Assessment of Pesticide Usage in Up-Country Vegetable Farming in Sri Lanka

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FOREWORD

Overuse, misuse and abuse of agrochemicals are much discussed subjects in the recent past, especially after rapid increase of chronic kidney disease in the farming areas. Although the use of pesticides results in minimizing pre and post harvest losses, improving the productivity and producing fresh looking outputs, reducing the labour input, and proving stable and predictable yield by reducing the risk of crop failures, the economic, environmental and social cost incurred in the over use of pesticides is huge and irrecoverable. Therefore regulation of pesticide import, distribution and filed level application plays a decisive role in the sustainable development of the country.

Failure to select appropriate pesticides, poor timing, unsuitable frequency in application and improper dosage of application are some of the possible indiscriminate practices in pesticide use, which would results in high cost of production, poor yield and low quality of produce. The costs of pesticide pollution are high because of damage done to agricultural production by development of pest resistance, and impacts on other production processes, the environment and human health. Farmers exposed to pesticides incur costs due to hospitalization, physician consultation, self-treatment and loss of labour days. Pesticides accumulation in the human body would cost long term effects to the present and future generations.

Therefore, this study on use of pesticides in upcountry vegetable farming and their determinants is timely and relevant for the policy makers and the development practitioners to formulate appropriate policies and practices in the use of pesticides. The future polices would carefully balance competing and conflicting interests of farmers' welfare, consumer welfare, food security, environment and public health.

E.M. Abhayarathna
Director

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ABSTRACT

Pesticides have become inevitable ingredients in vegetable cultivation with green revolution technologies. However indiscriminate use of pesticides causes health hazards to humans and long lasting bad effects to the environment. The cost of pesticides imposed damage has to be borne by the society as a whole. Upcountry vegetable farming is one of the intensive cultivated farming systems which consumes a high volume of pesticides and fertilizers, especially due to short duration of crops and highly favourable humid conditions for rapid spread of pests and diseases.

The major objective of this study is to estimate the level of pesticide (insecticides, fungicides and herbicides) use and to investigate the factors affecting overuse/misuse. Primary data for the study was collected from 240 farmers randomly selected among potato, beans, cabbage and leeks cultivators from selected areas in the Badulla and Nuwara eliya districts.

According to the findings of the study, about five percent of the active ingredients of pesticides used in the upcountry vegetable farming belong to not permitted Class (ib) type, while another 34 percent belong to the category of restricted use (Class (ii)). About 47 percent of the farmers prefer to use Organophosphate (OP) group of insecticides, as they believe these pesticides give quick results and are cheaper despite their toxicity and harmful nature on the environment. Green pesticides and Integrated Pest Management methods are not popular as they do not bring quick results.

About 40 percent of the farmers always apply pesticides prior to the appearance of any symptoms of pest or disease as a precautionary safety measure. The numbers of pesticide overdosing farmers are 38 and 41 percents in the Badulla and Nuwara-Eliya respectively as they believe that recommendations and prescriptions given in the pesticide product labels are insufficient. Nearly 53% of farmers mix two or more chemicals together to make a cocktail mixture as they believe such mixtures save their labour time and are more effective in controlling pests and diseases. In the case of availability of excess amount of pesticides solution after spray, the majority of the farmers do environmentally hazardous activities with surplus solution, such as repeatedly applying the chemical to the same crop (71%) and storing the solution for future use (11%). Nearly 30 percent of farmers do not adhere to the 2-3 weeks pesticide free period that should be allowed before harvesting the final product. About 63% of upcountry vegetable farmers wear protective garments during the pesticide spraying, but use of boots and gloves are limited to 11 and 37 % of the farmers respectively. Non use of boots has risk of exposure to pesticides, especially in fields with stagnated water.

Most of the issues at the user's level are associated with lack of awareness, poor attitudes and behaviours of farmers and weaknesses in the extension system. Thus, there is a need for strong awareness campaigns through all possible means including print and electronic media to educate farmers and change their attitudes and to empower the farmer organizations to tackle the issues at farm level. Green band pesticides should be promoted by reducing the prices through tariff reduction and

through farmer level awareness programmes. Instead of using different trade names for same chemical it is recommended to give common names (Generic names) for the pesticides based on the active ingredient to reduce the misuse of pesticides. Considering the development of new pesticide technologies and the safer products, it is recommended to permit smaller than 50 ml size packs which will take into account the requirement of given pesticide per unit area and small land holdings. As considerable proportion of the farmers had the perception of non existence of specified strength in the pesticide label, it is recommended to carry out regular quality tests for the products available in the market by a recognized organization.

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CHAPTER ONE

Introduction

1.1 Background

Up country vegetables cultivation is most popular among the farmers in Badulla and Nuwara-Eliya districts in the central highlands of Sri Lanka. Potato, Leeks, Carrot, Beet-root, Beans and Cabbages are the major vegetable crops cultivated in the area. Table 1.1 shows the extent of cultivation, and total production of the major upcountry vegetables at national level. Beans (*Phaseolus vulgaris*), tomato (*Solanum lycopersicum*), cabbage (*Brassica oleracea*) and radish (*Raphanus sativus*) are the four major up-country vegetables in terms of total extent, while potato, cabbage, beans and carrot (*Daucus carota*) are the most prominent crops in total production (Table 1.1).

The use of high-yielding varieties, inorganic pesticides and fertilizers (agro chemicals) has led to a significant increase in agricultural production. However, indiscriminate use of agro chemicals, especially of chemical pesticides has caused negative externalities such as health hazards to human and other beneficial organisms, pollution of the environment and water, resistance to pesticides, and outbreaks of secondary pests (Dutcher, 2007). In tropical countries, side effects of pesticides occur more frequently and are more visible than in temperate regions. Climatic conditions also make the utilization of protective gear very uncomfortable. Undesired side effects are long lasting in nature and imposed damage costs have to be borne by the society as a whole.

Traditionally, soil in the upcountry at elevation over 600m is being exploited for potato and vegetable production in Sri Lanka. The environment in the upcountry areas is highly suitable for a year round cultivation of potato and high value vegetables. However the land extent under potato and vegetable cultivation is around 60, 000ha which is comparatively low when compared to the area under tea plantation. Therefore potato and vegetables are cultivated on an intensive and commercial scale.

Vegetables are quite different from most perennial crops as they have a short period of about 2-3 months in the field but produce high quantities of biomass. Therefore, most farmers in the upcountry tend to use high quantities of pesticides and fertilizers. The cold and humid climatic conditions of the upcountry combined with high yielding varieties of crops and the increasing use of chemical fertilizers provides a conducive environment for the development and multiplication of pests and diseases.

On the other hand consumer demand and price for vegetables depend on healthy, succulent and fresh looking vegetables with no visible rashes or damages caused by pests or diseases. In order to satisfy the demand, farmers have to tackle pest and disease problems by all means. The use of agrochemicals including pesticides has been recognized to be the immediate and cheaper way to produce unblemished vegetables and increased farm productivity. This practice has unfortunately created numerous problems associated with pesticide abuse as mentioned earlier.

Table 1.1: Cultivated Extent and Production of Up-country Vegetables at National Level in 2009

Crop	Extent (ha)	Production (mt)
Beans	7910	40,513
Cabbage	4016	62,774
Potato	3784	51,294
Radish	3342	33,889
Carrot	2896	35,830
Beetroot	2693	26,664
Leeks	1680	26,793
Knolkhol	1435	12,289

Source: Department of Agriculture, Pocket Book of Agricultural Statistics, 2010

There are various methods, to reduce crop losses from pest disease attacks, including biological, chemical and, mechanical methods, and use of pest-resistant crops. But, agro-chemical measures have the advantage over others because they are convenient to use, attain quick control and are able to reduce pests to extremely low levels. However the intensive uses of agro-chemicals have a direct impact on human health, not only through the contamination of the water sources but also through acute and chronic pesticide poisoning of the ecosystem.

A pesticide can be defined as any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Pests can be insects, mice and other animals, unwanted plants (weeds) fungi, or microorganisms like bacteria and viruses. In addition pesticides include plant regulator, defoliants or desiccants.

There is a disagreement among scientists about the contribution of pesticides to crop production (e.g., Reducing losses) and the negative impacts of their use on the environment and human health. For example, Oerke *et al* (1995) had reviewed a large number of literature that show that chemical pesticides have significantly reduced pest related crop yield losses. It has been estimated that, there would be around 50% yield loss without the use of pesticides due to pre and post harvest damages (Yudelman *et al*, 1998). On the other hand, there are also a substantial number of studies that show negative impacts of chemical pesticides. Several economic studies have questioned whether current patterns of pesticide use are economically and socially efficient (Pimentel and Lehman, 1992; Pingali and Roger, 1995; Yudelman *et al*, 1998). Some studies have shown that the costs (both economic and social costs) related to pesticide use in crop production were higher than the gains from the reduction of crop yield losses (Pingali and Roger, 1995).

Pesticide use in vegetable has become a usual feature in farming despite most farmers do not fully understand about the systematic handling and appropriate use. As farmers often lack accurate knowledge about pests and their control, spraying decisions are sometimes non-optimal. Farmers with sufficient capital are willing to invest in chemical control measures assuming that using lower than recommended dosages is better than no control at all.

In addition, farmers generally lack knowledge about proper pesticide management, including safe pesticide handling and storage. While studies of pesticide productivity are relatively common, few researchers have assessed the farmer's pesticide adoption behavior. In fact, there have been no recent studies on the socio-economic impacts of chemical pesticides.

To achieve optimal pesticide use, answers to the following questions are essential to formulate effective policies and regulations on pesticide uses: What is the extent of use of pesticides by farmers? What are the major factors that affect farmers’ decisions on pesticide applications? What is the productivity of pesticide use in upcountry vegetable production?

1.2 Research Objectives

The general objective of this study is to estimate the level of pesticide (insecticides, fungicides and herbicides) overuse and to investigate the factors affecting the overuse/misuse.

Specific Objectives are;

- To find out the pesticide use profile in upcountry vegetable farming
- To find out determinants of agrochemical use
- To estimate efficiency of vegetable cultivation
- To make policy recommendations to minimize damages caused by pesticides

CHAPTER TWO

Methodology

2.1 Area of the Study

Upcountry districts play a dominant role in producing vegetables in the country. Badulla and Nuwara-eliya are the most leading vegetable producing districts in the region throughout the year both in terms of extent and quantity.

Table 2.1 indicates the main vegetables produced in the Badulla and Nuwara-eliya districts as a percentage of the total country production. According to the table, large quantities of beans, cabbages and leeks and 100% of potato production come from the Badulla and Nuwara-eliya districts. Therefore, Potato, Beans, Cabbage and Leeks have been selected for this study.

Table 2.1: Distribution of Crops by District

Crop	District production as a percentage of total production in 2009		
	Badulla	Nuwara-eliya	Total
Beans	46	14	50
Leeks	10	86	96
Cabbage	33	38	71
Carrot	32	60	92
Beetroot	11	50	61
Radish	16	30	46
Knolkhol	33	51	84
Tomato	24	17	41
Potato	78	22	100

Source: Department of Census and Statistics

Agrarian Development Centre (ADC) Divisions with the highest number of farmers cultivating selected crops in both Nuwara Eliya and Badulla districts were selected for the detailed data collection. Bogahakumbura, Boralanda, Mirahawatta, and Keppetipola ADC areas from the Badulla District and Kandapola, Pundalu Oya, Meepilimana, Nuwara Eliya and Lindula ADC areas of the Nuwara Eliya district were selected for the study.

2.2 Sampling

Considering the available resources and the limited time, a total sample of 240 were selected for the survey. Input usage, cultural and agronomical practices are different in both Badulla and Nuwara- eliya districts due to variations in agro ecological conditions. Therefore total sample of 240 farmers were divided as given in the Table 2.2.

Table 2.2: Distribution of Sample According to Crops and the District

Crop	Badulla District No. of farmers	Nuwara Eliya District No. of farmers
1. Potato	30	30
2. Cabbage	30	30
3. Leeks	30	30
4. Beans	30	30

2.3 Data Sources and Method of Data Collection

Primary and secondary data were collected using different tools. Structured questionnaire, key informant interviews, focus group discussions, and direct field observations were used to collect primary data, while published and unpublished reports were sources of the secondary data.

Pre-tested structured questionnaire was used to interview the randomly selected farmers from selected localities. The information pertaining to certain socio-economic aspects of farmers and consumers, such as family size, education level, size of land holdings, cropping pattern; details on vegetable cultivation; namely, the area under cultivation, land preparation operations, inputs used and the outputs obtained were collected from the questionnaire survey. In addition, data on prices of inputs and outputs, method of sale, handling of pesticides, awareness of farmers on the toxicity level of pesticides, safety measures followed during applications of chemicals and behavioural aspects before and after were also collected in the nearest harvesting season in 2012.

2.4 Data Analysis

Tabular and descriptive analysis was used to examine different socio-economic factors of the upcountry vegetable farmers and the use of pesticides. Econometric model was used to assess the factors affecting efficiency of vegetable production and causes of inefficiency.

2.4.1 Efficiency analysis

2.4.1.1 Stochastic parametric frontier model

The stochastic parametric frontier model was first proposed by Aigner *et al.* (1977) and Meeusen and Ven den Broeck (1977). Recent development of the parametric stochastic frontier approach (Battese and Coelli, 1995) is used to estimate efficiencies in production of vegetable. The stochastic frontier model considers both inefficiency and random disturbances as reasons for production being not at the frontier. The proposed model is as follows;

$$Y_i = f(x_i, \quad) + £_i$$

$$£_i = v_i - u_i ; \qquad i = 1, 2 \ldots, N \qquad (1)$$

Where, Y_i is production of the i^{th} farm, x_i is vector of inputs of production of the i^{th} farm, β is a vector of unknown parameter to be estimated. ε_i is the composed error term consist of two independent elements u and v. v_i is the error term of i^{th} producer for all possible random variation in output due to factors outside the farmer's control such as weather and pest and diseases. It is assumed that distributer normally, identically and independently with 0 mean and σ_v^2 variance, N (0, σ_v^2). u_i is a non negative error term denoting inefficiency of the i^{th} producer, which Aigner *et al*., (1977) assume having either half normal or exponential distribution. In this study the distribution of u_i is half-normal and identical, N (0, σ_u^2). According to literature discussed above, half normal distribution is more appropriate than normal distribution in the practical situation.

Equation (1) specifies the stochastic frontier production function in terms of the original production values. The technical inefficiency effect, U_i, in the stochastic frontier model (1) can be specified as:

$$U_i = z_i\delta + W_i \qquad (2)$$

Where,
z_i - vector of explanatory variables associated with technical inefficiency of production
δ - vector of unknown coefficients
Wi, - random variable, defined by the truncation of the normal distribution with zero mean and variance σ^2.

2.4.1.2 Maximum likelihood estimation

Stochastic frontier functions can be estimated using maximum likelihood method. According to Battese and Corra (1977) the variance ratio parameter (γ), which relates the variability of u_i (σ_u^2) to total variability can be calculated as follows;

$$\gamma = \frac{\sigma_u^2}{\sigma^2}$$

Where, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ (3)

So that, $0 \le \gamma \le 1$

In the case of σ_v^2 = 0, γ would be equal to 1 and all the differences in the producer yield and efficient yield is a result of management factors under the control of producer. In the case of σ_u^2 = 0, γ would be equal to 0, which means all the differences between farmer's yield and efficient yield is due to factors that the producer has no control over them.

2.4.1.3 Hypothesis testing

H_0 : $\pm^2 = 0$

H_1 : $\pm^2 > 0$

Where, γ statistics is used for hypothesis testing. If likelihood ratio (LR) > χ^2, null hypothesis (H_0) is rejected. It means that there are inefficiencies and the function could be estimated using Maximum Likelihood methods. If H_0 is not rejected, Ordinary Least Square method gives the best estimation of the function.

2.4.1.4 Estimation procedure

The Cobb-Douglas (CD) production function was used to study the resource use efficiency and influence of inputs on vegetable yield. The production function of the following type was specified in the present study. The stochastic frontier production function of Cobb-Douglas type is defined in logarithmic form as;

$\ln Y_i = \beta_0 + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_3 + \beta_4 \ln x_4 + \beta_5 \ln x_5 + \beta_6 \ln x_6 + \beta_7 \ln x_7 + \beta_8 \ln x_8 + \beta_9 \ln x_9$ (Vi - Ui)-- (4)

The stochastic frontier production, defined in equation (4), is a linearised approximation of a Cobb-Douglas production function.

In the stochastic frontier,
Y = Yield in each farm (kg/ac)
X_1 = Dolomite cost seed rate (Rs)
X_2 = Seed cost (Rs/ac)
X_3 = Organic fertilizer (Rs/ac)
X_4 = Chemical fertilizer cost (Rs/ac)
X_5 = Micronutrient cost (Rs/ac)
X_6 = Plant growth hormone cost (Rs/ac)
X_7 = Machinery cost (Rs/ac)
X_8 = Pesticide cost (Rs/ac)
X_9= Labour cost (Rs/ac)

The estimates were obtained using computer programme, FRONTIER Version 4.1 (Coelli, 1996). The stochastic frontier co-efficient estimates of this model (Coelli, 1996) indicate the contribution of these variables on dependent variable (i.e. yield) in response to the increment of respective variables. Positive coefficients indicate the percentage increment in yield in response to one percent increment in respective independent variable. All independent variables are measured in monetary terms because different farmers had used different kinds of the same input for an example organic fertilizer includes cow dung, compost, etc., and therefore quantity wise measuring is not reasonable.

2.4.1.5 Sources of inefficiency

Level of efficiency differs from farm to farm and it depends on both farm and farmer characteristics. The inefficiency estimates coming from the frontier production function imply the contribution of farmer related exogenous variables on inefficient usage of inputs. Depending on the co-efficient calculated for these exogenous variables, the inferences could be drawn. Negative co-efficient of an inefficient variable implies the reduction of inefficiency with the presence of the respective exogenous variable. The inefficiency variables considered in this analysis are the age of the farmer, education level, type of primary employment, land size, access to extension services, and district. Type of primary employment, access to extension service and district were considered as dummy variables in the analysis.

2.4.1.6 Description of dummy variable

Type of primary employment ($D_{1)}$	=Full time farmer=1, otherwise=0.
Access to extension (D_2)	= Access to a training =1, otherwise=0
District (D_3)	= Badulla district = 1, otherwise= 0

CHAPTER THREE

Setting of the Study

3.1 Pesticide Use Trends in Sri Lanka

Pest control in the past was primarily based on cultural, physical and mechanical methods or there was no pest control at all due to natural tolerance characteristics of traditional crop varieties. Investment on pesticides was also not feasible due to low yield potential of traditional crop varieties. However, with the green revolution technologies, the natural tolerance characteristics of crop varieties disappeared demanding chemical control of pests to ensure high yields to feed ever growing population. Farmers perceived that higher yield losses were due to pest attack (Selvarajah and Thiruchelvam, 2007). The cultivation of high yielding varieties of paddy under irrigated condition was 100% and the cultivation of high breed and high yielding varieties of vegetables and cash crops also had tremendously increased. Seed was only one of the inputs of the green revolution package. It was important to apply a considerable amount of fertilizers and agro chemicals to harness the full benefit of the package.

Table 2.1 indicates the import volumes of pesticides (insecticides, herbicides and fungicide) to Sri Lanka during the last six years. It shows that herbicides were the most commonly used pesticides in the country followed by insecticides. Paddy cultivation absorbs the higher amount of herbicides compared to insecticides and fungicides. However, use of insecticides is very high in vegetable sector followed by fungicides, but use of herbicides is very minimal (Nagenthirarajah and Thiruchelvam, 2008). Fungicides are highly used in Potato cultivation where Propineb and Mancozeb are the most common fungicides (Liyanage *et al*, 2004).

Bulk amount of pesticides had been imported into the country as formulations. Herbicides are the most used category of agro-chemicals amounting to around 70% of total imports by 2011. The table further indicates that the majority of the pesticides were imported as formulated products and importation for the local formulation was less (only 13% of total imports by 2011). According to Sri Lanka regulations, the companies which wanted to carry out the local formulation of pesticides were required to have ISO standard certified premises.

According to Wilson (1998), pesticide use in Sri Lanka had increased by almost 110 times between 1970 and 1995. As per data maintained by the Registrar of Pesticides, imports of technical grade materials of pesticides had increased by 5.3 times whereas imports of formulated products had increased 11.4 fold in 2005 compared to 1995. Table 2.1 indicates the enormous increase in the imports of herbicides both in the form of technical materials and formulated products. Import of insecticides in technical materials has decreased, while formulated insecticides imports have increased by 9%.in 2011 compared to 2006. Overall pesticide imports show about 50% increase by 2011 compared to the imported volume of 2006. Most commonly used insecticide in Sri Lanka by volume is Carbofuran followed by Diazinon and

Cholropyrifos. Although the import volume of Carbofuran in the form of active ingredient is lower, the volume used locally as an insecticide is high as formulation contains only 3% of the active ingredient. Among the herbicide, Glyphosate is most popular followed by MCPA and 3, 4 DPA. The use of Choloropyrifos becomes more popular after banning of broad spectrum Organo Phosphate pesticide of Endosulfan in 1998 (Taylor, 1999). The highest consumed fungicide is Mancozeb.

Table 3.1: Volumes of Pesticides Imported to Sri Lanka during 2006-2011 (In mt)

Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**% change in 2011 compared to 2006**
Tech. Material							
Insecticides	128.38	115.65	199.3	107.43	144.38	90.50	-29%
Herbicides	207.94	88.3	178.12	274.78	1605.58	1118.94	+438%
Fungicides	0.40	1.5	0.9	0.25	2	0.40	0
Sub Total	**336.72**	**205.45**	**378.32**	**382.46**	**1751.96**	**1209.84**	**+260%**
Formulations							
Insecticides	1576.41	1184.74	1585.74	1036.74	1843.95	1712.58	+9%
Herbicides	3197.06	4143.69	3808.39	2744.95	5366.63	5031.05	+116%
Fungicides	847.56	722.25	872.64	599.8	1048.02	949.40	+12%
Sub Total	**5621.03**	**6049.99**	**6266.77**	**4381.49**	**8258.6**	**7693.03**	**+37%**
Total	**5957.75**	**6255.44**	**6645.09**	**4763.95**	**10,010.56**	**8902.87**	**+49%**

Source: Records maintained by Registrar of Pesticides (2012)

About 107 active ingredients of different pesticides have been registered at the office of the Registrar of pesticides by 2011 (Annex 1) which are currently marketed in the form of 482 commercial products. The profile of registered Agricultural pesticides is shown in the Table No. 3.2. There are number of household pesticides imported to the country to cater to the demand of domestic (Ex: Control of rats and cockroaches), Industrial (Ex: Paint industry), public health (Ex: Mosquito control, hospital cleaning) and veterinary needs (Table No. 3.3).

Table 3.2: Profile of Registered Agro Pesticides

Category	**No. of Active Ingredients**	**No. of Marketed Products**
Insecticides	46	234
Fungicides	27	97
Weedicides	33	149
Molluscicides	1	2
Total	107	462

Source: Registrar of Pesticides (2012)

Table 3.3: Profile of Registered Household Pesticides

Category	No. of Active Ingredients	No. of Marketed Products
Domestic	27	66
Public Health	22	48
Industrial	17	48
Veterinary	2	4
Total	67	166

Source: Registrar of Pesticides (2012)

As Nagenthirarajah and Thiruchelvam, 2008; and Watawala *et al*, 2003 have shown, pesticides have been misused and overused highly in the agricultural sector of Sri Lanka over the years. Sri Lankan farmers use stronger concentrations of pesticides with increased frequency of applications and mixing of different pesticides together to combat pest resistance compared to neighboring countries like India (Chandrasekara *et al*, 1985). According to the same report they have found after examining 20 year pesticide use data of farmers in Matale, Nuwara-Eliya, Badulla and Kandy Districts that, 59% of the farmers had used more than recommended amount of pesticides in their vegetable cultivations. A recent study conducted among the intensive cultivating farmers in the hill country shows that, about 45% of farmers prefer to use more pesticides than the recommended amount and apply them in higher frequencies to ensure better results in crop productivity (Watawala *et al*, 2010). Over use of insecticide for vegetable cultivation is not limited to up country areas. It was found that, farmers in the Vavuniya district in the Northern Province also use pesticides extensively for upland vegetable cultivation as their crops are more susceptible to pests and diseases and as they could get higher economic return from cash crop cultivation (Nagenthirarajah and Thiruchelvam, 2008). According to Selvarajah and Thiruchelvam (2007), about 60% of farmers in the Vavuniya district had applied 30-40% higher concentrations of pesticides than the recommended dosage.

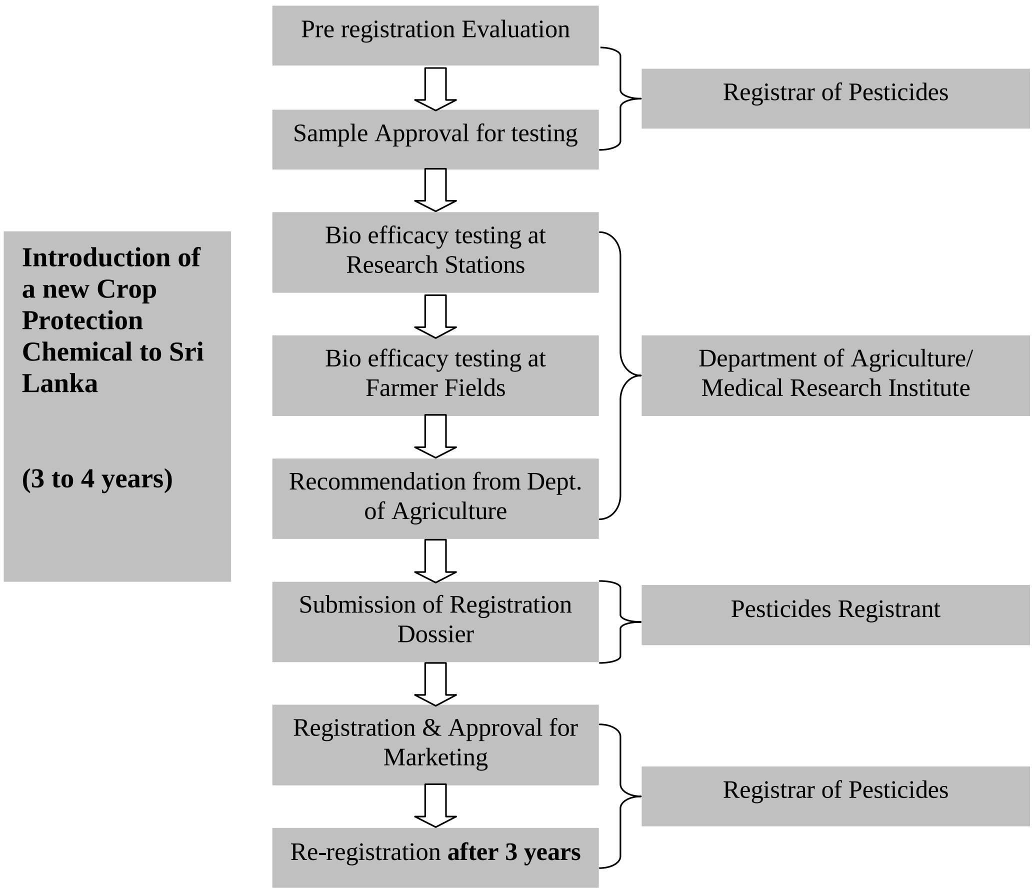
The reasons for the overuse of pesticides as per Watawala *et al* (2010) are limited knowledge of the farmers about adverse effects of pesticides they use. Selvarajah and Thiruchelvam (2007) have found that, there is no significant relationship between the strength of spraying mixtures with farmers' education, experience and cultivated extent. Similarly, some researchers have argued that, indiscriminate use of pesticides by Sri Lankan farmers is generally not due to lack of knowledge or lack of awareness on the harmful effects of pesticides (Nagenthirarajah and Thiruchelvam, 2008; Van der Hoek *et al*, 1998). However, Selvarajah and Thiruchelvam (2007) stated that, farmers in the Vavuniya district were unaware of the long-term and short term effects on their health by wrong pesticide usage. At the same time Wilson and Tiddsell, (2001) have stated that, farmers in Sri Lanka have a tendency to ignore technical recommendations and depend on their own experience often leading to indiscriminate application. The importance of education and training of farmers in the developing countries is being increasingly recognized as a major vehicle to ensure safe use of pesticides (Aktar *et al*, 2009).

3.2 Pesticide Regulatory Framework in Sri Lanka

Pesticides in the world are manufactured under the guidelines of the World Health organization (WHO) and the Food and Agricultural Organization (FAO). Pesticides are imported and distributed in Sri Lanka in compliance with the provisions of the Control of Pesticides Act No 33 of 1980 and the Amended Act No 6 of 1994. The Act regulates importing, packing, labelling, storing, transporting and using pesticides in the country.

Import of new pesticide molecule is a long process and need to follow strict procedures to obtain clearance. At each time of pesticide import, it is necessary to obtain import approval from ROP and import license should be issued by the Controller of Imports. The ROP has to undertake specified testing of the particular active ingredient and stability of the chemical before granting approval. The import procedure needed to be followed in importing new pesticides is illustrated in Figure 3.1. The process theoretically takes 3-4 years, but practically this might take up to 5 years. The registered products are constantly subjected to the latest international developments either at the time of re-registration after every three years or as and when necessary.

Figure 3.1: Pesticide Registration Process



Source: Adopted from the Presentation made to media by “Crop Life Sri Lanka” on 11th July 2011

The Control of Pesticide Act No. 33 of 1980 and amended Act No.6 of 1994 include the rules and regulations that should be taken into consideration in storing and selling agro-chemicals. According to the amendment made in 1994, "no person shall sell or offer for sale any pesticide except under the authority of a certificate issued by an authorized officer". This certificate should be exhibited in a conspicuous place and it has to be renewed yearly.

According to the Act, no person can store pesticides in bulk if there is no special store kept for that purpose. The store should be kept locked when loading or unloading is not in progress. A study conducted by Aheeyar *et al* (2011) revealed that, large-scale traders have separate warehouses for bulk storage of pesticides, but retail traders have a tendency to store their excess goods in a corner of the same shop though it is prohibited by law.

In addition GOSL issues special gazette notifications to regularize pesticide import from time to time. For example, pesticides with Arsenic or Mercury as the active ingredient are prohibited by special gazette notification of June 6th 2001. However, it does not provide any authority to prohibit importation of pesticides with Arsenic as minute impurities. Nevertheless, from 1st January 2012, all the imported agricultural and household pesticides have to be randomly checked by an authorized analyst for the existence of Arsenic, Cadmium, Cobalt, Chromium, Mercury, Nickel, Lead, Tin, Thallium and Cyanide. These chemicals should not be present in detectable quantities or should be less than the FAO standards if any detected.

There are many post registration activities to monitor proper handling, storage and usage of pesticides as per label directions and in compliance with the rules and regulations of the country. These post monitoring activities are followed diligently.

a) Monitoring of pesticides outlets to check adoption of rules and regulations in storing and selling of pesticides, especially the sale of restricted pesticides
b) Detecting unauthorized packing, repacking, labelling and adulteration of products
c) Monitoring the pesticide formulation process
d) Analysing of crops and commodities for pesticide residues and establishing maximum permissible limits to ensure safety of dietary intake
e) Monitoring pesticide poisoning cases due to exposure during formulation, storage and use

As per the Control of Pesticide Act No. 33 of 1980, Director General of Agriculture has powers to nominate Agricultural Officers of his Department as Authorized Officers to supervise the implementation of the Act. Currently two Agricultural Officers have been appointed for each district as Authorized Officers to enact the rules and regulations in the Act. The Authorized Officers have to provide training to the traders, and inspect whether the pesticide shops fulfil the requirements mentioned in the Act. The issuing of licences to pesticide shops and motivating traders to obtain a license is one of the duties of the Authorized Officers. One of the major responsibilities of these officers is to ascertain whether any person goes against any provision of this Act or any regulation or order made by the Act. The other function is to obtain samples of pesticides for the determination of deterioration, adulteration or decomposition. In addition, do all other acts or things which are connected with or are for furtherance of the exercise, performance and discharge of the powers, duties and functions under this Act.

However, inadequate laboratory facilities limit the performance of the monitoring activities of pesticide formulation process, analysis of pesticide residues in food commodities and establishing maximum permissible pesticide residues in food commodities. Overall, the post registration monitoring activities of pesticides are dormant and carried out on an ad-hoc basis due to lack of trained manpower, insufficient financial allocation, lack of laboratory facilities or non availability of laboratory facilities and other field support requirements. Unless the above facilities and resources are provided, the implementation of the Act would be limited.

There are several initiatives carried out in the past to ensure the safety of pesticides through the above monitoring process. The regulator takes actions from time to time to substitute the problematic pesticides with safer and less toxic chemicals considering chronic and acute chemical toxicity. The insecticide DDT, which is one of the Persistent Organo Phosphates (POPs), was banned from agricultural uses in 1970 and for all other uses such as vector control since 1976. In 1996, Chlordane, the last of the POP pesticide was banned for all uses in Sri Lanka. The ROP has banned several pesticides in the past (Table 2.4) and some of the pesticides were allowed to be imported in restricted quantities (Table 2.5). It is necessary to provide information on toxicity level, recommended concentration and pre-harvest interval for pesticide use and self life of the pesticide in the pesticide label for easy reference to all users. The ROP is mandated to provide training and awareness to farmers on safe handling, use and storage of pesticides by conducting awareness programmes, through enforcement officers and using mass media.

Table 3.4: List of Banned Pesticides by 2012

Active Ingredient	Chemical Family	Year of banning
Endrin	Organochlorine	1970
Chlorobenzilate	Organochlorine	1976
Chlordimeform	Formamidine	1980
Dieldrin	Organochlorine	1980
Phosphamidon	Organophosphate	1980
Thalium sulphate		1980
2,4,5-T	Phenox	1984
Ethyl parathion	Organophosphate	1984
Methyl parathion	Organophosphate	1984
Aldrin	Organochlorine	1986
Lindane	Organochlorine	1986
HCH (mixed isomers)	Organochlorine	1987
Mercury compounds		1987
Arsenic (arsenites and arsenates)	Inorganic	1988
Heptachlor	Organochlorine	1988
Leptophos	Organophosphate	1988
Captafol	Thalimide	1989
Dichloropropane	Chloro Carbon	1990
Aldicarb	Carbamate	1990
Quintozene (PCNB)		1990
Pentachlorophenol	Organochlorine	1994
Methamidophos	Organophosphate	1995
Chlordane	Organochlorine	1998
Endosulfan	Organochlorine	1998
Paraquat	Organochlorine	After 2008
Fenthion	Organophosphate	2010
Dimethoate	Organo phosphate	2010

Note: In addition to above list, the government has banned the importation of Propeneil, Carbofuran, Cabaryl and Cholropyrifos by 2012

Source: Records maintained by the Registrar of Pesticides (2012)

Table 3.5: List of Restricted Agricultural Pesticides by 2013

Generic Name	Type of Pesticide
alpha-cypermethrin	Insecticide/ Acaricides
aluminium phosphide	Rodenticides
benzalkonium chloride	Fungicide/Algicides
beta-cyfluthrin	Insecticide
bifenthrin	Insecticide/ Acaricides
boric acid	Insecticide
bupirimate	Fungicide
deltamethrin	Insecticide
difenacoum	Rodenticides
d-trans allethrin	Insecticide
fenhexamid	Fungicide
iprodione	Fungicide
lambda-cyhalothrin	Insecticide
methyl bromide	Fumigant
monocrotophos	Insecticide
ortho-phenylphenol	Fungicide
permethrin	Insecticide
s-bioallethrin	Insecticide
temephos	Insecticide
transfluthrin	Insecticide

Source: Records Maintained by the Registrar of Pesticides (2013)

Sri Lanka has successfully phased out a number of hazardous pesticides. According to WHO classification there are five different classes of pesticides in use depending on their toxicity and hazardous level (Table 2.6). Class 1A and Class 1B are categorized as red band pesticides and are extremely and highly hazardous to human health and the environment. Red band pesticides are totally banned in Sri Lanka since 1995 and it has been officially notified in the extraordinary gazette notification No. 1190/24 of 6th June 2001. Sri Lanka has also banned the imports of some of the moderately hazardous yellow band pesticides as well. The imports of persistent organic pollutants such as Organo phosphates and Organo chlorates are also totally banned and cannot be imported. The MSMA, an herbicide containing Arsenic as the active ingredient, was imported to Sri Lanka previously mainly to use in rubber plantations, was stopped after 2001.

Many pesticides banned in Sri Lanka are still being used in a number of regional countries without any control. For example one of the Organo phosphate class ii pesticide named as Endosulfan has been banned in Sri Lanka since 1998, but this is still used in many other regional countries. The country is moving towards class iii blue band and Class iv green band pesticides. Very recently, in mid of 2012, the government of Sri Lanka banned the import of Propeneil, Carbofuran, Cabaryl and Cholropyrifos after identifying these pesticides in urinal residues.

Table 3.6: Pesticide Classification by WHO

Classification	LD $_{50}$ for rats (mg/kg of body weight)			
	Oral		Dermal	
	Solid	Liquid	Solid	Liquid
Extremely Hazardous (Class ia)-Red band	5 or less	20 or less	10 or less	40 or less
Highly Hazardous (Class ib)-Red Band	5-50	20-200	10-100	40-400
Moderately Hazardous (Class ii)-Yellow band	50-500	200-2000	100-1000	400-4000
Slightly Hazardous (Class iii)-Blue Band	Over 500	Over 2000	Over 1000	Over 4000
Unlike to Present Acute Hazard (Class iv)-Green Band	Over 2000	Over 2000		

Source: World Health Organization, 2006

It was acknowledged by the professionals, scientists and pesticide importers in the country that, the regulatory framework in the country is more vigilant and procedures adopted are very tight in importing pesticides compared to all South Asian countries and many of the regional countries. FAO (1996) also has reported that the Registrar of Pesticides in Sri Lanka has been successful in regulating pesticides. The importers of pesticide are highly satisfied with both the procedures followed by the ROP and the field trials conducted by the DOA, considering the safety and effectiveness of the new molecule in the local environment, though it is time consuming.

3.3 Effects of Pesticides on Environment

Pesticides can contaminate soil, water, and other fauna and flora. In addition to killing insects or weeds, Pesticides can be toxic to a host of other organisms including birds, fish, beneficial insects, beneficial microorganisms and non-target plants.

Although several categories of agro-chemicals have been banned or phased out in the country considering their harmful effects and persistent nature in the environment, several groundwater contaminants such as 2-4D, MCPA (Herbicides) and Carbofuran (insecticide) are still being used and are most popular among farmers. Run-off of pesticides flowing into water bodies has the potential to significantly impact aquatic organisms by inhibiting growth and causing weaknesses in reproductive failure. Fungicides have higher amount of Zinc and Manganese which has a high risk of polluting groundwater and surface water sources.

Water resources are polluted by pesticides in numerous ways;

a) Application of herbicides to control aquatic weeds
b) Discharging surplus pesticide formulation to waterways after spraying
c) Washing of sprayers and other containers in the waterways

d) Runoff and erosion of pesticide treated soil
e) Accidental spillage of pesticides
f) Aerial sprays of pesticides

Organo chlorines and Organo-phosphates groups of pesticides have been detected in significant concentrations through research carried out at Walawe and Nilwala rivers (De Silva, 2003). It has been estimated that, more than 50% of pesticides applied to crops miss their target and fall onto the soil surface (Mathes, U.d.). Organo Chloro and some other pesticides can persist in the ground for years. Though all pesticides are non systemic, they can be absorbed by plants and transferred to animals through the food chain. Organo phosphate and Carbomate pesticides are non persistent, but their toxicity and damages to non target species are very high.

The pesticide industry is growing fast worldwide. Development of a new pesticide product needs a huge investment. According to Mc Dougall (2010), discovery and development of a pesticide take about 10 years and had absorbed around 256 million dollars in 2005 to introduce a new active ingredient. Green band pesticides are safer products to the environment and human health, but the cost of the product is comparatively higher. Another aspect of safer products is their less quick down action, compared to traditional pesticides. This does not mean that they are slow in action, but knocking down of pests cannot be immediately visualized. This issue needs more awareness among farmers about the effectiveness of the product.

3.4 Effects of Pesticides on Human Health

The frequent and indiscriminate application of highly hazardous pesticides in high concentrations has been often irrational and has posed serious health and financial risks to the farmers. It also affects the sustainability of agriculture. Pesticides applied to crops can find their way into food chains in a number of ways. Exposure to pesticides causes short-term as well as long-term illnesses. Human health hazards like cancer, kidney ailment and reproductive problems are known to be the major delayed outcomes of careless use of pesticides in addition to immediate health effects. Wanigasuriya *et al*, (2007) have found that, farmers using pesticides are more exposed to risk factors of chronic renal failure.

There are possibilities of contamination of animal products by various agro chemicals, especially in the upcountry due to insufficiency of grazing lands. Livestock farmers in the upcountry tend to feed the animals with crop residues that are contaminated with agrochemicals (Fischer *et al*, 2011). A study conducted in Magastota, Nuwara Eliya district shows that, milk samples collected from farmers constituted the residues of Propineb, Tebucanozole and Cholorothalonil, but lower than maximum residue level. However, it has been noted that, there is a risk from other unidentified agrochemicals present in the milk sample (Chamindal *et al*, 2012)

Farmers handling and spraying pesticides using hand sprayers suffer from numerous morbidity effects (Sivayoganathan *et al*, 1995; Nagenthirarajah and Thiruchelvam, 2008). According to Jayakkody (2009, quoted from Lanka Newspapers.com) the majority of pesticide users (70 percent) had used more than the stipulated dosage and a majority (82 percent) had symptoms of extreme toxicity following spraying. According to Wilson and Tiddsell (2001), estimated private cost of farmers' exposure to pesticides in Sri Lanka was on an average Rs. 5465 per year at 2000 prices. The value would be much higher if we consider the indirect costs associated with pesticide exposure such as discomfort, stress, pain and suffering. The value estimated using the contingent valuation method for ill health resulting from exposure of pesticides give a higher figure of Rs 11, 471 per year (Ibid). Sales promotion activities and credit facilities had contributed to the excessive pesticide use. This problem has not been counteracted by an agricultural extension service (Hoek Van der *et al*, 1998). The economic impact of pesticides in non-target species (including humans) has been estimated at approximately $8 billion annually in developing countries (Aktar *et al*, 2009).

The relative risk levels of two commonly used fungicides in potato cultivation in Nuwara-Eliya, Bandarawela and Welimada on surface and groundwater resources are given in the table No. 8. Uptake by humans through consumption of larger fish with elevated tissue pesticide concentrations is a human health concern. Pesticides can also leak into groundwater causing additional human health concerns in drinking water from contaminated wells. Therefore consumption of such water has a reasonable health risk. Heavy metals in water can cause bio accumulation in fish and other fauna and flora.

Table 3.7: Relative Risk Levels and Toxicity

Pesticide	**Location**	**Risk Level**		**Toxicity level**	
		Groundwater	**Surface water**	**Groundwater**	**Surface water**
Mancozeb	Nuwara eliya	EH	EH	H	H
	Welimada	H	EH	M	H
	Bandarawela	H	EH	H	H
Propeneb	Nuwara eliya	EH	EH	M	H
	Welimada	M	H	M	M
	Bandarawela	M	H	M	M

Note: EH-Extremely high; H- High; M-Medium
Source: Watawala *et al*, 2010.

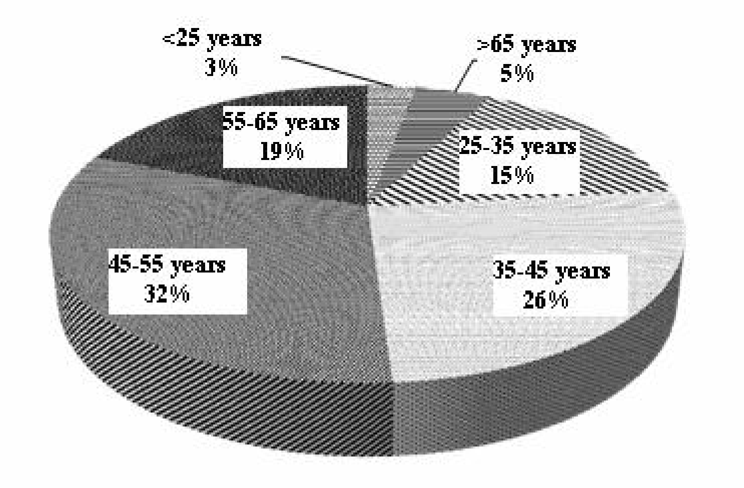
CHAPTER FOUR

Determinants of Pesticide Usage in Up Country Vegetable Farming

4.1 General Characteristics of the Sample farmers

Age of the responded population varied between 22 to 72 years and most of the farmers were in the age group of 45-55 years followed by 35-45 year age categories (Figure 4.1). The age category indicates a considerable proportion of younger farmer involvement in vegetable cultivation. Most of the farmers were educated up to GCE ordinary level and around 23 percent of farmers had been educated up to GCE Advanced Level. As shown in Table 4.1, education levels were almost similar in two studied districts.

Figure 4.1: Age Distribution of the Sample Farmers



Source: Authors' Survey Data, 2012

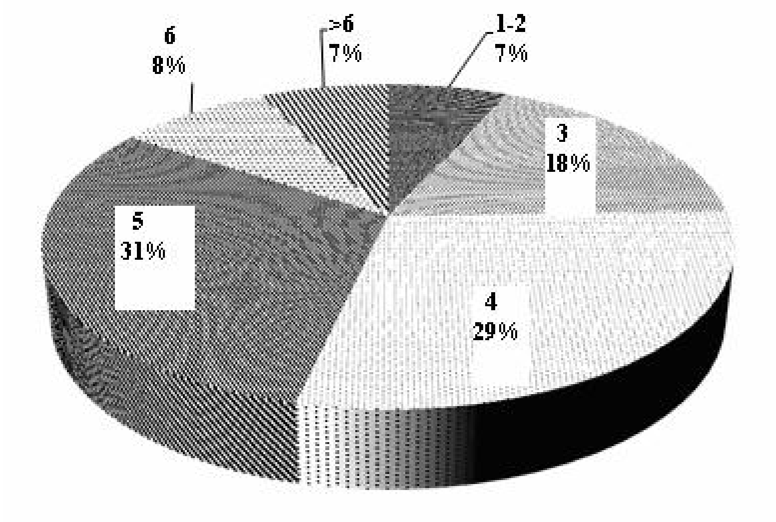
Table 4.1: Level of Education among Sample Farmers

Education category	Nuwara Eliya District		Badulla District	
	No. of farmers	% of farmers	No. of farmers	% of farmers
Up to grade 5	14	12	14	12
Grade 6 - grade 10	32	27	27	23
GCE O/L	45	38	48	40.5
GCE A/L	27	22.5	27	23
Higher education	1	0.5	2	1.5
Total	119	100	118	100

Source: Authors' Survey Data, 2012

The average family size of the sample was 4.41 in the both districts. As illustrated in figure 4.2 nearly 60 percent of the sample population consisted of 4 to 5 members including both parents and two to three children. The average family size indicates the limited availability of family labour for cultivation.

Figure 4.2: Family Sizes of the Study Population



Source: Authors' Survey Data, 2012

Table 4.2 presents primary employment of the vegetable cultivators in the Nuwara Eliya and Badulla districts. More than 90 percent of the sample farmers in the Badulla district and 85 percent in the Nuwara Eliya district cultivated Vegetables and Potato as their primary employment. Therefore, the number of people involved in secondary income earning activities was lower. Only 27 percent of farmers in the Badulla district and 36 percent in the Nuwara Eliya district were engaged in secondary employments.

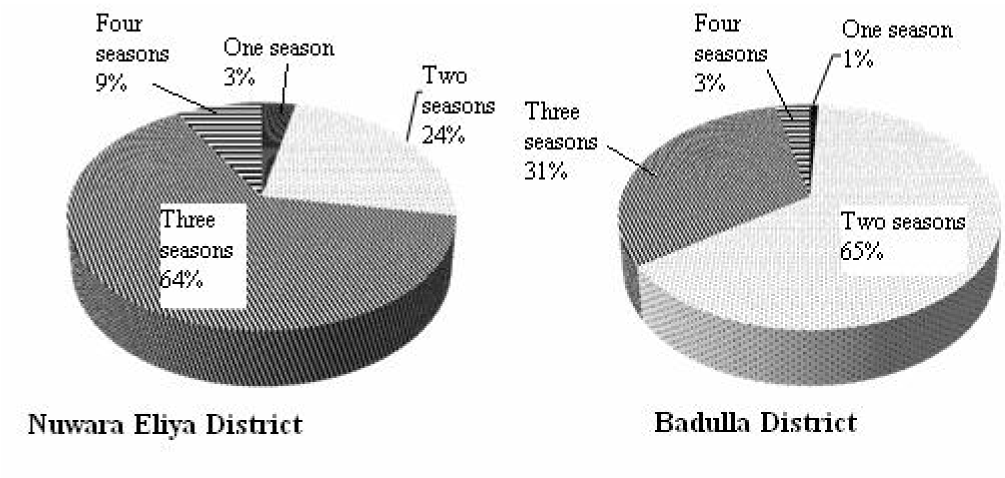
The study findings show that, most of the up-country vegetable farmers preferred to choose three to four months age varieties as such crops normally had a higher market price. Approximately 64 percent of the farmers in the Nuwara Eliya District normally cultivated three seasons per year and another 24 percent cultivated two seasons per year. Out of the total interviewed farmers in the Nuwara Eliya district, only nine percent cultivated four seasons per year. Similarly, 65 percent and 31 percent of the farmers in the Badulla district cultivated two and three seasons per year respectively. Nonetheless, the number of farmers who worked four seasons per year was less than 3 percent.

Table 4.2: Primary Employment of the Sample Farmers

Type of Employment	Nuwara Eliya District		Badulla District	
	No of farmers	% of farmers	No of farmers	% of farmers
Vegetable /potato cultivation	101	85	107	91
Animal husbandry	1	1	0	0
State sector permanent job	8	6.5	4	3
Private sector permanent job	1	1	3	2.5
Self-employment	5	4	0	0
Agricultural labour	2	1.5	0	0
Plantation agriculture	0	0	3	2.5
Other	1	1	1	1
Total	119	100	118	100

Source: Authors' Survey Data, 2012

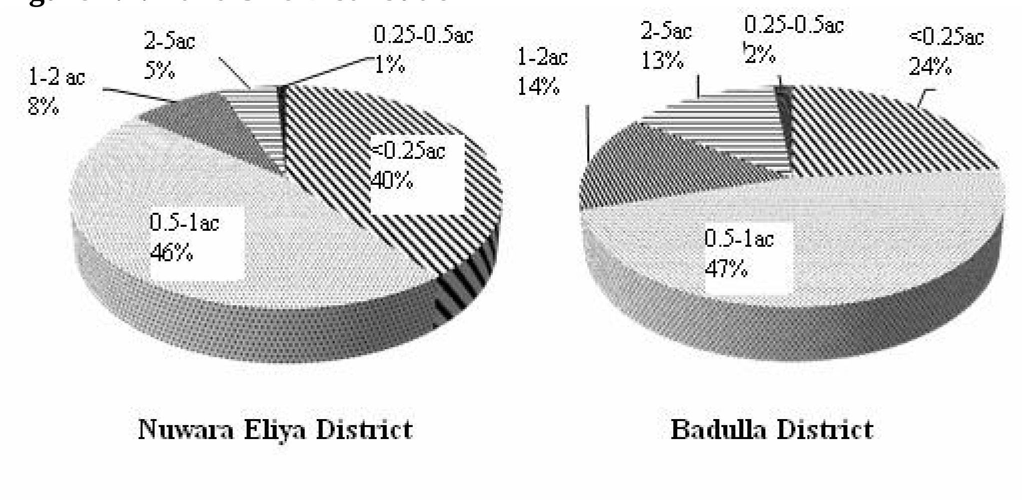
Figure 4.3: No. of Vegetable Seasons Cultivated per Year



Source: Authors' Survey Data, 2012

One of the main characteristics of upcountry vegetable farming is farmers' possession of small land holdings. As illustrated in Figure 4.4, 40 percent of the vegetable cultivating lands in the Nuwara Eliya district were equal or less than 0.25ac and another 46 percent of the holdings came under the category of half to one acre. Only 13 percent of the farmers had more than 1 ac of land under vegetable cultivation in the district. In the Badulla district, only 24 percent of farmers had a land extent of less than or equal to 0.25 ac for vegetable cultivation and 47 percent of the holdings came under the category of half to one ac. The number of farmers operating more than one acre extent of land was approximately 27%. The findings on land available for vegetable cultivation in the Badulla district indicate the comparatively bigger land holdings for vegetable cultivation than in the Nuwara Eliya District. (Figure 4.4)

Figure 4.4: Land Size Distribution



Source: Authors' Survey Data, 2012

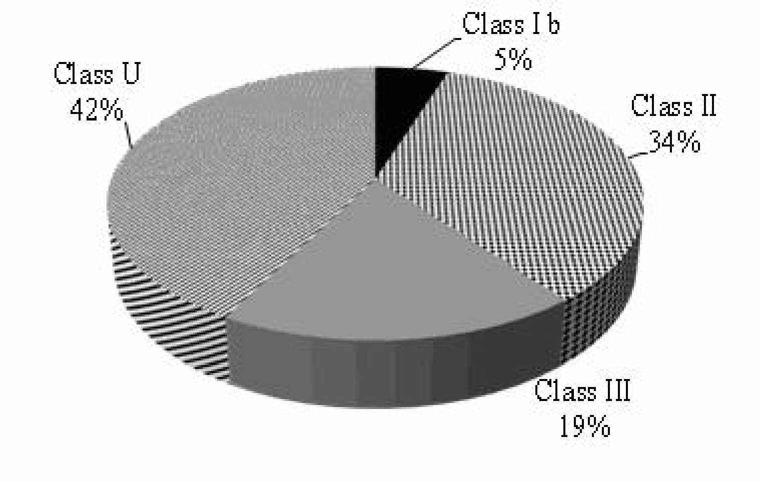
4.2 Types and Properties of Pesticides Used in Upcountry Vegetable Farming

Upcountry vegetable farmers in the study area use a total of 73 commercially branded pesticides which can be categorized into 39 active ingredients. The trade names of the pesticides include 44 insecticides, 25 fungicides and 4 herbicides. Out of the total number of active ingredients used in the upcountry vegetable cultivation, 42 percent belongs to WHO hazardous class U (class iv), which are unlikely to present any acute hazard in normal use. Out of the total Class U pesticides based on available active ingredients, 69 percent is fungicides.

FAO (2003) has recommended through its Pesticide Code of Conduct that, WHO Ia and Ib pesticides should not be used in developing countries, and if possible class II should also be avoided. Research findings reveal that, five percent of the active ingredients used in vegetable farming belong to class Ib. About 34 percent of the pesticides used are in class (ii) in which 85 percent of the active ingredients belong to insecticides group.

Most commonly used type of pesticide by up country vegetable farmers is insecticides (48 percent) followed by fungicides (47 percent). Nuwara Eliya district farmers use higher amount of fungicides than Badulla district farmers due to favourable climatic conditions prevailed in the Nuwara Eliya district for high fungus attacks. Out of all pesticides used 51 percent are insecticides in the Badulla district and 46 percent in the Nuwara Eliya district (Table 4.1).

Figure 4.5: Level of Different Classes of Pesticides used in Up Country Vegetable Farming



Source: Authors' Survey Data, 2012

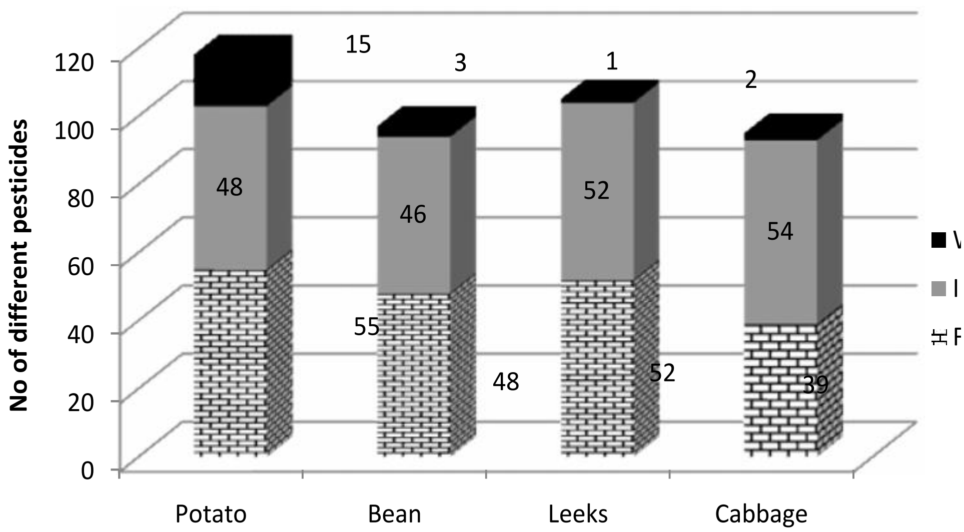
Table 4.3: Share of Different Category of Pesticides Used by Farmers (%)

Type of pesticide	Badulla District	Nuwara Eliya District	Total
Insecticide	51	46	48
Fungicide	41	52	47
Weedicide	8	2	5

Source: Authors' Survey Data, 2012

Types of different pesticides used by different crops are illustrated in figure 4.6. Potato farmers used highest number of different pesticides (118) followed by Leeks cultivators (105). Nearly 50 different types of fungicides and over 40 types of insecticides are used by the upcountry vegetable farmers. Herbicide usage is low in upcountry vegetable farming and potato farming. However, utilization of herbicides is higher in potato cultivation compared to vegetable farming. Reason for the low level of herbicide use in the cultivation of vegetable crops is that, these vegetables are usually cultivated soon after harvesting of potato (main crop), which does not involve application of herbicides. Another reason for low use of chemical weed control in up country vegetable cultivation is the practice of manual weeding after crop establishment in the field.

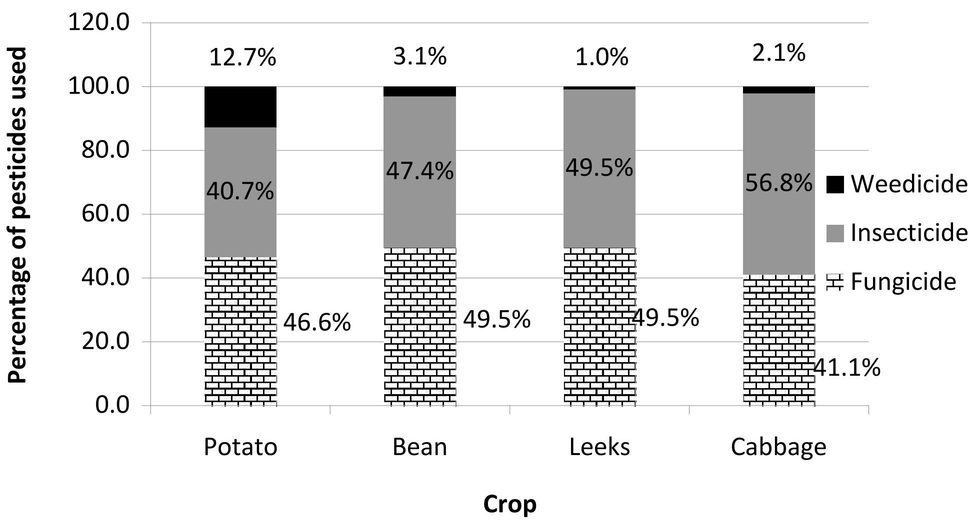
Figure 4.6: Total Number of Different Pesticides Used in the Cultivation of Four Different Crops



Source: Authors' Survey Data, 2012

Out of the total pesticides used for potato farming, 47, 41 and 13 percents are fungicides, insecticides and Herbicides respectively. In Leeks and Beans, nearly equal amounts of insecticides and fungicides are used but in cabbage, insecticide usage is higher, due to high pest attack. Otherwise it directly affects the quality of the product.

Figure 4.7: Percentage of Different Types of Pesticides Used in Different Crops



Source: Authors' Survey Data, 2012

4.3 Farmers' Attitude on Timing of Pesticide Application

The most common method of pesticide application is the use of liquid formulations. Liquid pesticides are commonly sold as concentrates to be diluted before or at the time of loading the product into the sprayer. Measuring the correct amount of pesticide, mixing and loading are indeed one of the hazardous steps in handling pesticides. Furthermore, inaccurate dilutions reduce pesticide effectiveness and increased concentration is expected to induce the development of pesticide resistance. The majority of the farmers (92%) use the measuring device which comes with the pesticide bottle to measure the pesticide for mixing, but some of the farmers use the bottle cap to measure the chemical.

Farmers have the liberty of choosing time of pesticide application viz; spraying after the appearance of symptoms of pest and/or disease attack or spraying the chemical in pre-scheduled intervals. Farmers were inquired about the common system for pesticide application. The findings are given in table 4.4. About 40 percent of the farmers always apply pesticide as a precautionary measure prior to the appearance of any symptoms of pest or disease, though it is needed for only selected pests and diseases. They frequently apply pesticides without considering the significant appearance of pests and diseases. Another 38 percent apply pesticides prior to the appearance of symptoms for selected pests and diseases. However, 37 percent of farmers apply pesticides only after the appearance of the symptoms of pest or disease, which is mostly recommended. Repeated application of chemicals is practiced during the occurrence of persistent infestation and on rainy days as decided by farmers on their own. The decision of farmers on timing of pesticide application is significantly related to type of vegetables they have grown (P= 9.297). Earlier study done by Chandrasekara *et al*, 1985 reported that, about 63.5% of vegetable farmers in all three cultivating regions (up, mid and low country) use pesticides prior to appearance of pests.

Table 4.4: Farmers' Decision on Pesticide Application

Time of pesticide Application	**Always (for all pests and diseases)**		**For selected pests and diseases**	
	No of farmers	**% of farmers* (N=237)**	**No of farmers**	**% of farmers* (N=237)**
Before the appearance of symptoms as a precautionary measure	92	39	89	38
After the appearance of symptoms	88	37	23	10
During pest and disease attack in the neighbouring farm	3	1	9	4
Applies only during severe damages	7	3	-	-

*Multiple answers may increases the total percentage more than100
Source: Authors' Survey Data, 2012

4.4 Use of Information in the Pesticide Label

Pesticide label contains information to guide the user for the correct and safe use of the pesticide including recommended dosage and type of suitable crops, toxicity level, symptoms of pesticide poisoning, first aid measures and so on. Therefore it is strongly recommended to read the product label before use of the product. According to the survey results, 90 percent of farmers in the Badulla district and 81 percent farmers in the Nuwara Eliya districts read the instructions given in the label before using it. The main reason for not reading the label is that, they do not feel the necessity of reading as they have long time experience in pesticide use as well as experience in the use of the same pesticide several occasions.

Table 4.5 demonstrates the farmers' consideration on information available in the pesticide label. More than 90 percent of the farmers pay their attention to the expiry date of the product (shelf life) and 88 percent of them are concerned about the way of using the pesticide. Around 90 percent of the farmers are not anxious about the colour band of the pesticide they purchase. The statistical analysis shows that, reading of the information given in the pesticide packs/bottles is significantly related to the level of education of the farmer (P = 27.369)

Table 4.5: Farmers' Anxiety on Information Available in the Pesticide Label

Label Information	Concerned		Not concerned	
	No of farmers (N=237)	% of farmers*	No of farmers (N=237)	% of farmers*
1. Expiry date (shelf life)	220	93	16	7
2. Method of use	208	88	29	12
3. Concentration	198	83.5	39	16.5
4. Colour band	28	12	209	88

*Multiple answers give the total percentage more than 100
Source: Authors' Survey Data, 2012

Every pesticide that is registered in Sri Lanka should show up its' level of toxicity in the label using the standard colour band. Red colour banded pesticides are the highest poisonous which are not allowed to be used in Sri Lanka. Yellow colour is the second highest level of toxicity and most of the pesticides in the Sri Lankan market are yellow banded. Blue band is the 3rd level of toxicity and green band are the lowest toxic category. Only 31 percent of the Badulla district vegetable farmers and 20 percent of the Nuwara Eliya district farmers were aware of the colour band denoted in the pesticide packs. Out of the total number of farmers in the Badulla district who were aware of colour band, only 55 percent have ever paid attention to colour band when purchasing a pesticide, while it was limited to 33 percent in the Nuwara Eliya district. Farmers who had used green label pesticides said that, green labels products in the market are limited to some selected products. About 31 percent of farmers, who had knowledge on green band but had not used it, have expressed that the specific products are not available in the local market. Another 25 percent of farmers, who had an awareness of green label product, have not used the products due to lack of quick knock down action of pest and diseases.

4.5 Sources of Information on Pesticides

Table 4.6 shows the sources of advice farmers received on selection of pesticides according to their priority. According to the findings, 35 percent of farmers rely on extension officers as the first source of information to choose a pesticide for a given pest or disease. Nearly 25 percent of farmers depend on their own experience as the first priority to select a suitable pesticide and another 24 percent of vegetable farmers depend on pesticide dealers to select pesticides. Very few (4 percent) select pesticides from the information distributed through print and electronic media such as newspapers, television and radio, as the first source of information. According to overall findings, 77% of farmers have some kind of linkage with formal extension source to obtain information, but the absence of proper grass root level extension service has forced them to rely on their own experience, pesticide dealers, and activities of fellow farmers which may differ from appropriate recommendations.

Table 4.6: Priority Source of Information Used by Farmers

Priority of the source	Source of information as a percentage of the total (N=237)				
	Extension officer	Pesticide dealers	Fellow farmers	Own experience	Printed and electronic media
1st priority	35	24	12	25	4
2nd priority	8	22	25	6	-
3rd priority	30	3	4	2	-
4th priority	4	-	-	0	22

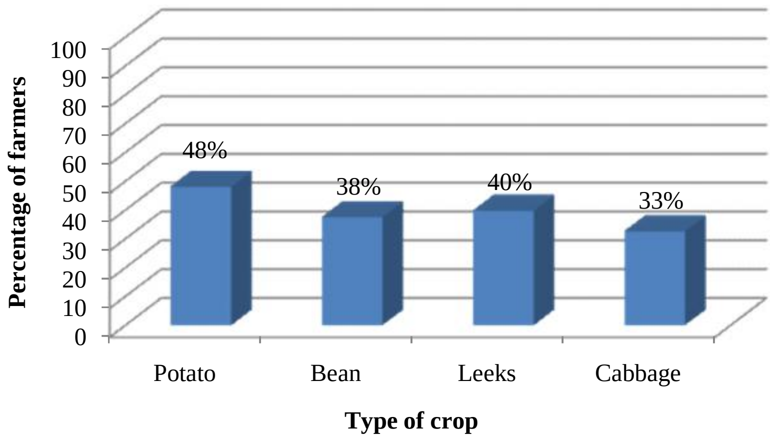
Source: Authors' Survey Data, 2012

Training and awareness programmes play a key role in building capacities of farmers in the use of right pesticide correctly. Therefore, farmers were inquired about the training received on pesticide application and safety measures. However, only 27 percent of farmers had received training related to pesticide use. Out of the total training receivers, 63% of farmers have attended the training conducted by private companies involved in pesticide marketing. The participation in the government sponsored training programmes conducted by the Department of Agriculture and Potato Research Institute was limited to 37% as farmers had to travel spending more time and money to attend these programmes. As private sector companies conducted training and demonstration program at farmers field, farmer participation in these cases were higher than government sponsored training programmes.

4.6 Quantity of Pesticide Use

The survey findings indicate that most of the farmers do not follow the instructions on the recommended dosage of pesticide given on the pesticide label and they are overdosing. This number is 38 and 41 percent of the farmers in the Badulla and Nuwara Eliya districts respectively. The majority of the pesticides over users apply 50% more than the recommendation given in the label. As shown in figure 4.8, trend of overdosing is higher among potato farmers (48 percent) followed by Leeks farmers (40 percent). Overall about 33-48% of the vegetable farmers use overdoses of pesticides.

Figure 4.8: Percentage of Farmers Applying More than Recommended Dosage



Source: Authors' Survey Data, 2012

About 37 percent of over dosing farmers believe that, it is essential to overdose chemicals as pesticides available in the market do not have strength as per the specifications given in the label. Reason of the 35 percent of the overdosing farmers is that they need to ensure immediate results of pest and disease management, without considering the fact on different pesticides that are varied from time to act. Nevertheless, 28 percent of the farmers apply more dosages based on their past experience of non-effectiveness of applying the recommended dosage in controlling pests and diseases.

Pesticides users in the up country areas of vegetable production usually spray in a preventive manner and spray between short intervals although this is not recommended. These findings have been confirmed by earlier researches as well (Watawala *et al*, 2010; Chandraseklara *et al*, 1985). The frequent application of highly hazardous pesticides in high concentrations has been often irrational and posed serious health and financial risks to the farmers. Farmers believe that more intensive the dose of pesticide applied; it is better for the crop. The farmers view is that applying higher doses of pesticides than recommended would bring higher yield, less post harvest losses and good quality product.

Spraying of chemicals over the leaf, under the leaf and to root system are required to be considered in method of pesticide application, but some farmers lack this knowledge forcing them to ineffective pesticide application. This might be one of the reasons for repeated applying and using over dosages of pesticides. Another reason for the ineffective use of pesticides is lack of farmer awareness or not bothering about the availability of different types of nozzles and requirement of adjustments of nozzles for different types of agro chemicals to make the spray efficient and effective. Field observations and results of key informant discussions show that all types of agro-chemicals are sprayed using same nozzles by most farmers and there is no alteration in the nozzle type for different agrochemicals. Sprayer pressure nozzles that are not adjusted and remaining in the same space for different application lead to the application of inappropriate doses than the recommended.

Almost all the vegetable farmers in the up country vegetable farming system have been completely depended on chemical pesticides to manage pest and diseases. If a particular chemical is ineffective in controlling a given pest or disease, farmers use different strategies to curb the incidence. Roughly, 77 percent of the farmers prefer to change the brand of pesticide, while 21 percent of the farmers increase the dosage of the same brand of pesticide and 2 percent of farmers mix two or more different chemicals to control pest and diseases in the case of ineffectiveness of applying single pesticide. However, mixing of pesticides is a common practice among most vegetable growers irrespective of the effectiveness of the single chemical application. According to the survey, an average of 53 % of the sample farmers has a habit of preparing pesticide cocktail mixtures, where mixing of two pesticides is the most common practice. Approximately 51 percent of cocktail pesticide makers believe that such mixtures save the time; while another 31 percent anticipate that such mixtures are more substantive and therefore effective in controlling pests and diseases.

4.7 Pesticide Application Practices

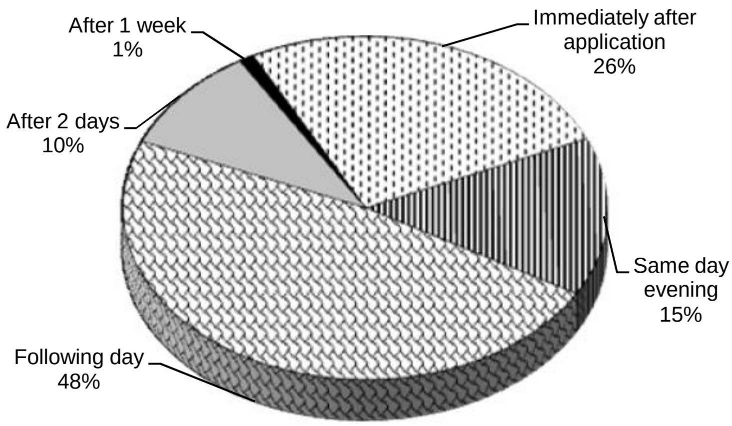
The majority of the farmers (73 percent) spray chemicals towards the wind direction in order to prevent the wind effect directly on chemical applicator, but 23 percent of farmers do not consider the wind direction during the application which has serious health effects on the spraying farmer. These farmers believe that it is not always practical to apply pesticides considering the wind. Approximately 73 percent of the farmers usually apply pesticides early in the morning while 13 percent applies in the evening. Almost all farmers apply fungicides and herbicides in the morning but, insecticides are in the evening. The reason given by the farmers for the choice of evening hours for the application of insecticides is that insects are active in the night than day time and consequently they believe the application of chemicals in the evening would provide maximum effects on insects. Nevertheless, farmers trust that spraying of fungi in the morning is more effective due to the absorption of the fungicide in the leaf surface in the form of dust/crystal due to heavy sunshine during the day.

The re-entry period[1] is the time gap necessary to maintain between pesticide application and the re-entry to the pesticide applied field. The time gap is to allow the chemical to dissipate in the environment in order to reduce the health effect to humans. Most of the Organophosphates and Organo-chlorates need a minimum interval of 72 hours. Although 65 percent of the farmers were aware of the idea behind the re-interval period, 41 percent usually go to the field same day of pesticide application to observe the effects of spraying (figure 4.9) despite 32 percent of them are aware of their folly. Another 48 percent of farmers enter the field in the following

[1] The re-entry time (RET) (or re-entry period) is the minimum amount of time that must pass between the time a pesticide was applied to an area or crop and the time that people can go into that area without protective clothing and equipment

day and 10 percent stay on for two days to re-enter the field after spraying. The re entry intervals to the pesticide sprayed field is significantly related to the level of education (P= 43.999) of the farmer.

Figure 4.9: Re-entry Interval



Source: Authors' Survey Data, 2012

About 66 percent of farmers who work in the field immediately after application perceived that they there was no harmful effect due to this practice. More often than not, people do not realise the connection between exposure to pesticides and diseases. This is because there are no obvious symptoms of poisoning immediately following exposure. The reason expressed by them for their action was that time and labour limitations. WHO has recommended displaying a danger sign board in all the newly pesticides applied fields but it had not been practiced in any of the locations.

Farmers do the application of pesticides prior to harvesting to make the harvest fresh and storable until it reaches the market without considering the safety period required, thus increasing the risks of residues being consumed. Past research findings also indicate that 8% of farmers apply pesticides prior to marketing (Chandrasekara *et al*, 1985). According to the recommended guidelines, farmers should allow 1-3 weeks chemical free period depending on the pesticide before harvesting of the crop to reduce the residual effects of pesticides. The present research finding indicates that, about 30% of the farmers harvest the produce within seven days of pesticide spraying (Table 4.7). The reasons for the action are given in table 4.8.

Table 4.7: Minimum Time Interval between Pesticide Applications and Harvesting

Harvesting time after application of pesticides	% of the farmers (N=237)
Following day	2
After 3-4 days	3
After a week	25
After two weeks	70

Source: Authors' Survey Data, 2012

Table 4.8: Reasons for Harvesting the Produce within the Pre-Harvest Interval

Reasons	% of the farmers (N=65) *
Unawareness about the harmful effects	12
Reduces the postharvest losses	11
To improve the quality of harvest	32
Unexpected increase of vegetable prices	40
Request by the collectors/wholesalers	5

* No. of farmers harvesting the vegetables without considering the minimum time interval required between pesticide applications and harvesting

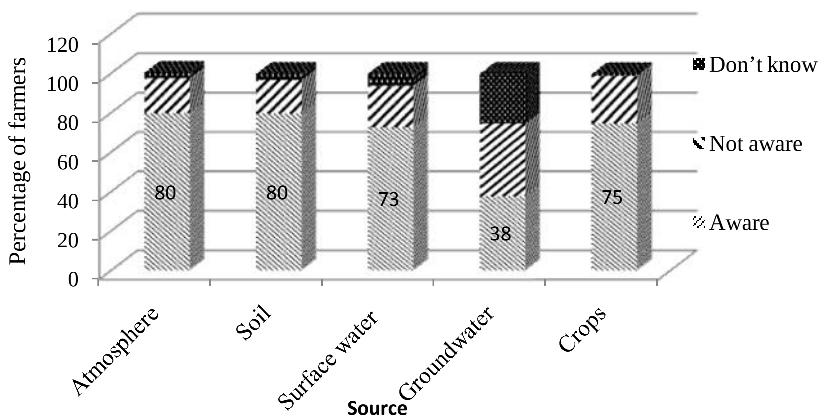
Source: Authors' Survey Data, 2012

4.8 Safety and Storage Practices

4.8.1 Farmers' knowledge on pesticide residues

Out of the total volume of pesticide mixture applied to the field, only about 20-30% is absorbed by the crops and the rest is left in the environment (Huang, 2001). Therefore over application of pesticides has more harmful effects on the environment. More than 75 percent of the farmers were aware of the fact that pesticide residues remain in the environment, viz. atmosphere, soil and surface water sources. However, 25 percent of the farmers lack any knowledge on the impacts of pesticide on groundwater (Figure 4.10). More than 96 percent of the farmers are aware of the beneficial organisms that live in soil and 87 percent of them have an understanding about the harmful effects of pesticides on the beneficial organisms like earthworms and beneficial insects.

Figure 4.10: Awareness of Availability of Pesticide Residues in Various Sources



Source: Authors' Survey Data, 2012

The survey has found that 92 percent of farmers store pesticide bottles in a safe location within or outside the house to make them inaccessible to children (Table 4.9).

The rest of the farmers mostly place the bottles in unsafe locations in the house without considering safety precautions.

Table 4.9: Storage of Pesticides

Storage of pesticides	Farmers response (N=237)	
	No of farmers	% of farmers
Farmer field	20	8.5
Safe location	198	83.5
Inside the house	19	8.0

Source: Authors' Survey Data, 2012

4.8.2 Disposal of used bottles and plastic containers

Disposal of empty pesticide packs is a safety concern and has environmental consequences. Most farmers (43%) dispose empty glass bottles with the garbage, and another 39 percent safely bury empty bottles in the ground. About 8 percent of the farmers have sold empty glass bottles to bottle collectors while 9 percent of the farmers have thrown their empty glass bottles in the irrigation channels and outside the houses.

In case of plastic bottles and polyethylene packing materials, 46 percent of the farmers have burned them and another 27 percent have placed them in the garbage. However, 18 percent of the farmers have safely buried their plastic containers but, 5% of the farmers have thrown their empty plastic/polythene containers in the irrigation channels and outside the house without any concerns on the consequences of their actions (Table 4.10). But according to the field observations this number should be higher than farmer perceptions. Because farmers in Sri Lanka are generally aware of the danger of improper pesticide use and are often knowledgeable regarding disposal measures that should be taken. However, as evidenced by past studies, farmers modify their responses to suit what they consider appropriate for the questionnaire (Taylor, 1998).

Table 4.10: Disposal of Empty Pesticide Bottles

Method of Disposal	% of Farmer responses (N=237)	
	Glass bottles	Plastic bottles/ Polythene bags
Thrown to irrigation channels, ground, outside house	9%	5.5%
Buried in the ground	39%	18%
Burning the package (polythene, paper, plastic)	-	46%
Sold	8%	2%
Dump into garbage	43%	27%
Keep the bottles and cans for other uses	1%	2%

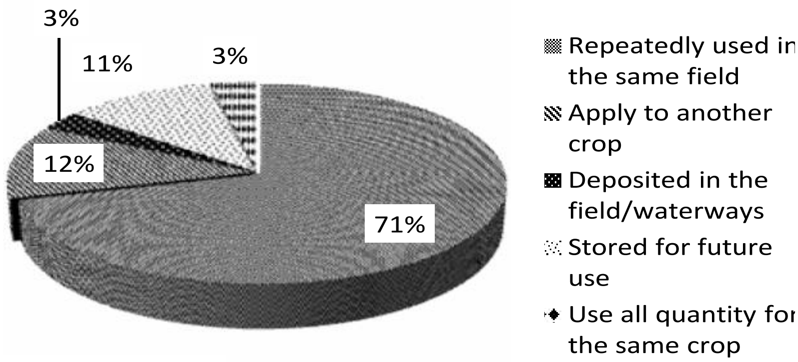
*Multiple answers may increases the total percentage more than 100

Source: Authors' Survey Data, 2012

The disposal of pesticides to the environment with a long residual action is more hazardous to human beings and the environment (Foster *et al* 1991; Fielding *et al* 1992). The residual action is possible not only by unsafe disposal of pesticides packing materials and containers, but also by putting down of unused/balanced pesticide mixture. The survey has found that, the later problem was not a serious issue unlike the disposal of empty bottles. Only about 3 percent of the farmers release the remaining pesticide mixture into the environment that would harm the human and animal health.

Approximately 71 percent of the farmers have repeatedly used the excess spray solution prepared for the same crop, while 12 percent have used the excess spray solution to another crop. As illustrated in figure 4.11, 11 percent of farmers have stored the excess solution for future use. The method of disposing excess pesticide solution is significantly related to the type of crop cultivated (P = 20.886)

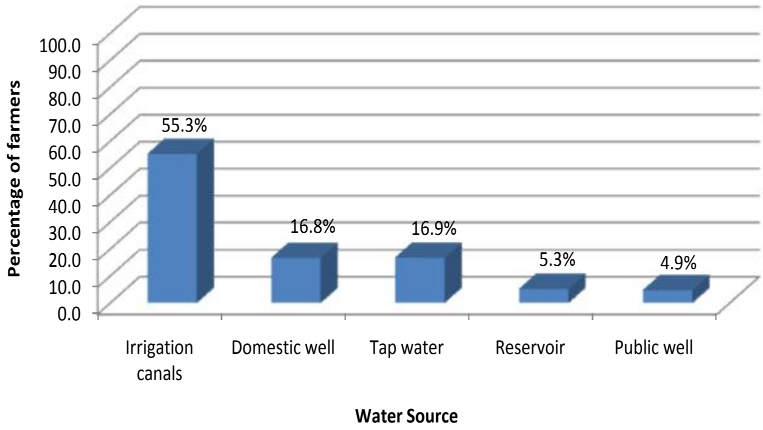
Figure 4.11: Disposal of Remaining Pesticides in the Sprayer



Source: Authors' Survey Data, 2012

The study has found that over 95 percent of farmers are in the good habit of washing their sprayers after use. However, the majority of them wash the sprayers in the irrigation channels and reservoirs (60%) and another 34 per cent of farmers use domestic water sources such as domestic well and tap to wash the sprayers (Figure 4.12). The act of the majority is indeed causing pollution of common water sources.

Figure 4.12: Washing of Pesticide Sprayers



Source: Authors' Survey Data, 2012

4.8.3 Use of safety clothes

As noted in the FAO guidelines, there are certain standards which should always be adhered by pesticide applicators to protect them against any harmful exposure of pesticides during the handling and application. One of the important recommended measures is wearing of standard protective clothes and masks during pesticide applications. The minimum FAO requirement for all types of pesticide operations is lightweight cloth covering most parts of the body. In practice this includes a long-sleeve upper garment, a garment covering the lower body including legs, footwear (boots or shoes) and, if spraying high crops, a hat and face mask.

It is universally acknowledged that the primary route of exposure to pesticides is via the skin, because pesticide products can splash or spill into exposed skin during pouring and mixing of concentrated pesticide formulations and spraying when dust can contaminate exposed skin or clothing (FAO, 1990). Therefore wearing of protective clothes is the most important safety measure aimed to avert or minimize skin contamination as far as possible and, if this occurs, to ensure efficient decontamination. According to the survey findings, more than 63 per cent of farmers wear clothes covering most parts of the body and a hat (Table 4.11). The number of farmers wearing protective garment/overall (a protective garment to cover most part of the body) is high in the Nuwara Eliya district (72 percent) than in the Badulla district. Wearing of protective clothes is not a big issue for Nuwara Eliya district farmers as it has a cooler clime. However, the warmer tropical climatic condition makes farmers uncomfortable and discourages using protective garment.

Table 4.11: Level of Usage of Protection Clothes

Use of Protective Cloths	Badulla District (N=120)	Nuwara Eliya District (N=120)	Total (N=240)
	No.& % of farmers	No.& % of farmers	No.& % of farmers
Wearing of protective garments/ Overall	66 (56%)	86(72%)	152(63%)
Boots	8 (6%)	19 (16%)	27(11%)
Mask	74 (63%)	64 (54%)	138(58%)
Gloves	43 (36%)	46 (38%)	89(37%)
Goggles	4 (3%)	3 (2.5%)	7(3%)
Hat	79 (67%)	73 (61%)	152(64%)

Source: Authors' Survey Data, 2012

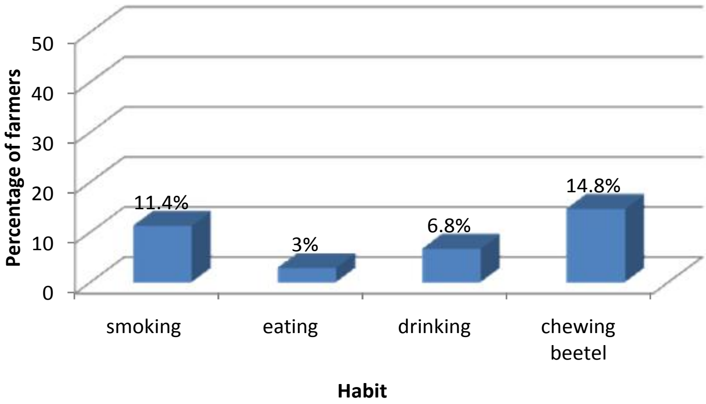
In order to prevent the inhalation of chemical particles it is recommended to wear a mask covering nose and mouth. However, only 58 percent of the farmers use mask during the pesticides application. Number of farmers using protective gloves is as low as 38 percent during pesticide formulation, pouring, mixing, loading and spraying. Only 11 percent of farmers wear boots at the time of pesticide application. Most of the farmers are not willing to use foot wears in their fields as they culturally consider the field as a sacred place. Another reason for not wearing boots is the difficulty of wearing in muddy soils. However, not wearing of boots has a high possibility of pesticide exposure in vegetable cultivation. Non wearing of boots is more critical in fields with stagnant water such as rice fields where pesticides contaminate water resulting in high possibility of dermal exposure. Wearing a protective cover for eye is important especially when applying pesticides for crops like beans, but very few (3 percent) wear goggles (eye cover) while spraying.

4.8.4 Adoption of safe hygienic practices during spraying

Another basic principle needed to be adopted in working with pesticides for the personal protection is maintaining good hygiene to avoid direct contamination of pesticides. It is strongly recommended that the pesticide operators do not eat, drink or smoke during the spraying and that they do not touch their bare skin with soiled hands or gloves.

According to the research findings, farmers involved in eating and drinking during pesticides spraying is very rare (Figure 4.13), but involvement in chewing beetles and smoking is relatively high among agricultural workers despite their awareness of possible harmful effects. Proper body washing or bathing after spraying is another recommended practice, especially before consumption of food or drink and going to toilet. The study results reveals that, 47 percent of the farmers had bathed immediately after finishing the spray, while 49 percent of the farmers bathe after completion of work of the day. Few farmers (4%) mentioned that bathing after pesticide application was not strictly followed by them.

Figure 4.13: Farmers' Unhygienic Activities during Spraying



Source: Authors' Survey Data, 2012

4.9 Incidence of Insecticide Poisoning among Upcountry Vegetable Farmers

According to the FAO (1997), Sri Lanka ranks higher in the Asia Pacific Region with respect to pesticide-related health hazards. Annually the total number of pesticide accidents in Sri Lanka is around 20,000 of which 1,600 are fatal with 70% of this being suicide attempts. Routine occupational exposure during pesticide application often causes chronic health effects. Pesticides may accumulate in body fat following incidental exposure to the residues in air, water, soil and food. Chronic and incidental exposure raises the possibilities of carcinogenic, teratogenic, mutagenic and reproductive effects (WHO 1993).

About 90 percent of the farmers were aware of the fact that regular exposure to pesticides is harmful to human health, and 76 percent were aware that different pesticides have different effects to the human body, but 18 percent of the farmers wrongly believe that there is no bad health effect by using different types of chemicals. The majority of the farmers (92 percent) know that pesticides can be absorbed into the body. Most likely route of exposure for pesticide operators is via the skin. According to the FAO, during conventional application of pesticides, the amount of contamination from inhalation is a tiny fraction of contamination by skin exposure and oral intake. About 82 and 86 percent of farmers responded that pesticides can be absorbed in to body via skin and mouth respectively and more than 90 percent of farmers had known that pesticides can get into the body through inhalation.

Pesticide related injury cases were found among 26% of the sample farmers. The injuries were not restricted to the spraying farmer, but also women and children, due to their involvement in the spraying process. Of all the reported cases, 50% were skin injuries, a finding which reflects the inadequate use of safety precautions, inappropriate spraying equipment, and the non-availability or inconsistent use of protective gears (Table 5.8). Nevertheless, 83% of the injured persons had taken appropriate action by consulting a doctor immediately after poisoning.

4.10 Farmers' Knowledge on Integrated Pest Management (IPM)

Integrated pest management (IPM) technique is not popular among the up country vegetable farmers and only 24 percent of the farmers are aware of IPM. Only four percent of farmers practice IPM. The level of awareness of IPM highly varied between two selected districts and it is 36% in the Badulla district and 11% in the Nuwara Eliya district. Farmers who had practiced IPM emphasized that IPM has helped to increase yield while reducing the cost of production and environmental damage. The main reasons given by farmers for not practicing IPM are listed in table 4.12.

Lack of understanding about the IPM is one of the primary causes hindering the adoption of IPM. The research findings indicate that, 23 percent of farmers in the Badulla district and 10 percent of farmers in the Nuwara Eliya district had no trust on IPM technique; therefore, they were reluctant to rely on IPM for pest control. Another 21 percent of farmers believed that, IPM takes relatively longer time to control pests and diseases unlike the chemical method of control. However 20 percent of farmers expressed that IPM was not suitable to the climatic conditions with high humidity and low temperature in up country which helps rapid spread of pest and diseases. Another 19 percent believed IPM cannot control all pest and disease incidence. As the IPM has several components, 12 percent of farmers considered IPM is a complicated method to control pest and diseases. All up country vegetables are short term high value economic crops and therefore farmers were reluctant to experience any risk. Approximately six percent of farmers are not willing to use IPM as a risk aversion strategy.

Table 4.12: Reasons for not Using IPM

Reasons	**% of farmers (N=237)**	
	Badulla	**Nuwara Eliya**
Do not know about IPM	47	58
No trust on IPM strategy	24	11
IPM is time-consuming method of pest control	17	5
IPM is difficult to adopt in the existing field condition	11	11
IPM unable to control all the pests and diseases	9	11
IPM is complicated method of pest control to adopt	10	3
IPM is risky strategy to adopt	4	2
IPM is a costly method of pest control	1	0

*Multiple answers may increase the total percentage above 100
Source: Authors' Survey Data, 2012

Another interesting finding of the study is that, 15 percent of farmers in the Badulla district and 25 percent of farmers in the Nuwara Eliya district cultivate separate chemical free plots of vegetables for home consumption, as they are aware of the adverse effects of the pesticides on human health because of the enormous quantity of chemical pesticides applied to the vegetable fields.

CHAPTER FIVE

Technical Efficiency of Vegetable Cultivation

5.1 Technical Efficiency of Vegetable Cultivation

Individual farm level technical efficiencies were estimated for potato, beans, leeks and cabbage separately for a single season in the year 2012.Table 5.1 shows the model estimated for four different crops. The estimate of γ is equal to one for Potato and more closer to one in Leeks and cabbage, as well as estimated standard error is significant at 1% significance level. These results indicate that the vast majority of residual variation is due to inefficiency effect U_i, and that the random error V_i, is approximately zero. Therefore total productivity variation in potato farming and 99 percent variation in Leeks and cabbage and 79 percent variation in beans are explained by the model.

Table 5.1: Model Estimates of Selected Crops

Parameter	Potato	Beans	Leeks	Cabbage
$\pm^2 = \pm_u^2 + \pm_v^2$	0.706 (3.949*)	1.493 (2.580**)	0.577 (5.624*)	3.561 (3.106*)
$\gamma = \pm_u^2 / \pm^2$	1.000 (124362.4*)	0.796 (6.891*)	0.996 (20.508*)	0.985 (112.419*)
Log likelihood	- 18.294	- 60.891	- 31.779	- 45.892
LR test	48.942	20.107	20.181	63.468
Mean Technical Efficiency	64%	72%	58%	64%
Maximum efficiency	100%	91%	97%	92%
Minimum efficiency	4%	4%	7%	3%

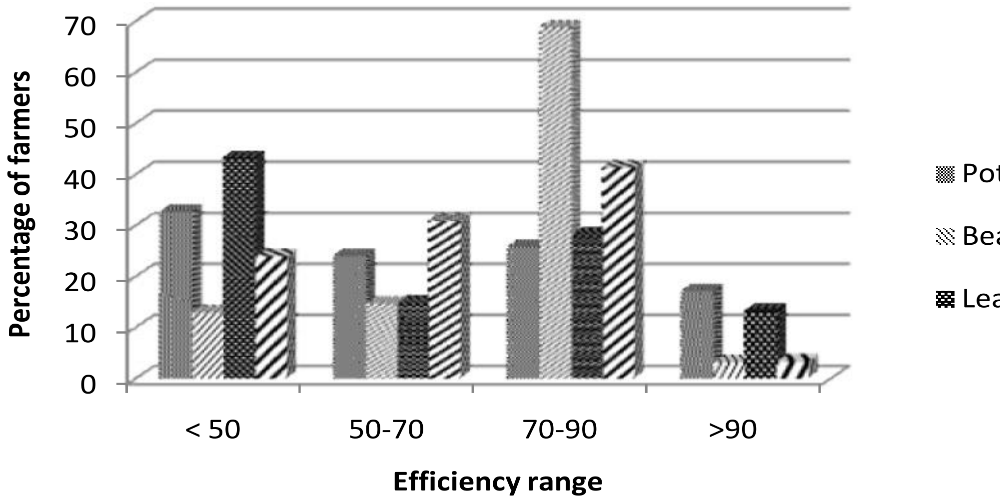
* Significant at 1%, ** Significant at 5%

The observed variations in production efficiency among up country vegetable farmers were mainly due to differences in farm practices of sample farmers rather than random factors that are not within the control of farmers. One sided LR test of $\gamma = 0$ provide statistics of 48.942 for Potato, 20.107 for beans, 20.181for Leeks and 63.468 for Cabbage models respectively which exceeds the chi-square critical value at five per cent. Hence the traditional average response function is not an adequate representation of the data and the stochastic frontier model does appear to be a significant improvement over an average production function.

The mean technical efficiency of potato and cabbage farmers in the upcountry areas was estimated as 64 per cent which indicate that the average farmers produced 64 per cent of the maximum attainable output for given input levels. In other words an average of 36 percent of production was lost due to inefficiency. The mean technical efficiency of the beans and cabbage farmers were 72 per cent and 58 percent respectively. This implies that, on average, nearly half the cabbage production was lost due to inefficiencies in their production techniques.

The important finding of efficiency analysis is the huge discrepancy between the maximum and minimum efficiency levels. Efficiency values range from 100 to 4 percent among potato farmers, 91 to 4 percent in beans, 97 to 7 percent in leeks and 92 to 3 percent in cabbage farmers. This demonstrates the wide differences in the individuals' farm efficiency level. Thus, the mean technical efficiency level may not indicate the actual picture of the distribution of individual farm efficiency levels. Figure 5.1 illustrates the frequency distribution of individual farms' technical efficiencies.

Figure 5.1: Distribution of Farmers' Technical Efficiency Indices



Most of the potato farmers (33 percent) and leeks farmers (43%) come under the category of less than 50 percent efficiency. For beans comparatively larger percentages of farmers (69%) come under the efficiency category of 70-90 per cent. Most of the cabbage farmers come under the category of 70–90 percent of efficiency. The distribution of the technical efficiency scores suggests that there is a big potential to increase the technical efficiency among the sample farmers. The mean technical efficiency of the potato and cabbage farmers is 64 percent and, therefore in the short run they can increase their production by 36 per cent by increasing technical efficiency. Similarly, efficiency levels of bean farmers have the ability to increase their efficiency by 28 per cent without changing current levels of inputs. The leeks farmers show the lowest level of input use efficiency and they can increase their output level more than 42 percent by changing their management practices with the same level of input quantities.

5.1.1 Efficiency estimates of potato farmers

Maximum likelihood estimates of Stochastic Production Frontier for potato production are presented in table 5.2. According to the findings, organic fertilizer, chemical fertilizer and micronutrient were only parameters, significantly affecting the production efficiency of potato farmers. As shown in the table, above three parameters show positive values of 0.042, 0.134 and 0.065 respectively. The positive significant relationship between potato yield, organic fertilizer, inorganic fertilizer, and micronutrient use, explains that, 1 per cent increase in quantity of each input used would increase potato yield by 0.042, 0.134 and 0.065 respectively.

Table 5.2: Maximum Likelihood Estimates for Potato

Parameters	Coefficient	SE	t-ratio
Intercept (β_0)	5.953	0.970	6.140*
Dolomite (β_1)	0.014	0.014	1.022
Seeds (β_2)	0.081	0.066	1.237
Organic fertilizer (β_3)	0.042	0.022	1.921***
Chemical fertilizer (β_4)	0.134	0.059	2.256**
Micronutrients (β_5)	0.065	0.016	4.003*
Plant Hormones (β_6)	0.011	0.015	0.712
Machinery (β_7)	0.010	0.016	0.623
Pesticides (β_8)	0.021	0.029	0.710
Labour (β_9)	-0.031	0.054	-0.575

* Significant at 1%, ** Significant at 5%, *** Significant at 10% level

5.1.2 Efficiency estimates of beans farmers

Table 5.3 shows the estimated coefficients for beans production in upcountry vegetable farming. The costs of seed, organic fertilizer, chemical fertilizer, machinery and labour have shown positive relationships with bean yield.

Table 5.3: Model Estimates for Beans

Parameters	Coefficient	SE	t-ratio
Intercept (β_0)	-0.423	1.239	-0.342
Dolomite (β_1)	-0.037	0.030	-1.241
Seeds (β_2)	0.262	0.131	1.994***
Organic fertilizer (β_3)	0.073	0.032	2.284**
Chemical fertilizer (β_4)	0.104	0.046	2.240**
Micronutrients (β_5)	-0.048	0.026	-1.847***
Plant Hormones (β_6)	0.041	0.028	1.496
Machinery (β_7)	0.071	0.029	2.481**
Pesticides (β_8)	0.039	0.047	0.820
Labour (β_9)	0.349	0.141	2.470**

* Significant at 1%, ** Significant at 5%, *** Significant at 10% level

Farmers use different level of spacing and different types of bean seeds which are available in the market at different prices. By increasing seed, organic fertilizer and chemical fertilizer costs by 1 percent yield would be increased by 0.262, 0.073 and 0.102 units respectively. Labour positively affects production of beans at 5 percent significant level indicating that one unit increase in labour can increase yield by 0.349. Bean is a labour intensive crop, as it has average 5-7 harvestings in a season. Therefore labour has a positive relationship with beans yield. If machinery cost is increased by 1 percent in bean production, yield would increase by 0.071 percent. As bean is commonly cultivated in terraced lands, farmers usually practice manual ploughing which is labour intensive. The farmers who use two wheel tractors for land preparation are found to be more efficient. Micronutrient has a negative relationship with bean yield, increase in micronutrient cost by 1 percent decrease yield by 0.048 when compared with efficient user, which implies of overuse of micronutrients in bean production.

5.1.3 Efficiency estimates of leeks farmers

As shown in table 5.4, dolomite, organic fertilizer, micronutrients, plant hormones and labour have significant and positive affects on leeks yield in up country vegetable farming.

Table 5.4: Model Estimates for Leeks

Parameters	Coefficient	SE	t-ratio
Intercept (β_0)	4.415	2.022	2.184**
Dolomite (β_1)	0.075	0.037	2.012**
Seeds (β_2)	0.073	0.073	0.998
Organic fertilizer (β_3)	0.044	0.021	2.103**
Chemical fertilizer (β_4)	0.008	0.140	0.057
Micronutrients (β_5)	0.045	0.008	5.708*
Plant Hormones (β_6)	0.034	0.015	2.232**
Machinery (β_7)	0.019	0.015	1.214
Pesticides (β_8)	-0.030	0.019	-2.162**
Labour (β_9)	0.278	0.146	1.905***

* Significant at 1%, ** Significant at 5%, *** Significant at 10% level

One unit increase in cost of dolomite, organic fertilizer, micronutrients, plant hormones will leads to increase in leeks yield by 0.075, 0.044, 0.045 and 0.034 respectively. Additional one percent increase in labour usage increase the leeks yield by 0.278. Costs associated with pesticides showed significant negative effects. Negative value for the co-efficient of pesticide as an input implies that, one percent increase in cost of pesticides would result in reduction of leeks yield by 0.03 percent. The findings explain that the overuse of pesticides by the farmers to cut down the risk of crop losses due to pests and diseases would result in lower yield in leeks production.

5.1.4 Efficiency estimates of cabbage farmers

Table 5.5 represents the maximum likelihood estimates for the stochastic production function for cabbage cultivation in upcountry. The results indicate that none of the input variable has any significant relationship with cabbage yield.

Table 5.5: Model Estimates for Cabbage

Parameters	Coefficient	SE	t-ratio
Intercept (β_0)	11.360	1.385	8.204*
Dolomite (β_1)	0.039	0.027	1.454
Seeds (β_2)	0.049	0.082	0.593
Organic fertilizer (β_3)	0.005	0.015	0.326
Chemical fertilizer (β_4)	-0.019	0.033	-0.586
Micronutrients (β_5)	-0.004	0.018	-0.215
Plant Hormones (β_6)	0.022	0.017	1.312
Machinery (β_7)	-0.008	0.019	-0.408
Pesticides (β_8)	0.014	0.051	0.268
Labour (β_9)	-0.197	0.130	-1.512

* Significant at 1%, ** Significant at 5%, *** Significant at 10% level

5.2 Reasons for the Inefficiency in Vegetable Cultivation

The results of the maximum likelihood estimation of the inefficiency models of four crops in up country vegetable farming are summarized in table 5.6.

Significant relationship and positive sign of age variable in beans and cabbages indicate that young farmers are more efficient than the older, which implies that younger farmers are more efficient in input usage. The education of the farmers is significant only in inefficiency model of potato and in all the other three vegetables it remains insignificant but the direction of the coefficients is in accordance with the past literature on the behavior of this variable (Udayangani *et al*, 2006). Negative and significant relationship of education with inefficiency in potato cultivation explains that farmers with higher education qualifications are more efficient than farmers with lower education level. Similarly, the positive role of extension service measured by variable training emerged as a significant factor behind the inefficiency of the farmers in all crops except in beans. Farmers who have an access to proper training or extension services are more efficient because they have updated knowledge on better agricultural practices as well as on input usage.

Table 5.6: Inefficiency Estimates for Vegetable Cultivation

Variable	Potato	Bean	Leeks	Cabbage
Age	-0.013 (-0.566)	0.183 (1.921***)	0.024 (2.457**)	0.002 (0.060)
Education	-0.224 (-2.600**)	-0.076 (-0.921)	-0.016 (-0.612)	-0.141 (-1.164)
Extent of cultivation	0.489 (0.514)	-1.040 (-1.165)	0.436 (3.073*)	3.402 (2.282**)
Primary employment	0.138 (0.152)	3.413 (1.517)	0.225 (0.259)	0.860 (0.739)
Training	-1.568 (-2.131**)	-0.348 (-0.604)	-0.889 (-2.247**)	-8.019 (-2.398**)
District	-0.658 (-0.816)	- 0.425 (-0.452)	- 0.511 (-0.961)	- 4.043 (2.030**)

* Significant at 1%, ** Significant at 5%, *** Significant at 10%

Extent under cultivation has positive and significant relationship with inefficiency of leeks and cabbages. The findings indicate that, with the decrease of area under cultivation inefficiency has reduced. As vegetables are cultivated continuously throughout the year with high labour inputs in small land holdings of sloping hilly areas, the increasing of the land extent causes managerial problems and contributes to inefficiencies.

District variables have negative signs in inefficiency models for all crops and it implies that the Badulla district farmers are more efficient than the Nuwara Eliya district farmers, but the relationship is only significant in cabbage. Because of high relative humidity and low temperature in the Nuwara Eliya district, pest and disease incidence are high compared to the Badulla district, therefore Nuwara Eliya farmers use more inputs like pesticides, micronutrients and plant growth hormones than Badulla district farmers. When comparing technical efficiency levels in the two districts, the Badulla district farmers are able to get higher yields from the same level of input than the farmers who cultivate same crop in the Nuwara Eliya district due to the advantage of favored environmental conditions.

CHAPTER SIX

Conclusions and Recommendations

6.1 Major findings

6.1.1 Socio-Economic Characteristics of Upcountry Vegetable farming

1. About 64 percent of the farmers in the Nuwara Eliya District cultivate three seasons per year while 10 percent of the farmers cultivate four seasons per year. However, 65 percent of farmers in the Badulla district cultivate only two seasons per year and the number of farmers cultivating three crops per year is limited to 30 percent.
2. Vegetable cultivating farmer landholdings in the Nuwara Eliya district are equal or less than 0.25ac for 40 percent, but that is limited to 24 percent of farmers in the Badulla district indicating comparatively bigger land holdings for vegetable cultivation in Badulla than in Nuwara eliya.

6.1.2 Profile of the Pesticides Used

1. Almost all the commercial vegetable farmers use pesticides as the main method of managing pest and diseases since they are easily available, simple and easier to apply, less labour intensive and "highly" effective.
2. Upcountry vegetable farmers in the study area use a total of 73 commercially branded pesticides belonging to 39 different active ingredients. Although class (ia) and (ib) pesticides should not be used and class (ii) is for restricted use, about 05 and 34 percent of the active ingredients used in vegetable farming belong to class (Ib) and class (ii) respectively.
3. About 47 percent of the farmers prefer to use Organophosphate (OP) group of insecticides, such as; Chlorpyriphos, Profenophos and Phenthoate as farmers believe that they are highly effective in knocking off the pests and comparatively cheaper despite their toxicity and harmful nature on the environment.
4. Out of the total pesticides used by up country vegetable farmers, use of insecticides and fungicides was almost 47-48 percent, but in the Nuwara Eliya district use of fungicides was slightly higher (52% of the total pesticides) because of more conducive conditions for fungal attack. Potato farmers use the highest number of different pesticides (118) followed by Leeks farmers (105).
5. Green band pesticides are not popular among farmers as they were not available in the local market or available product was not providing immediate results as perceived by farmers.
6. IPM is not a popular method in vegetable farming which is practiced by only four percent of the farmers. The practicing farmers have realized the cost reduction and increase of yield while minimizing the environmental damage.

6.1.3 Pesticide Application and the Dosage

1. About 40 percent of the farmers always apply pesticides prior to the appearance of any symptoms of pest or disease as a precautionary safety measure. Another 38 percent apply pesticides prior to the appearance of symptoms of selected pests and diseases.
2. Most of the farmers do not follow the dosage instructions given on the pesticide label. The numbers of pesticide overdosing farmers are 38 and 41 percents in Badulla and Nuwara-Eliya respectively as they believe that recommendations and prescriptions given in the pesticide product labels are not appropriate.
3. About 48% of potato farmers and 40% of leeks farmers use more pesticides than recommended. The purpose of overdosing chemicals as perceived by 35 % of farmers is to obtain quick results while 28% use overdose with their past experience of controlling pests and diseases. Farmers have failed to understand that different chemical have varied actions and therefore take time to act. This is one of the reasons for their suspicion on the strength of the pesticide.
4. Nearly 53% of farmers mix two or more chemicals together to make a cocktail mixture as they believe such mixtures save their labour time and are more effective in controlling pests and diseases.

6.1.4 Source of Information, Training and Awareness on Pesticide

1. Formal source of extension as the first priority of information in selecting pesticides is limited to 35% of the total farmers, while the rest mostly depend on pesticide dealers, own experience and information provided and experiences presented by the fellow farmers.
2. Only 31 and 20 percent of the vegetable farmers in the Badulla and Nuwara Eliya districts respectively have the knowhow on the colour band denoted in the pesticide packs. However, attention paid to the colour band was limited to 55 and 33 percent of farmers in the Badulla and Nuwara Eliya districts respectively.
3. About 90 percent of farmers in the Badulla district and 81 percent farmers in the Nuwara Eliya district read the instructions given on the label of the packing before using chemicals. Though majority of the farmers pay attention to the expiry date of the product and method of using the pesticide, nearly half the farmers are not concerned about the colour band (toxicity level) of the pesticide.
4. Over 75% of farmers have an understanding of the environmental pollution and harmful effects on beneficial organisms in overdosing of chemicals, but 25% are not aware of groundwater contamination.

5. About 23 percent of farmers are aware of Integrated Pest Management (IPM), but only four percent have applied the knowhow in up country vegetable cultivation.
6. Only 27% of the farmers have had some sort of training on pesticides. Out of the total trained participants, majority of the trainees (63%) have attended training programmes conducted by private chemical companies as these programmes were implemented at filed level and were easy to access by farmers.

6.1.5 Safety and Precautionary Measures

1. About 63% of upcountry vegetable farmers wear protective garments during the pesticide spraying, but use of boots and gloves are limited to 11 and 37 % of the farmers respectively. Tropical warmer climate discourages farmers to use protective clothes. Non use of boots has risk of exposure to pesticides, especially in fields with stagnant water.
2. Farmers are conscious about the direction of wind during pesticide application, but 23 % of them do not bother about wind direction. The majority of farmers apply pesticides during the morning hours, but some prefer to apply insecticide in the evening as they believe insects are active in the evening.
3. The number of farmers involved in eating and drinking during pesticide spraying is limited to 3-6%. However, smoking and chewing betel is done by 11% and 15% of farmers respectively. About 47% of farmers bathe or do a body wash immediately after spraying while another 49% bathe at the end of days' work.
4. About 90% of the farmers store pesticide bottles in a safe location, not reachable by children, but only 40% of farmers safely bury the empty glass bottles. Empty plastic containers and packing materials are burnt by 46% of the farmers, while 18% of the farmers safely burry the packs.
5. In case of availability of excess amount pesticides solution after spray, the majority of the farmers do environmentally hazardous activities with surplus solution, such as repeatedly application of the chemical to the same crop (71%) and store the solution for future use (11%).
6. Although the majority of farmers have the good habit of washing the sprayers after application, 60% of them have used common public resources such as irrigation channels and reservoirs for washing.
7. Unexpected increase of vegetable prices is one of the factors motivating farmers to harvest vegetables without considering the minimum time interval required between pesticide applications and harvesting. According to the findings, nearly 30 percent of farmers do not adhere to the 2-3 weeks pesticide free period that should be allowed before harvesting the final product.

8. Pesticide related injury cases were reported among 26% of the farmers which are mainly skin injuries indicating inadequate safety measures practiced in spraying.

6.1.6 Technical Efficiency of Vegetable Cultivation

1. The variations in production efficiency among up country vegetable farmers were mainly due to differences in farm practices of the farmers rather than random factors that are not within control of farmers.
2. Experience gained by older farmers has helped to reduce the inefficiency in beans and cabbage cultivation, while level of education has a significant and negative relationship in causing inefficiency in potato farming. The decrease of area under cultivation has reduced inefficiency in cabbage and leeks.

6.2 Recommendations

- Instead of using different trade names for the same chemical, it is recommended to give common names (Generic names) for the pesticides based on the active ingredient to reduce the misuse of pesticides. Considering the competiveness in the pesticide market, companies market different generic products with their company names in order to establish their own identity.
- As considerable proportion of farmers had the perception of non existence of specified strength in the pesticide label, it is recommended to carryout regular quality tests for the products available in the market by a recognized organization.
- The commercial advertisements carried out by the companies for sale and the use of pesticides must be regularized by establishing procedures and standards. It is highly recommended to undertake field level demonstrations of particular products by relevant companies instead of commercial advertisements.
- Considering the development of new pesticide technologies and the safer products, it is recommended to permit smaller than 50 ml size packs which will take into account the requirement of given pesticide per unit area and small land holdings
- Disposal of empty pesticide containers/packing materials without polluting the environment is one of the problems faced by farmers. Therefore it is essential to introduce a collection system for empty containers at farm level and /or the introduction of a suitable system for disposal. Providing an incentive for farmers to return the empty bottle/containers to dealers is recommended for pilot testing.
- It is recommended to mention the “re-entry period” of particular product (the time period to lapse after spraying of pesticides to enter the field without protective cloths) in the pesticide label.

- In intensive pesticide use areas, pest clinics should be set up periodically to identify old and new emerging pests, to provide advice to farmers on appropriate pesticides and to guide available alternative control methods.
- Most of the issues at the user's level are associated with lack of awareness, negative attitudes and behaviours of farmers and weaknesses in the extension system. Thus, there is a need for strong awareness campaign through all possible means including print and electronic media to educate farmers and change their attitudes and to empower the farmer organizations on the highlighted issues at the farmers' level.
- Grass root level extension system should be strengthened by capacity building and by regular updating the knowledge levels of Agricultural Instructors/Enforcement Officers, Agricultural Officers/Authorized Officers. There should be a routine monitoring and follow up mechanisms at the field level on the work undertaken by the Enforcement Officers and Authorized Officers.
- Green band pesticides should be promoted by reducing the prices through tariff reduction and through farmer level awareness programmes. It is also important to improve extension services to promote the green band pesticides and IPM.
- Agrochemical dealers, as potential sources of information on pesticide use, must be kept up-to-date with information about the nature and consequences of pesticides they handle. They must be directed along the lines of a pharmacist so that they can dispense pesticides that meet the symptom described by the farmer. The impact of training agrochemical dealers on productivity and safety should also be evaluated.
- Agricultural Instructors and Extension Officers who work closely with farmers should be trained in current technologies regarding safe and careful use of pesticides. Their training should cover appropriate pesticides for certain crops and pests, correct dosages and application timing and appropriate application technologies. A good extension network should be developed to disseminate that information to the farmers at field level.
- The mass media should be entrusted to explain safety practices in pesticide use. General information about protective clothing, safe storage and disposal of pesticides, and appropriate application technologies should be promoted through print and electronic media.
- The capacity of ROP in terms of human resources and physical resources should be increased to undertake efficient and effective monitoring programme work with respect to contamination/adulteration of pesticides and also to cooperate with the private sector. It is highly recommended to provide accredited laboratory facilities for ROP with the financial supports of the private sector.

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