AGRICULTURAL HAZARDOUS WASTE: UNDERSTANDING THE HAZARDOUS WASTE CYCLE IN THE MAIZE PRODUCTION CHAIN AND TESTING A METHODOLOGY TO COLLECT WASTE INFORMATION FOR THE DEVELOPMENT OF A WASTE REGISTER

by

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Mini-dissertation (MOB791) submitted in the partial fulfilment of the requirements for the degree

MASTERS IN ENVIRONMENTAL MANAGEMENT

In the Faculty of Natural and Agricultural Sciences

Centre for Environmental Management

University of the Free State

Bloemfontein

January 2014

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Abstract

The management of agricultural chemicals and waste is imperative in order to ensure proper resource protection and good environmental management. Various studies done in South Africa have illustrated the impact of agricultural waste and chemical mismanagement on the environment and on water resources in particular. Nationally, South Africa aims to manage waste streams by means of a hazardous waste register and locally the provincial departments of Environmental Affairs and Tourism in South Africa should develop such waste registers.

This masters project is based on a proposal to develop a hazardous waste source inventory for the Free State province through the Department of Economic Development, Tourism and Environmental Affairs (DETEA) of the Free State Province. The development of a hazardous waste source inventory is important to effectively manage various kinds of hazardous waste sources. Hazardous waste spans various industries (medical waste, industrial waste, agricultural waste) and it can be a huge task to develop a waste register for each province in South Africa. With reference to agricultural waste, the impact of agricultural hazardous waste on water resources is becoming an increasing concern and challenges in the agricultural waste management industry in South Africa are on the rise. The aim of this study was to understand the waste cycle and test a methodology for collecting waste information for the development of a waste database, with a specific focus on agricultural waste in the maize sector. Additional aims included determining whether the agricultural maize sector uses and disposes of its agro-chemicals and other production cycle wastes effectively and to propose alternative management options for more effective management of these chemicals.

In order to delimit the study, this study focused specifically on agricultural waste associated with the maize production cycle. The methodology followed in this study was also used in similar studies in other countries (Sweden, France, UK, USA) and involved the development of questionnaires and semi-structured interviews for farmers and chemical distribution agents. Qualitative data obtained from the questionnaires was analysed thematically and quantitative data was analysed using Excel and IBM Statistical Package for Social Sciences (SPSS) version 10.

The objective of the study was achieved by developing questionnaires that address questions related to chemical usage and waste in the maize sector. These questionnaires were administered to farmers and chemical distributors in the selected sampling areas. Questionnaire development took place through interviews with parties such as FS Agriculture, Grain SA and pre-testing was done on maize farmers and other relevant people. Results from the questionnaires were used together with data from chemical distributors, databases and literature to develop a baseline indication of chemical usage and waste in the agricultural maize sector.

The study showed that determining average volumes of agro-chemicals used in different phases of the maize production sector can be quite complex. This complexity is due to various factors – pesticides may have different names but the same active ingredients, a single pesticide can be used for different pests (by using different concentrations and application methods), in some cases there is uncertainty amongst farmers on how to effectively apply these pesticides, whether the agro-chemical is in a granular or liquid form, and factors like soil type, climate conditions and varying types and amounts of pests and weeds which influences agro-chemical usage in different areas. All these factors make it very difficult to calculate average pesticide volumes used per production cycle just for the maize industry. If one takes into account that agriculture spans a much wider production industry than just maize (e.g. vegetables, cotton etc) the complexity increases even more. This study illustrates the fact that another more effective approach may be required to gather accurate data to populate waste databases for each province. Alternative approaches can include web surveys or voluntary registration by farmers and reporting of chemical type and volumes used either by post or on a web based system.

This research addressed key questions related to hazardous waste management in the agricultural maize sector in South Africa and tested a methodology for gathering information to populate hazardous waste registers. The development of hazardous waste registers is a very important waste management tool which the DETEA aims to employ to ensure proper resource protection and waste management, and this study may make valuable contributions towards the development of such waste registers.

Keywords: agriculture, maize sector, hazardous waste, waste management, waste register, resource protection, pesticides, insecticides, herbicides, fertilizers, agro-chemicals

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List of Acronyms

AVCASA	Association of Veterinary and Crop Associations of South Africa
bt	Bacillus thuringiensis
DAFF	Department of Agriculture, Forestry and Fisheries
DBSA	Development Bank of South Africa
DEA	The Department of Environmental Affairs
DEAT	The Department of Environmental Affairs and Tourism
DETEA	The Department of Economic development, Tourism and Environmental
DWAF	Department of Water Affairs and Forestry
FAO	Food and Agricultural Organisation of the United Nations
GM	Genetically Modified
IPM	Integrated Pest Management
K_2O	Potassium oxide
N	Nitrogen
NEM: WA	National Environmental Management Waste Act
P_2O_5	Phosphorus pentoxide
PCO	Pest Control Operator
PCOR	Pest Control Operator Regulations
RR	Round Up Ready
SAWIS	South African Waste Information System
SPSS	Statistical Package for Social Sciences

UK	United Kingdom
USA	United States of America

Glossary of terms

Pesticides	Insecticides and herbicides
Agro-chemicals	Insecticides and herbicides and fertilizers

Declaration

I, Arjen Nell, 2005095621, declare that this mini-thesis is my own work, that it has not been submitted for any other degree at University of the Free State or any other University or any higher education institution, and that all resources that I have used or quoted are indicated in the text and acknowledged in the list of references.

Arjen Nell

Chapter 1 Introduction

This chapter describes the background and rationale for the study, as well as the study scope and limitations, the objectives, aims and the research question.

1.1 Background and rationale

In terms of the National Environmental Management Waste Act (NEM: WA) (Act No. 59 of 2008), hazardous waste is defined as any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment.

With ever more limited resources available in the world, proper environmental management and the associated management of waste is becoming more important. Challenges in the waste management industry in South Africa are also becoming clearer (Usher *et al,* 2004). Agriculture is the single largest non-point source of water pollutants in South Africa (Conrad *et al;* 1999, Scotcher, 2009), and the impact of agricultural hazardous waste on groundwater and surface water resources is becoming an increasing concern (van der Laan *et al,* 2012;Jovanovic *et al,* 2012; Görgens *et al,* 2012, Usher *et al,* 2004). The inefficient and increased use and disposal of insecticides, herbicides and fertilizers, as well as lubricants, fuels and oils in the agricultural sector also leads to various other impacts and can include air pollution, declining soil health, ecosystem degradation, loss of biodiversity, species change and climate change. Some of these chemicals can also build up in food chains far from their original source (Scotcher, 2009; DAFF, 2010; WWF, 2009; Conrad *et al,* 1999).

In South Africa, various pieces of legislation address waste management in the agricultural sector, with the aim of reducing wastage of chemicals and protecting the environment during pesticide application. In 2010 the Pesticide Management Policy recognised the fact that South Africa lacks the establishment of a pesticide usage database and monitoring system which gathers information on common conditions of use and the impact thereof on the environment and on human health (DAFF, 2010). Additionally, the National Waste Management Strategy (DEA, 2011) which was released in 2011 stressed that there are too few compliant hazardous waste management facilities in the country and this negatively affects the safe disposal of hazardous waste streams.

To address the above concerns, the South African Waste Information System (SAWIS) which forms part of the South African National Waste Management Strategy (DEA, 2011) was established in 2005. The aim of SAWIS is to collect reliable national waste data to support the needs of local, provincial and national government, and to provide information that is accessible to interested and affected parties, which will support effective integrated pollution and waste management (DEAT, 2005c). DEAT (2005c) stipulates all the reasons why the development of a waste source inventory is important and with that also highlights why the development of a hazardous waste source inventory is important. The importance of such an inventory or the establishment of a pesticide usage database will be discussed in more detail in section 2.4.1.

In 2012 the National Waste Information Regulations which was to take effect on the 1st of January 2013 were published. The purpose of these regulations is the implementation of a reporting system to the SAWIS for general and hazardous waste. With regards to hazardous waste, these regulations require the parties who;

- generate in excess of 20kg of hazardous waste per day
- recycle in excess of 500kg of hazardous waste per day
- treat of any quantity of health care risk waste
- dispose of any quantity of hazardous waste to land
- export hazardous waste out of South Africa

to report to SAWIS. These regulations do however not include the reporting of agro-chemical waste by farmers (DEA, 2012).

As stated above, SAWIS requires that the provincial departments of Environmental Affairs develop waste inventories. This masters project developed out of a proposal to develop a hazardous waste source inventory for the Free State province through the Department of Economic Development, Tourism and Environmental Affairs of the Free State Province (DETEA). The first line of action for DETEA in developing this inventory, is the identification, characterisation and quantification of hazardous waste types as well as their sources. This will enable the DETEA to have a clear record of the types and amounts of hazardous waste produced in the province. Such a register will serve as a preliminary step for sound hazardous waste management in the Free State province, and such a record is important to ensure the health of people and the environment (DETEA, n.d).

Another important aspect that this study focuses on is the minimization of the impact of agro-chemicals on the environment by introducing better management and monitoring of chemicals used in the agricultural sector. Management and monitoring can be improved by determining exact amounts of chemicals used and understanding the waste cycle of chemicals in the environment (DEAT, 2005a; DEA, 2011).

1.2 Aim of the study

The main objective of the study is to understand the waste cycle associated with the maize production cycle. It includes questions such as the volumes and types of waste generated in the maize sector and whether the agricultural sector (with specific focus on the maize sector) uses and disposes of its agro-chemicals and other production cycle wastes effectively.

Secondary objectives include:

- Testing a methodology for hazardous waste information gathering, to determine whether this methodology will be effective in gathering waste management data for the development of provincial waste inventories in South Africa
- Making recommendations towards the effective management of agro-chemicals, agro-chemical waste and other production cycle wastes

These objectives can be met by gathering information on quantities of agro-chemicals (insecticides, herbicides, and fertilizers) that are supplied to maize farmers per hectare per growth season and triangulating these to the quantities of chemicals actually applied to the crops per hectare per growth season. Links will also be made between the recommended application rates per hectare as recommended by the chemical distributor. This is to be determined by means of interviews, taking into consideration rainfall, soil type and expected yield and by determining the amounts actually applied by the farmer per ha (to be determined by questionnaire).

Figure 1 is a schematic diagram explaining the comparisons to be performed in order to triangulate data. The aim is to determine how much of the supplied agro-chemical products are actually used, which will give a more accurate indication of whether the farmer uses more or less than the recommended amounts. The questionnaire will take into consideration the quantities wasted through spilling and aging, and the quantities that are disposed of. The methods of disposal and the treatment of these wastes will also be determined.

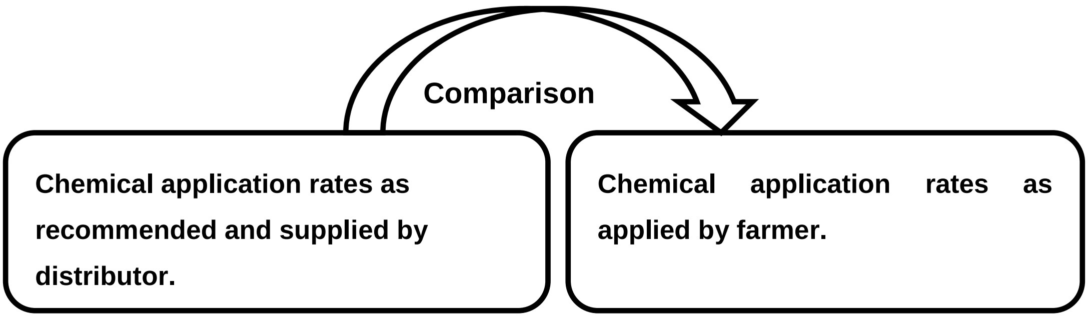

Figure 1: Triangulation of data

1.3 Scope and limitations of study

Although this study aims to test a methodology for estimating volumes of waste for these waste inventories, the study was focused in its scope. The study focused specifically on the maize production sector and aimed to analyse agro-chemical, fuel and lubricant usage and associated waste generation in this sector. The study area was also confined to a particular maize production area within South Africa, being the western maize production region.

A detailed questionnaire on chemical and waste management practices was administered to 13 farmers in the specified district. The farmers' chemical distributors were also interviewed to triangulate data on chemical usage obtained from the farmers. Based on the detailed assessment of farmers in one specific climatic area of the maize production zone, it was assumed that the results of this study will be specifically representative of maize production in this climatic area (this assumption was confirmed by one of the key interview respondents during development of the farmer questionnaire). Areas in other climatic zones may have different results.

1.4 Research question

The main aim of the study is to understand the agricultural hazardous waste cycle in the maize production sector and to test an information gathering method to see if it is effective and accurate for gathering information on chemicals and waste management in the agricultural sector. Based on this aim, the main research question can be framed as follows:

Research question: **What does the agricultural hazardous waste cycle in the maize sector look like?**

In order to answer this question a basic flow diagram was developed to understand the maize production sector and to identify chemical usage and waste generation that may be associated with each phase of the maize production cycle. Figure 2 below illustrates a basic maize production cycle.

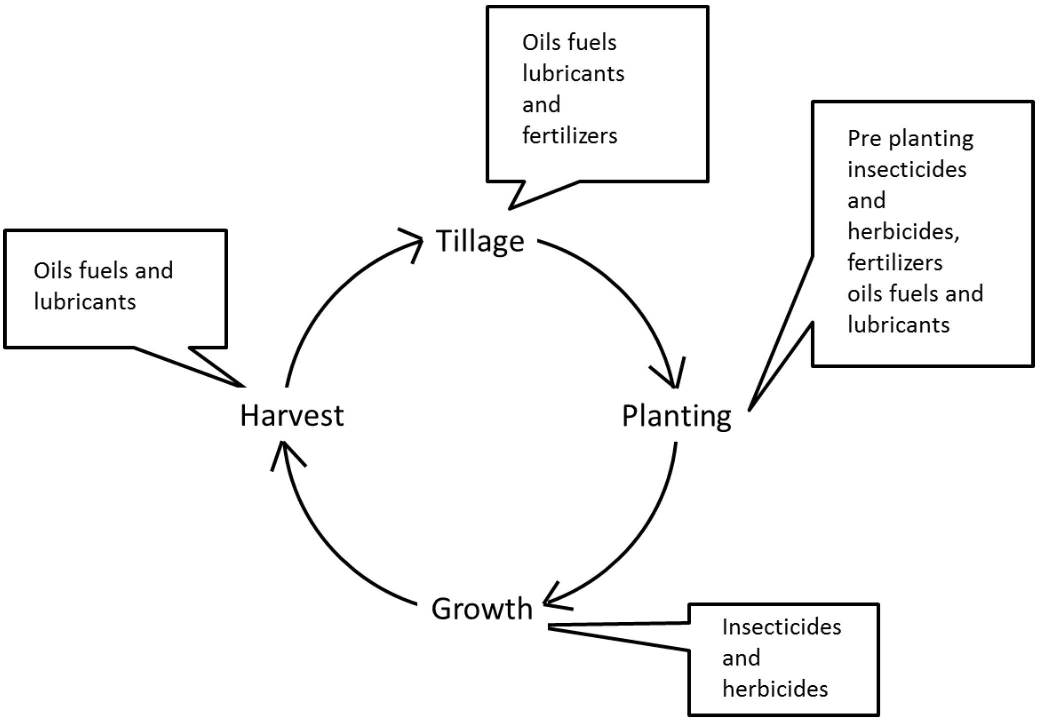

Figure 2: Basic maize production cycle with the attendant agro-chemical application stages and potential waste/pollution points.

Sub-questions that are associated with the main question include:

- What types and volumes of hazardous agro-chemicals are used and disposed of in the maize sector?
- Does the maize sector use and dispose of agro-chemicals effectively?
- How can agro-chemical waste be better managed?

These sub-questions have been addressed in the farmers' questionnaire and in the interview to chemical distributors by including questions such as:

- What is the recommended chemical use for each farm as recommended by the chemical distributor?
- What is the chemical application rate to the farmland by the farmers?
- What volumes of waste (including agro-chemical packaging, containers, oils and lubricants) or surplus are generated by the agricultural sector? (To be determined through an analysis of the questionnaires and interviews).
- How are these wastes or surplus agro-chemicals disposed of?

The interviews and questionnaires that were administered during this study, gathered information on the main question and sub-questions with the aim of testing a possible methodology that can be followed to gather waste information during the development of waste inventories for the provinces. A review of the results of these questionnaires would indicate if the methodology of using questionnaires to gather this type of data is efficient.

Chapter 2 Literature review

All relevant information gathered during the literature review was used to provide sufficient insight into the issues surrounding agro-chemical management, to assist with the development of the study methodology and to create a baseline for the assessment of the actual data gathered during the study.

Literature that provided background information for the study will first be discussed and it will be explained how this literature aided in the identification of themes to be included in the farmer questionnaire. This will be followed by literature that supports the questions in the farmer questionnaire and which also aided in the development of the farmer questionnaire. The literature will be discussed in the order of the themes as it appears in the farmer questionnaire as follows:

- Geographical information (section 2.2.1)
- Technical information (section 2.2.2)
- Waste cycle information (section 2.2.3)
- Storage disposal wastage and cleaning (section 2.2.4)
- Weather conditions (section 2.2.5)
- Characteristics of chemicals (section 2.2.6)
- Servicing (section 2.2.7)
- Legal compliance (section 2.2.8)

The chemical distributor interview was developed using information gathered during the literature review as well as informal discussions with agriculture specialists. Information used to aid in the development of the interview is discussed together with the sections on the literature that was used for the farmer questionnaire.

Finally, literature regarding the impact of agro-chemicals on water resources and agro-chemical management will be discussed.

2.1 Background information

Literature was consulted for a better understanding of the maize plant, for maize farming in general, and agro-chemicals usage in maize farming. Literature was also used extensively to understand the maize production cycle and pathways that chemicals could follow during the maize production cycle, which was used to identify themes that had to be included in the farmer questionnaire.

Figure 3 below shows the different pathways that chemicals can follow during the maize production cycle. It was developed by the author after consulting DAFF (2011), Grain SA (2010), SANS (2010), SAQA (2006) and Govender & Sheard (2012). This diagram served to assist the author to identify different themes that had to be included in the farmer questionnaire.

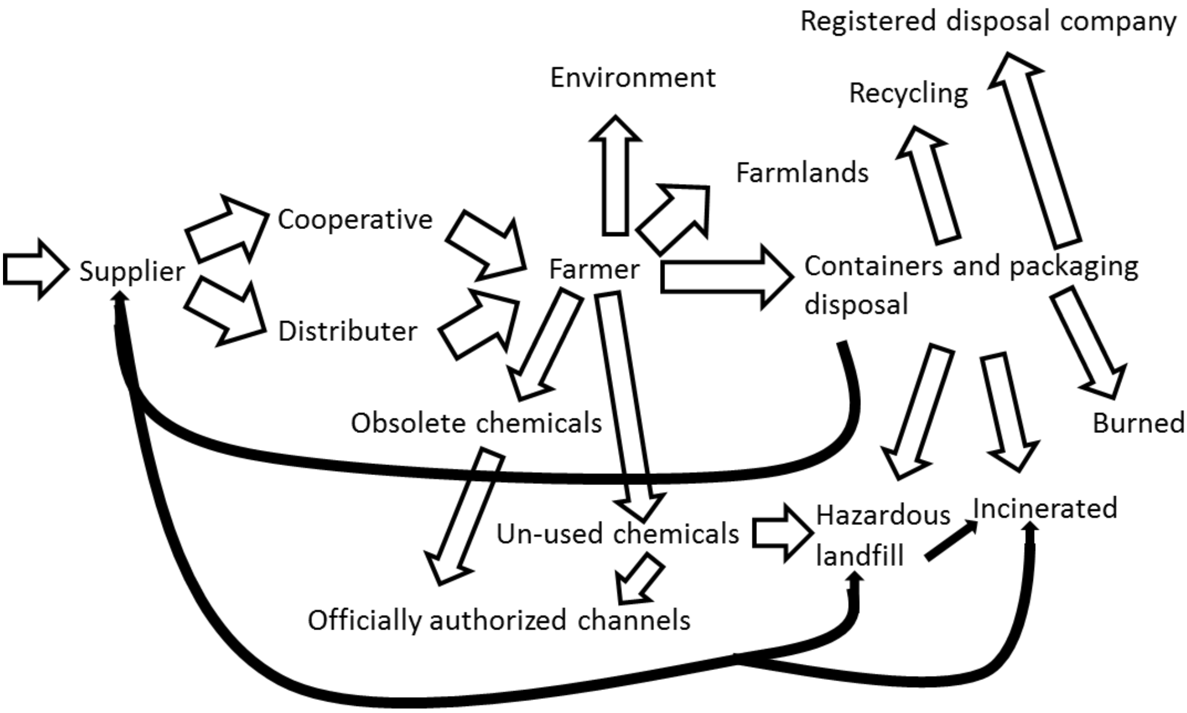

Figure 3: Different routes that agricultural chemicals can follow from manufacturing to disposal or re-use

The distribution of chemicals that can be seen in Figure 3 shows that chemicals travel from the supplier to the cooperative or distributor and from there to the farmer. The farmer applies the chemicals and the chemicals then enter the environment via land-based application, or excess are disposed of. Figure 3 illustrates why interviews had to be held with both chemical distributors and farmers, in order to serve as confirmation of the pathways of chemicals as well as amounts applied.

The pathways of chemicals were extensively analysed in the theme on chemicals management (storage, disposal, wastage and cleaning) and the waste cycle information theme in the farmer questionnaire.

2.2 Literature supporting the development of the farmer questionnaires

This section describes literature that was used during the development of the different themes of the farmer questionnaires and focuses on:

- geographical information
- technical information
- waste cycle information
- storage and disposal information
- weather conditions
- characteristics of the chemicals
- servicing of farm implements and vehicles
- and legal compliance

2.2.1 <u>Geographical information</u>

Figure 4 below is an indication of the different maize production regions in South Africa which was used to roughly indicate where the respondents used in the study are located. The maize production regions that are indicated in this map, were obtained from ARCGCI (2011).

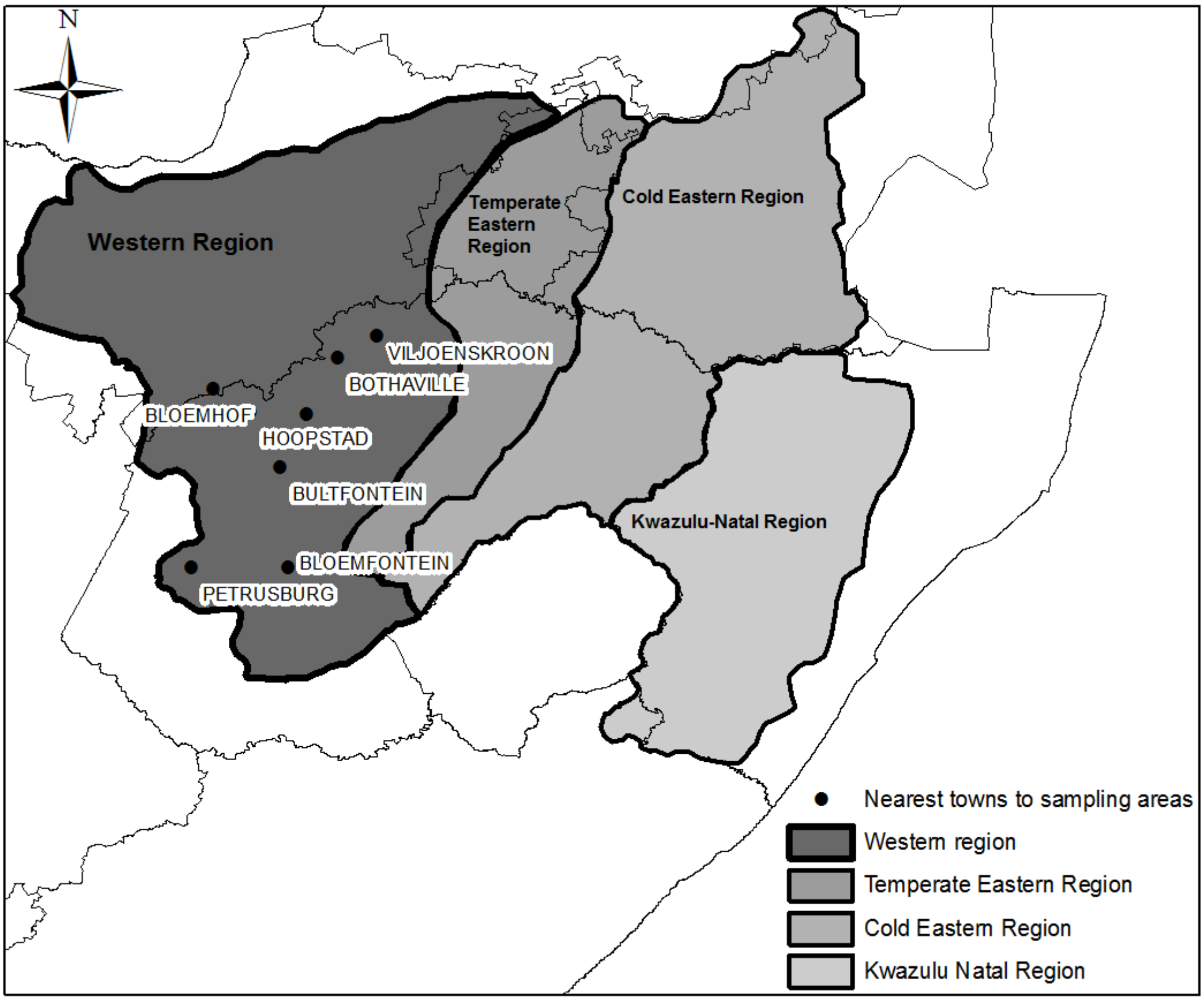

Figure 4: Maize production regions in South Africa

Figure 5 below shows the annual mean precipitation for the Western Maize Production Region. The Western Maize Production Region falls within an area where rainfall ranges from about 350mm to 750mm and increases from the west to the east. The farms used in the study are distributed across the width of the Western Maize Production Region and therefore falls within different rainfall regions with in the region. The distribution of the farms in the western region helped to ensure that a combination of both dry land and irrigated farms were selected for the study.

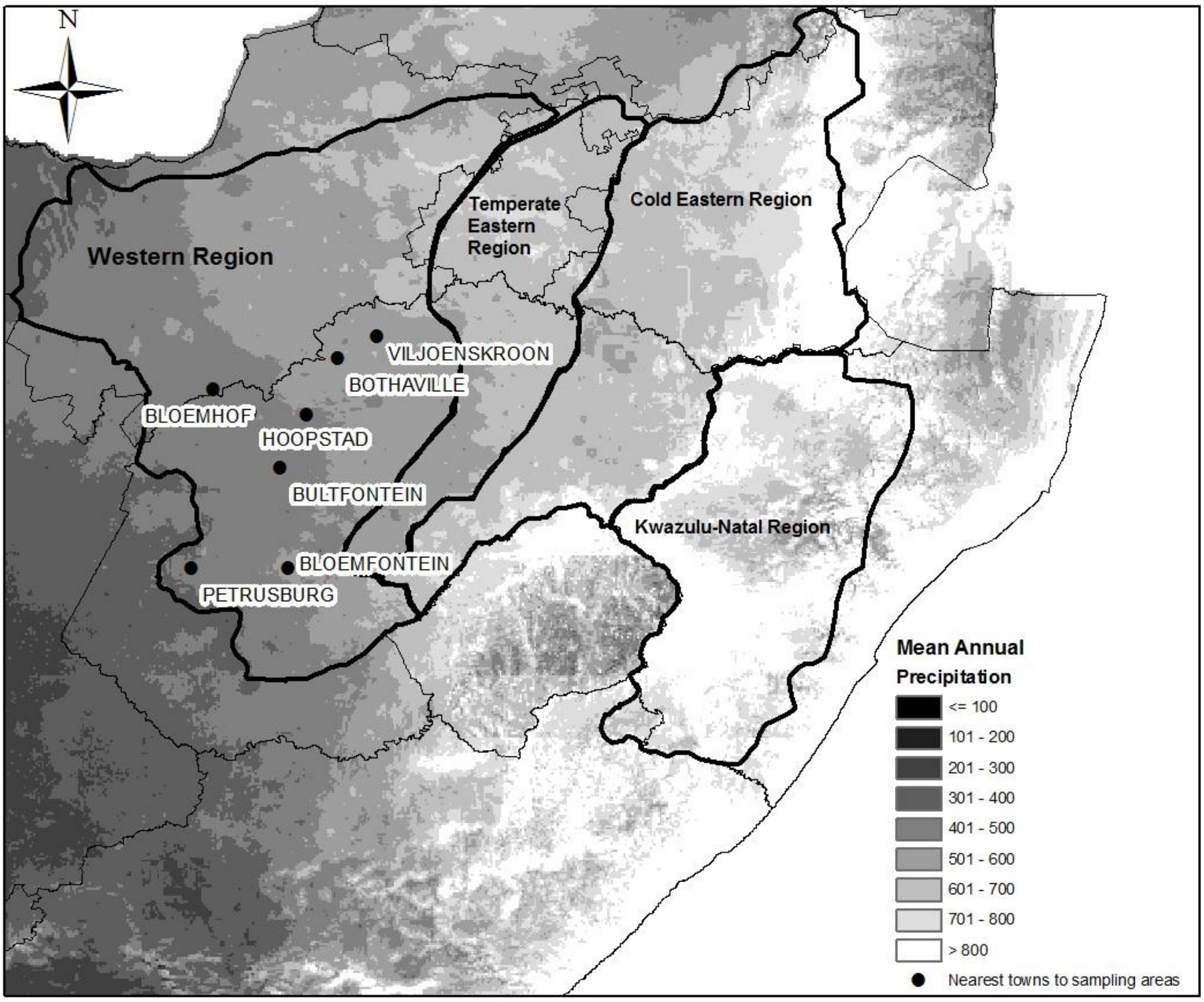

Figure 5: Mean annual precipitation for the Western Maize Production Region (Schulze, 1997)

The average yield in tons/ha of dry land and irrigated maize as well as the ratio of dry land to irrigated maize can be found in Grain SA (2013) and was used to compare reported yields for irrigated and dry land maize by respondents who completed the farmer questionnaire.

Different kinds of maize that can be cultivated were found in Monsanto, (n.d.) and in discussions with Ceronio (Personal Communication, 2013).

2.2.2 Technical (operational information)

A list of plant nutrition and pest control equipment that is used in agriculture was found in DAFF (2013a). This included fertilizer spreaders, manure spreaders, lime spreaders, mist blowers, and boom sprayers. This information was used together with an interview with Anton Botha (Grain SA) (Personal communication, 2013), hereafter Botha, to develop the operational information theme of the farmer questionnaire.

2.2.3 Waste cycle information

A literature review was performed on waste cycle information in order to inform the questions that relates to waste management on the farm that had to be asked in the farmer questionnaire.

The Pest Control Operator Regulations (PCOR) (DAFF, 2011) which forms part of the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act No. 37 of 1947) (RSA, 1947) was consulted during the development of the waste cycle information theme of the farmer questionnaire. Neither farmers nor chemical distributors are required to register as a Pest Control Operator (PCO) since they do not make money out of the application of chemicals on farms. As soon as a person is hired by a farmer and they are paid to apply chemicals he is by law required to be registered as a PCO. Famers in general however normally make use of a free service from a chemical distributor for services that include the supply and application of agro-chemicals, as well as recommendations on volumes to use and the calibration of equipment. Chemical distributors are in other words not legally obligated to register as a PCO but it would be advantageous if they did (Jordaan, 2013, E-mail correspondence). The PCOR explains how agro-chemicals should be used, applied, stored and disposed of. This is important for proper management thereof, and therefore the most important regulations from the PCOR relevant to this study were included in the literature review (DAFF, 2011). It must be noted that these regulations are not specifically aimed at chemical distributors, but that they are very relevant to chemical distributors. According to Rafferty (Personal Communication, 2013) who is a chemical distributor from Cipla Agricare, the PCOR are aimed at both PCOs and chemical distributors.

Table 1 lists information related to the waste cycle of agro-chemicals that is considered important in backing the questions in this theme of the farmer questionnaire and that have been considered during the development of the questionnaire.

Table 1: Information related to the waste cycle of agro-chemicals

Theme	Information related to the waste cycle of agro-chemicals
Waste cycle information	• A PCO must have knowledge of various formulations of agro-chemicals and the safe use thereof. He must know when it is unnecessarily used or misused in specified regulation specifications and agro-chemical labelling. [1] • A supervisor who has adequate experience and knowledge of the application of pesticides must be appointed. [3] • A PCO must have knowledge of weed, disease and general insect characteristics used for identification. [1] • The trade name of the pesticide used, its active ingredient, the pest/disease/weed that it targets, and the total amount (or concentration in g/l) applied in weight and volume must be recorded. (Major must). [1,2,3] • A PCO or the business that instructs him should keep record of the method and rate of application of agro-chemicals. [1] • Record of all fertilizer applications must be kept, including trade name and type of fertilizer. The amount of fertilizer applied in weight and volume must also be recorded (Recommended). [2] • A PCO must understand the correct use and application rates as is indicated on the label of the agro-chemical packaging. [1] • A PCO must be familiar with Integrated Pest Management (IPM) and its techniques. [1]
References	1: DAFF, 2011 2: Grain SA, 2010 3: SANS, 2010

*"Recommended" or "Major must" indicates the importance level of the specific regulation as described by The Food Safety Requirements for the Grain Industry (Grain SA 2010).

In the process of determining the amount of chemicals used on farms it is essential to obtain data to form a baseline as recommended by chemical companies and chemical distributors. The waste cycle data that was gathered in the questionnaires administered to the farmers should be triangulated with existing data that gives an idea of quantities of agro-chemicals that can be expected to be used in maize agriculture. For insecticides and herbicides this data was checked with total insecticide and herbicide use data for the districts to which agro-chemical distributors supply. For fertilizers, data was gathered from fertilizer distributors as well as from cooperatives and fertilizer industries.

Various sources were used in the process of establishing whether there is any data available on total volumes of agro-chemicals used in the Free State and in the Western Maize Production Region. It was found that there is no single database that monitors agro-chemical use in South Africa on provincial or national level (Naidoo & Buckley, 2003; Dickinson, 2013, Personal Communication; Borstlap, 2013, Personal Communication; Van Zyl, 2013, Personal Communication; Armour, 2013, Personal Communication).

The Food and Agricultural Organisation of the United Nations (FAO) (2005) provides further baseline information for fertilizers and includes the percentages of maize fertilized and the quantities in kg/ha of Nitrogen (N), Phosphorus pentoxide (P_2O_5) and Potassium oxide (K_2O) that are used on maize. This information was valuable for confirmation of the calculated volumes of fertilizer used during maize production. This information can be seen in Table 2 below.

Table 2: Proportion of crops fertilized and rate of use (FSSA, 2004 cited in FAO, 2005)

Crop	**Proportion of crops fertilized**	**N**	**P_2O_5**	**K_2O**
Maize	**95**	**Rate, kg/ha of fertilized area**		
		55	30	6

Highveld Gerbils (*Gerbilliscus brantsii*) are a common problem on maize farms due to the destruction they cause to maize plants and this is a concern as the poison that is used to kill Highveld Gerbils is known to be very toxic (Botha, Personal Communication, 2013). This poison can potentially be very harmful to animals and birds and also to the environment. Questions related to poisons administered to manage Gerbils and the characteristics of these poisons have also been included in the farmer questionnaire (see question 21 and 72 in appendix C).

2.2.4 Storage, disposal and wastage of agro-chemicals, cleaning and disposal of agro-chemical packaging and containers and cleaning and storage of agro-chemical application equipment

Table 3 gives information related to storage, disposal and wastage of agro-chemicals, the cleaning and disposal of agro-chemical packaging and containers and the filling, calibration, cleaning and storage of agro-chemical application equipment. This information supports the questions that were asked in the theme on storage and disposal of waste (questions 38 to 68) in the farmer questionnaire and allows for the assessment of the state of agro-chemical management on farms.

Table 3: Information related to storage, disposal of wastage and cleaning

Theme	Information related to storage, disposal of wastage and cleaning
Storage disposal wastage and cleaning	**Storage facilities** • An application must be made to the local authority to get permission for the construction of a pesticide store on a farm. Permission must be obtained from all relevant departments (including, public health, local fire authority) after which a certificate of occupancy will be issued and which must be in accordance with the national building regulations. [3] • Agro-chemicals must be stored and disposed of in a way that minimizes hazards to human health and the environment. [1] • The agro-chemical store must be above the 50 year flood line but preferably above the 100 year flood line. [3] • The store room must be separate building, at least 10 meters away from any livestock buildings or dwellings or where flammable materials are stored. A minimum of 5 meters is recommended between the store and other buildings and if it is part of a complex, it must be totally sealed off. [3] • Agro-chemicals should be stored in a well-ventilated, secure, cool and dry building that does not allow access to animals or unauthorised persons. [4] • Storage for pesticides should also be fire-resistant (including load bearing roof components), lockable door (preferably steel), well lit, able to retain spillage (damp resisting smooth cement floor), and should be built from materials that are robust and structurally sound and non-combustible. Equipment should be available to deal with spillages (Recommended). [2,3,4] **Storage of agro-chemicals** • The storeroom must only be used for pesticides and if necessary, equipment used to apply these. [3] • Insecticides, herbicides, fungicides and growth regulators should be separated from each other in the store room to prevent accidental mixing of chemicals. Herbicides are recommended to be stored completely separately. [4] • Powders and granular products should be stored on upper shelves and liquids on lower shelves. This will minimize damage in the event of leakage of liquids. [3,4] • Group Ia and Ib (red band) pesticides should be stored in a separate locked and fenced of area (Recommended). (see 2.2.6 - characteristics of chemicals). [2,3,4] • Flammable liquids must be stored in a separate room or compartment of the storeroom. [3] • Inorganic fertilizers (powders, granules or liquids) must be separated from other agro-chemicals to prevent cross contamination (recommended) and must be stored in a manner for it to pose a minimum risk to the environment and to water resources. Liquid fertilizer stores must be bunded (or capacity to 110% of the biggest container if there is no applicable legislation). (Major must). [2] • Metal and plastic drums of 20 litres and more should not be stacked more than 2 tiers high. [4] • As cement floors tend to sweat pesticides in paper bags, fibreboard drums and fibreboard boxes should be placed on pallets and away from walls to prevent moisture from building up. [3, 4] • All containers and bags must be adequately marked and labels should be clearly visible. If the labels are destroyed the packaging or container should be remarked with a marking pen that clearly states the contents of the container. [3,4]
References	1: DAFF, 2011 2: Grain SA, 2010 3: SANS, 2010 4: SAQA, 2006

*"Recommended" or "Major must" in indicates the importance level of the specific regulation as described by The Food Safety Requirements for the Grain Industry (Grain SA 2010).

Table 3 continued

Theme	Information related to storage, disposal of wastage and cleaning
Storage disposal wastage and cleaning	**Storeroom management** • Records must be kept of the quantities of agro-chemicals purchased, issued and returned. The exact type and quantity of agro-chemicals on hand must be available at all times. [4] • Agro-chemicals should be used on a first in first out basis to prevent chemicals from becoming obsolete. [3,4] • Agro-chemicals that have only been partly used must be resealed and returned to the store. [4] • Only the quantity of agro-chemicals needed in one season must be bought. [3] • One or two literate persons must be in charge of the storeroom if the farmer does not do so himself, and they must understand the implications of incorrect handling of chemicals. [3] • Farmworkers must be aware of the dangers associated with pesticides especially regarding empty pesticide containers. [3] **Cleaning and disposal** • Pesticide waste should either be disposed of at a hazardous waste disposal site or sent back to the local suppliers or sent to a registered disposal company. [3] • Obsolete or un-wanted agro-chemicals should be stored securely and disposed of through officially authorized channels (Recommended). [2] • Empty agro-chemical containers should not be re-used, not even after they have been washed. They may only be used to hold the same product. It should be triple rinsed, punched and flattened and then buried at a registered hazardous waste disposal site on or off the farm. This site should be flat with a gentle slope, on high ground with ground water at least 2 meters deep, at least 100 meters but preferably 1000m from the nearest water source. It must not have sandy soils, and must be fenced in with a signpost (Major must). [2,3,4,5] **Cleaning and disposal** • Empty triple rinsed agro-chemical containers (with the exception of plastic drums previously used for chemicals) can be sent to a registered reprocessing company (SANS 10406). [3] • Empty triple rinsed agro-chemical containers which are considered unserviceable can be considered for recycling into building materials. [3,5] • Empty metal drums that cannot be recycled should be sent to a registered hazardous waste site or back to the suppliers. [5] • Pesticide containers should preferably be sent back to the supplier or a registered disposal company. [3] • If empty punctured containers cannot immediately be disposed of or sent for recycling they must be stored in a secure place under lock and key and in such a manner that they do not pollute the environment. [3,5] • Paper, waste bags and mildly contaminated items must be burned and redundant agro-chemicals and severely contaminated items must be incinerated. This can also include empty containers. [4] • The incineration of combustible agro-chemical containers and empty plastic packaging is illegal in South Africa. [3,5]
References	2: Grain SA, 2010 3: SANS, 2010 4: SAQA, 2006 5: Govender, Sheard, 2012

*“Recommended” or “Major must” in indicates the importance level of the specific regulation as described by The Food Safety Requirements for the Grain Industry (Grain SA 2010).

Table 3 continued

Theme	Information related to storage, disposal of wastage and cleaning
Storage disposal wastage and cleaning	**Cleaning and disposal** • Empty triple rinsed agro-chemical containers (with the exception of plastic drums previously used for chemicals) can be sent to a registered reprocessing company (SANS 10406). [3] • Empty triple rinsed agro-chemical containers which are considered unserviceable can be considered for recycling into building materials. [3,5] • Empty metal drums that cannot be recycled should be sent to a registered hazardous waste site or back to the suppliers. [5] • Pesticide containers should preferably be sent back to the supplier or a registered disposal company. [3] • If empty punctured containers cannot immediately be disposed of or sent for recycling they must be stored in a secure place under lock and key and in such a manner that they do not pollute the environment. [3,5] • Paper, waste bags and mildly contaminated items must be burned and redundant agro-chemicals and severely contaminated items must be incinerated. This can also include empty containers. [4] • The incineration of combustible agro-chemical containers and empty plastic packaging is illegal in South Africa. [3,5] **Wastage** • A PCO or the business that instructs him should keep record of any spillages of agro-chemicals that occurred during the application thereof.[1] **Implements, vehicles and smaller equipment** • A PCO or the business that instructs him should keep record of the type of equipment used for the application of the agro-chemicals. [1] • The mixing, filling and cleaning processes associated with spray equipment must be done in a separate bunded facility (floor made of non-porous material), with adequate drainage, restricted entry area, and must be done in a manner to prevent contamination of water resources and the environment (Major must). [2,3,4]
References	1: DAFF, 2011 2: Grain SA, 2010 3: SANS, 2010 4: SAQA, 2006 5: Govender, Sheard, 2012

*"Recommended" or "Major must" in indicates the importance level of the specific regulation as described by The Food Safety Requirements for the Grain Industry (Grain SA 2010).

Table 3 continued

Theme	Information related to storage, disposal of wastage and cleaning
Storage disposal wastage and cleaning	**Implements vehicles and smaller equipment** • These facilities and appropriate measuring equipment must be adequate for the mixing of agro-chemicals to ensure that correct handling and filling procedures, as stated on labels, can be followed (Major must). [2] • All machinery must be washed with clean water after application of agro-chemicals. If this is not done it can contaminate the environment and even the equipment. [4] • All other equipment, such as knapsacks, brushes and mixing equipment must be washed with an appropriate liquid soap and then well rinsed. [4] • The correct amount of chemicals for only one application must be mixed. The measuring equipment must be triple rinsed and this liquid should be added to the mixture before it is made up to the volume. [3, 5] • Surplus application mix or tank washings applied over untreated crops should not result in over application of chemicals (Major must). [2] • A PCO must know the appropriate use of equipment. He must also have knowledge on how to calibrate equipment, and it should be calibrated annually by a competent person. Calibration of equipment is extremely important to ensure that the correct amount of agro-chemicals are applied and to ensure that the target pest is adequately controlled (Major must). [1,2,4] • A PCO must ensure that equipment used to mix, load and apply agro-chemicals is used as instructed by the agricultural chemical supplier. [1] The following information is required for calibration: • Litres required per hectare • Spacing of crops • Tractor speed • Pump pressure • Number of nozzles to be used [4]
References	1: DAFF, 2011 2: Grain SA, 2010 3: SANS, 2010 4: SAQA, 2006 5: Govender, Sheard, 2012

*"Recommended" or "Major must" in indicates the importance level of the specific regulation as described by The Food Safety Requirements for the Grain Industry (Grain SA 2010).

More information on the disposal of agro-chemicals and agro-chemical packaging and containers was also obtained from Dickinson (Dickinson, 2013, Personal Communication).

The Adoption of Pesticide Management Policy for South Africa (DAFF, 2010) which forms part of the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act No. 36 of 1947) (RSA, 1947) recognises that it is important that a programme to collect old, out of date or un-wanted pesticides should be initiated to avoid the build-up of obsolete pesticides used by farmers and by other users. Programmes like these should be initiated by the Department of Agriculture Forestry and Fisheries. They also recognise that it is important that these programs should include the collecting and recycling of plastic pesticide containers used by farmers (DAFF, 2010).The Association of Veterinary and Crop Associations of South Africa (AVCASA) works on various environmentally sound container management strategies as part of their waste management plan submitted to the Department of Environmental Affairs (Govender, Sheard, 2012). AVCASA also plays an important role in management of obsolete pesticides and was involved in a clean-up project that was completed in 1999. They are currently also busy launching such a clean-up project together with the Department of Environmental Affairs and DBSA (Dickinson, Personal Communication, 2013)

Naidoo & Buckley (2003) provided valuable information on pesticide use and disposal in South Africa including how to reduce pesticide use. It proposes and assesses methods that can be used to dispose of agro-chemicals. It also provides information on obsolete agro-chemical stocks and on the clean-up project which was completed in 1999. It also makes recommendations to improve management of agro-chemicals in South Africa.

The International Labour Organisation (1991) was used for questions and different options listed for the questions in this theme and also provided background information for the study. Information that was obtained from this document includes different kinds of agro-chemical spillages, how packaging and containers should be disposed of, safe handling and use of agro-chemicals and agro-chemical packaging, and the transport, transfer, storage, dispensing and application of agro-chemicals. These are all international perspectives.

2.2.5 Weather conditions

Table 4 gives information on weather conditions that were taken into consideration during the development of the questions related to weather conditions in the farmer questionnaire. Weather conditions are also an important factor to take into consideration when gathering data for an agro-chemical usage database (NSW EPA, 2013).

Table 4: The role of weather conditions on agro-chemical applications

Sub-Theme	Information related to weather conditions
Weather conditions	• It is important that climatic conditions are taken into consideration when applying agro-chemicals especially if the chemicals are applied by way of spraying. [4] • Spraying operations should not be done in adverse weather conditions and instructions on the label regarding wind speed must be followed. [3] • High wind speeds can result in spray drift which leading to poor spray coverage which in turn can lead to poor control of the pest or disease that is targeted. Spray drift can also damage other crops, pollute water sources and cause environmental harm. It is recommended that foliar sprays should not be applied with wind speeds exceeding 12 km/h. [4] • It must be ensured that crops are dry before foliar sprays are applied. If the crops are wet the agro-chemicals will be diluted and less effective. Spraying should never take place while it is raining. A general rule is that 6 hours of no rain is required after the application of agro-chemicals. If more than 10mm of rain falls within this period, the chemicals should be re-applied. [4] • Most agro-chemicals are applied during the summer months and therefore care should be taken that oil sprays are not applied when temperatures exceed 30°C. For this reason applications are often done at night in warmer areas. Oil sprays can result in fruit burn in hot conditions. Ultraviolet light can also influence certain chemicals and these should also be applied at night. [4]
References	3: SANS, 2010 4: SAQA, 2006

The questions related to weather conditions can be seen in question 69 to question 71 of the farmer questionnaire that is included in appendix C.

2.2.6 Characteristics of chemicals

Table 5 relates to information of chemical characteristics and includes the hazard classes into which agro-chemicals are divided. These were included in the theme on agro-chemical characteristics in the farmer questionnaire.

Table 5: Information related to characteristics of chemicals

<table>
<tr><th>Theme</th><th>Information related to characteristics of chemicals</th></tr>
<tr><td>Characteristics of chemicals</td><td>

A PCO must understand warning terms, symbols, classifications, instructions and other information that commonly appears on agro-chemical labels. He must also know the toxicity of the agro-chemicals.
Before applying agro-chemicals a PCO must issue treatment notice with the hazards of the agro-chemicals that will be used. [1]

The toxicity class, description, colour codes and pictograms of the chemicals are given below [1,4]:
<table>
<tr><th>Toxicity class</th><th>Description</th><th>Colour code</th><th>Pictogram</th></tr>
<tr><td>Ia</td><td>Extremely Hazardous - Very Toxic</td><td>Red</td><td></td></tr>
<tr><td>Ib</td><td>Highly Hazardous - Toxic</td><td>Red</td><td></td></tr>
<tr><td>II</td><td>Moderately Hazardous - Harmful</td><td>Yellow</td><td></td></tr>
<tr><td>III</td><td>Slightly Hazardous - Caution</td><td>Blue</td><td></td></tr>
<tr><td>IV</td><td>Acute hazard unlikely in normal use</td><td>Green</td><td></td></tr>
</table>
</td></tr>
<tr><td>References</td><td>1: DAFF, 2011
4: SAQA, 2006</td></tr>
</table>

The characteristics (hazard classes) of insecticides, herbicides and poison used for Highveld Gerbils as reported by farmers were analysed by comparing there to the official hazard classes of the relevant agro-chemicals. The official hazard classes for insecticides and Highveld Gerbil poison was found from a list than contains all insecticides as well as their hazard classes (DAFF, 2013b). Official hazard classes for herbicides and in some cases dilution rates were found in, Agrian (2013), BASF, (2012), BASF, (2013), Villa Crop Protection, (2010), Villa Crop Protection (2011), Villa Crop Protection, (2012), Villa Crop Protection, (2013a), Villa Crop Protection (2013b), Villa Crop Protection, (2013c), Monsanto, (2002), Monsanto, (2008), Syngenta Crop Protection, (n.d), Syngenta Crop Protection, (2004), Syngenta Crop Protection, (2006), Syngenta Crop Protection, (2008), Drexel Chemical Company, (n.d), Eviro-crop, (2012) and Agronica, (2009).

After some debate about the toxicity of fertilizer and whether to see it as a toxic agro-chemical or not, the dangers thereof was verified by Bijay-Singh *et al,* (1995) and Jiao *et al*, (2012), where they describe the dangers fertilizers can pose to humans and the environment. Questions related to the usage of fertilizer are thus included in the farmer questionnaire under questions 25, 26, 29-34, 38-52, 57 and 72 (see Appendix C).

2.2.7 Servicing

Table 6 touches on information related to servicing and cleaning of equipment as well as the storage of fuel.

The aim of this theme was to gather information on the amounts of fluids used during servicing of implements and vehicles and the storage, disposal and wastage of these fluids as well as fuel. The questions related to servicing can be seen in question 74 to question 95 of the farmer questionnaire (see appendix C).

Table 6: Information related to servicing of implements and vehicle

Theme	**Information related to Servicing (Implements, vehicles, disposal and storage)**
Servicing (Implements, vehicles, disposal and storage of oils fuels and lubricants)	• A PCO must ensure that equipment used to mix, load and apply agro-chemicals are kept in a safe operating condition and that such equipment is maintained, repaired and cleaned by workers who have been trained to do so in a safe manner. A PCO should also ensure that equipment is in a safe condition before repair and maintenance work including welding operations is carried out. [1] • Fuel storage tanks should be bunded in order to limit, divert, contain, minimize and manage fuel spillages so as to prevent fires which could pose a risk to humans, nearby property and the environment. [6]
References	1: DAFF, 2011 6: SANS, 2004

2.2.8 Legal compliance

The agricultural sector must comply with various pieces of legislation which can relate to farming practices, agro-chemical application, waste management on the farm as well as who distributes chemicals, how these are distributed and how chemicals are disposed of.

Table 7 lists aspects of legislation that were deemed to be relevant during the study and the questionnaire development.

Table 7: Legislation used in study and questionnaire development

Theme	Information on legal compliance
Legal compliance	Legal compliance includes the compliance to all of the legislation and regulations discussed above. Waste management is governed by many different departments, acts, policies, regulations and strategies in South Africa and it is quite complex. The bodies with the relevant acts, regulations, policies strategies and standards that fall under them and which were used in this study are indicated below: ***Department of Environmental Affairs and Tourism*** THE NATIONAL ENVIRONMENTAL MANAGEMENT WASTE ACT NO 59 OF 2008 (NEM:WA, 2008). • National waste management strategy. WIS needs analysis. Free State Provincial Waste Information Systems Workshop (DEAT, 2005a) • South African National Profile (DEAT, 2005b) • National Waste Management Strategy Implementation. Waste Information System Framework Document. Final Report (DEAT, 2005c) • National Waste Management Strategy (DEA, 2011) • National Waste Information Regulations (DEA, 2012) • Terms of Reference for Development of a Hazardous Waste Source Inventory (DETEA, n.d.) ***Department of Agriculture Forestry's and Fisheries*** FERTILIZERS, FARM FEEDS, AGRICULTURAL REMEDIES AND STOCK REMEDIES ACT, 1947 (ACT NO. 36 OF 1947) (RSA, 1947) • Adoption of Pesticide Management Policy for South Africa (DAFF, 2010) • The Pest Control Operator Regulations (DAFF, 2011) • Guide to machinery costs (DAFF, 2013a) • List of insecticides sorted alphabetically according to the active ingredient/s (DAFF, 2013b) ***Department of Water Affairs and Forestry (DWAF)*** NATIONAL WATER ACT (ACT NO. 36 OF 1998) (NWA, 1998) • National Toxicity Monitoring Programme: Report on phase 3: Pilot implementation and testing of the design (Jooste *et al*, 2008). ***South African National Standards*** • The handling, storage and disposal of pesticides. SANS 10206: 2010 (SANS, 2010) • Above-ground storage tanks for petroleum products. SANS 10131: 2004 (SANS, 2004)

It is clear that there are numerous pieces of legislation that govern chemicals and the management thereof in South Africa. Unfortunately the legislation is fragmented and this results in difficulties for many stakeholders and interested and affected parties to know which legislation is relevant to their specific field of operation. This is not only true for government but also for non-governmental parties (DEAT, 2005b). The use of pesticides is managed through fourteen different pieces of legislation in South Africa and this is administered by seven different government departments. This results in serious deficiencies in the effectiveness and the scope of legislation (Rother *et al*, 2008).

Specific legislation that overlap includes the Hazardous Substances Act, the Occupational Health and Safety Act (particularly the Regulations for Hazardous Chemical Substances) and the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act. These overlaps are specifically for packaging and labelling, the management of hazardous substances and the use of personal protective clothing. These overlaps complicate the successful implementation of the legislation and the latter therefore needs a coordinating mechanism to ensure its effectiveness (DEAT, 2005b).

Furthermore the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act No. 36 of 1947) (RSA, 1947) is out-dated and needs updating. It has been amended a few times since its inception in 1947 but has never been systematically revised (DAFF, 2010).To address some of the challenges regarding regulations on pesticide management in South Africa, the Pesticide Management Policy was published in 2010 (DAFF, 2010). It recognises the shortcomings of the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies (Act 36 of 1974) and some of these shortcomings which are relevant to this study are listed below:

- There is no requirement for the re-evaluation of old chemicals or the review of registered pesticides
- The lack of the establishment of a pesticide use database and monitoring system which gathers information on common conditions of use and the impact thereof on the environment and human health
- There are no requirements for prior certification and training to use/apply the most toxic pesticides (group I and II)
- The lack of capacity for research on crop production and alternative pest control measures
- It does not adequately encourage registration that favours reduced reliance on pesticides and pesticides with lower risk
- The Act does not adequately address the problem of the handling and disposal of stockpiled obsolete pesticides or pesticide container management
- The act inadequately integrates across government departments

The main objectives of the Pesticide Management Policy (DAFF, 2010) are listed below:

- The improvement of the legislative framework to ensure that South Africa is better protected from environmental and health risks posed by pesticides
- The integration of relevant international initiatives and agreements from other government departments
- To encourage the development and use of alternative techniques and pesticide products and reduce dependence on chemical plant protection products

- Improvement in registration of pesticides and public participation processes, and increased transparency regarding access to information

According to Du Plessis & Allsopp, (n.d.) SANS 10206 (SANS, 2010) summarises all these laws regarding the handling, storage and disposal of agro-chemicals on farms.

International obligations and agreements which contribute to the safe use of pesticides on a global scale and to which South Africa are signatories include the following (DAFF, 2010):

- The Rotterdam Convention on the Prior Informed Consent Procedure (PIC) for Certain Hazardous Chemicals and Pesticides in international trade, which obliges an exporter of certain hazardous chemicals to obtain consent of the country who receives the chemicals before delivery
- The Vienna Convention on the Protection of the Ozone Layer and the Montreal Protocol on Substances That Deplete the Ozone Layer. Ozone depleting substances include methyl bromide, which is a form of pesticide. South Africa has to take the necessary steps and action to control the use of this pesticide
- The Stockholm Convention on Persistent Organic Pollutants (POPs) which aims to protect the environment and human health from POPs
- The Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and their Disposal

The main objectives of the Basel convention (DAFF, 2010; Naidoo & Buckley, 2003) are the following:

- The disposal of as much hazardous waste as possible in the country of origin
- The reduction of hazardous waste to a minimum
- To ensure that hazardous wastes are not shipped to countries that do not have the administrative, legal and technical capacity to manage and dispose of these wastes in an environmentally sound manner
- To cooperate on the transfer of technology, exchange of information, and the harmonization of standards, codes and guidelines
- To enhance the control on imports and exports of hazardous waste

DEAT (2005b) indicates the legislation that exits for the different stages in the life cycle of agro-chemicals as well as pesticides for public health and consumer use. For agro-chemicals legislation exists for the import, production, storage, transport, distribution/marketing, use/handling and disposal of agro-chemicals. The same applies for pesticides for public health and consumer use except that there is no legislation for use/handling and disposal thereof.

Table 8 indicates the complexity of the management of pesticides for the different stages of the product in its lifetime between the different government departments. Pesticides are indicated by “A” in the table.

Table 8: Department responsible for the management of pesticides through its life cycle[1] (Adapted from DEAT, 2005b)

Stage of life-cycle / Department concerned	Importation	Production	Storage	Transport	Distribution / Marketing	Use / Handling	Disposal	Hazard Management
Environmental Affairs (DEAT)	A,P,I,C	A,P,I,C					A,P,I,C [5]	A,P,I,C
Water Affairs and Forestry (DWAF)			A,P,I,C				A,P,I,C [6]	A,P,I,C
Minerals and Energy (DME)		I (relevant to mining)				I (relevant to mining)[3]		
Health (DOH)[2]	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C
Agriculture (NDA)	A	A	A	A	A	A		
Labour (DOL)		A,P,I,C	A,P,I,C	A,P,I,C		A,P,I [4] C		
Trade and Industry (DTI)	A,P,I,C	A,P,I,C						
Transport				A,P,I,C		A,P,I,C		
Social Services (DSD)						A,P,I,C		
Provincial and local government (DPLG)	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C	A,P,I,C
Safety and Security[7]	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)
Foreign Affairs	A,P,I,C							
South African Defence Force	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)	I (explosives)

1 For each positive response concerning a broad group of chemicals, one of the following letters are indicated:
A – Pesticides
P – Petroleum products
I – Industrial
C – Consumer Chemicals
Mandates in terms of legislation are indicated by circles

2 All hazardous chemicals
3 Management of hazardous chemicals used in the mines
4 Management of chemicals used in all work places except Mines and the shipping industry
5 Management of all disposal besides for disposal sites
6 Disposal of wastes (Disposal sites)
7 Management of explosives besides of those handled by the Defence force, the Mines and Works Act and ammunition
Regulated by any law other than the Explosive Act of 1956

2.3 **Impacts of agro-chemicals on water resources and how it can be managed**

This section briefly discusses impacts of agro-chemicals on water sources, in order to illustrate the importance of the proper management of chemicals in the agricultural sector.

2.3.1 Impacts of agro-chemicals on water resources

The biggest source of non-point water pollution in South Africa is agriculture (Scotcher, 2009). When farms are poorly managed it allows insecticides, herbicides, poisons and nutrients such as fertilizers and manure to drain into groundwater resources as well as rivers, lakes and coastal zones. Field runoff and spray drift are also of great concern (Schwarzenbach *et al*, 2010). Fertilisers that enter water resources encourage algal growth and cause smell and taste problems which have devastating effects on the environment and also on humans. This also increases the cost of water treatment. Agro-chemicals of all chemical classes have been detected in South Africa`s groundwater and are also wide spread in surface water bodies. This pollution causes water in many areas to be un-potable and some are so polluted that it can't even be used for irrigation (Scotcher, 2009).

Agricultural point source pollution can also be a problem and includes agro-chemicals that run off hard surfaces such as storage areas and during accidental spills. Point source pollution like this can drain into the soil and reach other water resources or can distribute via sewer systems (Schwarzenbach *et al*, 2010).

2.3.1 Management techniques to reduce agro-chemical pollution of water resources

In the National Water Act (NWA) (Act No 36 of 1998) it is stipulated that water resources must be protected and water pollution should be prevented. Part 4 of Chapter 3 of the act deals with the prevention of pollution and it particularly emphasises the pollution of water that results from of activities on land (DAFF, 2010).

In order to ensure compliance of agro-chemicals with the NWA (Act No 36 of 1998), the Department of Water Affairs (DWA), formerly known as Department of Water Affairs and Forestry (DWAF), has initiated a National Toxicity Monitoring Programme of which the third phase of the design of the program ran between June 2006 and October 2007. This programme monitors the levels of a number of agro-chemicals in surface water and groundwater resources to help protect the environment. Sampling areas for this phase of the programme included the Jukskei River in Gauteng and the Middle Vaal which spans over Mpumalanga, Gauteng and North West Province (DAFF, 2010; Jooste *et al*, 2008).

It is important to evaluate the impacts of agro-chemicals using long term monitoring and targeted research, as agro-chemicals that accumulate in the environment can be very harmful to humans and the environment (Ansara-Ross *et al*, 2009; Choung *et al,* 2012; Du Preez *et al*, 2005).

There should be strong ties between monitoring/research and regulations. Monitoring and research can be used to establish a baseline of chemicals that are used, to identify changes in agro-chemical pollution, specific danger spots and problematic agro-chemicals. Socio-economic studies should also be used to assess the impact of agro-chemicals on farming practices, the environment and human health. Geographic Information Systems (GIS) is a valuable tool that can be used for this monitoring. Without sufficient and reliable data Government cannot manage these agro-chemicals to ensure that they do not pose a risk to people and the environment (DAFF, 2010).

In Great Britain, pesticide usage data together with maps of crops under cultivation, groundwater, soil, rivers, other waterways, water abstraction points as well as agro-chemical properties and models of movement through different soils are used in a complex Geographical Information System developed by the Environmental Agency (Williams, 1997 cited in Thomas, 2003). This is used to predict the likely appearance of agro-chemicals at abstraction points to facilitate the monitoring of agro-chemicals in water. This will also aid the avoidance of unnecessary monitoring of agro-chemicals where they are unlikely to appear at a specific point according to the models (Thomas, 2003).

Another method that can be used to reduce agro-chemical pollution is to release fewer agro-chemicals and/or less toxic agro-chemicals into the environment. Practices that reduce the movement of agro-chemicals to groundwater and surface water resources should also be used. This can be done by placing restrictive requirements on users. Examples of this is restricting aerial spraying to a certain proximity to water sources and instituting buffer zones (DAFF, 2010).

Alternative chemicals with other chemical formulations which are less persistent and toxic to the environment can also be used (Naidoo & Buckley, 2003).

2.4 **Improved agro-chemical waste management in the maize sector**

An important aspect that this study also focuses on is the minimization of the impact of agro-chemicals on the environment by introducing improved management and monitoring of chemicals used in the agricultural sector. Management can be improved by determining exact amounts of chemicals used and understanding the flow of chemicals in the environment. Understanding the flow of chemicals in the maize sector in particular is the aim of this study and it ties in with the aim of the DETEA project that is focused on gathering information to develop the waste database. Knowing types and volumes of chemicals used and its movement through the environment, should assist greatly in improving the management and monitoring capabilities of the DETEA. Once the movement of these chemicals through the environment can be effectively monitored, unnecessary wastage could also be limited (DEAT, 2005a; DEA, 2011).

2.4.1 Importance of an agro-chemical usage database

Some of the important advantages of an agro-chemical usage database are discussed below.

A database of agro-chemical usage is imperative for government to be informed on the current status of agro-chemical use. If data is available of the product range in which agro-chemicals occur, the crops on which they are used, and the extent to which those crops are treated, it can give a clearer representation of the levels of agro-chemicals to which people and the environment are exposed. It is also essential to have accurate usage data available to develop indicators of the effects of agro-chemicals on the environment (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002; NSW EPA, 2013).

Once agro-chemical usage data is regularly gathered and a collection of annual data sets is available, changes of agro-chemical use/trends from year to year can be monitored (Thomas, 2003; DEAT, 2005a; DEAT, 2005c). Different factors work together to influence the volumes of agro-chemicals that are used on crops. These include differences in weather conditions which influence the range of weeds, diseases and pests requiring control, and the introduction of new agro-chemicals which may replace older products and which may be applied at much lower rates per hectare. Changing prices or demand for certain crops can also influence the amounts of agro-chemicals that are used in a season (Thomas, 2003).

It is imperative that knowledge of local and national uses and requirements are available for all agro-chemicals. If farmers cannot operate without a particular pesticide and there are no alternatives available, this must be borne in mind during its review. This is where reliable usage data is very important in order for the removal of a pesticide to be quantified. Alternatively this data will also assist in identifying a decline in use of a certain pesticide in favour of safer alternatives. The withdrawal of the pesticide not being used can then be accelerated. With reliable estimates of the actual rates of use, the percentage of a crop that is treated and the number of times that it is treated, much more accurate data which may be a lot less than maximum label recommendations will be available. The continued approval of products may be significantly affected if such data is not available (Thomas, 2003).

A summary of the advantages of a pesticide usage database are listed below:

- It can be a valuable tool in the monitoring of agro-chemical contamination of groundwater and surface water resources (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002).
- It will aid in research and development in the field of waste management (DEAT, 2005c)
- It will aid decision making by government (DEAT, 2005a; DEAT, 2005c).
- A statistically sound usage database can be used to draw up operator exposure models (Thomas, 2003).
- It can be used to monitor the effects that changing policies have on agro-chemical use and can support new policy development (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002; DEAT, 2005a; DEAT 2005c).
- Farmer specific data on agro-chemical usage can be used to evaluate if their current practices can be improved or optimised (Thomas, 2003).
- In the United Kingdom (UK) usage data has provided the foundation for the development of monitoring systems which monitors Maximum Residue Levels (MRLs) (Thomas, 2003).
- It will support public access to information and create awareness (DEAT, 2005a; DEAT 2005c)
- It will create jobs and aid in capacity building (DEAT, 2005a)
- It will facilitate waste management planning (DEAT, 2005a, DEAT, 2005c)
- It will aid the control and enforcement of principles, policies and legislations (DEAT, 2005a)

In the surveys used to gather the usage data, detailed information on sprayer technology including cab type, boom width, handling mechanism, nozzle type and maintenance would be extremely useful, but the time that it takes to obtain the usage data from the farmers is a concern. Such data has been collected in the past by leaving the questionnaire with the farmer in order for him to complete it and return it in his own time (Thomas, 2003).

Methodologies that are currently in use around the world for the collection of pesticide usage data include personal visits, postal surveys, telephone interviews, compulsory returns of all spraying records from all pesticide users and lastly collation of sales statistics. This will be discussed in more detail in Chapter 3.

2.4.2 Additional methods to improve agro-chemical waste management

- Agro-chemical waste management on farms can be improved by implementing extended producer responsibility (EPR). This extends the financial and/or the physical responsibility of the producer of the product, until after it has been used and shall include the resultant waste of the product. This means that the manufacturer of the product will be responsible for the treatment, recycling or disposal of for example the agro-chemical containers. For such a system to be successfully implemented, a levy could be charged on the price of the product to fund the waste management thereof, but this will depend on the way the system is designed and implemented (Govender & Sheard, 2012).
- A pesticide bank which aims to monitor pesticides on the end-user or supplier level and which monitors shipments to ensure that stocks are only replenished when necessary, can be implemented to prevent pesticide stocks from accumulating. By keeping pesticide stocks as small as possible, pesticide disposal should be minimized (Naidoo & Buckley, 2003).
- Industry waste management plans (IndWMPs) are essentially working documents that are produced by an industry which demonstrates how the waste they produce will be managed. By implementing this, industries can ensure that they comply with the waste act (Govender & Sheard, 2012).
- Sustainable pest management can be implemented by introducing incentives and disincentives. Disincentives will involve the introduction of a registration levy on pesticides. This levy will be based on the potential damage of the pesticide to the environment and to human health. Such a levy will encourage pesticide users to consider alternatives such as non-chemical and low risk pesticides (bio-pesticides) which can make this industry more competitive. Incentives will on the other hand include the introduction of low or no registration levy fees for companies who want to register bio-pesticides or organic farming practices (DAFF, 2010).
- All chemical companies (large and small) should fall under the same umbrella body or federation of bodies, as this would allow government to effectively access agro-chemical sales data, allowing them to identify high-risk areas based on intended use and sales (Naidoo & Buckley, 2003).
- Management practices should focus on the basic functional elements of waste management. This includes storage, collection, transportation and treatment/disposal. It is often a problem in developing countries that hazardous waste is not separated from municipal waste and therefore hazardous waste often ends up on general waste sites (Kahn *et al* n.d).

2.4.3 Associations who are involved in agro-chemical and agro-chemical waste management in South Africa

The Responsible Container Management Association of Southern Africa (RCMASA) was formed to enable industries to take a pro-active approach to becoming self-regulatory and to make a positive contribution to protect the environment and also the health and safety of people. The association adopted the international principles of Responsible Container Management in order for South Africa to achieve responsible container management. The association is aimed at all parties involved in the life cycle of chemical containers from the manufacturer to final disposal or recycling thereof (DEAT, 2005b).

The Chemical and Allied Industries` Association (CAIA) launched Responsible Care in South Africa which addresses concerns about manufacture, transport, storage, use and disposal of chemicals (DEAT, 2005b).

The Chemical Sector Information System for Southern Africa (ChemISSA) is an internet based information system that covers the manufacturing, consumption and trade of all chemical products in all the member states of the SADC. It is an initiative of the Department of Trade and Industry (DTI) and the Council for Scientific and Industrial Research (CSIR). It provides an in-depth chemical trade analysis as well as basic data. It is however inaccessible to the public as there is a substantial charge for its use (DEAT, 2005c).

2.4.4 Methods to reduce agro-chemical usage

Reducing agro-chemical usage is an important aspect to reduce the introduction of these chemicals to the environment and to ensure more effective management of agro-chemicals on farms.

There are several methods that can be used to reduce die volumes of pesticides that are used on farms and to ensure that all pesticides that are bought are used up. This can be done by moving away from conventional agricultural practices where toxic pesticides are used and introducing sustainable agriculture and green chemistry. These two go hand in hand (Naidoo & Buckley, 2003).

Sustainable agriculture takes the whole farming environment into account. This includes the agricultural system and the ecological system. It is based on a concept to apply ecological principles and concepts to the management and development of agriculture (Rother & Jacobs, n.d.).

There are a range of farming practices which fall under sustainable agriculture and these will be briefly discussed below:

- Organic farming is a farming practice where no pesticides or synthetic fertilizers are used (Rother & Jacobs, n.d.). It includes the use of organic matter, biological and botanical control and intercropping. It involves the development of bio-chemicals that are made from natural products such as animals, plants, bacteria and minerals that are less toxic to the environment.
- Biological control involves using natural enemies to control pests. It also includes bio-pesticides. An example of biological control is Bacillus thuringiensis (bt) maize. This is also known as green chemistry. This type of farming is becoming more popular but is not viable when the increased yields needed for a growing human

population is taken into consideration (Rother & Jacobs, n.d; Naidoo & Buckley, 2003).

- Biodynamic farming is closely related to organic farming and further includes farming practices which take the cycles and rhythms of nature into consideration. An example of this is lunar planting which enhances the forces of nature (Rother & Jacobs, n.d.).
- Agro-forestry is a practice where trees are grown along with crops with the aim to control pests and to increase biodiversity. It also helps to increase production and protects soil against erosion (Naidoo & Buckley, 2003).
- Permaculture is the development of an agricultural system which duplicates or imitates the interrelationship and structure found in nature (Rother & Jacobs, n.d).

Bio-chemicals have some benefits over conventional chemicals but also have some disadvantages. To develop safe and effective bio-chemicals requires multi-disciplinary and holistic thinking which is a challenge for the industry. To make the market profitable is also a daunting task. In South Africa the current priority is only to know how much hazardous chemicals there are in the waste streams and therefore there is still a long way to go before alternatives like these (which are still developing and are risky) can be implemented safely and effectively (O`Brien *et al*, 2009; Names and characteristics of pesticides, n.d.; Scotcher, 2009; FAO, n.d.; Quinn *et al,* n.d.)

IPM takes some of the above mentioned farming practices into consideration. It is an effective and environmentally sensitive approach that relies on a combination of common-sense methods to control pests. This includes biological control measures like natural predators and parasitoids of pests, genetic manipulation like bt maize, cultural practices like agronomic practices and judicious use of selective pesticides to stabilize crop production while reducing hazards to the environment and to humans. IPM also focusses on when pesticides should be applied to control pests to ensure that pesticides are not applied when it is not necessary and further also to ensure that the correct pesticides are applied (Naidoo & Buckley, 2003).

Precision agriculture aims to restructure the total system of agriculture towards high efficiency, low input, and sustainable agriculture (Hendriks, 2011).

Lastly it is important that developing countries must learn from developed countries (Kahn *et al* n.d).

Chapter 3 Methodology

This chapter will describe the methodology followed for gathering agro-chemical data for the western maize production region of South Africa. Firstly, methodologies that are being used in other countries, mostly in Europe, for gathering agro-chemical usage data will be discussed together with the criteria which are considered to be the most important to take into consideration when selecting the sampling area. Lastly the methodology and sampling for this study will be described, taking into account international practice for similar studies.

3.1 Methods used for gathering pesticide usage data around the world

The importance of gathering pesticide usage data has been recognised in Europe and the USA and they have already successfully implemented several methods that can be used to gather this data. Five broad methodologies are currently in use and include the following (Thomas, 1999):

- Personal visits
- Postal surveys
- Telephone interviews
- Compulsory returns of pesticide use from farmers
- Sales statistics

3.1.1 Personal visits

Personal visits to representative sample farmers are currently being used in Sweden, France the UK and United States of America (USA).

This is a very accurate method especially where the data is gathered by trained persons (Thomas, 1999). It is important that the surveyor collecting the data should be well prepared with a well-structured questionnaire on which to collect the data. With this method a farmer can and should be warned in advance that he will be visited in order for him to collect all the relevant data in advance (Thomas, 1999). The interviewer should be very familiar with the questionnaire to avoid placing an unfair burden on the respondent and to ensure that no time is wasted in completing the questionnaire. The interviewer should practice to read the questions out loud without stumbling over words or phrases (Babbie, 1995). The interviewer must ensure that he follows question wording exactly as it is on the questionnaire, as slight changes in wording can influence the answer of the respondent (Babbie, 1995; Sullivan, 2001). The interviewer should also ensure that he records the responses exactly as it is said by the respondent as some important detail may be lost if an answer is summarized, paraphrased or if bad grammar is corrected. With personal visits it is important that the interviewer should be appropriately dressed. The general rule is that the interviewer should be dressed similarly as the respondent. The respondent will then feel the most comfortable and will be more approachable (Babbie, 1995).

With this method much better quality data is gathered than other methods like postal surveys, as trained personnel can ensure that no important information is omitted and can explain any ambiguities in questions to the farmer if necessary (Babbie, 1995, Thomas, 1999; Sullivan, 2001). An example of this is a farmer who thinks that pesticides only include insecticides, and not herbicides and fungicides etc. Another example is for instance seed treatments that are often not taken into consideration by farmers (Thomas, 1999).

The interviewer can also decrease the number of “don’t knows” and “no answers” as he can probe the respondent for answers. This method has the highest response rate and allows for long and complex questionnaires (Neuman, 2011). Respondents are much more reluctant to turn down an interviewer who stands on their doorstep than to throw away a questionnaire which they received in the post (Babbie, 1995). A further advantage of personal visits is that the interviewer can make observations, for example, the confidence in which the farmers answers the questions, or the general conditions on the farm like the condition of the agro-chemical storeroom or conditions of implements and vehicles (Babbie, 1995; Neuman, 2011; Sullivan, 2001). The interviewer can ensure that the proper person responds and that questions are answered in the correct sequence (Sullivan, 2001). With a personal visit it is easier to spend more time on questions and to answer a long questionnaire where an hour or longer is appropriate (Sullivan, 2001).

This method allows all the relevant crops to be covered in one visit without over-complicating the data gathering process (Thomas, 1999).

The biggest disadvantage of personal visits is that it is time consuming and it also involves high costs. Interview bias is also a risk in face to face interviews. The interviewer’s tone of voice, appearance and wording of questions can all affect the answers that the respondent provides (Neuman, 2011; Sullivan, 2011).

Computer assisted personnel interviews (CAPI) can also be used in a personal visit where the interviewer will bring a laptop and the respondent will fill in the questions on the laptop. The interviewer will then encourage the respondent to complete the questionnaire and will explain anything that is unclear (Neuman, 2011).

3.1.2 Postal surveys

Postal surveys has been used in the Netherlands (Thomas, 1999) to gather pesticide data.

Before a questionnaire is send to a farmer he should be asked, with a letter, if he still cultivates the relevant crop, and whether he is willing to participate in the survey. If he agrees, a questionnaire specific to the crop for which the data is needed and which caters for the likely practices that are expected for that specific time is send to him (Thomas, 1999). The questionnaire should also be accompanied by a letter that explains what the survey is about (Babbie, 1995; Thomas, 1999; Neuman, 2011; Sullivan 2001).

The response rate of postal surveys is often very low and therefore researchers have developed a number of methods to increase response rates (Babbie, 1995; Thomas, 1999; Neuman, 2011). One way to increase response rates is to make it as easy as possible for the respondent to return the questionnaire. This can be done by accompanying the questionnaire with a self-addressed and stamped envelope so that the respondent doesn’t have to go through too much trouble to return the questionnaire (Babbie, 1995).

This can be taken even further with a self-mailing questionnaire. When such a questionnaire is folded in a certain way the returning address appears on the outside of the questionnaire and is then immediately ready to be posted back to the researcher. This allows for the respondent to not worry about losing the envelope in which it should be returned. Care should however be taken that the questionnaire complies with postal regulations (Babbie, 1995).

Thomas (1999) suggests that to increase the rate of return, the sampling size has to be increased until the desired number of responses is expected to be returned. For example, if a response rate of no more than 30% is expected and data from a 1000 farmers is needed, it means that 3333 questionnaires should be sent out in order to achieve the target.

Low response rates can also be limited by sending reminder letters to non-respondents but this adds to the time and cost of data collection. A cover letter that explains what the survey is about and who the sponsor of the survey is, also helps to increase the response rate (Neuman, 2011; Sullivan, 2001).

Furthermore the researcher has no control over the conditions under which the questionnaire is filled in. For example, the respondent can be distracted from the questionnaire while filling it in. Also, someone else other than the sampled respondent may fill in the questionnaire without the researcher having any control over it (Neuman, 2011).

The researcher can also not visually observe the respondent's reactions and cannot observe the surroundings (Neuman, 2011).

A further disadvantage of this method is that farmers may only provide information that they want the enquirer to know (Thomas, 1999). There is also a risk that the farmer will misinterpret questions or that he will leave out information that he did not know was necessary to include (Neuman, 2011; Thomas, 1999). It is important that the personnel who analyse the questionnaire after it has been returned must also be well trained in order for them to pick up misinterpretations or information that might not be accurate (Thomas, 1999).

Postal surveys need to be less complex than personal visits or telephone interviews to ensure that the farmers understand what is expected of them (Thomas, 1999; Neuman, 2011).

Some advantages of this method are that it has very low costs (much less expensive than personal visits) (Thomas, 1999), and can easily cover a very wide geographical area. The respondent can complete the questionnaire when it is convenient for him and can check personal records for information. Checking personal records should be an advantage when gathering data on agro-chemical usage (Neuman, 2011).

Postal surveys can be sent out several times a year during important times such as just after agro-chemicals have been applied. This will allow the farmer to fill in the questionnaire while the information is still fresh in his memory and will reduce the burden on the farmer to complete the information all at once at the end of a growing season or year (Thomas, 1999).

These surveys are only repeated every two to three years and the farmers who were used in the previous survey are not used again in the next one. This reduces the burden on farmers (Thomas, 1999).

3.1.3 Telephone interviews

Telephone interviews have been used in Sweden in order to save the time and cost of travelling. It is much the same as personal visits but can be more difficult to execute if information that is needed is too complicated. It should not be expected that all the crops that are cultivated on a farm will be covered in a single phone call (Thomas, 1999).

A letter which gives the farmer an idea of the structure of the interview should be sent to him beforehand for him to familiarise himself with the proceedings that will follow, and the trained personnel who do the interview should have a structured questionnaire to guide them (Thomas, 1999).

Comparative studies that have been done in Sweden in 1990 and 1992 showed that the difference between personal visits and telephonic interviews is of little importance if the telephonic interviews are done by trained personnel and if the information that is required is not overly complex (Thomas, 1999).

Almost all people have telephones and therefore almost anyone can be reached by telephone. With sufficient available resources it is possible to reach 1500 respondents within just a few days and with call-backs, response rates can be as high as 80% (Neuman, 2011).

It is more expensive than postal surveys but provide almost all of the benefits of personal visits and is also cheaper than personal visits. Some probes can also be used (Neuman, 2011; Sullivan, 2001).

It is a quick method (Sullivan, 2001), you can dress as you please and is safer than personal visits (Babbie, 1995). The researcher may also receive more trustworthy answers over the phone than received in person (Sullivan, 2001).

Some disadvantages are that people can easily hang up as it is much easier to think of excuses to not continue with the phone call (Babbie, 1995). Telephone questionnaires must be quite short in duration with max duration of about 20 minutes (Sullivan, 2001). Questions must also be simple and uncomplicated. A researcher can make no observations and answering machines can make it difficult to reach people (Sullivan, 2001).

Computer assisted telephone interviewing (CATI) is a system that is widely used where the interviewer sits in front of a computer which automatically makes the calls. The interviewer wears a headset and microphone and reads the questions from the computer. The interviewer can immediately type in the response on the computer and the computer will automatically move on to the next question. This saves a lot of time in the analysis of the information (Neuman, 2011; Sullivan, 2001).

3.1.4 Compulsory returns of all spraying records from all pesticide users

This is a more advanced method and the only place where this is implemented is in California in the USA. This method is executed by farmers who return monthly pesticide usage reports via post. The administration and computing that is needed to handle such a vast amount of data is complicated to set up initially but once it is up and running it is a very effective method. This methodology might be particularly useful in smaller countries (Thomas, 1999; Radcliffe, 2002).

3.1.5 Web surveys

This is very fast and inexpensive and can make use of visual images, or even audio or video (Neuman, 2011). It can also reach people around the world (Sullivan, 2001). Further it can present different questions for different answers. Some disadvantages of this method include coverage, privacy and verification and design issues (Sullivan, 2001). This method can be implemented by sending out an email to which the respondent must respond or the survey can be available on a website (Sullivan, 2001). Web surveys are a tool that can be used in the compulsory returns of sales statistics.

3.1.6 Collation of sales statistics

This method can be used if the necessary resources for one of the methods discussed above are not immediately available. This method however does not adequately substitute for the statistically sound data that is gathered through surveys. Some advantages of this method include the following (Thomas, 1999):

- It is relatively inexpensive
- It is theoretically accurate
- They are quick to produce
- Comparison can be made between actual usage as reported by farmers and quantities that are sold by chemical companies
- The data can be used to make estimates for years when surveys were not done

Some of the disadvantages include the following (Thomas, 1999):

- Data will only represent a part of total sales
- Retrieval of data on products that are unique to single companies might be a problem
- Analysation of data to active substances used on specific crops might be complicated
- Sales figures do not accurately represent usage as stockpiling might occur at chemical distributors or at farmers
- As the same chemicals are used on different crops sales figures cannot distinguish between pesticide use on a specific crop
- Sales data normally does not provide any information on regional differences in use.
- Sales data my include pesticide use in other sectors outside of agriculture
- Data on weights sold cannot be accurately converted to area that is treated or to the application rate that is used as many farmers in the UK apply much less than the recommended volumes of pesticides. The rates at which farmers apply pesticides are also very variable which makes any estimates of use very difficult
- The same classification system has to be used for all pesticides, otherwise it will be impossible to interpret sales data meaningfully

Pesticide usage surveys should ideally be done annually, but depending on the method used this is nearly impossible as resources are often a problem and the burden it places on farmers becomes too high. In the UK the most important crops are surveyed every two years and other crops every four years (Thomas, 1999).

3.2 Criteria for pesticide data gathering

The criteria that are considered to be the most important in the process of gathering pesticide usage data include the following:

- The crop that is treated (including the season in which it is planted) (Thomas, 1999)

- The areas of the crop under cultivation. The pesticide usage per hectare per crop can then be multiplied by the total area under cultivation to calculate a national estimate for a specific crop (Thomas, 1999; Thomas, 2003)
- The area of the crop that is treated (The area of the crop treated will not necessarily be the same as the area of the crop that is planted. If an area of crop is treated twice the area treated will be double that of the area planted. Further factors that may influence this are spot treatments, buffer zones and refuge areas) (Thomas, 1999)
- The pesticide product that is used (Thomas, 1999; NSW EPA, 2013; DETEA, n.d.). The ideal is to obtain the full product name since the active ingredients can then be accurately determined. Some farmers only know what active ingredient they want to apply and do not know the name of the product used. This can result in not knowing all the active ingredients that were applied. It is also important that the whole name of a pesticide should be recorded. Products with the same name but with different prefixes and suffixes normally have the same main active ingredient but the rest of the active ingredients differ. It is also important to know if the product applied was in granular or liquid form (Thomas, 1999)
- The amount used or the rate of application (kg/ha or ℓ/ha). This can be the concentrated amount or the ready to use mix (Thomas, 1999; NSW EPA, 2013; DETEA, n.d.)
- The hazard rating class of the agro-chemicals (DETEA, n.d.)
- Biological control methods that are used, (Thomas, 1999)
- The date of the application (Thomas, 1999; NSW EPA, 2013),
- The equipment that was used to apply the pesticide and the method of application (Thomas, 1999; NSW, EPA, 2013),
- The property address and area on the property where it was applied (NSW EPA, 2013; DETEA, n.d.),
- Weather conditions during application including wind speed and direction and if there was a significant change in weather during an application it also needs to be reported (NSW EPA, 2013)

Factors like farming intensity, pest and disease pressure and climate and general farming practices often result in significant changes in pesticide use between different regions. The size of a farm can also play a role in the volumes of pesticides applied. In the UK large farmers are more likely to apply less chemicals and to apply it at less than the recommended rates. In the Netherlands however there seems to be no difference in the application rates between different farm sizes. Larger farmers may be better trained and might be willing to apply less pesticides when pest pressure is lower or will be more aware of new products which require lower application rates. Soil type can also influence pesticide use. If the variety or the cultivar of a crop is known to demand varying pesticide inputs this should also be taken into consideration (Thomas, 2003).

If there is a slight under- or over sampling of a certain crop it can be corrected by using a correction factor derived from the total area of the crop that is within a region, divided by the raised estimate of a crop cultivated in that region (Thomas, 2003).

3.3 **Methodology used in this study**

A qualitative methodology was used for this study. This included structured questionnaires which were administered to farmers and telephonic interviews to chemical distributors. These questionnaires and interviews were both quantitatively and qualitatively analysed. Formal and informal interviews were also conducted with relevant people from Free State Agriculture and Grain SA and these were qualitatively analysed.

The most important information to answer the research question of the study came from questionnaires that were administered to maize farmers and telephonic interviews that were held with the agro-chemical distributors who supply agro-chemicals to these farmers. Further information was also obtained by means of structured interviews, informal interviews and e-mails to co-operatives, chemical industries, associations and agricultural unions. In the process of obtaining background information on maize agriculture, in the development of the study methodology and to aid in the development of the farmer questionnaire, specific literature that included, databases, reports, books, guidelines, articles and legislation was reviewed. Sources were also used to gather information regarding monitoring of treatment and disposal of agro-chemical waste and for making recommendations on effective agro-chemical management. Literature also provided information of the impact of agro-chemical waste on water resources and how this can be minimized

In the process of the pre-development of the farmer questionnaire a structured interview was held with Jack Armour from Free State Agriculture to clarify certain issues. The questions (divided into themes) for this interview can be seen in Appendix A. This included the reviewing of the themes for the interview with the chemical distributors to ensure that all the necessary questions were included, as well as a review of questions posed to farmers, to ensure that suitable and relevant questions were included in the questionnaire to the farmers.

An informal interview was also held with Anton Botha (Grain SA) to further aid in the predevelopment of the questionnaire to the farmers.

An interview was used for the organised agricultural supplier end of the supply chain (chemical distributor) and can be seen in Appendix B. Chemical distributors provided information on how farmers determine the quantities of agro-chemicals to apply, the quantities of agro-chemicals recommended to maize farmers, total quantities of agro-chemicals which they supply to their districts, as well as information on what farmers do with agro-chemical packaging and containers after use. Further information specific for fertilizer usage was also obtained from fertilizer industries, co-operations and fertilizer distributors.

An administered questionnaire which is compatible to the chemical distributor interview was used for the user end of the chain (the farmers) and can be seen in Appendix C. This questionnaire was used to obtain volumes of agro-chemicals used on farms and has additional questions aimed at agro-chemical usage, storage, disposal and wastage and issues of surrounding management of waste products such as packaging and containers and storage and disposal of oils, fuels and lubricants.

The intention was to triangulate information on agro-chemical usage at the two ends of the supply chain by comparing amounts of agro-chemicals ordered by farmers, applied by farmers, amounts recommended to farmers by chemical distributors, and amounts recommended on agro-chemical packaging. Average usage rates of agro-chemicals per hectare as reported by dry land and irrigated farmers was compared to each other and was also used to calculate estimates for total agro-chemical usage for the Free State, North West, Gauteng and for the Western maize production region of South Africa. With this data, an idea of the potential waste streams that are present in these regions could be determined in order to better understand this sector. Average usage rates for dry land and irrigated farmers combined was also compared to average usage rates as reported by chemical distributors. Understanding possible waste streams is the first step in developing a waste inventory or database to ensure better agro-chemical waste management in South Africa.

The farmer and chemical distributor questionnaires were translated from English to Afrikaans as they are more familiar with Afrikaans terms and are more comfortable in answering the questions in their home language. The translation of the questions was done by the researcher and was informally confirmed by agricultural researchers as correct.

Before the questionnaire was administered to the farmers, three pre-tests were done on three farmers outside of the study sample area to test the understandability and relevance of the questions. The farmers who were used for the pre-tests were reached through personal contacts.

3.3.1 Sampling

Thirteen farmers in the western maize production region of South Africa were targeted. Botha was used to gain access to four of the thirteen farmers that were used in the study. These farmers where selected by Botha after the criteria for the selection of the relevant farmers were provided to him. This criterion required that both dry land and irrigated farmers should be included, that they must be situated in the Free State, that they should be prominent leaders in the agricultural industry and have the necessary knowledge to suitably inform the project. The remaining nine farmers were reached through personal contacts.

The sampling areas as identified through Grain SA and personal contacts included four dry land farms, two irrigated farms and seven farms which are both dry land and irrigated. The dry land farms are located near Petrusburg, Wesselsbron/Hoopstad, Viljoenskroon and Bloemhof. The two irrigated farms are located near Bloemhof and Bothaville. The irrigated and dry land farms are located near Bloemfontein, Petrusburg, Bultfontein/Wesselsbron, and Bloemhof. Figure 6 illustrates the sampling areas of the farmers used in the study.

A subjective arbitrary classification was made on the size-scale of the farmers who participated in the study, where farmers who cultivate less than 500ha were regarded as small scale farmers and farmers who cultivate 500ha and more were regarded as large scale farmers. According to this classification eleven large scale farmers and two small scale farmers was used in the study.

The interview with FS Agriculture (Jack Armour) informed the selection of the sampling area. After this interview it was concluded that type of maize cultivated, soil type and expected yield will not play a role in the selection of the sampling areas. It was however concluded that the climatic regions and irrigated and non-irrigated maize will play a role.

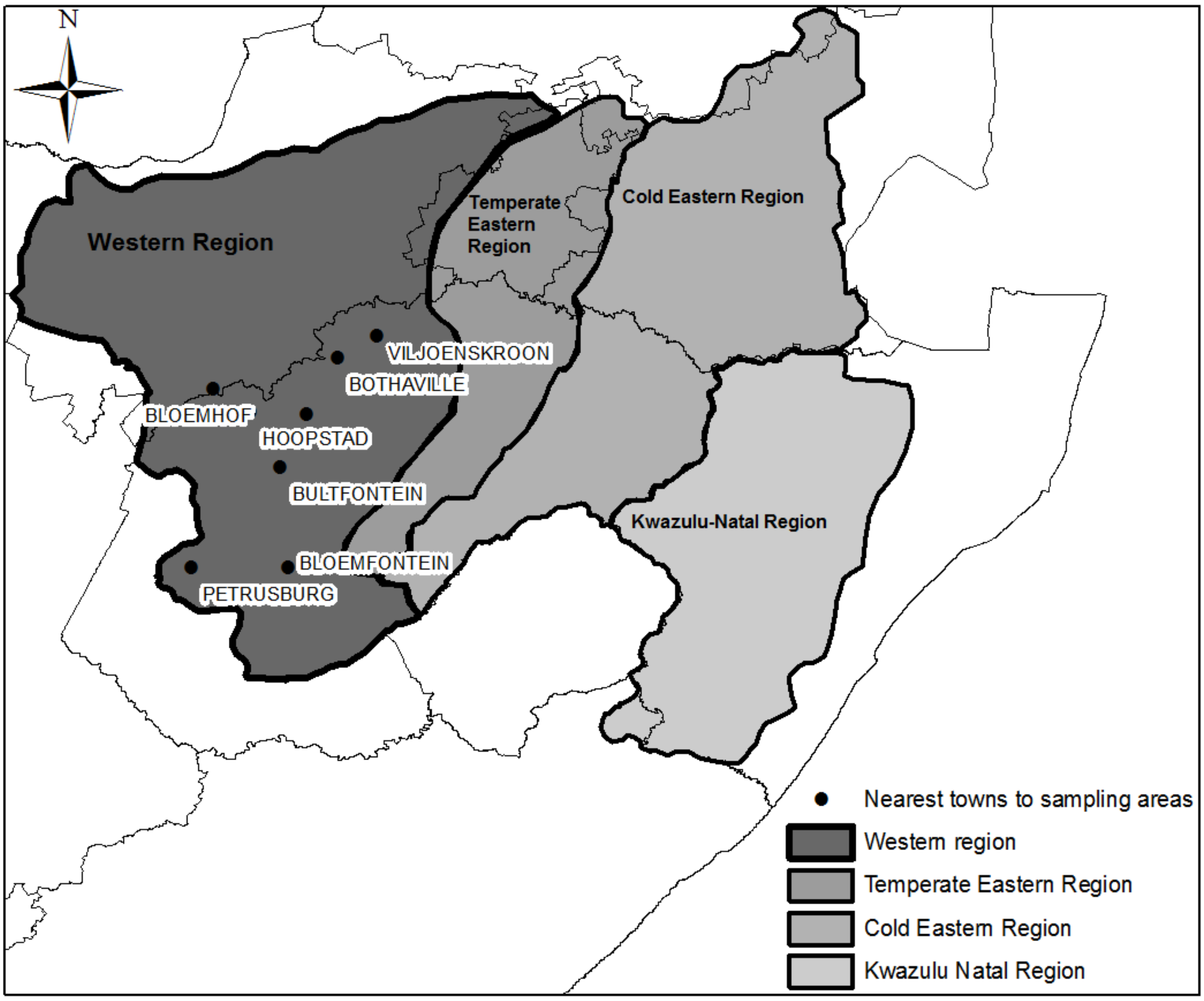

Figure 6: Sampling areas used for the study

Some of the bigger and more commercially successful farms in the region were targeted since this would lead to a more representative sample for the Free State. Selecting larger units (farms) gave a better representative coverage and therefore a better representation of the chemical waste streams. The names of the sampled farms and farmers were kept anonymous at all times to ensure that the study is executed in an ethical manner. This also made the information gathering process easier since the farmers knew that they were entering a secure research environment.

Twelve chemical distributors were interviewed for the study. Eleven of the twelve chemical distributors were approached through the farmers to whom they supply. One chemical distributor was also a farmer to whom the farmer questionnaire was administered and was reached through a personal contact. Contact details of the chemical distributors were obtained from the farmers after which they were telephonically contacted to complete the interview.

3.4 Limitations of the study

Limitations of the study included time constraints and quality of the data that were obtained and are discussed below.

3.4.1 Time constraints

Administering a detailed farmer questionnaire such as the one administered by the researcher takes time and limited the number of people who could be targeted for this study. The specific farmer questionnaire used in this study, took between 40 minutes and 2 hours to administer. The distance that had to be covered between farms was also a major time constraint and complicated the logistics of conducting the study. This resulted in a limited sample size that could be analysed for the study making it difficult to generalise results and to calculate accurate waste volumes. Finding people who are willing to put aside large amounts of time and to reach these people when they have available time was also a challenge. It is therefore probable that using this methodology to obtain information to populate a database could be quite time consuming and resource intensive (both from a human resource as well as financial resource perspective).

As the questionnaire was already lengthy, it proved to be too time consuming to collect the exact full names of all the chemicals used. This caused difficulties where the hazard class rating of the pesticides were compared to the official hazard class ratings of the pesticides. Farmers have to be warned in advance if detailed information on the exact product names is needed in order for them to have quick access to it when the questionnaire is administered. The two questions on the quantity of agro-chemicals ordered and the quantity of chemicals applied, also proved to be a problem. The aim of these two questions is to verify quantities of agro-chemicals used on farms, but the similarity of the questions leads to a repetition of information required from the farmer which a) can be confusing for the farmer and b) can easily lead to the respondent becoming impatient and irritated.

3.4.2 Quality of data

By not always obtaining the full name of the agro-chemical used (as mentioned in 3.4.1) also negatively influenced the quality of the data. Further a standard was not set to ask the respondent for either the trade name or the active ingredient of the agro-chemical used. This resulted in a mixture of trade names and active ingredients reported by the respondents which complicated the analysis of the data.

Some of the respondents (excluding chemical distributors) were apprehensive of the study and it is conceivable that some respondents might not have been quite truthful in their responses. This may make the data and calculated waste and chemical amounts less accurate. Questions were posed in the questionnaire in such a way as to re-confirm answers, by asking the same question in different ways. An example is where the farmer is asked how much of a chemical he applies for instance for a specific pest during a specific part of the production cycle. He is then asked how he determines the amount to be applied. If he states that he uses package instructions, the researcher could double check the supplied information by performing a calculation himself. If he stated that he followed recommendations from the chemical distributor, then the researcher could double check information between what amounts the distributor recommended and what amounts the farmer stated he applied. These strategies should minimize information errors, but could not exclude erroneous data.

Chapter 4 Results and discussion

This chapter will elaborate on the results of the interviews and questionnaires and will discuss these results. The data was analysed and interpreted using IBM SPSS statistics. Microsoft Excel 2010 was also used for representation of basic statistical analysis. Qualitative information was analysed thematically and is described in this chapter.

In sections 4.1 and 4.2 the results of interviews with key informants will be discussed {an interview with Jack Armour (Free State Agriculture) and an unstructured interview with Anton Botha (Grain SA)}. These interviews were conducted to aid in the development of the questionnaire administered to the farmers and in preparing for the interviews with agro-chemical distributors. The results of three farmer questionnaire pre-tests will be discussed in section 1.3 after which the results of the questionnaires administered to the farmers (section 1.4) and the interviews with the chemical distributors (section 1.5) will be discussed.

4.1 Interview with Free State Agriculture as a key informant for questionnaire development

An interview with Jack Armour (Operations manager: Land reform, AgriBEE, Farm management, Municipal liaison and resource conservation), hereinafter "Armour" was held on the 8^{th} of March 2013 to aid in the process of developing the questionnaire for the farmers. The results are discussed for each theme as it was dealt with in the interview.

The main themes include:

- Main determinants of variation in chemical use
- Type of maize that should be targeted
- Areas to be targeted
- Implements, equipment and vehicles typically used on farms
- Chemical disposal

4.1.1 Main determinants of variation in chemical use

Armour stated that it is generally regarded that chemical use as compared between white and yellow maize will be much the same. He did however recommend that seed companies like Monsanto be contacted to obtain more information on the difference in chemical use between white and yellow maize. Factors that can however play a more significant role in the variation in chemical use are the following:

- Financing plays a role in the type of maize planted and the available finances also determines what types of spraying programmes (types and amounts of chemicals applied to crops) are used.
- Some farmers make a judgment on how much chemicals to apply by just looking at the condition of the crops, others decide after establishing what the plant's needs are, others rely entirely on the guidance they get from the agro-chemical distributor that supplies to their region. The spraying programmes used by farmers are often similar between farmers who farm close to each other in a specific area.

- The amount of chemicals used on Genetically Modified (GM) crops and conventional crops does differ but about 80% of maize cultivated in the Free State is Round Up Ready (RR) maize. This will be further discussed in the next theme.
- It is also generally regarded that irrigated maize will need more pesticides and fertilizers but less herbicides than dry land maize. Irrigated maize needs less herbicides because of the shadow of closer plant spacing which kills weeds early on (Hussein *et al,* 2008). Warmer regions will also demand more chemicals than colder regions.
- Fertilizers play a role in the expected yield but not insecticides and herbicides. The narrower the spacing of the rows is in which the maize is planted (plant density) the more fertilizer will be used and the higher the yield will be. Other factors that play a role in the amount of chemicals used are soil cultivation, and the managerial abilities of the farmer (du Plessis, 2003).
- The tillage system used can also have an impact on the amount of chemicals used. Under no till, higher application of herbicides is needed and intensive herbicide management is necessary. This is because there is an earlier occurrence of leaf diseases under no till circumstances. It also requires special and adapted planters and more expensive equipment. Stubble mulch tillage also creates greater possibility of leaf diseases. Ploughing during winter or early spring and crop rotation will reduce certain weeds (du Plessis, 2003).
- Soil will play a role in the amount of fertilizer used. Soil can also play a role in the amount of insecticides and herbicides used. When maize is planted in good soils, the plants will be stronger and therefore more resistant to attacks from pests and plant illnesses.
- Weather also plays a role in the amount of chemicals used. When it is very dry, chemicals do not last as long as it would have in wetter conditions. Weather changes every year and therefore chemical use based on weather conditions is never constant.

It was recommended by Armour that factors like soil type, different expected yields, tillage systems and crop variety (conventional or variety of GM) not be used in the selection of the sampling areas for this study as these variables will complicate the study too much. The different climatic regions and the use of irrigated and dry land maize is the most executable and practicable variants to use in the determination of the sampling area. These two factors also play a role in the amount of agro-chemicals used (which was backed by Armour in the interview) and provide sufficient variety in differences in agro-chemical usage between different regions for the purposes of this study.

Armour also stated that famers would be able to give quick and accurate answers when asked to list all the chemicals used under each chemical group (insecticides, herbicides, fertilizers).

4.1.2 <u>Type of maize that should be targeted</u>

Because RR maize forms such a large part of the maize cultivated in the Free State (as mentioned in 4.1.1) it is accepted that other types of maize will not play a big enough role to influence how the sampling areas are chosen. It was also decided that the use for which the maize is processed for (popcorn, waxy, green maize and silage) will not play a role in how the sampling areas are chosen

Farmers typically cultivate more than one maize type on their farms. This is to ensure that there are other types of crops available when one crop maybe fails. Farmers also typically process the maize for different uses in case the demand for one kind suddenly drops. In this way they minimize their risk. The type of maize planted also depends on current market prices, and the contracts received by the farmers, environmental conditions, seasonal outlook, cultural systems, market niche and market value. In dry land maize the amount of stored water in the soil is important. The timing, amount of planting rain, and risks of temperature and water stress at critical times is also important (Birch *et al,* n.d.).

The different kinds of GM crops found in South Africa also include long season types (higher yields under low populations), short season types (higher yields in high populations and ideal under irrigation), short medium short, medium and medium late (Bondesio, n.d.). Conventional maize is also cultivated in the Free State but is probably less than 20% of total maize cultivated (Armour, Personal communication: 2013).

Both GM and conventional crops were included in the sampling area.

4.1.3 Areas to be targeted

The areas to be targeted were determined after gathering information on the type and variety of maize (irrigated, dry land, GM, conventional) soil type, expected yields, tillage systems, and climate regions. None of above mentioned variables played a role in the selection of the sampling areas. As was concluded, the sampling areas were only selected based on the different climatic regions and irrigated and non-irrigated crops.

4.1.4 Implements, equipment and vehicles typically used on farms

Amounts of fuel used on farms were not included in the questionnaire. Questions rather focused on fuel spillages, where implements and vehicles are re-fuelled, where fuel is stored, and the number of implements and vehicles on farms.

According to Armour handheld equipment is not often used to apply chemicals, and is only used in places which are difficult to reach by other larger vehicles.

4.1.5 Chemical disposal

Armour recommended that Gerrit Verdoorn be contacted for more information on where chemicals are taken when disposed of. It was however confirmed that some of the chemicals are stored on the farms and some are taken away by the agro-chemical distributors that serve that specific farm. It was suggested that, instead of asking a farmer how much of a chemical is wasted, it must rather be asked whether chemicals are wasted and what percentage of the chemical is wasted.

No important legislation was proposed other than what is already used in the study.

The waste cycle diagram was found to be sufficient and was recommended to stay as simple as possible.

4.1.6 Further correspondence

Contact details for Oranje-Riet irrigation scheme and Sand-Vet irrigation scheme were obtained. These are the two largest irrigation schemes in the Free State and could be used when considering selecting irrigated farms for the sample area. It was proposed that Grain SA must rather be used instead of FS Agriculture for further development of the questionnaires and to gain access to farmers in the different sampling areas. This is because Grain SA will be able to give better guidance and answers relating to the grain industry because that is their specific focus, where the focus of FS Agriculture is broader.

Armour also confirmed that the farmers associations can be given criteria on which to select farms in each of the districts used in the study.

4.2 Interview with Grain SA as a key informant for questionnaire development

An unstructured interview was held with Anton Botha (Member of Executive and Management Committee of Grain SA), on the 27th of May 2013 to aid in the pre-development of the questionnaire for the farmers. He is the regional manager of region 20 which includes Bloemfontein, Boshof, Brandhof, Bultfontein, Dealesville, Dewetsdorp, Hertzogville, Reddersburg and Vryburg. The results from the unstructured interview are discussed below.

It was proposed by Botha that the questionnaires to the farmers and chemical distributors should be translated to Afrikaans since this is the language in which they operate and are more comfortable. The main reason for this is because they are used to using Afrikaans terms and English terms can potentially lead to confusion. They will also be able to express themselves better when answering open ended questions in Afrikaans.

A question on the type of maize that is cultivated on the farm was adjusted to cater for the fact that 5% of maize cultivated on the farm should according to legislation be conventional crops (Kruger *et al*, 2011).

According to Botha (Personal Communication: 2013) rats (Highveld Gerbils) are currently a big problem in the maize industry and the chemicals used to kill them are very toxic. It was therefore proposed that questions on types and amounts of chemicals used for killing gerbils should be included in the questionnaire.

Under the theme: Waste Cycle Information, it was suggested that the questionnaire should include questions on the use of treated maize seeds since this can have a big impact on the amounts of chemicals used on farms (Botha, Personal communication: 2013). Treated maize is normally coated in insecticide and/or fungicide dressings. This protects seedlings against soil and seed borne diseases and pests and therefore reduces the amount of pesticides that are applied to it, later during the production cycle (Hugo, 2013).

Fertilizers are seen as having potential environmental impacts (Jiao *et al*, 2012; Bijay-Singh, 1995). Botha however feels that fertilizers are normally not toxic, nor hazardous, and do not hold significant threats for people or the environment and that it does not need to be included in the analysis of toxic chemicals. It was however decided that fertilizers will still be included in the analyses since the studies of Jiao *et al* (2012) and Bijay-Singh (1995) suggest that they are hazardous and could be dangerous for humans and the environment. In the questionnaire where farmers are asked how toxic the chemicals that they use are, an option of chemicals being non-toxic was included to cater for the above mentioned comment.

It was confirmed that the term “per production cycle per ha” is the correct term to use with questions relating to volumes of chemicals used on farms. It was also confirmed that the waste production cycle diagram is appropriate and sufficient.

The matter of chemical theft was however said to be important and it was proposed that a question on this should be included. According to Botha (Personal Communication: 2013) stolen chemicals are used to kill guinea fowls, which could result in chemicals ending up in places where it should not be.

A question was added that asks if a farmer disposes of or re-uses chemical packaging and containers when they are empty and two more options namely “taken to general waste site” and “collected by chemical distributor” were added as options to the question of how farmers dispose of empty packaging and containers.

Botha provided contact details of four distinguished maize farmers (of which one is also a Regional Manager of Grain SA) in the Free State who was used in the study.

4.3 **Pre-test results**

This section discusses the pre-test results that were used to finalise the questionnaire that was administered to the farmers. The pre-test was administered to three farmers and the results of these will now be discussed.

4.3.1 Respondent 1

The first pre-test was administered to an irrigation farmer in the Jacobsdal area whose farm falls just outside of the western maize production region (refer to Figure 6). The questionnaire took the farmer 90 minutes to complete.

The farmer owns nine farms and he specified that the area under maize cultivation is 40 ha and that the total area of the farms is 200 ha. It had to be rechecked afterwards and it was found that maize was only cultivated on two of the nine farms. It was decided that the farmers will be specifically asked how many farms they have on which maize is cultivated.

It was also found that the options listed under the question relating to the types of GM maize cultivated by the farmer were incomplete and irrelevant. The options relating to different growing seasons which included long season, short medium short season, medium season, medium late season and short season were removed as this information is not applicable to this study. The farmer indicated that he cultivates 100% yellow RR maize and also 100% staple gene maize. What the farmer actually cultivates is yellow staple gene maize. There was no option in the questionnaire to choose between yellow staple gene and white staple gene maize. These options were then included. It was found that white and yellow staple gene maizes are both RR and has the bt gene (Monsanto, n.d.). The option of double gene maize was removed as this also refers to staple gene. The option of single gene hybrid was removed as all maize seeds are hybrids and single gene means that the seed is either RR or has the bt gene (Ceronio, Personal communication 2013). To conclude it was found that white RR, yellow RR, white bt, yellow bt, white staple gene and yellow staple gene should be the only main maize cultivars from which the farmer can select for what is cultivated on his farm.

The question on whether the farmers use any maize hybrids was incorrect as the actual meaning of the question was to ask the farmer whether he uses any treated maize seeds. It was found that all maize seeds are hybrids and this led to the removal of the "single gene hybrid" option under the question discussed above (Ceronio, Personal communication 2013). The question on whether the farmer uses any maize hybrids and the questions related to this were then changed to refer to "treated maize" and not maize hybrids.

Under the question where it needed to be indicated what the characteristics of the chemicals are that are used by the farmer it was found that there was some confusion regarding the scale that was given to choose the answer from. The least hazardous option was listed as "acute hazard" (which means very hazardous) when it should actually have read, "acute hazard unlikely in normal use". The scale options were clarified and made more understandable by including the colour bands and the hazard symbols associated with each hazard rating where applicable (SAQA, 2006).

4.3.2 Respondent 2

The second respondent was a farmer in the Kroonstad region. The questionnaire was generally not very well completed in that some questions were incomplete and others misunderstood. It is expected that all the problems with the questionnaire could have been avoided if the questionnaire was administered to the farmer. The first and third questionnaires were accurately completed and this is an indication that factors other than the questionnaire itself resulted in the poor quality of the second pre-test. Other than this no other glitches were identified in this questionnaire.

4.3.3 Respondent 3

The third respondent completed the pre-test accurately and comprehensively. It wasn't necessary to make any major changes to the questionnaire. The fact that the questionnaire was accurately filled in without it being administered to the farmer was a good indication that the questionnaire is ready to be used for the actual study.

4.4 Farmer questionnaire results

After the pre-tests were concluded, and the questionnaire modified it was administered to 13 farmers in the western maize production region. In this section all the questions administered to the farmers will be discussed per theme as it appeared in the farmer questionnaire.

4.4.1 Geographical information

All the farms identified for this study are situated in the western maize production region of South Africa and fall within the borders of the Free State, refer back to Figure 6 to see the sampling area. The farmers either have single consolidated farming units or dispersed farming units. Dispersed farming units range from two farms to twenty farms per farmer.

The geographical locations of the farms were divided into seven different regions, each identified by the closest town to the farm. The number of farms in each geographical area is indicated in Figure 7 below.

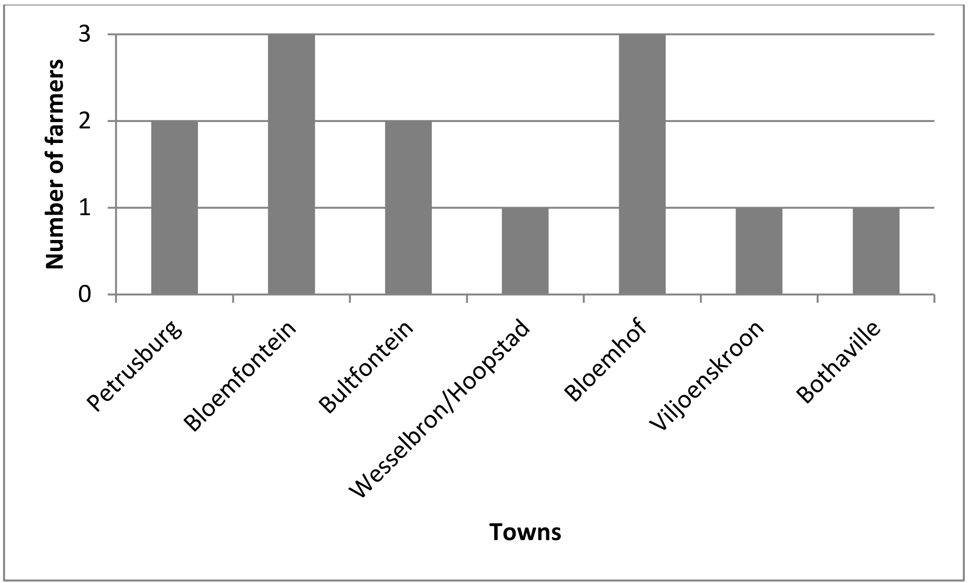

Figure 7: Number of farmers in each geographical area

The farmers used in the study include seven farmers who cultivate both dry land and irrigated maize, four farmers who only cultivate dry land maize and two farmers who only cultivate irrigated maize. Figure 8 below graphically represents the above by indicating hectares of dry land and irrigated maize per respondent.

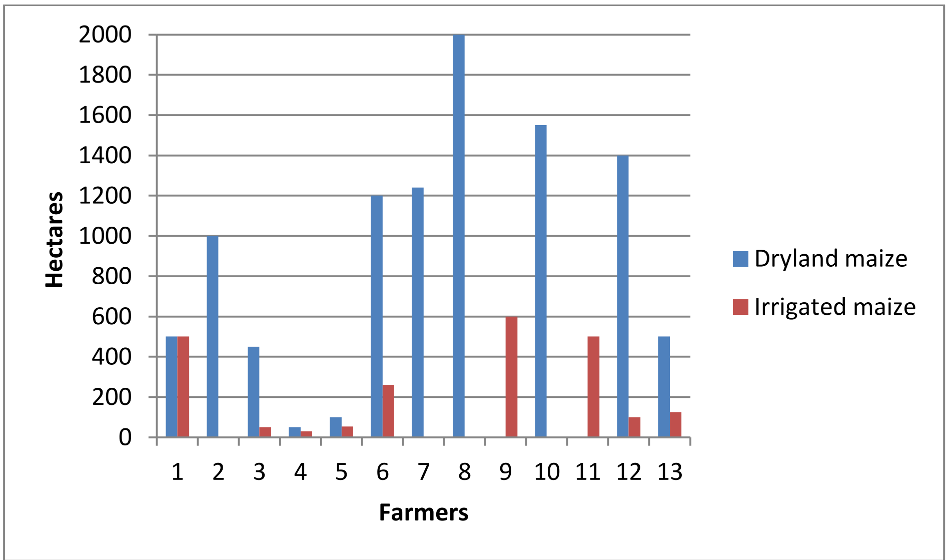

Figure 8: Distribution of dry land and irrigated maize

In Figure 9 the percentages of dry land to irrigated crops for the study sampling area, the Free State, the western maize production region and South Africa is given. In the sampling area, 82.82% of cultivated maize is dry land and 18.18% is irrigated. In the Free State, the western maize production region and in South Africa as a total respectively, the proportions of dry land maize to irrigated maize are as follows; 95.12% to 4.88%, 94.97% to 5.03% and

91.28% to 8.72% (Grain SA, 2013), see Figure 9. The sampled respondents seem to be a fair representation of the maize production region and differences. The reason for the difference between the reported percentage of irrigated vs. dry land maize in the sampling area when compared to the other regions is as a result of the small sample size. Total farm sizes of the farms used in this study range from 120 ha to 14000 ha.

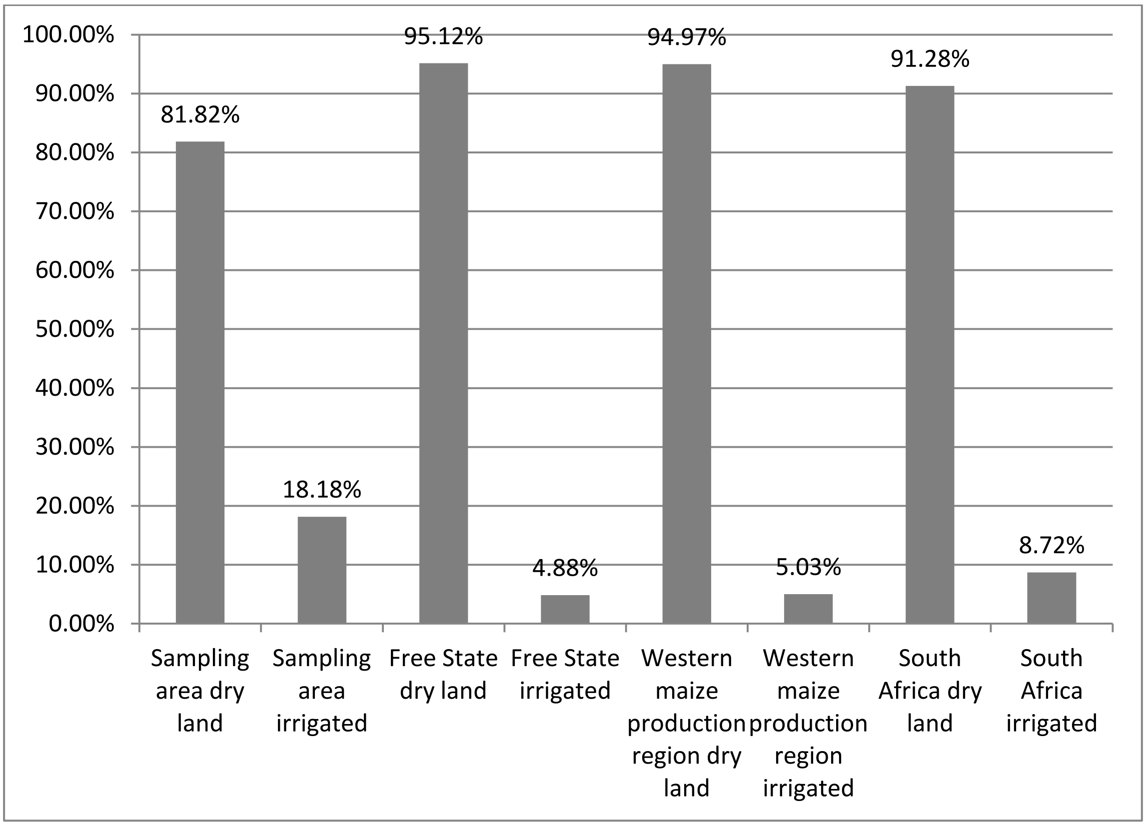

Figure 9: Percentage dry land vs. irrigated crops for the study sampling area, the Free State, the western maize production region and South Africa

The soil types reported by respondents mainly consisted of sand and sand/loam, with sand content ranging from 20% to 100% and clay content ranging from 5% to 40%. Bainsvlei, Hutton, Clovelly and Avalon include all the soil forms that were reported by the farmers, while the reported annual rainfall ranged from 350mm to 650mm. As was seen in Figure 5 the reported annual precipitation was accurately reported by the farmers in the Western Maize Production Region where the rainfall in the regions in which their farms fall range from approximately 350mm to 650mm.

The total maize production yield for each farmer was either reported as an average or an amount for the last one to three production cycles. An average was calculated for the amounts that where reported per production cycle. The average reported yield in tons per hectare per farmer for dry land maize can be seen in Figure 10. No data is shown for the first farmer as he indicated an average yield for both dry land and irrigated maize which totalled 11 tons. The average yield for all dry land farms is 4.46 ton/ha. The average yield for dry land maize farms as reported by Grain SA in South Africa is 3.57 ton/ha (Grain SA, 2013). The questionnaire results and reported statistics (Grain SA, 2013) are in the same order of magnitude.

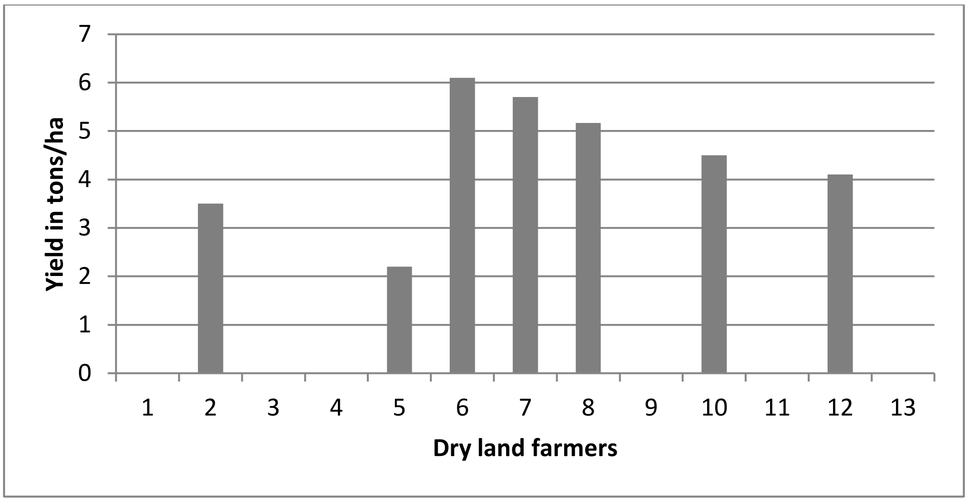

Figure 10: Yield in tons for dry land farmers

Figure 11 shows the yield for irrigated farms in tons per hectare. The average yield for all irrigated farms from respondent answers is 10.97 ton/ha while the average for irrigated maize farms in South Africa is 9.58 ton/ha (Grain SA, 2013). The questionnaire results and reported statistics (Grain SA, 2013) correspond fairly well, with survey results being 14.51% higher than the Grain SA figure.

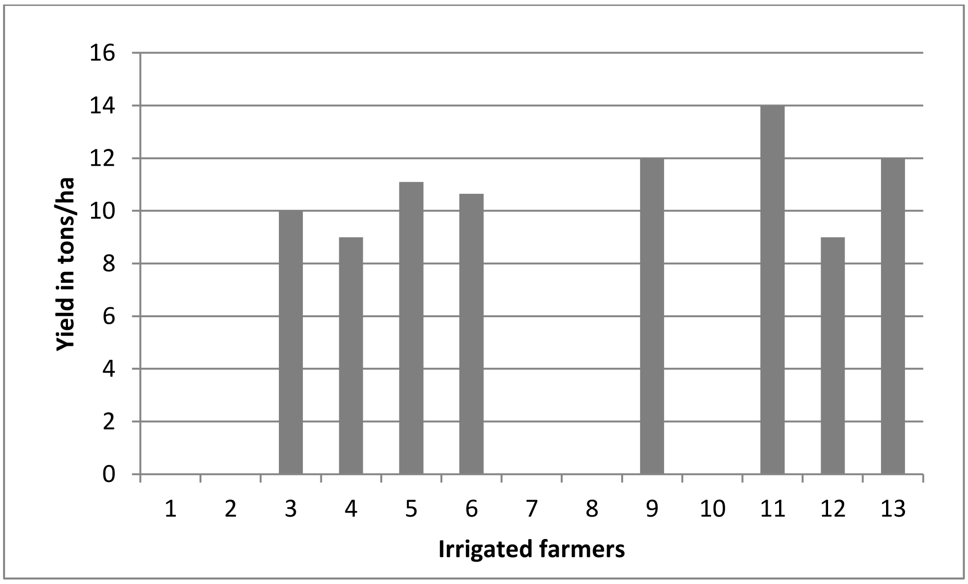

Figure 11: Yield in tons for irrigated farmers

Table 9 and Table 10 indicate the percentage of conventional maize vs. GM maize that was reported to be cultivated per farmer for dry land and irrigated maize. Farmers who plant GM maize with the bt gene are required to plant conventional maize which should make up either 5% (may not be sprayed with chemicals) or 20% (may be sprayed with chemicals) of the total area under maize cultivation on the farm. This is known as the refuge area. The refuge area is needed because when the stem borer also feeds on conventional maize it prevents them from becoming resistant to the bt gene (Kruger *et al*, 2011). Armour (Personal Communication: 2013) stated that 5% of maize should to planted as a refuge area. A respondent to the questionnaire reported that the refuge area should be 10% of the area planted to maize. One farmer reported that he only plants 5% refuge area because then no chemical applications are needed and this saves him money. This seems to be an effective way to reduce chemical usage.

Grain SA, (2010) states that there should be documented records of planting, use or production of GM cultivars.

Table 9: Percentage conventional vs. GM maize for dry land farmers

Respondent	Conventional (%)	GM (%)
R1	2	98
R2	20	80
R3	0	100
R4	100	0
R5	10	90
R6	10	90
R7	5	95
R8	30	70
R9	Not applicable	Not applicable
R10	0	100
R11	Not applicable	Not applicable
R12	5	95
R13	100	0
Average	**18.2**	**81.8**

Table 10: Percentage conventional vs. GM maize for irrigated farmers

Respondent	Conventional (%)	GM (%)
R1	Not available	Not available
R2	Only dry land	Only dry land
R3	10	90
R4	100	0
R5	10	90
R6	10	90
R7	Only dry land	Only dry land
R8	Only dry land	Only dry land
R9	100	0
R10	Only dry land	Only dry land
R11	5	95
R12	5	95
R13	100	0
Average	**42.5**	**57.5**

From the above tables one can see that dry land farmers more often plant GM maize (81.8% is reported by respondents to be GM crops), although this is not a generalizable trend as some dry land farmers do plant high percentages of conventional maize. For irrigated farmers the percentage of GM vs conventional maize is more equal (42.5% on average plant conventional crops vs 57.5% on average who plant GM crops). The combined average for dry land and irrigated maize as reported by respondents is 69.65% which corresponds well with maize planting trends in South Africa, where GreenHome (2012) reports that 77% of maize production in South Africa is GM. Armour (Personal communication, 2013) reported that GM maize probably makes up more than 80% of maize cultivated in the Free State.

The percentage of each type of GM crop that is cultivated per farmer for dry land and irrigated maize are indicated in Table 11 and Table 12 below.

Information on crop types and varieties can be useful when assessing the impact of herbicide resistant crop and GM crops on chemical use. A study by Benbrook (2012) showed that the use of herbicide resistant crops increased the use of herbicides by 239 million kilograms in the United States between 1996 and 2011. The reason for this is the spread of glyphosate-resistant weeds which brought about substantial increases in the number and volume of herbicides applied. The use of bt crops reduced insecticide applications by 56 million kilograms between 1996 and 2011. This study was done for herbicide resistant maize for soybeans and cotton and for bt maize and cotton.

Table 11: Type of GM crop cultivated indicated in percentages for dry land maize

Respondent	White RR (%)	Yellow RR (%)	bt white (%)	bt yellow (%)	White staple gene (%)	Yellow staple gene (%)
R1	0	0	0	0	0	100
R2	0	60	30	0	0	10
R3	0	10	0	0	0	90
R4	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional
R5	0	0	0	100	0	0
R6	0	0	100	0	0	0
R7	0	0	90	0	0	10
R8	0	0	100	0	0	0
R9	Only irrigated and conventional	Only irrigated and conventional	Only irrigated and conventional	Only irrigated and conventional	Only irrigated and conventional	Only irrigated and conventional
R10	7	2	0	0	73	18
R11	Only irrigated	Only irrigated	Only irrigated	Only irrigated	Only irrigated	Only irrigated
R12	0	0	15	15	35	35
R13	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional
Average	**0.777**	**8**	**37.222**	**12.777**	**12**	**29.222**

Table 12: Type of GM crop cultivated indicated in percentages for irrigated maize

Respondent	White RR (%)	Yellow RR (%)	bt white (%)	bt yellow (%)	White staple gene (%)	Yellow staple gene (%)
R1	Not available	Not available	Not available	Not available	Not available	Not available
R2	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land
R3	0	0	0	100	0	0
R4	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional
R5	0	0	100	0	0	0
R6	0	0	100	0	0	0
R7	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land
R8	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land
R9	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional
R10	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land	Only dry land
R11	70	0	30	0	0	0
R12	0	0	25	25	25	25
R13	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional	Only conventional
Average	**14**	**0**	**51**	**25**	**5**	**5**

For dry land maize bt white (37.222%) and yellow staple gene (29.222%) maize is the most popular GM maize that is planted by the respondents. For irrigated maize bt white (51%) and bt yellow maize (25%) is the most popular GM maize that is planted.

It is important to have all the information that is discussed above available when compiling a agro-chemical usage database as it can directly or indirectly have an impact on the amount of chemicals that are used. Statistics on total areas of different varieties of maize are vital to have when pesticide usage rates for different varieties of maize are to be calculated (Thomas, 1999).

4.4.2 Technical/operational information

Figure 12 is an indication of the total number of implements, vehicles and smaller items of equipment that was reported by respondents to be used on farms to apply agro-chemicals. It was found that only some of the bigger farmers use self-propelled sprayers and therefore the number of these is low. Boom sprayers are the most common implements that are used to apply agro-chemicals. Tractors are used to tow most of these implements and are also used for other activities on the farm and large numbers of them are used on farms. Handheld sprayers are not commonly used on farms and are more regularly used to apply chemicals in gardens rather than on crops. The number of implements vehicles and smaller equipment types used on farms gives an indication of the extent of equipment that should be cleaned to ensure that chemicals do not spread to un-wanted places.

According to Thomas (1999) and NSW EPA (2013) it is also important to know with what equipment agro-chemicals are applied as this can have an impact on operator or bystander safety.

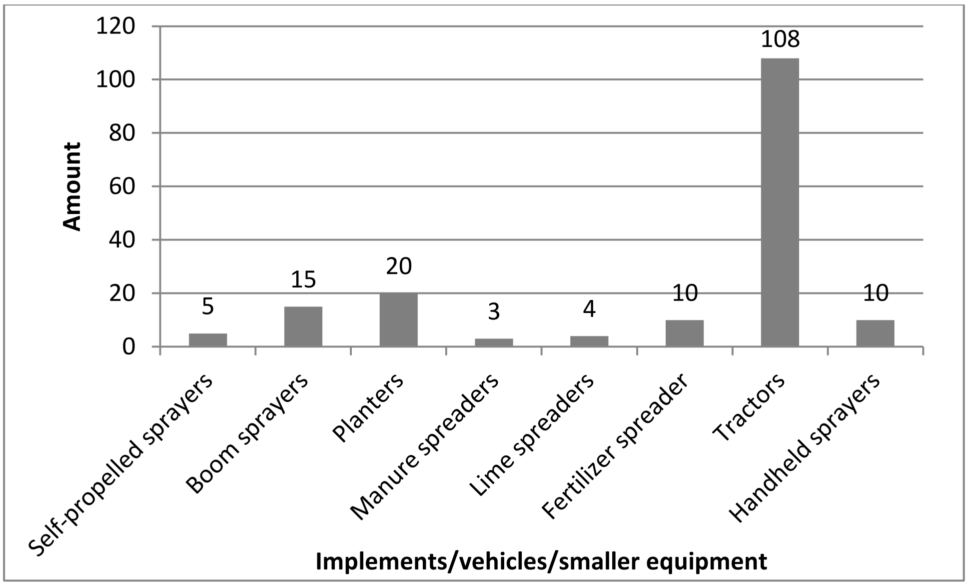

Figure 12: Total number of implements, vehicles and smaller equipment

4.4.3 <u>Waste cycle and chemical usage information</u>

This theme mainly focused on gathering information on the total volumes of insecticides, herbicides and fertilizers used in maize agriculture in order to form a baseline of total volumes of agro-chemicals used in the western maize production region of South Africa. Further data that was gathered includes the trade names/active ingredient of the agro-chemical applied by farmers, the pest or weed that the agro-chemical targets and where in the production cycle the chemical is applied. Information gathered also focussed on how effectively these chemicals are used.

DAFF (2011), Grain SA (2010), and SANS (2010) state that the trade names of all pesticides, their active ingredients, the pest/weed/disease that they target, and the total amount (or concentration in g/l) applied in weight and volume must be recorded. Grain SA (2010) also states that records of all fertilizer applications must be kept and must include the trade name, type of fertilizer, the amount thereof applied in weight and also the volume. All this data is essential in the compilation an agro-chemical usage database (Thomas, 1999).

In the process of determining the amount of agro-chemicals used on farms it is also essential to obtain data to form a baseline as recommended by chemical companies and chemical distributors. The waste cycle data that was gathered in the questionnaires administered to the farmers should be triangulated with existing data that gives an idea of quantities of agro-chemicals that can be expected to be used in maize agriculture.

There are no datasets available in South Africa on total volumes of agro-chemical usage, and therefore also no data available on total volumes of agro-chemical usage specifically on maize farms (Dickinson, 2013, Personal Communication; Borstlap, 2013, Personal Communication; Van Zyl, 2013, Personal Communication; Armour, 2013, Personal Communication; Naidoo & Buckley, 2003). One method by which this data can possibly be gathered is to approach all the companies that distribute agro-chemicals and to enquire volumes from them. There are about nine large companies in the agricultural sector and these include among others, Laeveld Agro-chem, Technichem, Bayer, Monsanto, New Lands and Syngenta. There are numerous smaller companies and all together could be in the region of thirty companies (Borstlap, 2013, Personal Communication). According to Rother and London (2008) cited in Naidoo & Buckley (2003) there are about 165 chemical companies in South Africa. Most of these companies fall under AVCASA and the Chemical and Allied Industries Association (CAIA). These associations are umbrella organisations which monitor and co-ordinate these chemical companies. AVCASA represents most of the transnational pesticide companies but some of these companies are not represented at all (Naidoo & Buckley, 2003).

According to Dickinson (Personal Communication, 2013) there was, long ago, data available on the total volumes of agro-chemicals that are used. The data was collected from chemical companies. It was not for a specific region or for any specific activities. Chemical companies showed less and less interest in providing the data and eventually the capturing of this data died down.

Waste cycle information

The method used in this study was to administer questionnaires to the farmers. Information was gathered on what insecticides, herbicides and fertilizers are applied, the concentrated quantities thereof in ℓ/ha, the pest or weed that the agro-chemical targets, and where in the maize production cycle the agro-chemical is applied. Table 13 to Table 18 shows raw data as gathered.

Table 13 shows that a variety of insecticides are used to target different pests for dry land maize. These include beetles, cutworm, and nematodes. The pests that were most prevalent in this maize production region are cutworm as well as nematodes. Most insecticides are used with planting and during the growth cycle. In Table 14 it is clear that a wide variety of herbicides are used for dry land maize to target weeds, broadleaves and grass. These herbicides are mostly applied during planting and growth of the maize crop. Table 15 shows that fertilizers that are used on dry land farms are mostly applied before and during planting. Fertilizers include N, P, K, at proportions of 2:3:2, 3:2:0, 3:1:0, 4:2:1. Table 16 shows that different insecticides are used mostly during planting and growth of the maize plant for irrigated maize to target cutworm, stalk borer as well as red spider. Table 17 shows that similar herbicides were used as for the dry land maize (Table 14) to target leaves, broadleaves, grasses and weeds during planting and growth. In Table 18 it is clear that similar fertilizers are used for irrigated maize as for dry land maize (Table 15) except for fertilizers such as ANO, 501 liquid and 502 liquid which are applied every two weeks.

Some of the agro-chemicals, identified by bold and underlined text in the tables that follow, were not included into agro-chemical usage totals (except the first bullet point). Reasons for their exclusion (or inclusion) are listed below:

- Lambda is an insecticide but was also reported to be used as a herbicide by two respondents for dry land and irrigated maize. These are bold and highlighted in Table 14 and Table 17. The products were however included in the totals for herbicides as the chemical distributor reported the same amounts for the same product for both dry land and irrigated maize.
- Counter (an insecticide) was reported in kilograms and is applied in granular form and was not included in insecticide totals as it cannot be converted to litres. Counter is bold and highlighted in Table 13.

- Triazine (a herbicide) was reported in kilograms and was not included in herbicide totals. Triazine is applied in granular form and not in liquid form and therefore was not converted to litres. Triazine is bold and underlined in Table 14.
- 2, 4-D Ester (a herbicide) was reported in kilograms but according to label instructions this product is a liquid. The label is unclear on the quantity of the product that should be diluted with water and therefore it was not included in the totals for herbicides (Villa Crop Protection, 2012). 2,4-D Ester is bold and underlined in Table 14 and Table 17.
- Curator (an insecticide) was reported in kilograms and was not included in insecticide totals as no extra information on how to convert this product to liters was found. Curator is bold and underlined in Table 16.
- Two respondents reported to use liquid fertilizers and these were also not included in fertilizer totals as the main unit used for fertilizers is kilograms. Unfortunately the researcher could not obtain enough information on the types and names of the liquid fertilizers to convert these volumes. These fertilizers are underlined and bold in Table 15 and Table 18.

One product was converted for calculation purposes and is discussed below:

- Slash 710 SG (a herbicide) was reported in kilograms and was converted to litres following label instructions. A minimum concentration of 1% (1kg in 100ℓ water) is recommended. The concentrated amount was therefore converted from 5.2kg/ha to 5.2ℓ/ha (Villa Crop Protection, 2012). This respondent reported a total amount of 12.43ℓ/ha for herbicides and therefore the Slash 710 SG is assumed to already have been included in that total. Slash is italicized in Table 14 and Table 17.

In Table 16 “Flisietelikate” is placed in inverted commas as the correct name for this product is unclear.

Table 13: Waste cycle information on dry land maize farms for insecticides

Respondent	Insecticide	Amount applied by farmer	Pest Targeted	Where in maize production cycle applied
R1	None because of bt	0	n/a	n/a
R2	Sumi alpha	0.25ℓ/ha	Beetles etc.	With planting
R3	Vantex	0.05ℓ/ha	Cutworm etc	Just after planting
R4	Lambda	0.06ℓ/ha 0.06ℓ/ha	Cutworm, stalk borer	Just before planting and during growth
R5	None (bt and treated seed is enough)	0	n/a	n/a
R6	Karate	0.08ℓ/ha	Cutworm	With planting and again 4 weeks after emergence
R7	**Counter**	**4.5kg/ha**	Nematodes	With planting
R8	None but sometimes karate	Sometimes 0.08ℓ/ha	Nematodes	
R9	Only irrigated	Only irrigated	Only irrigated	Only irrigated
R10	Sipermetrien	0.12ℓ/ha	Cutworm	Just before planting
R11	Only irrigated	Only irrigated	Only irrigated	Only irrigated
R12	Attack	0.07ℓ/ha	Cutworm	With planting
R13	None	n/a	n/a	n/a

Table 14: Waste cycle information on dry land maize farms for herbicides

Respondent	Herbicide	Amount applied by farmer	Weed targeted	Where in maize production cycle applied
R1	Roundup	1ℓ/ha	Weeds	During growth
R2	Roundup Power Max	10ℓ/ha	Broadleaves, weeds, grasses	During growth
R3	Roundup Power Max	1.7ℓ/ha	Dubbeltjies, thorns, thorn apple	3 weeks after plant
R4	Guardian	0.5ℓ/ha	Weeds	During planting
	Terbusien	0.85ℓ/ha	Grasses, weeds	During planting
	Roundup Power Max	1ℓ/ha	n/a	During growth
R5	Cantron 480 SC	0.13ℓ/ha	n/a	After till
R6	**Lambda**	**0.08ℓ/ha**	n/a	Just after planting
	Callsito	0.16ℓ/ha	Thorns, grasses, weeds	n/a
	Gardomil	1.7ℓ/ha	Thorns, grasses, weeds	n/a
	Lexar pack (Mesotrione, Terbusien, Metolachlor)	1.5ℓ/ha	n/a	n/a
R7	**Triazine**	**1kg/ha**	Broadleaves	During planting and growth
	Acetachlor	0.45ℓ/ha	Grasses	During planting and growth
	Mesotrione	0.3ℓ/ha	Grasses	During planting and growth
	S-Metolachlor	0.45ℓ/ha	Grasses	During planting and growth
	Roundup	0.8ℓ/ha	Broadleaves, grasses, weeds	Before plant
R8	Tenderbaf	0.187ℓ/ha	n/a	Just after plant
	Callisto	0.15ℓ/ha	n/a	Just after plant
	Primagram Gold 660sc	1.5ℓ/ha	n/a	Just after plant
	Karate	0.075ℓ/ha	n/a	Just after plant
	Aqua-right	0.2ℓ/ha	n/a	During growth (8 leaves)
	Callisto 480sc	0.2ℓ/ha	n/a	During growth (8 leaves)
	Gardomil Gold 600 SC	1.2ℓ/ha	n/a	During growth (8 leaves)
	Karate Zoom	0.15ℓ/ha	n/a	During growth (8 leaves)
	Complement Super	0.08ℓ	n/a	n/a

Table 14: Waste cycle information on dry land maize farms for herbicides (cont.)

Respondent	Herbicide	Amount applied by farmer	Weed targeted	Where in maize production cycle applied
R9	Only Irrigated	Only Irrigated	Only Irrigated	Only Irrigated
R10	Atrazine	2ℓ/ha	Thorn apple, Cocklebur	After planting
	Guardian	0.5ℓ/ha	Grasses, broadleaves	Before planting
	Roundup	4.5ℓ/ha	Variety	Before planting
	Cantron	0.25ℓ/ha	Broadleaves	After planting
	Harness	0.75ℓ/ha	Grasses	After planting
R11	Only Irrigated	Only Irrigated	Only Irrigated	Only Irrigated
R12	*Slash 710 (roundup)*	*5.2ℓ/ha*	Variety	Throughout cycle
	2,4-D Ester	**1kg/ha**	Broadleaves	n/a
	Select	0.375ℓ/ha	Grasses	After planting
	Terbusien 600	1.75ℓ/ha	Broadleaves	After planting
	Remus	1.7ℓ/ha	Grasses	Before planting
R13	Extrazine/Atrazine	2ℓ/ha	Broadleaves	Before emergence

Table 15: Waste cycle information on dry land maize farms for fertilizers

Respondent	Fertilizer	Amount applied by farmer	Where in maize production cycle applied
R1	2:3:2	120kg/ha	With planting
R2	3:2:0 or 3:1:0	150-200kg/ha	With planting
R3	2:1:0 (30)	200kg/ha	During planting
	Urea	50kg/ha	During planting
R4	2:3:2 (35)	300kg/ha dry	n/a
	2:3:2 (35)	**300ℓ/ha liquid**	n/a
R5	n/a	200kg/ha ordered	n/a
R6	Pre-mixed package	200kg/ha	Before plant
	Urea MAP	150kg/ha	During planting
R7	K	15kg/ha	Before and during plant
	MAP (P)	35kg/ha	Before and during plant
	Urea (N)	110kg/ha	Before and during plant
R8	n/a	250kg/ha	n/a
	n/a	121kg/ha	n/a
R9	Only irrigated	only irrigated	Only irrigated
R10	N (KAN)	220kg/ha	Before planting
	NPK 4:2:1 (21)	260kg/ha	During planting
R11	Only irrigated	only irrigated	Only irrigated
R12	N	90kg/ha	With planting
	P	18kg/ha	With planting
	K	9kg/ha	With planting
R13	MAP 4:2:7	200kg/ha	With planting
	Urium	100kg/ha	After emergence (8 leaves)

Table 16: Waste cycle information on irrigated maize farms for insecticide

Respondent	Pesticide	Amount applied by farmer	Pest targeted	Where in maize production cycle applied
R1	"Flisietelikate"	0.2ℓ/ha	Insects	During growth
R2	Only dry land	Only dry land	Only dry land	Only dry land
R3	Vantex	0.05ℓ/ha	Cutworm	Just after planting
R4	Lambda	0.12ℓ/ha and 0.12ℓ/ha	Cutworm and stalk borer	With planting and during growth
R5	None bt does job but 150ml/ha lambda can be applied	0	n/a	n/a
R6	Karate	0.08ℓ/ha	Cutworm	With planting
R7	Only dry land	Only dry land	Only dry land	Only dry land
R8	Only dry land	Only dry land	Only dry land	Only dry land
R9	Karate	0.1ℓ/ha		During growth
	Dursban	1ℓ/ha	Stalk borer	n/a
	Curator	**15kg/ha**	Red spider	With planting
R10	Only dry land	Only dry land	Only dry land	Only dry land
R11	Attack	0.15ℓ/ha and 0.1l/ha		After plant and during growth
R12	Attack	0.07ℓ/ha	Cutworm	With planting
R13	Akito	0.2ℓ/ha	Worms	During growth
	Mesomol	0.25ℓ/ha	n/a	During growth
	Chlorofirifos	1ℓ/ha	n/a	During growth

Table 17: Waste cycle information on irrigated maize farms for herbicides

Respondent	Herbicide	Amount applied by farmer	Weed targeted	Where in maize production cycle applied
R1	Acetachlor	3ℓ/ha	Leaves, grasses	During till
	Roundup	3ℓ/ha	Weeds	During growth
R2	Only dry land	Only dry land	Only dry land	Only dry land
R3	Metholochlor	1ℓ/ha	Grasses before emergence	During growth
	Atrazine	1ℓ/ha	Broadleaves	During growth
R4	Guardian S EC	1ℓ/ha	Weeds	With planting
	Terbusien super 600	1.7ℓ/ha	Weeds, grasses	With planting
	Cantron 480 SC	0.26ℓ/ha	n/a	n/a
	Roundup power max	2ℓ/ha	n/a	During growth
R5	**Lambda**	**0.08ℓ/ha**		
R6	Gardomil Gold	0.5ℓ/ha	Weeds	With planting
	Lexar pack (Mesotrione, Terbusien, Metolachlor)	1ℓ/ha	Weeds	With planting
	Amistar	0.5ℓ/ha	Thorns, grasses	With planting
R7	Only dry land	Only dry land	Only dry land	Only dry land
R8	Only dry land	Only dry land	Only dry land	Only dry land
R9	Atrazine	1ℓ/ha	Broadleaves, weeds	After planting
	Acetachlor	0.5ℓ/ha	Broadleaves, weeds	After planting

Table 17: Waste cycle information on irrigated maize farms for herbicides (cont.)

Respondent	Herbicide	Amount applied by farmer	Weed targeted	Where in maize production cycle applied
	Cantron	0.25ℓ/ha	Broadleaves, weeds	After planting
R10	Only dry land	Only dry land	Only dry land	Only dry land
R11	Gardomil Gold	2.5ℓ/ha	Grasses, broadleaves	Just before plant
	Dual	0.6ℓ/ha	Grasses, broadleaves	Just before plant
	Campus	0.1ℓ/ha	Grasses, broadleaves	During growth
	Dash	1ℓ/ha	Grasses, broadleaves	During growth
	Atranex	1.5ℓ/ha	Grasses, broadleaves	During growth
R12	*Slash 710 (Roundup)*	*5.2ℓ/ha*	Variety	Throughout cycle
	2,4-D Ester	**1kg/ha**	Broadleaves	n/a
	Select	0.375ℓ/ha	Grasses	After planting
	Terbusien 600	1.75ℓ/ha	Broadleaves	After planting
	Remus	1.7ℓ/ha	Grasses	Before planting
R13	Atrazine	2ℓ/ha	Broadleaves	Before emergence

Table 18: Waste cycle information on irrigated maize farms for fertilizers

Respondent	Fertilizer	Amount applied by farmer	Target	Where in maize production cycle applied
R1	2:3:2 (35)	400kg/ha	Plant fertilizer	With planting
	Amoniumsulfate	500kg/ha	Top fertilizer	After planting
R2	Only dry land	Only dry land	Only dry land	Only dry land
R3	Urea	200kg/ha	n/a	During growth
	2:3:2 (30)	450kg/ha	n/a	With planting and during growth
R4	2:3:2 (35)	300kg/ha dry	n/a	n/a
	2:3:2 (35)	**300kg/ha liquid**	n/a	n/a
R5	n/a	900kg/ha (ordered)	n/a	After planting
R6	Pre-mixed package	200kg/ha	n/a	Before planting
	Urea MAP	150kg/ha	n/a	With planting
R7	Only dry land	Only dry land	Only dry land	Only dry land
R8	Only dry land	Only dry land	Only dry land	Only dry land
R9	N	220kg/ha	n/a	During planting
	P	60kg/ha	n/a	During planting
	K	75kg/ha	n/a	During planting
R10	Only dry land	Only dry land	Only dry land	Only dry land
R11	2:3:2	300kg/ha	n/a	With planting
	Urea	200kg/ha	n/a	Before planting
	N (Urea)	100kg/ha	n/a	Repeated every 2 weeks
	ANO	100kg/ha	n/a	Repeated every 2 weeks
	ANO	100kg/ha	n/a	Repeated every 2 weeks
	501 liquid	100kg/ha	n/a	Repeated every 2 weeks
	502 liquid	150kg/ha	n/a	Repeated every 2 weeks
R12	N	110kg/ha	n/a	With planting
	P	18kg/ha	n/a	With planting
	K	9kg/ha	n/a	With planting
R13	MAP 4:2:7	200kg/ha	n/a	With planting
	Urea	100kg/ha	n/a	After emergence (8 leaves)

For fertilizers only, two dry land and two irrigation farmers reported their usage in the amounts of N P and K used. When comparing the average amount of N P and K used in South Africa as reported by FAO (2005) the amounts used by farmers are higher. Although the amounts reported by the FAO (2005) for the country is not strictly comparable to the region investigated in this study due to differing climates and soils between the different regions, this comparison serves to determine whether fertilizer usage are of a similar range. The comparison can be seen in Table 19.

Table 19: Comparison of fertilizer usage rate of South Africa to N, P and K usage rate of dry land and irrigated farmers (FSSA, 2004 cited in FAO, 2005)

Crop	Proportion of crops fertilized (%)	N	P_2O_5	K_2O
Maize		**Rate, kg/ha of fertilized area**		
South Africa	95	55	30	6
R7 (dry land)		110	35	15
R12 (dry land)		90	18	9
R9 (irrigated)		220	60	75
R12 (irrigated)		110	18	9
Average		**132.5**	**32.75**	**27**

Table 20 lists the different poisons that were reported to be used to kill Highveld Gerbils. From this information the toxicity of the products that are used can be assessed (see 4.4.4.5) and it is also an indication of the amounts of these poisonous products that could eventually end up harming or killing non- target organisms.

Table 20: Poison and volumes used for Highveld Gerbils

Respondent	Highveld Gerbils poison used	Amount applied by farmer
R6	Zinc sulphite mixed with molasses and syrup	n/a
R7	Zinc phosphide and Ridak	80g/ha
R8	Hyper Rat	100x10kg
R9	Zinc phosphide with cooking oil and peanut butter	1kg/50kg seed
R10	Aviknaag (chopped grain with Zinc phosphide) Metoxin gas (Magnesium phosphide)	n/a
R11	Zinc sulphite	1kg on 50kg weed seed that gerbils then eat or 5ml per hole
R12	Ridak (not zinc sulphite)	n/a

<u>Comparisons between quantities of agro-chemicals ordered, applied and recommended</u>

Data on the volumes of insecticides, herbicides and fertilizers was gathered for quantities of agro-chemicals ordered by farmers in order to be compared with quantities applied by the farmers. This data was gathered through the farmer questionnaires. Comparing the quantities ordered to the quantities applied by farmers is a possible method to assess wastage of agro-chemicals. Data was further verified by asking the chemical distributors of the farmers what volumes of agro-chemicals they recommend to the farmers. Chemical distributors were also asked what the total quantities of insecticides, herbicides and fertilizers are that they supply to farmers in their districts. This data was gathered via the chemical distributor interviews.

Data captured via the farmer questionnaires and chemical distributor interviews proved to be less than ideal with respect to identifying trends and confirming comparability between sets of data and therefore is not ideal to assess possible wastage of agro-chemicals. The reasons for this are most likely factors such as:

- Small sample size
- Confusion between different quantities of pesticides used from season to season
- Influence of individual farmer choices possibly as a result of:
    - Cash flow restrictions
    - Risk taking
    - Experimentation

Comparisons were however still made between the datasets by classifying the data as comparable or not comparable. This was done by calculating a percentage change between different data sets for each farmer. These variances between the data were subjectively classified in groups where data with a variance of less than 50% is classified as comparable and data with a variance of more than 50% is classified as not comparable. Comparisons were made between the following data sets for each farmer.

- Agro-chemicals applied vs. agro-chemicals ordered for dry land farmers
- Agro-chemicals recommended vs. agro-chemicals applied for dry land farmers
- Agro-chemicals applied vs. agro-chemicals ordered for irrigated farmers
- Agro-chemicals recommended vs. agro-chemicals applied for irrigated farmers
- Average agro-chemical usage for dry land and irrigated maize vs. average for dry land and irrigated district totals

Table 21 shows the volumes of insecticides ordered and applied for both dry land and irrigation farmers as well as the quantities recommended by chemical distributors. It then shows the total volumes of insecticides as reported by chemical distributors for specific districts, the size of the maize lands and a self-calculated usage in ℓ/ha for each district. Averages in ℓ/ha are also given for volumes of insecticides ordered and applied by farmers for dry land and irrigated maize as well as for the two combined. The average usage rate per hectare in ℓ/ha for all the districts combined is also given.

Table 21: Quantities of insecticides as reported by farmers and chemical distributors for dry land and irrigated farms including totals for districts

Insecticide	Farmer dry ordered (ℓ/ha)	Farmer dry applied (ℓ/ha)	Agent dry recom (ℓ/ha)	Farmer irr ordered (ℓ/ha)	Farmer irr applied (ℓ/ha)	Agent irr recom (ℓ/ha)	Districts	Total pes district dry and irr (ℓ/ha)	Total maize area in district (ha)	District dry and irr (ℓ/ha)
R1	5.000	**0.000**	**0.000**	Not available	0.200	Not available				
R2	**0.250**	**0.250**	Not available	no irr	no irr	no irr				
R3	**0.050**	**0.050**	**0.050**	**0.050**	**0.050**	**0.050**	**Bloemfontein, Petrusburg, Bultfontein, Edenburg, Redersburg**	60	1200	0.050
R4	**0.150**	**0.120**	**0.120**	**0.300**	**0.240**	**0.240**				
R5	**0.000**	**0.000**	**0.150**	**0.000**	**0.000**	**0.150**	**Bloemfontein region**	5500	8000	0.688
R6	Not available	0.080	1.495	Not available	0.080	1.495				
R7	**4.5kg**	**4.5kg**	7kg	no irr	no irr	no irr				
R8	**0.000**	**0.000**	**0.000**	no irr	no irr	no irr	**Warrenton, Hertzogville, Hoopstad, Bloemhof**	10000	40000	0.250
R9	no dry	no dry	no dry	Not available	**1ℓ 15kg**	**3ℓ 18kg**	**Christiana, Bloemhof, Hertzogville, Hoopstad**	6500	12000	0.542
R10	**0.120**	**0.120**	**0.100**	no irr	no irr	no irr	**Wesselsbron**			
R11	no dry	no dry	no dry	n/a	**0.250**	**0.250**				
R12	Not available	0.070	1.020	Not available	0.070	1.021				
R13	**0.000**	**0.000**	**0.000**	**1.000**	**1.450**	**1.200**	**Schweizer Reneke, Bloemhof, Migdol, Goudina, Amalia**	4000	35000	0.114
Average		**0.069**			**0.371**		**Total pes|Total area|avg ℓ/ha**	26060	96200	**0.329**
Avg applied dry and irr										**0.220**

*Dry – Dry land *Avg - Average *Insec - Insecticides *kg – Kilogram *ha - Hectare
*Irr – Irrigated *Agent – Chemical distributor *Recom – Recommended *ℓ - Litres

Note: All data that is in bold represent data that is comparable between what the farmer applies and what the farmer orders and between what is recommended by the chemical distributor and what is applied by the farmer. The same applies for data in normal text but is not comparable. Data highlighted in grey for respondents was reported in kilograms and was not included in the totals as the main unit used to report insecticides usage was ℓ/ha.

For the data that is available for dry land farmers for insecticides, 88.89% (n=8) is comparable for the volumes applied by farmers and the volumes ordered by farmers, and 77.77% (n=7) is comparable for the volumes recommended by chemical distributors and the volumes applied by farmers.

For irrigated farms 100% (n=4) is comparable between volumes applied by farmers and volumes ordered by farmers, and 75% (n=6) is comparable for volumes recommended by chemical distributors and volumes applied by farmers.

For respondent five, the volume as recommended by the chemical distributor (0.150 ℓ/ha) and the volume applied by the farmer (0.000 ℓ/ha) was according to the opinion of the researcher subjectively classified as comparable since it was not possible to calculate a percentage change with a zero value.

For respondent nine, the kilogram values were added to the litre values by assuming similar specific gravities (s.g.) of $1g/cm^3$ for both the fluid and solid substances in the absence of specific s.g. information. A percentage change was thereafter calculated between the volume of insecticides recommended by the chemical distributor and the volume of insecticides applied by the farmer.

The average combined volume of insecticides used for dry land and irrigation maize farms is comparable with the calculated district average.

Average insecticide use for irrigated farms was higher than that for dry land farms. According to Armour (Personal Communication, 2013) it is generally regarded that chemical usage is higher for irrigated maize than for dry land maize.

For dry land farmers only 50% (n=5 out of the 10) apply insecticides exactly according to chemical distributor recommendations, and for irrigation farmers 37.5% (n=3 out of 8) apply insecticides exactly according to chemical distributor recommendations.

Table 22 shows the volumes of herbicides ordered by dry land farmers, applied by dry land farmers, quantities recommended by chemical distributors, and the same for irrigation farmers. It then shows the total volumes of herbicides as reported by chemical distributors for specific districts, the size of the districts and a self-calculated usage rate in ℓ/ha for herbicides for each district. Averages in ℓ/ha are also given for volumes of herbicides applied by farmers for dry land and irrigated maize as well as for the two combined. The average usage rate per hectare in ℓ/ha for all the districts combined is also given.

Table 22: Quantities and total quantities of herbicides as reported by farmers and chemical distributes for dry land and irrigated farms including totals for districts

Herbicides	Farmer dry ordered (ℓ/ha)	Farmer dry applied (ℓ/ha)	Agent dry recom (ℓ/ha)	Farmer irr ordered (ℓ/ha)	Farmer irr applied (ℓ/ha)	Agent irr recom (ℓ/ha)	Districts	Total her district (ℓ)	Total maize area in district (ha)	District dry and irr (ℓ/ha)
R1	3.000	1.000	Not available	Not available	6.000	Not available				
R2	**10.000**	**10.000**	Not available	no irr	no irr	no irr				
R3	7.000	**1.700**	**1.700**	**3.000**	**2.000**	**2.000**	**Bloemfontein, Petrusburg, Bultfontein, Edenburg, Redersburg**	40 000	9 000	4.444
R4	**2.000**	**2.480**	**2.480**	**4.000**	**4.960**	**4.960**				
R5	5.000	**0.080**	**0.080**	5kg	**0.080**	**0.080**	**Bloemfontein region**	12 500	8 000	1.563
R6	Not available	**3.360**	**3.750**	Not available	2.000	Not available				
R7	Not available	**2l 1kg**	**1.700**	no irr	no irr	no irr	**Wesselsbron**	87 500	25 000	3.500
R8	Not available	**3.742**	**5.000**	no irr	no irr	no irr	**Warrenton, Hertzogville, Hoopstad, Bloemhof**	140 000	40 000	3.500
R9	no dry	no dry	no dry	Not available	**1.750**	**2.200**	**Christiana, Bloemhof, Hertzogville, Hoopstad**	35 000	12 000	2.917
R10	Not available	8.000	Not available	no irr	no irr	no irr				
R11	no dry	no dry	no dry	Not available	**5.700**	**4.200**				
R12	Not available	12.430	3.95l 1kg	Not available	12.430	3.95l 1kg				
R13	**2.000**	**2.000**	**1.600**	**2.000**	**2.000**	**1.600**	**Schweizer Reneke, Bloemhof, Migdol, Goudina, Amalia**	250 000	35 000	7.143
Average		**4.254**			**4.102**		**Total her|Total area|avg ℓ/ha**	565 000	129 000	**3.844**
Avg applied dry and irr										**4.178**

*Dry – Dry land *Recom - Recommended *Her – Herbicides *kg – Kilogram *ha - Hectare
*Irr – Irrigated *Agent – Chemical distributor *Avg – Average *ℓ - Litres

Note: All data that is in bold represent data that is comparable between what the farmer applies and what the farmer orders and between what is recommended by the chemical distributor and what is applied by the farmer. The same applies for data in normal text but is not comparable. Data highlighted in grey for respondents was reported in kilograms and was not included in the totals as the main unit used to report herbicides usage was ℓ/ha.

For dry land farmers 50% (n=3) of available data are comparable for volumes applied by farmers and volumes ordered by farmers, and 87.5% (n=7) are comparable for volume recommended by chemical distributors and volumes applied by farmers.

For irrigated farmers 75% (n=3) of available data is comparable for volumes applied by farmers and volumes ordered by farmers, and 85.71% (n=6) is comparable for volumes recommended by chemical distributors and volumes applied by farmers.

For respondent five, litres were compared to kilograms where the percentage change between volume of herbicides applied by the farmers and the volume ordered by the farmer was calculated.

For respondents seven and twelve, the kilogram value was added to the litre value to calculate the percentage change between the datasets assuming similar specific gravity (s.g.) of $1 g/cm^3$ for both the fluid and solid substances in the absence of s.g. information.

The average volume of herbicides for dry land and irrigated farms put together is comparable to the average calculated from district totals.

Average herbicide use for dry land farms was slightly higher than for irrigated farms and corresponds to Hussein *et al* (2008) who confirms this statement (4.1.1). For dry land farmers only 37.5% (n=3 out of 8) apply herbicides exactly according to chemical distributors recommendations, and for irrigation farmers 42.86% (n=3 out of 7) apply herbicides exactly according to chemical distributor recommendations.

Table 23 shows the mass of fertilizers ordered, and applied by dry land farmers, quantities recommended by chemical distributors for dry land farmers, and the same for irrigation farmers. Averages are also given in kg/ha for mass of fertilizers applied for dry land and irrigated farms as well as for the two combined.

Table 23: Quantities and total quantities of fertilizers as reported by farmers and chemical distributors for dry land and irrigated farms

Fertilizers	Farmer dry ordered (kg/ha)	Farmer dry applied (kg/ha)	Agent dry recom (kg/ha)	Farmer irr ordered (kg/ha)	Farmer irr applied (kg/ha)	Agent irr recom(kg/ha)
R1	Not available	120	Not available	Not available	900	Not available
R2	**150**	**175**	Not available	no irr	no irr	no irr
R3	**250**	**250**	**250**	**650**	**650**	**650**
R4	**100**	**100**	Not available	**300kg 300ℓ**	**300kg 300ℓ**	Not available
R5	**200**	**200**	Not available	**900**	**900**	Not available
R6	**350**	**350**	Not available	500	350	Not available
R7	Not available	**160**	**167**	no irr	no irr	no irr
R8	**250kg 121ℓ**	**250kg 121ℓ**	610	no irr	no irr	no irr
R9	no dry	no dry	no dry	Not available	355	1000
R10	Not available	480	Not available	no irr	no irr	no irr
R11	no dry	no dry	no dry	Not available	1050	Not available
R12	Not available	117	Not available	Not available	137	Not available
R13	**300**	**300**	Not available	850	300	Not available
Average		**227.454**			**549.111**	
Avg applied dry and irr	**388.283**					

*Dry – Dry land | *Avg – Average | *kg - Kilogram
*Irr – Irrigated | *Recom – Recommended | *ℓ - Litres
*Agent – Chemical distributor | *ha - Hectare

Note: All data that is in bold represent data that is comparable between what the farmer orders, what he applies and what is recommended by the chemical distributor. The same applies for data in normal text but is not comparable. Data highlighted in grey was reported in litres and was not included in the totals as the main unit used for fertilizers are kilograms.

Very little data is available for quantities recommended by chemical distributors. The reason for this is that chemical distributors either supply insecticides and herbicides, or fertilizers to farmers, but seldom both. For this reason only insecticide and herbicide distributors were initially reached. Data for quantities of fertilizers used was gathered from cooperatives, fertilizer industries and also a few fertilizer distributors but not necessarily the distributors for the farmers used in the study.

For dry land farmers 100% (n=7) of available data is comparable between amounts applied by farmers and amounts ordered by farmers. Data for only three chemical distributors are available for amounts of fertilizer recommended to farmers, where 66.6% (n=2) of this data is comparable to what is applied by farmers.

For irrigated farms 80% (n=4) of available data is comparable between quantities applied by farmers and quantities ordered by farmers. Data for only two chemical distributors are available for quantities of fertilizer recommended to the farmer. Of this 50% (n=1) is comparable to the quantities applied by farmers. Respondents four and eight use both solid and liquid fertilizer.

The average fertilizer use for dry land farms (227.455kg/ha) is a lot less than the average fertilizer use for irrigated farms (549.110kg/ha). According to La Cock (Personal communication: 2013) the average fertilizer use for dry land farms are much less than those for irrigated farms. A good average for dry land fertilizer is 150-200kg/ha and for irrigated farms is 700-1100kg/ha.

Table 24 shows the total volumes of fertilizers for dry land and irrigated maize as reported by chemical distributors for specific districts. It also shows the size of the districts and a self-calculated usage rate in kg/ha for each of the districts. An average fertilizer usage rate in kg/ha for all the districts combined is also given.

Table 24: District totals for fertilizers as reported by chemical distributors

Districts	Total per district (kg)	Total maize area in district (ha)	District dry & irr (kg/ha)
Bultfontein	17 000 000	76 000	223.68
Wesselsbron	14 000 000	63 500	220.47
Westford-Bothaville Hoopstad Bultfontein, Wesselsbron	70 000 000	190 000	368.42
Provert-Bloemfontein, Soutpan, De Brug	12 000 000	22 300	538.12
Warrenton, Hertzogville, Hoopstad, Bloemhof	15 000 000	50 000	300.00
Omnia 1 Christiana, Bloemhof, Hertzogville, Hoopstad	9 000 000	30 000	300.00
Omnia 2 Christiana, Bloemhof, Hertzogville, Hoopstad	12 000 000	70 000	171.43
Omnia 3 Christiana, Bloemhof, Hertzogville, Hoopstad	15 000 000	70 000	214.29
Driehoekkunsmis (Free State, North-West)	30 000 000	120 000	250.00
Bloemhof	7 000 000	35 000	200.00
Bloemfontein, Petrusburg, Reddersburg, Bultfontein	not available	not available	350.00
Total fer|Total area|avg kg/ha	**201 000 000**	**726 800**	**285.13**

*Fer – Fertilizers *Irr – Irrigated *Kg - Kilogram
*Avg – Average *Dry – Dry land *ha - Hectare

The average fertilizer mass as reported for maize by dry land and irrigation farmers (388.28 kg/ha, see Table 23) are comparable to the average for fertilizer district totals (285.13 kg/ha, see Table 24). Although these figures can strictly not be compared due to differing soils and climates, it is still compared so see if usage figures are in a similar range.

Volumes of chemical usage for the Western maize production region

Table 25 shows the area under white and yellow maize for dry land and irrigated maize for the Free State, North West and Gauteng. These three provinces were selected as they form the main part of the western maize production region. Therefore the totals in Table 25 are assumed to be more or less what the totals will be for the western maize production region.

Table 25: Total area maize (Grain SA, 2013)

Province	Dry land			Irrigation		
	White (ha)	Yellow (ha)	Total	White (ha)	Yellow (ha)	Total
Free State	715 000	455 000	1 170 000	10 000	50 000	60 000
North West	545 000	159 000	704 000	20 000	16 000	36 000
Gauteng	67 000	41 500	108 500	7 000	2 000	9 000
Total (Western maize production region)	**1 327 000**	**655 500**	**1 982 500**	**37 000**	**68 000**	**105 000**

In Table 26 the total areas of white and yellow maize for dry land farms were combined and multiplied by the average insecticide, herbicide and fertilizer use as reported by dry land farmers to arrive at a total agro-chemical use for each province. The totals for each province were summed to obtain the total chemical use for the western maize production region. In Table 27 the same was done as in Table 26 but for irrigated maize. It must again be noted that different soils and climates as well as varying types and amounts of insects and weeds reported for the different provinces makes this comparison less than ideal, nevertheless it serves to check whether average pesticide usage reported per province is in a similar range to those reported by farmers for the province under investigation.

Table 26: Total dry land maize agro-chemical usage per province and for western maize production region

Region	Free State	North West	Gauteng	Western maize production region
Total dry land white and yellow maize (ha)	1 170 000	704 000	108 500	**1 982 500**
Avg insecticide usage (ℓ/ha)	0.069	not available	not available	
Total insecticide usage (ℓ)	80 730	48 576	7 487	**136 793**
Max for dry land insecticide (ℓ/ha)	0.250	not available	not available	
Min for dry land insecticide (ℓ/ha)	0.000	not available	not available	
Median for dry land insecticide (ℓ/ha)	0.070	not available	not available	
Avg herbicide usage (ℓ/ha)	4.254	not available	not available	
Total herbicide usage (ℓ)	4 976 967	2 994 688	461 539	**8 433 195**
Max for dry land herbicides (ℓ/ha)	12.430	not available	not available	
Min for dry land herbicides (ℓ/ha)	0.080	not available	not available	
Median for dry land herbicides (ℓ/ha)	2.350	not available	not available	
Avg fertilizer usage (kg/ha)	227.454	not available	not available	
Total fertilizer usage (kg)	266 116 500	160 124 800	24 678 325	**450 919 625**
Max for dry land fertilizers (kg/ha)	480	not available	not available	
Min for dry land fertilizers (kg/ha)	117	not available	not available	
Median for dry land Fertilizers (kg/ha)	200	not available	not available	

*Avg – Average *ha – Hectare *ℓ - Litres *Kg – Kilogram
*Min – Minimum *Max – Maximum

Table 27: Total irrigated maize agro-chemical usage per province and for western maize production region

Region	Free State	North West	Gauteng	Western maize production region
Total irrigated white and yellow maize (ha)	60 000	36 000	9 000	**105 000**
Avg insecticide usage (ℓ/ha)	0.371	not available	not available	
Total insecticide usage (ℓ)	22 267	13 360	3 340	**38 967**
Max for irrigated insecticides (ℓ/ha)	1.450	not available	not available	
Min for irrigated insecticides (ℓ/ha)	0.000	not available	not available	
Median for irrigated insecticide (ℓ/ha)	0.200	not available	not available	
Avg herbicide usage (ℓ/ha)	4.102	not available	not available	
Total herbicide usage (ℓ)	246 133	147 680	36 920	**430 733**
Max for irrigated herbicides (ℓ/ha)	12.430	not available	not available	
Min for irrigated herbicides (ℓ/ha)	0.080	not available	not available	
Median for irrigated herbicides (ℓ/ha)	2.000	not available	not available	
Avg fertilizer usage (kg/ha)	549.111	not available	not available	
Total fertilizer usage (kg)	32 946 600	19 767 960	4 941 990	**57 656 550**
Max for irrigated fertilizers (kg/ha)	1 050	not available	not available	
Min for irrigated fertilizers (kg/ha)	137	not available	not available	
Median for irrigated Fertilizers (kg/ha)	355	not available	not available	

*Avg – Average *ha – Hectare *ℓ - Litres *Kg – Kilogram
*Min – Minimum *Max – Maximum

Table 28 shows the potential impact if only 1% of the total applied volume of agro-chemicals enter the environment beyond the target application area through run-off, leaching, poor application methods or any other mishap and this is before possible wastages, surplus disposals etc.

Table 28: Potential agro-chemical pollution volumes

	Insecticides (ℓ)	Herbicides (ℓ)	Fertilizers (kg)
Dry land maize application	136 793	8 433 195	450 919 625
Irrigated maize application	38 967	430 733	57 656 550
Totals for maize production	175 760	8 863 928	508 576 175
Potential pollutants at 1% by volume through run-off, leaching etc	1 758	88 639	5 085 761.75

The impact of treated maize on chemical usage

All farmers use treated maize seeds and the most popular of these are Gouchu and Avicta. The use of treated maize should reduce the amounts of chemicals used on crops as treated maize provides resistance to nematodes and insects (Syngenta Crop Protection, 2005).

Figure 13 gives an indication of the impact that the dry land farmers "feel" treated maize has on their chemical usage. A "substantial impact" means that substantially fewer chemicals are used and "no impact" means that fewer chemicals are not used. One farmer indicated that treated maize has no impact at all on the amount of chemicals he uses. This is an indication of in-effective chemical use since he should be able to apply fewer chemicals to his maize without having problems with nematodes and insects damaging the maize (Syngenta, 2005).

The largest number of farmers feel that treated maize substantially reduces the amounts of chemicals applied to maize and only 10% (n=1) of farmers feel that treated maize has no effect at all on reducing chemicals usage.

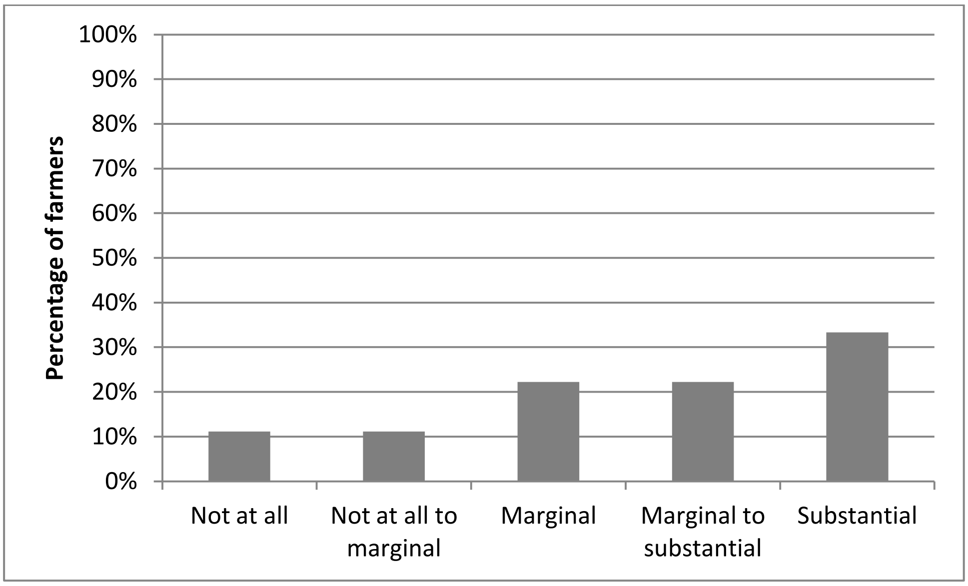

Figure 13: Impact of treated maize on chemical usage for dry land farmers

Figure 14 gives an indication of the impact that irrigation farmers feel treated maize has on their chemical usage. The largest number of respondents (42.86%, n=3) feel that using treated maize has a substantial impact on the volumes of chemicals used where it reduces the amount of chemicals applied to maize.

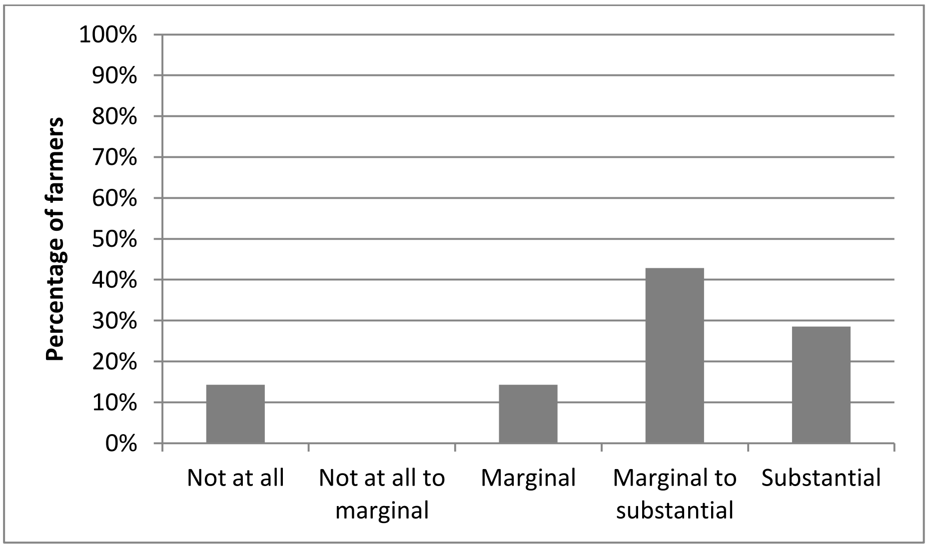

Figure 14: Impact of treated maize on chemical usage for irrigated farmers

Application of poison for Highveld Gerbils

Eight of the thirteen farmers reported to have problems with Highveld Gerbils (*Gerbilliscus brantsii)* (Campbell *et al,* 2011) (known as "Springhaasrotte" by the farmers) on their farms. This is of concern because the poison used to kill Highveld Gerbils is generally very toxic (Botha, Personal Communication, 2013). The products reported to be used to control the Highveld Gerbils on farms include zinc phosphide (Zn_3P_2), zinc sulphide (ZnS) and magnesium phosphide (Mg_3P_2).

According to DAFF (2013b) the chemical product used for gerbils is zinc phosphide. As no information could be found on zinc sulphide for use as a poison to kill gerbils, and because of the similar naming of the two chemicals (especially in the Afrikaans vernacular where they are known as "sink fosfiet" and "sink sulfiet" respectively) it is possible that there could be confusion amongst the farmers regarding the correct name of the chemical substance to be used on the Highveld Gerbils. More information on magnesium phosphide as rat poison could also not be found.

Zinc phosphide is typically mixed with molasses and syrup, peanut butter and cooking oil, or mixed with chopped grain. Reported amounts of zinc phosphide used are 80g/ha. Two farmers reported 1kg with 50kg seed, or 5g per Highveld Gerbil hole. Trade names for products used as reported by farmers include, Aviknaag and Hyper Rat. Ridak is another product that is used with Difenacoum as the active ingredient (BASF, 2013). Farmers reported that poison used on Highveld Gerbils is not always very effective and a breakthrough is still needed on how to control them. One method to reduce Highveld Gerbils is to till. Farmers who choose not to till can potentially have bigger problems with gerbils as the tillage process kills the gerbils. It is understood that farming practices are complicated and that the practice of no-till has other benefits. A farmer reported that in order to identify a method to effectively and affordably control Highveld Gerbils much research still needs to be done and he recommended that a real effort should be made to develop methods to effectively and economically solve the problem of this pest. The toxicity of the chemicals currently used will be further discussed in section 4.4.4.5.

Results on how farmers determine amounts of agro-chemicals to apply on farms

Figure 15 shows where farmers obtain information on quantities of agro-chemicals to apply. Seventy seven percent of farmers (n = 10) obtain information, from the chemical distributors, while 15.38% (n = 2) determine volumes themselves. The two farmers who calculate these themselves received training on how to do this and one of them is a chemical distributor himself. One farmer (7.69%) uses information from the chemical distributor as well as that on packaging. It is concluded that 100% of farmers get information on chemical application rates from reliable sources. This ensures that chemicals are purchased and applied to maize in a controlled way, without unnecessary wastage.

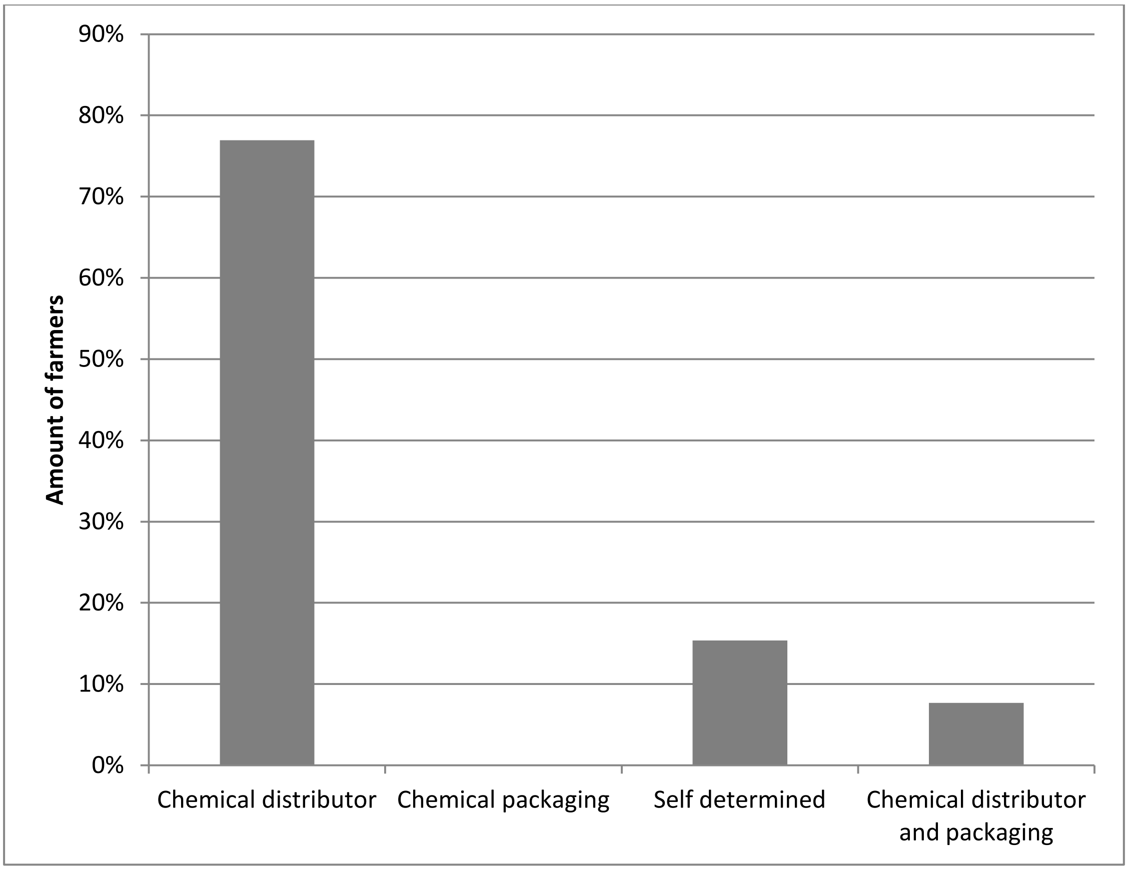

Figure 15: Different sources of information on chemical application rates used by farmers

Figure 16 illustrates to which extent farmers order the amounts of chemicals recommended by chemical distributors. For insecticides, 8.33% of farmers (n = 1) order less than recommended volumes, 75% (n = 9) of farmers order the recommended volumes and 16.67% (n = 2) order more than the recommended volumes. For herbicides, 7.7% (n = 1) order less than recommended volumes, 84.6% (n = 11) of farmers order the recommended volumes and 7.7% (n = 1) order more than the recommended volumes. For fertilizer 92.3% (n = 12) of farmers order the recommended volumes and 7.7% (n = 1) order more than the recommended volumes. It is clear that with only a few exceptions, farmers order the recommended amounts of chemicals. The farmer who orders less insecticides and herbicides does this because it saves costs and he is of opinion that lower dosages of chemicals are still effective. He uses a high run spray ("hoogloopspuit") which applies the chemicals very effectively and this makes it possible for him to apply less than the recommended amounts of chemicals.

Of two farmers who order more insecticides than is recommended, one does this to not run out of insecticides during the season, and the other sometimes orders more during wet seasons. The farmer who orders more than the recommended amount of herbicides and fertilizers does this to reduce the standing time of crops when his chemicals are depleted. From this explanation it appears that the recommended amount is normally not enough for this particular farmer.

One farmer who normally does not use insecticides did not respond to the question regarding the amount of insecticides used and therefore there are only 12 responses for insecticide usage.

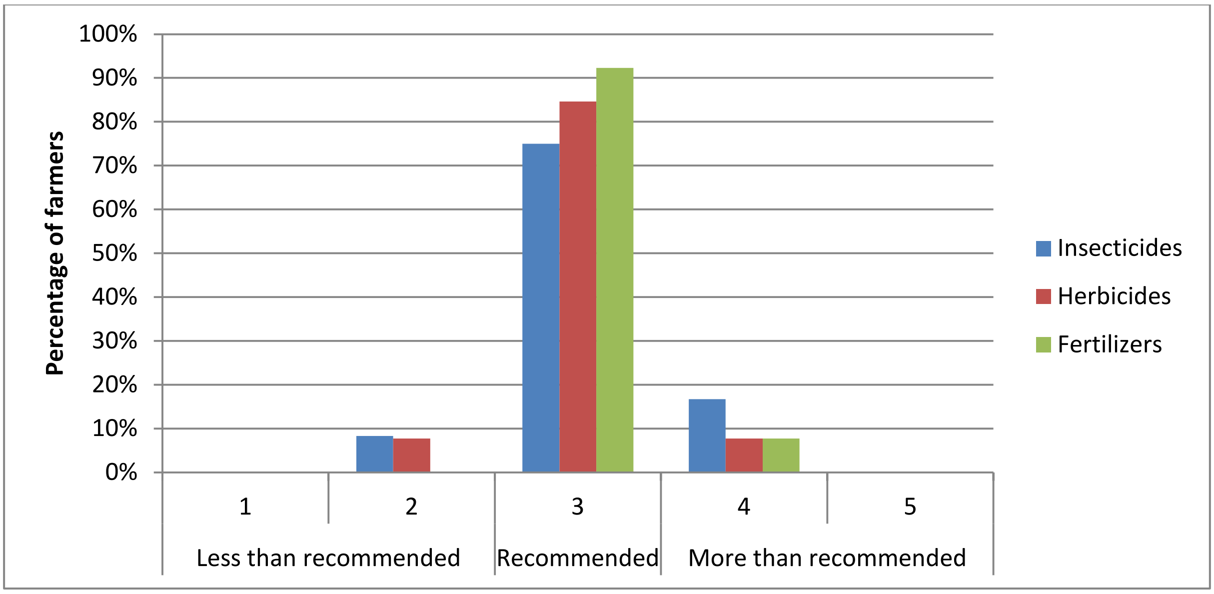

Figure 16: Recommended amounts of agro-chemicals ordered by farmers

In Figure 17 below the amounts of agro-chemicals applied by farmers are indicated on a scale from one to five. For insecticides, 8.33% of farmers (n = 1) apply less than recommended volumes and 91.67% (n = 11) of farmers apply the recommended volumes. For herbicides, 15.38% (n = 2) apply less than recommended volumes and 84.62% (n = 11) of farmers apply the recommended mass. For fertilizer 100% (n = 13) of farmers apply the recommended volumes. No farmers reported applying more than the recommended amounts. The fact that no farmers apply more chemicals than the recommended amounts may be due to the fact that chemical costs can be very high. One of the farmers who applies less than the recommended amount of herbicides explained that it sometimes happens that he runs out of time and therefore never applies all the chemicals that are needed. The second farmer who applies less is the same one mentioned above who orders less than the recommended amount of insecticides and herbicides. As the case for the previous section for agro-chemicals ordered, one farmer did not respond to the question regarding insecticides usage.

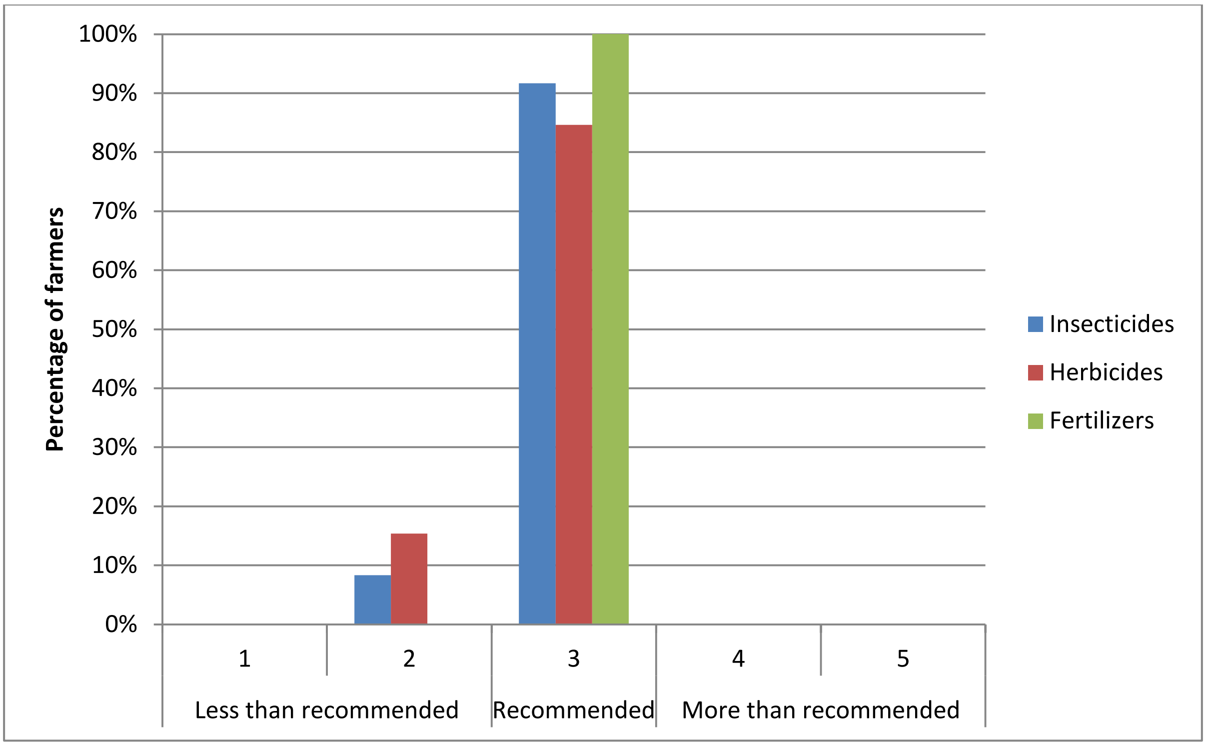

Figure 17: Recommended amounts of agro-chemicals applied by farmers

All the information gathered and discussed in section 4.4.3 contributes to the establishment of an agro-chemical usage database. As already stated, some of the most important data that should be captured in such a database includes the areas of crop under cultivation (Thomas, 1999; Thomas, 2003), the agro-chemical products used (Thomas, 1999; NSW EPA, 2013; DETEA, n.d.), the amount of the product used (Thomas, 1999; NSW EPA, 2013; DETEA, n.d.), the hazard rating class of the agro-chemicals (DETEA, n.d.), and the weather conditions during application (NSW EPA, 2013). Reasons why the development of an agro-chemical usage database is important include amongst others an indication of concentration levels of agro-chemicals to which people are exposed (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002), for monitoring changes for agro-chemical use (Thomas, 2003; DEAT, 2005a; DEAT, 2005c), to monitor the effects that changing policies has on agro-chemical use (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002; DEAT, 2005a; DEAT, 2005c), a valuable tool for the monitoring of groundwater and surface water contamination by agro-chemicals (Thomas, 2003; Aquatech, 1997 cited in Radcliffe, 2002), and for evaluation of current farming practices in order to be improved upon (DEAT, 2005a; DEAT, 2005c).

4.4.4 Storage, disposal and wastage of agro-chemicals, cleaning and disposal of agro-chemical packaging and containers and cleaning and storage of agro-chemical application equipment

This theme focuses on the methods and safety of the storage and disposal of chemicals and chemical packaging and containers, the determination of quantities of chemicals wasted and how they are wasted, how chemical application equipment is managed and cleaned, the role that weather conditions play on the application of chemicals and what knowledge farmers have on the characteristics of chemicals being used.

A once-off project with the aim of collecting and destroying obsolete and unwanted agro-chemicals as well as agro-chemical packaging and containers was conducted by the Department of Agriculture in 1998 and who funded AVCASA to run the project. The first step of the project was to create an inventory of obsolete chemicals. This inventory also included contaminated soil sites. The information gathering phase for the inventory relied on the response of farmers to a postal survey to access stocks of unwanted farm agro-chemicals. The postal survey records indicated that South Africa had 603 tons of obsolete pesticides. After the retrieval process this volume increased to 1050 tons of obsolete pesticides. These obsolete pesticide stocks accumulated over a period of 30 years (Naidoo & Buckley, 2003; Dickenson, Personal Communication, 2013). The waste was taken to Chloorkop where it was sorted, after which it was taken to a waste incineration facility in Wales. A similar project is currently being launched and the Department of Environmental Affairs, AVCASA and the Development Bank of Southern Africa (DBSA) are involved in this. AVCASA is struggling to get the project off the ground and are awaiting feedback from Government (Dickinson, Personal Communication: 2013). This kind of project should not be a once-off effort, but should be a continuous project that will ensure that agro-chemical waste is continuously collected and destroyed to prevent the build-up of these chemicals on farms. This will ensure that agro-chemicals will be less of a threat to the environment.

AVCASA also works on various other environmentally sound container management strategies as part of their waste management plan as submitted to the Department of Environmental Affairs (Govender, Sheard, 2012).

Results regarding storage, disposal, wastage and cleaning obtained from the farmer questionnaires are discussed in sections 4.4.4.1 to 4.4.4.5.

4.4.4.1 Chemical usage, storage and disposal

Figure 18 indicates results on chemical usage from the farmer survey on a scale of one to five. Seven respondents (53.85%) use almost all insecticides and 46.15% (n=6) use all insecticides. For herbicides 61.54% (n=8) use almost all herbicides, and 38.46% (n=5) use all herbicides. For fertilizers 53.85% (n=7) use almost all fertilizers and 46.15% (n=6) use all fertilizers. The largest number of farmers reported that they use almost all of each of the chemical groups with a slightly lesser number reporting use of all of the chemicals. One farmer reported that the size of containers in which chemicals are supplied can result in a farmer buying more chemicals than is needed. An example is a farmer who needs 30 litres of herbicides but the containers are only available in 20 litres. In this case the chemical distributor will supply the farmer with two 20 litres containers resulting in the farmer having 10 litres more herbicide than he actually needs.

To put the above-mentioned problem into perspective, SANS (2010) states that only the quantity of agro-chemicals needed in one season must be bought by a farmer.

This problem can be solved by making smaller containers available which will add up to the exact amount that a farmer needs. This is however still not the perfect solution. The ideal would be to eliminate the use of all containers. This can be achieved by installing big tanks on farms which should be filled up with the exact quantities of agro-chemicals needed for the season. This will eliminate packaging and container waste which in turn will solve a host of problems surrounding these; including the illegal burning of these waste types.

In the meantime the current mechanisms in place for the collection and removal of agro-chemicals and agro-chemical waste should be improved. Results have shown that in some areas only, chemical distributors pick up old containers and obsolete agro-chemicals.

According to SANS (2010) pesticide waste should be sent back to the local supplier, to a registered disposal company or it should be disposed of at a registered hazardous waste disposal site.

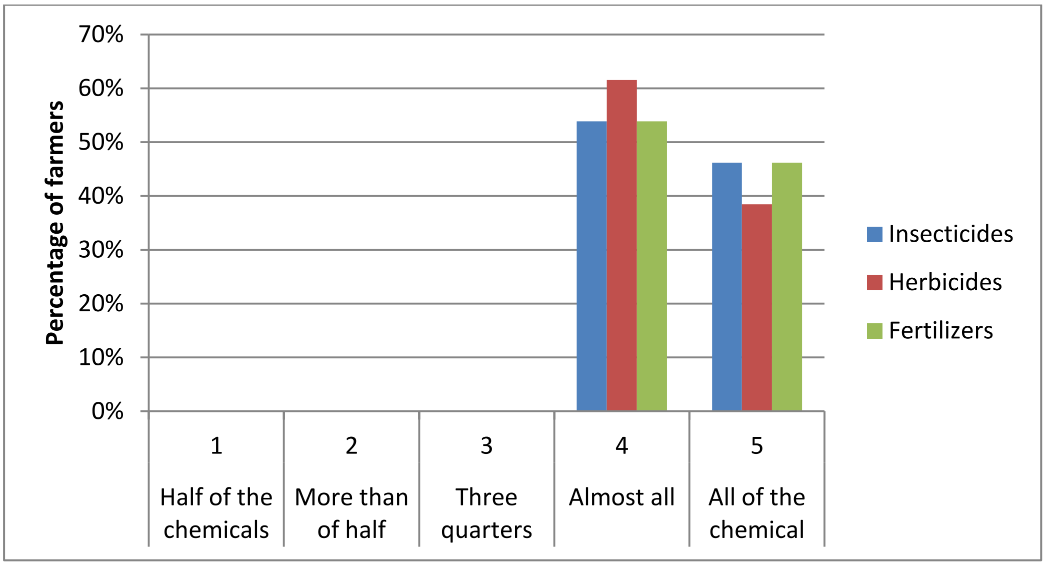

Figure 18: Chemical usage

Figure 19 indicates the number of farmers who store each chemical type. A large percentage of respondents store their chemicals, 66.67% (n=8) store insecticides, 69.23% (n=9) store herbicides and 76.92% (n=10) store fertilizers. Results from the questionnaires have shown that all agro-chemicals are normally not used up all at once and therefore will be stored at some time. One of the two farmers who do not use insecticides did not respond to whether insecticides are stored or not.

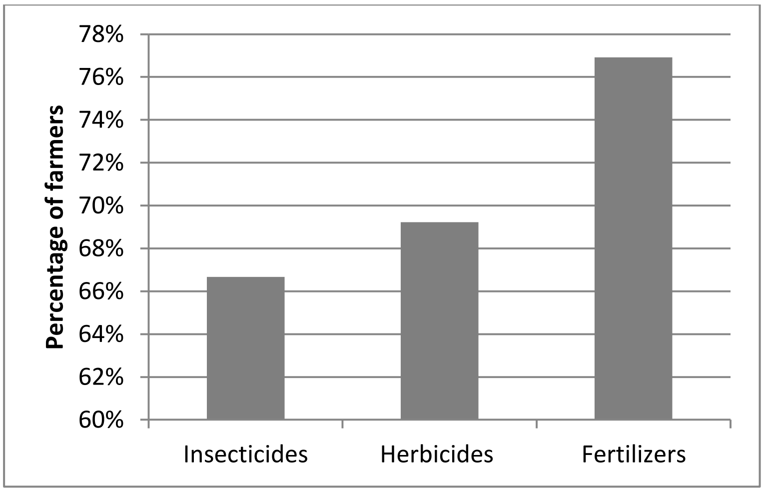

Figure 19: Percentage of farmers storing each chemical group

Figure 20 indicates for how long each chemical group is stored. For insecticides 30% (n=3) of respondents store them for 1-3 months, 10% (n=1) for 3-7 months and 10% (n=1) indicated that they do not store them for longer than a year. For herbicides 40% (n=4) store it for 1-3 months, 10% (n=1) indicated that they do not store it for longer than a year, 40% (n=4) store it until the next season/year, and 10% (n=1) indicated that they store it for one year and longer. For fertilizer 18.18% (n=2) store it for 1-3 months, 18.18% (n=2) store it for 3-7 months, 18.18% (n=2) indicated that they do not store it for longer than a year, 36.36% (n=4) store it until the next season/year and 9.09% (n=1) store it for one year and longer. Two farmers did not respond to this question and one farmer only gave an answer for the duration of fertilizer storage. Results from questionnaires have shown that famers who store chemicals until the next season/year will generally use these chemicals in the next season and will take the amounts of chemicals left in the storerooms into consideration when buying new chemicals.

As was already mentioned, SANS (2010) states that only the quantity of agro-chemicals needed in one season must be bought by a farmer which suggests that chemicals may not be stored until the next year or season. There is some room for improvement on this matter as five farmers store chemicals for one year and longer.

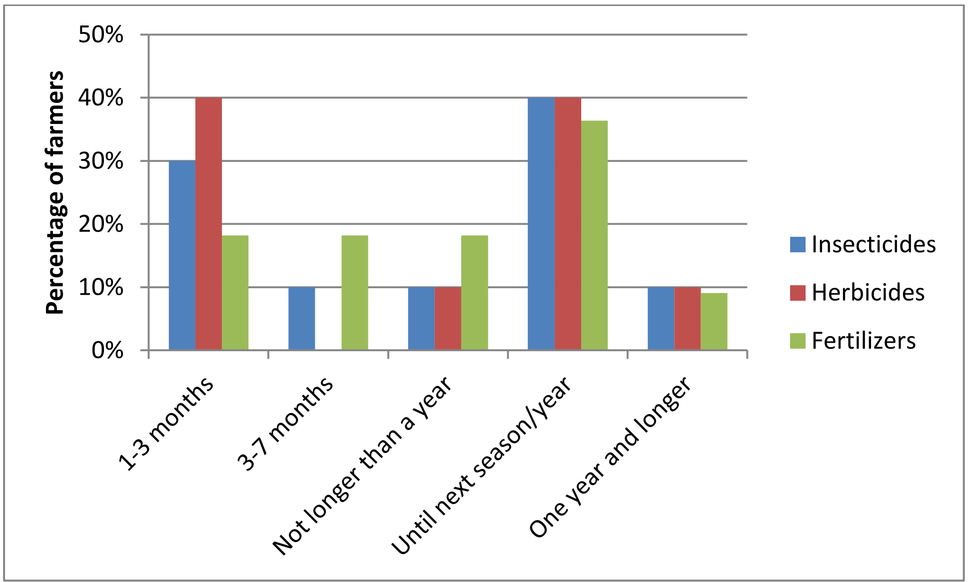

Figure 20: Time period over which farmers store each agro-chemical group

Figure 21 illustrates how safe farmers feel the storage facilities on their farms are for each of the chemical groups. For insecticides 8.33% (n=1) feel that it is not safe, 25% (n=3) feel that it is safe and 66.67% (n=8) feel that it is very safe. For herbicides 7.69% (n=1) feel that it is not safe, 7.69% (n=1) feel that it is fairly safe, 30.77% (n=4) feel it is safe, and 53.85% (n=7) feel that it is very safe. For fertilizers 7.69% (n=1) feel it is not safe, 7.69% (n=1) feel it is slightly safe, 46.15% (n=6) feel it is safe, and 38.46% (n=5) feel it is very safe.

The main reasons that farmers listed for why they felt they have safe storage facilities include the following:

- storage facilities are locked
- that there is limited access
- it is far away from water resources
- chemicals are separated from each other

- store rooms have signs
- storerooms are well ventilated
- steps and walls prevent leakages
- stock control
- stored in tanks and placed on pallets

One farmer reported that Global Gap, a food safety company, inspects the storage facilities of his farm and therefore it is always up to standard. The packaging of produce for distribution also takes place on this farmer's farm and includes potatoes and carrots. One farmer did not respond to the question of storage facilities for insecticides because he does not use insecticides. Because he does not use insecticides, which are the most toxic, his storage facilities for the rest of his chemicals are not particularly safe either. Some farmers felt that special storage facilities are not needed for fertilizers since they are not dangerous and therefore store fertilizers in open areas. One farmer said that he does not have a special locked store for his chemicals. It was also noted that the condition of the storage facilities of one of the farmers, who scored himself a four on a scale from one to five for all three chemicals, was very bad. Fertilizer was spilled on the garage floor and there were loads of herbicides that the farmer did not seem to have been aware of. He explained that the extra herbicides are from the previous owner and that it is not being used.

There are many regulations on how chemicals should be stored and farmers generally feel that these regulations are too difficult to comply with and sometimes too strict. The combined responses of all the farmers used for the study basically covered all the important safety measures that are required for chemical storage rooms.

Some important safety measures that were not mentioned includes fire resistance, lighting, structurally sound and non-combustible building materials and availability of equipment to deal with spillages (Grain SA, 2010; SANS, 2010; SAQA, 2006). A detailed explanation of how chemicals should be stored is discussed in 2.2.4 in Table 3.

The chemical storage facilities of farmers were not physically investigated and therefore an accurate judgement of the appropriateness thereof cannot be made. It is however a concern that the combined responses of all farmers still did not cover all the regulations that are applicable and the fact that farmers feel the regulations are quite strict and difficult to comply with is a sign that chemical storage facilities are in general not up to standard.

About half of the farmers used for the study are some of the bigger, more commercially successful and trend setting farmers whereas the other half may fall in a slightly lower to much lower class. Results seem to indicate that the larger commercial farmers do comply or come close to complying with regulations whereas the smaller scale farmers fall short by quite a margin. This trend would have to be confirmed by a larger study sample.

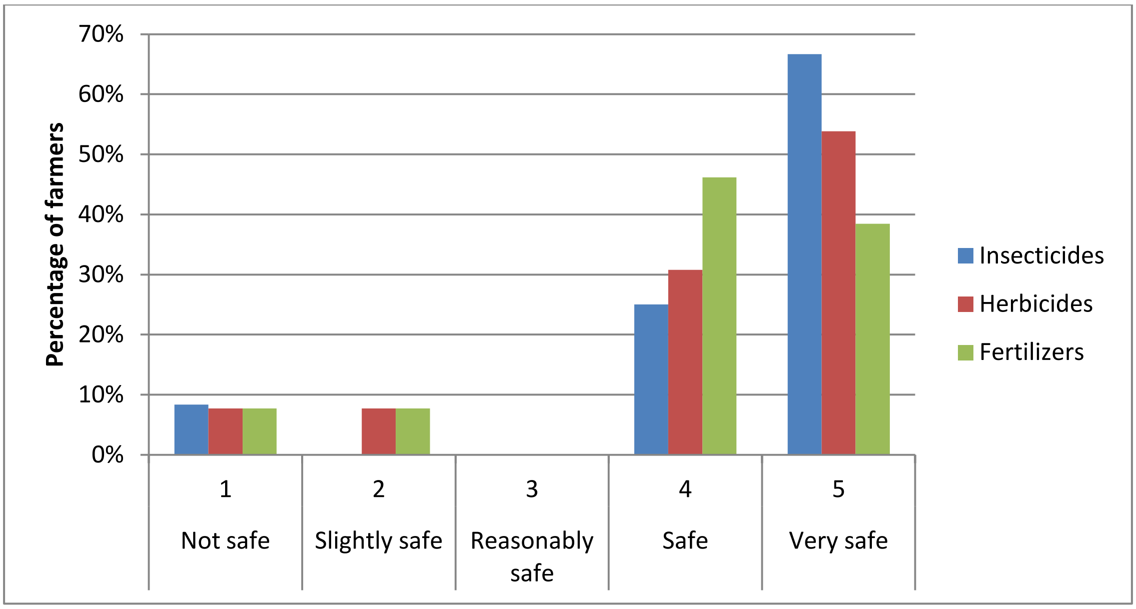

Figure 21: Safety of agro-chemical storage facilities

Figure 22 indicates the number of farmers who occasionally dispose of, and those who do not dispose of each of the chemical groups. For insecticides 41.67% (n=5) occasionally dispose of them, and 58.33% (n=7) do not dispose of them at all. For herbicides 38.46% (n=5) occasionally dispose of them, and 61.54% (n=8) do not dispose of them at all. For fertilizers 30.77% (n=4) occasionally dispose of them, and 69.23% (n=9) do not dispose of them at all. One farmer who does not use insecticides did not respond to whether he disposes of insecticides or not.

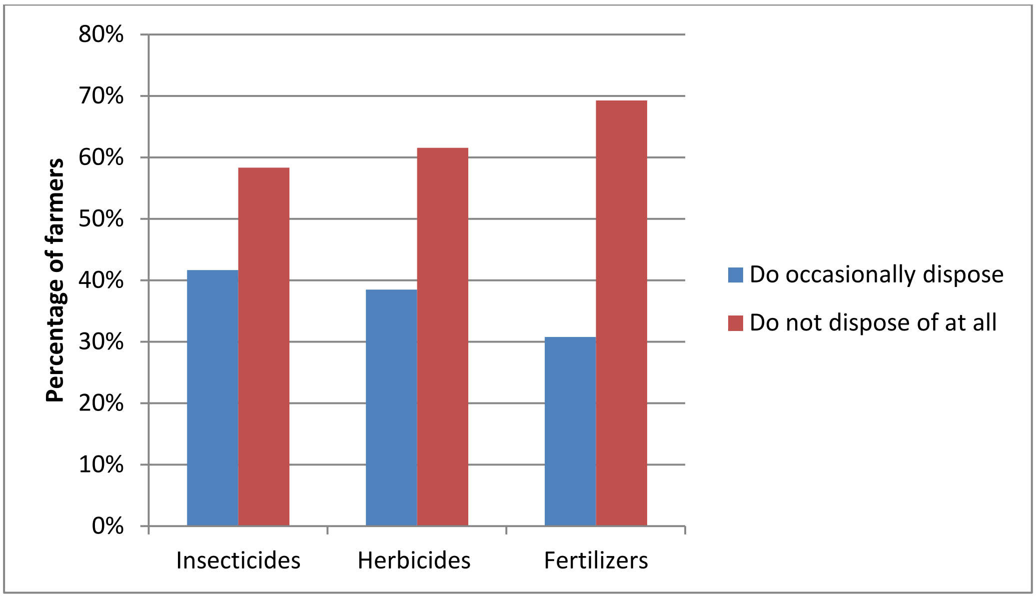

Figure 22: Disposal of agro-chemical groups

Data for only three farmers is available on how chemicals are disposed of. Between the three farmers two methods were reported on how chemicals are disposed of. This includes disposal of chemicals in holes in the ground after which it is covered with soil. One farmer explained that the hole is lined with bricks and that it is a sort of drain. The water then evaporates and the chemicals stay behind in the hole. He feels that his method is of the safest in the region when it comes to disposal of chemicals and tank washings. The other reported method is that the chemicals are burned. Chemicals that are burned are typically those that are left over in containers and are therefore burned when containers are burned. One farmer said that the University of the Free State once collected fertilizer on his farm.

Another disposal method that can be used for agro-chemicals is encapsulation. This is however a costly method and can actually only be seen as storage and not disposal as the waste is not destroyed and the toxicity thereof is also not reduced (Naidoo & Buckley, 2003).

Un-used pesticides should be disposed of in a safe manner, as obsolete pesticides can be a source of severe pollution and can be a threat to human development, human health and the environment. The FAO estimated that, in 1998 there were approximately 15 000 to 20 000 tons of obsolete pesticides that required disposal in Africa and some countries in the Middle East. Obsolete pesticide stocks in South Africa were in excess of 1050 tons in 1999. Because there are no safe disposal facilities for obsolete pesticides, obsolete stocks are constantly increasing (Naidoo & Buckley, 2003).

SANS (2010), states that pesticide waste should be sent back to the local supplier or to a registered disposal company. Pesticide waste can also be disposed of at a registered hazardous waste disposal site.

Data from only two farmers was obtained on how safe they feel the disposal of chemicals on their farms is. One, who dumped chemicals in holes in the ground, responded that it is reasonably safe for all the chemical groups, and the other, who burns the chemicals, responded that it is very safe for insecticides and herbicides. He does not dispose of fertilizers.

Table 29 indicates the total amounts of chemicals wasted in litres. Only two farmers responded that none are ever wasted. Most farmers responded that only very small amounts are spilled and wasted. Average percentages of total amounts reported as wasted for insecticides were 0.390%, 0.123% for herbicides and 0.135%for fertilizers. This includes when blocked chemical application equipment is cleaned, while diluting, during cleaning of chemical tanks and when chemical containers fall over. One farmer said that there was big chemical wastage during the floods in 1988. Another farmer explained that herbicide, over time, drained and collected at the bottom of a tank. By the time he discovered and removed the deposits of chemicals, a total amount of two full wheelbarrows were removed.

Table 29: Percentages of total amounts of chemicals wasted by farmers

Respondent	Insecticide (%)	Herbicide (%)	Fertilizer (%)
R1	2	0.02	0.01
R2	0.5	0.5	0.5
R3	0.05	0.05	0.05
R4	0	0	0.02
R5	0	0	1
R6	0.005	0.005	0.01
R7	0	0	0
R8	1	1	
R9	0	0	0
R10	0.5	0	0
R11	0.01	0.01	0
R12	1	0.01	0.03
R13	0.005	0.005	0
Averages	0.390	0.123	0.135

Figure 23 below illustrates the number of case type spillages reported by farmers. When the farmers were asked if they sometimes spill chemicals (where only a yes or a no answer was required) most of them elaborated their answers by explaining when and how they spill chemicals. This question however exposed numerous other ways which were not previously mentioned by the farmers in which chemicals are sometimes spilled. The most common reason reported by farmers for the spillage of agro-chemicals is during transfer from container to applicator.

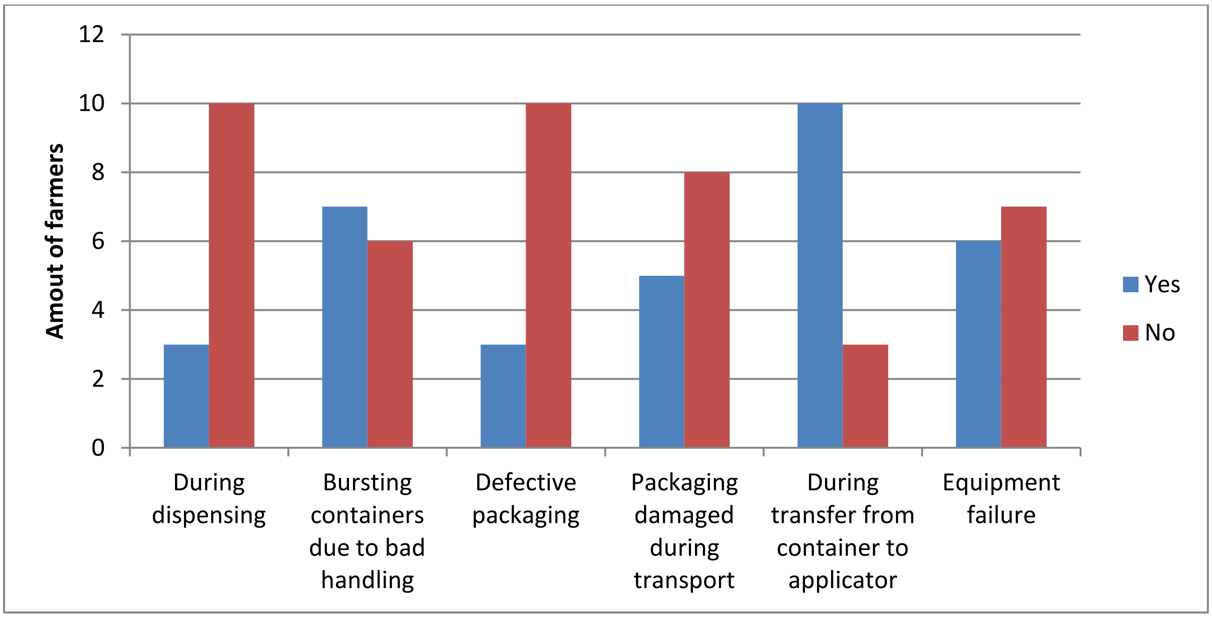

Figure 23: Types of agro-chemical spillages and number of farmers per case type

Three farmers reported that they waste chemicals because of expiration thereof. One farmer reported that 2% of insecticides and herbicides are wasted because of expiration, another reported 1% and another less than 0.5% of insecticides and herbicides wasted for this reason. Fertilizers never expire as farmers reported that it is always fully used up. One farmer reported that expired chemicals go back to the chemical distributor and are therefore not wasted. Fertilizer spills are normally swept up and placed back in packaging to be re-used. Other chemical spills are sprayed with water, left on the ground and sometimes covered with soil. One farmer reported a fertilizer wagon that fell over. Figure 24 below (photo taken by author) is an example of fertilizer spillage on a gravel road near one of the farms used in the study.

Figure 24: Example of fertilizer spillage on gravel road

Figure 25 shows views of farmers on whether theft is a problem. For insecticides 84.62% (n=11) reported that it is not a problem, 7.69% (n=1) indicated that it may be a problem and 7.69% (n=1) indicated that it is a small problem. For herbicides 100% (n=13) indicated that it is not a problem. For fertilizers 92.31% (n=12) indicated that it is not a problem, and 7.69% (n=1) indicated that it is a small problem.

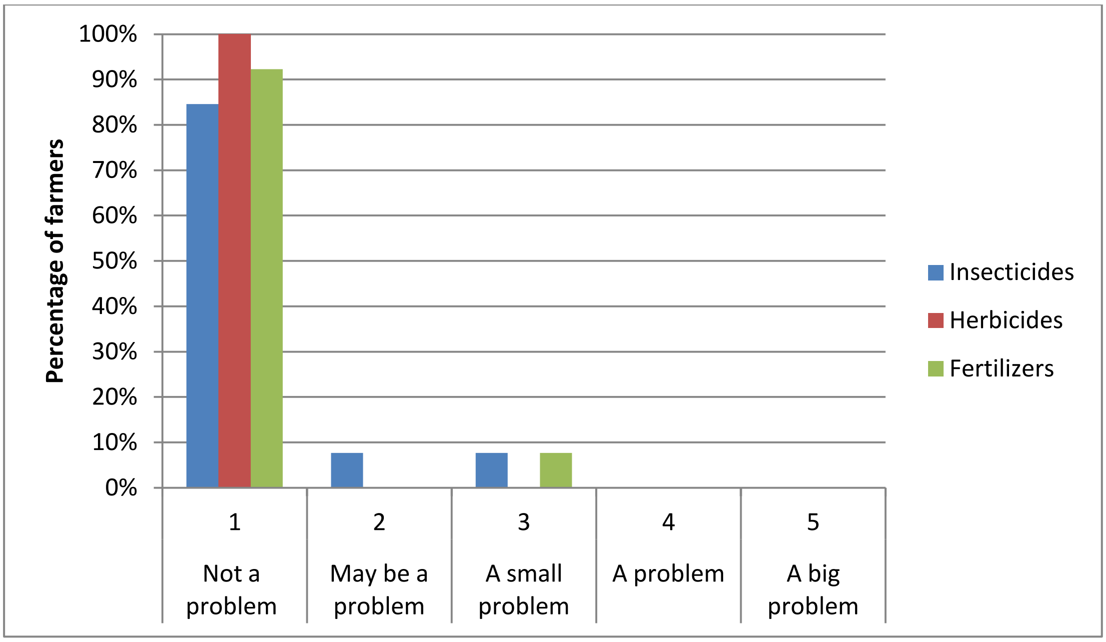

Figure 25: Theft of agro-chemicals on maize farms

It is clear from the survey results that the theft of chemicals is generally not a big concern. Farmers reported that it is difficult to notice when and how many chemicals are stolen. One farmer reported that 24 tons of fertilizer was stolen at his neighbour and another reported that the insecticide, Counter, was stolen and consumed by a person which lead to his death. Counter is a granular insecticide.

4.4.4.2 Management of chemical packaging and containers

Figure 26 indicates what farmers do with chemical packaging and containers when they are empty. In total 46.15% (n=6) dispose of them immediately, 23.08% (n=3) re-use them and dispose of later, and 30.77% (n=4) dispose of some of them immediately and the rest they re-use and dispose of later.

The chemical packaging and containers which are re-used by farmers are normally herbicide containers and fertilizer packaging. Herbicide containers are reportedly used for feeding buckets for sheep and one farmer reported that it is used to make beer in. Some are also taken away by farm workers or just stored on the farm. Insecticides containers are normally immediately burned and not re-used. Farmers reported that herbicides and fertilizer are much less toxic than insecticides and for this reason insecticide packaging and containers are not re-used.

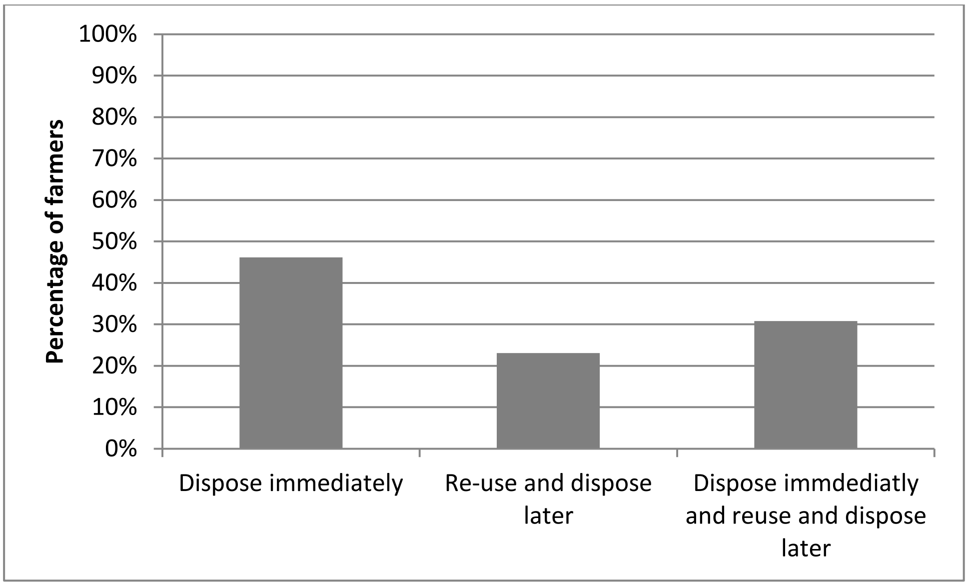

Figure 26: What happens to agro-chemical packaging and containers after use?

Figure 27 is a further indication of how chemical packaging and containers are disposed of by farmers. A total of 69.23% (n=9) of farmers burn packaging and containers, 30.77% (n=4) have containers removed by the chemical distributor, and 7.69% (n-1) are taken to a collection point.

One farmer indicated that only some of his packaging and containers are taken away by his chemical distributor. From these results it is clear that most of the chemical packaging and containers are handled in an improper way, which is against regulations (SANS, 2010).

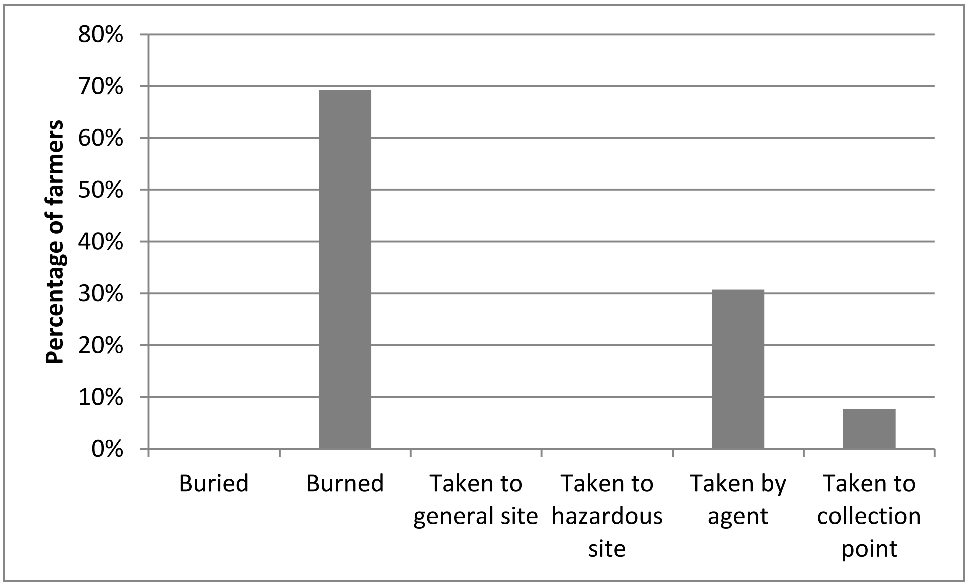

Figure 27: Methods used by farmers to dispose of agro-chemical packaging and containers

According to Grain SA (2010), SANS (2010), SAQA (2006), and Govender, & Sheard (2012), packaging and containers other than aerosol dispensers should be triple rinsed, shattered (in the case of glass containers) punched with holes (in the case of plastics and metal containers) or flattened before it is disposed of at a hazardous waste disposal site.

With the exception of plastic drums empty triple rinsed insecticides containers that are rendered unserviceable may be sent for recycling. Empty containers can be sent to a registered waste disposal company or back to the suppliers (SANS, 2010). Empty packaging and containers may never be re-used, unless it is used to hold the same chemicals (Grain SA 2010); (SANS 2010); (SAQA 2006) and (Govender & Sheard 2012). Govender & Sheard (2012), and SANS (2010) state that if empty chemical packaging and containers are not immediately disposed of, they should be stored in a safe place where they would not threaten the environment. In SAQA (2006) it is stated that paper waste bags and mildly contaminated items may be burned.

Since the majority of packaging and containers are either re-used or immediately burned they are never treated in this way. Five farmers reported that containers are triple rinsed. Only one of them does this before they are burned and also punches holes in them. The rest are rinsed before they are re-used and therefore no holes are punched in them, and they are also not flattened. Two farmers reported that fertilizer packaging is not cleaned before it is re-used. Packaging and containers are mostly cleaned with water, at the same place where chemicals are mixed.

Figure 28 indicates how safe farmers feel their cleaning method to clean chemical packaging and containers is. For insecticides, out of a total of five responses, 40% (n=2) indicated that it is reasonably safe, 20% (n=1) indicated that it is safe, and 40% (n=2) indicated that it is very safe. For herbicides, out of a total of seven responses, 57.14% (n=4) indicated that it is reasonably safe, 14.29% (n=1) indicated that it is safe, and 28.57% (n=2) indicated that it is very safe. The majority felt that the process is reasonably safe.

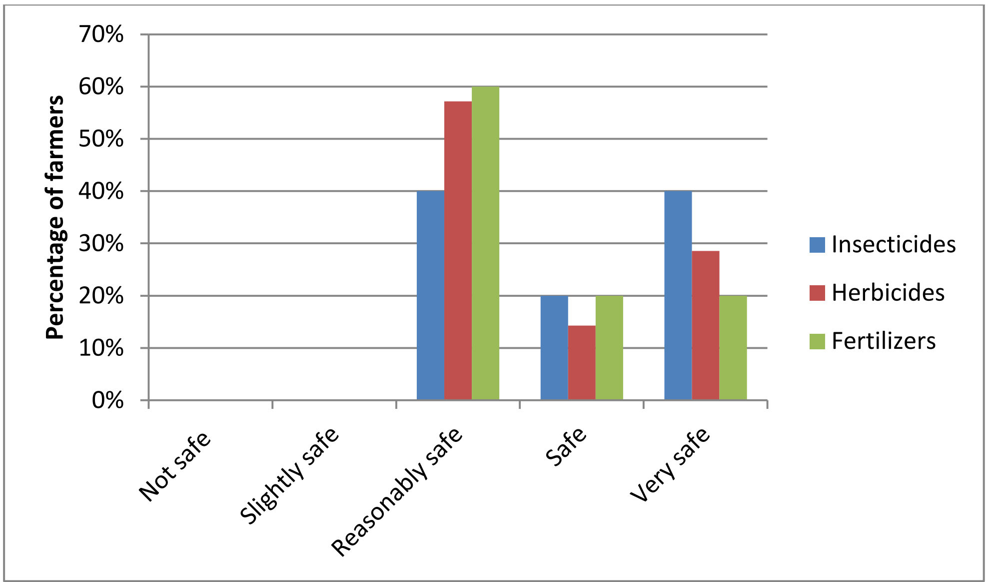

Figure 28: Safety of method used to clean agro-chemical packaging and containers

4.4.4.3 Management of chemical implements, vehicles and smaller equipment

Figure 29 indicates how often implements, vehicles and smaller equipment used to apply chemicals are cleaned. For implements 15.38% (n=2) of farmers sometimes clean them, 23.08% (n=3) fairly often clean them, and 61.54% (n=8) often clean them. For vehicles 15.38% (n=2) sometimes clean them, 7.67% (n=1) fairly often clean them, and 76.92%

(n=10) often clean them. Out of four responses 25% (n=1) fairly often clean smaller equipment, and 75% (n=3) often clean these.

Eight farmers reported that implements are washed with water and high pressure sprays and five reported using soap or a product known as “Flush All”, which dissolves and breaks down the chemicals. The same methods are used for cleaning vehicles and one farmer reported that a special cleaning agent is used to clean smaller equipment.

According to SAQA (2006) all machinery must be washed with clean water after application of agro-chemicals and knapsacks, brushes and mixing equipment should be washed with an appropriate liquid soap after which it must be well rinsed. There is room for improvement on the methods used to clean agro-chemical application equipment as well as how often it is done. It is, however, not stated in the regulations how often implements, vehicles and smaller equipment should be washed and generally farmers do this as required, based on how frequently the equipment is used.

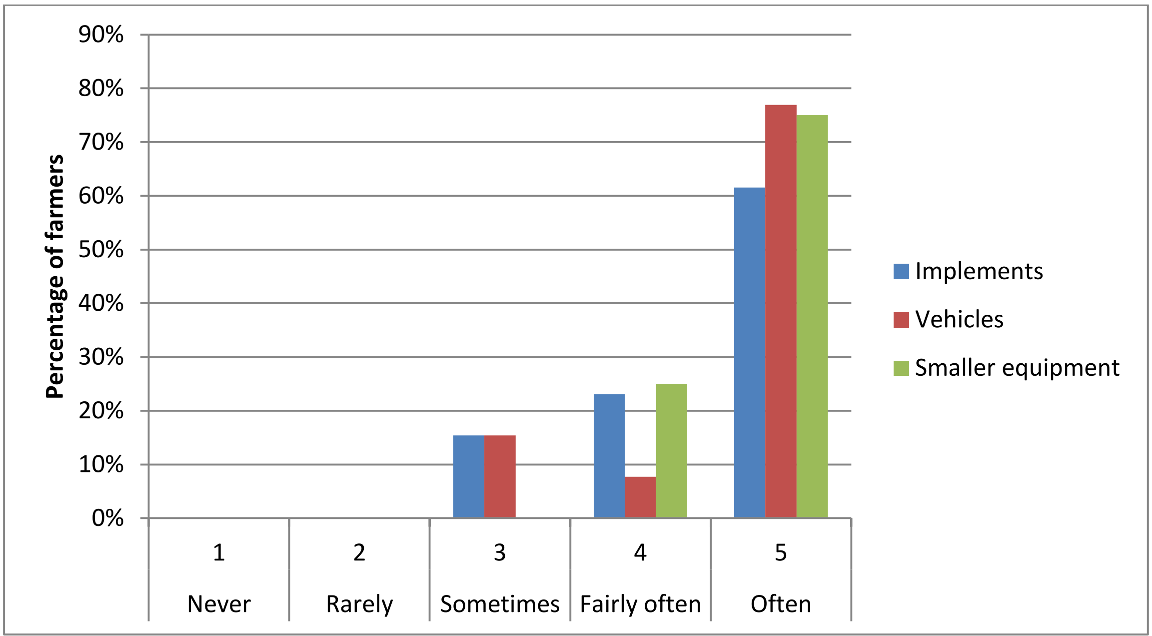

Figure 29: Frequency of cleaning of implements, vehicles and smaller equipment

Six farmers reported that implements are cleaned on the soil either adjacent to the farm house or storeroom. Another six reported that they are washed in a wash bay and another washes on paving after which the water drains to soil. One farmer reported that after washing implements, water is disposed of in hole/drain in the ground. Vehicles are also mostly washed in wash bays or adjacent to farm houses and storerooms. Two farmers reported that smaller equipment is also washed in wash bays.

Ten farmers reported that chemical application tanks are filled on the farm lands. Other places where tanks are filled include at boreholes, at dams, at water pumps, at taps near the home, at chemical tanks and in storerooms.

According to Grain SA (2010), SANS (2010) and SAQA (2006), mixing, filling and cleaning of agro-chemical application equipment must be done in a separate bunded facility. It should have a floor made of non-porous material, adequate drainage (contaminated water should be able to drain away effectively) and a restricted entrance. It should be done in a manner that prevents contamination of water resources and the environment. Cleaning points were not physically inspected and therefore a well-informed judgement could not be made on this. It is assumed that wash bays are the more appropriate option for the mixing, filling and cleaning of equipment, and from survey results one can conclude that most farmers generally do not comply with the strict regulations as stated above.

Figure 30 indicates the suitability of cleaning points (wash bays) on farms. Out of seven respondents 42.86% (n=3) indicated that it is relatively suitable, 28.57% (n=2) indicated that it is nearly suitable and 28.57% (n=2) indicated that it is suitable.

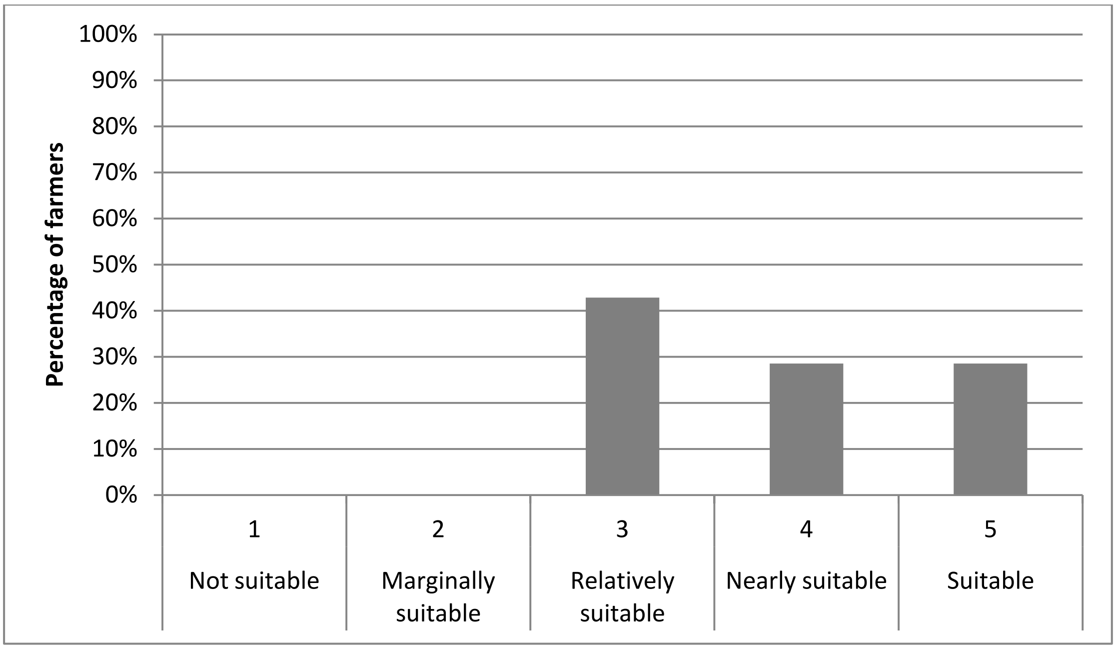

Figure 30: Suitability of cleaning points

No farmers indicated that they use specific filling points for the filling of agro-chemical spray tanks and therefor no data was gathered in this regard and consequently no farmers comply to regulations in this regard. A total of 84.62% (n=11) immediately dispose of surplus tank washings and only 15.38% (n=2) re-use it on untreated land.

Only one farmer responded to whether the concentration of tank washings is determined before it is used on untreated land and responded that it is not determined. It is expected that in a bigger sample size the total number of farmers who use surplus tank washings to treat crops will be small. Grain SA (2010) states that surplus mix or tank washings applied to untreated crops should not result in the over application of chemicals.

A total of 33.33% (n=4) feel that their disposal practice is relatively safe, 50% (n=6) feel that it is safe, and 16.67% (n=2) feel that it is very safe while 7.69% (n=1) did not respond to this question. One farmer reported that it is dry in his region and therefore leaching is limited. He also mentioned that the washings are diluted and therefore holds less of a threat to the environment. Three other farmers reported that disposal takes place far away from water resources and therefore they feel that the disposal process is safe to very safe.

All implements and smaller equipment are stored in storerooms. SANS (2010) states that an agro-chemical storeroom must only be used for the storage of pesticides and only if necessary, for the equipment used to apply them. No further legislation was found on how implements and smaller equipment should be stored.

Regarding calibration of implements, 7.69% (n=1) of total farmers reported that equipment is moderately well calibrated, 15.38% (n=2) reported that it is well calibrated, and 76.92% (n=10) reported that it is very well calibrated.

It was observed that farmers seem to spend much time on the calibration of implements to ensure that minimal volumes of chemicals are wasted. Chemicals are very expensive and therefore everything is done to minimize wastage. Data for only one farmer is available for the calibration of smaller equipment and this farmer reported that it is very well calibrated.

Ideally, calibration should take place each time that the equipment is used with a different tractor or when a different nozzle is used or when any modification or repairs is carried out, but institutions such as the Department of Agriculture, Forestry and Fisheries and Grain SA mostly only require that equipment should be calibrated annually by a competent person to ensure the correct amount of agro-chemicals is applied to ensure that the target pest is adequately controlled (DAFF, 2011; Grain SA, 2010; SAQA, 2006).

4.4.4.4 The role that weather conditions play during chemical application

Weather conditions are also always taken into consideration when applying agro-chemicals to minimize wastage of agro-chemicals and this can be seen in Figure 31 where 91.67% (n=11) of respondents reported that they always consider weather conditions and 8.33% (n=1) reported they mostly take weather conditions into consideration.

SANS (2010) and SAQA, (2006) explains the importance of taking weather conditions into consideration when applying chemicals and details on this can be found in 2.2.5.

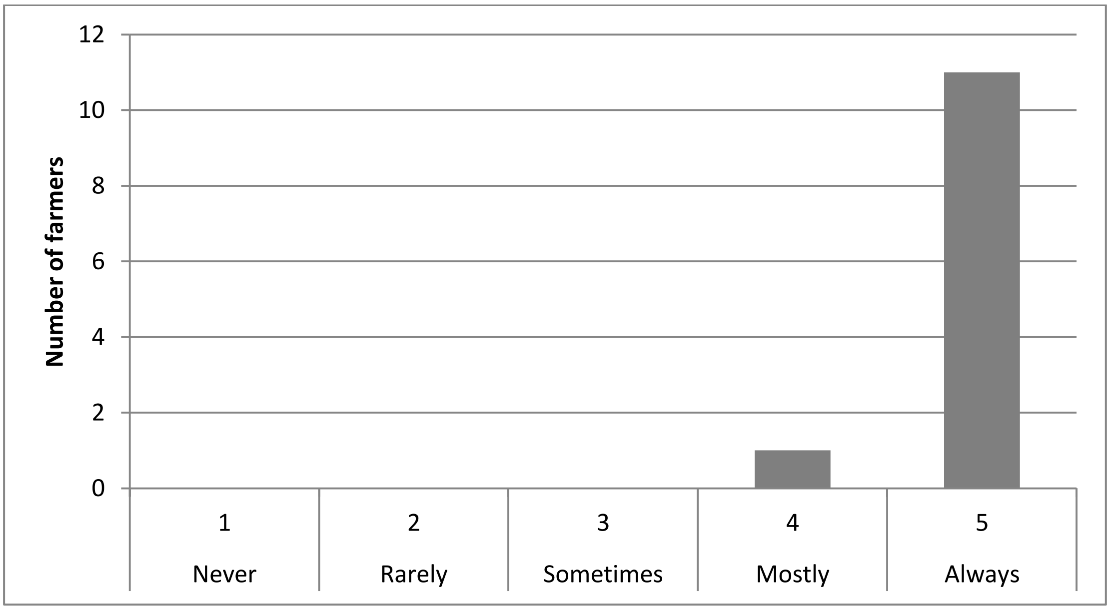

Figure 31: Consideration of weather conditions when applying agro-chemicals

Farmers reported that ineffective agro-chemical application does sometimes happen but rarely. This is indicated in Figure 32. Other than as a result of weather conditions, agro-chemical applications can also be ineffective because of chemicals that do not work as well as expected incorrect recommendations by the chemical suppliers, or inaccurate calibration of equipment. When weather conditions influence agro-chemical applications, it is normally unavoidable. An example is when weather suddenly changes while a farmer is busy with an application.

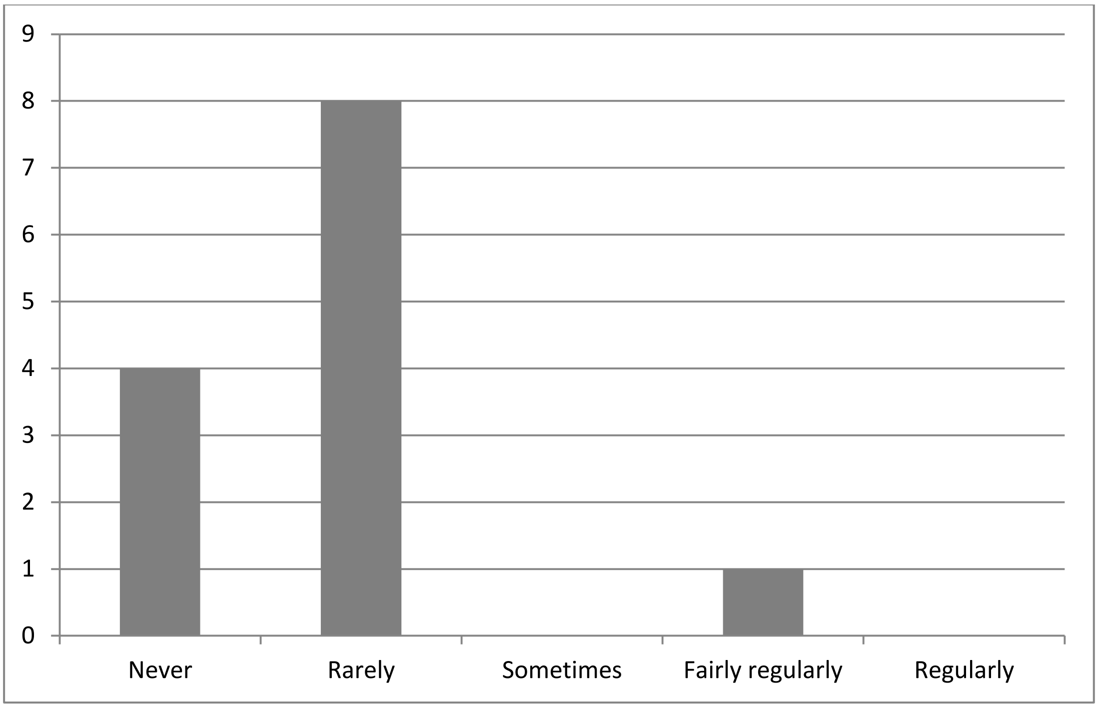

Figure 32: Ineffectiveness of agro-chemical application

Seven farmers reported that they never repeat applications after it was ineffective. Six farmers indicated that they have repeated applications once. One case was due to incorrect recommendations and one case due to agro-chemicals that were ineffective.

4.4.4.5 Characteristics of agro-chemicals (toxicity and classification)

Figure 33 indicates percentages per toxicity group of agro-chemicals used as reported by the maize farmers.

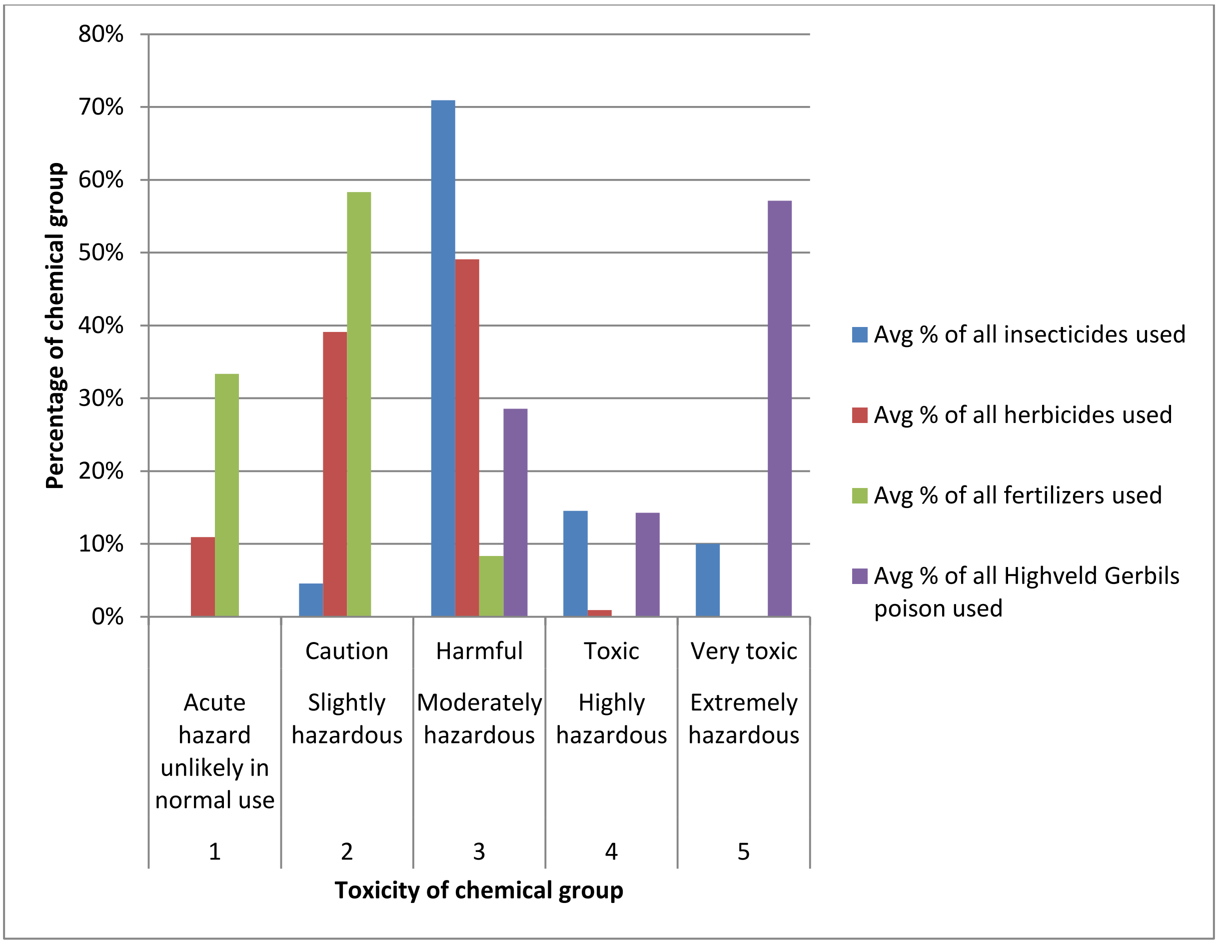

Figure 33: Toxicity of chemical groups

The toxicity as reported by respondents for insecticides, poison used for Highveld Gerbils and herbicides are analysed in Table 31 to Table 33. This will be done by comparing the hazard class rating of each of the products used by each respondent to the official hazard class rating. The accuracy of how the farmer rated a chemical is also explained in the "status" column. Table 30 can be used as reference for the identification of hazard classes.

Some assumptions were made to the specific herbicide products that were used. This is because the full name of the product was not always recorded. The full names for the specific herbicide products as it was used for the assessment of hazard classes are indicated in the "Product name" columns in Table 33. The chemical names listed in the "official hazard class rating" column are the names as reported by the farmers. For insecticides, the different products that could have been used by the farmers were taken into consideration during the hazard class assessment.

When collecting data for an agro-chemical usage database, it is important that the full name of the product should be recorded. A slight change in the name of a product such as a different prefix or suffix to the same name may influence what the active ingredients of the product are and this can influence the characteristics of the agro-chemical (Thomas, 1999). To gather this information in sufficient detail is however a time consuming process and may require some preparation by the farmer prior to the administering of the questionnaire. This is an area where this study could have been improved.

Table 30: Indication of hazard classes of agro-chemicals (DAFF, 2011; SAQA, 2006)

IV	III	II	Ib	Ia
Acute hazard unlikely in normal use	Slightly hazardous	Moderately hazardous	Highly hazardous	Extremely hazardous
	Caution	Harmful	Toxic	Very toxic
				

Table 31: Comparison between official hazard class ratings and hazard class ratings as reported by farmers for insecticides

Respondent	Product name	Official hazard class rating	Hazard class reported by farmer	Status (what farmer thinks of chemical compared to official rating)	References
R1	Flisietelikate	Not available	50% in III 40% in II	Not available	1
R2	Sumi-Alpha	Ib and III	60% in Ib and 40% in II	Accurate to more toxic	1
R3	Vantex	III	100% in II	More toxic	1
R4	Lambda	II and III	100% in II	Uncertain	1
R5	None				1
R6	Karate	Karate: II			1
R7	Counter	Counter: Ib	100% in Ia	More toxic	1
R8	None				1
R9	Karate, Dursban, Curator	Karate: II Dursban: II and III Curator: not available	100% in II	Accurate	1
R10	Sipermetrien	Sipermetrien: II	100% in II	Accurate	1
R11	Attack	Attack: not available	100% in II	Not available	1
R12	Attack, Mesomol, Chlorofirifos	Attack: Not available Mesomol: not available Chlorofirifos: 1b, II, III, IV	Not available		1
R13	None				
References	1 DAFF 2013b				

Table 32: Comparison between official hazard class rating and hazard class rating as reported by farmers for Highveld Gerbil poison

Respondent	Product name	Official hazard class rating	Hazard class reported by farmer	Status (what farmer thinks of chemical compared to official rating)	References
R1	Zinc sulphite (assumed as zinc phosphide)	Ia, Ib, III	Ia	Might be accurate or more toxic	1
R2	Zinc phosphide Ridak	Zn_3P_2: Ia, Ib, III Ridak: III	Ia	Might be accurate or more toxic but more toxic for Ridak	1,2
R3	Hyper Rat (Zinc phosphide)	Hyper Rat: III	Ia	Much more toxic	1
R4	Zinc phosphide	Ia, Ib, III	II	More or less toxic	1
R5	Aviknaag, Zinc phosphide, Metoxin	Aviknaag: not available Zn_3P_2: Ia, Ib, III Metoxin: not available	Ib	Could be accurate	1
R6	Zinc sulphite (assumed as zinc phosphide)	Ia, Ib, III	Ia	Could be accurate	1
R7	Ridak	III	II	More toxic	2
References	1 DAFF 2013b 2 BASF 2013				

Table 33: Comparison between official hazard class rating and hazard class rating as reported by farmers for herbicides

Respondent	Product name	Official hazard class rating	Hazard class reported by farmer	Status (what farmer thinks of chemical compared to official rating)	References
R1	Round up Power Max & Acetachlor	Both in III	30% in IV 20% in III 40% in II 10% in Ib	More and less toxic	1,2
R2	Round up Power Max	III	100% in II	More toxic	1
R3	Round up Power Max, Metholachlor & Atrazine 90 DF	Round Up Power Max: III Metholachlor: II Atrazine: II	40% in III 60% in II	Accurate	1,5,14
R4	Round up Power Max, Terbusien Super 600 SC, Guardian S EC, Cantron 480 SC	Round up PM: III Terbusien: II Gaurdian: II Cantron: III	20% in II 80% in III	Accurate	1,3,6,8
R5	Cantron 480 SC	Cantron: III	Farmer had no opinion but believes that it is not toxic.	More toxic	3
R6	Callisto 480 SC, Gardomil Gold 600 SC, Terbusien Super 600 SC, Lexar pack(Mesotrione, terbusien, metolachlor)	Callisto: III Gardomil Gold: II Terbusien: II Lexar Pack – Mesotrione: III Terbusien: II Metolachlor II	100% in III	Accurate less toxic	3,5,6,10,12
R7	Triazine, Acetachlor 900 EC, Mesotrione, S-metolachlor, Round up	Triazine: n/a Acetachlor: III Mesotrione: III S-metolachlor (for metholachlor), II or III Round up: III	100% in II	Accurate to more toxic	1,2,3,5
References	1 Agrian, 2013 2 Villa Crop Protection, 2010 3 Villa Crop Protection, 2011 4 Villa Crop Protection, 2012 5 Villa Crop Protection, 2013a 6 Villa Crop Protection, 2013b	7 Villa Crop Protection, 2013c 8 Monsanto, 2002 9 Monsanto, 2008 10 Syngenta Crop Protection, n.d. 11 Syngenta Crop Protection, 2004 12 Syngenta Crop Protection, 2006		13 Syngenta Crop Protection, 2008 14 Drexel Chemical Company, n.d. 15 Agronica, 2009 16 Enviro-crop, 2012 17 BASF, 2012	

Table 32: Comparison between official hazard class rating and hazard class rating as reported by farmers for herbicides (cont.)

Respondent	Product name	Official hazard class rating	Hazard class reported by farmer	Status (what farmer thinks of chemical compared to official rating)	References
R8	Tenderbaf, Callisto 480 SC, Primagram Gold 660 SC, Aqua right, Karate Zoom, Complement super	Tenderbaf: n/a Callisto: III Primagram: II Aqua right: n/a, Karate Zoom: n/a Complement super: n/a	80% in III 20% in II	Accurate	10,13
R9	Atrazine 90 DF, Cantron SC E, Acetachlor 900 EC	Atrazine: II Cantron: III Acetachlor: III	100% in II	Less toxic	2,3,15
R10	Atrazine 90 DF, Guardian S EC, Round Up, Cantron 480 SC, Harness extra	Atrazine: II Guardian: II Round up: III Cantron: III Harness: III	100% in III	Mostly accurate but also more toxic	1,3,8,9,14
R11	Gardomil Gold 600 SC, Duel II Magnum, Campus, Dash HC, Atranex WG	Gardomil Gold 600 SC: II Duel: III Campus: n/a Dash: II, Atranex: II	100% in II	Accurate and slightly more toxic	11,12,15,17
R12	Slash 710 SG, 2,4-D Ester EC, Select, Terbusien Super 600 SC Remus 960, Extrazine	Slash: III 2.4D Ester: II Select: n/a Terbusien, II Remus: II Extrazine: III	90% in IV 10% in III	Accurate but mostly more toxic	4,6,7,14,16
R13	Atrazine 90 DF	Atrazine: III	Farmer had no opinion	Not available	14
References	1 Agrian, 2013 2 Villa Crop Protection, 2010 3 Villa Crop Protection, 2011 4 Villa Crop Protection, 2012 5 Villa Crop Protection, 2013a 6 Villa Crop Protection, 2013b	7 Villa Crop Protection, 2013c 8 Monsanto, 2002 9 Monsanto, 2008 10 Syngenta Crop Protection, n.d. 11 Syngenta Crop Protection, 2004 12 Syngenta Crop Protection, 2006			13 Syngenta Crop Protection, 2008 14 Drexel Chemical Company, n.d. 15 Agronica, 2009 16 Enviro-crop, 2012 17 BASF, 2012

Most farmers reported fertilizers to be in the "slightly hazardous" class and many also classified the fertilizers as "acute hazard unlikely in normal use". Fertilizer packaging does not indicate a hazard class like those in Table 30, but it can still be dangerous to people if they are exposed to the fumes or dust in confined spaces (La Cock, Personal communication, 2013). La Cock (Personal communication, 2013) told the story that his wife took ill due to the inhalation of fertilizer fumes. According to Glasser (2002) fertilizer fumes can especially be dangerous to people who are living or working near fertilizer factories. An example is a person who worked at a phosphate fertilizer factory and during this time developed illnesses including auto-immune disorders, chronic lung disease, blood disorder, swelling, chronic fatigue, cardiac arrhythmia and memory loss. He was unable to work further at an age of 39 (Glasser, 2002). Glasser (2002) also reports that people living near phosphate fertilizer plants are twice as likely to develop leukemia. It is therefore important that fertilizers are stored in well ventilated areas.

Figure 34 represents the criteria on which farmers based their answers in order to determine the characteristics of agro-chemicals. Most of the farmers reported that fertilizer packaging does not indicate its toxicity levels and therefore most of the answers regarding fertilizers were self-determined. This statement was verified by inspecting fertilizer packaging in a fertilizer storeroom.

If farmers are well informed of the hazard rating of chemicals it should enable them to use the chemicals with the necessary care.

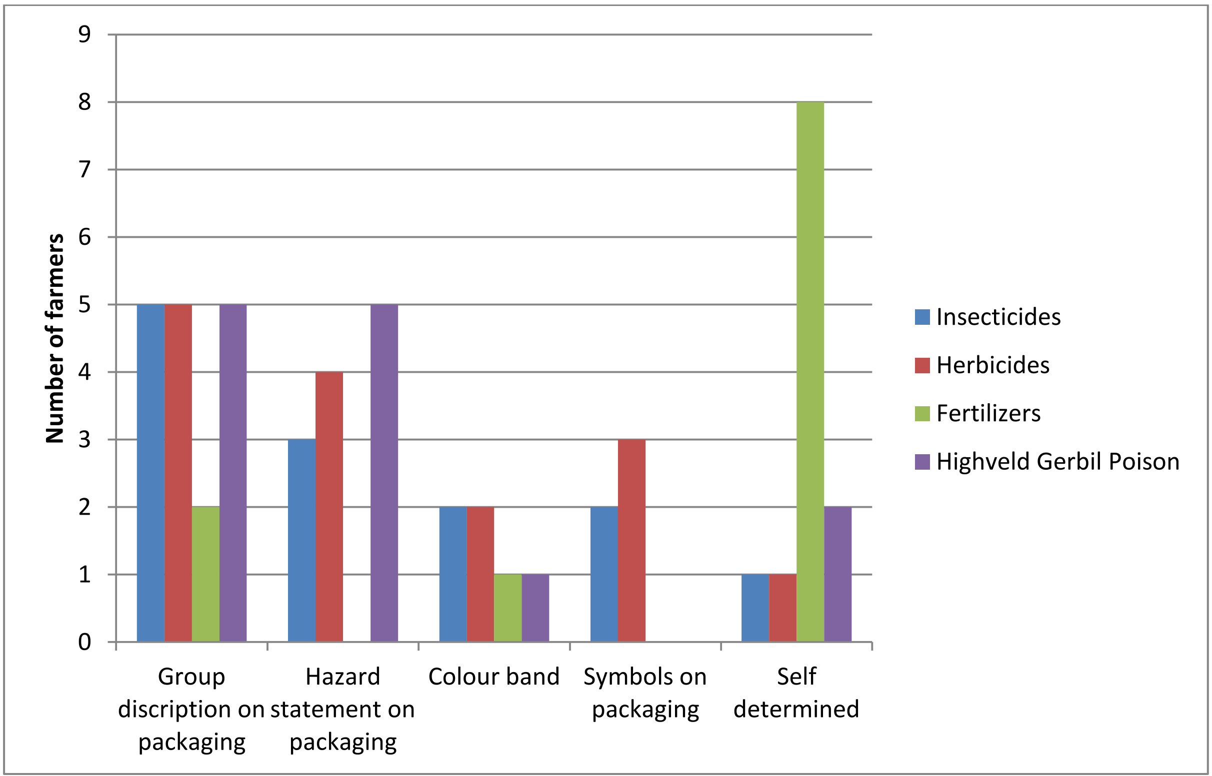

Figure 34: Criteria on which farmers based answers regarding characteristics of chemicals

4.4.5 Servicing of implements

This section will discuss the servicing of implements, tow implements and vehicles, as well as the storage, disposal and wastage of oils, fuels and lubricants.

4.4.5.1 Implements, vehicles and tow implements

Eleven of the thirteen farmers reported that they own large fuel driven implements. These implements, including tractors and tow implements, are serviced on the farms. A Service interval for fuel driven implements and tractors mostly ranges from every 100 to 500 hours, every six months, every year and "as needed". Service intervals mostly depend on the specific service plans and the age of the implements and tractors. Towed implements are mostly serviced as is needed. Three farmers reported that they are serviced every 500 hours, another every 50-250 hours and another farmer reported servicing every six months or before use like for example before harvesting. Tow implements mostly need only grease and are greased as is needed. One farmer greases tow implements every week and another reported that some implements are never serviced.

Table 34 is an indication of the reported amounts of oils and other fluids (excluding hydraulic fluids) that are drained out of implements and tractors as well as lubricants (including grease) that are used on implements and tractors per production cycle. These amounts can be very variable as they depend on service plans, how often the equipment and implements are used and their age.

Table 34: Volumes of oils, lubricants and other fluids used on farms

Respondent	Oils (ℓ)	Other fluids (ℓ)	Grease (ℓ)
R1	400	50	45
R2	250	60	1
R3	40	0	0
R4	60	0	5
R5	15	0	0
R6	1 600	0	1
R7	640	250	0
R8	945	0	0
R9	180	0	0
R10	60	0	40
R11	250	0	1
R12	104	0	1
R13	45	0	0
Average	**353**	**27.692**	**7.231**

The average volume of oil used on a maize farm is 353 litres, other fluids 27.692 litres and greases 7.231 litres. All farmers fill their implements and vehicles with fuel on the farms except for one who reported that vehicles are filled with fuel both on and off the farm.

Tractors are mostly serviced on the farm and pick-ups (bakkies) are mostly serviced at the closest dealers/agencies. Pick-ups are serviced once every 10 000km or 15 000km or once a year.

4.4.5.2 Storage, disposal and wastage of fuel

Only two of the thirteen farmers reported that fuel spillages do not occur on their farms. Two farmers reported large fuel spillages that occurred on their or other farms of 9000 litres and 3000 litres respectively. The rest of the farmers reported that it happens now and again and only in small quantities of 0.5 – 5 litres, with the biggest spills being of about 20 litres. All farmers reported that the most common reason for fuel spillages is negligence. Spillages are either just left on the soil or covered with soil. One farmer reported that soil is removed and another reported that during a big spill, fuel was sucked up with pumps and the soil was removed.

Oils, fuels and lubricants are disposed of once or twice a year or when implements and vehicles are serviced. Figure 35 illustrates the methods used for the disposal of oils, fuels and lubricants. Seven farmers (53.85%) reported that old oils are stored in big tanks or containers before it is picked up by oil companies, while 0.769% (n=1) reported it to be buried, 15.38% (n=2) said that it is burned and 23.07% (n=3) reported that it is never disposed of.

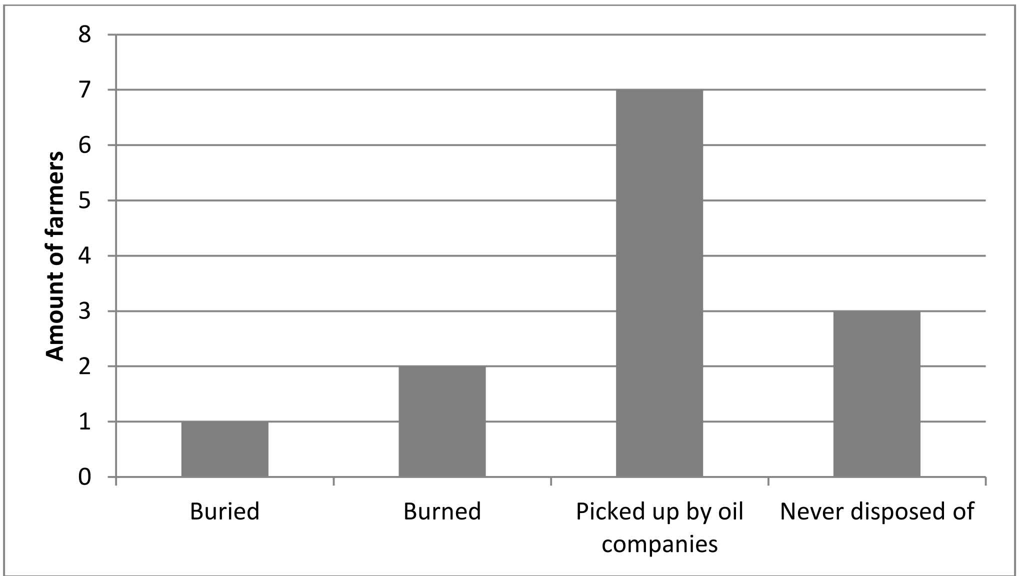

Figure 35: Methods used for the disposal of oils, fuels and lubricants

Old and new oils are generally stored separately, where new oils are stored in storerooms and old oils in storerooms or outside in tanks or containers. All fuel is stored above ground and one farmer (7.69%) reported that fuel is stored above and underground. In terms of above-ground storage of fuels, 15.38% (n=2) of farmers have a pit and bund walls and 7.69% (n=1) only have a pit to ensure safe storage of fuels, while 76.92% (n=10) used none of these features to ensure safe storage of above-ground fuel. Only two farmers reported that underground water monitoring has been done before. This is clearly an area where proper management on the farm is lacking. One farm is also a wedding venue and guest house and therefore underground water monitoring has been done as guests use groundwater.

4.4.6 Legal compliance

Table 35 illustrates how familiar respondents are with legislation on different aspects. The majority of farmers reported that they are reasonably familiar, familiar, or fully familiar with legislation. Two farmers did not elaborate on how familiar they were with legislation related to chemical disposal, the one stating that he does not dispose of chemicals and the other plainly saying that he does not comply. There were a number of cases where farmers said that they are familiar with legislation but admitted that they do not comply with it. One farmer responded that Caltex is in charge of fuel storage facilities and thereby said that he does not have to be familiar with legislation regarding fuels. One farmer also admitted that he has never read any laws but scored all his answers in the yellow to green zones which indicates him to be reasonably to fully familiar with legislation.

Table 35: Familiarity of maize farmers to legislation

Legislation	Not familiar at all	Slightly familiar	Reasonably familiar	Familiar	Fully familiar
Chemical usage	0.00%	0.00%	38.46%	46.15%	15.38%
Chemical storage	0.00%	0.00%	23.08%	38.46%	30.77%
Chemical disposal	0.00%	7.69%	23.08%	30.77%	23.08%
Treatment of agro-chemical packaging and containers before disposal	15.38%	7.69%	23.08%	30.77%	23.08%
Disposal agro-chemical packaging and containers	7.69%	7.69%	38.46%	15.38%	30.77%
Cleaning of implements, vehicles and smaller equipment used to apply chemicals	15.38%	0.00%	30.77%	30.77%	23.08%
Storage of implements, vehicles and smaller equipment used to apply chemicals	23.08%	7.69%	15.38%	23.08%	30.77%
Farm servicing facilities	23.08%	7.69%	0.00%	46.15%	15.38%
Fuel storage facilities	15.38%	7.69%	15.38%	23.08%	30.77%
Disposal of lubricants, oils and other fluids	15.38%	7.69%	23.08%	53.85%	0.00%
Storage of lubricants, oils and other fluids	23.08%	0.00%	15.38%	46.15%	15.38%

Figure 36 rates the appropriateness of legislation as judged by farmers. Farmers had the option to respond to this question on a scale of one to five but only responded for legislation to be appropriate or slightly strict. Farmers who feel that legislation is slightly too strict were relatively evenly spread for all legislation categories. Two farmers did not respond to this question.

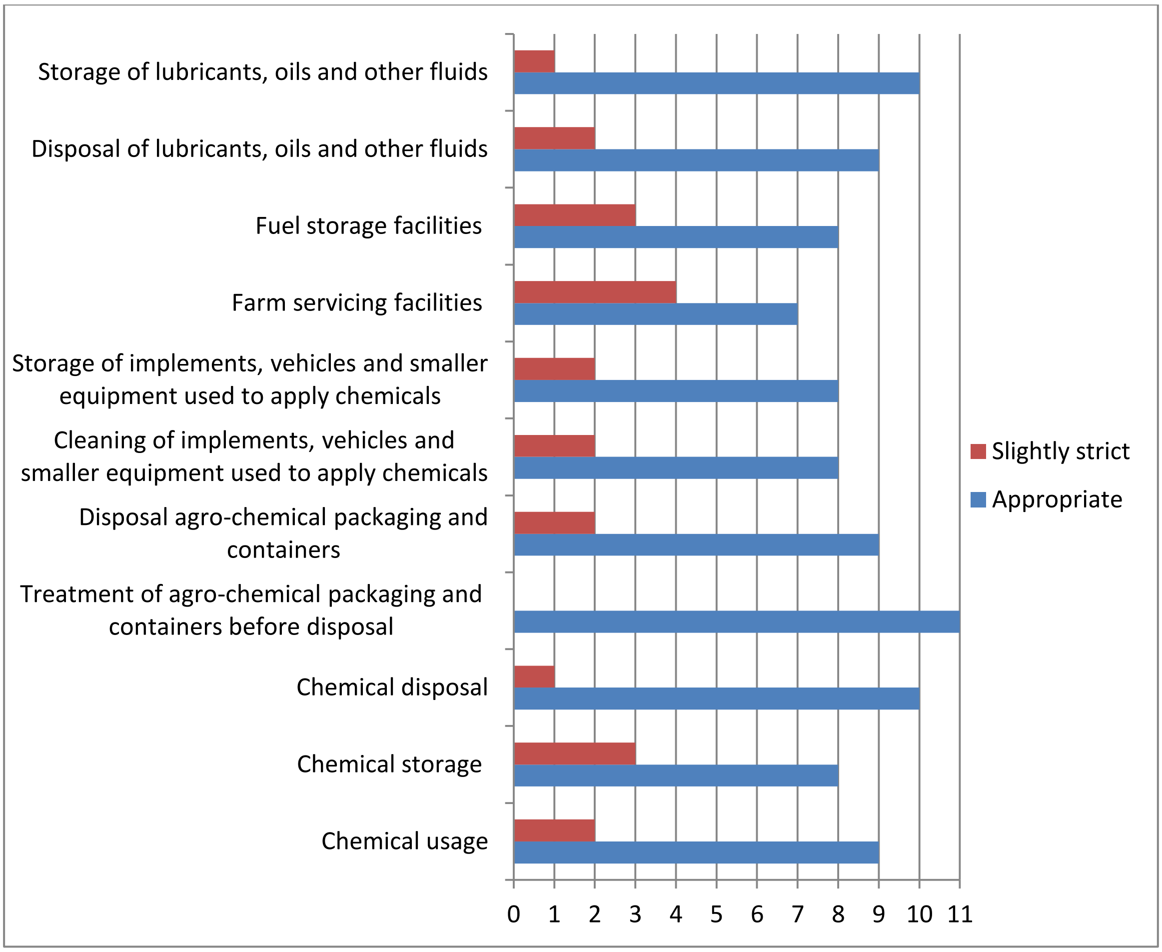

Figure 36: Appropriateness of legislation

Legislation on pesticide management in South Africa needs to be improved. This includes the revision of the Fertilizer and farm feeds act (DAFF, 2010) and solving the problem of the fragmented approach to pesticide management in the country (DEAT, 2005b).

4.5 **Chemical distributor questionnaire results**

The interviews with chemical distributors consisted of three themes which include:

- Determination of application volumes of chemicals
- Determination of recommended volumes of chemicals
- Waste disposal

4.5.1 Determination of application volumes of chemicals

Twelve telephonic interviews were conducted with the chemical distributors who supply agro-chemicals to the farmers who were used in the study. One of the chemical distributors supplies to two of the farmers who were used in the study.

Farmers determine the amount of chemicals to apply by following the recommendations that are made by the chemical distributors. Chemical distributors base their recommendations on the label that is available on all chemical packaging and containers. They take into consideration factors such as the type of soil, the clay content of the soil (especially important), the weed spectrum and size of weeds and the specific pests and quantity of them that are of concern for the particular year. Chemical distributors will also calibrate chemical application equipment according to their final recommendations.

Chemical distributors generally feel that farmers do have sufficient access to information on the quantities of chemicals that should be applied on a specific crop and to a specific size of land. Chemical distributors reported that this information is available on the label of the chemical packaging and containers; otherwise the farmers can obtain the information from the chemical distributors themselves. Some farmers, however, do not concern themselves with the guidelines available to them and rarely read the labels.

One chemical distributor felt that farmers do not have enough information and that this is why their (chemical distributors) services are required. Another responded by suggesting that some do have enough information and others do not and that farmers generally do not have enough information. Another chemical distributor responded by saying that the level of service to the farmer depends on the chemical distributor. Some farmers have to help themselves where in other cases farmers receive much assistance from the chemical distributors.

Eight of the twelve chemical distributors responded that 100% of the farmers to whom they supply, make use of their recommendations and advice on the amount of chemicals to apply. Two distributors responded that 99% of farmers make use of their services. The remaining two distributors respectively suggested that 95% and 90-95% of farmers made use of their services. Last mentioned respondent said that some farmers give the impression that they know how to calculate the correct amounts of chemicals to apply and others really do know. The converse of above mentioned percentages holds true for the percentages of farmers who calculate the amounts of chemicals needed themselves.

Chemical distributors were asked if they have in the past been blamed by farmers for crop failures. Eight chemical distributors reported that they have been blamed for crop failures while four reported that they have not been blamed. It is clear that most chemical distributors have been blamed by farmers for crop failures. This is also an indication that farmers depend on chemical distributors to make the correct recommendations to them regarding the use of agro-chemicals.

4.5.2 Determination of recommended volumes of chemicals

Ten chemical distributors (83%) said that they keep records of the amounts of pesticides sold to farmers. The other two said that records are available on financial statements and other systems which imply that records are being kept. Therefore 100% (n=12) of chemical distributors keep record of the amount of pesticides sold to farmers.

Five chemical distributors (45.4%) responded that farmers do sometimes buy more or less chemicals than what they recommend. One chemical distributor was also one of the farmers to whom the questionnaire was administered and therefore the question was not applicable. It was highlighted that this happens very rarely. One chemical distributor said that farmers may buy more chemicals for difficult weeds and another said that calibration is only about 90% accurate and that chemicals are never fully used up. This may lead to farmers buying fewer chemicals than recommended.

This theme also included questions to verify the quantities of insecticides, herbicides and fertilizers as reported by farmers to the quantities supplied by chemical distributors to their farmers. Also included were questions on the total volumes of chemicals supplied by the chemical distributor to his district. This data was already discussed in section 4.4.3.

4.5.3 Waste disposal

Chemical distributors were asked in an open question how farmers dispose of agro-chemicals and their responses are indicated in Figure 37. Fertilizers are never disposed of as it is expensive and extra fertilizers are used on lands or used the next season. Fertilizer spillages are also easily swept up to be placed back in packaging and used on lands. Pesticides are not often thrown away and normally not much stands over to the next season. When new pesticides are ordered the pesticides from the previous season are taken into consideration and are used up before the new pesticides are used. One chemical distributor reported that farmers should dispose of pesticides in such a way that it is exposed to the sun and consequently chemically broken down by the sun. Pesticides that are taken away by chemical distributors can be made available to other farmers who need them allowing the farmers from which the pesticides came to be refunded. Old pesticides can also be traded in for new ones.

Figure 37: Disposal of agro-chemicals as reported by chemical distributors

Figure 38 is a summary in response to an open question on the disposal of chemical packaging and containers that are no longer used by farmers. Burning the packaging and containers is by far the most common method of disposal, this also being an illegal method for certain types of packaging. Packaging and containers are recycled by AVCASA and recycled material is used to manufacture plastic furniture. Chemical distributors also try to provide the farmers with packaging which according to law, may be burned.

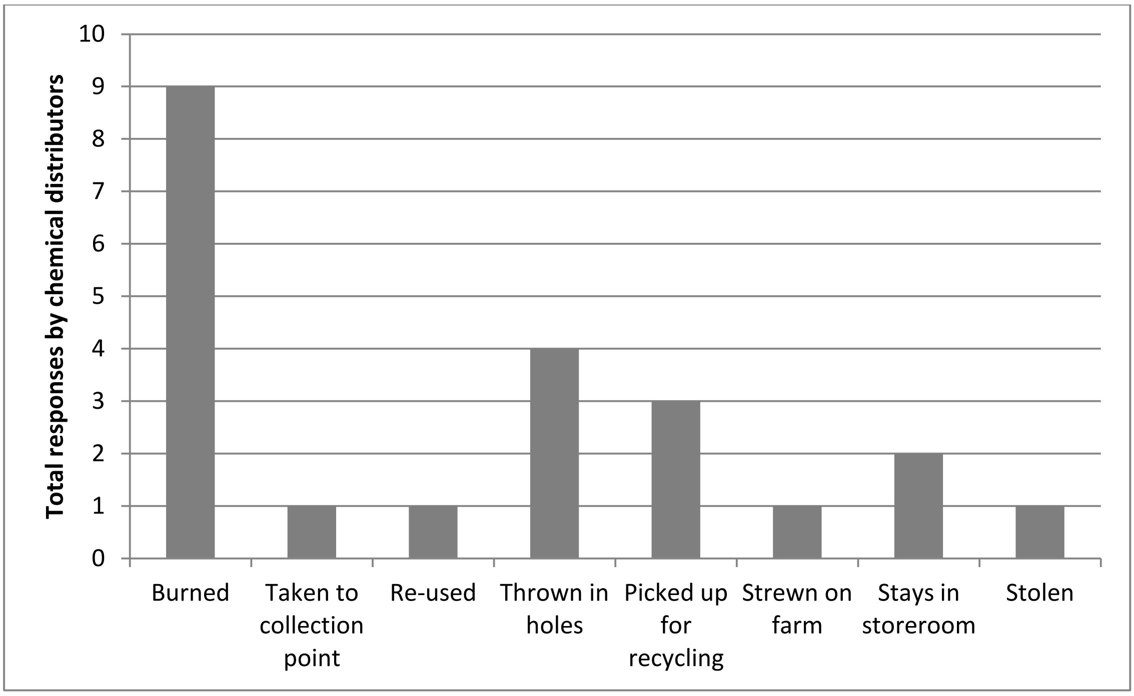

Figure 38: Disposal of agro-chemical packaging and containers as reported by chemical distributors

No methods to minimize fertilizer packaging waste are being implemented except for some packaging that is specially manufactured in such a way in order for it to be re-used for other purposes, like for example to store seed (La Cock, 2013, Personal Communication).

All fertilizer packaging should be lined with a plastic liner on the inside. When packaging is re-used, this liner should be removed and then the packaging is safe to be re-used (La Cock, 2013, Personal Communication).

Chapter 5 Conclusions and Recommendations

This chapter summarizes the research into key questions related to hazardous waste management in the agricultural maize sector in South Africa and tested a methodology for gathering information to develop hazardous waste registers. The development of hazardous waste registers is a very important waste management tool which the DETEA aims to employ to ensure proper resource protection and waste management in South Africa.

The main conclusions of the study showed that determining average volumes of agro-chemicals used in different phases of the maize production sector can be quite complex. This complexity is due to various factors – pesticides may have different names but the same active ingredients, a single pesticide can be used for different pests (by using different concentrations and application methods), in some cases there is uncertainty amongst farmers on how to effectively apply these pesticides, whether the agro-chemical is in a granular or liquid form, and factors like soil type, climate conditions and varying types and amounts of pests and weeds which influences agro-chemical usage in different areas. All these factors make it very difficult to calculate average pesticide volumes used per production cycle just for the maize industry. If one takes into account that agriculture spans a much wider production industry than just maize (e.g. vegetables, cotton etc) the complexity increases even more. This study illustrates the fact that another more effective approach may be required to gather accurate data to populate waste databases for each province. Alternative approaches can include web surveys or voluntary registration by farmers and reporting of chemical type and volumes used either by post or on a web based system.

Summarized conclusions that can be drawn from the study are given in section 5.1. Conclusions are listed according to the main themes that were investigated in the farmer questionnaire and the conclusions from the chemical distributor interviews are incorporated into the farmer questionnaire conclusions. Section 5.2 will make recommendations for the improvement of the management of agro-chemicals on farms in general. In section 5.3 recommendations will be made on alternative methodologies that could be utilized to gather data for the development of an agro-chemical database.

5.1 Summarized conclusions

The summarized conclusions will discuss the following results as obtained during the farmer surveys and chemical distributor interviews:

- Geographical information
- Technical / operational aspects as well as implements and vehicle servicing
- Waste cycle information
- Storage, disposal and wastage of agro-chemicals, cleaning and disposal of agro-chemical packaging and containers and cleaning and storage of agro-chemical application equipment
- Characteristics of agro-chemicals

Geographical information

The mean annual precipitation was accurately reported by the respondents and ranges between 350mm-750mm in the Western Maize Production Region.

Technical / operational aspects as well as implements and vehicle servicing

Servicing of vehicles was addressed under technical and operational aspects. The main conclusions were that only some of the bigger farmers use self-propelled sprayers. Boom sprayers are the most common implements that are used to apply agro-chemicals while tractors are used to tow most of these implements and are also used for other activities on the farm. Large numbers of tractors are thus used on farms and require servicing. A Service interval for fuel driven implements and tractors was found to range from every 100h to 500h hours, every six months, once every year or “as needed”. Service intervals mostly depended on the specific service plans and the age of the implements and tractors. Towed implements are mostly serviced as is needed, with a wide range of reported intervals (ranging from every 500 hours, every 50-250 hours, every six months to servicing just before use like for example harvesting). Towed implements mostly need only grease and are greased as is needed and thus servicing of tow implements is not seen as a large contributor to chemical contamination. Tractors are mostly serviced on the farm and pick-ups (bakkies) are mostly serviced at the closest dealers/agencies. Almost all respondents reported that their implements and vehicles are filled up with fuel on farms, making fuel storage and spillage an important aspect to consider in terms of chemical management.

Only two out of the thirteen farmers (15.38%) reported that fuel spillages do not occur on their farms. Of the farmers who reported spillages, two farmers respectively reported large fuel spillages of 9000 litres and 3000 litres that occurred on their or other farms. The balance of the farmers reported that spillages occur infrequently and only in small quantities (0.5 and 5 litres with largest spills of about 20 litres). All farmers reported that the most common reason for fuel spillages is negligence. Spillages are managed by either just leaving on the soil or covering the spill site with soil. One farmer reported that soil is removed and another reported that after a large spill, fuel was sucked up with pumps and the soil was removed. Oils, fuels and lubricants are disposed of either once a year or twice a year or when implements and vehicles are serviced. Just over half of respondents reported that used oil is stored in big tanks or containers before it is picked up by oil companies. The rest of the respondents bury, burn or never dispose of it.

Only two farmers reported that underground water monitoring (which is important to detect fuel or other chemicals in groundwater) had been done before. This is clearly an area where proper management on the farm is lacking. One farm is also a wedding venue and guest house and therefore underground water monitoring has been done as guests use groundwater.

Waste cycle information

Regarding waste cycle information it was found that there is currently no agro-chemical usage database available in South Africa. This is problematic as such data is required for the proper management of chemicals in the environment.

During the survey with the farmers, issues related to trade names and active ingredients were encountered. The importance of collecting the full name of the specific agro-chemical used was highlighted as products with different prefixes and suffixes can have different active ingredients which can mean that the products can fall in different hazard classes. Not having the full names of all products used caused difficulties in the comparison of the hazard classes as reported by the farmers to the official hazard classes of the pesticides and will be problematic during the establishment of a database. It is recommended that farmers should keep detailed information on the agro-chemicals (full names etc) that they use on the farm.

All farmers use treated maize seeds. Most farmers felt that treated maize has a substantial or slightly less than substantial effect on the amount of chemicals they use, although some farmers also felt that the effect is only marginal or that it has no effect at all.

In terms of pesticide usage the following points are important:

- Average insecticide use for irrigated farms was slightly higher than that of dry land farms. It is generally accepted that insecticide and fertilizer use is higher for irrigated maize than for dry land maize. The collective average volume of insecticide used on dry land and irrigated maize farms was comparable to the average insecticide use as calculated from district totals as reported by chemical distributors.
- Results have shown that 50% of dry land farmers apply insecticides exactly according to chemical distributor recommendations while 37.5% of irrigation farmers apply insecticides exactly according to chemical distributor recommendations.
- Average herbicide use for dry land farms was slightly higher than that of irrigated farms. The reason for this is the shadow caused by closer plant spacing at irrigated maize that kills of weeds early on. The average volume of herbicide usage for dry land and irrigated farmers combined was comparable to the average calculated from district totals as reported by chemical distributor.
- Results have shown that for dry land farmers 30% of farmers apply herbicides exactly according to chemical distributor recommendations and for irrigation farmers 42.86% of farmers apply herbicides exactly according to chemical distributor recommendations.
- Possible reasons why reported amounts of pesticides applied by farmers and reported amounts of pesticides recommended by chemical distributors are sometimes not comparable are the following:
    - Small sample size
    - Confusion between different quantities used from season to season
    - Influence of individual farmer choices possibly as a result of:
        - Cash flow restrictions
        - Risk taking
        - Experimentation
    - The discrepancies between application as recommended and actual application may also be due to over application of chemicals, which would have negative consequences on the environment.

Very little data was available for quantities of fertilizers recommended by fertilizer distributors. The reason for this is that chemical distributors either supply insecticides and herbicides or fertilizers to farmers but not both. This not initially being known; only insecticide and herbicide distributors were contacted. Data for quantities of fertilizer used was gathered from co-operatives, fertilizer industries and also a few fertilizer distributors but not necessarily the distributors of the farmers used in the study. The following points are important regarding fertilizer usage:

- It is generally expected that fertilizer usage on dry land farms is much lower than that of irrigated farms. An acceptable average for dry land farms is 150-200 kg/ha and for irrigated farms is 700-1100 kg/ha. Results from the survey have shown that the average fertilizer use for dry land farms is 227.455 kg/ha and 549.110 kg/ha for irrigated farms and these correlate well with the averages mentioned above.
- The average fertilizer usage as reported by dry land and irrigation farmers (388.28 kg/ha) is more than the average fertilizer usage rate calculated from district totals (285.13 kg/ha). This discrepancy may be explained by the sampling size and also the ratio between dry land and irrigated farms used, as well as the variation in soil types and climates as reported within the specific district. Further investigation and more accurate data are however required to elaborate on possible reasons for this discrepancy.

The total areas (in hectares) of white and yellow maize for dry land and irrigated farms were combined and multiplied by the average insecticide, herbicide and fertilizer usage rates as reported from dry land and irrigation farmers, to calculate a total agro-chemical use for each province as covered by the western maize production area (Free State, North West and Gauteng). The rates for each of the three provinces were totalled to obtain the total agro-chemical use for the western maize production region for dry land and irrigated maize. For dry land maize this was 136 793 litres for insecticides, 8 433 195 litres for herbicides and 450 919 625 kilograms for fertilizers. For irrigated maize this was 38 967 litres for insecticides, 430 733 litres for herbicides and 57 656 550 kilograms for fertilizers.

In terms of determining the amounts of chemicals to be applied during the different maize production phases, the following aspects are important:

- The majority of farmers reported that they obtain the information on how much chemicals to apply from their chemical distributors while the balance reported that they determine it themselves. The farmers who calculate it themselves do however have training on how to do it; therefore all farmers receive recommendations on how much chemicals to apply from reliable sources.
- All chemical distributors reported that farmers determine the amounts of chemicals they apply based on the recommendations made by the chemical distributors but they also reported that there is a very small percentage of farmers who calculate these amounts themselves. Chemical distributors base their recommendation on the label that is available on all chemical packaging and containers and also take factors such as type of soil, clay content of soil, weed spectrum, size of weeds and specific pests that are a problem for the specific year into consideration. Chemical distributors will also calibrate chemical application equipment according to their final recommendations.
- Chemical distributors mostly feel that farmers have sufficient access to information on the quantities of chemicals that should be applied on a specific crop and to a

specific size of land although some farmers do not concern themselves with this information.

- Results have shown that with a few exceptions farmers do order the recommended amount of chemicals. Almost half the chemical distributors reported that farmers do sometimes buy more or less pesticides than what they recommended, but it was highlighted that this happens very rarely.

All chemical distributors keep records on the amounts of pesticides they sell to farmers and these may be an important source of information during the development of a database.

Storage, wastage and disposal of chemicals

Storage and disposal of chemicals and un-used or empty chemical containers are important aspects to manage if one aims to limit exposure of these chemicals to the environment. A once-off project with the aim to collect and destroy obsolete and unwanted agro-chemicals as well as agro-chemical packaging and containers was conducted by the Department of Agriculture and who funded AVCASA to run the project in 1998. A similar project is currently being launched and the Department of Environmental Affairs, AVCASA and the DBSA are involved in this but AVCASA is struggling to get the project off the ground and is awaiting feedback from Government. It is recommended that these kinds of projects should not only be a once off effort but should be a continuous program that will ensure that agro-chemical waste is continuously collected and destroyed so as to prevent build-up of these chemicals on farms and to limit unwanted introduction of these chemicals to the environment.

Most farmers reported that they use almost all agro-chemicals with the balance reporting that all the chemicals purchased were used. One farmer reported that the size of containers in which chemicals are supplied can result in a farmer buying more chemicals than needed. An example is a farmer who needs 30 litres of herbicides but the containers are only available in 20 litres. In this case the chemical distributor will supply the farmer with two 20 litre containers resulting in the farmer having 10 litres more herbicide than he actually needs. It is recommended that smaller containers be made available so that the exact amount of chemicals required by the farmer can be supplied. Another possible solution is for farmers to acquire large tanks on their farms which then could be filled up with the exact quantities that are needed for the season. With this method, agro-chemical packaging and container waste will also be eliminated and it will solve the problem of the illegal burning of packaging.

In the meantime, the current mechanisms in place for the collection and removal of agro-chemicals and agro-chemical waste should be improved as results have shown that this is not widely done. A strategy that can be followed to achieve this is the extended producer responsibility (EPR) program. This extends the financial and/or physical responsibility of the producer of the product, or the resultant waste of the product, until after it has been used. This means that the manufacturer of the product will be responsible for the treatment, recycling and/or disposal of for example the agro-chemical containers. The correct way to dispose of pesticide waste is to return it to the local supplier, send it to a registered disposal company or to dispose of it at a registered hazardous waste disposal site.

Results from the questionnaires have shown that all agro-chemicals are normally not used up immediately after delivery and therefore will be stored at some time. In terms of storage, the following aspects are important:

- Agro-chemicals are stored for periods ranging from 1 month to more than a year. Results have shown that farmers who store chemicals until the following season/year will generally use these chemicals in the following season and will take the amounts of chemicals left in the storerooms into consideration when buying new chemicals. Only the quantity of agro-chemicals required for one season may be purchased by a farmer. With this it is assumed that chemicals may not be stored to a next year or season. Regarding this matter there is some room for improvement as five farmers reported that they store chemicals for one year and longer.
- Most farmers reported that the agro-chemical storage facilities on their farms are safe or very safe. The main reasons farmers gave for why they feel they have safe storage facilities include:

    - storage facilities are locked
    - limited access
    - far away from water resources
    - chemicals are separated from each other
    - store rooms have signs
    - storerooms are well ventilated
    - steps and walls prevents leakages
    - stock control is implemented
    - agro-chemicals are stored in tanks and placed on pallets

- Some farmers felt that special storage facilities are not needed for fertilizers since it is not dangerous and some therefore store fertilizers in open areas. There are numerous regulations covering the storage of agro-chemicals and farmers generally feel that these regulations are too difficult to comply with as they are too strict. The combined responses of all the farmers used for the study covered most of the important safety measures that are required for chemical storage rooms. Some important safety measures that were not mentioned include:

    - Fire resistance
    - Good lighting
    - Constructed of materials that are structurally sound and non-combustible
    - Availability of equipment to deal with spillages

- The chemical storage facilities of farmers were not physically investigated and therefore an accurate judgement of the appropriateness thereof cannot be made. This is important as the storage facilities of a farmer who scored himself a four on a scale of five (safe) turned out to be in very bad shape. It is, however, a concern that the combined responses of all farmers still did not cover all the regulations that are needed and the fact that farmers feel the regulations are quite strict and difficult to comply with is a sign that chemical storage facilities are generally not as good as they should be. Results seem to indicate that the larger commercial farmers do comply or come close to complying with regulations whereas the smaller scale farmers fall short by quite a margin, but this trend would have to be confirmed by a larger study sample.

Regarding disposal of chemicals –

- Roughly 60% of farmers do not dispose of agro-chemicals at all where the rest will occasionally dispose of it.
- Two methods were reported on how chemicals are disposed of. The first is disposal in a hole in the ground which is lined with bricks which causes the water to evaporate

after which the chemicals stay behind in the hole. The second method is burning the chemicals together with the packaging and containers.

- Most chemical distributors responded that agro-chemicals are not disposed of by farmers but stand over to the next season for it to be used then. Other methods of "disposal" included the trading in and replacement of agro-chemicals, the removal thereof by the chemical distributor, and the retention thereof in storerooms without ever being discarded. According to chemical distributors fertilizers are never disposed of as the product is too expensive and spillages can easily be swept up and re-used. Pesticides are not often thrown away and normally not much is retained until the following season. When new pesticides are ordered the pesticides retained from the previous season are taken into consideration and are used before the new pesticides are used. Pesticides that are taken away by chemical distributors can be made available to other farmers who need them and the farmers from where the pesticides came can be refunded. Old pesticides can also be traded in for new ones.

Pesticides can be managed in the following ways –

- Encapsulation is an alternative method that can be used for the disposal of agro-chemicals. This is however a costly method and can actually only be seen as storage and not disposal, as the waste in not destroyed and the toxicity thereof is also not reduced.
- Pesticide disposal can also be prevented by eliminating accumulation. This can be achieved by keeping stocks as small as possible and by not over stocking. A pesticide bank which aims to monitor pesticides at end-user or supplier level and to monitor shipments to ensure that stocks are only replenished when necessary, can be implemented to reach this goal.
- It is recommended that pesticide waste should be sent back to the local supplier or to a registered disposal company or should be disposed of at a registered hazardous waste disposal site.

Respondents were asked to report on spillage and wastage of agro-chemicals and the following results can be reported:

- Only two farmers responded that no agro-chemicals are ever wasted. Most farmers responded that only very small amounts are spilled and wasted. The average percentage reported as wasted by respondents for insecticides was 0.39%, 0.123% for herbicides and 0.135% for fertilizers. These percentages include waste as a result of cleaning of chemical application equipment, diluting, cleaning of chemical tanks and chemical containers falling over.
- The most common reason reported by farmers for the spillage of agro-chemicals is during transfer from container to applicator. A close second is the bursting of containers due to bad handling and equipment failure. Other cases included damaging of packaging during transport, defective packaging and spillage during dispensing.
- Only three farmers reported that they waste chemicals because of expiration thereof with quantities of between only 0.5% to 2% of their stock. Farmers reported that fertilizers never expire as they are always fully used up. It is recommended that obsolete agro-chemicals should be sent back to the chemical distributor.
- Fertilizer spills are normally swept up and placed back in packaging to be re-used. Other chemical spills are sprayed down with water, left on the ground and sometimes covered with soil.
- In general, results have shown that the theft of chemicals is a very small problem and farmers reported that is difficult to know whether and how much chemicals are stolen.

In terms of disposal of empty packaging and containers, the following points are important:

- Almost half of respondents immediately dispose of empty agro-chemical packaging and containers whereas the other half will re-use these and dispose of them later or will immediately dispose of only some of their packaging and containers.
- The chemical packaging and containers which are re-used by farmers are normally herbicide containers and fertilizer packaging as these are less toxic than insecticide packaging and containers. SANS recommends that empty pesticide packaging and containers should be triple rinsed, punched with holes, flattened and sent to a hazardous waste disposal site, registered waste disposal company or back to the suppliers or for recycling. Fertilizer packaging with liners can be re-used after the liners have been removed. It is however recommended that all fertilizer packaging should be lined to ensure that all fertilizer packaging supplied to farmers can be safely re-used. Pesticide containers may be re-used if they are used to hold the same product. Paper waste bags and mildly contaminated items may be burned. If packaging and containers cannot be immediately disposed of they should be stored in a place where they will not contaminate the environment.
- Almost all chemical distributors reported that agro-chemical packaging and containers are burned by farmers. Other methods of disposal of packaging and containers included:
    - taken to collection point
    - re-used
    - thrown in holes
    - picked up for recycling
    - strewn all over farm
    - remains in storeroom and gets stolen
- Chemical distributors also try to provide the farmers with packaging which, according to law, may be burned.
- The majority of farmers felt that the cleaning method used to clean agro-chemical packaging and containers are reasonably safe.
- The most common method for the disposal of packaging and containers is to burn them even though this is illegal in South Africa.

The following results were obtained regarding the cleaning of implements, vehicles and smaller equipment:

- The majority of farmers reported they often clean implements, vehicles and smaller equipment with also the majority reporting the use of high pressure sprays and water. About half of the farmers use a product known as Flush All, which dissolves and breaks down the chemicals. It is recommended that all machinery must be washed with clean water after application of agro-chemicals, and knapsacks, brushes and mixing equipment should be washed with an appropriate liquid soap after which it must be well rinsed. There is room for improvement of the methods used to clean agro-chemical application equipment as well as how often it is done. It is however not stated in regulations how often implements, vehicles and smaller equipment should be washed and generally farmers do this as required, based on how frequently the equipment is used.
- Six farmers reported that implements are either cleaned on the ground, adjacent to the farm house or storeroom. Another six reported that they are washed in a wash bay and another on paving after which water drains to soil. One farmer reported that after washing implements, water is disposed of in a hole/drain in the ground. Vehicles are also mostly washed in wash bays or next to farm houses and

storerooms. Two farmers reported that smaller equipment is also washed in wash bays.

- The majority of farmers reported that chemical application tanks are filled up on lands. Other places include at boreholes, at dams, at water pumps, at taps near the house, at chemical tanks and in storerooms.
- It is recommended that mixing, filling and cleaning of agro-chemical application equipment must be done in a separate bunded facility. It should have a floor made of non-porous material, adequate drainage and a restricted entrance. It should be done in a manner that prevents contamination of water resources and the environment. Cleaning points were not physically inspected and therefore a well-informed judgement could not be made on this. It is assumed that wash bays are the more appropriate option for the mixing, filling and cleaning of equipment and from survey results one can conclude that most farmers generally do not comply with the strict regulations mentioned above.
- The minority of farmers felt that they have suitable cleaning points (wash bays) for implements and vehicles. The majority felt that the cleaning points are relatively suitable or nearly suitable.
- No farmers indicated that they use specific filling points for the filling of agro-chemical spray tanks and therefor no data was gathered in this regard and therefore no farmers comply to regulations in this regard.
- Only a very small percentage of farmers re-use surplus tank washing on untreated land whereas the rest will immediately dispose of it.
- Only one farmer responded to whether the concentration of tank washings are determined before it is used on untreated land and responded that it is not determined. It is recommended that surplus mix or tank washings that are applied over untreated land should not result in an over application of agro-chemicals.
- Half of respondents reported that the disposal of surplus tank washings are done so in a safe manner where almost as many feel that it is relatively safe and the smallest percentage feel that it is very safe.

Regarding the storage of implements, vehicles and smaller equipment the following was found:

- All implements and smaller equipment are stored in storerooms. It is recommended that agro-chemical storerooms must only be used for the storage of pesticides and only if necessary, for the equipment used to apply it. No further legislation was found on how implements, vehicles and smaller equipment should be stored.

Regarding the calibration of equipment the following was found:

- A large majority of farmers reported that implements are very well calibrated. Farmers are very focussed on ensuring that implements are very well calibrated to ensure minimisation of wastage of chemicals and costs. It is recommended that equipment should be calibrated annually by a competent person to ensure that the correct amounts of agro-chemicals are applied and to ensure that the target pest is adequately controlled.

The following results were found regarding the role that weather conditions play in the application of pesticides:

- Almost all farmers always take weather conditions into consideration when applying agro-chemicals.
- Farmers reported that ineffective agro-chemical application does sometimes happen but rarely. Other contributing factors reported by farmers which can result in

ineffective application of agro-chemicals include, agro-chemicals that do not work as well as expected, incorrect recommendations by the chemical distributors and inaccurate calibration of equipment.

- About half of respondents reported they have repeated applications due to ineffective applications and the balance have not. Two of these cases were not weather related.

Characteristics of agro-chemicals

Most farmers reported insecticides to be moderately hazardous (harmful), most herbicides also to be moderately hazardous (harmful) but a large percentage to be slightly hazardous (caution), most fertilizers to be slightly hazardous (caution) and most Highveld Gerbil poison to be extremely hazardous (very toxic). When comparing the hazard class ratings as reported by farmers to the official hazard class rating of agro-chemicals it was found that for insecticides farmers generally accurately reported their toxicity but in some cases also reported them to be more toxic than they are. For herbicides the majority of farmers rated them to be more toxic than they really are but there were also cases that were accurately reported, and also some respondents who thought the chemicals are less toxic than they really are. Hazard class ratings for poison used for Highveld Gerbils were accurately reported and also reported to be more toxic than it really is. A limitation in this assessment was that the full names of products were not always obtained and therefore it was necessary to make some assumptions regarding the specific agro-chemicals that were used. Most fertilizers were reported to be slightly hazardous (caution) and were also well represented in the "acute hazard unlikely in normal use" class. Most farmers based their answers to how hazardous agro-chemicals are on the group description on packaging and hazard statements on packaging with a smaller percentage using the colour band, symbols on packaging and self-determination. For fertilizers however almost all the farmers self-determined their answers as fertilizer packaging does not indicate the hazard class rating thereof.

Legal compliance

The majority of farmers reported that they are reasonably familiar, familiar, or fully familiar with legislation. There were a number of cases where farmers said they are familiar with legislation but admitted that they do not comply with it.

When testing the opinion of farmers regarding the appropriateness of legislation they had the option to respond on a scale of one to five but only responded by suggesting legislation to be appropriate or slightly strict. Farmers who felt that legislation is slightly too strict were relatively evenly spread for all legislation types.

It is recommended that legislation on pesticide management in South Africa needs to be improved. This includes the revision of the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act and solving the problem of the fragmented approach to pesticide management in the country.

5.2 Methods to improve the management of agro-chemicals on farms and to reduce agro-chemical usage

The impact that agro-chemicals have on groundwater and surface water resources can be significant. Some management techniques to reduce agro-chemical pollution on water resources were highlighted and included the following:

- In order to evaluate the impacts of agro-chemicals it is important that long term monitoring of agro-chemical usage and research on agro-chemical management should be done and this should play an important role in the development of regulations.
- A national toxicity monitoring program which was initiated by DWAF to monitor agro-chemical levels in groundwater and surface water resources to help in protecting the environment.
- Pesticide usage data together with maps of crops under cultivation, groundwater, soil, rivers, other waterways, water abstraction points as well as agro-chemical properties and models of movement through different soils can be used in a Geographical Information System to predict the likely appearance of agro-chemicals at abstraction points and to facilitate the monitoring of agro-chemicals in water. It can also aid in avoiding unnecessary monitoring of agro-chemicals where they are unlikely to appear at a specific point according to the models.
- Agro-chemical pollution can be reduced by placing restrictions or requirements on users. This can be done by restricting aerial spraying to beyond a certain proximity to water sources and instituting buffer zones.
- Alternative chemicals with other chemical formulations which are less persistent and toxic to the environment can be used.

To enable South Africa to better manage its hazardous waste a hazardous waste database must be developed. Further reasons why the development of such a database is important include amongst others:

- It will give an indication of levels of agro-chemicals to which people are exposed to
- It can monitor changes in agro-chemical use
- It can monitor the effects that changing policies have on agro-chemical use
- It is a valuable tool in the monitoring of ground and surface water contamination by agro-chemicals
- Current farming practices can be evaluated in order to improve these practices if necessary

Some of the most important data that should be captured in such a database includes:

- The areas of crop under cultivation,
- the agro-chemical products used,
- the amount of such product used,
- the hazard rating class of the agro-chemicals,
- and the weather conditions during application.

Further methods to improve agro-chemical waste management includes:

- Implementation of extended producer responsibility (EPR) which extends the financial and/or the physical responsibility of the producer of the product, or the resultant waste of the product, until after it has been used
- A pesticide bank which aims to monitor pesticides at end-user or supplier level and which monitors shipments to ensure that stocks are only replenished when necessary so as to prevent pesticide stocks from accumulating
- Industry waste management plans (IndWMPs) which are essentially working documents that are produced by an industry which demonstrates how the waste they produce will be managed
- The implementation of sustainable pest management by the introduction of incentives and disincentives which will by means of levies or the absence thereof discourage the use of normal pesticides and encourage the use of bio-pesticides
- All chemical companies should fall under the same umbrella body or federation of bodies as this would allow government to effectively access agro-chemical sales data which will allow them to identify high-risk areas based on intended use and sales.
- Management practices should focus on the basic functional elements of waste management

Agro-chemical usage can be reduced by practicing and implementing the following techniques:

- Sustainable agriculture is a practice that takes the whole farming environment into account. It includes the agricultural system and the ecological system and it is based on a concept to apply ecological principles and practices for the management and development of agriculture rather than sustaining conventional farming practices where toxic pesticides are used. The following techniques form part of sustainable agriculture:
    - Organic farming is a farming practice where no pesticides or synthetic fertilizers are used but rather organic matter, biological and botanical control, and intercropping. It involves the development of bio-chemicals that are made of natural products such as animals, plants, bacteria and minerals that are less toxic to the environment.
    - Biological control involves using natural enemies to control pests. An example of biological control is bt maize.
    - Biodynamic farming is closely related to organic farming and further includes farming practices which take the cycles and rhythms of nature into consideration. An example of this is lunar planting which enhances the forces of nature.
    - Agro-forestry is a practice where trees are grown together with crops with the aim to control pests and to increase biodiversity. It also helps to increase production and protects soil against erosion.
    - Permaculture is the development of an agricultural system which duplicates or imitates the interrelationship and structure found in nature.

IPM takes some of the above mentioned farming practices into consideration. It is an effective and environmentally sensitive approach that relies on a combination of common-sense methods to control pests.

Precision agriculture aims to restructure the total system of agriculture towards high efficiency, low input and sustainable agriculture.

5.3 Alternative methodologies to farmer surveys to gather data for the development of a hazardous agro-chemical database

Other than using farmer surveys (personal visits) which can be time consuming and resource intensive, there are also alternative methods that can be used to gather data for a hazardous agro-chemical database. These are listed in Table 36 below and include the advantages and disadvantages of each:

Table 36: Advantages and disadvantages of alternative data gathering methods for a hazardous agro-chemical usage database

Data gathering method	Advantages	Disadvantages
Postal survey	• Low cost • Can be filled in by respondent when he has time • Can cover wide geographical area • Can be sent out several times during the year	• Low response rate • The researcher cannot control the conditions under which the questionnaire is completed or by whom it is completed • The researcher cannot observe the respondent or observe surroundings • The respondent can misinterpret questions
Telephone interviews	• Saves the cost of traveling • Can cover wide geographical area as almost all people have telephones • A quick method • It has almost all the advantages of personal visits • Cheaper and safer than personal visits • May receive more trustworthy answers over phone than with personal visits	• The survey cannot be too complicated • Respondents can easily hang up or make excuses not to continue with survey • Cannot be too long with max duration of about 20 minutes • Questions must be simple and uncomplicated • The researcher can make no observations • It can be difficult to reach people
Compulsory returns of all sales statistics	• The administration and computing that is required to handle such a vast amount of data is complicated to set up initially but once it is up and running it is a very effective method.	• The administration and computing that is required to handle such a vast amount of data is complicated to set up initially but once it is up and running it is a very effective method.
Web surveys	• Can reach people around the world • Can make use of visual images, audio or video • They can present different questions to different answers	• Coverage, privacy and verification
Collation of sales statistics	• It is relatively inexpensive • It is theoretically accurate • Statistics are quick to produce • Comparison can be made between actual usage as reported by farmers and quantities that are sold by chemical companies • The data can be used to make estimates for years when surveys were not done.	Some disadvantages included the following: • Sales figures do not accurately represent usage as stockpiling might occur at chemical distributors or at farmers • As the same chemicals are used on different crops sales figures cannot distinguish between pesticide use on a specific crop • Sales data may include pesticide use in other sectors outside of agriculture

This study has revealed the complex nature of the maize production industry and in particular has highlighted the interrelationship between this industry and the agro-chemical industry.

Clearly, if the environment is to be protected and the scarce water resources in the country are to be preserved for use by future generations, the influence of the agro-chemical industry on these resources needs to be highly controlled and where possible completely eliminated. The elimination of the reliance on agro-chemicals is a field of study on its own and needs to be driven by specialists in the field of agriculture, horticulture and entomology.

The management of the usage of agro-chemicals needs to be driven by environmental specialists, agricultural specialists and farmers, which will help to achieve a balance between the various requirements and acts governing agro-chemicals

This study has illustrated the need for a well-structured and accurate agro-chemical usage database which can serve as input into the development of a sustainable and enforceable agro-chemical management system.

The success of such a system is heavily reliant on buy in by the government through all its interested parties, by the agro-chemical industry as well as by farmers.

It is the opinion of the researcher that the implementation of a well-developed agro-chemical management plan is very achievable, should the following steps be taken:

- Obtain principle endorsement of the program by all interested parties
- Support farmers by "de-complicating" regulations, explaining to them in simplified terms what the regulations require from them
- Support farmers by developing standard design of minimal facilities required to comply with regulations. Support and assist farmers to construct these facilities
- Support farmers by developing and implementing a simplistic agro-chemical management process flow chart specifically tailored for their farms

The refinement and implementation of the above can be the subject of a national roll out which will need to be funded. The funding model would require detail development that could typically be funded 50% by government and with the balance made up by contributions/levies payable by other interested parties which will shift some financial responsibility for the conservation of our country`s resources to you and I.

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Acknowledgements

I would like to thank the following people and institutions for their contributions to this thesis:

The Centre for Environmental Management for the opportunity and financial support to carry out this study.

Surina Esterhuyse for all the time she sacrificed on me, for always being available and for putting up with me throughout the project. Without her help, support and valuable inputs this study would not have been possible. Her continuous lightning quick feedback was also essential for me to finish up on time. It was all much appreciated!

Dave Reynolds for his advice and support in the initial start-up of the project.

My colleagues at the Centre for Environmental Management, Ina, Willene, Esté, Tascha and Frank who provided me with essential help and support throughout this project without which I would not have been able to manage.

My father for the hours he put in to proofread my thesis, which was much appreciated!

My mother for her continuous support and encouragement throughout the project.

All the farmers and chemical distributers who were willing to participate in the study and who added value to this project.

Anton Botha (Grain SA) for assisting in the questionnaire development and identification of farmers used in the study.

Jack Armour (Free State Agriculture) for his assistance in the initial start-up of the project.

Nola Redelinghuys for her advice on questionnaire development.

Appendix A

Main themes and list of interview questions for the Free State Agriculture Operations manager: Land reform, AgriBEE, Farm management, municipal liaison and resource conservation.

The main themes to be investigated during the interview are:

1. Main determinants of variation in chemical use in the maize production industry
2. Type of maize that should be targeted in the study
3. Areas / districts to be targeted(will be determined after theme 1 and 2)
4. Implements, equipment and vehicles typically used on maize farms
5. Chemical use and disposal
6. Other

Questions per theme

1. Main determinants of variation in chemical use.

Office notes

The questions in this theme are aimed at establishing which maize types to target which will determine the sampling areas. This builds up to theme 2 where the actual question is asked.

1.1 Does the insecticide use between white and yellow maize differ?
1.2 Does the herbicide use between white and yellow maize differ?
1.3 Does the fertilizer use between white and yellow maize differ?

1.4 Does insecticide use between GM crops and conventional crops differ?
1.5 Does herbicide use between GM crops and conventional crops differ?
1.6 Does fertilizer use between GM crops and conventional crops differ?

1.7 What is the role of soil type in the amount of insecticides used?
1.8 What is the role of soil type in the amount of herbicides used?
1.9 What is the role of soil type in the amount of fertilizers used?

1.10 What is the role of rain fed vs. irrigated land in the determination of insecticide usage?
1.11 What is the role of rain fed vs. irrigated land in the determination of herbicide usage?
1.12 What is the role of rain fed vs. irrigated land in the determination of fertilizer usage?

1.13 What is the role of prevalent temperature range on the amount of insecticides used?
1.14 What is the role of prevalent temperature range on the amount of herbicides used?
1.15 What is the role of prevalent temperature range on the amount of fertilizers used?

1.16 Does the expected yield play a role in the amount of insecticides used?
1.17 Does the expected yield play a role in the amount of herbicides used?
1.18 Does the expected yield play a role in the amount of fertilizers used?

1.19 In questionnaire I ask farmer to list insecticides, herbicides and fertilizers used. Will they be able to list this or is it to a complicated question? How long will they need to answer this?

1.20 Do any other factors influence chemical usage? (Please list)

2. Type of maize that should be targeted in the study

2.1 Please list the different kinds of maize?

2.2 Please list (name) the different types of GM maize crops found in South Africa?

2.3 Is conventional maize widely used?

2.4 Do farmers typically focus on only one type of maize or do they mix maize types during a production season/cycle?(white/yellow, GM/conventional)

2.5 What determines the different kinds of maize cultivated?

2.6 Soil type?

2.7 Annual rainfall?

2.8 Dry land or irrigated?

2.9 Prevalent temperature ranges?

2.10 Chemical use?

2.11 Market value?

2.12 Demand?

2.13 Any other determinants?

2.14 Will it be possible to choose farmers based on the types of maize cultivated? Will it make sense to do in like this? The idea is to get a good representative average of chemical use on farms.

2.15 Can I give farmers associations the criteria on which to select farms in different districts?

2.16 How will I go about this process?

3. Areas/districts to be targeted (This can be determined after completion of theme one and two).

4. Implements, equipment and vehicles typically used on maize farms

4.1 Is the categorization of implements/vehicles/equipment suitable?

4.2 Will it be suitable to categorize the above mentioned between fuel driven and non-fuel driven that is used to apply chemicals?

4.3 What implements do they typically use to apply and transport chemicals? List all the general types of implements (tractors, planters, harvesters)

4.4 What vehicles do they typically use to apply and transport chemicals? (Transport Trucks)

4.5 What smaller equipment do they typically use to apply chemicals? (handheld herbicide sprayers) List please

4.6 What other implements and vehicles are typically used for other farming activities?

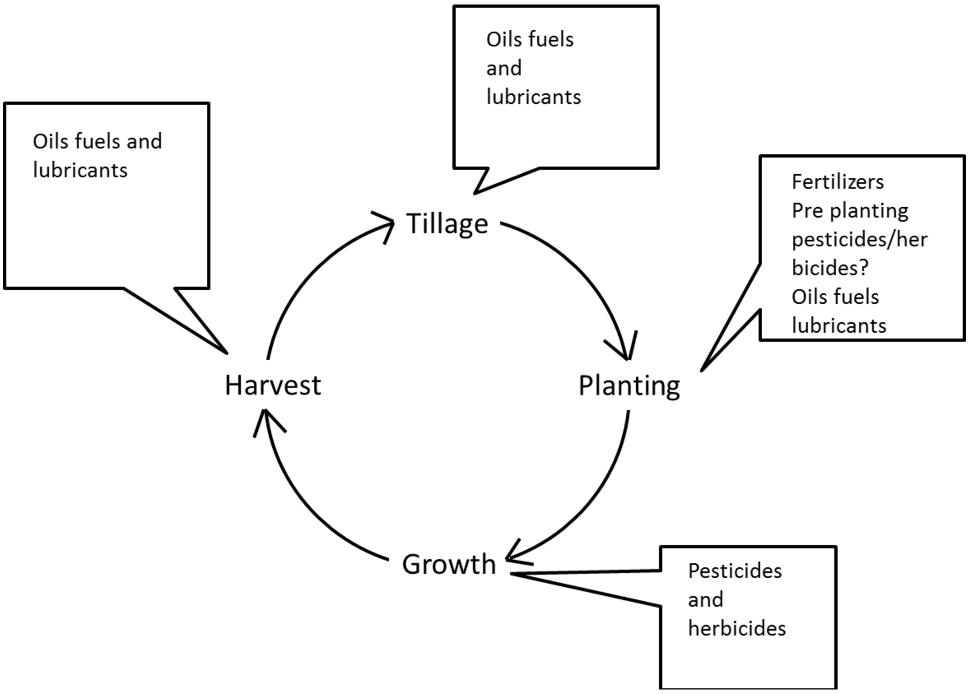
5. Chemical use and disposal

5.1 Are there places to where farmers can take left over chemicals for safe disposal?

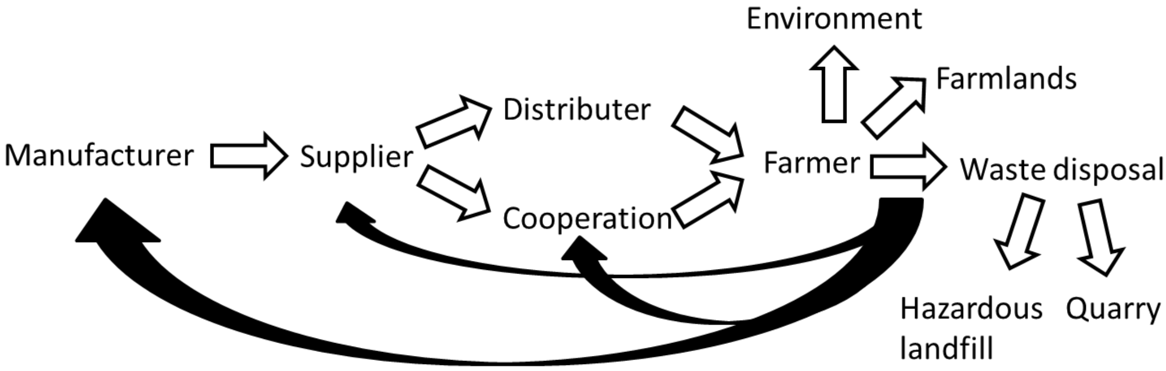
5.2 Will the farmers be able to give useful answers on how much chemicals are wasted or will I have to self-calculate from the answers to my structured questions in my questionnaires?

5.3 Please list the relevant regulations/legislation regarding chemical disposal?

5.4 How can the waste cycle diagram be enlarged towards a better understanding of the process? Farmers will be asked where in the cycle they apply what chemicals.



5.5 Is the chemical flow chain figure complete?



5.6 If they specify how much of a chemical is wasted, will they indicate it in tons, m^3 or something else?

6. Other

6.1 Are the “summer irrigated” and “Orange irrigation” specific geographical areas?

6.2 What are all the legislations that will be relevant for this study?

6.3 If I ask a distributor “What volumes of insecticide are recommended to maize farmers per production cycle per ha?” isn’t the question to broad? Will he be able to answer it? And same for supplied?

6.4 Would you please look through my questionnaire drafts for the supplier and farmers and give me your comments and observations on these?

Appendix B

Interview questions for organized agricultural supplier end of the supply chain (Chemical distributors and cooperatives).

The main themes to be investigated during the interview are:

1. Determination of application volumes of chemicals
2. Determination of recommended volumes of chemicals
3. Waste disposal

1. Theme: Determination of application volumes of chemicals

1.1 How do farmers determine how much chemicals to apply?

1.2 Do farmers have sufficient guidelines on how much crop specific chemicals to buy for application on a specific size (area) of land?

1.3 Where do they get the information on how much to apply?

1.4 Are the guidelines easily accessible?

1.5 What percentage of farmers make use of your services for amounts of chemicals to apply?

1.6 What percentage of farmers calculate the amounts of chemicals to use themselves?

1.7 Has it happened in the past that farmers blame you for crop failure?

2. Theme: Determination of recommended volumes of chemicals

2.1 Do you keep a record of the amounts of chemicals that you supply to farmers?

2.2 What volumes of insecticide were recommended to the maize farmer for the last production cycle per ha?

Dry land	
Irrigated	

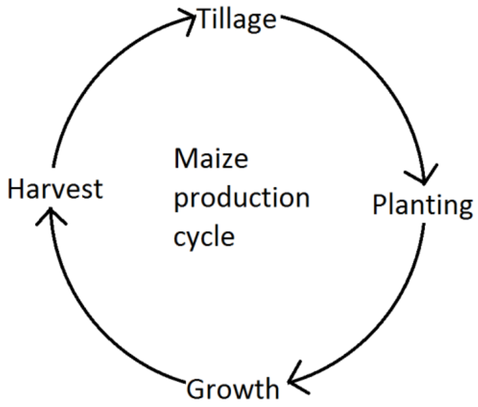
2.3 What volumes of herbicide were recommended to the maize farmer for the last production cycle per ha?

Dry land	
Irrigated	

2.4 What volumes of fertilizer were recommended to the maize farmer for the last production cycle per ha?

Dry land	
Irrigated	

Production cycle



2.5 Does the farmer buy the quantities that you recommend to him?

2.6 If not, why doesn't he listen to you?

2.7 What volumes of insecticide are supplied on average to maize farmers per growth season per ha?

2.8 What volumes of herbicide are supplied on average to maize farmers per growth season per ha?

2.9 What volumes of fertilizer are supplied on average to maize farmers per growth season per ha?

2.10 What is the total amount of insecticides supplied to maize farmers in the area you supply to?

2.11 What is the total amount of herbicides supplied to maize farmers in the area you supply to?

2.12 What is the total amount of fertilizers supplied to maize farmers in the area you supply to?

3. Theme :Waste disposal

3.1 What do maize farmers do with insecticides and herbicides that they do not use?

3.2 What do maize farmers do with fertilizers that they do not use?

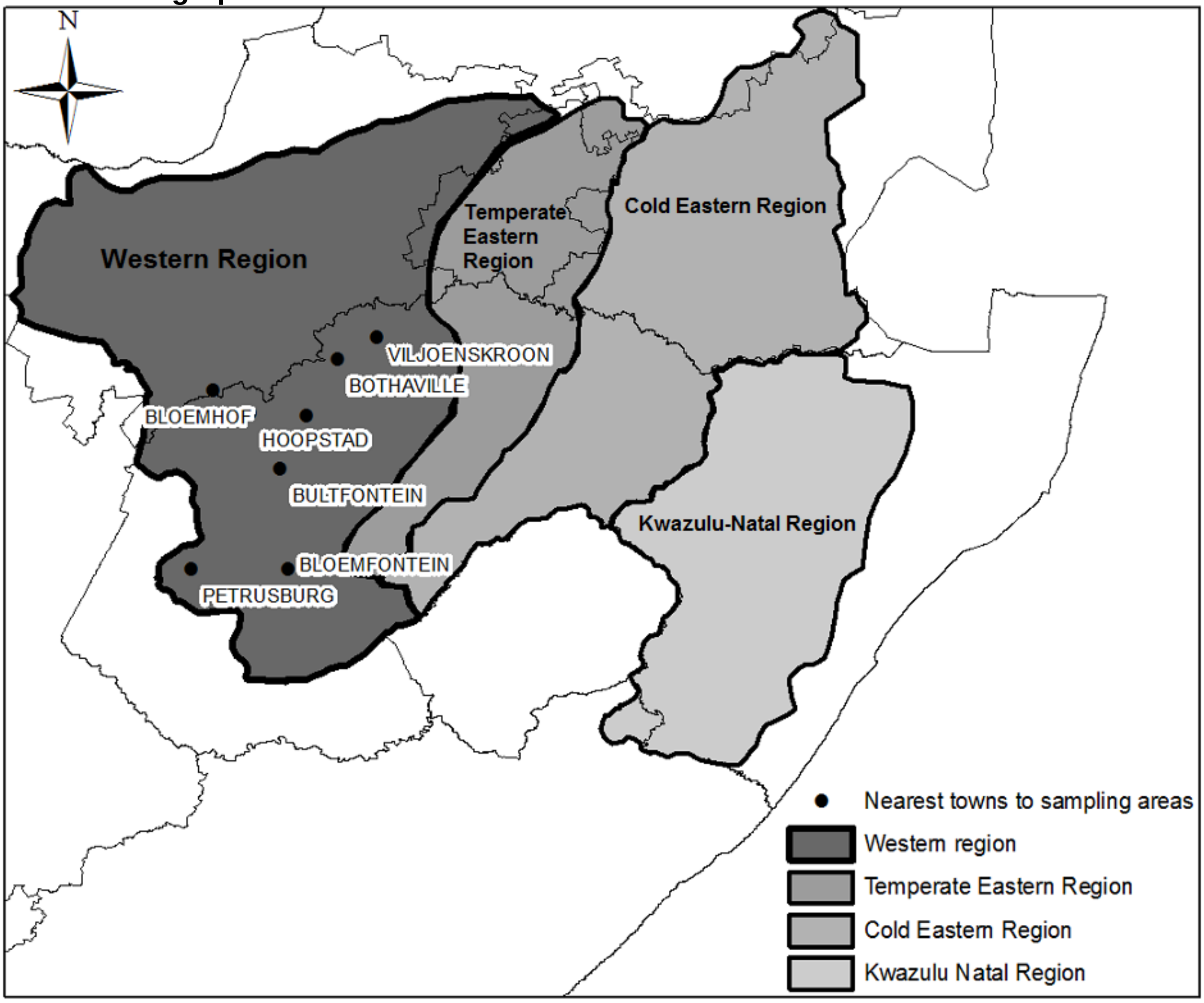
3.3 What do maize farmers do with chemical packaging and containers that they do not use?

Appendix C

<u>Questionnaire for organised agricultural user end of the chain (the farmers).</u>

Instructions: All answers must be indicated with an X except where otherwise indicated, where you must provide quantities, percentages or an open answer to an open question. Questions marked with a "*" must be answered twice by farmers who cultivate both dry land and irrigated maize.

Theme: Geographical information



1. Where is your farm located? See the geographical regions in the map above.

Western region	
Temperate eastern region	
Cold eastern region	
Kwazulu-Natal region	

2. Is your farm a single consolidated unit or a dispersed farming unit?

<u>Office use notes:</u>
A single consolidated unit is one farm while a dispersed farming unit may cover different farms in the same climate region or in different climate regions.

Single consolidated farming unit	
Dispersed farming unit	

Question 2.1 – 2.2 must only be answered if you have a dispersed farming unit.

2.1 If your farm is dispersed how many farm blocks (separate farms) do you have?

Number of farms	

2.2 Please indicate in which climate regions the other farms fall and how many in each region?

	Indicate with X	Number
Western region		
Temperate eastern region		
Cold eastern region		
Kwazulu-Natal region		

3. *What type of maize is cultivated on your farm?

Dry land	
Irrigated	
Dry land and irrigated	

4. If both dry land and irrigated maize are cultivated, are both cultivated in the western region?

Yes	
No	

Note for office use

If both dry land and irrigated maize are cultivated, and both fall within the western maize production region, the relevant extra information must be filled in on an extra questionnaire and a unique code must be indicated on each questionnaire as indicated below. Questions marked with a "*" must be answered in an additional questionnaire.

Farmer number	
Type of maize cultivated	

5. What is your closest town/City?

6. What type of soil do you have on your farm, and what is the sand and clay content percentage in the soil? (Please fill in the question as complete as possible)

Type of soil	
Clay content (in %)	
Sand content (in %)	

7. What is your annual rainfall (in mm)?

8. *Please indicate the area of land under maize cultivation at the applicable type of maize?

Dry land	
Irrigated	

9. What is the total area of the farming unit (ha)?

10. *Please indicate what your maize yield was for the last three seasons you have statistics for?

Growth season	**Yield in tonnes/ha**
2009-2010	
2010-2011	
2011-2012	
2012-2013	

11. *Please indicate the percentage of conventional maize vs. GM maize that you cultivate? The total percentages must add up to 100%.

Crop type	%
Conventional	
GM	

12. *If you plant conventional crops, please indicate the percentage of the type of conventional crops that is cultivated? The total percentages must add up to 100%.

Crop type	%
White	
Yellow	

13. *If you plant GM crops, please indicate the percentage of the types of GM crops that is cultivated and please specify if there are any others? The total percentages must add up to 100%.

GM crop type	%
White roundup ready	
Yellow roundup ready	
bt white	
bt yellow	
White staple gene	
Yellow staple gene	
Other (Please specify)	**%**

Theme: Waste cycle information

14. How much insecticides (in litres or kg) do you order per production cycle per ha?

15. How much herbicides (in litres or kg) do you order per production cycle per ha?

16. How much fertilizers (in litres or kg) do you order per production cycle per ha?

17. Do you use any dipped/treated maize?

Yes	
No	

18. Please specify what percentage of your crops is dipped/treated maize?

Percentage dipped seed	

19. On a scale of 1-5, please indicate to what degree the use of dipped/treated maize has reduced your chemical usage, where 1 is not at all, 3 is marginally and 5 is substantially?

	1	2	3	4	5
	Not at all		Marginally		Substantially
	↔				
Degree of decrease in chemical usage					

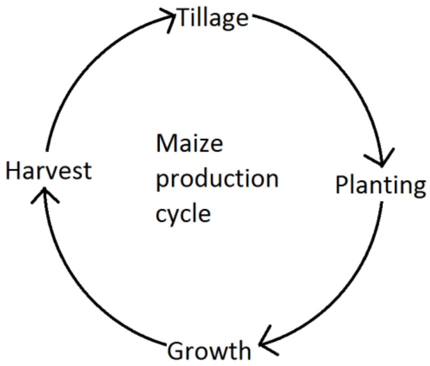
20. Do you have problems on your farm with rats as a pest?

Yes	
No	

21. Please list the chemicals that you use under insecticides, the amount of each applied per production cycle per hectare (litres or kg), and what the insecticide targets (e.g. rats, armyworms etc.)?

	List chemicals used under insecticides	Amount applied per production cycle per ha (in litres or kg)	What does this insecticide target (E.g. rats, armyworms etc.)?
1			
2			
3			
4			
5			
6			
7			

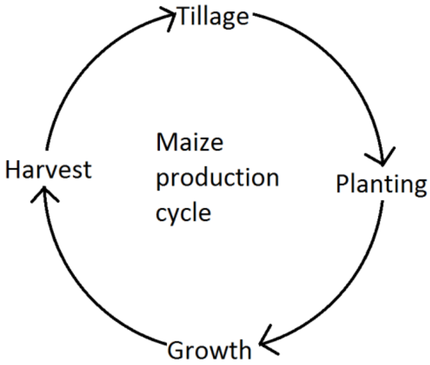
22. Please indicate where in the production cycle the insecticide is applied by writing the number of the insecticide, as is allocated to it in the left column in question 21, on the waste cycle figure below.



23. Please list the chemicals that you use under herbicides, the amount of each applied per production cycle per hectare (litres or kg) and the type of weed that the herbicide targets (e.g. herringbone grass, white goosefoot etc.)?

	List the chemicals that you use under herbicides	Amount applied per production cycle per ha (in litres or kg)	What type of weed do you target with this chemical (E.g. herringbone grass, white goosefoot)?
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

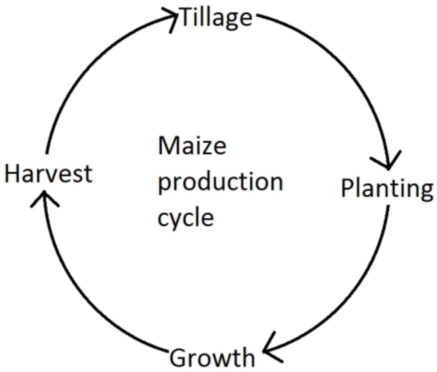
24. Please indicate where in the production cycle the herbicide is applied by writing the number of the herbicide, as is allocated to it in the left column in question 23, on the waste cycle figure below.



25. Please list the chemicals that you use under fertilizers and the amount of each applied per production cycle per hectare (litres or kg)?

	List the chemicals that you use under fertilizers	Amount applied per production cycle per ha (in litres or kg)
1		
2		
3		
4		
5		
6		
7		

26. Please indicate where in the production cycle the fertilizer is applied by writing the number of the fertilizer, as is allocated to it in the left column in question 25, on the waste cycle figure below.



27. Where do you get information on how much agro-chemicals to apply? If there is any other sources please specify.

Agro-chemical distributors	
Chemical packaging	
Self-determined	
Other (Please specify)	

28. If self-determined, please explain how you determine it?

29. On a scale of 1-5, please rate to what degree you order the recommended amount of insecticides, herbicides and fertilizers (chemical groups) where 1 indicates less than the recommended amount, 3 the recommended amount, and 5 more than the recommended amount.

	1	2	3	4	5
	Less than the recommended amount		Recommended amount		More than recommended
Insecticide					
Herbicide					
Fertilizer					

30. If you order less than the recommended amounts, please give a reason why you order less than the recommended amount for each of the relevant chemical groups?

Insecticides	
Herbicides	
Fertilizers	

31. If you order more than the recommended amounts, please give a reason why you order more than the recommended amount for each of the relevant chemical groups?

Insecticides	
Herbicides	
Fertilizers	

32. On a scale of 1-5, please indicate to what degree you apply the recommended amounts of each chemical group, where 1 indicates less than the recommended amount, 3 the recommended amount and, 5 more than the recommended amount.

	1	2	3	4	5
	Less than the recommended amount		Recommended amount		More than recommended
Insecticide					
Herbicide					
Fertilizer					

33. If you apply less than the recommended amount, please give a reason?

Insecticides	
Herbicides	
Fertilizers	

34. If you apply more than the recommended amount, please give a reason?

Insecticides	
Herbicides	
Fertilizers	

Theme: Operational information

35. Which implements and how many of each do you use to apply chemicals? If any other implements are used please specify.

	Mark with an X	Amount
Self-propelled sprayers		
Sleeve boom		
Boom sprayers		
Planters		
Manure spreaders		
Lime spreaders		
Fertilizer spreader		
Other (Please specify)		

36. Which vehicles and how many of each do you use to apply chemicals? If any other vehicles are used please specify.

	Mark with an X	Amount
Tractors		
Airplanes		
Quads		
Other (Please specify)		

37. Which smaller equipment and how many of each do you use to apply chemicals? If any other smaller equipment is used please specify.

	Mark with an X	Amount
Backpack handheld sprayers		
Other (please specify)		

Theme: Storage, disposal, wastage and cleaning Chemicals

38. On a scale of 1-5, please rate each chemical group based on its usage, where 1 means that you used half of the chemical, 3 means you used three quarters of the chemical, and 5 is all of the chemical. Base your answer on the production cycle.

	1	2	3	4	5
	Half of the chemical	More than half	Three quarters of the chemical	Almost all of the chemical	All of the chemical
	⟷				
Insecticide					
Herbicide					
Fertilizer					

39. Please indicate for each chemical group whether you store it or not.

	Yes	No
Insecticides		
Herbicides		
Fertilizers		

40. If you store any of the chemical groups, please specify for how long you store each chemical group(s).

Insecticide	
Herbicide	
Fertilizer	

41. On a scale of 1-5, please indicate whether you have safe storage facilities for your agro-chemicals, where is 1 is not safe, 3 is reasonably safe, and 5 is very safe.

	1	2	3	4	5
	Not safe		Reasonably safe		Very safe
	⟷				
Insecticides					
Herbicides					
Fertilizers					

42. Please explain your answer for each of the chemical groups in question 41.

Insecticides	
Herbicides	
Fertilizers	

43. For each chemical group please indicate whether you occasionally dispose of it or not?

	Do occasionally dispose	Do not dispose of at all
Insecticides		
Herbicides		
Fertilizers		

If you occasionally dispose of chemicals, please answer questions 44 and 45. If not, please proceed to question 46

44. If you dispose of chemicals, please specify how each chemical group is disposed of?

Insecticide	
Herbicide	
Fertilizer	

45. If you dispose of chemicals, please rate on a scale of 1-5 to which degree your agro-chemicals are safely disposed of, where 1 is not safe, 3 is reasonably safe, and 5 is very safe.

	1	2	3	4	5
	Not safe		Reasonably safe		Very safe
Insecticides					
Herbicides					
Fertilizers					

46. Do you sometimes accidently spill chemicals?

Yes	
No	

If you did accidentally spill chemicals in the past, please complete question 47 and 48. If not, please proceed to question 49.

47. If you had accidental spillages in the past, please specify for each chemical group what percentage was wasted on average per production cycle through spilling?

	Average % wasted
Insecticide	
Herbicide	
Fertilizer	

48. If accidental spillages occur how is it handled? Please indicate with all types of spillage that has occurred on your farm and explain how it was handled? If any other types of spillage occurred please specify and explain how it was handled.

	Indicate with X	How is spillage handled?
During dispensing		
Bursting containers due to bad handling		
Defective packaging		
Package damaged during transport		
During transfer from container to applicator		
Equipment failure		
Other(Please specify)		

49. Please specify for each chemical group what percentage is wasted through aging per production cycle?

	%
Insecticide	
Herbicide	
Fertilizer	

50. On a scale of 1-5, please indicate how safe obsolete agro-chemicals are stored and disposed of?

	1	2	3	4	5
	Not safe		Reasonably safe		Very safe
	↔				
Stored					
Disposed					

51. Please indicate to what extent theft of chemicals is a problem on your farm, where 1 indicates that it is not a problem, and 5 indicates that it is a big problem?

	1	2	3	4	5
	Not a problem				A big problem
	↔				
Insecticides					
Herbicides					
Fertilizers					

52. If there has been theft of agro-chemicals in the past, please indicate for each chemical group what the biggest amount is that was stolen in a production cycle (kg or litres)?

Insecticides	
Herbicides	
Fertilizers	

Chemical packaging and containers

53. What do you do with empty chemical packaging and containers after use? Please specify if you do anything else with it.

Dispose immediately	
Reuse and dispose later	
Other(Please specify)	

54. If packaging and containers are disposed of please specify how the packaging and containers for each of the chemical groups are treated before disposal by marking the relevant answers. Please specify if any other treatment methods are used.

	Insecticide	Herbicide	Fertilizer
Triple rinsed			
Holes punched into the base			
Flattened			
None of the above			
Other (Please specify)			

55. If chemical packaging and containers are re-used, is it cleaned before it is reused?

	Mark with X
Yes	
No	
No because it is re-used for the same chemicals	

56. If chemical packaging and containers are cleaned before disposal, please specify where it is cleaned?

57. On a scale of 1-5, please indicate for each chemical group whether the method used to clean chemical packaging and containers is safe for the environment where 1 is not safe, 3 is moderately safe and 5 is very safe.

	1	2	3	4	5
	Not safe		Moderately safe		Very safe
	⟷				
Insecticides					
Herbicides					
Fertilizers					

58. Please indicate how you dispose of empty packaging and containers and please specify if there are any other methods?

Packaging	
Buried	
Burned	
Taken to general waste site	
Taken to hazardous waste site	
Taken away by chemical distributor	
Taken to a collection point	
Other (Please specify)	

Containers	
Buried	
Burned	
Taken to general hazardous waste site	
Taken to hazardous waste disposal site	
Taken away by chemical distributor	
Taken to a collection point	
Other (Please specify)	

Chemical implements, vehicles and smaller equipment

59. On a scale of 1-5, please indicate whether you regularly clean implements, vehicles and smaller equipment that is used to apply agro-chemicals where 1 is never, 3 is sometimes and 5 is regularly.

	1	2	3	4	5
	Never		Sometimes		Regularly
	←				→
Implements					
Vehicles					
Smaller equipment					

60. How are agro-chemical implements, vehicles and smaller equipment cleaned?

Implements	
Vehicles	
Smaller equipment	

61. Where are agro-chemical implements, vehicles and smaller equipment cleaned?

Implements	
Vehicles	
Smaller equipment	

62. Where are agro-chemical spray tanks filled up?

62. On a scale of 1-5, please indicate whether cleaning points for cleaning of agro-chemical implements, vehicles and smaller equipment are suitably constructed, where 1 is not suitable and 5 is suitable.

	1	2	3	4	5
	Not suitable				Suitable
	←				→
Suitability of agro-chemical implements, vehicles and smaller equipment cleaning points					

63. On a scale of 1-5, please indicate whether filling points for the filling of agro-chemical spray tanks are suitably constructed, where 1 is not suitable and 5 is suitable.

	1	2	3	4	5
	Not suitable				Suitable
	←				→
Suitability of agro-chemical tank filling points					

64. Please indicate what you do with surplus tank washings.

Dispose	
Reuse on untreated land	

65. If you dispose of tank washings, please indicate on a scale of 1-5, how safe you dispose of tank washings for it to not pose a risk to the environment and water sources.

	1	2	3	4	5
	Un-safe				Very safe
	⟷				
Disposal of tank washings					

66. If tank washings are re-used on untreated land do you determine the concentration of the chemicals in the washings?

Yes	
No	

67. Where are agro-chemical implements and smaller equipment stored?

Implements	
Smaller equipment	

68. On a scale of 1-5, please rate your confidence on how accurate your agro-chemical application implements and smaller equipment are calibrated in order for minimal wastage of chemicals to occur where 1 is badly calibrated, 3 is moderately calibrated and 5 is very well calibrated?

	1	2	3	4	5
	Badly calibrated		Moderately calibrated		Very well calibrated
	⟷				
Implements					
Smaller equipment					

Weather conditions

69. On a scale of 1-5, please indicate to what extent weather conditions like wind, heat and rain are taken into consideration when insecticides and herbicides are applied where 1 is not taken into consideration and 5 is always taken into consideration.

	1	2	3	4	5
	Not taken into consideration				Always taken into consideration
	⟷				
Weather conditions					

70. On a scale of 1-5, please indicate how often it happens that chemical application is ineffective?

	1	2	3	4	5
	Never				Regularly
	⟷				
Ineffective chemical application					

71. In the case of ineffective application, how often is the application repeated?

Theme: Characteristics of agro-chemicals

72. Please indicate in percentages, the characteristics of the chemicals you use, for each type of chemical including chemicals used for rats, where 1 is acute hazard unlikely in normal use, 3 is moderately hazardous and 5 is extremely hazardous. The total percentages for each group must add up to 100%.

	1	2	3	4	5
	Acute hazard unlikely in normal use	Slightly hazardous	Moderately hazardous	Highly hazardous	Extremely hazardous
		Caution	Harmful	Toxic	Very toxic
					
Insecticide (please report in percentages)					
Herbicide (please report in percentages)					
Fertilizer (please report in percentages)					
Chemicals for rats (please report in percentages)					

73. Please indicate for each chemical group on which criteria you based your answer on in the question above? If your answer was based on any other criteria please specify.

	Insecticide	Herbicide	Fertilizer	Chemicals for rats
Group description on packaging				
Hazard statement on packaging				
Colour band				
Symbols on packaging				
Self-determined				
Other (Please specify in in columns to the right and indicate the relevant chemical group with an X)				

Theme: Servicing

Implements

74. Do you have self-propelled farming implements?

Yes	
No	

75. Where are fuel driven and tow farming implements serviced?

Fuel driven implements		**Tow implements**	
On farm		On farm	
Off farm (specify)		Off farm (specify)	

76. How often are fuel driven and towing implements serviced?

Fuel driven implements	**Tow implements**

77. Please give an estimate of how much oil and other fluids are drained out of self-propelled and un-motorised farming implements during a service?

Self-propelled implements	Amount (in litres)
Oil	
Other fluids	
Un-motorised	
Oil	
Other fluids	

78. Where are self-propelled farming implements refuelled?

On farm	
Off farm	

Vehicles

79. Where are vehicles serviced?

On farm	
Off farm	

80. If vehicles are serviced off farm, where is it serviced?

If vehicles are serviced on farm, please proceed to Question 81, if not please proceed to question 83.

81. How often are vehicles serviced?

Tractors	
Bakkies	

82. Please give an estimate (in litres) of how much oil and other fluids are drained out of vehicles during a service?

	Amount (in litre)
Oil	
Other fluids	

83. Where are vehicles refuelled?

On farm	
Off farm	

Storage disposal and wastage

84. Do you sometimes spill fuel?

85. Approximately how much is the biggest amount of fuel that has been wasted during a spillage?

86. What was the most common cause of fuel spillages?

•

87. How is fuel spillages handled?

88. How often are lubricants, oils and fluids disposed of?

89. How do you dispose of lubricants, oils and other fluids?

90. Where do you dispose of lubricants, oils and other fluids?

91. Where are lubricants, oils and other fluids stored?

92. Where is fuel stored?

Above ground tank	
Underground tank	
Other (Please specify)	

93. If above ground, please indicate if the tank has a pit and bund walls?

Pit	
Bund walls	
None of above	

94. If underground, please indicate whether the tank is lined or not?

Yes	
No	

95. Do you monitor groundwater for possible leakages?

Yes	
No	

Theme: Legal compliance

96. On a scale of 1-5, please indicate how familiar you are with the following legislation, where 1 is not familiar at all, and 5 is fully familiar? (Please provide trustworthy answers in these questions as this is important for the results of the study. Your name and your farms name will be kept anonymous at all times).

	1	2	3	4	5
	Not familiar at all				Fully familiar
	⟷				
Chemical usage					
Chemical storage					
Chemical disposal					
Treatment of agro-chemical packaging and containers before disposal					
Disposal agro-chemical packaging and containers					
Cleaning of implements, vehicles and smaller equipment used to apply chemicals					
Storage of implements, vehicles and smaller equipment used to apply chemicals					
Farm servicing facilities					
Fuel storage facilities					
Disposal of lubricants, oils and other fluids					
Storage of lubricants, oils and other fluids					

97. On a scale of 1-5, please rate how you view the following legislation where 1 is too lax, 3 is appropriate and 5 is too strict.

	1	2	3	4	5
	Too lax		Appropriate		Too strict
	⟷				
Chemical usage					
Chemical storage					
Chemical disposal					
Treatment of agro-chemical packaging and containers before disposal					
Disposal of agro-chemical packaging and containers					
Cleaning of implements, vehicles and smaller equipment used to apply chemicals					
Storage of implements, vehicles and smaller equipment used to apply chemicals					
Farm servicing facilities					
Fuel storage facilities					
Disposal of lubricants, oils and other fluids					
Storage of lubricants, oils and other fluids					

98. Have your neighbouring farmers to your knowledge had any problems with the law (e.g. have they been fined) in the past 5 years because they were not legally compliant? Please indicate the relevant answer.

	Yes	No
Chemical usage		
Chemical storage		
Chemical disposal		
Treatment of agro-chemical packaging and containers before disposal		
Disposal of agro-chemical packaging and containers		
Cleaning of implements, vehicles and smaller equipment used to apply chemicals		
Storage of implements, vehicles and smaller equipment used to apply chemicals		
Farm servicing facilities		
Fuel storage facilities		
Disposal of lubricants, oils and other fluids		
Storage of lubricants, oils and other fluids		

99. On a scale of 1-5, please indicate how you feel about action taken against violators of the law, where 1 is to lax, and 5 is too strict.

	1	2	3	4	5
	Too lax				Too strict
	⟷				
Action against violators of the law					