Possibilities to Minimize Pesticide Usage in Sri Lankan Paddy Cultivation: An Emphasis on Risk Management

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Research Report No: 226 December 2019

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First Published: December 2019

Final typesetting and lay-out by: Dilanthi Hewavitharana

ISBN: 978-955-612-254-1

FOREWORD

Rice being the staple food paddy cultivation plays a vital role in Sri Lankan agriculture over centuries. Increased rice production is an urgent requirement in the country to feed the ever-growing population. However, this proves to be an arduous task as many challenges continue to loom large. Pest attacks on the paddy cultivation are in the forefront of such challenges. Consequently, increased usage of chemical pesticides to ensure high rice production while ignoring the technical recommendations of pesticide application have given rise to an array of health and environmental issues.

This study explores possibilities to minimize pesticide usage in paddy cultivation based on technical aspects, farmer perception of risk of crop loss, risk of health due to pesticide use and other socio-economic factors. Further, the findings covered major paddy growing systems in Sri Lanka. Hence, it is my expectation that the findings and recommendations derived in this study would be helpful in minimizing pesticide usage in the Sri Lankan paddy cultivation.

I would urge the decision makers, international community, academia and civil society to regard this study not as the end point of an analytical endeavour but as a starting point for a dialogue on strategic policy choices and processes aimed at minimizing pesticide usage in paddy cultivation.

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ACKNOWLEDGEMENTS

We extend our gratitude to Mr. K.W.E. Karalliyadda, Mr. K. Udage and Mr. Keerthi B. Kotagama, former Directors of HARTI who provided required assistance to make this study a success. We also express our sincere gratitude to Mr. W.H. Duminda Priyadarshana, Director (Acting) of HARTI for his constant support in completing the research. Special appreciation is due to Mr. R.L.N. Jayatissa, former Additional Director, HARTI for encouraging us to conduct this study and the comments to improve the report. The research team also expresses sincere thanks to Mrs. S. Hitihamu, Head, Agricultural Policy and Project Evaluation Division of HARTI for her comments on the first draft.

We wish to express our sincere gratitude to the external reviewers, Prof. W.N. Wilson, Department of Geography, University of Colombo and Prof. H.M. Gunathilake for their valuable and constructive comments to improve the quality of the report.

Our special gratitude is due to all the farmers who provided information during the field survey. We are thankful to all the administrative and field level officers who extended support to gather primary data and provided other relevant information for this study.

We would like to thank Ms. S. Senanayake, Senior Statistical Officer, HARTI, Mr. J.K. Indraprabath and Ms. I.E. Wijesinghe Statistical Assistants, HARTI for their dedication extended during data collection, data tabulation and data analysis. Our special thanks are also due to Casual Investigators for their valuable contribution provided in field data collection and data processing.

We wish to convey our sincere thanks to Ms. L.A.K.C. Dahanayaka, Assistant Registrar (Programmes), HARTI for making administrative facilitation throughout the study. We also thank Ms. K.S.N. Perera for language editing and Mr. S.A.C.U. Senanayake for proof reading the report. Further, we extend our appreciation to the staff of the Publication and Printing Unit of HARTI for publishing the report.

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EXECUTIVE SUMMARY

Pesticides are widely used in agriculture to minimize pest infestations and thus protect crops from potential yield losses and inferior product quality. Even though rice is the staple food for more than half of the world population, the crop tops the highest estimated percentage yield loss due to pest damages. With the emergence of Green Revolution, chemical pesticide usage increased to ensure high rice production across the globe. While reflecting this global phenomenon majority of the paddy farmers in Sri Lanka tend to trust their experience over technical recommendations of pesticide application. Misuse and overuse of pesticides in rice cultivation lead to many health and environmental hazards. Although many studies have been conducted on pesticide use in Sri Lanka, scant attention has been paid to the perception of risk of crop loss and health aspects, created by pesticide use.

Therefore, the general objective of the study is to identify the possibilities to minimize pesticide usage in paddy cultivation in Sri Lanka with the focus on technical aspects, farmer perception of risk and other socio-economic factors. Multistage Random Sampling Technique was employed in sample selection. Three hundred and thirty paddy farmers representing three climatic zones of Sri Lanka were surveyed using a structured questionnaire. Exploratory Factor Analysis was performed to identify the farmer criteria in pesticide selection. Certainty Equivalent Method and Risk Attitude Scale were used to directly elicit farmer risk preferences.

According to the descriptive analysis, herbicides are the major category of pesticide use in the Sri Lankan paddy cultivation irrespective of the climatic zone and irrigation method. Majority of the surveyed farmers applied herbicides as a routine process with or without having weeds in their paddy fields. However, in terms of insecticides the majority considered a substantial presence of pests. Further, results of Chi-Square statistics also showed that there is a significant relationship between farmer knowledge on Economic Threshold Level and the intention to minimize pesticide usage.

Factor Analysis revealed six factors: environment and health, accessibility and financial, awareness and affordability, technical, information and operational and awareness on recommended pesticides. Based on the mean ranking, the top criteria identified were: previous experience and knowledge, follow the instructions given in the label, usage of legally approved pesticides, pest resistance due to pesticide usage and possibility to purchase at discounted price.

Two risk attitude measures were used to directly elicit farmers risk preferences: the expected utility framework and from responses to a multi-item scale. The results of risk attitude scale depicted that a relatively large group of farmers exhibit risk averse behaviour and it is consistent with risk attitude measures rooted in the expected utility approach by means of certainty equivalence.

The study recommended the need for alternatives in order to minimize pesticide usage. Even though, paddy farmers showed risk averse behaviour, there is a propensity to minimize pesticide usage through Integrated Pest Management techniques. Hence, a national level protocol is required, while incorporating the risk dimension of pest management and farmer risk perception.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AI	Agriculture Instructor
ARPA	Agriculture Research & Production Assistants
ASC	Agrarian Services Centre
CE	Certainty Equivalent
DCS	Department of Census and Statistics
DOA	Department of Agriculture
DS	Divisional Secretariat
DZ	Dry Zone
ETL	Economic Threshold Level
FAO	Food and Agriculture Organization
GN	Grama Niladhari
IPM	Integrated Pest Managemet
IZ	Intermediate Zone
JMPR	Joint Meeting on Pesticide Residues
KMO	Kaiser-Meyer-Olkin
SAICM	Strategic Approach to International Chemicals Management
WZ	Wet Zone

CHAPTER ONE

Introduction

Rice (*Oryza sativa*) is considered one of the most important staple food sources for more than half of the world population (IRRI, 2006) though serious yield losses are caused annually due to pest damages and disease attacks (Akhtar *et al*., 2009; Hu *et al.,* 2014). Paddy cultivation plays a vital role in Sri Lankan agriculture over the centuries since it is the staple food of the people of Sri Lanka. Paddy is cultivated as a wetland crop in all climatic zones in Sri Lanka during two major cultivation seasons namely *Maha* and *Yala*. Currently, around 0.792, million hectares of land cultivated in Sri Lanka for paddy and 1.8 million farmers are engaged in paddy farming as a livelihood (Weerahewa *et al.*, 2010**;** Central Bank Report, 2018).

1.1 Pest and Disease Management in Paddy Cultivation

In the traditional agriculture, various biological, botanical and mechanical methods were used by paddy farmers to control pests and diseases that were developed by their ancestors (Ulluwishewa, 1992). Further, there were minimal pest and disease attacks in traditional paddy farming due to the specific characteristics of traditional paddy varieties such as tolerance against the insect infections and resistance against the diseases (Singh and Sureja, 2008). With the onset of Green Revolution modern agricultural techniques were introduced and high rice production were supported by improved high yielding varieties, machinery, pesticides and inorganic fertilizer (Kumari, 2016).

High rice production is an immediate requirement in the country to feed the ever-growing population. However, this task seems impossible due to various hindrances. As revealed by Amuwitagama (2002) pest attacks is one of the major problems in the Sri Lankan paddy fields. Consequently, paddy has shown the highest estimated percentage yield loss due to pest damages which is 46.4 per cent per year (Zacharia and Tano, 2011). In addition, pesticides used in the paddy fields globally account for nearly 15 per cent of the total pesticides used for crop production (Agnihotri, 2000). However, with the introduction of modern agricultural methods tolerance characteristics of traditional paddy varieties have disappeared and the usage of chemical pesticides has increased to boost the rice production in Sri Lanka.

1.2 Pesticide Use Trends in Sri Lanka

Pesticide use in Sri Lankan agriculture began in early 1950s. Pesticide usage has shown a steady increase by almost 110 times between 1970 and 1995 (Wilson, 1998; Selvarajah and Thiruchelvam, 2007). In 1977 liberalized policies led to an increase in pesticides imports (Ministry of Primary Industries and Ministry of Agriculture, 2016). According to pesticide consumption data from 1995 to 2000, collected by the Food and Agriculture Organization (FAO), organophosphates were the highest used pesticide category within insecticides, amides in herbicides and dithiocarbamates in fungicides Sri Lanka. As per data maintained by the Registrar of Pesticides 2728.21 MT of pesticides were imported in 2017. Pesticide consumption has risen over time and continues to fluctuate with changes in cultivation extent, infestation levels and farm product prices (Ministry of Primary Industries and Ministry of Agriculture, 2016).

The DOA also records that insecticide use in rice declined as a result of the Integrated Pest Management (IPM) launched in 1984 but increased in vegetables and other field crops such as chilli and onion (Ministry of Primary Industries and Ministry of Agriculture, 2016). However, according to the paddy statistics report in 2017/2018 *Maha* season, insecticides had been applied in 74 per cent of the total sown extent of paddy and weedicides in about 81 per cent while corresponding percentage for hand weeding was 15 per cent (Department of Census and Statistics, 2018). Furthermore, pest management methods differ from farm to farm as most of the farmers in Sri Lanka practice small-scale paddy cultivation and there are a few large-scale farms in the country (Amuwitagama, 2002).

1.3 Pesticide Usage by Sri Lankan Farmers

Most of the Sri Lankan farmers acting on instinct tend to ignore technical recommendations which often leads to indiscriminate use (Wilson and Tisdell, 2001). According to Padmajani *et al.*, (2014), most of the farmers fail to follow the instructions on the recommended dosage given on the pesticide label. Herbicides are the most commonly used type of pesticide and majority of the paddy farmers applied herbicides prior to emergence of weeds as a routine process (Munaweera and Jayasinghe, 2017).

The literature revealed that farmers have a genuine problem of insufficient knowledge and information on pesticide usage (Nagenthirarajah and Thiruchelvam, 2008) as pesticides are commonly used as a precautionary measure to control pest and disease (Nagenthirarajah and Thiruchelvam, 2008; Ministry of Primary Industries and Ministry of Agriculture, 2016). Consequently, the evidence has established that the pesticides have been misused and over used in Sri Lankan agriculture over the years (Selvarajah and Thiruchelvam, 2007; Nagenthirarajah and Thiruchelvam, 2008; Padmajani *et al.*, 2014; Munaweera and Jayasinghe, 2017).

1.4 Problem Statement

Pesticide has become the most essential input in the modern agriculture that boosts the productivity and the quality of the cultivated crop (Oerke, 2006; Verger and Boobis, 2013). However, overuse of pesticides has led to many problems worldwide such as environmental, ecological, health, social and economic problems (Nagenthirarajah and Thiruchelvam, 2008; Padmajani *et al.*, 2014).

Excessive use of pesticide is common in Sri Lanka due to lack of knowledge and information on the detrimental effects of pesticides (Selvarajah and Thiruchelvam, 2007; Watawala *et al.,* 2010). Most of the farmers have a scant knowledge of plant protection, hence they apply pesticides as a routine practice to avert possible risks of pest attacks regardless of the presence of pests or pest population. Thus, misuse and overuse of pesticides have been rampant in the local agricultural sector (Watawala *et al.*, 2003; Nagenthirarajah and Thiruchelvam, 2008; Munaweera and Jayasinghe, 2017).

Further, farmers are reluctant to rely on technical recommendations as they perceive that risk of pest damages and consequent crop loss cannot be averted by available technical recommendations. Hence, information regarding farmer risk perception and behaviour with regard to pesticide usage is a prerequisite for any policy intervention initiative (Jin *et al.*, 2017).

Despite well-established evidence on the ill effects of pesticide use on health and environment, farmers continue to use pesticides indiscriminately. They tend to perceive that the risk of crop loss overweighs the environmental and health hazards. Further, only limited studies have been conducted on the risk perception of crop loss and risk of health. Hence, this study aims at identifying farmer risk perception of crop loss and risk of health. The findings will help policymakers to develop site specific action to minimize pesticide usage in Sri Lanka.

1.5 Objectives

1.5.1 Main Objective

To identify possibilities in minimizing pesticide usage in paddy cultivation based on technical aspects, farmer perception of risk of crop loss, risk of health due to pesticide use and other socio-economic factors.

1.5.2 Specific Objectives

1. To understand the technical aspect and problems in the existing methods of pesticide usage in paddy cultivation.

2. To assess the farmer criteria for selecting and using pesticides in the pest management process.

3. To estimate farmer perception of risk of crop loss due to pest damage and risk of health due to pesticide use.

4. To provide policy recommendations on possibilities to minimize pesticide usage in paddy cultivation.

1.6 Organization of the Research Report

This report consists of eight chapters. The introductory chapter provides the background and objectives of the study. The second chapter reviews the literature of past studies on pesticide usage in agriculture and farmer perception on pesticide usage. The third chapter is devoted the conceptual framework and theoretical model while the fourth chapter provides the research methodology and study locations. Chapter five, chapter six and chapter seven present the results and discussion of this study. The final chapter contains the conclusion and recommendations.

CHAPTER TWO

Literature Review

Pesticides have been an essential part of agriculture to protect crops and livestock from pest infestations and yield reduction for many decades. The importance of agricultural pesticides for developing countries is undeniable. However, the issue of human health and environmental risks has emerged as a key problem for these countries, several studies have revealed.

2.1 Role of Pesticide

Pesticides include naturally occurring and synthetic substances which are widely used in eliminating or controlling a variety of agricultural pests that cause crop damages and yield losses. Pest control and various forms of pesticides were further developed with advances in science and technology used extensively in agriculture, sanitation and domestic hygiene. Pesticide covers a wide range of compounds and could be broadly categorized into insecticides, herbicides, rodenticides, fungicides, nematicides and acaricides.

Definition of pesticide varied with time and countries. However, the core meaning remains more or less similar. Pesticides can be defined as a substance or mixture of substances deliberately released into the environment for preventing, destroying or controlling any pest including vectors and unwanted species of plants or animals (FAO, 1989; Zacharia and Tano, 2011).

2.2 Pesticide and Agriculture

Pesticides have played an important role in the success of modern food production and worldwide consumption of pesticides has undergone significant changes since the "Green Revolution" in 1960 (Zhang *et al.*, 2011). Worldwide pesticide production increased at a rate of about 11 per cent per year, from 0.2 million tons in 1950s to more than 5 million tons by 2000 (Carvalho, 2017). The use of pesticides varies greatly across the world due to the cost of the chemicals, man power and pests of being climatic and geographical specific.

Average application rates of pesticides have been computed by FAO and the highest average values, attaining 6.5–60 kg/ha, occurred in Asia and in certain countries of South America (FAO, 2013; Carvalho, 2017). China has the highest annual pesticide consumption in the world followed by the United States, Argentina, Thailand, Brazil and Japan (Pariona, 2017). The proportion of herbicides in pesticide consumption increased rapidly and the consumption of insecticides and fungicides/bactericides declined worldwide (Zhang *et al*., 2011). While in North America and West Europe, the use of herbicides in agriculture and in urban areas boomed in the lately. In Asia, the use of herbicides remained low and is contrasting with the use of insecticides that was very high (Carvalho, 2017).

Varieties and consumption of pesticides worldwide have been increasing dramatically with increasing human population and crop production. In addition to the increase in quantity of pesticides used, farmers use stronger concentrations of pesticides, increase the frequency of pesticide applications and mix several pesticides together to combat pesticide resistance by pests (Chandrasekara *et al.*, 1985; WRI, 1998). These trends are mostly noticeable in Asia and Africa (Wilson and Tisdell, 2001). In this process pesticide misuse has become more serious, resulting in heavy environmental pollution and health risk of humans (Zhang *et al.*, 2011).

Consequently, many international instruments have been used to address the negative effects of pesticides especially for minimization of use, control of distribution and management of waste. These instruments include conventions, treaties and codes of conduct. Examples for international conventions related to pesticide minimization and reducing the risk associated with pesticide use are Rotterdam Convention, Stockholm Convention, International Code of Conduct on Pesticide Management, The Strategic Approach to International Chemicals Management (SAICM) and The Joint Meeting on Pesticide Residues (JMPR) (FAO, 2018).

2.3 Risk and Pesticide Usage in Agriculture

Agricultural production is exposed to various types of risks due to several factors and these risks can be categorized into production risks, market risks, financial or institution risks (OECD,2009). Further, Barry *et al.*, (1999) typifies farmers' risk as: 1) production and yield risks, 2) market and price risks, 3) losses from severe casualties and disasters, 4) social and legal risks from changes in tax laws, government programmes, trade agreements, 5) human risks in the performance of labour, contracts, and management 6) risks of technological change and obsolescence. Significant evidences proved that both weather shocks and unpredictable pest damages can have significant effects on farm production (Lin *et al.,* 1974; Just and Pope, 1979, 2002; Antle, 1983; Antle and Goodger, 1984; Goodwin and Ker, 1998).

Farmer risk preferences play an important role in agricultural production decisions (Feder, 1980) while risk and uncertainty are two terms which are basic to any decision - making framework. Further, risk can be defined as imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known (Hardaker, 2004). Moreover, the risk in agricultural production can be exogenously caused by external factors or endogenously induced by farmers' production decisions. Accordingly, Knight *et al*., (2003) pest outbreaks are exogenously-caused risk while controlling pest outbreaks subject to risk and it is endogenously-induced.

2.4 Farmer Perception on Pesticide Usage in Crop Cultivation

2.4.1 Farmer Perception on Pesticide Usage: Global Context

The unsafe and indiscriminate use of pesticides is a major threat to farmer health and the environment. Many studies have been conducted to investigate the determinants of farmer pesticide usage behaviour according to their characteristics such as education attainment and perception of pesticide technologies, training, risk perception and attitudes towards pesticides (Wang *et al.,* 2018).

According to Pariona (2017), China is the largest pesticide consumer in the world. Extensive use of pesticides is detrimental to farmer's health and the environment in China. Consequently, as noted by Jin *et al.,* (2017) the frequency of pesticide application by local farmers is high and improper disposal of pesticides after use is a common practice in the Anqiu County, China. Further, probability of pesticide overuse is significantly decreased with farmer risk perception, willingness to reduce pesticide use, better social relationships, and strict government monitoring. Hence, the perception of risk can be an important element in education and communication efforts.

Sharifzadeh *et al.,* (2018) explored the farmer criteria for pesticide selection. Performance and effectiveness criteria, awareness and information criteria, technical and operational criteria, environmental criteria, and financial affordability and accessibility criteria, were identified as key decision criteria for farmers' pesticide selection and use. Further, this study revealed that there is a statistically significant relationship among of the five groups of criteria and various socio-economic characteristics of farmers. According to Parveen *et al*., (2003), farmers in Hiroshima, Japan have good knowledge on technical aspects of the pesticide, but this is not reflective at the cognitive level. They showed moderately favourable attitudes about the risk of pesticide usage.

2.4.2 Farmer Perception on Pesticide Usage: Regional Context

Agricultural expansion for livelihood security has led to an increase in pesticide application in the South Asian region (Gupta, 2012). Misuse and overuse of pesticide is very common among farmers in developing countries (Nagenthirarajah and Thiruchelvam, 2008). Consequently, the literature has also provided significant evidences on the farmer perception on pesticide usage in the South Asian Region.

Chemical pesticides were the primary choice of over 80 per cent growers for pest management and over 90 per cent of growers rely on local pesticide retailers for technical knowledge of pesticide selection, handling, and use in Nepal. Ninety percent of the growers were aware of adverse effects of pesticides on human health and to the environment. However, 70 per cent growers received at least one short-term training on IPM and all of them neither knew the harmful effects of pesticide residues nor practiced proper pesticide disposal methods (Rijal *et al.,* 2018). Age, level of schooling, experience in rice cultivation and socio-economic conditions were found to be major influential factors in pest management decision (Rahaman *et al.,* 2018). Hence, farmer knowledge on pesticides and safe use of pesticides are considered as the most important factors for implementing an any effective pest management programme (Rijal *et al.,* 2018).

2.4.3 Farmer Perception on Pesticide Usage: Sri Lanka

Pesticide usage in paddy cultivation has increased with the introduction of modern agricultural techniques since mid-1960s. Similar to other developing economies, Sri Lanka has also faced with pesticide related issues and these issues have become a major concern in the recent past (Nagenthirarajah and Thiruchelvam, 2008).

A study conducted in the Vavuniya District by Selvarajah and Thiruchelvam (2007), revealed that most of the farmers in the study area were unaware of the long-term effects of pesticides. In addition, when farmers perceived high yield loss, they tend to use more pesticides expecting quick return. Most of the farmers often ignored technological recommendations and use their own experiences when using pesticides as they believed that pesticides are less effective. Moreover, farmers need more information on the effects of pesticides on health and safety training needs to be improved in order to eliminate the adverse effects.

According to Munaweera and Jayasinghe (2017) the most commonly used type of pesticide in Sri Lankan rice cultivation is herbicides and most of the farmers apply herbicides prior to emergence of weeds as a routine process. Household size, farming experience, type of irrigation, training related to pest control and extent under cultivation have significant effect on the decision on adopting or non-adopting the insecticides and herbicides. Moreover, most of the issues at the user level have occurred due to lack of awareness, poor attitudes and farmer behaviour. More than 75 per cent of the paddy farmers are smallholders with a land area of less than one hectare and only around three percent of farmers cultivate larger than two hectare of paddy lands (Department of Census and Statistics, 2002). Therefore, the application of pest management methods varies from farm to farm.

Liu and Huang, (2013) revealed that higher pesticide use is characteristic of risk-averse farmers who are wary of crop failure, while lower pesticide use characterizes loss-averse farmers who are wary of health concerns. Consequently, effective risk management in agriculture strongly depends on behavioural factors of farmers including risk aversion and perception. Therefore, it is essential to consider the farmer risk perception of crop loss due to pest damages and risk perception of health due to pesticide usage when investigating the farmer pesticide use behaviour in paddy cultivation (Sulewski and Kloczko-Gajewska, 2014).

CHAPTER THREE

Conceptual Framework

Risk and uncertainty are the two basic terms in any decision-making process (Hardaker, 2004). Decisions under certainty occur when decision outcomes are known with certainty. The decision-maker is supposed to know the probabilities of each state of nature in a risk situation compared to being unable to specify the probabilities of each state of nature in an uncertainty situation. According to Fleisher (1990) uncertainty defines as a situation in which the decision-maker is not aware of the outcome of every action and risk means a situation in which the decision maker is aware of the possible outcomes and will affect the well-being of the firm or decision-maker and which involves the chance of gain or loss. Therefore, the risk is also affected by the expectations of the decision-maker. Hardaker *et al*., (1997) defines uncertainty as imperfect knowledge and risk as uncertain consequences.

3.1 Sources of Risk in the Farm Business

Several research studies have classified risks according to the type and characteristic of the risk: production risk, market risk, financial risk, technological risk, accident risk, institutional risk and human risk (Boehlje and Trede 1977; Sonka and Patrick 1984; Castle *et al.,* 1987; Nelson 1990; Hardaker *et al.,* 1997). Production risk is due to the biological production process of agricultural products. Factors causing production risk are weather, pests and diseases. Financial risk is influenced by the amount and structure of debt, the availability of financing and the timing of incomes and expenditures. Technological risk is due to the development of new technology, methods and recommendations. Accident risk may affect both means of production and members of the farm business. Risk affecting means of production may be natural catastrophic and injury to a farmer or other family members which may halt or cut down production. Institutional risk results from the interest of government and other institutions influencing agriculture through various laws, regulations and rules. Human risk is due to the unpredictability of individuals in production. In this study mainly focus on production risk due to pest damage and the possible health risk. Meuwissen *et al.,* (1999) found a significant relationship among perception of risk, several socio-economic and farm related variables.

3.2 Risk Management Strategies in Farm Business

Risk can be removed or reduced by institutional or farm-level measures. Sonka and Patrick (1984) divide risk management in the farm business into two dimensions. The first deals with the utilization of risk management strategies to prevent uncertainties or to reduce the impact of uncertainties on the farm. The second dimension relates to the acquisition of information about uncertainties and taking risk consciously into the decision-making process. In this research the second type of the risk management strategy is evaluated where the production risk can be reduced by selecting more secure alternative which is cost effective.

Decision-making has been widely discussed in several disciplines using a variety of approaches, methodology, and point of views. In this research the two alternatives are defined as:

1. Application of pesticides at Economic Threshold Level (ETL)[1]
2. Application of pesticides in existing method of use

3.3 Theoretical Approaches to Decision - making

3.3.1 Rational Decision-making

Several schools of thought and scientists have studied decision-making using a variety of approaches and classifications. Keen and Scott Morton (1978) divide the approaches of decision-making into five classes: rational decision making, bounded rationality, decision-making as an organizational process, decision-making as a political process and decision-maker as individual. Rational behaviour assumes that; (Cyert and March, 1963; Hogarth and Reder, 1987; Blaug, 1992).

1. The decision-maker aims at maximizing his objectives
2. Each alternative and its consequences are known, if a decision problem includes uncertainty and the probabilities are known
3. The decision-maker has a preference or a utility system, which permits him to rank all sets of consequences and to choose the most preferred alternative

The expected utility model used to study the rational behaviour under risk and uncertainty (Robinson *et al.,* 1984). The expected utility model presumes that the decision-maker assigns an appropriate utility for each consequence, summarizes the utility of all consequences into one utility measurement and then chooses an alternative with the highest expected utility (Keeney and Raiffa,1976).

The expected utility model is commonly illustrated by a utility function, which illustrates decision-makers' attitudes towards risk. A concave utility function implies risk aversion, a linear function implies risk neutrality and a convex function implies risk preference (Kreps, 1988). According to previous studies, the expected utility of the decision maker or the farmer depends on many factors such as decision-makers' attitudes towards risk (Fleisher, 1990), the size of the farm, income level of the farmer, socio economic factors (Meuwissen *et al.,*1999), education level and information processing (Van Raaij,1988).

3.3.2 Theoretical Model

The components of the model consist of production factors, economic factors, farmer (decision-maker) and operational environment. The theoretical model assumes a farm

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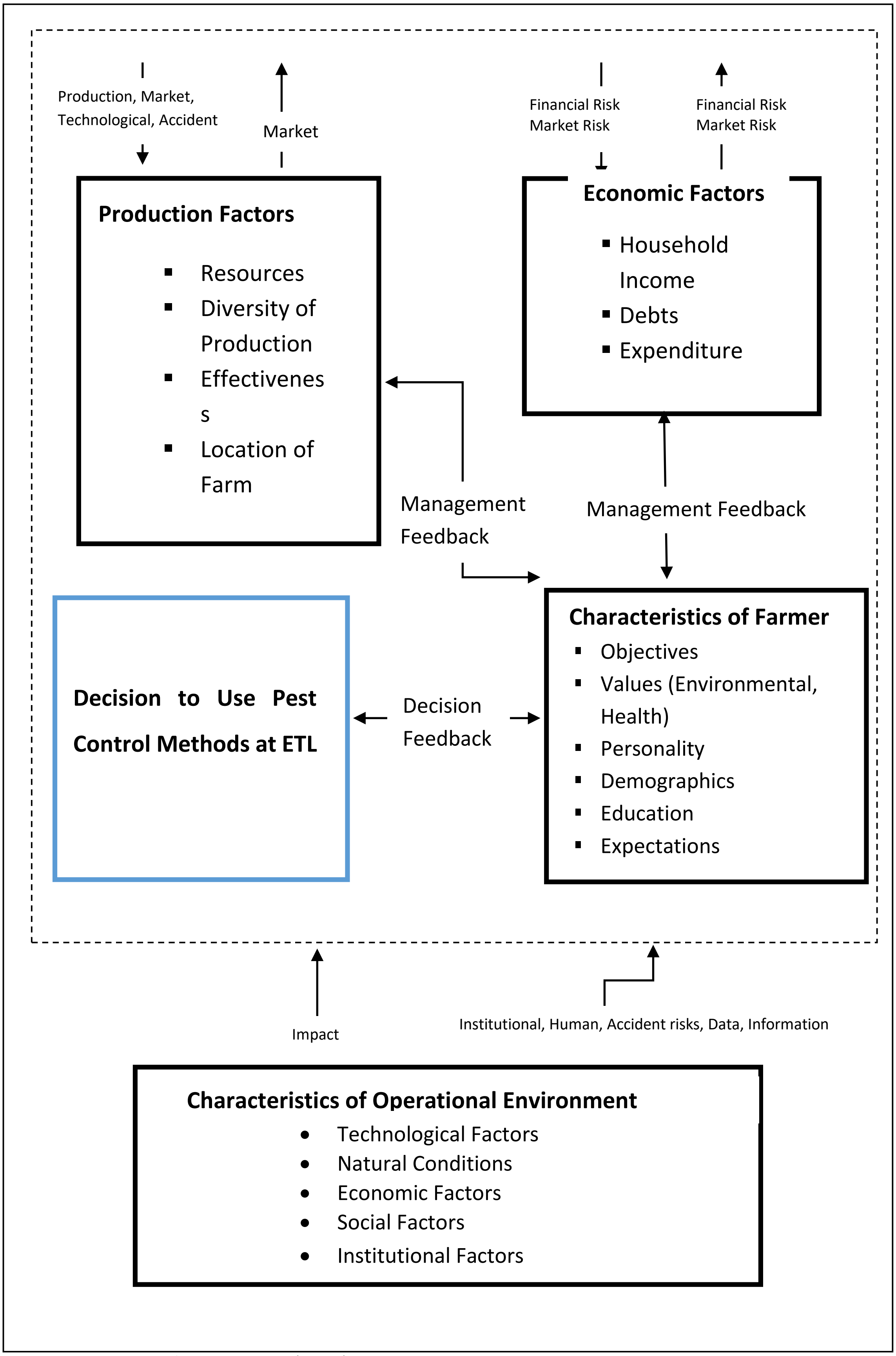
[1]The economic threshold is defined as the pest density or amount of plant damage at which the marginal benefit of control just equals the marginal cost of control (Sexton *et al.,* 2007).

business as an open system which consists of natural conditions, as well as economic, social, technological and institutional factors which have the impact on farmer risk-taking attitude. The strategic gap (decision problem) is due to changing the decision on

1. Application of pesticides at ETL
2. Application of pesticides in existing method of use

Economic Threshold Level (ETL) and Economic Injury Level (EIL) are the two basic components in pest management. Economic injury level is the level of lowest population density causing an economic damage and it justifies the cost of treatment and the pest population (Mi *et al*., 1998). Economic threshold level is the pest population density at which pest control should be initiated or the level of pest population above which economic damage would occur without management practices (USDA-ERS, 1997; Mi *et al*., 1998) Economic damage means where the yield loss increases the treatment costs (Tomerlin, 2005). In Sri Lanka, 85 per cent of farmers in the Badulla district applied pesticides to their crops before emergence of any pests or symptoms. In Nuwara Eliya district this was recorded at 66 per cent. This also shows that even though chemical controls are used even before pest damage has exceeded economic threshold levels and the use of pesticides as a precautionary measure has become more common in Sri Lankan agriculture (Ministry of Primary Industries and Ministry of Agriculture, 2016).

Further, there is lack in research efforts on farmer perception of risk of crop loss due to pest damage and farmer decision on application of pesticides as recommended by relevant authorities. Therefore, the first objective of this study is to understand the technical aspect and problems of existing methods of pesticide use in paddy cultivation. In the second objective, researchers mainly focus on the farmer criteria on selecting and using pesticides. Finally, the third objective is mainly focused on estimating farmer perception of risk of crop loss due to pest damage and health risk due to pesticide usage. In achieving the third objective researchers hypothesized that if farmers have same utility for two alternative management approaches there is a possibility to minimize the use of pesticides up to ETL.



Source: Adopted from Sonkkila (2002)

Figure 3.1: Theoretical Model

CHAPTER FOUR

Methodology

4.1 Data Collection Methods

4.1.1 Primary Data Collection

The primary data collection was done using different tools and primary data sources such as pre-tested structured questionnaire, key informant interviews, discussions with Agriculture Instructors (AI) and Agriculture Research and Production Assistants (ARPAs).

4.1.2 Secondary Data Collection

The secondary data were mostly collected from secondary data sources such as journal articles, reports, databases of the Department of Census and Statistics (DCS) and Food and Agriculture Organization (FAO), Registrar of Pesticides and publications in the Department of Agriculture and its affiliated institutions.

4.2 Study Location and Sample Selection

The field survey covered 330 paddy farmers who cultivated paddy during 2018 *Yala* and 2017/2018 *Maha*. The sample size was determined proportionate to the population and Multistage random sampling method was employed.

- In the first stage, ten districts with the highest number of paddy farmers were purposively selected from major paddy cultivating areas representing the Dry Zone (DZ), Intermediate Zone (IZ) and Wet Zone (WZ).
- In the second stage two to three Divisional Secretariats (DS) were selected from each district based on the number of farmers, the paddy sown extent and the method of irrigation.
- In the third stage, two or three Agrarian Services Centers (ASC) were selected from each district based on number of farmers and paddy sown extent.
- In the fourth stage, two or three Grama Niladhari (GN) divisions were selected from each district based on the number of farmers and the paddy sown extent.
- In the final stage, paddy farmers were selected randomly from each GN division which consisting 330 paddy farmers cultivating under major, minor irrigation schemes and rain-fed.

Table 4.1: Study Locations

Zone	District	Divisional Secretariat Divisions	No. of Farmers
	Anuradhapura	Horowpothana	**37**
		Rajanganaya	
	Mahaweli H	Thambuththegama	
		Talawe	**30**
Dry Zone		Nochchiyagama	
	Ampara	Uhana	**32**
		Mahaoya	
	Polonnaruwa	Thamankaduwa	**31**
		Hingurakkoda	
		Medirigiriya	
	Kurunegala	Polpitigama	**65**
		Ibbagamuwa	
	Matale	Galewela	**15**
Intermediate Zone		Naula	
	Badulla	Kandeketiya	**20**
		Rideemaliyadda	
	Ratnapura	Embilipitiya	**34**
		Imbulpe	
		Kalawana	
	Kalutara	Bulathsinhala	**33**
Wet Zone		Mathugama	
	Matara	Thihagoda	**33**
		Kamburupitiya	
		Devinuwara	

Note: Mahaweli H is included as special agricultural district (DCS, 2018)
Source: Authors' own compilation

4.3 Data Analysis and Analytical Techniques

4.3.1 **Objective 1:** Understanding the technical aspects and problems of the existing methods of pesticide use in paddy cultivation.

In achieving the above, data were collected regarding issues relevant to the methods of current pesticide use and reasons for these problems. Descriptive analysis was conducted.

Table 4.2: Technical Aspects and Problems

Data	Data Source
Technical Aspects	
ETL of paddy pests	Department of Agriculture
Recommended dosage of pesticide application	Rice Research Institute Office of the Registrar of Pesticides
Recommended frequency of application	Key Informant Survey
Identification of Problems	
Knowledge on pest and diseases	
Time of pesticide application	Structured Questionnaire Survey
Knowledge on ETL of paddy pests	
Level of adaptation on ETL application	
Farmers' risk perception (health and crop loss)	

Source: Authors' own work

4.3.2 **Objective 2:** Assessing the farmer criteria for selecting and using pesticides in pest management process.

The Friedman test was used to examine significant differences between the importance of each variable related to farmer criteria for the present pesticide use and rank variables in case of differences. As stated in the literature factor analysis is used to examine the underlying patterns for a large number of variables by defining sets of variables that are highly interrelated, known as factors (Hair *et al.,* 2014). Therefore, farmer criteria for the existing pesticide use were reduced to more manageable levels using factor analysis with a total of 20 individual criteria and SPSS version 20.0 was employed in analysis. Six factors were identified: environment and health criteria, accessibility and financial criteria, awareness and affordability criteria, technical criteria, information and operational criteria and awareness on recommended pesticides criteria. The variables reliability gained by Cronbach Alpha was 0.7.

In this study, Principal Component Analysis was applied using Varimax Rotation with Kaiser Normalization, a cut-off point of 1 for Eigenvalues and factor loadings greater than 0.4.

4.3.3 **Objective 3:** Estimating farmer perception of risk of crop loss due to pest damage and risk of health due to pesticide usage.

Two methods were used to directly elicit farmer risk preferences (Penings and Garcia, 2001)[2]. One is derived from the expected utility framework and the other one is derived from responses to a multi - item scale (Churchill, 1995).

[2]Penings and Garcia (2001) focus on directly elicited risk-attitude measures as opposed to risk attitude measures that are quantified indirectly from observed behaviour (Moscardi and Janvry,1977).

The expected utility model has been used extensively to investigate the behaviour under risk. In this study the certainty equivalence technique is employed to assess the utility function. Using both exponential and power functions, researchers measure the curvature of the utility function as a measure of risk attitude (Arrow, 1965; Pratt, 1964). Under the expected utility model, the research employed the certainty equivalent (CE) as a welfare measure, decomposing welfare effects into two parts: mean effects and the Arrow-Pratt risk premium (measuring the cost of risk) (Chavas and Shi, 2015). When the decision maker is risk averse, his welfare and decisions generally depend on his risk exposure. According to Pratt (1964), the decision maker is risk averse if U(y) is concave in y. In general, the risk premium reflecting the cost of risk measured in units of (x) is the sure amount of satisfying, the risk premium of the decision maker is denoted by R(x) and it is measuring the implicit cost of risk. Further, R(x) can be defined as the maximum amount an individual is willing to pay to avoid risk (Antle, 1988).

When considered a decision maker faces certain two alternative management choices yielding either a consequence x_l or a less preferable consequence x_2, with equal probability. Inevitably, the expected consequence E(x) of the two alternative choices is $(x_1 + x_2)/2$.

The alternative management choices referred in this study is:

a. Application of pesticides at ETL
b. Application of pesticides in current method of use

(1) $E(x) = (x_1+x_2)/2 = (p)x_1 + (1-p)x_2$ with $x_1< x_2$

The certainty equivalent CE defined in equation (3) includes two terms: mean output (Expected consequence) E(x), minus the risk premium, R(x), measuring the implicit cost of risk. As such, CE(x) in equation (2) is a risk-adjusted welfare measure for the producer, evaluated in units of x. Further, substituting in the expected utility model with the Von Neumann- Morgenstern utility u we can obtain u $(CE(p) = pu(x_1) + (1-p)u(x_2)$.

(2) $CE(x) = \frac{1}{-c} * (\ln(e^{-cx2} - e^{-cx1}) - \ln(c*(x_1-x_2)))$ (Keeney and Raiffa, 1976)

(3) CE(x) = E(x) – R(x)

The cost of risk R(x) is obtained from equation (4) and it depends on both risk exposure due pest damage and health risk of pesticides and risk preferences represented by U(y).

(4) R(x) = E(x) – CE(x)

For risk averse utility function, $u[px_1 + (1-p) x_2] > pu(x_1) + (1-P)u(x_2) = E(x) > CE(x)$ where $0<p<1$ (Keeney and Raiffa, 1976). In here researchers conducted the risk analysis under alternative risk preferences and assumed that the cost of risk R(x) will increase when the farmer becomes more risk averse. Further, according to Kahnemann and Tversky's Prospect Theory (1979) a positive difference between E(x) and CE(x) indicates risk-averse behavior while negative difference points to risk-seeking behavior.

Finally, the study evaluates the mean yield E(x), risk premium R(x) and certainty equivalent CE(x). The CE(x) value shows the welfare effect of two alternative decisions. The risk premium R(x) shows the farmers' willingness to be indifferent between two alternative approaches. In this it is hypothesized that if farmers have same utility for two alternative management approaches there is a possibility to minimize the use of pesticides up to ETL.

CHAPTER FIVE

Socio Economic Profile of Paddy Farmers

5.1 Main Socio-Economic Characteristics of the Surveyed Sample

The total sample consists of 330 paddy farmers and descriptive statistics revealed that about 95.8 per cent of the farmers were male. It also reveals that most farmers engaged in Sri Lankan paddy cultivation as a livelihood are male. With respect to the findings the average household size of all districts is 4.09, which is in accordance with the national statistics (Central Bank Report, 2018). Further, this result implies the emerging labour scarcity problem for future farming activities where the household size plays a significant role in the functioning of agricultural sector especially in paddy cultivation.

5.1.1 Age Distribution

Table 5.1: Age Distribution of Surveyed Paddy Farmers

Age Category (Years)	Frequency	Percentage
< 45	64	19.4
45 - 55	83	25.2
55 - 65	112	33.9
65 - 75	63	19.1
> 75	8	2.4

Source: Authors' own compilation based on field survey (2018)

Majority of the farmers are 55–65 years old (33.9%) and the mean age of all districts is 55.07 years. With respect to the total sample 55.4 per cent of the surveyed farmers were above 55 years while 19.4 per cent of the total sample were below 45 years. This results imply that most of the farmers engaging in paddy cultivation belong to the aged population and indicate that the lower participation level of young farmers in Sri Lankan paddy cultivation as an income generating activity.

5.1.2 Education Level of the Respondents

Table 5.2: Education Level of Farmers

Education Level	Frequency	Percentage
No Education	5	1.5
Grade 1-5	60	18.2
Grade 6-10	129	39.1
G.C.E. O/L	94	28.5
G.C.E. A/L	32	9.7
Higher Education	10	3.0

Source: Authors' own compilation based on field survey (2018)

According to the results presented in Table 5.2, majority of the respondents (39.1%) have studied up to grade 6-10 and 28.5 per cent of the farmers have passed G.C.E. Ordinary Level Examination. With respect to statistics only 9.7 per cent of farmers have completed their G.C.E Advanced Level Examination while three per cent of surveyed farmers have higher educational qualifications such as diplomas and degrees.

5.1.3 Type of Farming and Farming Experience

Table 5.3: Type of Farming

Farming Type	Frequency	Percentage
Full time	212	64.2
Part time	118	35.8

Source: Authors' own compilation based on field survey (2018)

The results of Table 5.3 show that majority of the farmers (64.2%) engage in paddy cultivation as their primary occupation. This implies that these farmers solely depend on paddy cultivation as their livelihood, thus it is the major income source for them. Further, 35.8 per cent of farmers engage in paddy cultivation as a secondary source of income.

Table 5.4: Farming Experience

Farming Experience(Years)	Frequency	Percentage
< 15	46	13.9
15 - 30	105	31.8
30 - 45	128	38.8
45 >	51	15.5

Source: Authors' own compilation based on field survey (2018)

The descriptive statistics (Table 5.4) reveal that farmers have average 30 years of paddy farming experience and most of the farmers (38.8%) have 30-45 years of paddy farming experience. This result indicates that majority of the farmers are well experienced and their farming experience is very useful for identification of common pests and diseases in the cultivation. According to the results, only 13.9 per cent of the surveyed farmers have less than 15 years of paddy farming experience.

5.1.4 Land Ownership and Land Extent

Table 5.5: Land Ownership Rights

Ownership and Tenure Systems	Frequency	Percentage
Singly owned	243	73.6
Ande	63	19.1
Ande / Singly owned	17	5.2
Other	7	2.1

Source: Authors' own compilation based on field survey (2018)

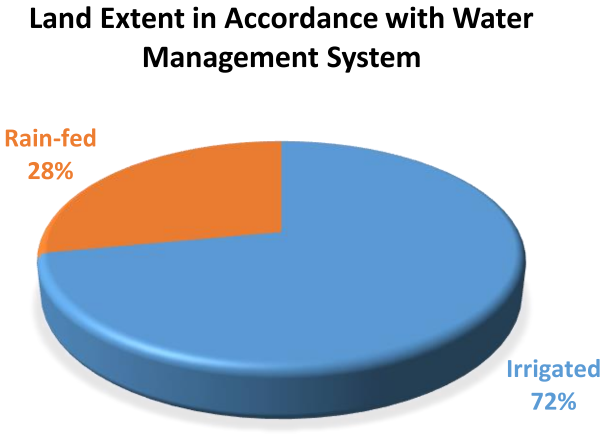
According to Table 5.5, majority of the surveyed farmers (73.6%) have singly owned paddy lands. Further, 19.1 per cent, 5.2 per cent and 2.1 per cent of the sown extent during 2017/2018 *Maha* season had been under *Ande*, *Ande*/Singly owned and other category respectively. Other category of ownership includes joint ownership and *thattu maaru*.

Table 5.6: Cultivated Land Extent in 2017/2018 *Maha* Season

Extent (Ac)	Frequency	Percentage
< 5	303	91.8
5 - 10	24	7.3
> 10	3	0.9

Source: Authors' own compilation based on field survey (2018)

Table 5.6 depicts that majority of farming households in the study area (91.8 per cent) cultivate less than five-acres in 2017/2018 *Maha* season. It was observed that most of the paddy lands in WZ especially in Kalutara, Matara and Ratnapura districts less than five acres since most of the farmers in WZ engage in paddy cultivation as subsistence farming rather than commercial farming. According to the statistics around 8.2 per cent of the total farming households have 5 Ac or > 5 Ac of paddy lands and majority (7.3%) of these paddy lands belonged to irrigated system. However, the average land size of all districts is around 2.2351 Ac while minimum and maximum are 0.25 Ac and 15 Ac respectively. Furthermore, Figure 5.1 shows the cultivated land distribution in *Maha* 2017/2018 under irrigated and rain-fed systems. This is in accordance with the national paddy statistics (Department of Census and Statistics, 2018).



Source: Authors' own calculation based on field survey (2018)

Figure 5.1: Cultivated Land Extent under Irrigated and Rain-fed Systems

5.1.5 A Brief Description of 2017/2018 *Maha* Season

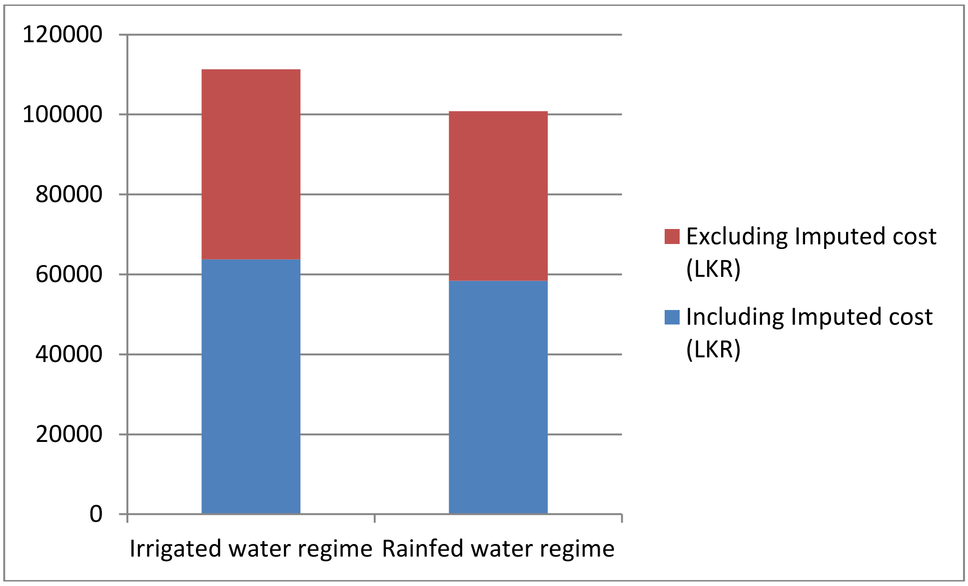
According to the findings in Table 5.7 the average paddy yield of irrigated system is 1560.29 Kg/acre whereas it is 1233.30 Kg/acre in rain-fed system and it is accordance with the national paddy statistics of the Department of Agriculture, 2018. The average gross return was 66210.83 LKR/acre under irrigated system and 52621.80 LKR/acre in rain-fed system.

Table 5.7: Yield and Gross Farming Income in 2017/2018 *Maha* Season

Variable	Irrigation System	
	Rain-fed	Irrigated
Average Yield per Acre (Kg)	1233.30	1560.29
Gross Farming Income per Acre (LKR)	52621.80	66210.83

Source: Authors' own calculation based on field survey (2018)

5.2 Cost of Cultivation

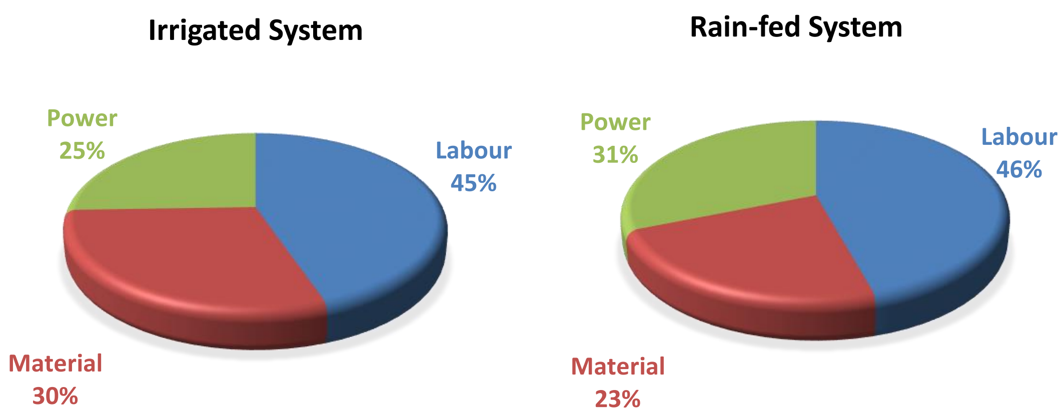


Source: Authors' own calculation based on field survey (2018)

Figure 5.2: Cost of Cultivation of Paddy (Whole Island)

The breakdown of the cost of cultivation per acre for the whole island according to cash and imputed cost is graphically represented in Figure 5.2. The total cost per acre for irrigated water system including imputed cost was 63754.84 LKR/acre and excluding imputed cost was 47533.09 LKR/acre. In rain-fed water system, the total cost was 58403.24 LKR/acre and 42451.62 LKR/acre was incurred as cash cost.

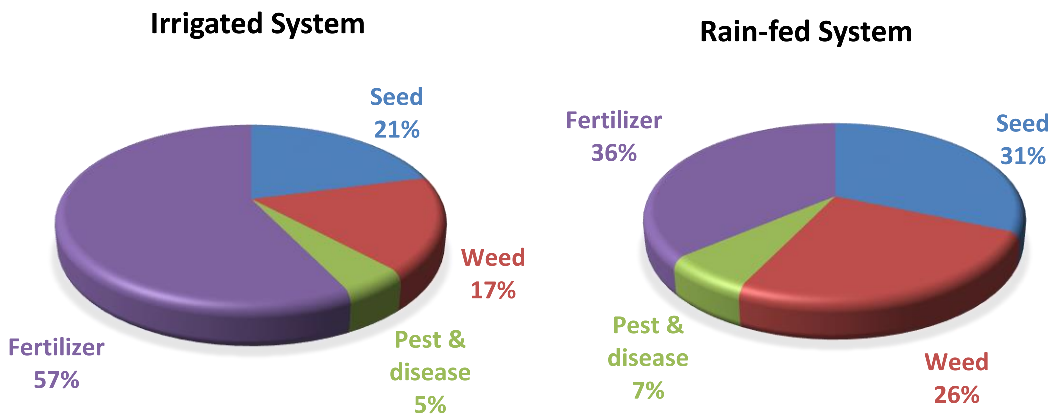
5.2.1 Cost Structure



Source: Authors' own calculation based on field survey (2018)

Figure 5.3: Major Components of Total Cost of Cultivation

The breakdown of the total cost to the three major variable components as labour, material and power is presented in Figure 5.3. In irrigated system, share of labour cost is 45 per cent while the remaining is incurred on power (25%) and material (30%). Further, it is in accordance with the national paddy statistics (Department of Agriculture, 2018). In the rain-fed system, the cost share of labour, power and material are 46, 31 and 23 per cent respectively.



Source: Authors' own calculation based on field survey (2018)

Figure 5.4: Input Cost Incurred in Paddy Cultivation

A breakdown of the material cost in the two paddy cultivating systems is depicted in Figure 5.4. When compared with rain-fed water system, the percentage share of the material cost is higher in the irrigated water system that could be attributed to the high material cost incurred on fertilizer (57%).

CHAPTER SIX

Pesticide Use Patterns in Paddy Cultivation

6.1 Pesticides Types in Use

Sixty six pesticides were in use during the survey period (2017/2018 *Maha* season) and it included 28 herbicides, 32 insecticides and six fungicides. Further, these trade names can be categorized into 30 active ingredients. Classification of pesticides used by responded farmers and their toxicological class are shown in Table 6.1.

Table 6.1: Classification of Pesticides Used by Paddy Farmers in Study Area

Active Ingredient	WHO Toxicity Class*
Herbicides	
Bispyribac sodium 40 g/l + Metamipof 100 g/l SC	NC
MCPA	NC
Azimsulfuron	U
Bispyribac-sodium	NC
Pretilachlor 300 g/l + Pyribenzoxim 20 g/l EC	NC
Pretilachlor	U
Carfentrazone-ethyl 240 g/l EC	NC
Insecticides	
Thiamethoxam	NC
Carbosulfan	II
Etofenprox	U
Imidacloprid	II
Chlorantraniliprole 20% + Thiomethoxam 20% WG	NC
Flubendiamide	NC
Tebufenozide	NC
Fenobucarb	NC
Fipronil	II
Diazinon	II
Buprofezin	U
Chlorantraniliprole	NC
Ethiprole	NC
Fungicides	
Tebuconazole	III
Carbendazim	U
Flutolanil	U
Hexaconazole	U

(* II: Moderately hazardous; III: Slightly hazardous; U: Unlikely to pose an acute hazard in normal use; NC: Not classified)

Source: Authors' own compilation based on field survey (2018)

The most commonly used herbicides are MCPA (48.5%), Pretilachlor (34.54%), Azimsulfuron (9.7%) and Bispyribac-sodium (9%). Frequently used insecticides are Carbosulfan (42.6%), Fenobucarb (19.32%), Etofenprox (10.79%) and Thiamethoxam (6.25%). The surveyed paddy farmers are rarely use fungicides. Among those Tebuconazole (33.33%), Hexaconazole (18.52%) and Carbendazim (11.11%) are common.

It was observed that majority of the paddy farmers use recommended pesticides in accordance with Registrar of Pesticides (2018), however very few number of paddy farmers applied pesticides that are recommended for other crops such as vegetables. These types of pesticides include Diuron, Phenthoate, Emamectin benzoate, Quinalphos, Captan and Sulphur.

6.2 Pesticide Usage in Wet Zone, Dry Zone and Intermediate Zone

The results shown in Table 6.2 reveal that the paddy farmers in the study area applied herbicides as an essential input irrespective of climatic zone and method of irrigation. Insecticides are the second largest group of pesticides used by paddy farmers in Sri Lanka whereas the fungicide usage is minimum in Sri Lankan paddy cultivation when compared to vegetable cultivation.

Table 6.2: Pesticide Usage in Irrigated and Rain-fed Systems

Type of Pesticide	Irrigated System		Rain-fed System	
	Responses	Percent of Cases*239	Responses	Percent of Cases*91
Herbicides	239	100.0	91	100.0
Insecticides	140	58.58	36	39.56
Fungicides	22	9.21	5	5.49

Note: Total percentage of categories used for pesticide usage in Irrigated and Rain-fed systems exceed 100, due to providing multiple responses.

Source: Authors' own calculation based on field survey (2018)

6.3 Frequency of Pesticide Application in *Maha* and *Yala* Seasons

Frequency of herbicide application is high in both *Maha* and *Yala* season irrespective of climatic zone and method of irrigation. The average number of pesticide application in both 2017/2018 *Maha* and 2018 *Yala* seasons is shown in Table 6.3 and Table 6.4.

Table 6.3: Pesticide Application in 2017/2018 *Maha* Season

Pesticide application (No.of applications)	Frequency								
	Herbicides			Insecticides			Fungicides		
	DZ	IZ	WZ	DZ	IZ	WZ	DZ	IZ	WZ
0	0	0	0	54	33	67	121	89	93
1	124	82	85	64	57	28	7	11	7
2	3	16	15	4	7	4	2	0	0
3	3	2	0	6	2	1	0	0	0
4	0	0	0	2	1	0	0	0	0
Mean	1.07	1.20	1.15	0.75	0.78	0.39	0.08	0.11	0.07

Source: Authors' own calculation based on field survey (2018)

In the *Maha* season frequency of insecticide application is lower than the *Yala* season in both DZ and WZ. However, frequency of insecticide application is largely similar (mean=0.8) in both *Maha* and *Yala* season in IZ. There is no difference in frequency of average fungicide application in both *Yala* and *Maha* seasons with respect to IZ and WZ.

Table 6.4: Pesticide Application in 2018 *Yala* Season

Pesticide Application (No. of Applications)	Frequency								
	Herbicides			Insecticides			Fungicides		
	DZ	IZ	WZ	DZ	IZ	WZ	DZ	IZ	WZ
0	0	0	0	43	22	44	99	58	66
1	104	53	59	55	37	24	6	7	5
2	1	11	12	3	5	0	2	0	0
3	2	0	0	4	1	3	0	0	0
4	0	0	0	1	0	0	0	0	0
5	0	1	0	1	0	0	0	0	0
Mean	1.05	1.23	1.17	0.77	0.77	0.46	0.09	0.11	0.07
Respondents(N)	107	65	71	107	65	71	107	65	71

Note: 23 sample farmers in DZ, 35 sample farmers in IZ and 29 sample farmers in WZ did not cultivate in *Yala* season.

Source: Authors' own calculation based on field survey (2018)

6.4 Farmer Decision on Pesticide Application

6.4.1 Time of Insecticide Application

Majority of the surveyed farmers (73.9%) applied insecticides considering the presence of pests or pest population since most of them are aware of ETL from their own experience and detrimental effects of excessive insecticide application. Alarmingly, 10.3 per cent of farmers applied insecticides in their paddy field before appearance of pests or symptoms as a preventive measure or seven per cent of farmers applied insecticide as a routine procedure. The literature has also cited similar situations in Sri Lanka with respect to paddy cultivation (Amuwitagama, 2002; Munaweera and Jayasinghe, 2017). For instance, Amuwitagama, (2002) noted that majority of the paddy farmers applied insecticides to control pests and few of the farmers applied insecticides to prevent pest infestations while others applied them with uncertainty. Nearly nine per cent of the farmers did not apply insecticides since most of them are engaged in subsistence paddy farming. A few farmers among that category currently practiced indigenous methods especially *kems*[3] in place of chemical methods to minimize pest damages in their cultivation since they upheld religious practices in farming.

Table 6.5: Association between Knowledge on ETL and Time of Insecticide Application

Knowledge on ETL	Time of Application (Insecticides)				
	Before appearance of pest	After appearance of pest	As a routine procedure	Not applied	Total
Yes	4 (1.9%)	185 (88.5%)	11 (5.3%)	9 (4.3%)	209 (100.0%)
No	30 (24.8%)	59 (48.8%)	12 (9.9%)	20 (16.5%)	121 (100.0%)
Total	34 (10.3%)	244 (73.9%)	23 (7.0%)	29 (8.8%)	330 (100.0%)

Source: Authors' own calculation based on field survey (2018)

ETL is one of the fundamental concepts of pest management which is defined as the pest damage level where the value of incremental reduction of yield is equal to the cost of preventing its occurrence (Amuwitagama, 2002). Therefore, it plays a vital role in farmer decision making at the time of pesticide application. Further, Table 6.5 indicates that majority of the farmers (88.5%) with knowledge on ETL, applied insecticides after appearance of pests. However, farmers who have knowledge on ETL applied pesticides before appearance of pests (1.9%) or as a routine practice (5.3%) or not applying (4.3%) respectively.

6.4.2 Time of Herbicide Application

Table 6.6: Herbicide Application

Time of Application	Frequency	Percentage
As a routine process	290	87.9
After emergence of weeds in the paddy field	35	10.6
During primary land preparation	5	1.5

Source: Authors' own compilation based on field survey (2018)

Herbicide application is more prominent in study areas regardless of the paddy growing system. Majority of the surveyed farmers (87.9%) applied herbicides as a routine practice with or without emergence of weeds in their fields. In general, within

[3]*Kem* is a practice, technique or custom followed in order to obtain some favourable effect from a problem (Senanayake, 2006).

0 to 28 days after sowing herbicide was applied. About 10.6 per cent of the sample farmers purposively applied herbicides after emergence of weeds to minimize the input cost and labour cost. It was observed that only 1.5 per cent of the sample farmers applied weedicides during primary land preparation where majority of the sample farmers practiced mechanical and physical weed control methods. The literature has also presents substantial evidence on the importance of land preparation and water management method to control weeds in the paddy fields (Singh and Sureja, 2008).

6.4.3 Pesticide Application Patterns

It was observed that less than one per cent of the sample farmers applied herbicides before ploughing. However, majority of the farmers (43%) applied herbicides within 0 to 21 days after sowing/planting (DAS/DAP) to eliminate common annual grasses, sedges and broad-leaf weeds including *Echinochloa crus-galli* (Cockspur Grass, Barnyard grass / *Velmaruk)*, *Ischaemum rugosum* (*Gojarawalu*/*Kudu kedu*), *Cyperus difformis* (*Welhiriya*), *Cyperus iria* (*Thunessa*), *Fimbristylis spp*. (*Kudametta*), *Isachne globose* (*Batadella*) and *Echinochloa glabrescens* (*Bajiri*).

Table 6.7: Stage of Pesticide Application in Paddy

Stage of Application	Type of Pesticide	Frequency	Percentage
Before ploughing (*Puran keteema*)	Herbicides	2	0.6
0 - 14 DAS/DAP	Herbicides	97	29.4
14 - 21 DAS/DAP	Herbicides/Insecticides/ Fungicides	45	13.6
21 - 28 DAS/DAP	Insecticides/ Fungicides	12	3.6
One month AS/AP	Insecticides/Fungicides	22	6.7
45 DAS/DAP (1.5 month)	Insecticides/Fungicides	35	10.6
Two months AS/AP	Insecticides/Fungicides	27	8.2
75 DAS/DAP (2.5 months)	Insecticides/Fungicides	65	19.7
Three months AS/AP	Insecticides/Fungicides	25	7.6

Source: Authors' own compilation based on field survey (2018)

Most of the insecticide and fungicide are applied within 14-90 days to control rice insects and diseases including common insects as paddy bug (*Leptocorisa oratoria*), brown plant hopper (*Nilaparvata lugens*), rice thrips (*Stenchaetothrips biformis*) and stem borer (*Scirpophaga incertulas*) as well as fungal diseases like rice blast /*kola paaluwa* (*Magnaporthe grisea*). The results presented in the Table 6.7 imply that the pesticide applications are made by responded farmers at different growth stages of paddy. The results also further confirm the findings of Amuwitagama (2002).

The study findings revealed that none of the farmers applied pesticides after threshing or during storage. Further, it was observed that some of the sample farmers (7.27%) have applied Imidacloprid for seed treatment to prevent pest and disease attacks that can occur in the future. These farmers reported that the application of Imidacloprid is a successful preventive measure to control Rice Thrips (*Stenchaetothrips biformis*) in paddy cultivation.

6.5 Handling Behaviour of Pesticides by Paddy Farmers

Table 6.8: Pesticide Spraying Operators

Type of Applicator	Frequency	Percentage
The respondent	210	63.6
The hired applicator	118	35.8
Other family member	2	0.6

Source: Authors' own compilation based on field survey (2018)

Table 6.8 depicts that majority of the paddy farmers (63.6%) apply pesticides by themselves and 35.8 per cent of farmers hired a person for pesticide application mainly due to health reasons (Table 6.9). As mentioned in Table 6.9, 21.9 per cent of the farmers reported that they have no time for pesticide application since paddy cultivation is their secondary occupation. In addition, farmers hired pesticide applicators due to having lack of experience in handling knapsack sprayers (17.6%) and not having sprayers (11.4%).

Table 6.9: Reasons for Hired an Applicator

Reason	Responses (N)	Percentage of Cases *(121)
Health consideration	63	55.3
Time Management	25	21.9
No experience in the task	17	17.6
No ownership of sprayers	13	11.4
Total	121	106.1

Note: Total percentage of categories used for reasons for hiring an applicator exceeds 100, because many of the farmers in study area have multiple responses.

Source: Authors' own compilation based on field survey (2018)

6.6 Safety Practices, Storage and Disposal of Pesticides

Safety measures used by the paddy farmers are summarized in Table 6.10. Majority of the paddy farmers (95.5%) read the instructions given on the pesticide label prior to the use of pesticides. Of them only 81.8 per cent followed the instructions printed on the label before mixing pesticides. However, 18.2 per cent of the farmers did not follow the instructions but mostly depend on their own experiences. It was observed that the farmers who did not follow the instructions often applied an over dosage of pesticides while some others applied less than the recommended dosage.

Table 6.10: Farmer Practices in Pesticide Handling

Safety Practices in Pesticide Handling	Practiced (Percentage)	
	Yes	No
1. Read the label on the bottle/package	95.5	4.5
2. Follow the instructions on the label	81.8	18.2
3. Precautionary measures are taken while spraying pesticides		
▪ gloves	36.1	63.9
▪ goggles	10.9	89.1
▪ hat	60.6	39.4
▪ mask	46.7	53.3
▪ boots	4.2	95.8
▪ full length trousers	67.9	32.1
▪ full sleeve shirt	73.6	26.4
4. Spray pesticides against direction of the wind	82.7	17.3
5. Refrain from eating, drinking or smoking while spraying pesticides	59.4	40.6
6. Cleaning the sprayer's nozzle		
▪ using a thin wire	22.4	77.6
▪ using water pressure inside the tank	94.5	5.5
7. Refrain from cleaning used pesticide bottle or pesticide sprayer in water ways	71.8	28.2

Source: Authors' own compilation based on field survey (2018)

Protective measures during and after pesticide application are important to reduce exposure to pesticides (Jallow *et al.,* 2017) since there are three possible ways of occupational pesticide exposure; dermal, oral and inhalation. About 47 per cent of farmers wear mask during pesticide handling however the great majority avoid it disregarding the importance of wearing a mask to reduce pesticide exposure through inhalation. Of total sample around 36 per cent of farmers used gloves both during the preparation and application of the pesticide, indicating a positive sign of farmers towards safe pesticide handling. Full length trousers and full sleeve shirts were used by 67.9 per cent and 73.6 per cent of farmers respectively. It was observed that majority of farmers (95.8%) did not wear boots due to discomfort when worn in marshy paddy lands.

Around 60.6 per cent of farmers wear the hat during pesticide application. It is reported that taking a bath and cleaning of the personal protection equipment and garments are done by majority of the farmers immediately after application which is a positive indication of their knowledge on safe pesticide handling. As presented in Table 6.10 majority of the farmers used some kind of personal protective equipment, though none of them used the complete protective equipment as recommended due to reasons such as the cost, carefree attitude, not paying serious attention to potential health risk and discomfort to use in hot climatic conditions. Similar situations are also reported in the literature (Devi, 2009). Furthermore, a large majority of the farmers refrained from consuming food and drink and smoking while spraying pesticides, a fact that could be attributed to awareness of precautionary methods to reduce occupational pesticide exposure.

Only 82.7 per cent of farmers reported that they considered direction of the wind when spraying pesticides. The literature also provided similar instances (Devi, 2009; Jallow *et al.,* 2017). The most common pesticide application equipment in the study area is the knapsack sprayer and cleaning of the equipment is done immediately after the application. Majority of farmers (94.5%) reported that the cleaning of sprayer nozzle is done by using high pressure of water inside the tank. The farmers used various types of water sources for sprayer cleaning as irrigation channels, public wells, domestic wells and paddy fields. With respect to the total sample majority of the farmers refrained from cleaning the used pesticide bottle or pesticide sprayer in the irrigation canal or river, however they dispose the washed water to paddy fields or to open field.

6.6.1 Storage and Disposal Methods of Pesticides by Paddy Farmers

Table 6.11: Farmer Practice on Pesticide Storage after Procurement

Pesticide Storage	Frequency	Percentage
Open shed outside the house	161	49.7
Open field (Home garden/paddy field)	91	27.6
Inside the house	47	14.2
Use the same day of procurement	28	8.5

Source: Authors' own compilation based on field survey (2018)

Farmer attitudes towards storing of pesticides after procurement are shown in Table 6.11. The majority of farmers (49.7%) reported that they stored pesticides in an open shed while 27.6 per cent of the respondents stored it in the open field. With respect to the total sample 14.2 per cent of the farmers stored pesticides in the house and they commonly used shelves, cabinets and concrete slabs to store pesticide containers. However, few farmers reported that they stored pesticides in locked chemical store in their house or in a special chest provided by Agrarian Service Centers (ASC), a sign of their increased awareness to safety practices in using pesticide. It was observed that about 8.5 per cent of farmers did not store pesticides since they used pesticides on the same day of procurement.

Table 6.12: Unused Leftover and Residual Solutions of Pesticides

Disposal of Unused leftover/ Residual Solutions	Frequency	Percentage
Store and use in next cultivation season	203	61.5
Purchase only the amount needed	95	28.8
Other	32	9.7

Source: Authors' own compilation based on field survey (2018)

Majority of farmers (61.5%) reported that leftover pesticide solutions were stored for future use, taking the expiry dates into consideration. However, 28.8 per cent of farmers purchased only the required amount while the rest either utilized the whole pesticide mixture when prepared (4.2%) or applied leftover pesticides on other crops (2.7%) or disposed them to irrigation channels in the field (1.2%) or to the open field (0.9%) or provide them to fellow farmers (0.7%).

Table 6.13: Disposal Practices of Pesticides

Method of Disposal	Responses	Percentage of Cases*(330)
Bury on farm	127	38.6
Disposed as garbage	110	33.4
Burn in the farm	73	22.2
Reuse for other purposes	40	12.2
Other	21	6.4
Total	371	112.8

Note: Total percentage of categories used for method of disposal exceed 100, because many of the farmers in study area have multiple responses.

Source: Authors' own calculation based on field survey (2018)

Farmers practice various methods to dispose the empty pesticide bottles and packages. The common way of disposing of empty pesticide containers is to dispose as garbage (33.4%) or bury them on the farm (38.6%). Further, 22.2 per cent of farmers burn the empty containers. Alarmingly, 12.2 per cent of farmers reported that they reuse the empty pesticide containers for household and other purposes. Moreover, few farmers (4.6%) disposed them to tanks, agro wells and irrigation channels.

CHAPTER SEVEN

Farmer Perception on Pesticide Usage

7.1 Farmer Knowledge on Pest Management

7.1.1 Selection of Proper Pesticide

Table 7.1: Sources of Information Regarding Pesticide Selection

Sources of Information	Responses	Percentage of Cases*(N=322)
Own knowledge and experience	269	83.5
AI/ARPAs	149	46.3
Pesticide dealers	103	32.0
Neighbour farmers	88	27.3
Training programmes	34	10.6
Total	644	199.7

Note: Total percentage exceeds 100 due to multiple responses.
Source: Authors' own calculation based on field survey (2018)

Most of the paddy farmers (97.6%) stated that they have adequate knowledge on selecting proper pesticide to control pest and disease. Therefore, majority of farmers select pesticides based on their experience (83.5%). Further, 46.3 per cent of farmers rely on AI or ARPAs guidance regardless of whether they have previous experience or not. Usually, most of the farmers tend to consult AI or ARPAs in case of unfamiliar pest attack in their paddy fields. However, 32 per cent of farmers depend on pesticide dealers while 27.3 per cent of farmers rely on fellow farmers. Unsatisfactory grass root level extension services may be the main cause for this. Moreover, only 10.6 per cent of farmers had received training regarding pesticide application.

7.1.2 Farmer Knowledge on Economic Threshold Level

Table 7.2: Farmer Perception on ETL

Awareness on ETL	Frequency	Percentage
Yes	209	63.3
No	121	36.7

Source: Authors' own compilation based on field survey (2018)

The ETL is one of the basic components in pest management. Information on pest density and potential crop loss is important to decide the use of pesticide. Consequently, Table 7.2 indicates that around 63.3 per cent of the surveyed farmers were aware of ETL. In this case, theoretical knowledge on ETL as well as threshold levels developed by farmers were considered.

Table 7.3: Sources of information on ETL

Information Source	Responses (N)	Percentage of Cases* (N=209)
Own experience	134	63.5
AI/ARPAs	63	29.9
Training programmes	30	14.2
Other	8	3.8
Total	235	111.4

Note: Total percentage exceeds 100 due to multiple responses.
Source: Authors' own calculation based on field survey (2018)

Farmers (63.5%) make decisions on the time of pesticide application as they trust their instincts in determining the minimum pest population levels requiring control measures. However, 30 per cent of the farmers received information on ETL through AIs and ARPAs. Moreover, 14.2 per cent of farmers received training related to pesticide application and technical knowledge on threshold levels. The rest educated via mass media (Television) and formal education means.

Table 7.4: Association between Knowledge on ETL and Intention to Minimize Pesticide Usage

Knowledge on ETL	Intention to Minimize Pesticide Usage		Total
	Yes	No	
Yes	114 (54.5%)	95 (45.5%)	209 (100.0%)
No	51 (42.1%)	70 (57.9%)	121 (100.0%)
Total	165 (50.0%)	165 (50.0%)	330 (100.0%)

Pearson Chi-Square Statistics$X_2^2 = 4.711(p = 0.03)$
Source: Author's own calculation based on field survey (2018)

According to Chi Square test statistics (p=0.03) at 95 per cent confidence, the knowledge on ETL has significant influence on intention to minimize pesticide usage. The percentage of farmers who are having knowledge on ETL, intending to minimize pesticide usage is 54.50.

7.2 Farmer Criteria for Pesticide Selection

7.2.1 Factors Affecting Pesticide Selection

Exploratory Factor Analysis was used to reduce the variables for identifying the effective factors on farmer pesticide selection criteria. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in this research is 0.586 (0.5 is considered as acceptable value) showing that the data is adequate for factor analysis. On the other hand, the value of Bartlett's test of sphericity was significant at the 95 per cent confidence level ($X_2^2 = 1005.26, p = 0.000$).

Table 7.5: The Extracted Factors with Eigenvalues, Percentage of Variance and Cumulative Percent Variance

	Factor Name	Eigenvalue	Percent of Variance of Eigenvalue	Cumulative percent variance
1.	Environment and health criteria	2.290	11.45	11.45
2.	Accessibility and financial criteria	2.175	10.87	22.32
3.	Awareness and affordability criteria	1.796	8.98	31.30
4.	Technical criteria	1.387	6.93	38.24
5.	Information and operational criteria	1.269	6.34	44.58
6.	Awareness on recommended pesticide criteria	1.140	5.70	50.28

Source: Authors' Own Calculation based on field survey (2018)

The results of factor loadings, eigenvalues and percentages of variance are summarized in Table 7.5. Six components with eigenvalues greater than one were extracted, which all together accounted for 50.28 per cent of the total explained variation. Further, Factor 1 consisted of two items of the variable list and explained 11.45 per cent of the total variance, with an eigenvalue 2.29. Based on the sub-items of the criteria list, Factor 1 was termed 'environment and health criteria' as it is related to adverse health and environment effects of pesticides. Factor 2 consisted with four items and they highlight the way of access and the importance of financial aspects for farmers when selecting and using pesticides. Therefore, the Factor 2 was labeled 'accessibility and financial criteria' and it accounted for 10.87 per cent of the total variance, with an eigenvalue of 2.175.

Further, Factor 3 consisted of four variables and termed as 'awareness and affordability criteria'. Factor 3 accounted for 8.98 per cent of the total variance, with an eigenvalue of 1.796. The Factor 4 consisted of four items and indicates technical aspects and farmers' experience on pesticide selection. Therefore, Factor 4 was termed as 'technical criteria' and accounted for 6.93 per cent of the total variance, with an eigenvalue of 1.387. Further, Factor 5 included four sub items and related to the information sources and pesticide handling behaviour of farmers. The Factor 5 termed as 'information and operational criteria' which accounted for 6.34 per cent of the total variance, with an eigenvalue 1.269. Furthermore, Factor 6 consisted of two variables related to the use of recommended pesticides by farmers and it was labelled as 'awareness on recommended pesticides'. The Factor 6 accounted for 5.70 per cent of the total variance, with an eigenvalue 1.14.

Table 7.6: Factor Analysis for Grouping Pesticide Selection Criteria

Variable Description	Factor Loading	Mean*	Rank
Low risk of being poisoned during handling	0.943	1.94	12
Low adverse environmental effects	0.936	1.83	14
Convenient accessibility (distance to the market)	0.761	2.20	8
Easy process of preparation for use	0.7	2.17	9
Possibility to buy at discounted price	0.6	2.28	5
Facility to pay for pesticides after harvesting	0.43	1.54	17
The wish of family members	0.583	1.22	19
Reduction of the required number of sprays per cropping season to destroy the target pest	0.563	1.14	20
Affordability	0.532	1.24	18
Trust in the brand	0.53	1.67	16
Previous experience and knowledge	0.617	2.77	1
Following the instructions as in the label	0.606	2.75	2
Following the colour codes in the labels	0.543	2.08	10
Pest resistance due to pesticide usage	0.399	2.41	4
On recommendation of other pesticide dealers	0.614	1.90	13
On recommendation of other farmers	0.613	2.01	11
Pesticides are indispensable for high yield	0.587	2.27	6
Ability to mix with other pesticides	0.527	1.69	15
Usage of legally approved pesticides	0.699	2.60	3
On the recommendation of government officers	0.625	2.20	7

Note: 1- Not Important, 2- Moderately Important, 3- Very Important

Source: Authors' own calculation based on field survey (2018)

The Friedman test was used to compare the mean reason effects for pesticide selection by farmers and this test shows that collectively the reasons of the respondents have the same effect on Farmer pesticide selection criteria. The Friedman test statistics is significant (P=0.0000) indicating that there is a significant relationship among the effect on reasons on the farmers' pesticide selection criteria. Table 7.6 shows the mean rating of each individual criteria. The top criteria identified were: previous experience and knowledge (mean 2.77), follow the instructions as in label (mean 2.75), usage of legally approved pesticides (mean 2.60), pest resistance due to pesticide usage (mean 2.41) and possibility to buy at discounted price (mean 2.28).

7.3 Farmer Knowledge and Training on Pesticides

7.3.1 Extension and Training on Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is a multifaceted approach to pest management that seeks to minimize negative impacts on the environment (Alam *et al.,* 2016). As noted by Rahman (2012), agricultural practices as well as knowledge on pest in particular agro ecosystems are essential components in successful IPM plan. Consequently, IPM in rice agro ecosystem provides tremendous net benefits to farmers in several countries (Alam *et al*., 2016). However, in Sri Lanka IPM was introduced as the most appropriate strategy for pest control in the agriculture policy prepared by the Government of Sri Lanka in 1995 (Ministry of Primary Industries and Ministry of Agriculture, 2016).

According to the literature insecticide use in rice declined as a result of the IPM programme launched in 1984 (Ministry of Primary Industries and Ministry of Agriculture, 2016). However, the present scenario is a twist in the literature since most of the farmers have not received formal training on IPM techniques (72.7%). However, most of the farmers (64.2%) were willing to participate in IPM training programmes in the future.

7.3.2 Farmer Willingness to Minimize Pesticide Usage

Table 7.7: Intention of Farmers to Minimize Pesticide Usage

Intention to Minimize Pesticide Use	Frequency	Percentage
Yes	165	50.0
No	165	50.0

Source: Authors' own compilation based on field survey (2018)

Accordingly, (Table 7.7) half of the farmers are willing to minimize pesticide usage. It was found there is no significant difference between those two percentages ($p = 1.00$).

Farmers intending to minimize pesticide usage mostly practiced other pest control techniques in place of chemical pesticides. Majority of them (52.7%) used mechanical and physical methods to control pest and diseases. Weeding (manually and using weeders), collection of insects by manually or using physical traps and water control techniques are the commonly used control methods.

Thirty-two per cent of the farmers practiced biological pest control methods since it is a natural method of controlling pests such as insects, mites, weeds and plant diseases using other organisms. Further, it relies on predation, parasitism, herbivory or other natural mechanisms. In these methods paddy pests are mostly destroyed or controlled by using predators. Consequently, the farmers have identified a large number of vertebrates, reptiles, birds and mammals predating on paddy pests. However, it was observed that birds are the major biological control agents operating in Sri Lankan paddy fields, which is similarly observed in the literature (Ulluwishewa, 1992). Farmers have developed various methods to attract birds feeding on harmful insects in their paddy fields. For instance, farmers mentioned that if "*Godawella*" damage is severe in the paddy field, portions of milk rice are placed on the paddy field to attract more beneficial birds to destroy the worms in the field. Some of the farmers in the study area placed coconut mid ribs (*Pol pithi*) in the paddy field to control rats. In this method coconut husks are placed on coconut fronds, then birds like owls can stay on it and they picked rats in the field. Moreover, biological pest control is an effective and environmentally friendly pest control method that can be practiced in paddy cultivation (Kumari, 2016).

Farmers (22.4%) also used indigenous methods (*Kems*) to control pest and diseases with an intention of minimizing harmful effects of pesticide while cutting down cost. Past studies also reported that the Sri Lankan paddy farmers used indigenous techniques to control pest and diseases (Irangani and Shiratake, 2013; Kumari, 2016). The traditional farmers with indigenous knowledge passed down from generations rely on such practices (Ulluwishewa, 1992). In addition, most of farmers drive towards sustainable pests and disease control methods that cause minimum disturbance to the natural ecosystem. It was observed that majority of the paddy farmers in WZ currently practising indigenous methods especially *kems* to control insect pests rather than using insecticides. For instance, ash treatment is commonly practised by farmers to control leaf eating caterpillars in the paddy fields. Further, certain paddy farmers in the study area stated that they have applied some plant species (*Euphorbia antiquorum*, *Cycas circinalis* and *Azadirachta indica*) to control pest and diseases.

Only 5.2 per cent of the farmers cultivated resistant paddy varieties and 4.2 per cent of the farmers used crop rotation as an alternative method to minimize pesticide usage. For instance, it was observed that farmers in the Kalutara district were aware of resistant varieties for Brown Plant Hopper (*Nilaparvata lugens*) and Rice Blast (*Magnaporthe grisea*).

Table 7.8: Reasons for Adopting Chemical Control Methods

Reasons for Adopting Chemical Control Methods	Responses (N)	Percentage of Cases*(165)
Low cost	79	48.5
More Effective	62	38.1
Other	31	18.9
Total	172	105.5

Note: Total percentage of categories exceeds 100 due to multiple responses.
Source: Authors' own calculation based on field survey (2018)

Majority of farmers (48.5%) practice chemical control methods as it is more economical. Around 38 per cent of the farmers perceived that traditional pest control methods including *kems* were not effective and not essential to control pest and diseases in their paddy cultivations. The other category includes poor knowledge on traditional pest control techniques (6.1%), chemical control being the most efficient method (3.7%), imitating the fellow farmers (3.7%) and farmer perception of pesticides as being indispensable for high yield (1.8%).

7.3.3 Farmer Knowledge on Banned/Restricted Pesticides in Sri Lanka

Table 7.9: Information Sources of Banning or Restricting Pesticides

Information Source	Responses (N)	Percentage of Cases*303
Mass Media (Television, Newspapers)	257	84.8
Agriculture Instructor	60	19.8
Pesticide Dealer	23	7.6
Fellow Farmers	10	3.3
Training Programmes	5	1.7
Total	355	117.2

Note: Total percentage of categories exceeds 100 due to multi responses.
Source: Authors' own calculation based on field survey (2018)

Most of the paddy farmers (94.8%) were aware of the banned or restricted pesticides. According to the literature, 41 pesticides and 11 insecticides have been banned and restricted respectively (Ministry of Primary Industries and Ministry of Agriculture, 2016). Further, the farmers are aware of 36 brands of pesticides of that category. Glyphosate and Paraquat are the popular ones falling in to the category and farmers were aware of the reasons for banning or restricting (Table 7.9).

Majority of the paddy famers (52.2%) reported that they have no issue regarding banning or restricting of those pesticides. However, 47.8 per cent of farmers stated they have faced several problems including difficulties in weed control (44.7%) and insect management (1.7%), having no effective substitutes (0.7%) and low quality harvest due to impurities (0.7%). For instance, banning of pesticides such as Carbofuran make difficulties to control stem borer, especially in the Polonnaruwa district. Consequently, some of the farmers in the study area tend to use similar types of banned/restricted pesticides and other alternatives in order to eliminate pests. Further, some farmers in the Dambulla district applied Monosodium glutamate as an alternative for Glyphosate and the farmers in the Anuradhapura district especially in Mahaweli H area applied similar type of pesticide for Glyphosate.

7.4 Farmer Risk Perception on Pesticide Usage

Agricultural production is exposed to various types of risk. Both weather shocks and unpredictable pest damages have significant impact on agricultural production. The choice of technology and management can provide options to reduce agricultural risk exposure. This study assesses production risk in agriculture using the expected utility model. Under the expected utility model, the research employed the Certainty Equivalent (CE) as a welfare measure, decomposing welfare effects into two parts: mean effects and the Arrow-Pratt risk premium.

Table 7.10: Expected Income Using ETL Pest Management and Income without Using ETL Pest Management

Climatic Zone	Expected Income Applying ETL (LKR/acre)		Income without Applying ETL (LKR/acre)	
	Mean	Std. Deviation	Mean	Std. Deviation
DZ	79,915.60	37,816.80	73,986.70	29,900.80
WZ	56,864.60	35,175.60	54,065.40	32,788.80
IZ	62,901.20	41,798.30	52,594.50	30,907.70
Mahaweli H	90,214.53	36,988.66	83,515.77	27064.42
All island	68,393.27	39,408.09	62,245.35	32,619.68

Source: Authors' own calculation based on field survey (2018)

According to Table 7.10 all island expected income from applying pesticides at ETL is 68,393.27 LKR/acre which is statistically significant (p=0.000) with the result of income without ETL. Further, it reveals that all island expected income obtained by applying pesticides at ETL level is significantly greater than the result of income without using ETL (p=0.000). The other climatic zones DZ, WZ, IZ and Mahaweli-H also have statistically significant difference between expected income with ETL application and without ETL. These results indicate that the farmers believed that they will cut down the cost of production by applying pesticides at ETL. This is in accordance with the Chi Square test statistics and it was found that the knowledge on ETL has significant influence on intention to minimize pesticide usage. Therefore, introduction of ETL to pest management process is a possible solution to minimize pesticide usage.

Table 7.11: Estimates of Mean Yield, Certainty Equivalent (CE) and the Cost of the Risk under Selected Scenarios (Tons/acre)

Description	Estimates				
	DZ	WZ	IZ	Mahaweli H	All Island
Mean Yield	2.0343	1.3126	1.5112	2.4031	1.6907
Risk Premium	0.0376	0.0007	0.0224	0.0553	0.0176
CE	1.9967	1.3119	1.4887	2.3478	1.6731

Source: Authors' own calculation based on field survey (2018)

The results of the Certainty Equivalent (CE) analysis imply that the risk premium (cost of risk) varied between 0.0007 to 0.0553 in all three climatic zones and Mahaweli H area. Consequently, Table 7.11 indicates that the all island risk premium is 0.0176 and it implies that the paddy farmers in Sri Lanka showing risk-averse behaviour which is in accordance with Kahneman and Tversky's Prospect Theory (1979). The lesser increment in cost of risk indicates that the farmers have the same utility for two alternative management approaches. Therefore, there is a possibility to introduce ETL in pesticide application process as a pest management tool.

7.4.1 Risk Attitude Scales

In this study farmers' risk preference or risk aversion was measured using Likert Scale from -4 ("I strongly disagree") to 4 ("I strongly agree"). The statements (items) are displayed in Table 7.12.

Table 7.12: Items Representing Farmer Risk Attitude

Item	
1	When controlling pests, I am willing to take risks in order to realize higher average returns.
2	I like taking some risk in cultivation.
3	When controlling pests, I prefer pesticides application / any type of pest control methods which can certainly reduce crop loss.
4	With respect to the conduct of cultivation, I don't like to take any risk by using innovative methods.

Source: Authors' own compilation (2018)

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.559 (0.5 is the acceptable value) which shows that the data is adequate for factor analysis. On the other hand, the value of Bartlett's test of sphericity was significant at the 95 per cent confidence level ($X_2^2 = 408.32, p = 0.000$). Exploratory factor analysis on the statements of Table 7.12 produced eigenvalues for first two factors of 2 and 1.04. That implies that the results support a two-factor model where the first factor explained 49.99 per cent of the variation and second factor explained 26.097 per cent of the variation in the data. The first two items in the Table 7.12 make up Scale 1; the last two items make up Scale 2. Further, reliability of the Scale 1 was 0.90 indicating good reliability for the construct measurement. However, reliability of the Scale 2 was 0.161, indicating low reliability. According to Hair *et al*., (2014), the reliability scale ranges from 0 and 1, with higher values indicating greater reliability. Based on the above mentioned risk attitude scales paddy farmers were divided into risk averse, risk neutral and risk seeking farmers. The split was based on the average sum of the score on the statements of the two scales. Farmers with negative sum scores were considered risk seeking and those with positive sum scores were considered risk-averse. Farmers with a sum score of zero were classified as risk neutral (Penings and Garcia, 2001).

Table 7.13: Classification of Farmers based on the Sum Scores of the Risk-Attitude Scales

Scale	Risk Averse (%)	Risk Neutral (%)	Risk Seeking (%)
Scale 1	83.7	4.2	12.1
Scale 2	37	35.6	27.4

Source: Authors' own calculation based on field survey (2018)

The results in Table 7.13 depicted that a relatively large group of farmers exhibit risk averse behaviour. However, for Scale 1 more farmers exhibit risk-averse behaviour than in Scale 2. Further, this is consistent with the findings of the risk attitude measures rooted in the expected utility approach.

7.4.2 Health Risk

Table 7.14: Risk Perception of Health

Risk perception	High	Average	Low	None
Frequency	234	60	26	10
Percentage	70.9	18.2	7.9	3.0

Source: Authors' own calculation based on field survey (2018)
Statement: How much health risk do you think you are exposed to while using pesticides in the farm?

According to the analysis 70.9 per cent farmers believed that when using pesticides, they are exposed to high health risk while 18.2 per cent believed pesticide use has an average risk. However, a very few believed pesticides have low health risk while only three per cent believed having no health risk when considering the pesticide use. Therefore, a great majority is aware that the use of pesticides causes a health risk. As stated by Liu and Huang (2013) loss averse farmers who are wary of health concerns tend to use less amount of pesticides in their cultivations. Consequently, farmer perceptions of health risks are also expected to influence the farmer behaviour.

7.4.3 Environment Risk

Table 7.15: Risk Perception of Environment

Risk perception	High	Average	Low	None
Frequency	219	71	32	8
Percentage	66.4	21.5	9.7	2.4

Source: Authors' own calculation based on field survey (2018)
Statement: How much environmental risk do you think you are exposed to while using pesticide?

As per the results of (Table 7.15) 66.4 per cent farmers believed that applying pesticides carry high environmental risk while 21.5 per cent believed that the environmental risk is average. A very few believed pesticides to have low or no environment risk. Therefore, a great majority of paddy farmers were aware of the environmental risk caused by pesticides.

CHAPTER EIGHT

Conclusion and Recommendations

8.1 Conclusion

- Herbicide is the major category of pesticide used in the Sri Lankan paddy cultivation irrespective of climatic zone and irrigation method. Majority of the paddy farmers (87.9%) applied herbicides as a routine procedure. Insecticides are the second largest group of pesticides used by paddy farmers whereas the fungicide usage is comparatively low with respect to other crop cultivation.

- Majority of the paddy farmers (73.9%) applied insecticides considering the presence of substantial amount of pests or pest population since most of them are aware of ETL by their own experiences and detrimental effects of excessive insecticide application. Further, farmers identify minimum pest population levels before they execute pest control measures.

- According to Chi Square test statistics it was found that the knowledge on ETL has significant influence on intention to minimize pesticide usage. Consequently, 70 per cent of the paddy farmers are willing to apply pesticides at ETL.

- Exploratory factor analysis was used to identify farmer criteria on pesticide selection. Six factors were identified such as criteria of environment and health, accessibility and financial, awareness and affordability, technical, information and operational and awareness on recommended pesticides. According to the mean ranking, the top criteria identified were: previous experience and knowledge, following the instructions as in the label, usage of legally approved pesticides, pest resistance due to pesticide usage and possibility to buy at discounted price.

- According to the descriptive analysis, 96 per cent of the paddy farmers read the instructions given on the pesticide label before application. However, only 82 per cent of the farmers followed the instructions printed on the label before mixing pesticides. It was observed that the farmers who did not follow the instructions often applied high dosage of pesticides while few farmers applied less than the recommended dosage.

- Most of the paddy farmers (73%) did not receive any formal training regarding IPM. However, most of the paddy farmers (64.2%) were willing to participate in such training programmes in the future.

- Fifty per cent of the paddy farmers are willing to minimize pesticide use and vice versa. Farmers intended to minimize pesticides practiced other pest control techniques besides the use of chemical pesticides. Mechanical control, physical control and *kems* are the frequently practiced types of other pest control techniques. Hence, there is a possibility to promote traditional methods as a means of minimizing pesticide usage.

- Most of the farmers (94.8%) were aware of banned or restricted pesticides via various types of information sources. Moreover, farmers were aware of the reasons for banning or restricting such pesticides. Mass media is the commonly used information source by farmers to obtain such information.

- According to the Certainty Equivalent Analysis it was revealed that the all island risk premium is 0.0176. It implies that the paddy farmers in Sri Lanka show risk-averse behaviour. Lesser increment in cost of risk indicates that the farmers have same utility for two alternative management approaches. Hence, there is a possibility to introduce ETL in pesticide application process as a pest management tool.

- Analysis of farmer risk perception revealed that the farmers believed that they are exposed to high health risk (70.9%) and environmental risk (66.4%) when using pesticides. Therefore, a great majority of paddy farmers were aware of health and environmental risk caused due to pesticides.

8.2 Recommendations

- Severity of pest infestation, degree of crop tolerance and control measures are location specific. The Department of Agriculture has already developed the ETLs for several pests. However, it is necessary to test the acceptance of these threshold levels by paddy farmers. Further, farmer experience and attitude towards risk are the key elements of decision making in pest control. It is recommended to consider the risk dimension of pest management and farmer risk averse behaviour to design pesticide application thresholds that are consistent with farmer management goals.

- Extension and training programmes on IPM and safe handling of pesticides are not adequate to fulfill the farmer requirements since majority of the farmers did not participate in such programmes. Hence, implementing of extension and training programmes are recommended with the consideration of risk averse behaviour of paddy farmers.

- Herbicide is the major category of pesticide use in the Sri Lankan paddy cultivation irrespective of climatic zone and irrigation method. Hence, further research efforts are recommended for identifying the economic impact of weeds in different rice growing systems.

- Preferably, awareness programmes through mass media and AI/ARPAs will be the better informed ways in order to follow the recommended pesticide dosages and safety measures to minimize health and environmental risk.

- Proper disposal mechanisms for empty pesticide bottles and packages should be introduced to minimize the detrimental effects on natural ecosystems.

- A monitoring mechanism as well as imparting trainings for retailers should be implemented for effective management of pests and diseases by means of achieving the goal of pesticide reduction.

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ANNEXES

Annex 1: List of Banned Pesticides by 2018

Active Ingredient	Year of Banning
Endrin	1970
DDT	1976
Chlordimeform	1980
Dieldrin	1980
Phosphamidon	1980
Thalium sulphate	1980
2,4,5- Trichlorophenoxyacetic acid	1984
Ethyl parathion	1984
Methyl parathion	1984
Aldrin	1986
Lindane	1986
Hexachlorocyclohexane (mixed isomers)	1987
Mercury compounds	1987
Arsenic (Arsenites and arsenates)	1988
Heptachlor	1988
Leptophos	1988
Captafol	1989
Dichloropropane	1990
Aldicarb	1990
Quintozene (PCNB)	1990
Pentachlorophenol	1994
Methamidophos	1995
Monocrotophos	1995 (Restricted)
Chlordane	1996
Endosulphan	1998
Paraquat	2010
Dimethoate	2010
Fenthion	2010
Cyromazin	2010
Alachlor	2011
Propanil	2014
Glyphosate	2015 (Allow for Tea & Rubber in 2018)
Carbofuran	2016
Carbaryl	2016
Chloropyrifos	2016

Source: Records maintained by the Registrar of Pesticides (2018)

Annex 2: Volumes of Pesticides Imported to Sri Lanka during 2006 – 2011 (in Mt)

	2006	2007	2008	2009	2010	2011
Technical Material						
Insecticides	128.38	115.65	199.3	107.43	144.38	90.5
Herbicides	207.94	88.30	178.12	274.78	1605.58	1118.94
Fungicides	0.40	1.50	0.90	0.25	2	0.4
Sub Total	**336.72**	**205.45**	**378.32**	**382.46**	**1751.96**	**1209.84**
Insecticides	1576.41	1193.74	1585.74	1036.74	1843.95	1712.58
Herbicides	3197.06	4143.69	3808.39	2749.75	5366.63	5031.05
Fungicides	847.06	722.25	872.64	599.80	1048.02	949.40
Sub Total	**5620.53**	**6059.68**	**6266.77**	**4386.29**	**8258.60**	**7693.03**
Total	**5957.25**	**6265.13**	**6645.09**	**4768.75**	**10010.56**	**8902.87**

Source: Records maintained by the Registrar of Pesticides (2018)

Annex 3: Volumes of Pesticides Imported to Sri Lanka during 2012 – 2017 (in Mt)

	2012	2013	2014	2015	2016	2017
Technical Material						
Insecticides	63.32	88.22	34.48	115.84	3.08	17.74
Herbicides	377.8	197.06	705.4	751.7	107	90
Fungicides	0.75	0	0	0	0	0
Sub Total	**441.87**	**285.28**	**739.88**	**867.54**	**110.08**	**107.74**
Insecticides	959.37	1243.46	702.91	1759.06	1151.3	658.03
Herbicides	4753.01	5958.32	4081.83	2862.74	2088.15	1298.32
Fungicides	776.44	987.15	935.92	1233.8	903.9	664.12
Sub Total	**6488.82**	**8188.93**	**5720.66**	**5855.60**	**4143.35**	**2620.47**
Total	**6930.69**	**8474.21**	**6460.54**	**6723.14**	**4253.43**	**2728.21**

Source: Records maintained by the Registrar of Pesticides (2018)