-26.07	22.46	-1.16
<i>Training access</i>	0.30	0.95	0.31	-7.74**	3.66	-2.11
<i>Location</i>	-6.32***	1.13	-5.58	2.35	2.00	1.07
<i>Pulses area</i>	-2.37**	0.94	-2.52	2.35	2.00	1.17
Total number of observation		108			58	

Std. err. means standard error.

Source: Own estimates

In the results of inefficiency models in no loss group, *age* and *credit access* are positively significant at 1% and 5% level, respectively, expressing that older farmers are more efficient than younger farmers, which is contradict with the result of loss group. The result of *credit access* can be given the same interpretation as in loss group. However, the coefficient of *experience* has a negative significant effect, which is opposite to the result of loss group, on profit efficiency at 5% level, revealing that less-experienced farmers are more efficient. The results of *training access* conducted by DOA are negatively significant at 1% and 5% levels, respectively, suggesting that conducting training can enhance the profit efficiency of farmers.

5.3.4 Frequency distribution of the profit efficiency for loss and no loss group

The frequency distributions of the profit efficiency indices of loss and no loss groups are illustrated in [Figure 5.1](#). The mean, minimum and maximum profit efficiency of both groups are demonstrated in [Table 5.6](#). The average profit efficiency indices are about 31% in loss group, while they are about 39% in no loss group. The average mean profit efficiency level is higher about 8% in no loss group than loss group, indicating loss group is less efficient than no loss group. The minimum and maximum efficiency levels in both groups are the same. However, when the number of the farmers with efficiency is checked, farmers who have the efficiency levels less than 1% are 35 farmers in loss group, while there are 19 farmers in no loss group. In [Figure 5.1](#), it is obvious that the frequency distribution of farmers with equal to or less than 50% level of profit efficiency is about 80% in loss group and 67% in no loss group. The number of farmers with efficiency level less than 50% is 86 farmers for each Model in loss group, and 39 farmers and 45 farmers in no loss group. Furthermore, the farmers with maximum efficiency levels are ten farmers (9% in frequency) in loss group, while 14 farmers (24% in frequency) in no loss group stand at the maximum efficiency level. In addition, compared to farmers between loss group and no loss group, those from no loss group are more

efficient than those from loss farmers, suggesting that low rainfall is a prominent problem for the achievement of high profit efficiency of the farmers in CDZ.

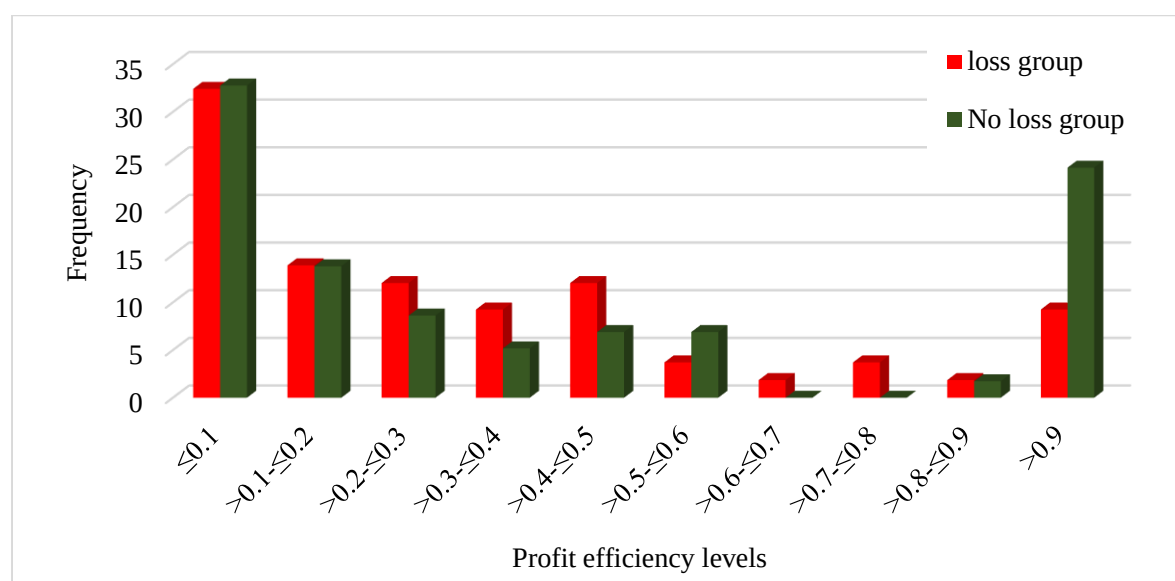


Figure 5. 1 Frequency distribution of profit efficiency of the farmers in loss group and no loss group

Source: Own estimates

Table 5. 5 Mean, minimum and maximum profit efficiency levels for loss and no loss group

Categories	Loss Group	No loss group
Mean	0.312	0.392
Minimum	0.001	0.001
Maximum	0.999	0.999

Source: Own estimates

5.4 Conclusion and policy recommendations

This chapter estimated the effect of uncertain and low rainfall on the profitability and profit efficiency of the farmers in CDZ of Myanmar where is a drought-prone area. Moreover, the study also emphasized on the effect of incorporating *rainfall at the early vegetative growth stage and flowering stage* as these stages are very sensitive to the availability of rain for soil moisture content for the plants. The benefit-cost analysis also performed for inquiry of the

economic loss due to low rain in the study areas using the yield loss reflected by the farmers' perception on low rainfall during growing season of pulses.

The result of benefit-cost analysis revealed that total revenue is higher in loss group than no loss group due to high price factor. However, farmers who face yield loss spent more expense in total variable cost for pulse production than those who did not face any loss. The result shows that the net profit of loss group is lower than no loss group with a profit loss of 22,242 Ks per ha, evidencing the negative impact of low fall on the profitability of pulse farmers.

There is a great opportunity to increase the profit efficiency of the farmers about 69% in loss group, and 61% in no loss group as a large number of farmers are almost inefficient, and the mean efficiency level is still very low. The phenomenon is more prominent in loss group, confirming that the farmers in the study area are suffered from less rainfall problem for their pulse production.

The results of stochastic frontier profit function estimation revealed that less *rainfall at the early vegetative growth stage* can reduce the profitability of the farmers who are affected yield loss due to low rainfall by mean of delay crop growth while increased *rainfall in the flowering stage* is undesirable for the achievement of high profit due to detrimental to flowering and pollination. However, pulse production in the study area is as rain-fed crop, and no irrigation facility and no other source of soil moisture availability are possible as it is a drought-prone area. The possible and feasible policy implication for the economic development of pulse farmers in these areas under the given circumstance is again the development of safety network like weather index-based crop insurance program for the farmers' income stability if they encounter the occurrence of lower or excessive rainfall condition, consequently yield and profit loss arises.

The results expressed that under low rainfall condition improvement of profitability of pulse farmers can be accomplished through the provision of seed with lower price and drought-tolerant varieties of pulses are essential features for reduction of seed used to ensure maximum profit attainment. Besides, the result shows that higher application of *chemicals* including herbicide, fungicide and insecticide can improve the profitability of farmers and thus, the efficient and effective application techniques of *chemicals* under the dry condition is also a considerable way of the cost-saving idea. More utilization of *fertilizers* consisting of granule chemical fertilizer and foliar fertilizer may decrease net return from pulse production. Even if the basal and side-dressing application of granule fertilizers is practiced, under low soil moisture content, they may not be effective the properties of the availability of these fertilizers by plant uptake. Therefore, good timing and understanding the condition of soil moisture level for fertilizer application is a need for effective use of these inputs. The specific fertilizer application technology should be conveyed to farmers adapted to the specific location of the farm. The *share area of pulses* may increase the profit from pulse production, generally suggesting that farmers should sow more lines of pulses in the mixed or intercropping pattern under low rainfall condition to resist the crop failure by drought although it needs to be assessed the profitability of other crops in this cropping system.

For the improvement of profit efficiency through the increment of farmers' managerial skill under yield loss situation from low rainfall, older farmers, less-experienced farmers, low-educated farmers, farmers from Magwe Region, credit access farmers and small-scale farmers should be encouraged to participate in the programs conducted for the upgrade of their knowledge and skill in the case of low rainfall encountered farmers. Moreover, the result of *credit access* can recommend to provide farmers not only cash but also material supports for avoiding the misuse of credit for farming activities.

In summary, this study is conducted to empirically assess the impact of low and uncertain rainfall during the pulse growing season of the CDZ. The results prove that less rainfall is a serious determinant for the achievement of maximum profitability and profit efficiency. As in the previous, weather condition like less rainfall is out of human control. Thus the confirmed suggestion for the farmer's economic development in the study area is the development of weather index-based crop insurance program along with other recommended policy implications regarding the farming practices.

Chapter 6

Coping strategy to mitigate climate change risk on economic loss of pulse production in Myanmar: Willingness to pay approach for weather index-based crop insurance

6.1 Introduction

Climate change is one of the major factors that decline agricultural productivity all over the world (Cline, 2007). Weather risk is typically highly correlated with agricultural production losses as a proxy of economic loss for farmers. This risk can be underwritten by weather index-based insurance and is becoming popular in low-income countries although the program is subjected to basis risk and high start-up cost. Many institutions suggested weather index-based crop insurance program as an instrument for enhancing the ability of farmers in lower-income countries to adapt climate change Collier et al. (2009).

Myanmar, an agro-based country, is no exception, and seriously suffers from weather distortion which makes farmers' production loss and income instability. Crop damage due to weather risks such as heavy rain, drought and hailstones was about (32,677) hectare in 2016, causing 7,630 million kyats (approximately 5.6 million US\$⁵) of economic losses to the farmers (DOA, 2016). Figure 6.1 shows the data of crop damage area (acre) and government provision for the victim farmers (million kyats). In 2016-2017, the replanted area of pulses in Bago, Yangon, Mandalay and Magwe Regions are 31,407, 8,699, 1,463 and 3,418 hectares, respectively (Figure 6.2). Currently, if farmers encountered any crop damage by severe weather incidence, the state government supports the victim farmers in the form of seed distribution to regrow and cultivation capital provision to compensate their losses in which compensation was usually done by ad-hoc observation and approval basis. However, it does, normally, not cover all the losses faced by farmers and was not received by each and every victim farmers. In the

⁵ 1 US\$ = 1362 Kyats (as of 29 December 2017)

significance and importance of pulse crops in the agriculture sector contributed to Myanmar economy, and its vulnerability, weather-related risk management system has been duly recognizing to be established. Therefore, this situation calls for a secured crop insurance program for the farmers which is an important safety net to help farmers manage the financial impacts of production risks, principally those caused by weather or uncontrollable pest and diseases.

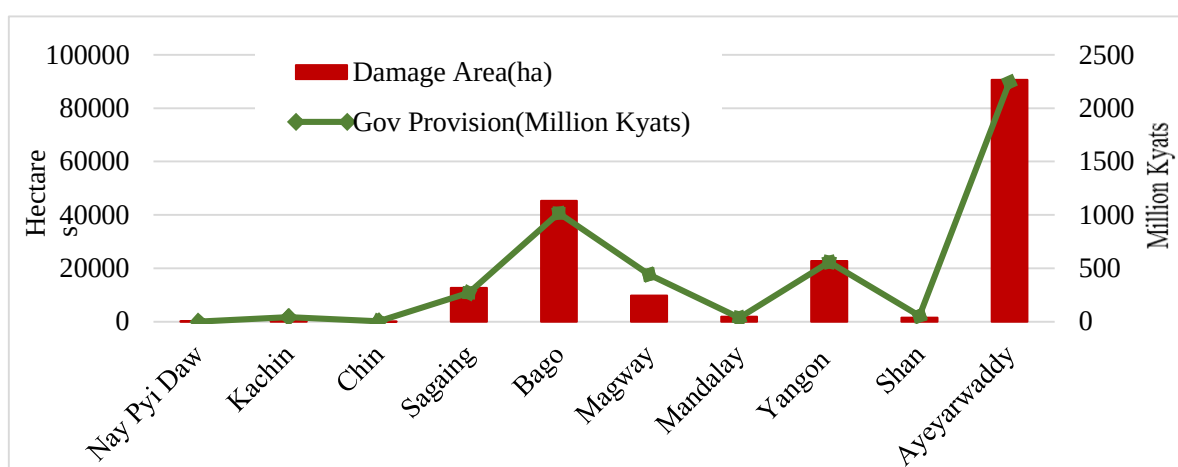


Figure 6. 1 Crop damage by heavy rain and government provision for compensation in 2016-2017

Source: DOA, 2018

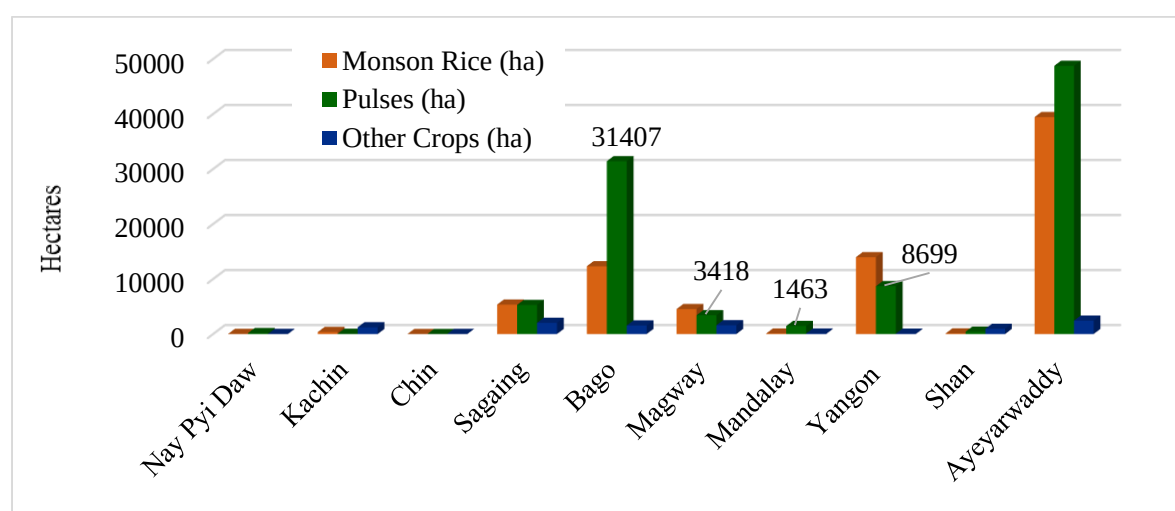


Figure 6. 2 Re-cultivated Area (Ac) and Crops

Source: DOA, 2018

6.1.1 Erratic rain in Lower Myanmar

As discussed in the previous chapter 2 and 4, erratic rain occurred during the crop growing season of pulses can hinder the efficiencies and profitability of the farmers. Rain occurrence during the sowing and seedling stage can damage and destroy the crops, whereas it can make flower shed and hinder fruit setting if it happens at the flowering stage. The Figures 6.3, 6.4, 6.5 and 6.6 show the average rainfall received during the crop growing season of pulses of November to February from 2008-2016 in each survey township of Lower Myanmar. The figures indicated that there is erratic rain during crop growing season, especially in 2015. The probability of heavy rain during growing season in Lower Myanmar for nine years is about 14% (at least once in both Bago and Yangon Regions). As seen in figures below, in 2015 November, the recorded erratic heavy rain destroyed many areas of pulses in the survey areas of Bago and Yangon regions in Lower Myanmar and consequently the farmers faced many difficulties to replant the pulses in term of not only capital reinvestment but also the seed requirement for planting again.

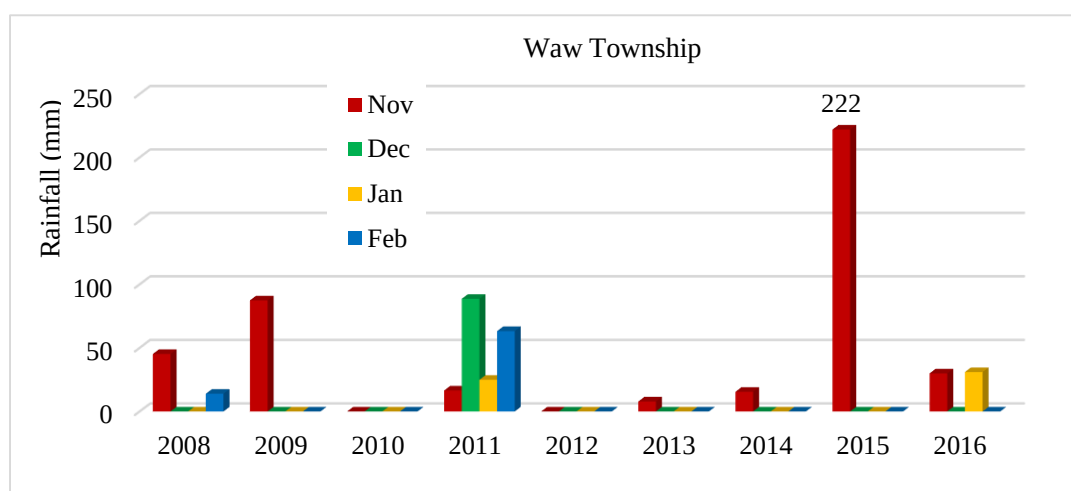


Figure 6. 3 Monthly rainfall of Waw township in the growing seasons of pulses (2008-2016)

Source: DOA, 2017

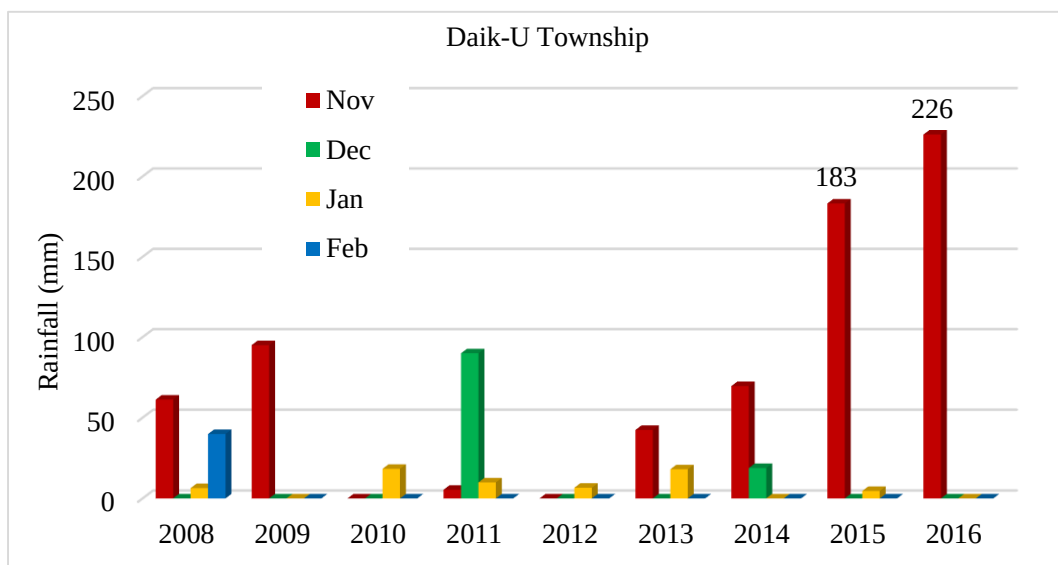


Figure 6. 4 Monthly rainfall of Daik-U township in the growing seasons of pulses
(2008-2016)

Source: DOA, 2017

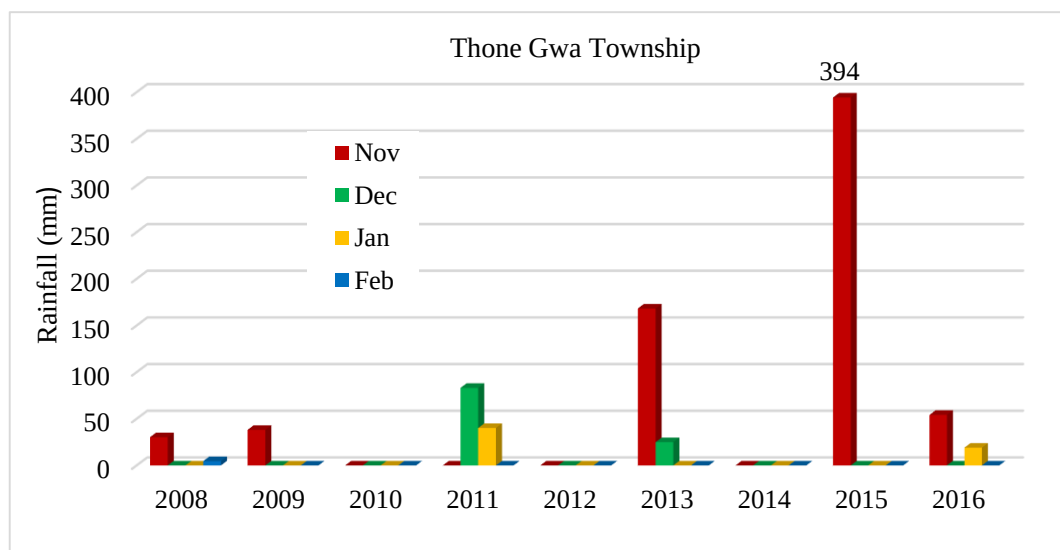


Figure 6. 5 Monthly rainfall of Thone Gwa township in the growing seasons of pulses
(2008-2016)

Source: DOA, 2017

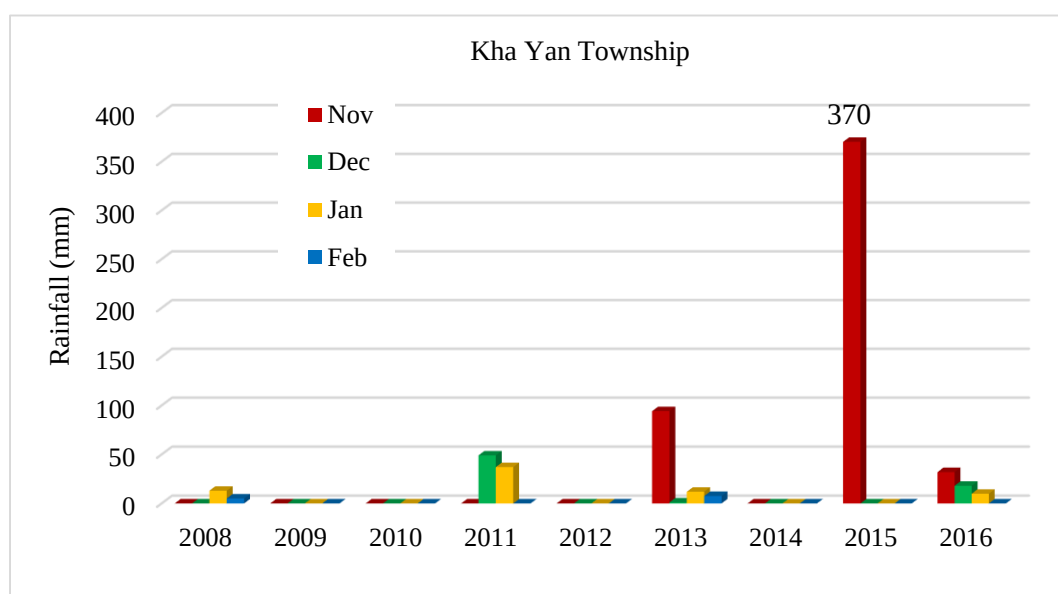


Figure 6. 6 Monthly rainfall of Kha Yan township in the growing seasons of pulses (2008-2016)

Source: DOA, 2017

6.1.2 Low rain in CDZ of Myanmar

Low rainfall leading to drought conditions is a common phenomenon in the CDZ of Myanmar with the limited water resources not only for agriculture but also for the human consumption. Agriculture in that areas is mostly rain-fed. The areas usually encountered drought during May-July, making the crop failure. Recently, the drought condition becomes more serious during the early growth stage of pulses. However, in 2016, farmers interviewed reported that they faced crop loss due to heavy rain in October, at the flowering stage of pulses, which may happen due to climate change (personal communication, 2016). When the crop insurance program is considered for the regions in CDZ, it should also pay attention not only to usual drought but also for the unexpected heavy rain.

In addition, Figures 6.7, 6.8, 6.9 and 6.10 show the average rainfall received during the crop growing season of pulses from 2008-2016 in each survey township of CDZ. The figures

indicated that there is erratic rain during crop growing season, especially in 2015. The probability of less rain during crop growing season in CDZ during nine years is about 11% (at least once in both Mandalay and Magwe Region).

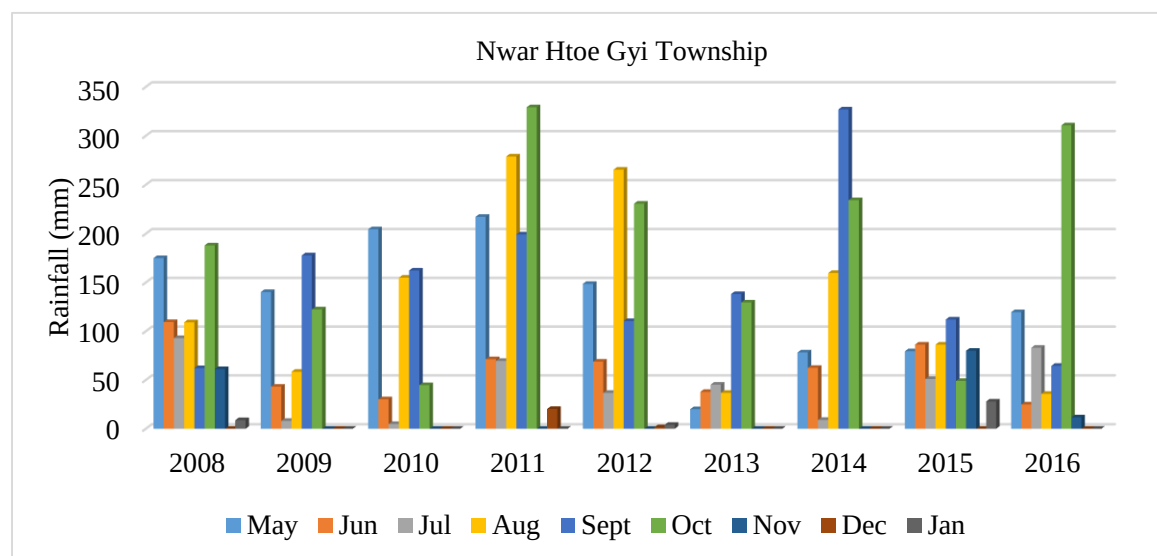


Figure 6. 7 Monthly rainfall of Nwar Htoe Gyi township in the growing seasons of pulses (2008-2016)

Source: DOA, 2017

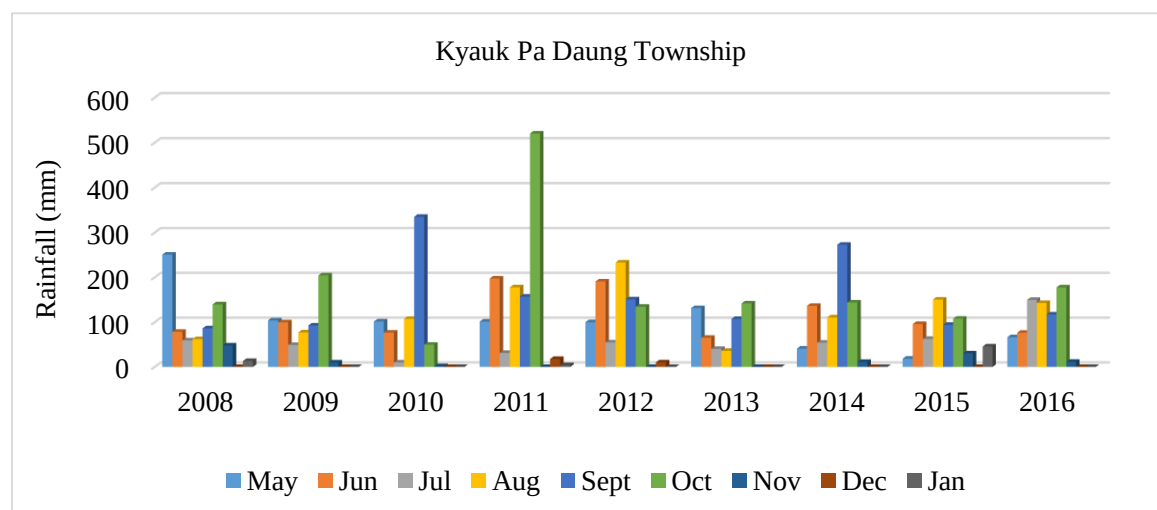


Figure 6. 8 Monthly rainfall of Kyauk Pa Daung township in the growing seasons of pulses (2008-2016)

Source: DOA, 2017

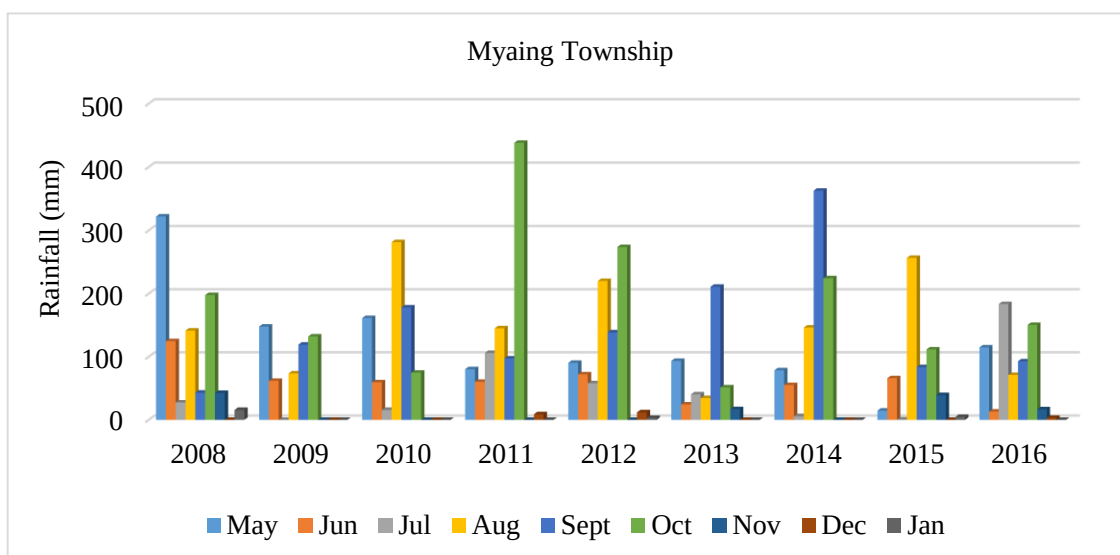


Figure 6. 9 Monthly rainfall of Myaing township in the growing seasons of pulses
(2008-2016)

Source: DOA, 2017

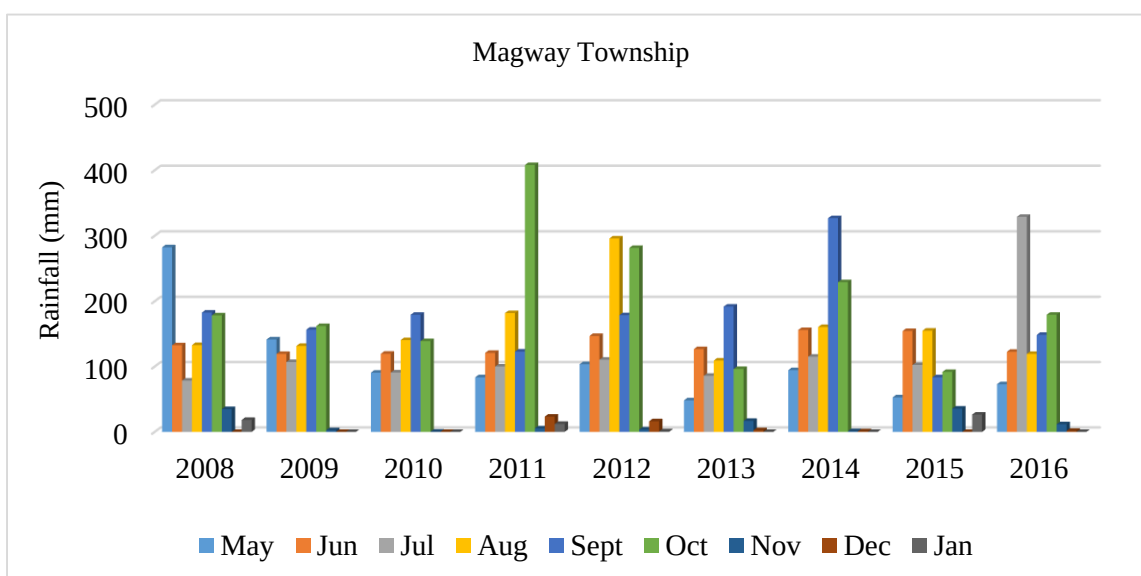


Figure 6. 10 Monthly rainfall of Magway township in the growing seasons of pulses
(2008-2016)

Source: DOA, 2017

6.1.3 Literature reviews of willingness to pay (WTP) for crop insurance in both developed and developing countries

Many studies have been carried out on weather index-based crop insurance program in developed and developing countries. Vandever (2001) studied on demand for area crop insurance using hypothetical insurance programs among lychee producers in northern Vietnam, where no formal agricultural insurance programs were developed during the study period. Liesivaara and Myyra (2014) researched WTP and its determining factors by applying Choice Experiment with mixed logit models for agricultural crop insurance in the northern EU, mainly focusing in a case study of Finland, where the crop insurance products are non-existent. The study done by Wen et al. (2015) was focused on the farmers' WTP for crop insurance in Pakistan where the crop insurance program is still underdeveloped, and the authors analyzed the WTP with the hypothetical premium rates and its determined factors. Arshad et al. (2015) evaluated the willingness to pay for crop insurance against extreme weather events in Pakistan where does not yet develop crop insurance scheme, with hypothetical insurance premium using Double-Bounded Dichotomous Choice (DBDC) Contingent Valuation Method with the estimation of WTP by logit model. Sarris et al. (2006) empirically explored WTP for and its welfare benefits of rainfall-based insurance in Tanzania by utilizing contingent valuation (CV) techniques. Yang et al. (2015) also evaluated WTP for soybean crop insurance in Jilin Province, China by using contingent valuation method (CVM) and its determining factors with the use of logit model. Conradt et al. (2015) investigated the performance of flexible weather index-based insurance design using farm-level panel data on wheat production from Kazakhstan based on growing degree days (GDD) concepts by quantile regression analysis.

Among them, the study done by Arshad et al. (2015) was focused on the farmers' WTP for crop insurance (flood and drought) in Pakistan where the crop insurance program is still underdeveloped, and the authors analyzed the WTP with the hypothetical premium rates and

its determined factors. Myanmar also has the same situation like Pakistan in crop insurance so that it is easy to follow their way of study.

This study is one of the first attempts to assess farmers' willingness to participate in and pay for weather index-based crop insurance in Myanmar to fulfill the need for the effective risk management solutions which has never been pressing before.

6.1.4 Present status of crop insurance program interest in Myanmar

The present situation of crop insurance program development in Myanmar is a very initial stage and still underdeveloped. But some international insurance companies from Japan, India, Switzerland and United States, which are interested in to invest in this issue, are now trying to pioneer the weather index-based crop insurance program and conducting the feasibility studies and preliminary trial test of insuring the paddy crop in some selected townships to verify whether there is a market potential or not for agricultural risk mitigation products and to find the most effective ways to distribute them to the farmers. However, no one has not yet done the research on farmers' willingness to join (WTJ) and willingness to pay (WTP) on weather index-based crop insurance program of pulses which is the most important fundamental need for the accelerative progress of the insurance program.

Therefore, investigation in the farmers' WTJ and WTP for a crop insurance program will contribute a supportive corner of the program initiative and be in need of current attempt to the development of agricultural insurance scheme in Myanmar as a safety net for farmers from risk aversion. To conduct the research, the research questions are coming up: (1) how many pulses farmers are willing to join (WTJ) in the weather based crop insurance program, (2) how much they are willing to pay (WTP) for the premium of the weather based crop insurance, and which factors are determining for their WTJ and WTP.

Accordingly, the main aim of this research is to provide the prerequisite information from the farmers' side which is essential for the development of effective weather index-based crop insurance program. The detail objectives are as follows:

1. to empirically investigate the pulses farmers' interest and WTJ in the crop insurance scheme,
2. to estimate the farmers' WTP for hypothetical premium levels of weather index-based crop insurance program, and
3. to identify the factors affecting the farmers' WTJ and WTP for weather index-based crop insurance program.

6.2 Research methodology

Since there is not yet an agricultural crop insurance market against weather extremes in Myanmar, a hypothetical insurance market situation was created to investigate the feasibility of the weather index-based crop insurance program and its demand by farmers. The two possible methods for the investigation of farmers' WTP for weather index-based crop insurance are contingent valuation method (CVM) and choice modeling, which were originally proposed for the valuation of non-traded environmental goods in the market. As in many literatures CVM is the most frequently adopted technique in case of hypothetical insurance markets, the method is applied to this study for the analysis of WTP for a hypothetical weather index-based crop insurance market in Myanmar.

The most widely applied CVM approach, double-bounded dichotomous choice (DB DC), initially proposed by Hanemann (1984), and extensively used in estimating WTP of non-marketed goods, was adopted to this study among other approaches such as single-bounded dichotomous choice (SB DC), bidding game, payment card and open-ended CVM. Given a higher level of precision in eliciting the WTP of the respondents, DB DC CVM is statistically more efficient than SB DC CVM, especially in the case of fewer observations (Mccarthy, 2003). Compared to SB DC approach, double-bounded logit model reduces the variance of the

estimated parameters significantly, and, there is a consistent decline in covariance (Hanemann et al., 1991). This immediately translates into a tighter confidence interval around the median WTP. The efficiency of the DBCVM lies in the fact that it defines more precise boundaries for the WTP in a closer neighborhood of the WTP/demand curve than that allowed for by the SBCVM. Mitchell and Carson (1989) stated that to measure the WTP of selected farmers Contingent Valuation Method (CVM), a non-market valuation method, is appropriate for a survey based economic research. Wen et al. (2015) also revealed that CVM is often used to assess the WTP of farmers related to various kinds of crop insurance researches. As mentioned above, in this study, CVM used in Arshad et al. (2015) will be adopted to estimate farmers' WTPs on weather index-based crop insurance by collecting the information on maximum WTP.

The demand for farmers' WTJ and WTP for weather index-based crop insurance for erratic rainfall occurrence during the pulse growing season in Lower Myanmar and less and heavy rainfall phenomenon for CDZ was separately elicited through a farm household survey applying DB DC CVM. To design the bid level and understand farmers' need for which growth stage they are willing to pay for insurance, pre-survey was conducted in 2016 while collecting data for efficiency analyses in both areas. Then, before conducting a field survey to farmers, relevant government officials responsible for insurance program development and authoritative persons from international and local insurance companies, who are interested in investing in crop insurance field, will be discussed for getting suggestions and comments on the draft questionnaire, in which their need and interest can be included. After that, the draft questionnaires were pretested for 30 farmers as in the pilot survey. Finally, the questionnaires for the hypothetical weather index-based crop insurance program was refined based on the above discussion and findings from the pilot survey. In the actual survey, six premium bid levels were designed and assigned randomly across the respondents to avoid starting-point bias (Mitchell and Carson, 1989).

Firstly, to identify the factors affecting farmers' WTJ in the hypothetical weather index-based crop insurance program, logit model following Aidoo et al. (2014) and Yang et al. (2015) is applied. The model is specified as follows:

$$\text{Logit}(P) = \alpha + \sum_{j=1}^n \beta_j X_j + u_i \quad (6.1)$$

where $\text{Logit}(P)$ is a dichotomous dependent variable expressing individual farmer's WTJ in the weather index-based crop insurance, α and β_j are the parameters to be estimated, $X_j, \dots, X_n$ are the independent variables which represents the factors affecting their WTJ in the weather index-based crop insurance and u_i is the random error term accounting for the unobserved factors. The model was estimated using the maximum likelihood estimation method.

In this study, the crop growing season was divided into two phases after discussing with the representative from the insurance company, who are designing the weather index-based insurance program for rice and sesame. Phase 1 is started from sowing time to before flowering time in the month of the beginning of November to end of December. The Phase 2 is from flowering time to first harvesting time in the month of the beginning of January to mid of February. The hypothetical payout for per acre of pulses in case of damage by erratic rain is about 100,000 Kyats.

The DB DC method specified by Hanemann et al. (1991) is applied to estimate the WTP for the hypothetical weather index-based crop insurance and factors affecting farmers' WTP. First, farmers are asked whether they are willing to participate in a weather index-based crop insurance program if the program is practically developed. If they say 'yes', the second question follows which growth stage of pulses they do insure and whether they can afford and willing to pay for the first initial bid as their choice on the phase. Then if they say 'yes' for the first bid, the second higher bid is offered to them. If they say 'no', the second lower bid level is conveyed and get their actual willingness to pay for the program. Based on these questions, the four possible outcomes are obtained:

1. π^{yy} = accepting both the first bid (β_i) and the follow-up second higher bid (β_i^u), ($\beta_i < \beta_i^u$),
2. π^{nn} = rejecting both the first bid (β_i) and the follow-up second lower bid (β_i^d), ($\beta_i^d < \beta_i$),
3. π^{yn} = accepting the first bid (β_i) and rejecting the follow-up second higher bid (β_i^u), and
4. π^{ny} = rejecting the first bid (β_i) and accepting the follow-up second lower bid (β_i^d).

Assuming a utility maximizing respondent, the formulas for these likelihoods are as follow.

$$\begin{aligned}
\pi^{yy}(B_i, B_i^u) &= \Pr\{B_i \leq \max \text{WTP and } B_i^u \leq \max \text{WTP}\} \\
&= \Pr\{B_i \leq \max \text{WTP} | B_i^u \leq \max \text{WTP}\} \Pr\{B_i^u \leq \max \text{WTP}\} \\
&= \Pr\{B_i^u \leq \max \text{WTP}\} = 1 - G(B_i^u, \theta)
\end{aligned} \tag{6.2}$$

Since, with $B_i^u > B_i$, $\Pr\{B_i \leq \max \text{WTP} | B_i^u \leq \max \text{WTP}\} \equiv 1$. Similarly, with $B_i^d < B_i$, $\Pr\{B_i^d \leq \max \text{WTP} | B_i \leq \max \text{WTP}\} \equiv 1$. Hence,

$$\pi^{nn}(B_i, B_i^d) = \Pr\{B_i > \max \text{WTP and } B_i^d > \max \text{WTP}\} = G(B_i^d, \theta) \tag{6.3}$$

When a ‘yes’ is followed by a ‘no’, we have $B_i^u > B_i$ and

$$\pi^{yn}(B_i, B_i^u) = \Pr\{B_i \leq \max \text{WTP} \leq B_i^u\} = G(B_i^u, \theta) - G(B_i, \theta) \tag{6.4}$$

When a ‘no’ is followed by a ‘yes’, we have $B_i^d < B_i$ and

$$\pi^{ny}(B_i, B_i^d) = \Pr\{B_i \geq \max \text{WTP} \geq B_i^d\} = G(B_i, \theta) - G(B_i^d, \theta) \tag{6.5}$$

Given a sample of N respondents, where B_i, B_i^u and B_i^d are bids used for the i th respondent, the log-likelihood function takes form

$$\begin{aligned}
\ln L^D(\theta) &= \sum_{i=1}^N \{d_i^{yy} \ln \pi^{yy}(B_i, B_i^u) + d_i^{nn} \ln \pi^{nn}(B_i, B_i^d) + d_i^{yn} \ln \pi^{yn}(B_i, B_i^u) + \\
&\quad d_i^{ny} \ln \pi^{ny}(B_i, B_i^d)\}
\end{aligned} \tag{6.6}$$

where d_i^{yy} , d_i^{nn} , d_i^{yn} and d_i^{ny} are binary variables; the DB DC model is estimated using log-normal and log-logistic model.

$$\text{Mean (WTP)} = \int_L^U (1 + e^{-(\beta_0 + \beta_1 \log T + \beta_2 X)})^{-1} dT \tag{6.7}$$

where $(1 + e^{-(\beta_0 + \beta_1 \log T + \beta_2 X)})^{-1}$ is the probability of saying ‘yes’. T = bid, U and L are the upper and lower limits of the integration.

$$\text{Median (WTP)} = \exp \left(\frac{-\widehat{\beta}_0 - \widehat{\beta}_2 \bar{X}}{\widehat{\beta}_1} \right) \quad (6.8)$$

where $\widehat{\beta}_0$, $\widehat{\beta}_1$ and $\widehat{\beta}_2$ are parameters to be estimated, $\bar{X}$ = mean of socio-economic variables. Zero protest bid are screened and excluded from the empirical model in this study. LIMDEP software (NLOGIT version 5) is used to estimate the parameters for the double-bounded logit regressions for crop insurance and to estimate the mean WTP.

6.2.1 Sampling design and data collection

Survey for primary data collection was conducted in Yangon and Bago Regions of Lower Myanmar, and Mandalay and Magway Regions in CDZ of Myanmar in August-September, 2017. A total of 831 farmers, 396 respondents from Lower Myanmar, in which the number of farmers who are not willing to join the program is about 53 farmers, and 434 samples from CDZ, in which 68 farmers responded that they are not interested in to join the proposed insurance program, were interviewed to elicit their WTJ and WTP on the six hypothetical premium prices of crop insurance levels. The survey methodology is a face-to-face interview on farmers’ WTP for weather index-based crop insurance using structured questionnaires which is designed by applying the hypothetical premium rates and indemnity levels.

6.2.2 Hypothetical scenario

Weather index-based crop insurance is a program tried to mitigate the production risk from severe weather conditions such as torrential or excessive heavy rain, scarcity of rain or drought during the growing season of the crops faced by farmers. In this program, firstly, farmers have to make a contract with the insurance company collaborated with or without government agencies by paying the designated premium money before planting season. If the crops were damaged by the rain or drought and if rainfall magnitude received will be exceeded

the predefined average historical rainfall during the growing season of pulses, the indemnity will be compensated to farmers after adjusting with the recorded historical rainfall data or satellite rainfall data using remote sensing technology for the respective locations.

Contracts are based on assessment of weather data, rather than property or yields, and payments are made when weather goes beyond certain metrics, regardless of the severity of the resulting impact on farms, meaning no subjective measures are required for payout. Weather index-based insurance (WII) is designed to mitigate the loss measurement problems. The mechanism is that if a certain measured weather index (for instance rainfall) is above (meaning flood) or below (meaning drought) a certain predefined threshold, then the insurance payment is made without any harvest loss assessment.

The contract has to be done for the successive 5 years and for the contract of the insurance policy, there are two kinds of contracts for different phases of growth of pulses: (1) contract designed for the period of sowing to vegetative growth stages starting from the beginning of November to end of December (2) contract for the period of reproductive to harvesting stages starting from January to end of February.

For each contract design, the price of the premium per acre of pulses will be 4,000, 8,000, 12,000, 16,000, 20,000, 28,000 Ks with the lowest value of 2,000 Ks and highest value of 35,000 Ks for each contract. If the rainfall at the nearest station near your location in the following year is below or above normal during the defined periods, then you will be paid an amount equal to 100,000 Ks which is the estimated cost of production per acre of pulses for each phase. The premium rate and indemnity are constructed after conducting the pilot survey as well as discussing with and getting the suggestions from the representative of the Japanese insurance company, who is now designating to introduce the weather index-based crop insurance program for rice and sesame farmers.

6.3 Results

6.3.1 Descriptive statistics of the variables used in the analyses for both WTJ and WTP

The descriptive statistics of the variables used in the analysis for both WTJ and WTP is presented in [Table 6.1](#). Among 396 sampled farmers in Lower Myanmar, about 87% of them responded that they are willing to join the weather index-based crop insurance program, while it was about 84% of 434 farmers from CDZ. The result indicates that there is a high demand for the insurance program, facilitating an important and valuable information to the insurance companies who want to invest crop insurance market in Myanmar. Moreover, when the farmers' perception on the choice of crop growth phases to insure their pulses are asked, 81% of the farmers are willing to join the Phase 1 while 57% want to insure for the Phase 2 in Lower Myanmar. On the other hand, only 33% interviewed farmers from CDZ are willing to participate in the insurance program for insuring Phase 1 whereas 88% are interesting in Phase 2.

In detail for Lower Myanmar (See [Table 6.2](#)), 147 farmers (37%) want to buy only the Phase 1 of the hypothetical contract for weather index-based crop insurance as they thought that weather risk for crop damage is more severe in the vegetative stage while 64 farmers (16%) want to join only to Phase 2. About 133 farmers are willing to buy both Phases to protect crop failure due to erratic rain. 13% of respondents answered that they do not want to participate in the program, mentioning many reasons such as they cannot afford to pay the premium, no belief on the company, no interest, belief on their own fortune, etc.

The farmers' perception of the choice of growth Phases for buying insurance in CDZ was depicted in [Table 6.2](#). Among 434 sample farmers, only 10% of them want to pay the insurance for the Phase 1 of the pulses while Phase 2 is occupied by 57%. In addition, 18% of farmers answered that they want to pay for both Phase 1 and 2. Only 15% of the sample farmers responded that they did not want to join the crop insurance program. The results highlighted

that the demand for the crop insurance program is allocated among farmers with their preference on the different growth Phases of the pulses.

Table 6. 1 Descriptive statistics of variables used in the models for Lower Myanmar and CDZ

Variables	Description	Lower Myanmar				CDZ			
		Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
<i>Willingness to participate</i>	Binary variable: Yes=1, No=0	0.87	0.34	0	1	0.84	0.36	0	1
<i>WTP for Phase 1</i>	Yes=1, No=0	0.81	0.39	0	1	0.33	0.47	0	1
<i>WTP for Phase 2</i>	Yes=1, No=0	0.57	0.50	0	1	0.88	0.32	0	1
<i>Gender</i>	Male=1, Female=0	0.92	0.27	0	1.00	0.88	0.33	0	1.00
<i>Age</i>	Years	50.80	11.63	23.00	84.00	53.31	12.74	25.00	85.00
<i>Education</i>	Years	6.39	4.14	0	16.00	4.97	3.70	0	15.00
<i>Experience</i>	Years	23.15	11.38	2.00	60.00	27.28	14.36	3.00	70.00
<i>Family labor participated in farming</i>	Persons	1.96	1.03	0	6.00	2.53	1.09	1.00	7.00
<i>Land ownership</i>	Yes=1, No=0	0.88	0.33	0	1	0.91	0.28	0	1
<i>Pulse area</i>	Hectares	5.72	6.15	0	44.52	2.16	1.71	0	10.12
<i>Access to government credit</i>	Yes=1, No=0	0.75	0.43	0	1	0.82	0.39	0	1
<i>Off-farm income</i>	Million Kyats	17.76	48.15	0	550	0.62	0.49	0	1
<i>Dummy for off-farm income</i>	Yes=1, No=0	0.53	0.50	0	1	0.63	0.48	0	1
<i>Agricultural income</i>	Million Kyats	9.39	12.20	0.16	98.30	2.46	3.29	0.03	42.10
<i>Crop loss due to rain last year</i>	Yes=1, No=0	0.24	0.43	0	1	0.34	0.47	0	1
<i>Previous experience encountered weather risk during five years</i>	Yes=1, No=0	0.89	0.31	0	1	0.77	0.42	0	1
Observations		396				434			

Source: Field survey, 2017

Table 6. 2 Statistics for willingness to participate for the two different phases of pulses in Lower Myanmar and CDZ

	Lower Myanmar		CDZ	
	No. of Farmer	Percent	No. of Farmer	Percent
Want to Join to only Phase 1	146	37%	42	10%
Want to Join to only Phase 2	64	16%	248	57%
Both Phases	133	34%	78	18%
Don't want to join	53	13%	68	15%
Total ample size	396	100%	434	100%

Source: Field survey, 2017

The majority of the interviewed farmers are male (92% in Lower Myanmar and 88% in CDZ), and their average *age* is about 51 and 53 years old. The average *education* level of the farmers in Lower Myanmar and CDZ is six years and five years, respectively, indicating that farmers are in the secondary and primary education level, with a wide variation from 0 year, no formal education and accomplished only monetary school level to 16 years, graduate level. The farmers are well experienced in pulse production, and their mean experience is 23 years and 27 years, respectively, in Lower Myanmar and CDZ. The *experience* also has a large range of 2 years to 60 years for Lower Myanmar farmers and three years to 70 years for CDZ due to the age difference of among farmers. On average, two persons per household is working in their own farm. Average *pulse area* sown is about 6 ha in Lower Myanmar in a range of 0 ha to 44.5 ha while farmers from CDZ averagely sows about 2.5 ha with minimum and maximum sown area of 0 ha and 10 ha, respectively, indicating that farmers from Lower Myanmar possess medium- or large-scale farm while those from CDZ are small-scale. About 53% of farmers from Lower Myanmar can generate *off-farm income* while 63% in CDZ as the CDZ farmers usually cautions to crop failure due to weather extreme and *off-farm income* becomes an important income source for their survival.

Regarding the perception of farmers to *crop loss* occurred by heavy or erratic or less rain in both study areas, 24% of farmers responded that they face erratic rain in Lower Myanmar and 34% of CDZ farmers answered that they faced *crop loss* during last growing season due to less rain and heavy rain. During the past five years, 89% of farmers faced crop damage by heavy rain in Lower Myanmar, whereas, in CDZ, 77% of farmers suffered from crop failure due to less rainfall.

The detail summary response answers for each level of the bid in each Phase of pulses are presented in Table 6.3 for Phase 1 and Table 6.4 for Phase 2 of Lower Myanmar and Table 6.5 Phase 1 and Table 6.6 for Phase 2 of CDZ.

Table 6. 3 Summary response answers for Phase 1 in Lower Myanmar

First bid	First bid and second higher bid				First bid and second lower bid				total
	Yes-Yes	%	Yes-No	%	No-Yes	%	No-No	%	
4000	22	39.29	17	30.36	8	14.29	9	16.07	56
8000	6	10.71	20	35.71	15	26.79	15	26.79	56
12000	7	12.07	14	24.14	9	15.52	28	48.28	58
16000	13	22.41	15	25.86	4	6.90	26	44.83	58
20000	6	10.34	15	25.86	4	6.90	33	56.90	58
28000	4	6.90	8	13.79	12	20.69	34	58.62	58

Source: Field survey, 2017

Table 6. 4 Summary response answers for Phase 2 in Lower Myanmar

First bid	First bid and second higher bid				First bid and second lower bid				total
	Yes-Yes	%	Yes-No	%	No-Yes	%	No-No	%	
4000	18	32.14	16	28.57	7	12.50	15	26.79	56
8000	4	7.14	15	26.79	8	14.29	29	51.79	56
12000	5	8.62	8	13.79	10	17.24	35	60.34	58
16000	6	10.34	9	15.52	5	8.62	38	65.52	58
20000	2	3.45	7	12.07	3	5.17	46	79.31	58
28000	4	6.90	10	17.24	13	22.41	31	53.45	58

Source: Field survey, 2017

Table 6. 5 Summary response answers for Phase 1 in CDZ

First bid	First bid and second higher bid				First bid and second lower bid				total
	Yes-Yes	%	Yes-No	%	No-Yes	%	No-No	%	
4000	8	13.33	8	13.33	4	6.67	40	66.67	60
8000	4	6.78	7	11.86	8	13.56	40	67.80	59
12000	9	14.75	10	16.39	3	4.92	39	63.93	61
16000	6	9.84	2	3.28	3	4.92	50	81.97	61
20000	2	3.23	10	16.13	1	1.61	49	79.03	62
28000	2	3.28	3	4.92	2	3.28	54	88.52	61

Source: Field survey, 2017

Table 6. 6 Summary response answers for Phase 2 in CDZ

First bid	First bid and second higher bid				First bid and second lower bid				total
	Yes-Yes	%	Yes-No	%	No-Yes	%	No-No	%	
4000	25	41.67	22	36.67	7	11.67	6	10.00	60
8000	10	16.95	15	25.42	22	37.29	12	20.34	59
12000	22	36.07	18	29.51	3	4.92	18	29.51	61
16000	28	45.90	8	13.11	5	8.20	20	32.79	61
20000	12	19.35	16	25.81	1	1.61	33	53.23	62
28000	9	14.75	7	11.48	6	9.84	39	63.93	61

Source: Field survey, 2017

6.3.2 Estimated results of factors affecting farmers' WTJ the hypothetical weather index-based crop insurance program

Estimated results of factors affecting farmers' WTJ the hypothetical weather index-based crop insurance program are reported in Table 6.7 for both Lower Myanmar and CDZ. Among variables incorporating into the logit regression model, for the farmers from Lower Myanmar, *family labor participated in farming* can encourage the acceptability of the payment of crop insurance. This finding is in line with the result of Agbekporu et al. (2014). The possible explanation for this variable might be family labor can not only save the cost but also earn some other off-farm income, which can make more desirable to buy the hypothetical crop

insurance contract. The result also explain that if *the family labor participant to farming* increase, the farmers will spend more money for crop insurance by saving labor cost.

Table 6. 7 Estimates of the Logit regression for the factor affecting WTJ the hypothetical weather index- based crop insurance program

Variables	Lower Myanmar				CDZ			
	Coefficient	Std. Err.	z-value	Marginal Effect	Coefficient	Std. Err.	z-value	Marginal Effect
<i>Gender</i>	-1.06	0.78	-1.36	-0.086	-1.12 **	0.55	-2.04	-0.105
<i>Age</i>	-0.02	0.02	-1.33	0.002	-0.03 *	0.01	-1.90	-0.003
<i>Education</i>	-0.02	0.04	-0.60	0.003	0.09 **	0.04	2.19	0.012
<i>Experience</i>	-0.01	0.02	-0.62	0.001	0.00	0.01	0.35	0.001
<i>Family labor participated in farming</i>	0.29 *	0.18	1.66	0.033	0.06	0.13	0.49	0.008
<i>Pulse area</i>	-0.04	0.03	-1.38	0.004	-0.05	0.09	-0.54	-0.006
<i>Off-farm income</i>	0.10	0.30	0.32	0.011	-0.32	0.29	-1.09	-0.038
<i>Agricultural income</i>	0.22 **	0.08	2.57	0.024	1.24 ***	0.07	3.59	0.029
<i>Crop loss due to rain last year</i>	1.02 **	0.47	2.16	0.092	0.69 **	0.32	2.13	0.078
<i>Previous experience encountered weather risk during five years</i>	0.46	0.44	1.06	0.058	0.31	0.31	1.01	0.040
Number of samples	343				366			
Log-likelihood function	-147.97				-173.98			
LR χ^2	15.80				28.86			
Pr (χ^2)	0.07				0.00			
Pseudo R ²	0.05				0.08			

***, **, and * indicate significance level at 1%, 5%, and 10% respectively. Std. Err. is the abbreviation of standard error.

Source: Own estimates

In CDZ, *gender* and *age* of farmers have a negative and significant relationship with the WTP indicating that male and older farmers are less willing to pay for the insurance. The

possible explanation might be that male farmers have own confidence to manage the farm even under the unfavorable weather condition and young farmers, moreover, are more willing to pay for the insurance revealing young farmers are more risk-taking than older farmers. The result also depicts that if the farmers are older one year of age, the WTP will decrease by 0.3%. Besides, *education* is positively significant at 5% level implying that the higher education level of farmers, the greater the demand for the insurance because the educated person can better understand the new product to be introduced and they are actively motivated to new innovation and challenges. The marginal effect of the *education* highlights that one year increases in education level can increase the probability of paying crop insurance about 0.9%.

In both areas, it obviously points out that *agricultural income* and *crop loss* due to weather risk encountered last year are significantly and positively related to the farmers' demand for crop insurance. This also highlights that farmers with higher *agricultural income* are more willing to pay than the low *agricultural income* farmers and farmers who faced *crop loss* during the previous year are more cautious and alerting that weather risk is a serious problem for most of the farmers and the evolvement of safety net for farmers like weather index-based crop insurance program is a need to mitigate the risks. The results obviously depict that if the *agricultural income* and *crop loss* due to rain increase by one, the probability of paying for crop insurance will increase by about 2% and 9% in Lower Myanmar and about 3% and 8% in CDZ, respectively. The results also point out that the farmers who encountered *crop loss* during the previous growing season are more likely to be participated in the weather index-based crop insurance. The result is in line with the finding of Wen et al. (2015), in which loss is positive and significant effect on farmers' willing to pay for crop insurance in Pakistan.

The chi-square value of log-likelihood ration (LR) test is significant at 10% level in Lower Myanmar case and 1% level in CDZ, indicating that the robustness of the variables in the models.

6.3.3 Farmers' WTP for weather index-based crop insurance in Lower Myanmar and CDZ

Table 6.8 reports the estimated results of the coefficients of logistic regression analysis performing maximum likelihood estimation by using NLOGIT 5 econometrics software. In Lower Myanmar, the results of both Phase 1 and Phase 2 show that *bid* effect coefficient and gender, having the negative sign at 1% significant level, are the most important determining factors for the farmers' decision of whether willingness to pay or not for weather index-based crop insurance. The results are indicating that the higher the price of the insurance, the lower the WTP and the male farmers are less willing to pay for the insurance. For the decision of the buying the insurance for Phase 1, *off-farm income* has a positive significant effect at 1% level, implying the farmers who earn income other than from agriculture are more willing to pay for insurance. This result is consistent with the intuition. Other factors determining whether to pay or not the insurance of Phase 2 are farmers' *age* and *experience*. *Age* is negatively significant at 5% level, indicating that older farmers do not want to pay much for the crop insurance. This may be due to less interest in the new product of older people.

In the case of CDZ, *bid* effect has a negative significant relation with the WTP of both Phases as in Lower Myanmar case, revealing that the more increase in the bid amount of the insurance premium, the fewer the 'yes' response and the lower WTP. In addition, WTP of Phase 1 of CDZ is significantly influenced by the *gender* of household head, *land ownership*, *pulse area* and *off-farm income*. The 1% positive significant effect of the *gender* variable on WTP indicates that male farmers are more interested in and willing to buy the insurance, which is opposite to the farmers in Lower Myanmar. The reasons might be different nature of risk encountered, and pulse cropping pattern and male farmers in CDZ are more enthusiastic to take a new challenge and their experience on risk encountered during the previous years is also a considering factor for them. Also, the coefficient of *pulse area* is negatively and significantly affected on the WTP, explaining that small-scale farmers are more willing to pay for the

insurance which may be because of high reliance of them on pulse production as a main income source for their economy.

Moreover, *land ownership* is positive and significant at 1% level in Phase 1 revealing that the farmers who are doing farming by tenants might prefer cheap premium price for insurance, compared to those who owns their land, while it is negatively significant at 1% level in Phase 2 indicating that tenant farmers are more willing to pay for insurance premium. *Off-farm income* is positively significant at 1% level in both Phases of CDZ. The interpretation of this result will go the same trend as the result of Phase 1 in Lower Myanmar.

In Phase 2 of CDZ, the different results from Phase 1 are the negative significant relation of farmers' *experience* and positive efficiency of *government credit* with WTP. In making a decision of buying crop insurance for Phase 2, less experienced farmers are more willing to buy due to the nature of risk-loving behavior of young people. *Government credit* can enhance the WTP of farmers for buying Phase 2.

The mean and median WTPs of both Phases in both study areas are mentioned in the lower part of Table 6.4. Depend on the different growth Phases and locations, the mean WTP varies. In Lower Myanmar, farmers' mean WTP for Phase 1 was quite high and it is about 12,438 Kyats per acre of pulses while the mean WTP for Phase 2 is about 9,683 Kyats (1 US\$ = 1,361 Ks on the time of the survey, August 2018) per acre. In CDZ, the mean WTP for Phase 1 is only 5,601 Kyats per acre whereas it is about 14,750 Kyats per acre for Phase 2, which is about three times of Phase 1. These differences are due to farmers' experience on risk encountered, and perception on the weather risk occurred. In Lower Myanmar, Phase 1 might be the riskiest period for the farmers to control weather uncertainty, and, on the other hand, in CDZ, farmers thought that Phase 2 is the most important Phase for achieving high productivity of pulses.

Table 6. 8 DB-logit regression results for weather index-based crop insurance in Lower Myanmar and CDZ

Variables	Lower Myanmar						CDZ			
	Phase 1			Phase 2			Phase 1		Phase 2	
	Coeff.	Std. Err.		Coeff.	Std. Err.		Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	19.54 ***	2.84		13.07 ***	2.95		3.12	2.33	15.13 ***	1.43
<i>Bid</i>	-1.81 ***	0.13		-1.51 ***	0.13		-1.05 ***	0.13	-1.68 ***	0.13
<i>Gender</i>	-1.01 ***	0.38		-0.68 *	0.39		2.06 ***	0.67	-0.06	0.31
<i>Age</i>	-0.01	0.01		-0.02 **	0.01		-0.01	0.02	0.01	0.01
<i>Education</i>	0.02	0.03		-0.01	0.03		0.02	0.04	0.05	0.03
<i>Experience</i>	0.00	0.01		0.03 **	0.01		0.02	0.02	-0.02 **	0.01
<i>Family labor participated in farming</i>	0.08	0.10		-0.10	0.13		-0.01	0.11	0.04	0.09
<i>Land ownership</i>	-0.42	0.31		-0.18	0.34		1.12 *	0.60	-0.73 *	0.44
<i>Pulse area</i>	0.01	0.03		-0.03	0.03		-0.16 *	0.09	0.09	0.07
<i>Access to government credit</i>	-0.12	0.26		0.57	0.43		0.15	0.40	0.48 *	0.27
<i>Off-farm income</i>	0.02 *	0.01		0.01	0.01		0.03 *	0.02	0.03 *	0.01
<i>Agricultural income</i>	-0.11	0.16		0.07	0.18		0.13	0.15	0.16	0.11
<i>Crop loss due to rain last year</i>	0.09	0.24		0.11	0.27		-0.24	0.27	0.00	0.22
<i>Previous experience encountered weather risk during five years</i>	0.03	0.37		0.43	0.35		0.22	0.30	-0.16	0.25
Number of samples	343			343			366		366	
Log likelihood function	-462.07			-413.26			-303.26		-461.65	
Mean WTP	12438			9683			5601		14750	
Median WTP	9192			6078			2017		11332	
(95% lower confident interval of median)	8205			5242			1415		10052	
(95% upper confident interval of median)	10297			7047			2875		12776	

Phase 1: period from sowing to before flowering, Phase 2: period from flowering to harvest.

***, **, and * indicate significance level at 1%, 5%, and 10% respectively.

Source: Own estimates

6.4 Conclusion and policy recommendations

This chapter assessed the farmers' interest and demand and their WTP for the hypothetical weather index-based crop insurance program intending for the future application of the research findings. The result of the logit model highlights that there is a high potential demand for the weather index-based crop insurance program. Farmers in Lower Myanmar are more interested in paying the premium for Phase 1 than Phase 2 considering the crop damage by erratic rain is serious at the sowing stage by making them replant the crop with the need of more capital. *Family labor involvement in farming, agricultural income and crop loss due to rain last year* are the major determining factors for participation of crop insurance program in Lower Myanmar, while in CDZ, *gender, agricultural income* as a main income source is the most prominent factor influencing for the participation of farmers in crop insurance, followed by *gender, crop loss due to rain last year, education and age* of household head. The farmers, who are young, have family labor and higher agricultural income and accomplish a higher education level, are higher willingness to participate in the crop insurance program. Moreover, those will become the future target group for the initial establishment and development of weather index-based crop insurance program in Myanmar.

Most of the farmers from Lower Myanmar are willing to join the Phase 1 of pulses, while those from CDZ want to join the Phase 2. The mean and median WTP of Phase 1 is quite higher than of Phase 2, confirming farmers are really willing to join Phase 1 in Lower Myanmar while farmers could afford to pay a higher premium of the insurance for Phase 2 in CDZ. As expected, the higher the bid level for both Phases in two study areas, the lower WTP for crop insurance. Based on the above results, young, female, well-experienced farmers who also have off-farm income from Lower Myanmar, and male, less-experienced, large-scale farmers who have own land, off-farm income and access to government credit from CDZ should become a target group for the successful evolvement of the weather index-based crop insurance program.

Chapter 7

Conclusions and policy implications

The main findings of the study will be summarized in this chapter, and the policy recommendation will be provided for production efficiency improvement under consideration of climate effect and the development of weather index-based crop insurance program in Myanmar.

7.1 Main findings and policy recommendations

By the concern that most farmers face heavy rain during the growing season of pulses and that crop damage and yield loss due to heavy rain caused extensive losses among farmers, this study was highly motivated to conduct by these factors.

7.1.1 Rainfall effects on efficiencies of the pulses farmers

First, the technical efficiency of pulse farmers considering the climate effect was analyzed by using the data collected from the pulse farmers in Lower Myanmar. The analysis was done by using not only the usual traditional inputs variables but also incorporating weather-related variables, specific *rainfall received at the flowering stage* and *replanting* the pulse when crop damage by rain. Weather-related variables prove that erratic rainfall during the growing season can be detrimental to productivity and yield, suggesting the need for the establishment of a safety net, such as a crop insurance program for income stability of the pulse farmers. The results also show that encouraging female and small-scale farmers in participating training program, provision of credit, and distributing of agricultural practices through accelerating extension services could be helped for the achievement of higher technical efficiency and productivity.

Secondly, assuming low rainfall, received during the early vegetative growth and flowering stages of pulses decreases the technical efficiency, productivity and yield of pulses

in CDZ, technical efficiency analysis was performed with the application of inputs used and rainfall and temperature at early vegetative and flowering stages. Two stochastic frontier functions with and without weather-related variables are performed for investigating the effect of these specific weather variables on technical efficiency. As a dry zone area, rain and temperature received at the early growth stage and flowering stage can increase the productivity of pulse. However, the study areas are drought-prone, and the result again demands that the need for a weather index-based crop insurance policy and program for the farmers as a safety net from the loss of the drought. Other feasible and possible ways to help farmers from loss by drought are to provide drought resistant varieties, conveying the adaptation measures for the drought to the farmers.

Third, this section tried to analyze and distinguish the effect of erratic rainfall on the profitability and profit efficiency of pulse farmers in Lower Myanmar. Based on the farmers' perception on the yield loss due to erratic rain during the 2015-2016 pulse growing season, two groups are divided as yield loss group and no yield loss group. Then farmers' profit efficiency is predicted including weather-related variables into the models in addition to the tradition inputs variables. On the other hand, benefit-cost analysis result was done, and the result indicates that yield loss farmers are more costly in capital investment and lower in profit efficiency. The findings highlight the profit loss of pulse farmers due to erratic rain incidence as well as the detrimental impact of erratic rainfall during the pulse growing season. Moreover, the stochastic frontier profit function result also confirms that yield loss farmers are less efficient than no loss farmers, pointing out that erratic rainfall received during the specific growth stage can reduce profitability in pulse production. The results of the stochastic frontier profit function also provide that the weather-related variables, the rainfall and dummy for replanting, should be incorporated in the model and rainfall variable has a negatively significant effect the profitability of the farmers within each group. To reduce economic loss and to prevent

farmers from low profit from pulse production, development of the safety network like weather index-based crop insurance program is the repeated and confirmed policy suggestion to the policymakers. Moreover, the farmers' socio-economic, managerial and demographic characteristics also determine the profit efficiency levels of farmers. Specifically, in loss group, the providing more access to credit, conducting more training program focusing on pulse production practices adapted to seasonal climate change with the target farmers who are female farmers, old household head and small-scale farmers for the improvement of the profit efficiency of the farmers. The result is also in line with the findings of Chapter 2.

Fourth, followed the same analytical framework as in the third section, benefit-cost calculation and profit efficiency analysis was conducted using data collected from farmers of CDZ. From the benefit-cost result, the net profit is higher in no loss group than in loss group, and total invested capital is higher for loss group than no loss group. The findings are also consistent with the results of Lower Myanmar, again pointing out the negative impact of low rain for the achievement of maximum profit for farmers. The profit efficiency level needs to be more improved for CDZ as the minimum profit efficiency is very low and it about 0.02%. In the stochastic frontier profit function estimation, increase in *rainfall at the early vegetative stage* is highly desirable for profit efficiency improvement and hence profitability while the result gives a surprise that *rainfall at the flowering time* can decrease profit efficiency for loss group farmers although the study area is drought-prone. This result is consistent with the findings of Chapter 2, where *the rainfall at the flowering time* also reduces the technical efficiency of farmers in Lower Myanmar. As this weather risk is unavoidable and controllable for the farmers, the repeated policy recommendation is the development of safety net like weather index-based crop insurance program to protect farmers from profit loss and help income stability. Provision of drought-resistant varieties of seed and efficient and effective application techniques of chemicals and fertilizer under a dry condition is a recommendation

for policy implication to reduce the cost of production and consequently high profitability. Moreover, older farmers, less-experienced farmers, low-educated farmers, farmers from Magwe Region, and small-scale farmers should be encouraged to participate in the programs to improve farmers' managerial skill for achieving high-profit efficiency.

7.1.2 Comparison of the results of stochastic frontier production function between Lower Myanmar and CDZ

The results of stochastic frontier production functions were compared between Lower Myanmar and CDZ and were shown in Table 7.1. The main differences of the results between two study areas were *rainfall at the flowering time*, *fertilizer* and *land preparation cost*. In the results, *rainfall at the flowering time* has a negatively significant effect on productivity in Lower Myanmar, indicating that rainfall received during the flowering time can decrease the yield of pulses, while this variable has a positive significant impact, implying rainfall occurred during the flowering time can enhance the flowering formation and fruit setting of the pulses, consequently increase productivity because CDZ is dry zone area and water scarcity is the main problem for crop production.

Moreover, *fertilizer* and *land preparation cost* has a negative relationship with the productivity in Lower Myanmar, explaining that these inputs are overused, and the more use of these inputs cannot be increased the yield of pulses anymore so that these inputs should be used with care and effective application technique of these inputs should be conveyed to farmers. However, the more utilization of *fertilizer* can improve the yield of pulses in CDZ, demanding the special requirement of conveying the farmers the effective and efficient utilization technology of fertilizer under dry condition. The more use of *land preparation cost* can increase the productivity as land preparation such as ploughing, harrowing and weeding with draught is the common activity in CDZ for soil moisture availability.

Table 7. 1 Comparison of the results of stochastic frontier production function between Lower Myanmar and CDZ

Lower Myanmar	Sign of coeff.	Significance	CDZ	Sign of coeff.	Significance
Production function					
<i>Replanting cost</i>	+	*	<i>Rainfall at early vegetative growth stage</i>	+	
			<i>Temperature at early vegetative growth stage</i>	+	***
<i>Rainfall at flowering time</i>	-	***	<i>Rainfall at flowering time</i>	+	***
			<i>Temperature at flowering time</i>	+	
<i>Seed rate</i>	+	***	<i>Seed rate</i>	+	***
<i>Fertilizer</i>	-		<i>Fertilizer cost</i>	+	***
<i>Chemicals</i>	+		<i>Chemicals</i>	+	*
<i>Human labor</i>	+	***	<i>Human labor</i>	+	***
<i>Land preparation cost</i>	-	***	<i>Land preparation cost</i>	+	***
Technical inefficiency effect function					
<i>100% yield loss from rain</i>	+	**			
<i>75% yield loss from rain</i>	+	**	<i>75% yield loss from rain</i>	+	
<i>50% yield loss from rain</i>	+		<i>50% yield loss from rain</i>	+	
<i>25% yield loss from rain</i>	+	**	<i>25% yield loss from rain</i>	+	
<i>Gender of household head</i>	-	**	<i>Gender of household head</i>	+	***
<i>Age of household head</i>	+				
<i>Experience of household head</i>	-		<i>Experience of household head</i>	-	
<i>Education of household head</i>	+		<i>Education of household head</i>	-	
<i>Credit access</i>	-	**			
<i>Participation in farmer organization</i>	-		<i>Participation in farmer organization</i>	-	
<i>Training access</i>	-	*	<i>Training access</i>	-	*
<i>Location</i>	-	*	<i>Location</i>	+	
<i>Pulse area</i>	-	**	<i>Pulses area</i>	+	***
Total number of observations	182			166	

Coeff. means coefficient.

Source: Own estimates

From the technical inefficiency effect function, the results of *gender* and *pulses area* are opposite in Lower Myanmar and CDZ. In Lower Myanmar, male and large-scale farmers are more efficient than female and small-scale farmers which are resulted in CDZ. The possible reason may be that in Lower Myanmar when erratic rain incidence occurred during the growing season, the active performance and definitive decision on farm management of male and large-scale farmers may be important to protect the crop damage by rain. However, in CDZ detail management of female and small-scale farmers is a good practice for achieving the high yield.

7.1.3 Comparison of the results of stochastic frontier profit function between Lower Myanmar and CDZ

The analysis results of stochastic frontier profit functions were compared between same groups of Lower Myanmar and CDZ and were shown in [Table 5.7](#). However, some variables are different between Lower Myanmar and CDZ. In this regard, *replanting cost* variable is not included in CDZ as after crop failure by low rain in CDZ, the crop cannot be replanted the crop like in Lower Myanmar where enough moisture is available by waiting some times after heavy rain incidence. In Lower Myanmar, *land preparation cost* variable was excluded because of correlation while it was included in CDZ. Moreover, share area of pulses variable is a lack in Lower Myanmar where pulses are sown as a sole crop while in CDZ they are grown in an intercropping or mix-cropping system with other crops. In profit inefficiency effect function, *gender* of farmers in CDZ is omitted in the analysis as almost all of the farmers are male.

In the results between loss groups of two study areas, *rainfall at the flowering stage* have a negative and significant relation with profitability while these variables of no loss groups of two areas have opposite findings with a negatively significant effect in Lower Myanmar and a positive and significant impact in CDZ. The estimated results of *normalized price of seed* have a negatively significant impact on profit of the farmers in loss groups of both areas. The *fertilizer* variables of loss groups also have a similar effect with the *normalized price of seed*.

In no loss groups of two areas, *normalized price of chemicals* variables and *chemicals* variables have the same positive relationship with profitability. The interpretation of for all these similarities of the results among the groups in two areas will be illustrated as in each respective result and discussion section of Chapter 4 and 5.

The main differences among the loss groups of two locations are *normalized price of chemicals* and *chemicals* in loss group, in which they are a negative effect on profit in Lower Myanmar while a positive impact of these variables on profitability in CDZ, indicating the separate policy recommendation of these variables for each study area. Besides, *normalized prices of human labor* and *land preparation cost*, and *fertilizer* of no loss groups have an opposite sign, implying increase of the *price of human labor* and *land preparation* can decrease the profitability for farmers in Lower Myanmar while enhancing the profit of the farmers in CDZ. Increase use of fertilizer can be improved the profitability for Lower Myanmar whereas it can lower in CDZ, highlighting the efficient and effective application technique of fertilizer under dry conditions required for farmers in CDZ.

In all groups of two areas, seed rate is positively and significantly related to profitability, pointing out the need of provision of improved varieties of seed and recommended rate of seed for each specific location.

From the profit inefficiency effect function, the results of *age* in loss groups of both areas have a positive relationship with profit inefficiency, while it has a negative effect in no loss groups. In loss groups of both areas, *pulses area* have a negatively significant impact on inefficiency, revealing large-scale farmers are profitably more efficient than small-scale farmers. The results of *credit access* have a contradict sign between both of loss and no loss groups, in which *credit access* can improve profit efficiency level of the farmers in Lower Myanmar, but in CDZ the farmers who are access to credit have a low-profit efficiency,

Table 7. 2 Comparison of the results of the stochastic frontier profit function between Lower Myanmar and CDZ

Lower Myanmar			CDZ		
Variables	Loss	No loss	Variables	Loss	No Loss
	Sign of coeff.	Sign of coeff.		Sign of coeff.	Sign of coeff.
Production function					
Replanting cost	+ ***		Rainfall at early vegetative growth stage	+ ***	- ***
Rainfall at flowering stage	- ***	- ***	Rainfall at flowering stage	- ***	+ ***
P _S	- ***	+	P _S	- **	- ***
P _F	- ***	+ ***	P _F	+	- ***
P _C	- ***	+ ***	P _C	+ *	+ ***
P _L	- ***	- ***	P _L	-	+ ***
P _{LP}	- ***	- ***	P _{LP}	+	+ ***
Seed rate	+ ***	+ ***	Seed rate	+ ***	+ ***
Fertilizer	- ***	+ ***	Fertilizer	- ***	- ***
Chemicals	- ***	+ ***	Chemicals	+ ***	+ ***
Human labor	- ***	+	Human labor	-	- ***
			Land preparation cost	+	- ***
			Share area of pulses	+ **	- ***
Profit inefficiency effect function					
Gender of household head	- **	+ **	-		
Age of household head	+ ***	- ***	Age	+ ***	- ***
Experience of household head	-	+ ***	Experience	- ***	+ **
Education of household head	-	+ ***	Education	- **	+
Credit access	- ***	- ***	Credit access	+ *	+ **
Participation in farmer organization	-	- ***	Participation in farmer organization	+	-
Training access	- ***	+ ***	Training access	+	- **
Location	-	+ ***	Location	- ***	+
Pulses area	- **	- ***	Pulse area	- **	+
Total number of observations	182			166	

Coeff. means coefficients.

Source: Own estimates

recommending the increased support of credit for farmers in Lower Myanmar and material provision for farming will be more appropriate for farmers in CDZ.

In no loss groups of both areas, farmers' *experience* has a negative effect on efficiency, depicting less-experienced farmers are more efficient and *experience* is not an important factor for the achievement of maximum profit under no crop damage by uncertain rain occurrence.

For no loss group of Lower Myanmar, *training access* is a negative impact on profit efficiency while it is positively related to efficiency, suggesting the requirement of effective and applied for training programs regarding farming practices for farmers in Lower Myanmar and encouragement of more participation of farmers in CDZ to the training programs.

7.1.4 Demand of and factors affecting WTJ of the pulse farmers for the weather index-based crop insurance

In this section, the demand for and factors affecting WTJ of the farmers for the hypothetical weather index-based crop insurance instrument was estimated by using the logit model. About 87% (345 farmers) among 397 farmers interviewed from Lower Myanmar and about 84% (365 farmers) of 434 samples answered that they are interested in and willing to join the hypothetical insurance program, indicating that a great demand exists in the future crop insurance market in Myanmar. Farmers from Lower Myanmar are more willing to join Phase 1 (81% of the samples) than Phase 2 (57%), whereas the interest of farmers from CDZ is opposite to those of Lower Myanmar, have more interest in Phase 2 (88%) than Phase 1 (33%), consequently their WTP is also higher for their preferred Phases. The results suggest the potential insurance companies to mainly focus on the farmers' preference when establishing the weather index-based crop insurance program in Myanmar. Only 13% of sample farmers in Lower Myanmar and 15% of the interviewed farmers in CDZ responded that they are not willing to join the program that they do not want to participate in the program, mentioning many reasons such as they cannot afford to pay the premium, no belief on the company, no

interest, belief on their own fortune, etc.. It can be implied that to be attracted those persons, more educational and awareness program is needed to be provided if the actual market for the product emerges.

The estimated results of the factors affecting farmers' WTJ the hypothetical weather index-based crop insurance program for Lower Myanmar explains that the WTJ is positively and significantly related to the *family labor*, *agricultural income* as a main income source and *crop loss due to weather risk encountered last year*. In CDZ, *agricultural income* and *crop loss due to rain last year* are the most important factors, followed by education and age. Therefore, when starting to establish a weather index-based crop insurance program, young farmers, farmers who have *family labor* and higher *agricultural income* and accomplishes higher *education* level should be targeted for the successful development of the program in CDZ. On the other hand, it can be concluded that if the insurance companies want to establish and expand their work, they should pay more attention to explain to low educated farmers about the program for their better understanding on the product. Moreover, for both study areas, *crop loss* is a common determining factor for the adoption of the hypothetical insurance program proving the farmers' awareness and perception on the consequences of low or heavy rainfall during the growing season of pulses.

7.1.5 Farmers' WTP and factors affecting WTP for weather index-based crop insurance

In this analysis, data eliciting farmers' WTP for insurance is demonstrated by using double bounded logit model for both Lower Myanmar and CDZ. The mean WTP is about 12,438 Ks per acre for Phase 1 and 9,683 Ks per acre for Phase 2 in Lower Myanmar with the median WTP of 9,192 Ks and 6,078 Ks, respectively, whereas it is about 5,601 Ks per acre for Phase 1 and 14,750 Ks for Phase 2 in CDZ with the median WTP of 2,017 Ks and 11,332 Ks, respectively. The results notify the insurance companies that the farmers have own capability

for the payment of crop insurance, which is higher with their preferred Phase for insuring their pulses.

For both areas, the high premium rate will be less attractive for farmers in paying the insurance, suggesting the careful calculation and setting of a premium rate for each Phase of pulses in each location will be necessary by considering the estimated WTP as a reference for the insurance companies. In Lower Myanmar, the development of weather index-based crop insurance program can be achieved by focusing on young, female, well-experienced farmers who also have off-farm income.

In CDZ, male farmers will be more likely to join the program compared to female farmers, as a nature of risk aversion by man. The farmers who are less- experienced, access to government, those who are growing pulses on their own land, and those who have off-farm income in addition to agricultural income seem to have high WTP on the insurance. Those farmers should be key persons in an initial stage of designation and establishment of the program for a rapid achievement among farmers.

In summary, erratic rainfall as heavy or low has a detrimental impact on the efficiencies, productivity and profitability of the pulse farmers. As a safety device to protect farmers from weather risk, weather index-based crop insurance is a feasible and potential tool which hope to evolve in the near future in Myanmar as most of the farmers are interested in the program and highly willing to participate in and pay for the insurance.

7.2 Research contributions and suggestion for the further studies

The results of the analysis incorporating rainfall variables received at the specific growth stage of the pulses is the new contribution to the literature of the efficiency study as it is the first attempt to use these variables in the efficiency analysis. The findings of the research will support the valuable information not only for the farmers' socio-economic improvement to the policymakers but also a valuable consideration for the insurance companies who are

interested in investment of agricultural insurance in Myanmar by reflecting the farmers' actual WTP on the insurance when they design for the insurance contract for the farmers.

Although the study focused on the pulses, the research approach should be expended to other crops, especially the most sensitive crop like rice to the climate change for the emergence of useful policy recommendation for each crop as the crops are usually different in growing nature.

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Appendix A: Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for loss group and no loss group in Lower Myanmar

Table A.1. Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for loss group of Lower Myanmar

Variables	Model (1) with weather related variables			Model (2) without weather related variables		
	Coeff.	Std. Err	t-ratio	Coeff.	Std. Err.	t-ratio
Production function						
Constant	23.10***	1.44	16.08	26.46***	0.95	27.86
P_S	-1.54***	0.10	-14.72	-1.67***	0.02	-75.41
P_F	-0.32***	0.03	-10.65	-0.01***	0.01	-2.43
P_C	-0.97***	0.09	-10.92	-1.23***	0.08	-14.81
P_L	-1.16***	0.07	-17.55	0.32**	0.16	2.03
P_{LP}	-0.20***	0.03	-6.56	-1.28***	0.02	-57.62
<i>Rainfall</i>	-0.30***	0.00	-115.46	-	-	-
<i>Dummy for replanting</i>	0.69***	0.06	11.50	-	-	-
<i>Seed rate</i>	0.54***	0.13	4.07	-0.33***	0.03	-11.16
<i>Fertilizer</i>	-0.57***	0.03	-18.45	-0.46***	0.02	-20.27
<i>Chemicals</i>	-1.01***	0.07	-13.66	-0.66***	0.09	-7.62
<i>Human labor</i>	-1.84***	0.08	-21.92	-1.18***	0.09	-12.40
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	17.76***	1.10	16.15	15.87***	1.07	14.81
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	1.00***	0.00	37116718.00	1.00***	0.00	44718559.00
Log likelihood function	-137.77			-144.70		
Profit inefficiency effect function						
Constant	-0.99	1.03	-0.96	-1.60	1.19	-1.34
<i>Gender</i>	-4.73**	1.68	-2.81	-4.57***	1.49	-3.07
<i>Age</i>	3.79***	1.27	2.98	3.15**	1.49	2.11
<i>Experience</i>	-0.04	0.84	-0.05	0.44	1.28	0.34
<i>Education</i>	-0.77	1.25	-0.62	-0.18	1.47	-0.13
<i>Credit access</i>	-6.86***	1.43	-4.80	-5.27***	1.72	-3.06
<i>Participation in farmer organization</i>	-1.26	1.06	-1.19	-2.12*	1.23	-1.72
<i>Training access</i>	-5.12***	1.36	-3.76	-2.78*	1.50	-1.86
<i>Location</i>	-0.21	1.20	-0.17	-0.11	1.01	-0.11
<i>Pulse area</i>	-1.79**	0.81	-2.21	-1.48**	0.62	-2.40

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level. Coeff. And Std. Err. are abbreviations for coefficient and standard error, respectively.

Source: Own estimates

Table A.2. Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for no loss group of Lower Myanmar

Variables	Model (1) with weather related variables			Model (2) without weather related variables		
	Coeff.	Std. Err	t-ratio	Coeff.	Std. Err	t-ratio
Production function						
Constant	6.80***	0.52	12.99	6.87***	1.07	6.44
P_S	0.07	0.07	0.98	-0.29	0.19	-1.50
P_F	0.11***	0.02	6.42	-0.04	0.04	-1.14
P_C	0.09***	0.03	2.91	-0.13***	0.03	-4.92
P_L	-0.28**	0.11	-2.53	-0.08	0.12	-0.65
P_{LP}	-0.47***	0.15	-3.21	-0.31*	0.18	-1.73
<i>Rainfall</i>	-0.11***	0.02	-5.38	-	-	-
<i>Seed rate</i>	0.34***	0.08	4.43	0.15***	0.05	2.97
<i>Fertilizer</i>	0.10***	0.01	10.63	-0.04	0.04	-0.96
<i>Chemicals</i>	0.11***	0.03	3.92	0.21***	0.03	8.46
<i>Human labor</i>	0.09	0.05	1.60	0.23***	0.04	5.84
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	23.01***	2.03	11.33	17.68***	0.93	18.91
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99***	0	8621144.00	0.99***	0	29527677.00
Log likelihood function	-159.79			-161.28		
Profit inefficiency effect function						
Constant	-2.71**	1.00	-2.72	-2.48***	1.00	-2.49
<i>Gender</i>	2.78**	0.99	2.81	3.71***	1.00	3.72
<i>Age</i>	-10.16***	0.92	-11.06	-9.27***	0.82	-11.33
<i>Experience</i>	8.63***	1.13	7.61	7.48***	0.95	7.90
<i>Education</i>	4.17***	0.92	4.55	4.24***	0.88	4.82
<i>Credit access</i>	-2.86***	1.02	-2.81	-1.67***	0.98	-1.70
<i>Participation in farmer organization</i>	-19.72***	1.56	-12.65	-16.97***	0.87	-19.59
<i>Training access</i>	3.56***	0.99	3.60	2.66**	0.99	2.69
<i>Location</i>	12.07***	1.00	12.04	11.32***	0.93	12.14
<i>Pulse area</i>	-5.37***	0.78	-6.91	-4.84***	0.79	-6.13

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level. Coeff. And Std. Err. are abbreviations for coefficient and standard error, respectively.
Source: Own estimates

Appendix B: Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for loss group and no loss group in CDZ

Table B.1. Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for loss group of CDZ

Variables	Model (1) with weather related variables			Model (2) without weather related variables		
	Coeff.	Std. Err.	t-ratio	Coeff.	Std. Err.	t-ratio
Production function						
Constant	-3.60**	1.62	-2.22	-6.30**	2.35	-2.68
<i>Rainfall at early vegetative growth stage</i>	2.39***	0.69	3.48	-	-	-
<i>Rainfall at flowering stage</i>	-0.66***	0.22	-2.98	-	-	-
P_S	-0.64**	0.26	-2.48	-1.27	1.45	-0.87
P_F	0.07	0.15	0.49	0.43**	0.15	2.93
P_C	0.19*	0.10	1.94	0.34**	0.15	2.27
P_L	-0.41	0.52	-0.78	-0.66**	0.23	-2.85
P_{LP}	0.01	0.47	0.01	-1.64***	0.33	-4.96
<i>Seed rate</i>	0.34***	0.08	4.38	0.25	0.25	1.03
<i>Fertilizer</i>	-0.14***	0.04	-3.45	0.04	0.07	0.50
<i>Chemicals</i>	0.19***	0.04	4.49	0.16	0.14	1.18
<i>Human labor</i>	-0.08	0.09	-0.92	-0.26	0.32	-0.80
<i>Land preparation cost</i>	0.18	0.47	0.38	1.77***	0.12	14.83
<i>Share area of pulses</i>	0.27**	0.12	2.20	0.28**	0.11	2.69
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	12.90***	1.27	10.19	9.87***	1.32	7.49
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99***	0.00	340677.73	0.99***	0.00	9747.77
Log likelihood function	-189.55			-193.03		
Profit inefficiency effect function						
Constant	0.28	0.99	0.28	0.40	0.96	0.42
<i>Age</i>	3.16***	0.75	4.20	3.00***	0.74	4.04
<i>Experience</i>	-2.54***	0.84	-3.02	-2.55***	0.80	-3.17
<i>Education</i>	-2.05**	0.96	-2.13	-2.06**	0.85	-2.41
<i>Credit access</i>	1.75*	0.99	1.77	1.37	0.87	1.57
<i>Participation in farmer organization</i>	0.71	1.06	0.67	1.20	1.00	1.20
<i>Training access</i>	0.30	0.95	0.31	0.01	0.79	0.01
<i>Location</i>	-6.32***	1.13	-5.58	-3.53***	0.90	-3.93
<i>Pulse area</i>	-2.37**	0.94	-2.52	-0.93	0.91	-1.02

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level. Coeff. And Std. Err. are abbreviations for coefficient and standard error, respectively.
Source: Own estimates

Table B.2. Maximum-likelihood estimates of the stochastic frontier profit functions of Model (1) and Model (2) for no loss group of CDZ

Variables	Model (1) with weather related variables			Model (2) without weather related variables		
	Coefficient	Std. Err	t-ratio	Coefficient	Std. Err	t-ratio
Production function						
Constant	16.55***	0.14	114.33	14.24***	0.98	14.46
<i>Rainfall at early vegetative growth stage</i>	-4.66***	0.02	-227.28	-	-	-
<i>Rainfall at flowering stage</i>	2.24***	0.02	112.71	-	-	-
P_S	-1.69***	0.03	-51.65	-1.77**	0.68	-2.61
P_F	-1.02***	0.02	-46.02	0.43	0.27	1.61
P_C	0.59***	0.01	110.36	0.41*	0.25	1.68
P_L	1.01***	0.03	37.61	1.33**	0.63	2.12
P_{LP}	0.16***	0.01	16.40	1.64***	0.34	4.83
<i>Seed rate</i>	1.10***	0.02	68.44	1.44***	0.46	3.12
<i>Fertilizer</i>	-0.47***	0.01	-59.40	0.09	0.15	0.62
<i>Chemicals</i>	0.86***	0.00	187.48	0.42**	0.19	2.24
<i>Human labor</i>	-0.46***	0.01	-48.13	-0.93**	0.50	-1.86
<i>Land preparation cost</i>	-0.17***	0.01	-18.49	-1.39***	0.22	-6.27
<i>Share area of pulses</i>	-0.36***	0.02	-23.53	-0.59***	0.20	-2.94
Variance parameters						
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	22.49*	12.04	1.87	9.49***	0.89	10.67
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99****	0.00	5452273.60	0.9***	0.00	1026372.50
Log likelihood function	-91.62			-108.24		
Profit inefficiency effect function						
Constant	-12.42	11.51	-1.08	-0.10	0.99	-0.10
<i>Age</i>	-2.83***	0.98	-2.89	0.17	0.73	0.23
<i>Experience</i>	3.30**	1.49	2.22	0.70	0.92	0.75
<i>Education</i>	1.08	0.92	1.17	0.19	0.83	0.23
<i>Credit access</i>	8.21**	4.19	1.96	0.17	1.09	0.16
<i>Participation in farmer organization</i>	-26.07	22.46	-1.16	-0.17	0.98	-0.17
<i>Training access</i>	-7.74**	3.66	-2.11	-1.58*	0.82	-1.93
<i>Location</i>	2.35	2.00	1.17	-0.26	0.98	-0.27
<i>Pulse area</i>	1.76	1.64	1.07	-1.16	0.94	-1.23

Note: ***, **, * represents significance at the 1% ($p < 0.01$), 5% ($p < 0.05$) and 10% ($p < 0.10$) level. Coeff. And Std. Err. are abbreviations for coefficient and standard error, respectively.
Source: Own estimates

Appendix C: Questionnaires for data collection for the Stochastic Frontier Analysis

QUESTIONNAIRES FOR FARM HOUSEHOLD SURVEY

Date:

Interviewer:

Question No.:

Place:

1. Information about Farm Household

- 1.1. Name of Interviewee
 1.2. Gender 1. ☐ Male 2. ☐ Female
 1.3. Ageyears
 1.4. Education (Schooling Years)years
 1.5. Head of farm household 1. ☐ Male 2. ☐ Female
 1.6. Farming Experienceyears
 1.7. Farm working status 1. ☐ Full time 2. ☐ Part time

2. Family Information

2.1. General information of household's members

No.	Name	Age	Relationship with interviewee (*)	Education		Occupation (***)	Off-farm Income (Ks/Year) (****)	Participation in agriculture (*****)
				Type (**)	If type 2, Formal Schooling years?			
1								
2								
3								
4								
5								
6								
7								

(*) 1 = Head of HH, 2 = Wife/husband, 3 = Daughter/Son, 4 = Parents, 5 = Others (specify)

(**)Type: No schooling=0, Monastery school =1, Formal school=2

(***) 1 = farming, 2 = off-farm (specify)

(****)The amount of off-farm income per year

(*****) 1 = yes, 2 = no

Note: If there are more than 7 members, please use the space below.

3. Information on Land Ownership and Land Use

- 3.1. Total Farm Size cultivatedAcres
- 3.2. Type of Farming 1. ☐ Own farm 2. ☐ Tenancy 3. ☐ Both
- 3.3. If tenancy or both, how many acre of land did you tenant the winter season of 2015? () Acres
How much have you paid for one acre of land per season ? () Ks
- 3.4. What is the type of your land and its soil fertility?
- | | |
|---|---|
| 1. ☐ Low land <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> 1. ☐ Good
 2. ☐ Fair
 3. ☐ Bad </div> | 2. ☐ Upland <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> 1. ☐ Good
 2. ☐ Fair
 3. ☐ Bad </div> |
|---|---|
- 3.5. What is the level of your land? 1. ☐ Flat 2. ☐ Sloping areas

4. Cropping information

4.1.	How many cropping season per year can you do farming in your farm? () cropping season/s	
4.2.	What crops and how many area did you cultivate in the winter season of 2015? Name of crops Area (Acres) a. () b. () c. () d. ()	
4.3.	Which kind of pulses crops did you grow in the winter season of 2015? Name of pulses Area (Acres) 1. () 2. () 3. () 4. ()	

5. Information on Pulses Production

5.1. Land preparation

For land preparation, how many machinery power, animal power and human labor did you use in winter season of 2015?

Works (Both Green Gram and Black Gram)	Family Labor		Hired labor			
	Quantity (persons)	Workday (days)	Quantity (persons)	Workday (days)	Wage rate (Ks/day)	Total Amount
Land Clearing (Human labor)						
Ploughing (Human labor)						
Harrowing (Human labor)						
Ploughing (Machinery)						

Ploughing (Animal)						
Harrowing (Machinery)						
Harrowing (Animal)						

5.2 Planting Cost

5.2.1 What is the seed rate per acre in winter season of 2015?

1. Green GramBsk /Acre 2. Black GramBsk/Acre

5.2.2. Sowing Seed Information and Seed Cost

Seed Cost	Green Gram			Black Gram		
	Quantity (Bsk)	Price/Bsk (Ks)	Total cost	Quantity(Bsk)	Price/Bsk (Ks)	Total cost
1.Own Seed						
2.Bought Seed						

5.2.3. What is the name of the cultivars of the Green Gram and Black Gram and their sown area?

	Name of Cultivars	Sown Area (Acres)	Remark
Green Gram	1.		
	2.		
	3.		
Black Gram	1.		
	2.		
	3.		

5.2.4. Labor Cost for sowing in winter season of 2015

Labor Cost	Family Labor		Hired labor			
	Quantity	Workday (days)/season	Quantity	Workday (days)/season	Wage rate (Ks/day)	Total Amount
For Green Gram						
Human (head)						
Animal (pair)						
Machinery (acre)						
Black Gram						
Human (heads)						
Animal (pair)						
Machinery (acre)						

5.3 Weeding Cost

5.3.1. Did you use Herbicides for weeding?

1. ☐ Yes 2. ☐ No.

5.3.2. If yes, how many times did you use it? times

5.3.3. Please give the following information for herbicides.

Name of Herbicides	Total use (Litre)	Price(Ks/unit)	Cost	For how many acre of land did you apply Herbicide?
For Green Gram				
1.				
2.				
For Black Gram				
1.				
2.				

5.3.4. How many labor did you use to spray herbicides in winter season of 2015?

Herbicide Application	Family Labor		Hired labor			
	Quantity (person)	Workday (days)/season	Quantity (person)	Workday (days)	Wage rate (Kyat / day)	Total Cost
For Green Gram						
1.						
2.						
For Black Gram						
1.						
2.						

5.3.5. For manually and machinery weeding, please give these information.

Weeding	How many times did you do weeding?	Family Labor		Hired labor			
		Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat / day)	Total Cost
For Green Gram							
Manual (Cost/time)							
Machinery(Cost/time)							
For Black Gram							
Manual (Cost/time)							
Machinery(Cost/time)							

5.4 Information on Fertilizer Usage and Cost

Organic Fertilizer Application

5.4.1 Did you apply organic fertilizers in your farm?

1. ☐ Yes 2. ☐ No.

5.4.2. If yes, how many times did you use it? times

5.4.3. What kinds of organic fertilizers did you use? Please give the follow information.

Name of Organic Fertilizer	Total Quantity (Kg/Litre/Bag)	Price(Ks/unit)	Cost
For Green Gram			
1.			
2.			
3.			
For Black Gram			
1.			
2.			
3.			

5.4.4. How many labor did you use to apply organic fertilizer in winter season of 2015?

Organic Fertilizer Application	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
3.						
For Black Gram						
1.						
2.						
3.						

Chemical Fertilizer Application

5.4.5 Did you apply chemical fertilizers in your farm?

1. ☐ Yes 2. ☐ No.

5.4.6. If yes, how many times did you apply it? times

5.4.7. What kinds of chemical fertilizers did you use? Please give the follow information.

Name of Chemical Fertilizers	Total use (Kg or Litre)	Price(Ks/unit)	Cost
For Green Gram			
1.			
2.			
3.			
4.			
For Black Gram			
1.			
2.			
3.			
4.			

5.4.8. How many labor did you use to apply chemical fertilizer?

Chemical Fertilizer Application	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
3.						
For Black Gram						
1.						
2.						
3.						

Hormone/ foliar fertilizer Application

5.4.9. Did you apply plant hormones in your farm as growth regulators?

1. ☐ Yes 2. ☐ No.

5.4.10. If yes, how many times did you use it? times

5.4.11. What kinds of plant hormones did you use? Please give the follow information.

Name of Hormones	Total use (Kg or Litre)	Price(Ks/unit)	Cost
For Green Gram			
1.			
2.			
3.			
For Black Gram			
1.			
2.			
3.			

5.4.12. How many labor did you use to apply plant hormones?

Hormone Application	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
3.						
For Black Gram						
1.						
2.						
3.						

5.5 Pesticide application

5.5.1. Did you apply pesticides in your farm to control pests and diseases?

1. ☐ Yes 2. ☐ No

5.5.2. If yes, how many times did you use it? times

5.5.3. What kinds of pesticides (Insecticide, Fungicide, etc.) did you use? Please give the follow information.

Name of Pesticides	Total use (Kg or Litre)	Price(Ks/unit)	Cost
For Green Gram			
1.			
2.			
3.			
4.			
5.			
For Black Gram			
1.			
2.			
3.			
4.			
5.			

5.5.4. How many labor did you use to apply pesticides?

Pesticide Application	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat / day)	Total Cost
For Green Gram						
1.						
2.						
3.						

4.						
5.						
For Black Gram						
1.						
2.						
3.						
4.						
5.						

5.5.5. What is the rate of your knowledge on the use of chemicals?



5.5.5. How did you know the use of Chemicals?

Item	Learn through				
	1.neighbors	2.Extension services	3. Newspaper/ TV/Radio	4.Personal Canvassing	Others, specify
Organic fertilizers	☐	☐	☐	☐	
Chemical fertilizers	☐	☐	☐	☐	
Hormones	☐	☐	☐	☐	
Herbicides	☐	☐	☐	☐	
Pesticides	☐	☐	☐	☐	

6. Information on Irrigation

6.1. Did you irrigate to the pulses field last growing season?

1. ☐ Yes 2. ☐ No.

6.2. If yes, how many times did you do irrigation? times

6.3. Please give the labor use information on irrigation.

Irrigation	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
For Black Gram						
1.						
2.						

7. Information on Harvesting

7.1. How many times did you harvest the crops?

1. Green Gram times 2. Black Gram times

7.2. How to harvest the crops?

1. ☐ Hand Picking 2. ☐ Uprooting 3. ☐ Harvested by Machinery

7.3. Labor use in harvesting

Harvesting (times)	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
3.						
For Black Gram						
1.						
2.						

8. Information on Drying, Threshing and Windowing

Drying, Threshing and Harrowing and Windowing (Times)	Family Labor		Hired labor			
	Quantity (person)	Workday (days)	Quantity (person)	Workday (days)	Wage rate (Kyat/day)	Total Cost
For Green Gram						
1.						
2.						
For Black Gram						
1.						
2.						

9. Information on Machinery/ Equipment and Cost in winter season of 2015

9.1. Which machineries did you use?

Item	From		Quantity	Cost	
	Own	Rent		Price(Ks/ unit)	Amount
1. Tractors	☐	☐			
2. Power Tiller	☐	☐			
3. Sprayer	☐	☐			
4. Weeding machine	☐	☐			
5. Water pump	☐	☐			
6. Harvester	☐	☐			
7. Thresher	☐	☐			
8. Air Blower	☐	☐			
9. Electric motor for irrigation	☐	☐			
10. Others					

10. Information on Fuel Cost

Activities	Fuel Used Quantity (Galloon)	Cost	
		Price(Ks/ unit)	Amount
1. Land Preparation			
2. Weeding			
3. Irrigation			
4. Spraying			
5. Harvesting			
6. Threshing			
7. Air Blowing			
8. Transportation from field to threshing ground			
9. Others			

11. Information on Yield and Income

Yields(Basket)/ harvested time	Store for seed (Bsk)	Consumption & Donation (Bsk)	Sold Amount			Remarks
			Quantity (Bsk)	Price/Bsk (Ks)	Income (Ks)	
For Green Gram						
1.						
2.						
3.						
Total for Green Gram						
For Black Gram						
1.						
2.						
Total for Black Gram						

12. Information on Marketing

Pre-selling Information

12.1. Did you sell the pulses in advance before harvesting?

1. ☐ Yes 2. ☐ No

12.2. If yes, how many baskets did you sell and what is the price for pre-selling?

..... Baskets (.....Ks/Bsk)

12.3. Why did you sell the pulses in advance?

1. ☐ For Production Cost 2. ☐ For household matter use

3. ☐ Other, please specify.

.....

Post Selling Information

12.4. Where did you market your pulses?

1. ☐ To village collectors
2. ☐ To near-by township wholesalers
3. ☐ Directly sell to exporters in Yangon
4. ☐ To other places. Please specify,.....

12.5. What is the difficulty you faced when you sold your products?

1. ☐ Transportation
2. ☐ Lack of information on pulses price
3. ☐ Cannot get money at once from the buyers
4. ☐ Other, please specify.....

12.6. How often do you receive the information of pulses market?

- ① always
- ② often
- ③ normally
- ④ sometimes
- ⑤ never

(Please circle the number)

Information from	Information level (1-5)				
	①	②	③	④	⑤
1.Other Farmers					
2.Neighbors					
3.Broker					
4.Wholesaler					
5. Through Extension Workers					
6.TV					
7. Newspapers					
8.Radio					
9.Internet					

13. Information on Marketing Cost

Marketing	Transportation charges (Ks/1.5 Bsk Bag)	Commission Fee (Ks/Bsk)	Labor Cost (Ks/Bag)	Total Cost
For Green Gram				
1.				
2.				
Total for Green Gram				

For Black Gram				
1.				
2.				
Total for Black Gram				

14. Information on Other Miscellaneous Cost

Miscellaneous Cost	Quantity	Price	Total Cost
1. Bags			
2. Sieves			
3. Baskets			
4. Rope			
5. Marker Pens			
6. Others			

15. Information on Source of Capital

15.1. What is your source of capital for cultural practices?

1. ☐ Own financial support 2. ☐ Loan 3. ☐ Others, specify.....

15.2. If loan, where is source of the loan? Please describe the following information.

Place of loan	Amount (Ks)	Interest rates (%)	Duration of loan(years)	Remark
1. Agri-Bank				
2. Village saving group				
3. Village Money Lender				
4. Wholesalers				
5. Friend or cousin				
6. Others				

15.3. What is the main purpose for your loan?

1. ☐ Machinery 2. ☐ Labor Cost 3. ☐ Chemical fertilizer 4. ☐ Herbicides
5. ☐ Insecticides 6. ☐ Others, specify.....

16. Information on Membership of Groups or Associations

16.1. Did you belong to any agricultural group/ association?

1. ☐ Yes 2. ☐ No.

16.2. If yes, please give the name. Name of group/ association: _____

16.3. How many times did you join cooperative activities per year?Times/ year

16.4. If no, why?

1. ☐ Not interested 2. ☐ Limitation in membership ability
3. ☐ Limitation in membership number 4. ☐ Others, specif.....

16.5. Which activities did you join?

1. ☐ Technological training on cultural practices 2. ☐ Training on pest & disease control
3. ☐ Training on the fertilizers & agro- chemical application 4. ☐ Others, specify.....

17. Information about Income Sources

17.1. Agricultural income

Source	Farm Size	Yield	Total Sale Amount	Price (Ks)	Total income/ year (Ks)
I. Crops (Acres)					
II. Livestock (Number)					
III. Fishery (Quantity)					

17.2. Non-agricultural income

No.	Source	Average revenue/month ('000 Ks)	Average income/year ('000 Ks)
1.	Labor wage		
2.	Trading and services		
3.	Pension		
4.	Salary		
5.	From abroad		
6.	Other (specify)		
Total incomes			

According to these information above, what is your household's main occupation?

.....

18. Information on Problems Encountered and Farmers' Option

18.1. Last growing season, did you face heavy rain / drought in your region?

1. ☐ Yes 2. ☐ No.

18.2. If yes, when did it happen?

- | | |
|--|--|
| 1. ☐ Planting Stage | 2. ☐ Vegetative Stage |
| 3. ☐ Flowering Stage | 4. ☐ Harvesting Stage |
| 5. ☐ Postharvest Handling Stage | |

18.3. Did you face any loss because of heavy rain / drought?

1. ☐ Yes 2. ☐ No.

18.4. If yes, how much did the heavy rain / drought make the crop destroy?

1. ☐ Extremely damaged the whole plot and needed replanting at all
2. ☐ Highly damaged in some parts of the plot and needed to replant only in damaged area
3. ☐ Moderately damaged and not needed to replant, but disturbed to crop growth
4. ☐ Slightly damaged in some parts of the plot and retarded the crop growth
5. ☐ Not at all

18.5. How much did you lose in crop productivity as a result of the heavy rain/ drought?

1. ☐ Extremely
2. ☐ Highly
3. ☐ Moderately
4. ☐ Slightly
5. ☐ Not at all

18.6. During last three years, did you face losses caused by heavy rain / drought in crop yield?

1. ☐ Yes 2. ☐ No.

18.7. How to deal for crop losses due to heavy rain / drought?

.....
.....

18.8. During growing season, what other kinds of problems except heavy rain / drought did you encounter?

- | | | |
|---|---|--|
| 1. ☐ Low price | 2. ☐ High cost of inputs | 3. ☐ No financial support |
| 4. ☐ Poor transportation | 5. ☐ Post- harvest problem | 6. ☐ Pests and diseases |
| 7. ☐ Labor Scarcity | 8. ☐ Low technology | |
| 9. ☐ Others, specify _____ | | |

19. What Changes would you like to happen?

- ① Strong agree
- ② Agree
- ③ No opinion
- ④ Disagree
- ⑤ Strongly disagree

(please circle the number)

Would like to	Your opinion(1-5)				
	①	②	③	④	⑤
1.More technical assistance	1	2	3	4	5
2.Need of crop insurance	1	2	3	4	5
3.More loan by government	1	2	3	4	5
4.Forming farmer cooperative groups	1	2	3	4	5
5.Improve transportation	1	2	3	4	5
6.Find export market more by Government	1	2	3	4	5
7.Easily access market information	1	2	3	4	5
8. Higher buying price by traders	1	2	3	4	5
9. Control of input price	1	2	3	4	5

20. What kind of information do you want to know more?

- 1. ☐ Price of Pulse 2. ☐ New technology 3. ☐ Marketing
- 4. ☐ Integrated Pest Management (IPM) 5. ☐ Others, specify.....

21. Do you know crop insurance?

Yes ☐ No ☐

22. If there is a crop insurance program to protect the crop damage by the weather condition, do you want to participate in this program?

Yes ☐ No ☐

23. If yes, how much money do you want to pay for premium per acre of pulses in one crop growing season?

.....Kyats/acre

24. How much money do you want to get for compensation of losses by weather?

.....Kyats/acre

Thank you for your kind attention and time!!!!

Appendix D: Questionnaires for data collection for WTP for weather index-based crop insurance

QUESTIONNAIRES FOR FARM HOUSEHOLD SURVEY

Date: _____
 Interviewer: _____
 Question No.: _____
 Place: _____

A. Information about Farm Household and Farm

A.1.	Name of Interviewee	
A.2.	Relationship with Household head	
A.3.	Name of Household head	
A.4.	Gender of HH Head	1. Male 2. Female
A.5.	Age of HH Head	years
A.6.	Education (Schooling Years) of HH Head	years
A.7.	Farming Experience	years
A.8.	Total Farm Size cultivated	Acres
A.9.	Type of Farming	2. Own farm 2. Tenancy 3. Both

B. General information of household's members and income sources

No.	Name	Age	Relationship with interviewee (*)	Education		Occupation (***)	Off-farm Income (Ks/Year) (****)	Participation in agriculture (*****)
				Type (**)	If type 2, Formal Schooling years?			
1								
2								
3								
4								
5								

(*) 1 = Head of HH, 2 = Wife/husband, 3 = Daughter/Son, 4 = Parents, 5 = Others (specify)

(**)Type: No schooling=0, Monastery school =1, Formal school=2

(***) 1 = farming, 2 = off-farm (specify)

(****)The amount of off-farm income per year

(*****) 1 = yes, 2 = no

Note: If there are more than 7 members, please use the space below.

B.2 Agricultural income

Source	Farm Size	Yield	Total Sale Amount	Price (Ks)	Total income/ year (Ks)
1. Crops (Acres)					

2. Livestock (Number)					
3. Fishery (Quantity)					

According to these information above, what is your household's main occupation?

.....

C. Basic information on Pulses Production

C.1 How many area of pulses did you cultivate in the winter season of 2016? Acres

C.2 Pulses yield and income

Name of pulses	Yields(Basket)/ harvested time	Store for seed (Bsk)	Consumption & Donation (Bsk)	Sold Amount		
				Quantity (Bsk)	Price/Bsk (Ks)	Income (Ks)
1.						
2.						
3.						

CV Scenario

D. Weather Index-Based Crop Insurance

D.1 Have you ever heard/known about Weather Index-Based Crop Insurance before?

1. Never Heard 2. Generally know 3. Know well

D.2 If the answer is 2 and 3, how do you know it?

1. Friend 2. TV/Radio/Newspaper/Journals
3. Internet 4. Insurance Company staff
5. Extension Staff 6. Other (Specify)

D.3 Description of the Weather Index-Based Crop Insurance

Weather Index-Based Crop Insurance is a program tried to mitigate the production risk from severe weather conditions such as torrential or excessive heavy rain, scarcity of rain or drought during the growing season of the crops faced by farmers. In this program, firstly, farmers has to make a contract with the insurance company collaborated with or without government agencies by paying the designated premium money before planting season.

If the crops was damaged by the rain or drought and if rainfall magnitude received will be exceeded the predefined average historical rainfall during the growing season of pulses, the indemnity will be compensated to farmers after adjusting with the recorded historical rainfall data or satellite rainfall data using remote sensing technology for the respective locations.

The benefit of Weather Index-Based Crop Insurance is no need to survey the loss in field, the payout for the damage will be swift and no moral risk. The disadvantage is whether the rainfall at the nearest meteorological station will be close to the farmers' received rainfall or not as the compensation will be decided based on the rainfall magnitude of the station.

Currently, the present situation of crop insurance program development in Myanmar is a very initial stage and still underdeveloped. But some international insurance companies from Japan, India, Switzerland and United States, which are interested in to invest in this issue, are now trying to pioneer the weather index-based crop insurance program and conducting the feasibility studies and preliminary trial test of insuring the paddy crop in some selected townships to verify whether there is a market potential or not for agricultural risk mitigation products and to find the most effective ways to distribute them to the farmers.

If they may extend the program for pulses crop in the future, it will be necessary to know the farmers' willingness to participate and pay for the program. This research will be very useful and effective not only for accelerative progress of the Weather Index-Based Crop Insurance program for pulses but also for the development of the efficient policy recommendation and implication to the policy makers as a safety net for farmers from risk aversion.

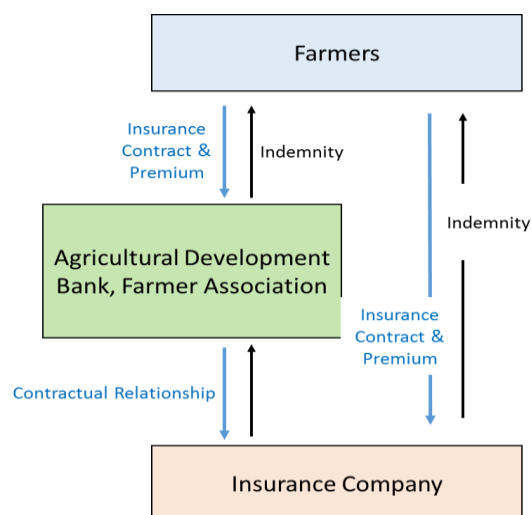


Figure 1. Weather Index-Based Crop Insurance Contract Model

Until now, there is no crop insurance program in Myanmar. So, we will use the above mentioned hypothetical premium levels for calculating farmers' willingness to pay for Weather Index-Based Crop Insurance. Therefore, you are kindly requested to answer with your genuine perception deeply considering on the hypothetical premium levels which may become a reference premium level if the program designs.

Based on historical rainfall data during the growing seasons of pulses in both Lower Myanmar and Upper Myanmar, the probability of heavy rain during growing season in Lower Myanmar during 9 years is about 14% (at least once in both Bago and Yangon Region) and about 11% in Central Dry Zone of Myanmar during 9 years is (at least once in both Mandalay and Magwe Region).

For the contract of the insurance policy, there are two kinds of contracts for different phases of growth of pulses: Phase (1) Contract designed for the period of Sowing to Vegetative growth stages starting

from the beginning of November to end of December, Phase (2) Contract for the period of Reproductive to Harvesting Stages starting from January to end of February. The trigger rainfall level for Phase (1) is 394 mm in Lower Myanmar and 278 mm in Central Dry Zone of Myanmar. On the other hand, the trigger rainfall level for Phase (2) is 88 mm in Lower Myanmar and 45 mm in Central Dry Zone of Myanmar.

The contract has to be done for the successive 5 years. For each contract design, the price of the premium per acre of pulses will be 4000, 8000, 12000, 16000, 20000, 28000 Kyats for each contracts. If the rainfall at the nearest station near your location in the following year is below or above normal during the defined periods, then you will be paid an amount equal to 100,000 Kyats which is the estimated cost of production per acre of pulses for each phases.

Heavy Rain incidence in Lower Myanmar from 2008-2016

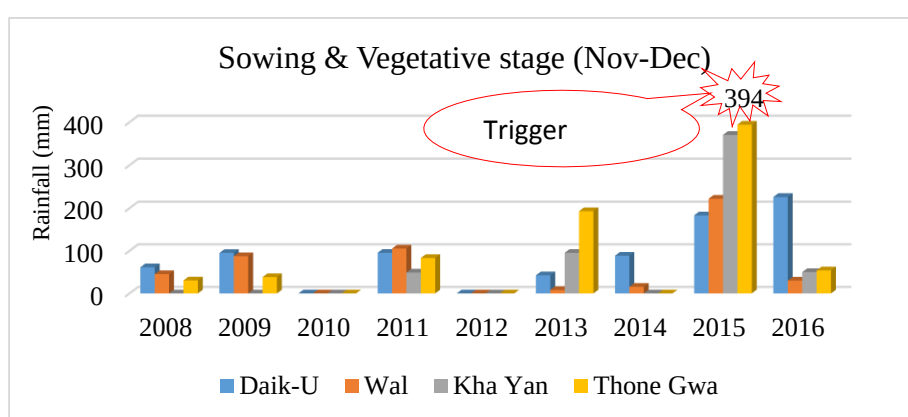


Figure 2. Historical rainfall of survey areas in the sowing time and vegetative growth stages of pulses (2008-2016)

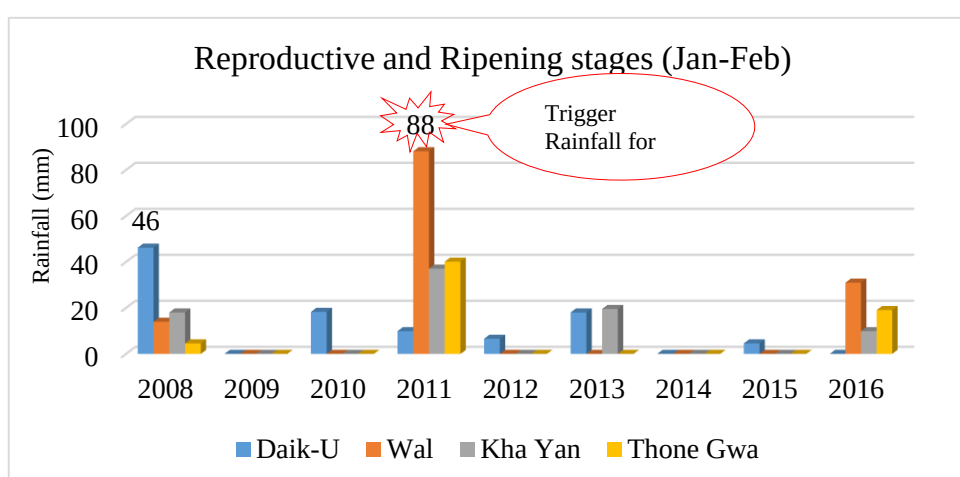


Figure 3. Historical rainfall of survey areas in the Reproductive and Harvesting stages of pulses (2008-2016)

Probability of Heavy rain during growing season in Lower Myanmar during 9 years is about 14% (at least once in both Bago and Yangon Region).



Figure 4. Pulses Damage of Heavy Rain in the seedling stage in Lower Myanmar in November, 2014

Source: Photo taken by Author

Drought Incidence in Central Dry Zone of Myanmar (2008-2016)

Probability of less rain during growing season in Central Dry Zone of Myanmar during 9 years is about 11% (at least once in both Mandalay and Magwe Region).

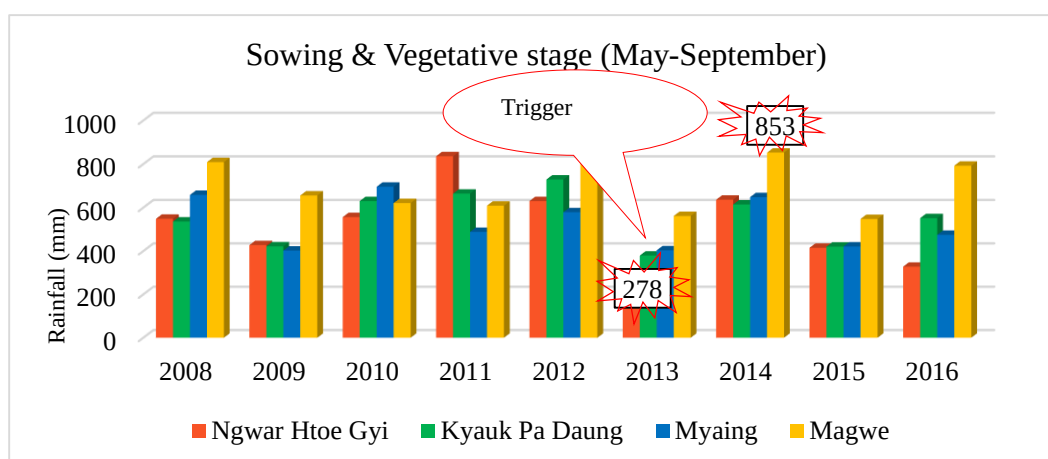


Figure 5. Historical rainfall of survey areas in the sowing time and vegetative growth stages of pulses (2008-2016)

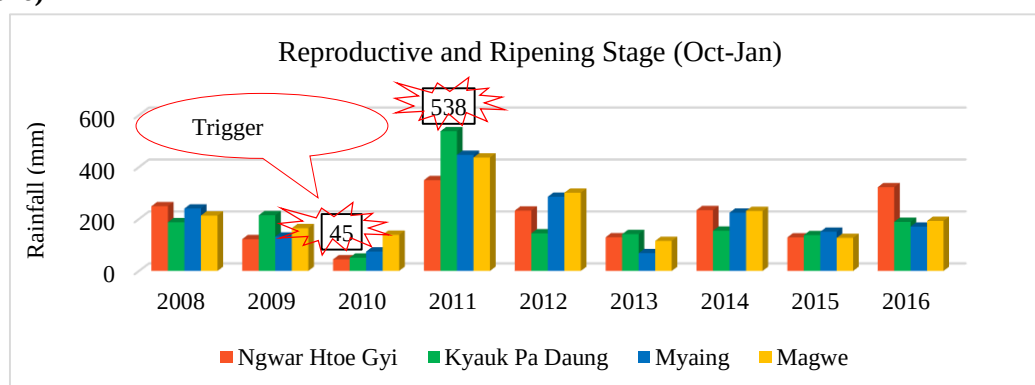


Figure 6. Historical rainfall of survey areas in the Reproductive and Harvesting stages of pulses (2008-2016)

Source: Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation

Farmers' perception on the different phases of insurance contract

1. If two insurance contract in the Weather Index-Based Crop Insurance program is available for two phases: Phase (1) is insurance eligible for the sowing to vegetative stage (from November 1 to December 31), and Phase (2) is for the period of reproductive to harvesting stages (from Jan 1 to Feb 28), which one do you want to insure for your pulses.
1. Phase (1) 2. Phase (2) 3. Both 4. No participate (go to Q19)
2. If it is chosen Answer (1), Please go to the CV questions for Phase (1).
3. If If it is chosen Answer (2), Please go to the CV questions for Phase (2)
4. If it is c2hosen Answer (3), Please go to the CV questions for Phase (1) and Phase (2)

Contingent Valuation Method

For Phase (1) from sowing to vegetative stage (Note: For Phase (2), the same questions will be prepared)

1. Would you be willing to pay the premium for 4000 Kyats/acre of pulses?
☐ Yes (go to Q2) ☐ No (go to Q3)
3. Would you be willing to pay the premium for 8,000 Kyats/acre of pulses?
☐ Yes ☐ No
4. Would you be willing to pay the premium for 2,000 Kyats/acre of pulses?
☐ Yes ☐ No
5. Would you be willing to pay the premium for 8,000 Kyats/acre of pulses?
☐ Yes (go to Q5) ☐ No (go to Q6)
6. Would you be willing to pay the premium for 12,000 Kyats/acre of pulses?
☐ Yes ☐ No
7. Would you be willing to pay the premium for 4,000 Kyats/acre of pulses?
☐ Yes ☐ No
8. Would you be willing to pay the premium for 12,000 Kyats/acre of pulses?
☐ Yes (go to Q8) ☐ No (go to Q9)
9. Would you be willing to pay the premium for 16,000 Kyats/acre of pulses?
☐ Yes ☐ No
10. Would you be willing to pay the premium for 8,000 Kyats/acre of pulses?
☐ Yes ☐ No

11. Would you be willing to pay the premium for 16,000 Kyats/acre of pulses?
☐ Yes (go to Q11) ☐ No (go to Q12)
12. Would you be willing to pay the premium for 20,000 Kyats/acre of pulses?
☐ Yes ☐ No
13. Would you be willing to pay the premium for 12,000 Kyats/acre of pulses?
☐ Yes ☐ No
14. Would you be willing to pay the premium for 20,000 Kyats/acre of pulses?
☐ Yes (go to Q15) ☐ No (go to Q16)
15. Would you be willing to pay the premium for 28,000 Kyats/acre of pulses?
☐ Yes ☐ No
16. Would you be willing to pay the premium for 16,000 Kyats/acre of pulses?
☐ Yes ☐ No
17. Would you be willing to pay the premium for 28,000 Kyats/acre of pulses?
☐ Yes (go to Q18) ☐ No (go to Q19)
18. Would you be willing to pay the premium for 35,000 Kyats/acre of pulses?
☐ Yes ☐ No
19. Would you be willing to pay the premium for 20,000 Kyats/acre of pulses?
☐ Yes ☐ No
20. Please give the reason/s you are not interested in participation of Weather Index-Based Crop Insurance Program.
 1. ☐ I cannot pay any amount of money for the insurance
 2. ☐ I am short of funds in the period before planting
 3. ☐ I have other pressing cash needs in the period before planting
 4. ☐ Encountering torrential rain or drought do not hurt me too much
 5. ☐ I have other means of covering losses due to torrential rain or drought
 6. ☐ Such kinds of rain-related phenomenon do not occur too often
 7. ☐ Without any reason
 8. ☐ Other (Please specify).....

E. Information on Farmers' Risks Encountered and Coping Mechanism

E.1. Last growing season, did you face heavy rain/drought in your region?

1. Yes 2. No.

E.2. If yes, when did it happen?

1. Planting Stage 2. Vegetative Stage
3. Flowering Stage 4. Harvesting Stage
5. Postharvest Handling Stage

E.3. Did you face any loss because of heavy rain/drought?

1. Yes 2. No.

E.4. If yes, how much did the heavy rain/drought make the crop destroy?

1. Extremely damaged the whole plot and needed replanting at all
2. Highly damaged in some parts of the plot and needed to replant only in damaged area
3. Moderately damaged and not needed to replant, but disturbed to crop growth making moderate amount of yield decrease
4. Slightly damaged in some parts of the plot and retarded the crop growth making small amount of yield decrease
5. Not at all

E.5. How much did you lose in crop productivity as a result of the heavy rain/ drought?

1. 80% and above
2. 60%
3. 40%
4. 20%
5. No damage

E.6 During last five years, did you face crop losses due to extreme weather conditions such as heavy rain/drought during the crop growing season of pulses?

- 1.. Yes 2. No.

E.7 If yes, how many times did you face? times

E.7 How to deal with crop losses due to heavy rain/drought?

1. I receive aid from the government
2. I receive aid of money from the family and relatives
3. I seek additional income through new income earning activities such as doing wage labor
4. Borrow money from the private loaners
5. Other(Please specify).....

F. Weather Information Sources

F.1 Are you interested in listening to/getting the weather forecast news from the media?

☐ Yes No ☐

F.2 If yes, how often do you listen to/get weather forecast news from the media?

1. ☐ Once a month
2. ☐ Once a week
3. ☐ Everyday
4. ☐ Twice a day
5. ☐ Every weather news broadcast
6. ☐ Other (please specify)

F.3. How to usually get weather information during pulses growing season?

- | | |
|--|---------------------------------------|
| 1. ☐ Neighbors/other people | 2. ☐ TV |
| 3. ☐ Radio | 4. ☐ Newspaper |
| 5. ☐ Journals | 6. ☐ Internet |
| 7. ☐ Do not access | |

F.4 How do you rate the usefulness of weather information you got for your crop management decision?

No Useful Somehow useful Useful Very Useful Extremely Useful

G. Information on Source of Capital

G.1. What is your source of capital for cultural practices?

1. ☐ Own financial support 2. ☐ Loan 3. ☐ Others, specify _____

G.2. If loan, what is source of the loan? Please describe the following information.

Source of loan	When do you usually receive the loan?	Amount (Ks)	Interest rates (%)	Duration of loan(years)
1. Agri-Bank				
2. Village saving group				
3. Village Money Lender				
4. Wholesalers				
5. Friend or cousin				
6. Others				

THANK YOU VERY MUCH FOR YOUR KIND COOPERATION!!!