Investigation of the Contamination of Water Resources by Agricultural Chemicals and the Impact on Environmental Health

Volume 2: Prioritizing human health effects and mapping sources of agricultural pesticides used in South Africa

Report to the

WATER RESEARCH COMMISSION

edited by

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A CD with pesticide use maps is enclosed at the back of this TT report.

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EXECUTIVE SUMMARY

BACKGROUND

Agricultural activity is potentially a source of a number of hazardous chemicals in water resources. Concerns have been expressed that some of the pesticides used in agricultural practice (crop spraying and animal disease control) may enter and pollute rivers and dams and cause endocrine disrupter effects in animals and humans that use the water for drinking and recreational purposes. A previous scoping study indicates that there is no clarity on the extent and level of contamination of water resources by agricultural products with ED (endocrine disrupting) properties. However, a number of WRC studies have been done, identifying different chemicals in different areas that are hazardous as well as having ED properties and some studies identified EDCs in water resources and indicated ED effects in sentinel species in and around contaminated water resources.

Most of these studies in South Africa are not specifically focused on the link between the chemicals used in agricultural practices and the impact on human health with water as a pathway. This project will focus specifically on agricultural chemicals. As stated in the scoping study, gaps in knowledge exist and research is necessary which will lead to guidelines for South African authorities to direct the safe use of agricultural chemicals in water resource management.

RATIONALE

According to the latest Department of Agriculture, Forestry and Fisheries (DAFF) database, there are a total of 8256 herbicides, insecticides and fungicides registered in South Africa. A review of internet databases show that many of the active ingredients of these pesticides are either carcinogenic or classified as EDCs, while for most pesticides these endpoints have yet to be definitively defined.

While pesticide monitoring studies are limited in South Africa, there is sufficient information to indicate that many currently used pesticides enter surface and groundwater. This is particularly relevant considering the fact that many communities do not have any or reliable access to treated water and often make use of water collected directly from the resource for drinking purposes. Given the potential human health effects associated with exposure to agro-chemicals and their intensity of use, in combination with the questionable supply and quality of drinking water in many South African communities, it is important to identify and prioritize a) pesticides that are particularly toxic, and b) areas where people may be exposed to these priority chemicals. Furthermore it is important to identify sources of priority compounds used in South Africa that could potentially result in exposure and associated negative effects on human and animal health. Intensive use of pesticides increases the potential for exposure to occur. Additionally pesticides vary greatly in terms of their toxicity and thus their potential to cause toxic effects upon exposure. Thus prioritisation procedures generally attempt to provide an integrated indicator of use and hazard.

OBJECTIVES AND AIMS

The overall aim of the project is to determine the extent and level of contamination by agricultural chemicals (pesticides, herbicides and plant growth regulants), including Endocrine Disruptive (ED) properties and selected risk assessments for the environment (animal and human health).

This was accomplished by addressing the following specific objectives:

1. To prioritise agricultural chemicals contaminating water for analyses based on hazard (e.g. toxicity and potency);
2. To analyse, *inter alia,* water and sediments for ED activity, e.g. the oestrogenic and anti-androgenic activity; and effects on the immune and thyroid functions, where applicable;
3. To chemically analyse for the active ingredients in samples for presence of specific pesticides by following accredited methods;
4. To assess the human exposure to EDCs in the selected chemicals through, *inter alia,* drinking water, food ingestion, dermal absorption and inhalation by measurement and modelling in selected areas;
5. To identify and assess the sources of agricultural chemicals in water resources for selected areas;
6. To assess the risks caused by agricultural chemicals for animal and human health.

This report deals specifically with objectives 1 and 5 of the project. Objective 5 was addressed through the production of maps illustrating estimated application rates (kg/ha) of over 200 pesticides used in agriculture in South Africa.

METHODOLOGY

Pesticide Prioritisation

Pesticide prioritisation was performed according to a modified method described in the literature and consists of two main phases. The first phase was aimed at identifying all active ingredients used in agricultural crop production within South Africa. Pesticides were then ranked according to four indices. First, active ingredients were screened based on their quantity of use and toxicity properties, thus eliminating less important pesticides (i.e. those with low usage and/or toxicity). Remaining pesticides were then prioritised based on quantity of use (Quantity Index – *QI*). Secondly, pesticides were scored on their potential to cause endocrine disruption, carcinogenic, teratogenic, mutagenic and neurotoxic effects. The individual scores for each endpoint were summed to provide a total toxicity score for each pesticide (Toxicity Potential – *TP*). The *TP* scores for each pesticide were then multiplied by a mobility score (determined by the Groundwater Ubiquity Score) to provide an indication of the potential environmental hazard of each pesticide (Hazard Potential – *HP*). Finally, the potential hazard of the chemical was expressed as a function of its total use in relation to the total use of all active ingredients applied in the country to give a weighted hazard score (Weighted Hazard Potential – *WHP*).

Pesticide Maps

The Census of Agriculture Provincial Statistics performed by Statistics South Africa in 2002 was used to estimate the spatial distribution of crop production in South Africa. The census collected data on crop area (ha) for commercial crops at a magisterial district level which was used to estimate the percentage agricultural area covered by a specific crop type within a magisterial district. This allowed for the development of maps that provide a spatial overview of important areas for the production of a specific crop. The census data was normalised according to FAO statistics on crop production in South Africa for the year 2009 so as to provide an estimate of total crop coverage per magisterial district in 2009.

Pesticide use data for South Africa was purchased from GfK Kynetec, an international market research company. Data was provided as the total amount of each active ingredient applied to all crops as well as on a crop by crop basis. Crop-specific data was only purchased for major crops grown in the country. Using the crop distribution maps and crop-specific pesticide use data it was possible to estimate the pesticide application per Magisterial District. The methodology assumes that the national total use of the applied pesticide (kg) was proportionally distributed to all Magisterial Districts in which the crop was produced (based on the proportion of the crop area in the Magisterial District to the national production area of the crop). By estimating the total application of a specific pesticide to all crops produced in a magisterial district, it was possible to generate maps providing an estimate of the application rate of over 200 pesticides per magisterial district. These maps were intersected with an agricultural land cover map (the 2009 National Land Cover produced by the South African National Biodiversity Institute (SANBI)) to provide a refined map illustrating the spatial distribution of estimated pesticide use across the country. The maps display average annual pesticide use intensity expressed as average weight (kilograms) of a pesticide applied to each hectare of agricultural land in a magisterial district.

RESULTS AND DISCUSSION

Pesticide Prioritisation

The *WHP* index was used to prioritise pesticides. However it was recognised that the quantity of use (*QI*) played a significant weight on the *WHP*. This weighting has the potential to exclude highly toxic and mobile pesticides from being included in a priority list. Therefore the top 25 ranked pesticides in each of the four indices were included in a final priority list, which were then ranked by their respective *WHP* scores. In total 69 pesticides feature in this list (as some pesticides featured in two or more of the four indices).

Rank	Active Ingredient	*QI*	*TP*	*HP*	*WHP*	Mobility
1	Atrazine	1014.42	17	68	3.6260	High
2	Mancozeb	2849.02	23	23	3.4445	Low
3	Acetochlor	656.545	23	46	1.5875	Medium
4	Ethylene-dibromide	252.486	23	92	1.2210	High
5	Terbuthylazine	674.413	16	32	1.1344	Medium
6	Glyphosate	3720.799	5	5	0.9779	Low
7	Sulphur	2337.28	7	7	0.8600	Low
8	Copper oxychloride	1225.806	13	13	0.8377	Low
9	Imidacloprid	252.167	15	60	0.7953	High
10	Metolachlor	443.707	14	28	0.6531	Medium
11	2,4-D-amine	355.102	15	30	0.5600	Medium
12	Alachlor	287.044	15	30	0.4527	Medium
13	MCPA	284.6	13	26	0.3890	Medium
14	Simazine	83.253	16	64	0.2801	High
15	Paraquat	345.127	13	13	0.2358	Low
16	Aldicarb	105	19	38	0.2097	Medium
17	MSMA	245.108	14	14	0.1804	Low
18	Trifluralin	160.416	20	20	0.1686	Low
19	Potassium-phosphite	236.154	9	13.5	0.1676	No Data
20	Diuron	96	15	30	0.1514	Medium
21	Metribuzin	106.08	12	24	0.1338	Medium
22	Hexazinone	84.607	7	28	0.1245	High
23	Cyanamide	203.252	11	11	0.1175	Low
24	Carbofuran	33.444	15	60	0.1055	High
25	EPTC	178.43	11	11	0.1032	Low
26	Fosthiazate	52.2	9	36	0.0988	High
27	s-metolachlor	113.317	16	16	0.0953	Low
28	Chlorpyrifos	148.47	11	11	0.0858	Low
29	Sulcotrione	21.075	16	64	0.0709	High
30	Bromoxynil	66.48	19	19	0.0664	Low
31	Terbufos	114.75	10	10	0.0603	Low
32	Chlorothalonil	140.007	8	8	0.0589	Low
33	Thiram	46.566	20	20	0.0490	Low
34	Copper-carbonate	148.725	4	6	0.0469	No Data
35	Thiamethoxam	22.8	9	36	0.0431	High
36	Benomyl	30.547	24	24	0.0385	Low
37	Copper hydroxide	177.561	4	4	0.0373	Low
38	Carbendazim	15.114	19	38	0.0302	Medium
39	Carbaryl	14.758	18	36	0.0279	Medium
40	Iprodione	12.635	18	36	0.0239	Medium
41	2,4-D	10.5	21	42	0.0232	Medium
42	Trichlorfon	4.37	25	100	0.0230	High
43	Bromacil	9.6	11	44	0.0222	High
44	Endosulfan	12.37	24	24	0.0156	Low
45	Cyproconazole	3.92	15	60	0.0124	High

Rank	Active Ingredient	*QI*	*TP*	*HP*	*WHP*	Mobility
46	Acephate	8.65	20	20	0.0091	Low
47	Dichlorvos	5.673	24	24	0.0072	Low
48	Buprofenzin	2.65	11	44	0.0061	High
49	Tembotrione	1.806	16	64	0.0061	High
50	Zineb	4.844	22	22	0.0056	Low
51	Triadimenol	1.213	17	68	0.0043	High
52	Thiodicarb	4.1	20	20	0.0043	Low
53	Deltamethrin	3.822	21	21	0.0042	Low
54	Tribenuron-methyl	1.313	13	52	0.0036	High
55	Triticonazole	1.3	13	52	0.0036	High
56	Fipronil	1.677	20	40	0.0035	Medium
57	Triadimefon	1.684	19	38	0.0034	Medium
58	Malathion	2.707	23	23	0.0033	Low
59	Sulfosulfuron	0.975	14	56	0.0029	High
60	Thiophanate	1.824	22	22	0.0021	Low
61	Propoxur	0.3	14	56	0.0009	High
62	Procymidone	0.302	24	24	0.0004	Low
63	Bifenthrin	0.15	23	23	0.0002	Low

Pesticide Maps

The maps produced from this project are the first of their kind for South Africa and provide a spatial overview of the likely distribution of specific active ingredients based on their application to crops and the distribution of those crops throughout the country. While a number of geographical and physicochemical factors influence the movement of pesticides into surface waters, the quantity and rate of application of pesticides used (and by implication the relative application rate) in an area is the most important indicator of the potential for contamination of non-target environments. In this respect, the maps provide important information not only in terms of estimated application rates but also in terms of identifying where in the country specific pesticides are most likely being applied.

It is however important to note the limitations associated with the assumptions used in the production of the maps. These include the following:

1 The magisterial district coverage is based on the 2002 Census of Agricultural Provincial Statistics and did not represent all total coverage as accurate statistics were dependent on farmers that responded to the census. Data was therefore normalised to reflect actual crop coverage as reported by the FAO (i.e. the area of each crop type in a magisterial district was multiplied by the ratio of total national area reported by STATSSA to total national area reported by the FAO);

2 The methodology assumes that a specific pesticide was evenly distributed to a specific crop regardless of the magisterial district the crop was produced in. Pesticide use data as displayed in the maps may therefore not reflect the local variability of pesticide management practices found within a magisterial district;

3 Due to the fact that the agricultural land cover does not discriminate between different crop types, pesticide use was aggregated up to a magisterial district level and assumed to be distributed across all agricultural land within a magisterial district. All agricultural land cover that fell within a magisterial district was therefore assigned a pesticide use category for the pesticide in question;

4 Crop production statistics may not have been available for all magisterial districts where a pesticide may have been applied to agricultural land, and therefore, are not displayed on the maps;

5 Pesticide use estimates are based on market research data for the year 2009;

6 Agricultural land cover used to display pesticide use rates is for the purpose of providing an indication of the spatial distribution of pesticide application and is not representative of actual agricultural land area used in the calculation of pesticide use rates.

Despite the limitations listed above, the data used in this study represent the best information currently available and therefore provide the best possible estimate of crop distribution and pesticide use in the country at present. Furthermore the limitations discussed here are not unique to South Africa and developed countries such as the USA and member states of the EU make use of similar approaches to estimate pesticide use at a national level.

CONCLUSIONS

The prioritisation approach presented in this report is simple, yet provides a first level of basic, important information that can be used to develop monitoring programmes, identify priority areas for management interventions and to investigate optimal mitigation strategies. The reliability of sales data as a proxy for pesticide use data has high associated uncertainty but is currently the most effective and widely used means of performing such assessments. An advantage of this methodology is that the final priority list of pesticides presented in this report was defined based on four indices, ensuring that highly toxic and mobile pesticides, as well as high use pesticides are considered. Furthermore, pesticide prioritisation processes generally aggregate estimated risks up to a national level. This is because pesticide data is often only available in terms of the total quantity of a pesticide sold (or used). The advantage of using crop-specific pesticide data allows for a more disaggregated overview of pesticide risks in that specific priority pesticides can be linked to specific crop types and specific crop types can be prioritised based on the profile of pesticide applied to the crops. This allows for a more refined spatial prioritisation of pesticide risks.

The pesticide use maps and supplementary data developed in this study provide the most detailed overview of pesticide use in South Africa produced to date. This information can be used to make national, provincial and catchment-based assessments of pesticide use which are essential for performing spatial assessments of human and environmental risk associated with pesticide use. Considering the large number of pesticides used in the country, the maps are particularly useful in identifying where specific pesticides are most likely to be applied, thereby prioritising those areas that are likely to be of greatest concern and can therefore make useful contributions to the design of water quality monitoring programmes and interpretation of monitoring data. This is particularly important considering the high cost associated with the analysis of pesticides in environmental samples.

The combined outputs of this report provide a valuable resource for planning future risk assessment and monitoring studies of pesticide contamination in South African water resources.

RECOMMENDATIONS FOR FUTURE RESEARCH

- This project focussed specifically on risks of agricultural chemicals to human health. Considering the high number of critically endangered endemic fish species as well as the vulnerability of aquatic ecosystems in general, it is recommended that a similar procedure be performed for prioritising risks to aquatic ecosystem health in South Africa. This will need to consider different toxicity endpoints than those used in this study.
- Decisions related to monitoring of pesticides in the selected study areas (refer to Volume 1 of this report) benefitted significantly from the crop-specific pesticide use data, prioritization matrix and pesticide use maps developed in this project. It is recommended that these resources be consulted when undertaking similar studies in the future.
- It is further recommended that regular updates of pesticide use data, spatial crop distribution (through additional census surveys) and associated pesticide use maps are produced and disseminated to ensure the availability of up to date information for use in design of monitoring programmes and risk assessment studies in South Africa. Maps produced as part of this project illustrate pesticide use for the year 2009. Data for the year 2014 will be available in June 2015.
- Mechanisms should be explored that facilitate the regular dissemination of pesticide use data for use in pesticide risk assessment in South Africa. The uncertainty in pesticide use estimates can be reduced by performing this type of assessment annually in order to obtain a range of pesticide use patterns and evaluate variation over time.
- Data on pesticide use is an essential input into assessing the risks of pesticides to the environment and human health. Geographical (e.g. slope, soil type, hydrological network) and weather (e.g. rainfall) characteristics (the data of which is readily available in South Africa, e.g. WR2005) also significantly influence the behaviour and movement of pesticides in the environment. The pesticide use maps produced in this project, together with other relevant data sources, therefore provide an ideal opportunity to perform spatially explicit risk assessments of pesticide use in the country, allowing for the identification of hotspot aquatic environments or human communities at greatest risk of exposure.

TECHNOLOGY TRANSFER

All data collected and produced during the course of this project is available from the CSIR, Natural Resources and Environment (Building 33, Meiring Naude Rd., Brummeria, Pretoria. 0001. Tel: (012) 841 4783; Email: jdabrowski@csir.co.za).

Pesticide Prioritisation

An excel spreadsheet (Prioritisation Tool.xlsx) facility has been attached to this report (Part 3) to enable users to prioritise pesticides according to multiple criteria. The spreadsheet makes use of filters which can be used to select specific crops or active ingredients or active ingredients with toxicological endpoints of interest (e.g. those that definitely have ED potential) and rank these according to any of the indices described above. While the *WHP* represents an integrated method of prioritisation (i.e. includes quantity of use, toxicity and environmental mobility) it was recognised that quantity of use contributes a significant weight to this index. Accordingly the spreadsheet allows users to prioritise according to all of the indices (*QI*, *TP*, *HP* and *WHP*) mentioned in the report. Furthermore a pesticide can be prioritised based on the quantity of its use relative to the total quantity of all pesticides applied to all crops in the country (i.e. the *WHP* is calculated relative to the aggregated use of all pesticides in the country) or on the quantity of its use relative to the total quantity of all pesticides applied to a specific crop of interest (i.e. total use of pesticides is disaggregated to specific crops to which they are applied, therefore allowing for a crop-specific prioritisation). Additionally crops can be prioritised by comparing the quantity of use of a specific pesticide on those crops.

Pesticide Maps

All data and maps produced from this project have been included on a CD attached to this report (Part 3). The following data can be accessed through an Excel application (MAPestSA.xlsx) available on the CD attached to this report (see back cover):

- Maps of estimated use (kg/ha) of 206 active ingredients in South Africa (access to the maps is dependent on the installation of ArcReader which can be downloaded from the CD or downloaded free of charge at http://www.esri.com/software/arcgis/arcreader (please note that users will have to register an account with Esri in order to download the software).
- Maps of crop area per magisterial district (displayed as a percentage of the national area covered by the crop).
- Summaries of active ingredient application (as kg and as a percentage) per crop (users can identify active ingredients applied to a crop by selecting a crop or alternatively the crops to which an active ingredient is applied can be identified by selecting an active ingredient of interest).
- Raw pesticide use data supplied by GfK Kynetec
- Estimated application (kg) of 206 active ingredients per Magisterial District.

- Estimated application rate (kg/ha) of 206 active ingredients per Magisterial District.
- Estimated application (kg) of 206 active ingredients per Province.
- Estimated national application (kg and kg/ha) of 206 active ingredients.

In addition GIS shapefiles created during this project are included in the CD, allowing users to perform their own geographical analysis of the derived data.

CAPACITY BUILDING

In total 4 Masters students contributed directly to the objectives of this project, of which one was involved in the research presented in this volume. Justinus Shadung graduated in 2013 with a MSc. in Aquatic Health from the University of Johannesburg. Full details of capacity building can be viewed in the Appendix to this report.

KNOWLEDGE DISSEMINATION

Three papers have been submitted and accepted in national and international peer reviewed journals, of which two papers originated from research documented in Parts 1 and 2 of this report. Research related to Part 1 of this volume (pesticide prioritisation) was published in the international journal Environment International (5.56 Impact Factor). In addition the priority list of pesticides produced in this part of this report, in combination with the mobility index has been used to identify pesticides for inclusion into the development of risk based water quality guidelines for irrigation (WRC Project No. K5/2399/4 – Revision of the 1996 South African water quality guidelines: development of a risk-based approach using irrigation water use as a case study). The development of pesticide use maps (Part 2) was published in the South African Journal of Science. In addition a CD with all relevant data and maps produced as part of this volume is also available (Part 3). Full details of knowledge dissemination can be viewed in the Appendix to this report.

ACKNOWLEDGEMENTS

This project was initiated by the Water Research Commission (WRC) of South Africa through a directed call and publication of associated terms of reference. The CSIR together with collaborators from the University of Pretoria and North West University responded to the call and carried out the research to meet the objectives stipulated in the terms of reference. The project was managed by the WRC.

The authors of this report acknowledge inputs from the Reference Group which significantly contributed to supporting and guiding the project team. The Reference Group was comprised of the following members:

Ms A Moolman	*Chairperson (2010-2011)*
Dr GR Backeberg	*Chairsperson (2012-2013)*
Dr S Mpandeli	*Chairperson (2014-2015)*
Dr SH Jooste	*Department of Water and Sanitation*
Prof NH Casey	*University of Pretoria*
Mr TR Nepfumbada	*Department of Agriculture, Forestry and Fisheries*
Mrs B Genthe	*CSIR*
Mr E van der Walt	*Agricultural Research Council*

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Prof N Duncan	*University of Pretoria (Pathology)*
Dr Gabre Kemp	*University of the Free State (Pesticide Analysis)*
Mr P Rankin	*GfK Kynetec (Pesticide Use Data)*

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PART 1: PRIORITISING AGRICULTRUAL PESTICIDES BASED ON ENVIRONMENTAL MOBILITY AND POTENTIAL HUMAN HEALTH EFFECTS

by

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1.1 INTRODUCTION

Agriculture is well developed in South Africa and contributes approximately 12.5% to the GDP. A wide variety of crops are produced, including maize, wheat, citrus, deciduous fruit, sub-tropical fruit and sugar cane. Given the intensity of agriculture in the country, South Africa is the highest user of pesticides in sub-Saharan Africa (Dalvie *et al.,* 2009), with over 8 000 pesticide formulations having been registered for use. As a result, a number of studies have highlighted the occurrence of pesticides in non-target environments in South Africa, particularly in ground and surface water (London *et al.,* 2000; Dabrowski *et al.,* 2002; Sereda and Meinhardt, 2005). This of particular concern given the potential health related impacts associated with exposure to many of these compounds.

This concern is particularly relevant in a country like South Africa. While many aspects of the South Africa are well developed, there is a large inequality in terms of socio-economic development and many South Africans live in conditions of poverty. While great progress has been made in improving water sanitation and supply, many poor South Africans do not have access to clean, treated, piped water and often make use of water collected directly from surface and groundwater resources. Furthermore the quality of piped water may also be questionable as highlighted by the Blue Drop Report commissioned by the Department of Water Affairs (DWA, 2010). This report assesses the ability of municipalities to provide water of sufficient drinking quality based on a number of indicators, including (amongst other criteria) compliance with the South African National Standard, submission of drinking water quality results to the DWA, credibility of drinking water quality analysis and the efficiency of a drinking water quality monitoring programme. Many municipalities across the country fall below what is regarded as a satisfactory standard for drinking water quality. By implication the potential for exposure to pesticides, even via piped drinking water supplies, is therefore increased.

Given the potential human health effects associated with exposure to agro-chemicals and their intensity of use, in combination with the questionable supply and quality of drinking water in poor communities, it is important to identify and prioritize those pesticides that are particularly toxic and areas where people may be exposed to these priority chemicals. Intensive use of pesticides increases the potential for exposure to occur. Additionally pesticides vary greatly in terms of their toxicity and thus their potential to cause toxic effects upon exposure. Thus prioritisation procedures generally attempt to provide an integrated indicator of use and hazard. This process generally involves ranking pesticides based on their toxicity (or hazard) and their use.

The last pesticide prioritisation process for South Africa was conducted using sales data from 1999 (Dalvie *et al.,* 2009). This process integrated data on pesticide use (kg) with toxicity data (oral LD50 for rats) to develop an acute toxicity indicator (ATI). Based on 1999 data, herbicides and fungicides were the most heavily used products, with sulphur, mancozeb, glyphosate, copper oxychloride and MCPA being the top five most used products in the country. However, in terms of potential toxicity, as ranked by the ATI, insecticides were regarded as the highest risk sector with aldicarb, terbufos, azinphos-methyl, methamidiphos and fenamiphos being the top five ranked active ingredients. Other international studies have focussed on carcinogenic endpoints (as opposed to acute toxicity) as a more relevant endpoint for exposure to the general public and have also included environmental characteristics (i.e. half-life) as an additional indicator of potential exposure. (Gunier *et al.,* 2001; Monge *et al.,* 2005; Valcke *et al.,* 2005). For all studies data on pesticide sales is used as a proxy for pesticide use.

Considering that communities are more likely to experience sub-acute exposure (i.e. either through consumption of contaminated water or inhalation of air), the aim of this report was to prioritize pesticides in South Africa based on their current use (2009 data) and potential to cause cancer and EDC effects. Additionally, the report aims to identify those crops accounting for a higher proportion of priority chemical use. This can be regarded as the first step in providing insight into the spatial distribution of priority pesticides across the country.

1.2 METHODS

Pesticide prioritisation was performed according to a modified method described in Valcke *et al.* (2005) and consists of two main phases. The first phase is aimed at identifying all active ingredients used in agricultural crop production within South Africa. These active ingredients were then prioritised based on usage and screened based on their toxicity properties, thus eliminating less important pesticides (i.e. those with low usage and/or toxicity). During the second phase of prioritisation, the remaining pesticides underwent various scoring procedures for their carcinogenic, teratogenic, mutagenic and EDC potential so as to rank pesticides in terms of their relative risk to human health. The half-life of pesticide active ingredients was also used to contribute to the scoring system and provides an indication of the persistence of a pesticide in the environment and thus its potential for exposure to humans.

1.2.1 Pesticide use data

Pesticide use data for South Africa was purchased from GfK Kynetec (http://www.gfk.com/gfk-kynetec/), an international market research company. The company provides quantified data on the use of formulated products country-by-country and crop-by-crop. Data is collected by GfK Kynetec's research associates who adopt a, bottom up (product-led) approach to data collection that relies on individual in-depth interviews with all those involved in the crop protection industry in each country. The approach used for the sigma research programme relies on the detailed knowledge and experience of those involved in the crop protection industry in each country. Through a series of expert interviews, each associate builds a complete and detailed picture of the market and product use in the country being researched, product brand by product brand and crop by crop.

Typically the research associates will complete interviews with:

- Agrochemical manufacturers (at Product Manager level)
- Agrochemical formulators and distributors
- Agrochemical trade associations
- Agrochemical importers
- Extension officers
- Crop advisors
- Government officers
- Crop research stations

The expert interview technique allows constant cross-referencing and confirmation of data. It is a very well established methodology for market quantification and has a number of benefits:

- Comprehensive coverage of all major crops in each market. Whilst interviewing farmers directly may provide a statistically representative sample this is resource intensive and very costly and thus is usually restricted to a small number of crops and in many countries is just not practical nor feasible.
- Successful provision of high quality data on fragmented or unstructured markets such as those in southern Europe and most developing economies.
- Comparable quality with panel surveys at a National level in key developed markets, for example, France and Germany.

Data purchased from GfK Kynetec is for the year 2009 and was the latest data available at the time of executing this project task. The full record of data is listed in the Appendix. An explanation of the data supplied can be viewed in (Table 1.1). Data was provided as the total amount of active ingredient applied to all crops (Table A1) as well as on a crop by crop basis (Table A2). Crop-specific data was only purchased for major crops grown in the country. Thus the total active ingredient summary for all crops will include crops not included in Table A2.

Table 1.1: Explanation of column headings provided in pesticide use data (see Table A2, Appendix)

Column	Explanation
Crop Group	Crop category
Crop	Name of crop
Sector	Identifies whether AI is a fungicide, herbicide, insecticide or growth regulator
AI	Active Ingredient
Crop Area	Total area covered by crop
Base Area	This is a reflection of the proportion of the crop treated by sector type. (e.g. if Herbicide Base area is 500 Ha and Crop area is 1000 Ha then 50% of the crop will be treated with a herbicide irrespective of the number of applications)
AI Area Treated	Total crop area treated by AI (ha x 10^3)
AI dose Rate	Application rate of AI to crop (L or kg/ha)
AI Volume	Total quantity of AI applied to crop (L or kg x 10^3)

1.2.2 Screening

1.2.2.1 Pesticide use screening

The total amount of pesticides used was the first criterion used to rank and prioritize pesticides, the assumption being that humans and/or livestock are more likely to be exposed to pesticides that are used more frequently or in higher quantities. All pesticides were ranked by volume of usage (kg) for the most recent year for which data was available (i.e. GfK Kynetec provides data for 2009). Pesticides were ranked based on their total national use as well as on a crop by crop basis. There was a large range in terms of the total amount of each active ingredient sold, ranging from 20 kg (mevinphos) to as much as 3 720 800 kg (glyphosate). For the purposes of this prioritisation process, those active ingredients with less than 1000 kg sold were excluded from any further analysis.

1.2.2.2 Toxicity screening

Relevant toxicity data was collected for each of the active ingredients retained after the initial pesticide use screening procedure. Pesticides for which positive or uncertain data was found for at least one of the toxicity endpoints considered were retained for further prioritisation. All pesticides retained after the initial use screening procedure recorded positive or uncertain data for the selected toxicity endpoints and were therefore all included in subsequent prioritisation procedures.

1.2.3 Prioritisation ranking system

Pesticides retained for the second phase of prioritisation were ranked according to a scoring system that uses a pesticide use or quantity index (*QI*), hazard potential (*HP*) and environmental exposure potential (*EEP*) as input parameters. As pesticide sales data was available on a product by crop basis it was possible to rank pesticides at a national scale (i.e. based on the total amount of active ingredient applied at a national scale) as well as at a crop-specific scale (i.e. based on the total amount of active ingredient applied to each major crop in the country). Crop-specific ranking of pesticides per crop allows for a more spatially explicit identification of high priority chemicals.

1.2.3.1 Quantity Index (QI)

The initial screening process retained 152 (of 203) active ingredients applied to crops at a national scale. These were all included in the latter prioritisation process. These 152 pesticides (19 003 400 kg in total) accounted for 99.8% of the total quantity of pesticides sold for 2009. Fungicides, herbicides and insecticides accounted for 41%, 50% and 8% of the total use, respectively.

1.2.3.2 Toxicity Potential (TP)

Pesticides were scored according to potential to cause cancer, EDC effects and neurotoxicity. The scoring system was adapted from that used by Valcke *et al.* (2005) (Table 1.2). For potential to cause cancer the scoring system was built according to the relative importance for each toxicodynamic criterion in the context of a cancer study: carcinogenicity > mutagenicity > teratogenicity. Thus, chemicals with evidence of causing cancer were scored higher than chemicals causing mutagenicity. Similarly, pesticides causing mutagenicity were scored higher than those causing teratogenicity. Two other rules were applied to create the toxicity scoring system. First, the score for “possible” evidence of a higher-ranked effect (i.e. 6 attributed to the possible link to cause cancer) was equal to the highest score (i.e. 6 for positive evidence of mutagenic effects) for a lower-ranked effect, assuming that a strong potential for a less important effect is at the same level as a weak potential for a more important effect. Second, the absence of status for a specific effect (i.e. No Data) was granted some value despite uncertainty. Although uncertainty does not necessarily imply weak effects, the score attributed was low because of a higher probability that strong effects would have been identified. Also, an undetermined status (i.e. No Data) for a more important effect had a higher score than an undetermined status for a less important effect. The source for data was the Pesticide Properties Database (FOOTPRINT, 2006). When two sources reported contradictory data, in general recent data were considered more relevant than old data or, when justifiable, the most critical were retained. For all endpoints, a value of 0 was attributed when the literature reported a proven absence of effects. The toxicity potential (*TP*) was obtained by summing, for each active ingredient, the values for the five criteria and adding a default value of 1. The latter was done to avoid zero scores in the subsequent treatment of the TPs.

Table 1.2: Scoring system used to rank pesticides based on toxicity endpoints for human health.

Toxicodynamic properties	Classification	Value
Carcinogenic and EDC	Yes	8
	Possible	6
	No Data	3
	No	0
Mutagenicity	Yes	6
	Possible	4
	No Data	2
	No	0
Teratogenicity	Yes	4
	Possible	2
	No Data	1
	No	0
Neurotoxicity	Yes	4
	Possible	2
	No Data	1
	No	0
Default Value		1

1.2.3.3 Environmental Exposure Potential (EEP)

The main objective of this prioritisation process was to identify pesticides posing risk to human health through contamination of water resources. Pesticides typically enter water resources through spray drift, leaching and/or runoff. Spray drift is largely a function of the application rate and this route of contamination is therefore considered through the quantity index used in the prioritisation process. The ability of a pesticide to move with the water phase (i.e. as a result of runoff or leaching), is heavily influenced by the physicochemical properties of the pesticide.

Two indices have been developed to provide a relative indication of the potential of a chemical to move via leaching and runoff. These are the Groundwater Ubiquity Score or GUS index (Gustafson, 1989) and the Surface Water Mobility Index or SWMI (Chen *et al.*, 2002), respectively. Both indices incorporate half-life and K_{OC} values of the compounds and provide a score giving an indication of mobility. Scores for the GUS index are on a logarithmic scale, with compounds with a value higher than 2.8 classified as highly mobile and those with a value less than 1.8 classified as non-leachers. The SWMI index provides a score between 1 and 0 with compounds scoring closer to 1 having a higher potential to move with runoff. A plot of GUS index scores against SWMI scores for all pesticides included in the prioritisation process, showed a very good correlation between scores (Figure 1.1). This analysis strongly indicates that pesticides prone to leaching are also prone to runoff loss and vice versa. Thus, use of either of the indices provides a reliable indication of the potential of a pesticide to enter water resources through both runoff and leaching. The GUS index was used as a measure of environmental exposure potential as it has been widely used as an indicator of pesticide mobility (Table 1.3).

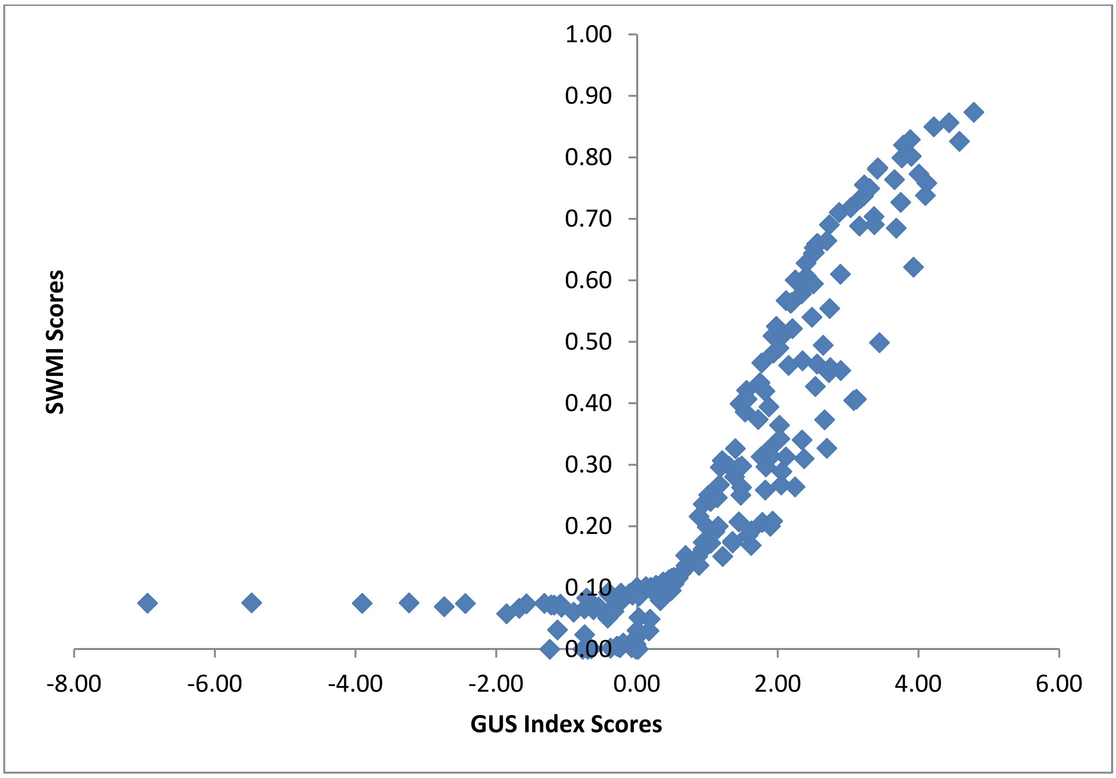

Figure 1.1: Graph plotting GUS Index scores against SWMI scores for all pesticides included in the prioritisation process.

Table 1.3: Scoring system used to rank pesticides in terms of their potential exposure risk to water resources based on their groundwater ubiquity score (GUS).

Environmental Exposure Potential	GUS Score	Value
High	GUS > 2.8	4
Medium	2.8 > GUS > 1.8	2
Low	30 > GUS < 1.8	1
No Data	No K_{OC} or DT_{50} value	1.5

1.2.3.4 Hazard Potential (HP) and Weighted Hazard Potential (WHP)

The Hazard Potential (*HP*) provides an indication of the potential for exposure to highly toxic pesticides and is calculated as follows:

$$HP_A = TP_A \times EEP_A$$

Where TP_A is the toxicity potential score of pesticide A and *EEP* is the environmental exposure potential score of pesticide A. Following this, the *HP* was multiplied by the proportion of the usage of the pesticide in question relative to the total usage of all pesticides included in the analysis, to obtain the weighted hazard potential (*WHP*):

$$WHP_A = HP_A \times \frac{QI_A}{Q_{tot}}$$

where HP_A is the Hazard Potential of pesticide A, QI_A is quantity of usage (kg) of pesticide A and Q_{tot} is the sum of quantities of usage (kg) of all the pesticides (19 024 000 kg). Toxicity and environmental scores and calculated indices for each active ingredient are provided in the Appendix in Table A3.

1.3 RESULTS

1.3.1 Ranking According to Indices

The 152 active ingredients were ranked according to each of the calculated indices and plotted as a function of their cumulative proportion contribution to the total applied quantity of all 152 pesticides (Figure 1.2). From this plot it is evident that the most heavily used pesticides appeared not necessarily as the most toxic, and vice versa, independently of whether *TP* or *HP* slopes are considered. The 25 pesticides with the highest *QI* and *WHP* accounted for 89% and 86% of the total quantity of selected pesticides usage, respectively. Their slopes largely overlapped, indicating that quantity of usage was a main determinant of the *WHP*. For the *TP* and *HP* indices, the 50 highest ranked pesticides accounted for only 38% and 29% of the total of selected pesticides, respectively. While quantity of use is an important factor in determining priority, it is also important to consider those highly toxic pesticides that, although not widely used, may still result in localised health problems. Thus, as in Valcke *et al.* (2005), the top 25 pesticides were ranked according to each index.

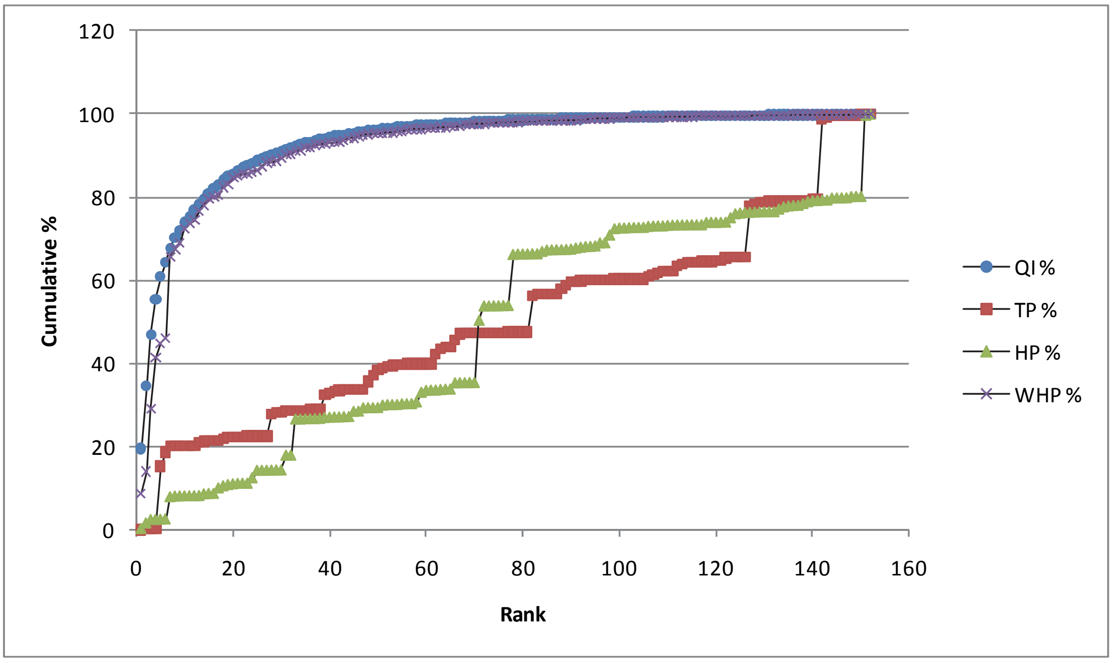

Figure 1.2: Cumulative percentage (by kg) of selected pesticides ranked in decreasing order according to *QI*, *TP*, *HP*, and *WHP*. Inclines in the slopes are associated to high-usage pesticides.

Table 1.4 shows the top 25 positions according to each of the four indices; *QI*, *TP*, *HP*, and *WHP*. Two pesticides occurred in each of the four indices (acetochlor and ethylene-dibromide), while another four pesticides (atrazine, mancozeb, imidacloprid and trifluarin) occurred within the top 25 of the *QI* and *WHP* indices as well one of the two toxicity indices (either the *TP* or the *HP*). Considering the relevance of all the indices a combined final list of pesticides was compiled that contained all of the top 25 pesticides that occurred in each of the four indices. These were then ranked according to their respective *WHP* scores and represented approximately 92% of the total quantity of pesticides applied in South Africa. In addition to the index scores, the mobility category into which the pesticide falls (based on the GUS score) is also included. This provides an additional level of information with respect to the likely pathway of exposure. For example, a number of pesticides included in the top 10 ranked priority pesticides have relatively low mobility. This would indicate that these pesticides are unlikely to pose a risk through the water pathway. However, this does not mean that these pesticides do not pose a high risk to human health. All the above mentioned pesticides are used in very high quantities. Therefore, depending on the method of application, there is a high chance of exposure, through, for example spray drift.

The 64 pesticides occurring in the final list of priority pesticides were included in a Principal Component Analysis (PCA) to determine how each of the indices influenced their inclusion in the final list of prioritised pesticides (Figure 1.3). Analysis was performed using the CANOCO programme. The results confirm the results shown in Figure 1.2, with the *QI* index strongly correlated with the 1st axis which accounts for 80.6% of the variation. The 2nd axis accounts for an additional 15.2% of variation and 95.8% of the total variation together with the 1st axis. The direction of the *QI* arrow points in the direction of steepest increase for the quantity of pesticides applied. Therefore, pesticides plotted towards the right of the graph, in the direction of the *QI* arrow, have higher usage (with glyphosate having the highest usage) than those plotted towards the left, in the opposite direction of the arrow (bifenthrin having the lowest usage). Similarly, the direction of the *WHP* arrow indicates the direction of greatest change, with atrazine having the highest *WHP*, followed by mancozeb, acetochlor, ethylene-dibromide and so on. Similarly those pesticides towards the top of the graph have higher toxicity as indicated by the direction of the *TP* and *HP* arrows. The fact that these two arrows lie so closely together indicates that there is a high correlation between the *TP* and *HP* indices. In general, those pesticide plotted in the top right hand quadrant of the graph are characterised as having high usage, high *WHP* and high toxicity. Those plotted in the bottom right quadrant also have high *QI* and relatively high *WHP* scores. The fact that they are plotted in the opposite direction of the *TP* and *HP* arrows indicates that there high *WHP* scores is largely due to their high usage. This is particularly evident for pesticides such as glyphosate, sulphur and copper carbonate and hydroxide all of which are characterised by having relatively low *TP* and *HP* scores. Those pesticides located in the top left hand quadrant are characterised by having relatively low usage, comparatively low *WHP* scores but high toxicity.

Table 1.4: Top 25 ranked pesticides in each of the calculated prioritisation indices (*QI* — quantity index, *TP* — toxicity potential; *HP* — hazard potential; *WHP* — weighted hazard potential)

Rank	Active Ingredient	*QI*	Active Ingredient	*TP*	Active Ingredient	*HP*	Active Ingredient	*WHP*
1	Glyphosate	3,721	Trichlorfon	25	Trichlorfon	100	Atrazine	3.63
2	Mancozeb	2,849	Benomyl	24	Ethylene-dibromide	92	Mancozeb	3.44
3	Sulphur	2,337	Endosulfan	24	Atrazine	68	Acetochlor	1.59
4	Copper oxychloride	1,226	Dichlorvos	24	Triadimenol	68	Ethylene-dibromide	1.22
5	Atrazine	1,014	Procymidone	24	Simazine	64	Terbuthylazine	1.13
6	Terbuthylazine	674	Mancozeb	23	Sulcotrione	64	Glyphosate	0.98
7	Acetochlor	657	Acetochlor	23	Tembotrione	64	Sulphur	0.86
8	Metolachlor	444	Ethylene-dibromide	23	Imidacloprid	60	Copper oxychloride	0.84
9	2,4-D-amine	355	Malathion	23	Carbofuran	60	Imidacloprid	0.80
10	Paraquat	345	Bifenthrin	23	Cyproconazole	60	Metolachlor	0.65
11	Alachlor	287	Zineb	22	Sulfosulfuron	56	2,4-D-amine	0.56
12	MCPA	285	Thiophanate	22	Propoxur	56	Alachlor	0.45
13	Ethylene-dibromide	252	2,4-D	21	Tribenuron-methyl	52	MCPA	0.39
14	Imidacloprid	252	Deltamethrin	21	Triticonazole	52	Simazine	0.28
15	MSMA	245	Trifluralin	20	Acetochlor	46	Paraquat	0.24
16	Potassium-phosphite	236	Thiram	20	Bromacil	44	Aldicarb	0.21
17	Cyanamide	203	Acephate	20	Buprofenzin	44	MSMA	0.18
18	EPTC	178	Thiodicarb	20	2,4-D	42	Trifluralin	0.17
19	Copper hydroxide	178	Fipronil	20	Fipronil	40	Diuron	0.15
20	Trifluralin	160	Aldicarb	19	Aldicarb	38	Metribuzin	0.13
21	Copper-carbonate	149	Bromoxynil	19	Carbendazim	38	Hexazinone	0.12
22	Chlorpyrifos	148	Carbendazim	19	Triadimefon	38	Cyanamide	0.12
23	Chlorothalonil	140	Triadimefon	19	Carbaryl	36	Carbofuran	0.11
24	Terbufos	115	Carbaryl	18	Iprodione	36	EPTC	0.10
25	s-metolachlor	113	Iprodione	18	Ethoprophos	36	Fosthiazate	0.10
26		106	Parathion-methyl	18	Fosthiazate	36		
27			Folpet	18	Imazamox	36		
28			Fenoxycarb	18	Thiamethoxam	36		

Table 1.5: Final list of priority pesticides ranked by the *WHP* (*Rank$_{WHP}$*) of the top 25 active ingredients occurring in each of the four calculated prioritisation indices.

Rank	Active Ingredient	*QI*	*TP*	*HP*	*WHP*	Mobility
1	Atrazine	1014.42	17	68	3.6260	High
2	Mancozeb	2849.02	23	23	3.4445	Low
3	Acetochlor	656.545	23	46	1.5875	Medium
4	Ethylene-dibromide	252.486	23	92	1.2210	High
5	Terbuthylazine	674.413	16	32	1.1344	Medium
6	Glyphosate	3720.799	5	5	0.9779	Low
7	Sulphur	2337.28	7	7	0.8600	Low
8	Copper oxychloride	1225.806	13	13	0.8377	Low
9	Imidacloprid	252.167	15	60	0.7953	High
10	Metolachlor	443.707	14	28	0.6531	Medium
11	2,4-D-amine	355.102	15	30	0.5600	Medium
12	Alachlor	287.044	15	30	0.4527	Medium
13	MCPA	284.6	13	26	0.3890	Medium
14	Simazine	83.253	16	64	0.2801	High
15	Paraquat	345.127	13	13	0.2358	Low
16	Aldicarb	105	19	38	0.2097	Medium
17	MSMA	245.108	14	14	0.1804	Low
18	Trifluralin	160.416	20	20	0.1686	Low
19	Potassium-phosphite	236.154	9	13.5	0.1676	No Data
20	Diuron	96	15	30	0.1514	Medium
21	Metribuzin	106.08	12	24	0.1338	Medium
22	Hexazinone	84.607	7	28	0.1245	High
23	Cyanamide	203.252	11	11	0.1175	Low
24	Carbofuran	33.444	15	60	0.1055	High
25	EPTC	178.43	11	11	0.1032	Low
26	Fosthiazate	52.2	9	36	0.0988	High
27	s-metolachlor	113.317	16	16	0.0953	Low
28	Chlorpyrifos	148.47	11	11	0.0858	Low
29	Sulcotrione	21.075	16	64	0.0709	High
30	Bromoxynil	66.48	19	19	0.0664	Low
31	Terbufos	114.75	10	10	0.0603	Low
32	Chlorothalonil	140.007	8	8	0.0589	Low
33	Thiram	46.566	20	20	0.0490	Low
34	Copper-carbonate	148.725	4	6	0.0469	No Data
35	Thiamethoxam	22.8	9	36	0.0431	High
36	Benomyl	30.547	24	24	0.0385	Low
37	Copper hydroxide	177.561	4	4	0.0373	Low
38	Carbendazim	15.114	19	38	0.0302	Medium
39	Carbaryl	14.758	18	36	0.0279	Medium
40	Iprodione	12.635	18	36	0.0239	Medium
41	2,4-D	10.5	21	42	0.0232	Medium
42	Trichlorfon	4.37	25	100	0.0230	High
43	Bromacil	9.6	11	44	0.0222	High

Rank	Active Ingredient	*QI*	*TP*	*HP*	*WHP*	Mobility
44	Endosulfan	12.37	24	24	0.0156	Low
45	Cyproconazole	3.92	15	60	0.0124	High
46	Acephate	8.65	20	20	0.0091	Low
47	Dichlorvos	5.673	24	24	0.0072	Low
48	Buprofenzin	2.65	11	44	0.0061	High
49	Tembotrione	1.806	16	64	0.0061	High
50	Zineb	4.844	22	22	0.0056	Low
51	Triadimenol	1.213	17	68	0.0043	High
52	Thiodicarb	4.1	20	20	0.0043	Low
53	Deltamethrin	3.822	21	21	0.0042	Low
54	Tribenuron-methyl	1.313	13	52	0.0036	High
55	Triticonazole	1.3	13	52	0.0036	High
56	Fipronil	1.677	20	40	0.0035	Medium
57	Triadimefon	1.684	19	38	0.0034	Medium
58	Malathion	2.707	23	23	0.0033	Low
59	Sulfosulfuron	0.975	14	56	0.0029	High
61	Thiophanate	1.824	22	22	0.0021	Low
62	Propoxur	0.3	14	56	0.0009	High
63	Procymidone	0.302	24	24	0.0004	Low
64	Bifenthrin	0.15	23	23	0.0002	Low

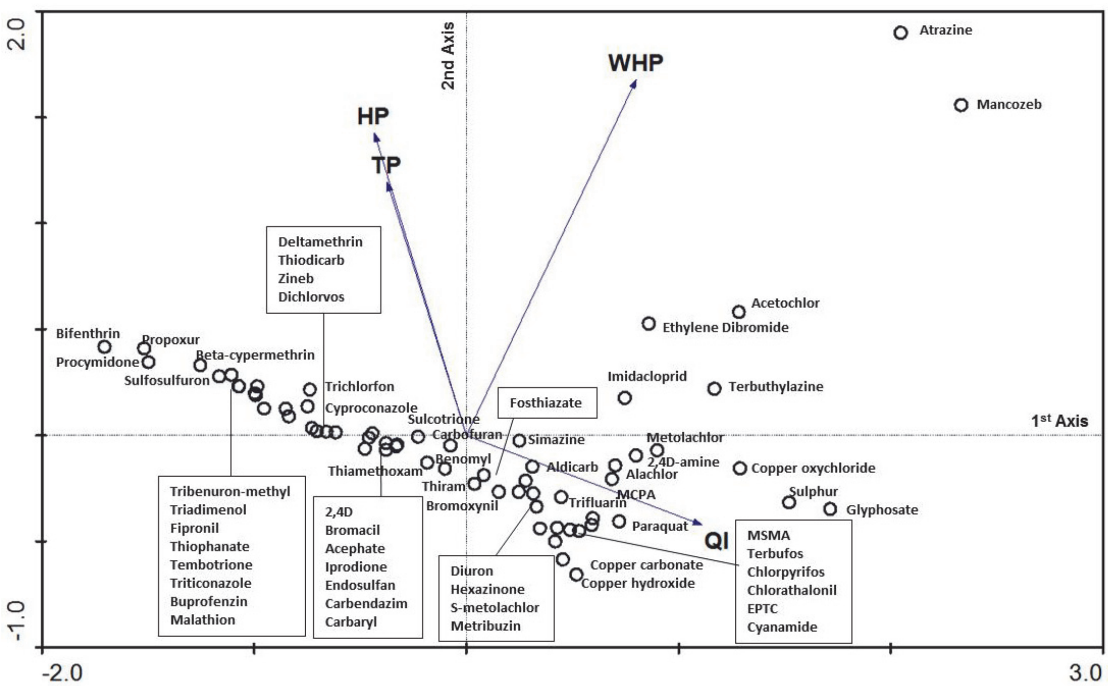

Figure 1.3: PCA plot illustrating the influence of four different pesticide prioritisation indices on 64 pesticides included in the final list of national priority pesticides.

1.3.2 Crop-specific Pesticide Prioritisation

As crop-specific pesticide use data was provided it was possible to calculate the *WHP* for priority pesticides per crop type. In this instance, the *WHP* for each pesticide applied to each crop was calculated using the ratio of the volume of application of the active ingredient to the crop (i.e. QI is the total quantity of the pesticide x applied to the specific crop and not the total applied to all crops) in relation to the total volume of all pesticides applied nationally. For each crop, the total *WHP* was calculated by summing the *WHP* scores for each active ingredient applied to that crop. The total WHP was expressed as a function of the total surface area (ha) to which the crop-specific pesticides were applied (Table 1.6). Data on the area of application was included in the pesticide use data obtained from the Sigma™ Programme and is also for the year 2009. This allowed for the prioritization of crops in terms of the WHP/ha and provides a more comparative means of prioritizing specific crops with respect to their potential risk to human health.

Table 1.6: Crops ranked according to the sum of *WHP* scores of active ingredients applied to each crop (Total *WHP*) and the sum of WHP relative to the total surface area to which crop-specific pesticides were applied (*WHP*/ha)

Rank	Crop	Total *WHP*	Crop	*WHP*/ha
1	Maize	8.5892	Tomatoes	0.2911
2	Potatoes	2.5749	Potatoes	0.2348
3	Citrus	2.0614	Citrus	0.1071
4	Grapes (wine)	1.6505	Apples	0.0633
5	Sugar Cane	1.1961	Pears	0.0584
6	Apples	0.6252	Grapes (table)	0.0379
7	Wheat	0.5892	Grapes (wine)	0.0349
8	Tomatoes	0.5605	Sugar Cane	0.0343
9	Grapes (table)	0.3971	Maize	0.0330
10	Soybeans	0.3897	Mangoes	0.0311
11	Sorghum	0.3483	Sorghum	0.0252
12	Peaches	0.2756	Plums	0.0234
13	Potatoes: Seed	0.2446	Peaches	0.0221
14	Pears	0.1958	Groundnuts	0.0219
15	Sunflower	0.1818	Potatoes: Seed	0.0217
16	Mangoes	0.1746	Sunflower	0.0157
17	Groundnuts	0.1645	Pineapple	0.0138
18	Barley	0.1549	Avocados	0.0122
19	Beans	0.1331	Apricots	0.0121
20	Avocados	0.0799	Soybeans	0.0117
21	Pineapple	0.0735	Wheat	0.0099
22	Plums	0.0594	Cotton	0.0097
23	Dry-Beans	0.0466	Beans	0.0091
24	Cotton	0.0450	Dry-Beans	0.0046
25	Apricots	0.0351	Bananas	0.0042
26	Bananas	0.0172	Barley	0.0032

This procedure also allows for a more spatial prioritisation of pesticides across the country by linking the indices with specific crops. Simply identifying the general distribution of the specific crop types allows for a first order assessment of where in the country priority pesticides are likely being applied.

1.3.3 Prioritisation Matrix

The 64 priority compounds, the ranking of crops and the quantity of use of each of the priority pesticides applied to the crops (expressed as a percentage of the total use of each active ingredient) was organised in a prioritisation matrix (Table 1.7). Priority pesticides are listed vertically in order of their rank (i.e. 1 to 64). Crops are listed horizontally (from left to right) in order of their rank. The shading of the cells highlights those priority pesticides that are used in high quantities on crops included in the analysis. The colour of the shading ranges from dark green (very low percentage use on the crop) to dark red (very high percentage use on the crop). The matrix thus integrates all of the prioritisation information to provide an integrated summary of priority chemicals and priority crops in the country.

Maize is clearly the most important crop with regard to application of high priority chemicals and accounts for a large percentage of the use of important chemicals. It is important to remember that the aim of the pesticide prioritization process was to identify high risk pesticides applied at a national scale. For this purpose the total quantity of the pesticide is a highly relevant indicator of potential risk and indicates that the chemical is widely used and therefore has high exposure potential. For the crop prioritization process it was also appropriate to express the *WHP* in terms of per hectare use. For example, maize had the highest total *WHP* which is clearly a result of it being the most widely produced crop in the country. This implies that at a national scale, pesticide use on maize is the leading contributor to total *WHP*. However, the effect of normalising the *WHP* relative to the surface area of application identifies tomatoes as the highest priority crop (and relegates maize to 8th in terms of priority). This implies that, whilst tomatoes do not account for the highest total volume of pesticide application, the total *WHP* of priority pesticides applied to this crop is high relative to the surface area for that specific crop. The *WHP*/ha is possibly the more relevant indicator for prioritizing crops as for example, communities living in close proximity to a tomato crop are potentially more at risk than those living adjacent to a maize crop. However considering that maize is more widely grown, covering a significantly larger surface area, there are more communities likely to be living in close proximity to a maize crop than a tomato crop. The total *WHP* therefore provides a national perspective of identifying which crops high priority pesticides are applied to, whilst the *WHP*/ha is useful for a site specific evaluation of the potential risk that pesticide application to a specific crop poses or for a comparative assessment between crops. The total *WHP* score for each crop was used to rank crops in the prioritization matrix (Table 1.7) as this metric is more meaningfully related to the output of the process used to rank the pesticides (which was also done at a national scale).

Table 1.7: An abbreviated version of the matrix that prioritizes active ingredients and crops in terms of their potential hazard to human and animal health (the full version can be obtained from the attached CD).

	Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	A.I/Crop	Maize	Potatoes	Citrus	Grapes(w)	Sugar Cane	Wheat	Apples	Tomatoes	Grapes(t)	Soybeans	Sorghum	Peaches	Potatoes(s)	Pears	Barley
1	Atrazine	87.83	-	-	-	7.48	-	-	-	-	-	4.24	-	-	-	-
2	Mancozeb	-	15.39	31.08	13.09	-	-	11.71	9.92	2.04	-	-	2.24	4.08	3.32	-
3	Acetochlor	84.71	5.69	-	-	1.13	-	-	-	-	5.69	-	-	-	-	-
4	Ethylene-dibromide	-	97.57	-	-	-	-	-	0.61	-	-	-	-	-	-	-
5	Terbuthylazine	92.20	-	-	2.89	0.83	-	-	-	1.41	-	2.67	-	-	-	-
6	Glyphosate	65.88	-	2.04	8.03	7.22	0.39	2.20	0.05	0.52	7.77	-	1.33	-	1.18	0.39
7	Sulphur	-	-	-	82.61	-	-	-	0.27	11.18	-	-	0.48	-	-	-
8	Copper oxychloride	-	5.69	5.55	10.47	-	-	5.06	13.52	0.90	-	-	13.52	4.44	1.53	-
9	Imidacloprid	11.48	-	68.18	-	-	1.04	5.83	-	-	-	1.02	-	1.94	1.39	-
10	Metolachlor	58.97	0.79	-	-	-	2.21	-	-	-	16.55	3.18	-	-	-	-
11	2,4-D-amine	59.69	-	-	-	2.95	24.33	-	-	-	-	6.33	-	-	-	-
12	Alachlor	41.64	7.63	-	-	8.56	-	-	-	-	14.68	10.09	-	1.47	-	-
13	MCPA	6.32	1.69	-	7.31	-	54.81	1.55	-	-	-	2.74	0.14	-	0.98	21.78
14	Simazine	68.17	-	4.20	13.81	-	-	0.60	-	12.61	-	-	-	-	0.60	-
15	Paraquat	9.73	10.05	15.61	7.88	11.97	1.78	11.22	3.58	3.07	1.60	-	2.64	-	2.31	1.09
16	Aldicarb	-	80.00	20.00	-	-	-	-	-	-	-	-	-	-	-	-
17	MSMA	-	-	-	-	96.48	-	-	-	-	-	-	-	-	-	-
18	Trifluralin	-	-	-	0.42	2.81	22.44	-	0.36	0.42	0.60	-	-	-	-	10.47
19	Potassium-phosphite	-	53.79	13.86	4.62	-	-	-	-	4.62	-	-	-	-	-	-
20	Diuron	-	-	-	-	100.00	-	-	-	-	-	-	-	-	-	-
21	Metribuzin	-	8.60	-	-	85.97	-	-	0.45	-	3.62	-	-	1.36	-	-
22	Hexazinone	-	-	-	-	100.00	-	-	-	-	-	-	-	-	-	-
23	Cyanamide	-	-	-	-	-	-	7.71	-	91.61	-	-	-	-	-	-
24	Carbofuran	72.78	4.81	-	-	-	-	-	-	-	-	10.00	-	-	-	-
25	EPTC	54.82	41.95	-	-	-	-	-	-	-	-	-	-	3.23	-	-
26	Fosthiazate	-	72.41	27.59	-	-	-	-	-	-	-	-	-	-	-	-
27	s-metolachlor	47.19	-	-	-	49.64	-	-	-	-	-	3.18	-	-	-	-
28	Chlorpyrifos	2.49	4.24	-	30.10	-	27.44	11.45	3.36	2.13	3.94	-	2.10	-	12.93	-
29	Sulcotrione	95.00	-	-	-	5.00	-	-	-	-	-	-	-	-	-	-
30	Bromoxynil	17.15	-	-	-	-	57.54	-	-	-	-	1.08	-	-	-	20.31
31	Terbufos	83.66	3.14	12.42	-	-	-	-	-	-	-	-	-	-	-	-
32	Chlorothalonil	-	54.22	-	-	-	-	-	17.47	-	-	-	-	15.36	-	-
33	Thiram	-	-	-	-	-	-	0.14	-	-	-	-	66.04	-	-	-
34	Copper-carbonate	-	-	-	-	-	-	-	34.22	-	-	-	-	32.00	-	-
35	Thiamethoxam	84.43	-	-	-	-	7.68	3.29	-	-	-	-	-	-	-	-
36	Benomyl	9.82	-	46.80	-	-	-	-	8.68	-	8.68	-	-	-	-	-
37	Copper hydroxide	-	10.60	-	36.36	-	-	-	6.06	-	-	-	-	-	-	-
38	Carbendazim	6.78	-	4.82	0.60	-	51.52	-	-	0.60	-	-	-	-	-	35.68
39	Carbaryl	8.64	-	0.27	25.75	-	-	15.94	-	4.02	-	-	0.41	-	0.41	-
40	Iprodione	-	-	-	24.90	-	-	-	20.18	9.16	-	-	8.07	-	31.66	-

1.4 DISCUSSION

The method adopted here was adopted from a study performed by Valcke *et al.* (2005) in Costa Rica. As highlighted in their publication, a major advantage of this method is that it relies on relatively simple input data that is readily obtainable from internet databases. While toxicity data is readily available, possibly the most important data required to apply this method is pesticide use data. Currently there is no publicly accessible source of information on pesticide use in South Africa. Market related sales data thus provides the best available indication of pesticide usage in the country. Sales data does not necessarily reflect an accurate assessment of actual use. For example farmers, may stock up on specific agro-chemical products in anticipation of forecasted weather events or pest outbreaks. These may not materialise and the product may therefore not be actually used. There is thus quite a large amount of uncertainty related to the use of this data and results or outputs should be interpreted accordingly. This is even more valid with respect to the crop-specific pesticide use data. While surveys, registration fact sheets and location of pesticide distributors may provide an indication of intended use, there are no enforcement mechanisms to ensure a product is in fact used on a specific crop and there is likely to be a fairly high degree of uncertainty related to these statistics. In spite of these limitations, application of this data in this prioritisation procedure is not a problem that is unique to South Africa and more developed countries such as the United States and member states of the EU also make use of sales data as a surrogate for pesticide use data (Thomas, 1999; Grube *et al.,* 2011).

Analysis and dissemination of information produced here clearly has broad implications for managing the risks of pesticides in the country, particular with respect to design of monitoring programmes. Simply by prioritizing in excess of 200 active ingredients regularly applied in the country it is possible to identify those most likely to pose risk to human health. This is particularly relevant in developing countries where narrowing a broad range of potential problem chemicals to a few high priority ones can be particularly useful in overcoming challenges related to monitoring, the availability of reliable analytical facilities and expensive analyses. Easier access to pesticide use data can facilitate additional research (e.g. modelling studies) and the production of outputs that can only help improve management of pesticides in a resource constrained country.

While the method described here is very similar to that described by Valcke *et al.* (2005), it does deviate in a number of significant ways. Firstly, our method has included endocrine disruption as a toxicity endpoint. While there has been significant evidence of endocrine disruption in humans as a result of exposure to DDT (Aneck-Hahn *et al.,* 2007) which is used in malaria control, other studies have also reported endocrine disrupting activity from samples collected from drinking water in rural communities in South Africa (Aneck-Hahn *et al.,* 2009).

Including endocrine disruption as an endpoint is tenuous, considering that for many active ingredients there is no data or only possible linkages to endocrine disruption. In fact, of the 152 pesticides that passed the initial quantity screening stage, only 9% were definite EDCs and 13% were definitely not EDCs, accounting for 22% of the total. The majority of pesticides have no data (57%) while 22% are possible EDCs. In spite of this lack of data even having information for a small number of pesticides can at least provide some level of precaution. Equally important is whether a compound is not an EDC. This is particularly relevant in a country where many people use boreholes and water collected from rivers for drinking purposes. Furthermore, the procedure described here and in Valcke *et al.* (2005) can be easily updated as more information becomes available.

The method described here also differs fundamentally in terms of evaluating the exposure potential of pesticides. The method proposed by Valcke *et al.* (2005) used half-life as the endpoint to classify potential exposure. A substance that is persistent in the environment (as measured by its half-life) is likely to pose a higher risk of exposure simply because it is available for a longer period after application. An important aspect to consider is the transport pathway that results in communities being exposed in non-target environments. Exposure typically occurs through aerial (i.e. breathing) and dermal exposure and through ingestion (i.e. via food and water). With respect to aerial and dermal exposure, the quantity of the applied pesticide (as indicated by the *QI*) provides a good indicator of contamination as the transport pathways resulting in this form of exposure (i.e. spray drift during application and volatilization of an applied compound) are strongly dependent on the use of the compound. In the South African context however, exposure through drinking water is a very important route of potential contamination. For this reason it was important to consider additional physicochemical properties that influence the movement of pesticides into water resources. Thus, in addition to half-life, the tendency of a pesticide to bind to organic carbon in soil (as indicated by the K_{OC} value) is an important property that influences its availability in the environment (Webb *et al.,* 2008). Pesticides with high K_{OC} values tend to bind with available organic carbon (e.g. in soil and sediment) and are less prone to runoff and leaching and therefore less likely to contaminate water resources used for human consumption. Use of the GUS index in combination with the *QI* provided a realistic assessment of all potential exposure routes. Including the mobility category associated with each prioritised pesticide provides a useful additional level of detail in assessing the possibility of contamination of water resources.

As pointed out by Valcke *et al.* (2005) and in this paper the four indices used in the prioritisation procedure each provide a relevant piece of information and provide an indication of attributes of specific pesticides that resulted in the pesticide being included in the final list of priority compounds. While Table 1.5 lists each of the index scores associated with each pesticide, the PCA analysis and associated ordination diagram provide a useful interpretation as to why each pesticide was included in the final list of priority compounds (Figure 1.3). For example pesticides located in the top left hand quadrant, while not used in high quantities at a national scale, have high toxicity scores and may therefore result in localised risks due to crop-specific use.

In this respect the crop prioritisation matrix is very useful for identifying which specific crops highly toxic pesticides are applied to and provides an additional spatial assessment of potential pesticide risks. Knowledge of the location of specific crops can therefore result in the identification of areas and communities that may be at risk to exposure of priority chemicals. For example, ethylene-dibromide is ranked 4th in terms of its health risk. It is one of the few pesticides that featured in each of the indices calculated during the prioritisation process (Table 1.4). Furthermore it is applied almost exclusively to potatoes (Table 1.7). Thus the prioritisation process described here is helpful in terms of establishing targeted monitoring programmes in targeted areas so as to obtain exposure data for a more detailed risk assessment. Considering ethylene-dibromide is identified as being highly mobile, risk mitigation measures can also be identified and implemented so as to minimise contamination of ground (e.g. through measures such as application rate reduction, product substitution and shift of the application date) and surface water (e.g. through implementation of edge-of-field buffer strips). Similarly trichlorfon was ranked as the highest pesticide on the *TP* and *HP* indices. Perusal of the matrix indicates that this pesticide is applied exclusively to citrus, which therefore provides insight as to where in South Africa this pesticide is likely to be used.

1.4.1 Comparison to Previous Studies

The only previous study attempted to prioritize pesticide use in South Africa was that performed by Dalvie *et al.* (2009). In contrast to this current study, the toxicity endpoints used to determine the relative toxicity of active ingredients was acute LD_{50} toxicity data for mammalian rats. The main focus of the study of the study by Dalvie *et al.* (2005) was to prioritize risk to occupational health (i.e. pesticide applicators and farm workers). In this setting, potential for exposure to pesticides is significantly higher than members of the general population and an acute toxicity endpoint is therefore possibly more relevant. While this methodology is extremely valuable in a country where information on pesticide use is scarce, the method does not take chronic effects into account. With respect to the general population, sub-acute exposure to pesticides is a far more likely exposure scenario and carcinogenicity and endocrine disrupting endpoints are thus a more realistic measure of hazard.

The study by Dalvie *et al.* (2009) identified sulphur (1 785 x 10^3 kg), mancozeb (1 381 x 10^3 kg), glyphosate (636 x 10^3 kg), copper oxychloride (466 x 10^3 kg) and MCPA (143 x 10^3 kg) as the top five most sold (by mass) active ingredients in 1999. Data for 2009 showed the same active ingredients as the top five most sold by mass, with the exception of atrazine replacing MCPA as the fifth most sold active ingredient. The quantities of all of the top five substances increased significantly in comparison to 1999 figures; sulphur (2 338 x 10^3 kg), mancozeb (2 849 x 10^3 kg), glyphosate (3 720 x 10^3 kg), copper oxychloride (1 226 x 10^3 kg) and atrazine (1 014 x 10^3 kg – not included in the list for 1999). Atrazine and glyphosate and sulphur are used predominantly on maize and grapes, respectively, whilst mancozeb and copper oxychloride are used on a wide range of crops. Considering maize is the most widely produced crop in the country it is therefore not surprising that atrazine and glyphosate are used in such high quantities.

1.5 EXCEL SOFTWARE

While the *WHP* as calculated above provides an integrated indicator of priority, it is recognised that users may want to prioritise pesticide according to different criteria (i.e. according to quantity of use, toxicity or environmental mobility alone). Users may also want to specifically identify and prioritise carcinogenic or ED pesticides only. Furthermore a crop-specific or pesticide specific prioritisation may be necessary. A spreadsheet facility has been attached to this report to enable users to prioritise according to multiple criteria. The spreadsheet makes use of filters which can be used to select specific crops or active ingredients or active ingredients with toxicological endpoints of interest (e.g. those that definitely have ED potential) and rank these (using the sort function) according to any of the indices described above.

1.5.1 Pesticide Prioritisation (National)

This worksheet contains data and indices and *WHP* scores as described in Section 1.2 of this report. Pesticides use data is therefore not crop-specific and is expressed as the total amount of pesticide used on all crops to which the pesticide is applied (Q_{tot} is therefore 19 024 000 kg, which is equal to the sum of pesticide use for all pesticide included in the prioritisation procedure – i.e. that that were applied at higher than 1 000 kg annually).

1.5.2 Pesticide Prioritisation (Crop Specific)

This worksheet enables users to choose a particular crop of interest and view pesticides applied to that crop as well as the *WHP* for each pesticide applied to that crop only (i.e. Q_{tot} used to calculate the *WHP* is the total quantity of all pesticides applied to that specific crop only). This enables users to identify high priority pesticides applied to a specific crop of interest. Prioritizing pesticide per crop as opposed to a national scale enables a more site specific prioritisation of agricultural chemicals which may not necessarily be reflected by the national prioritisation procedure. For example while only approximately 12% of trifluralin is applied to cotton and is ranked 18th nationally, the crop-specific prioritisation of cotton shows trifluralin to be the number one ranked pesticide in terms of priority (see attached spreadsheet). This is due to its relatively high toxicity and high use in comparison to other pesticides applied to cotton. Inclusion of the mobility category provides and additional level of assessment. Due to its high K_{OC} value, trifluralin is relatively immobile and is therefore unlikely to contaminate resources. Therefore the primary route of exposure is likely to occur during actual application (i.e. via spray drift). In contrast acetochlor, ranked 2nd, is more likely to enter water resources via leaching and or runoff.

1.5.3 Crop Prioritisation (Pesticide Specific)

This worksheet enables users to choose a particular active ingredient of interest and view which crops the pesticide is applied to as well as the *WHP* of that active ingredient for all the crops to which it is applied (i.e. Q_{tot} used to calculate the *WHP* is the total quantity of an active ingredient used on all crops to which it is applied). This enables users to identify high priority crops (based on quantity of use) to which a specific active ingredient is applied. This prioritisation procedure is useful for identifying crop production areas where a specific active ingredient of interest is likely to be applied.

1.5.4 Crop Matrix

The crop prioritisation matrix provides a convenient tool to identify priority pesticides and crops at a national scale. Including information on the percentage quantity of each compound applied per crop provides and additional level of information, which can potentially lead to a more detailed spatial prioritisation of chemicals by linking them to the specific crops they are applied to. Knowledge of the location of production areas of major crops can therefore result in the identification of areas and communities that may be at risk to exposure of priority chemicals. For example, ethylene-dibromide is ranked 4th in terms of its health risk. It is one of the few pesticides that featured in each of the indices calculated during the prioritisation process (Table 1.5). Furthermore it is applied almost exclusively potatoes (Table 1.7). This added crop-specific information thus provides valuable information in terms of identifying communities at risk of exposure to this chemical. Maize is clearly the most important crop with regards to application of high priority chemicals and accounts for a large percentage of the use of important chemicals.

1.6 CONCLUSIONS

The prioritisation approach presented here is simple, yet provides a first level of basic, important information that can be used to develop monitoring programmes, identify priority areas for management interventions and to investigate optimal mitigation strategies. The reliability of sales data as a proxy for pesticide use data has high associated uncertainty but is currently the most effective and widely used means of performing such assessments. An advantage of this methodology is that the final priority list of pesticides presented in this report was defined based on four indices, ensuring that highly toxic and mobile pesticides, as well as high use pesticides are considered. Furthermore, pesticide prioritisation processes generally aggregate estimated risks up to a national level. This is because pesticide data is often only available in terms of the total quantity of a pesticide sold (or used). The advantage of using crop-specific pesticide data allows for a more disaggregated overview of pesticide risks in that specific priority pesticides can be linked to specific crop types and specific crop types can be prioritized based on the profile of pesticide applied to the crops. This allows for a more refined spatial prioritisation of pesticide risks. This information in combination with the maps presented in Chapter 2 of this report therefore provides a valuable resource for planning future risk assessment and monitoring studies.

1.7 RECOMMENDATIONS FOR FUTURE RESEARCH

- This project focussed specifically on risks of agricultural chemicals to human health. Considering the high number of critically endangered endemic fish species as well as the vulnerability of aquatic ecosystems in South Africa, it is recommended that a similar procedure be performed for prioritising risks to aquatic ecosystem health in South Africa.
- Decisions related to monitoring of pesticides in the selected study areas (refer to Volume 1 of this report) benefitted significantly from the pesticide use data, prioritization matrix and pesticide use maps developed in this project. It is recommended that these resources be consulted when undertaking similar studies in the future.

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PART 2: DEVELOPMENT OF AGRICULTURAL PESTICIDE USE MAPS FOR SOUTH AFRICA

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2.1 INTRODUCTION

According to the latest Department of Agriculture, Forestry and Fisheries (DAFF) database, there are a total of 8256 herbicides, insecticides and fungicides registered in South Africa (www.daff.gov.za; accessed October 2012). A review of internet databases (FOOTPRINT, 2010), show that many of the active ingredients of these pesticides are either carcinogenic or classified as EDCs, while for most pesticides these endpoints have yet to be definitively defined. While pesticide monitoring studies are limited in South Africa, there is sufficient information to indicate that many current use pesticides enter surface and groundwater. This is particularly relevant considering the fact that many communities do not have any or reliable access to treated water and often make use of water collected directly from the resource for drinking purposes. Considering the importance of the agricultural sector and the number of active ingredients used in the sector, it is important to identify the source of priority compounds used in South Africa that could potentially result in exposure and associated negative effects on human and animal health.

The chemical prioritisation procedure (Chapter 1) evaluated active ingredients based on their usage, and physicochemical and toxicity properties. In the process high priority pesticides were identified. The pesticide use data specified crop-specific use of different pesticides. By mapping the distribution of different crop types across the country it is therefore possible to spatially map the distribution of the use of high priority chemicals across the country. This can provide a good spatial indication of the potential source areas of pesticides at a national level. As information on the extent of usage of a pesticide is a good indicator of potential contamination of non-target environments, maps of estimated pesticide use in South Africa could provide an essential element in establishing relationships between pesticide use, water quality and potential exposure to users of the water resource. This data, in addition with information on community access to water and/or quality of treated water, can provide valuable information on the likely sources of priority compounds across the country and for prioritizing catchments that should be monitored for targeted pesticide concentrations in water resources.

The aim of this chapter is to identify the potential sources of agricultural chemicals in water resources through the development of maps that provide a spatial assessment of use and likely sources of priority pesticides across the country. In the process of completing this task a large Excel database was produced.

2.2 METHODS

2.2.1 Crop Distribution

Knowledge on the spatial distribution of pesticides use is dependent on the spatial distribution of the crops to which they are applied. The Census of Agriculture Provincial Statistics performed by Statistics South Africa in 2002 (STATSSA, 2002) was used to estimate the spatial distribution of crop production in South Africa. The census collected data on crop area (ha) and production (tonnes) for commercial crops at a magisterial district level which was used to estimate the percentage agricultural area covered by a specific crop type within a magisterial district. This allowed for the production of maps that provide a spatial overview of important areas for the production of a specific crop (Figure 2.1). It is important to note that the magisterial district boundaries in South Africa have changed since 2002. For the purposes of this project the magisterial district boundaries as demarcated in 2002 were used for the spatial mapping of crop coverage and pesticide use. Furthermore, the census provides data only for farmers that responded. Consequently the census underestimates total area and production at a magisterial district and national level, but does provide as accurate an estimate of the relative distribution of crop coverage and production as is possible at this level of spatial detail.

The census data was therefore normalised to take this under-estimation into account, as well as to account for changes in area and production over time so as to provide an estimate of total crop coverage per magisterial district in 2009. The normalization procedure compared total crop coverage estimated by the 2002 STATSSA census data (i.e. the sum of the area of each crop type for all nine provinces) with total crop area statistics collected by the Department of Agriculture and Forestry (DAFF, 2012) and FAO (FAOSTAT, 2012) for 2009. DAFF only publishes crop area for a limited number of crops. Therefore DAFF data was compared to FAO data (which presents data for a larger number of crop types) to determine whether the two sources of data corresponded with one another. As can be seen from Table 2.1 the DAFF data was almost identical to that published by the FAO and consequently the FAO data, with its larger crop coverage data set, was considered reliable for the data normalization procedure. The crop normalization quotient was therefore expressed as the ratio of FAO to STATSSA crop coverage. The crop coverage reported by STATSSA for each magisterial district in South Africa was multiplied by the respective crop normalization quotient to derive a normalized crop coverage for each crop type in each magisterial district. The normalized area of each crop in each magisterial district was expressed as a percentage of the national crop area for the crop (Figure 2.1).

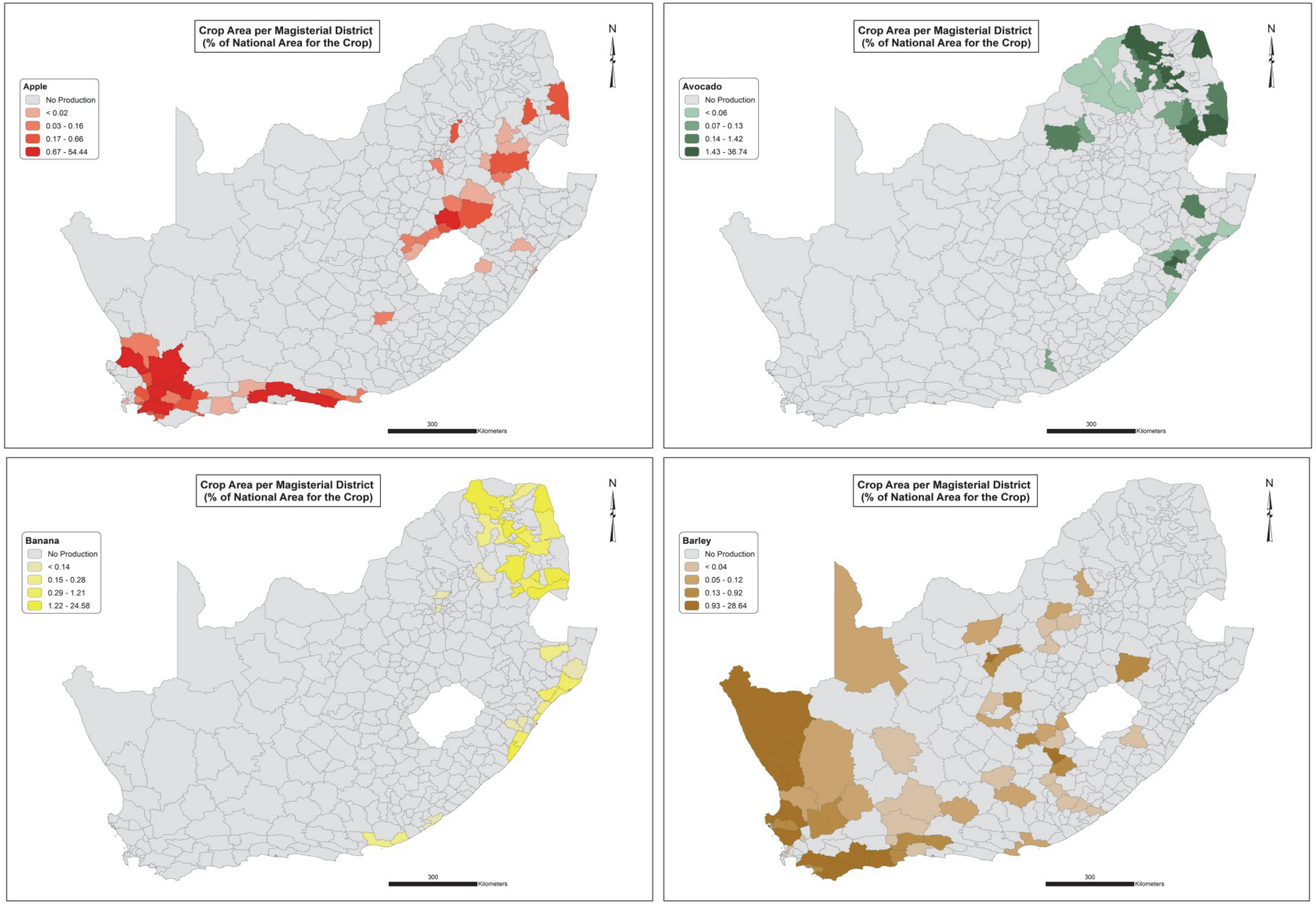

Figure 2.1: Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

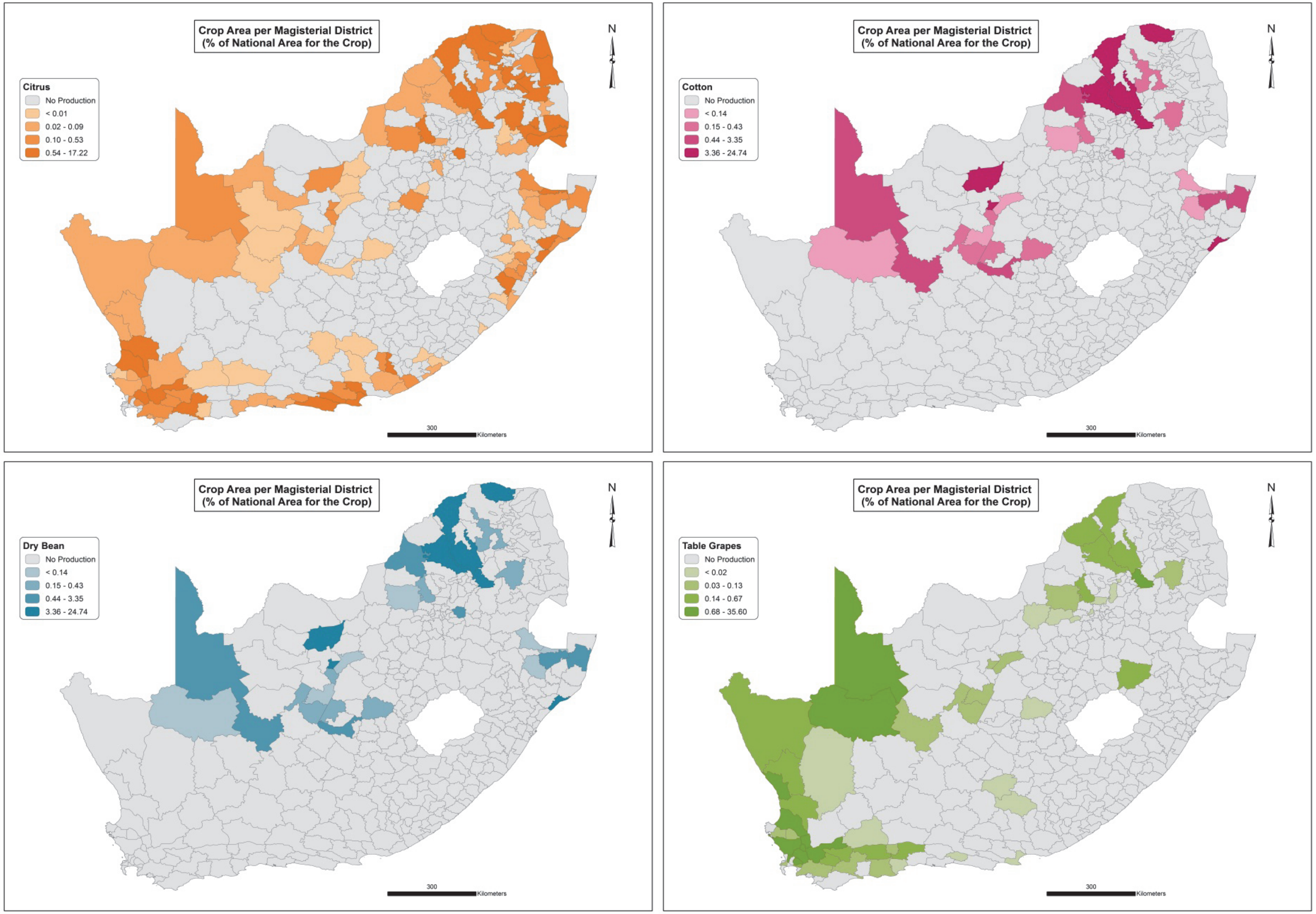

Figure 2.2 (cont): Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

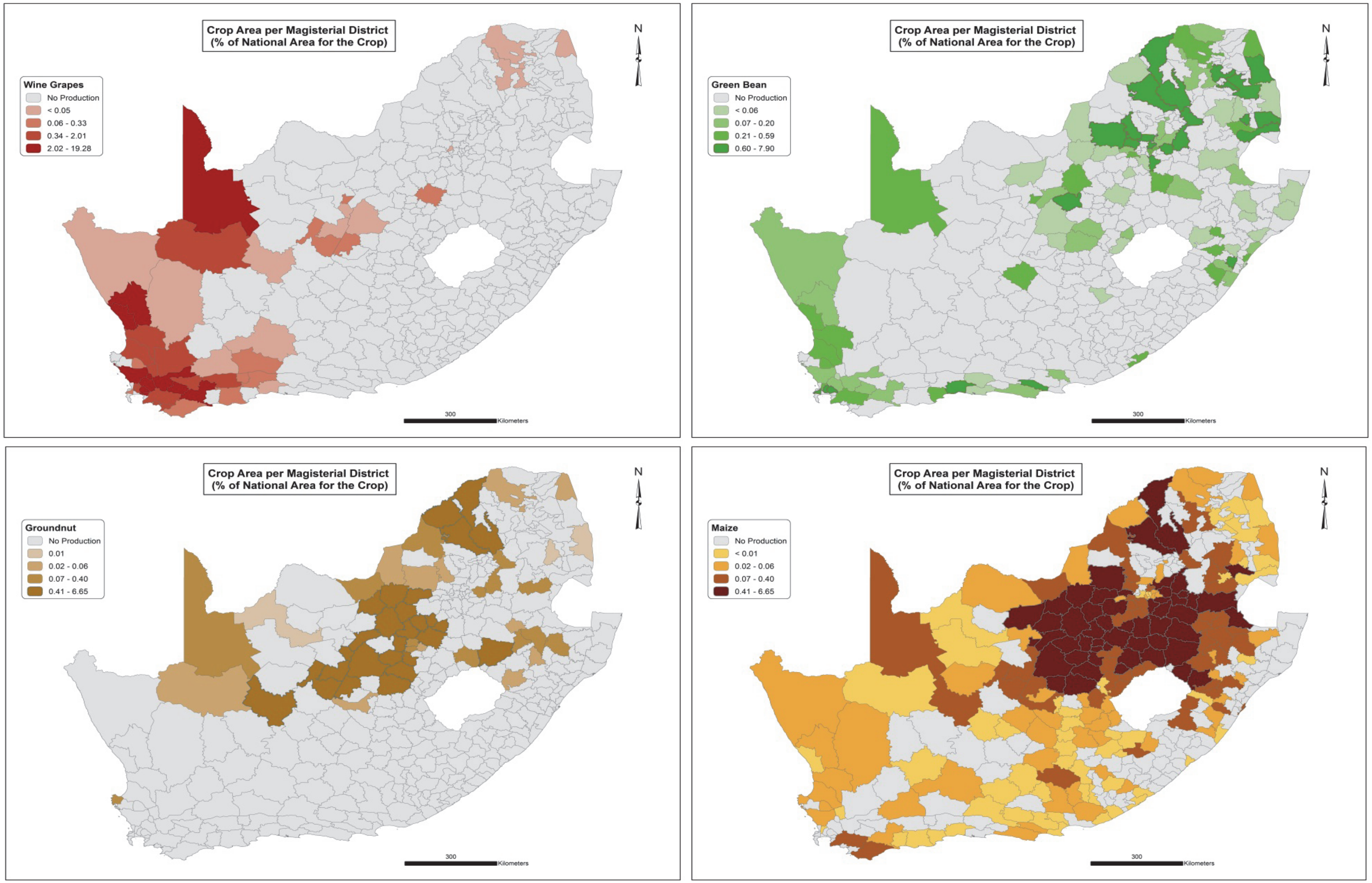

Figure 2.2 (cont): Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

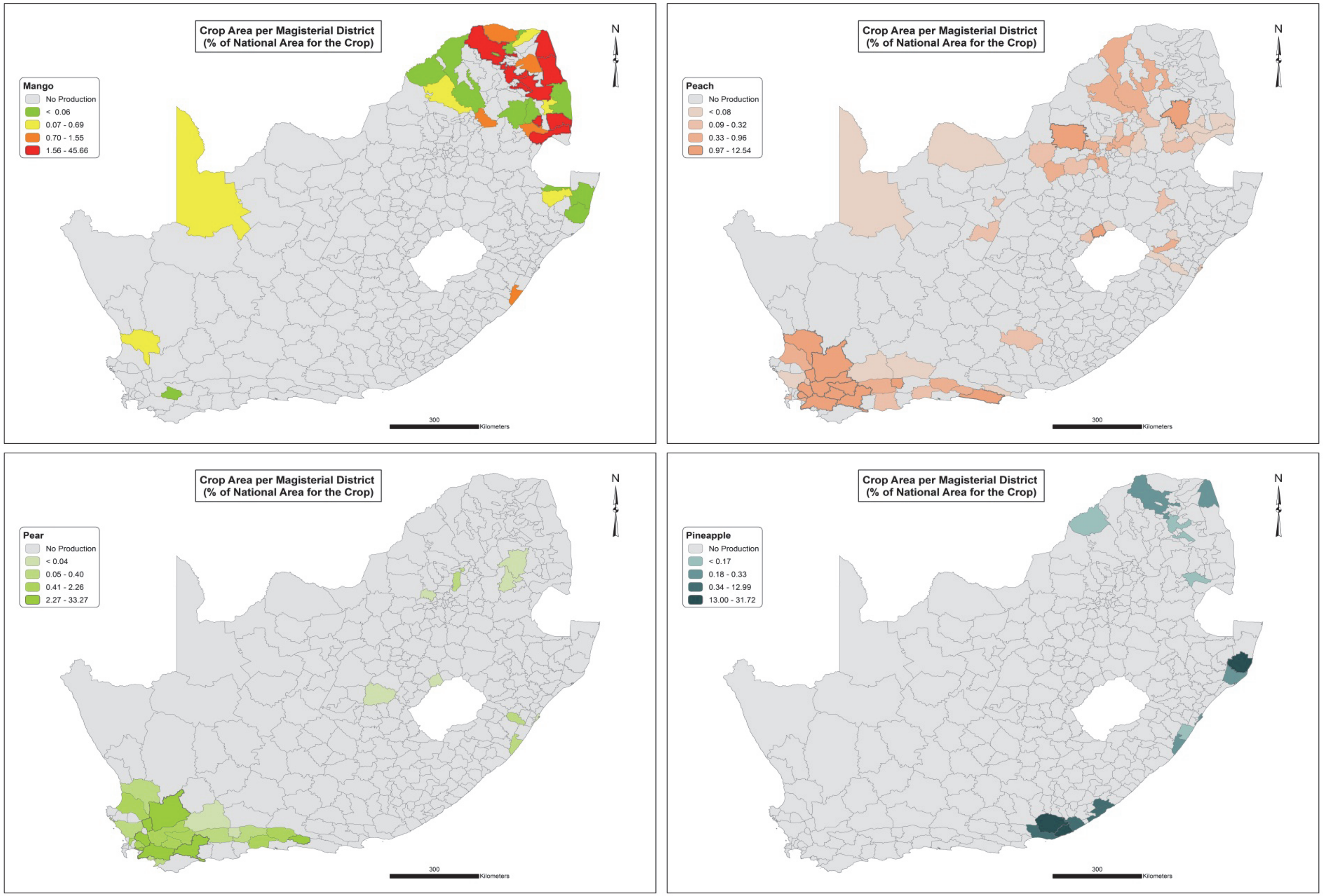

Figure 2.2 (cont): Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

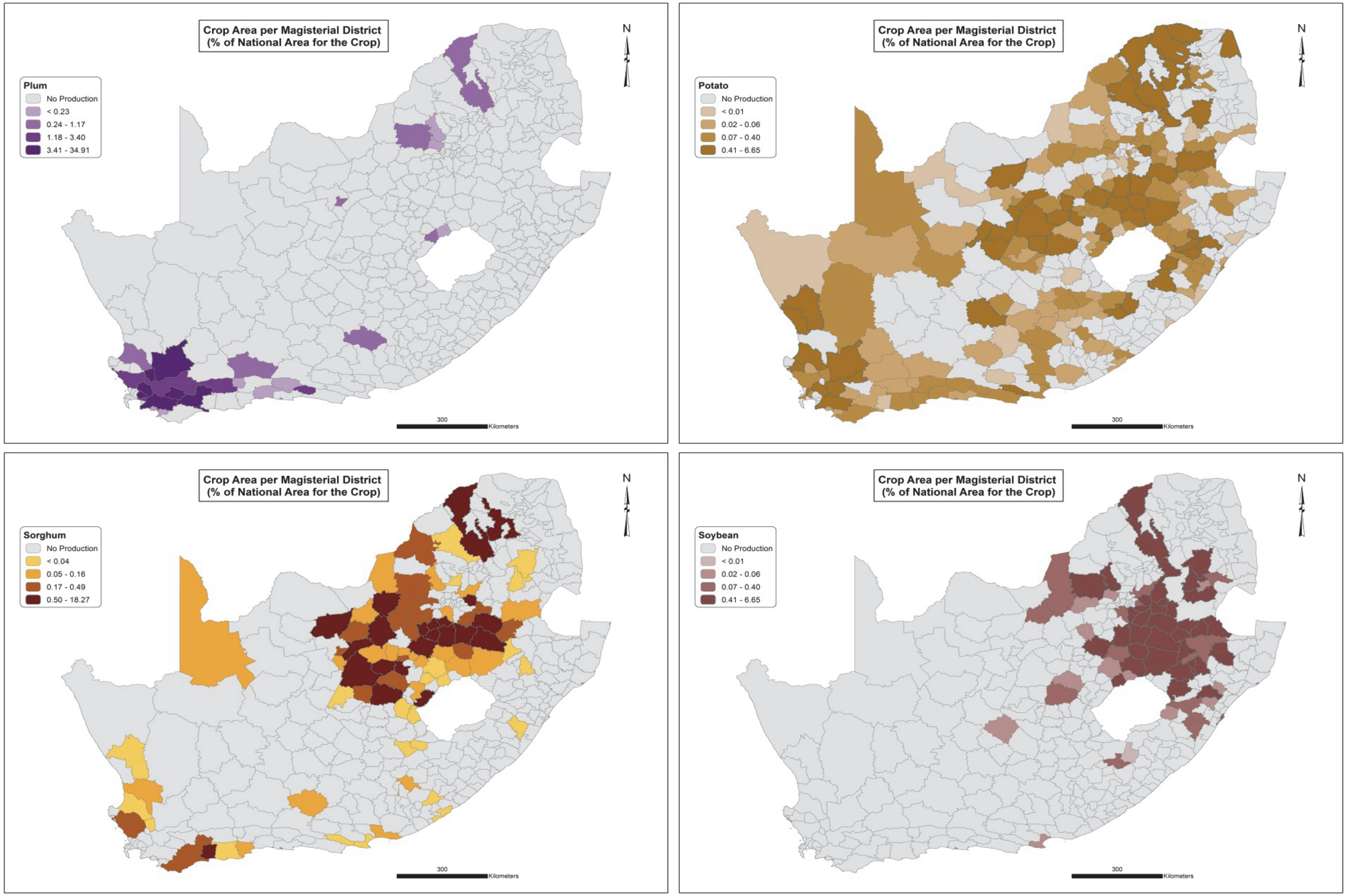

Figure 2.2 (cont): Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

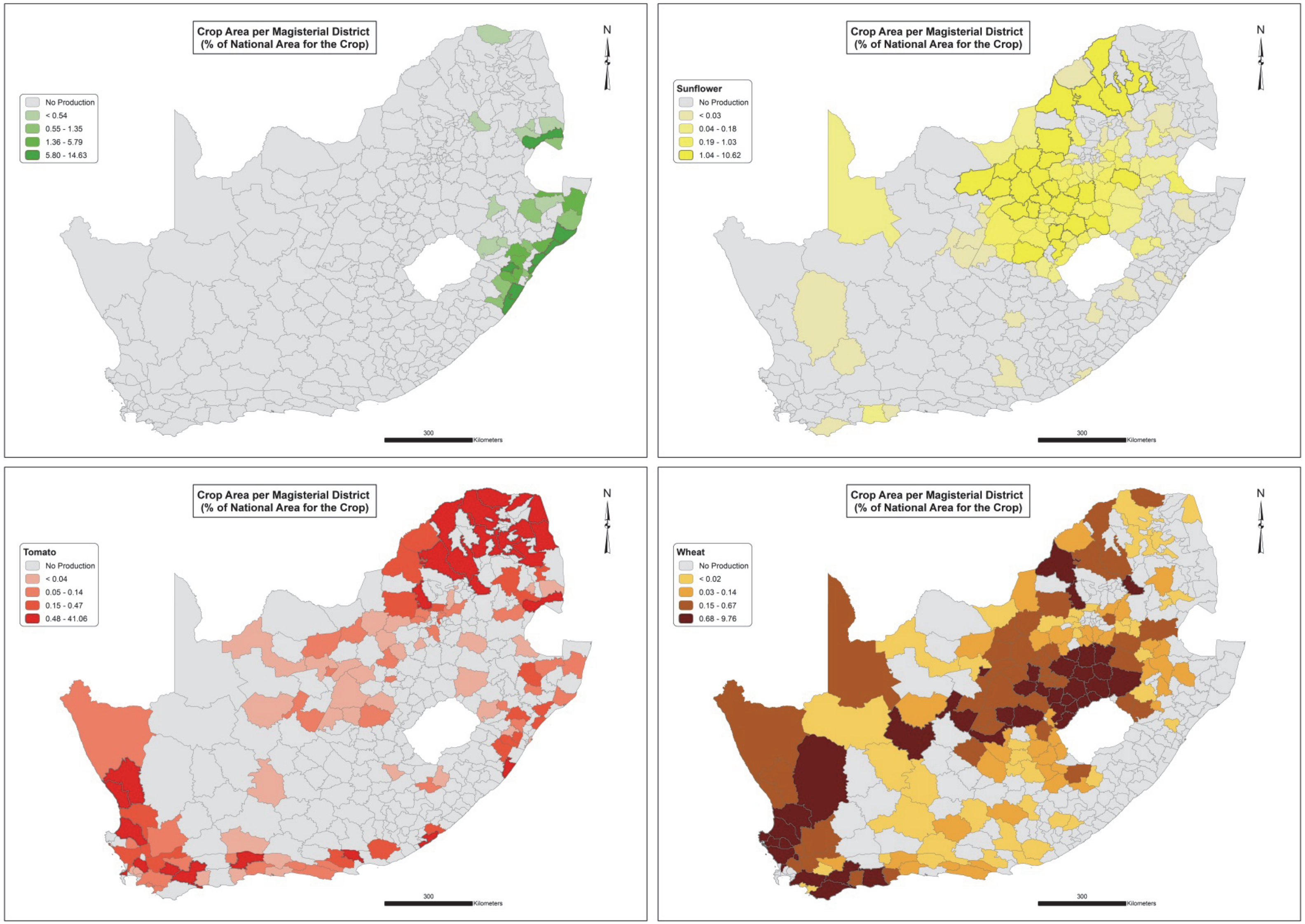

Figure 2.2 (cont): Spatial distribution of important crops produced in South Africa (data derived from StatsSA 2002).

Table 2.1: National crop area statistics reported by STATSSA, the FAO and DAFF. The ratio of FAO to STATSSA statistics was used to normalise crop area data for each magisterial district in South Africa.

Crop	Area (ha)			Ratio
	STATSSA	FAO	DAFF	FAO/STATSSA
Maize	1841887	2427500	2896000	1.32
Wheat	591008	642500	648000	1.09
Sunflower	298548	635800	636000	2.13
Sugar cane	224167	391000	391000	1.74
Lucerne	128640	128640		1.00
Grapes (wine)	65592	89448		1.36
Citrus	64596	69480		1.08
Soybeans	58991	237750	238000	4.03
Sorghum	56487	85500	86000	1.51
Groundnuts	53152	54550	53000	1.03
Barley	45433	74760	75000	1.65
Potatoes	41667	55000		1.32
Dry Beans	35782	43800	44000	1.22
Cotton	22099	11500	7000	0.52
Grapes (table)	18737	25551		1.36
Apples	16685	21000		1.26
Banana	15904	7500		0.47
Peaches	11149	10000		0.90
Pears	9694	10500		1.08
Avocado	9264	14500		1.57
Mangoes	8708	3500		0.40
Tomato	7938	7700		0.97
Pumpkin	7776	7776		1.00
Pineapples	6352	11500		1.81
Onions	6082	20500		3.37
Cabbage	5583	2400		0.43
Carrots	3671	5300		1.44
Green beans	3559	4000		1.12
Plums	2996	6500		2.17
Sweet potato	963	21000		21.81
Green peas	612	5500		8.99

2.2.2 National Pesticide Use Data.

Pesticide use data for South Africa was purchased from GfK Kynetec (http://www.gfk.com/gfk-kynetec/), an international market research company. The company provides quantified data on the use of formulated products country-by-country and crop-by-crop. Data is collected by GfK Kynetec's research associates who adopt a, bottom up (product-led) approach to data collection that relies on individual in-depth interviews with all those involved in the crop protection industry in each country. The approach used for the sigma research programme relies on the detailed knowledge and experience of those involved in the crop protection industry in each country. Through a series of expert interviews, each associate builds a complete and detailed picture of the market and product use in the country being researched, product brand by product brand and crop by crop.

Typically the research associates will complete interviews with:

- Agrochemical manufacturers (at Product Manager level)
- Agrochemical formulators and distributors
- Agrochemical trade associations
- Agrochemical importers
- Extension officers
- Crop advisors
- Government officers
- Crop research stations

The expert interview technique allows constant cross-referencing and confirmation of data. It is a very well established methodology for market quantification and has a number of benefits:

- Comprehensive coverage of all major crops in each market. Whilst interviewing farmers directly may provide a statistically representative sample this is resource intensive and very costly and thus is usually restricted to a small number of crops and in many countries is just not practical nor feasible.
- Successful provision of high quality data on fragmented or unstructured markets such as those in southern Europe and most developing economies.
- Comparable quality with panel surveys at a national level in key developed markets, for example, France and Germany.

Data purchased from GfK Kynetec was for the year 2009 and was the latest data available. Data was provided as the total amount of active ingredient applied to all crops as well as on a crop by crop basis. Crop-specific data was only purchased for major crops grown in the country. Together these crops accounted for approximately 97% of the total agricultural pesticide use for the country.

Table 2.2: Crops for which pesticide use data was included for the production of pesticide use maps in South Africa

Crops	
Apples	Mangoes
Apricots	Other
Avocado	Peaches
Bananas	Pears
Barley	Pineapples
Citrus	Plums
Cotton	Potatoes
Dry Beans	Sorghum
Grapes (table)	Soybeans
Grapes (wine)	Sugar Cane

Crops	
Green Beans	Sunflower
Groundnuts	Tomato
Maize	Wheat

2.2.3 Pesticide Use per Magisterial District

The amount of each pesticide applied to a crop was expressed as a percentage of the total national application. For example approximately 60% of the total national of 2.4-D-amine is applied to maize (Table 2.3). These percentages were used to estimate the percentage of the total amount of each pesticide applied to each crop in each magisterial district *(P%)*:

$$P\%_{x,y,z} = \frac{Area_{y,z}}{100} \times CApp_x$$

where *Area* is the proportion of crop type *(y)* in a magisterial district *(z)* expressed as a percentage of the total national coverage of the crop and *CApp* is the proportion of the pesticide *(x)* applied to the crop, expressed as a percentage of the total application of the pesticide. This assumes that a specific pesticide was applied equally (or at an identical application rate) to a specific crop regardless of the magisterial district the crop was produced in.

Table 2.3: Example of a summary of the application of 2,4-D-amine to crops produced in South Africa

Crop	Pesticide	Application (kg x 10^3)	Application (% of national use)
Maize	2.4-D-amine	211.946	59.7
Sorghum	2.4-D-amine	22.471	6.37
Sugar Cane	2.4-D-amine	10.464	2.97
Wheat	2.4-D-amine	86.400	24.37

The total estimated quantity (*Pq,* in kg) of each applied pesticide *(x)* to each crop type *(y)* in each magisterial district *(z)* was calculated as follows:

$$Pq_{x,y,z} = \frac{P\%_{x,y,z}}{100} \times TApp_x \ ;$$

where *TApp* is the total quantity of pesticide *x* applied to all crops in the country. From this data it was possible to estimate the total quantity (*Ptot*, in kg) of pesticide *(x)* applied within a magisterial district *(z)* regardless of crop type *(y)*:

$$Ptot_{x,z} = \sum_{y=1}^{n} Pq_{x,y}$$

In order to estimate the application rate of a pesticide per magisterial district it was first necessary to calculate the total area (*Atot*) of all crop types *(y)* within each magisterial district *(z)*

$$Atot_z = \sum_{y=1}^{n} Area_{y,z}$$

The estimated pesticide application rate (Pr, in kg/ha) of each pesticide *(x)* in each magisterial district *(z)* could be estimated by:

$$Pr_{x,z} = \frac{Ptot_{x,z}}{Atot_z}$$

2.2.4 Map Displays of Pesticide Use Data

Estimation of the application rate of different pesticides within all magisterial districts in the country enabled the production of maps displaying the estimated distribution of applied pesticides as well as their estimated application rate. The derived pesticide use database containing estimated pesticide application rates of 206 pesticides per magisterial district was imported into ArcGIS as a table and joined to corresponding magisterial districts in a shapefile demarcating their location as they appeared in 2002. This produced a shapefile containing information on the estimated application of pesticides per unit area of all agricultural land per magisterial district and allowed for the production of maps providing a spatial estimation of pesticides use per magisterial district across the country.

Each map displays, in five intervals, the amount of active ingredient applied over a magisterial district. The five class intervals were established independently for each of the compounds for which the magisterial districts had an associated pesticide application data point (greater than zero kilograms applied per hectare). Each class interval represents an equal number of data values from the distribution of the pesticide data, with the first interval representing the 20th percentile, the second representing the 40th percentile the third interval representing the 60th percentile and the 5th interval representing the 80th percentile. The STATSSA census did not provide agricultural statistics for some magisterial districts, particularly those that fall within the former homeland areas, and as such no pesticide use estimates could be calculated for these areas. As part of each map, a table lists, in order of use, the crop treated with the compound, the total amount (in kilograms) of the active ingredient applied to the crop, and the percentage of national use. Because the percentages are rounded, they do not always total 100 per cent. An example of the map produced for atrazine can be viewed in Figure 2.2.

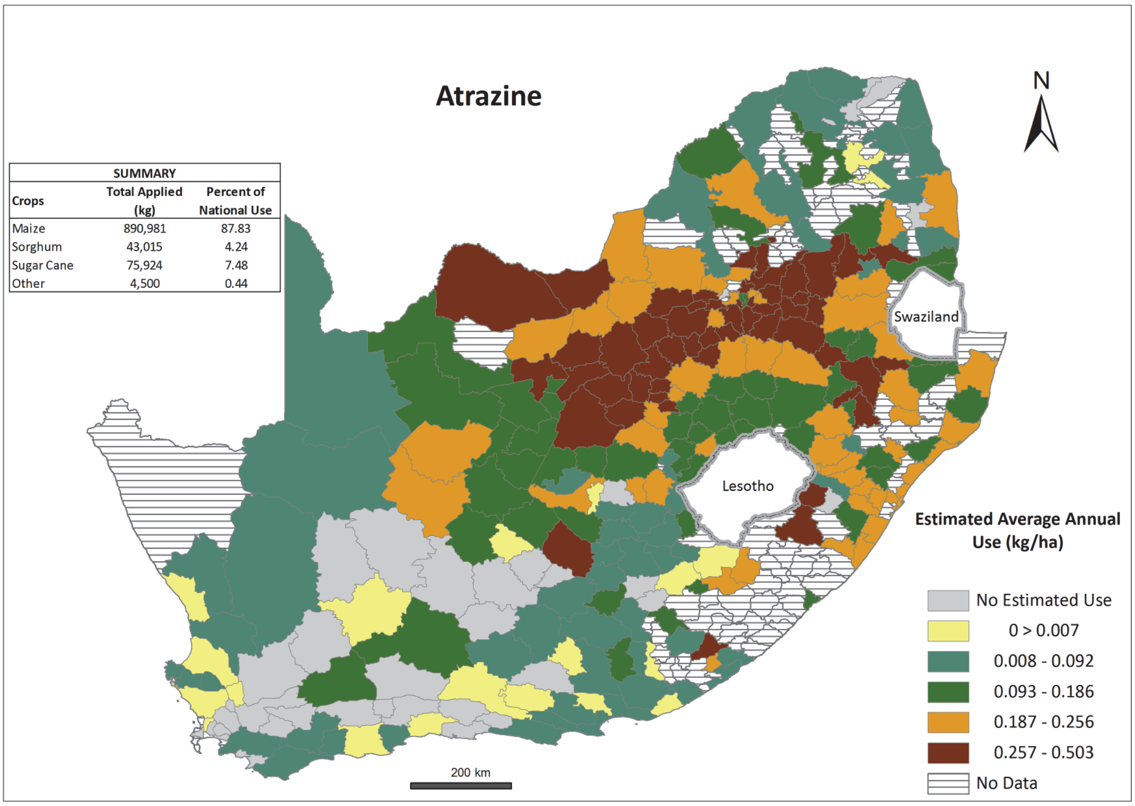

Figure 2.2: Map showing estimated average annual use of atrazine per hectare of agricultural land in magisterial districts of South Africa.

The maps display use of a pesticide as equally distributed across a magisterial district. Display of the pesticide use information was improved by using other ancillary data. For example, using ArcGIS, maps of the distribution of agricultural land cover could be linked to the pesticide use data per magisterial district. The agricultural land cover class category was extracted from the NLC 2009 (SANBI, 2009). This map displays the general distribution of agricultural land across the country. This map was intersected with the shapefile displaying pesticide use per magisterial district so as to create an improved graphical display of the distribution of agricultural land within each magisterial district (Figure 2.3). These maps provide a more detailed estimate of where in each magisterial district pesticides are most likely to be applied. This information is useful in terms of identifying communities or rivers that are most likely to be in close proximity to areas where pesticides are likely to be applied. The boundaries depicting water management areas (WMAs), as well as coverages of major rivers in South Africa were also added (Middleton and Bailey, 2009). This provides an additional level of information in by identifying WMAs and water resources that are most at risk of exposure to pesticides applied in agricultural areas.

Maps for 206 active ingredients used in South African agriculture can be obtained from the CD attached to this report.

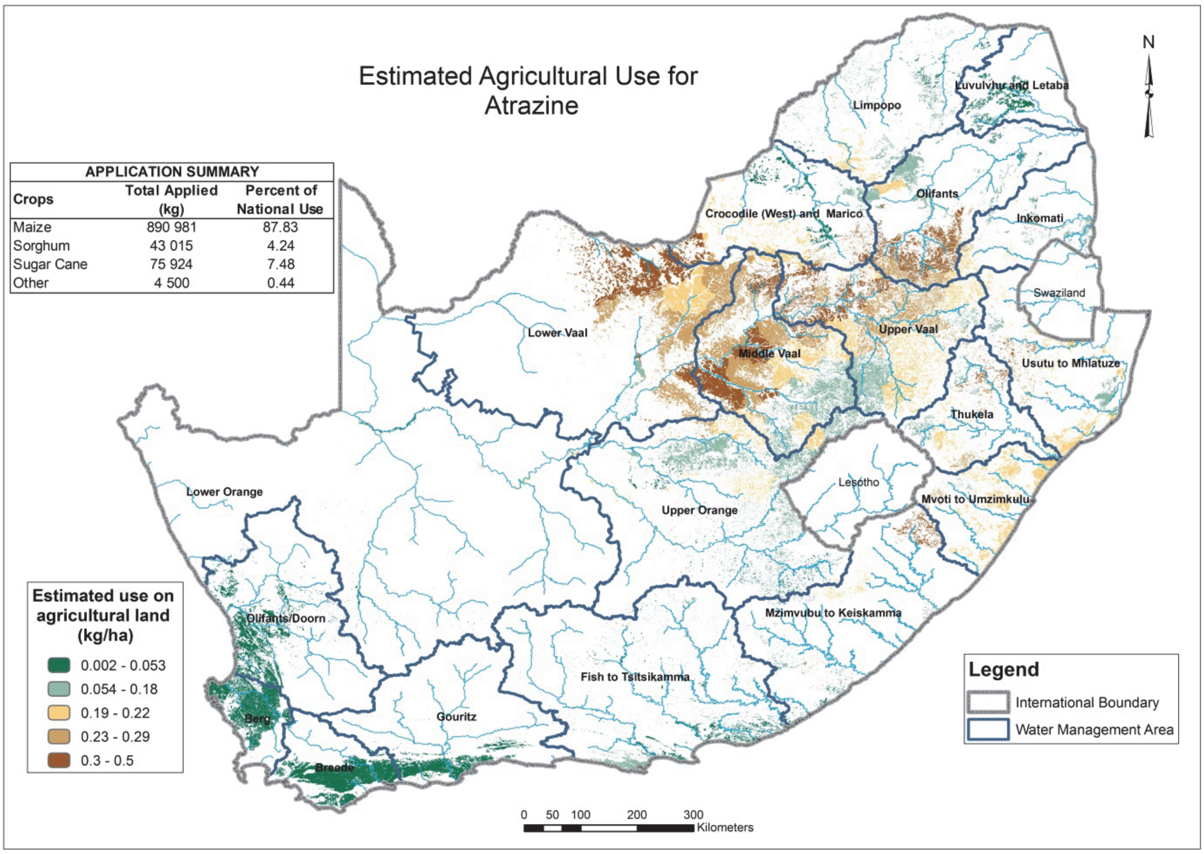

Figure 2.3: Estimated average annual application of atrazine to agricultural land in South Africa.

2.3 APPLICATION OF MAPS

The designed maps are intended to provide a spatial overview of the likely distribution of specific active ingredients based on the distribution of crops throughout the country. These maps are the first of their kind for South Africa and have a number of useful applications. First, for monitoring purposes, the maps can be used to provide an indication of which rivers or WMAs are likely to be exposed to pesticides that may be applied in the area. While a number of geographical and physicochemical factors influence the movement of pesticides into surface waters (Dabrowski *et al.*, 2002), the quantity of pesticides used (and by implication the relative application rate) is an important indicator of the potential movement of a pesticide from an agricultural area into a non-target environment. Considering the large number of active ingredients used in South Africa as well as the expense of monitoring these chemicals, the use of these maps in combination with information from the chemical prioritisation procedure (Chapter 1) provide valuable information in terms of identifying which pesticides should be monitored for and where they should be monitored. This will most likely vary from one WMA to another. The maps therefore provide a good estimate of the likely sources of high priority chemicals at a national scale.

Identification of source areas of priority chemicals provides the first step of information on which to prioritise areas where human and animal exposure to pesticides may be high. By combining the maps with other information such as the location of villages and their access to water, it may be possible to identify communities that may be at risk of pesticide exposure through use of river or groundwater for drinking purposes. Additionally, using the Blue Drop

Report on Drinking Water Quality Performance Management (e.g. DWA, 2010) as a proxy for the anticipated quality of drinking water supply, it may be possible to flag communities at risk of exposure through inadequate treatment of drinking water.

Additionally the maps could be used to provide a more detailed estimate of pesticide mobility at a national scale through integration into basic modelling initiatives. Apart from the quantity of pesticides used, the soil type, topography (i.e. slope) and climatic characteristics (i.e. rainfall patterns) of the catchment play a significant role in influencing the quantity of an applied pesticide that moves from an agricultural area into non-target environments. In this respect, the maps provide very important information not only in terms of estimated application rates but also in terms of identifying where in the country specific pesticides are most likely being applied. Integrating this data together with geographical data of slope, soil and climate in a GIS platform could further refine the estimates of potential sources of pesticides in the country. This applies to both surface runoff and leaching of pesticides into surface- and groundwater, respectively.

Apart from this study, the maps have application in ecological uses as well and could be used to identify the source of specific pesticides that may pose a risk aquatic and terrestrial ecosystems, conservation areas (e.g. through use of NFEPA maps) or species.

2.4 LIMITATIONS OF MAPS

While maps of this nature provide a useful indication of the spatial application of pesticides across the country, it is important to note the limitations of the maps. These limitations are largely associated with the quality of the data used to calculate estimated pesticide use and to a lesser extent the methodology used to calculate pesticide use.

2.4.1 Agricultural Census Data

The distribution of crops across the country formed a critical component of the final pesticide use estimation. This data was obtained from the STATSSA census performed in 2002. While the data provides a good estimate of the relative distribution of crops across magisterial districts in 2002, agricultural patterns may have changed since then and current pesticide use patterns may also have changed as a result.

Additionally, as described in the normalization procedure, not all farmers within a magisterial district may have responded to the census. As a result, total crop area estimates were under-estimated in comparison to national estimates and data had to be normalised accordingly. This normalization procedure applied a normalization factor to each crop type equally across all magisterial districts and therefore increased the crop production area by an equal proportion across all magisterial districts. This procedure may have built inaccuracies into the estimates as the ratio of STATSSA estimates to FAO statistics may vary from one magisterial district to another.

Finally it is important to note that the agricultural census did not collect crop production statistics from magisterial districts in former homeland areas. This is most likely because of the fact that agriculture in these areas is largely restricted to subsistence agriculture and therefore does not form a major role in the country's national food production. However this does not mean that pesticides are not being applied in these areas. Given the subsistence nature of crop production and the relative expense of plant protection products it is assumed that pesticide application in these areas is relatively low.

2.4.2 Pesticide Use Data

Currently there is no publicly accessible source of information on pesticide use in South Africa. Market related sales data thus provides the best available indication of pesticide usage in the country. A major limitation of the data is that the use of different pesticides is aggregated and quantified at a national level. The data therefore does not necessarily reflect an accurate assessment of actual use or regional differences in use of a chemical due to variation in climate (and associated pest problems) or farm management practices. Furthermore farmers may stock up on specific agro-chemical products in anticipation of forecasted weather events or pest outbreaks. These may not materialise and the product may therefore not actually be used. There is thus quite a large amount of uncertainty related to the use of this data and results or outputs should be interpreted accordingly. This is not a problem that is unique to South Africa and more developed countries such as the United States and member states of the EU also make use of sales data as a surrogate for pesticides use data (Thomas, 1999; Thelin and Gianessi, 2000; Grube *et al.,* 2011).

2.4.3 Methodology

The methodology assumes that the total quantity of pesticide applied to a specific crop is evenly distributed across the whole country. The estimates therefore do not take the local variability in pesticide application and management practices found within a magisterial district or across a regional landscape. It is important to note that the relative quantity of a pesticide applied to a crop was expressed as the total application of the pesticide to a specific crop (kg) type per unit area of **all agricultural land** within a magisterial district. The main variable in differentiating pesticide use between magisterial districts is therefore the percentage composition of all agricultural land in a magisterial district by the specific crop to which the pesticide is applied.

2.4.4 Integration with Land Cover Maps

It is important to note that the agricultural land area displayed in the maps does not correspond with the area used in the estimation of the calculation of pesticide use statistics. The agricultural land cover is used for display purposes and calculations of total pesticide use based on area calculations using the land cover map will not necessarily correspond with those derived from the excel database.

Due to the fact that the agricultural land cover does not discriminate between different crop types, pesticide use was aggregated up to a magisterial district level and assumed to be distributed across all agricultural land within a magisterial district. All agricultural land cover that fell within a magisterial district was therefore assigned a pesticide use category for the pesticide in question (Figure 2.3). In reality a section of agricultural land may not necessarily have an application of the pesticide if that specific land cover area is not covered by a crop to which the pesticide is applied. The land cover maps should therefore be used as a guide to indicate where agricultural land is located and the likelihood of application as represented by the application categories.

2.5 RECOMMENDATIONS

Despite the limitations listed above, the data used in this project data represents the best information currently available and therefore provides the best possible estimate of crop distribution and pesticide use in the country at present. Furthermore the limitations discussed here are not unique to South Africa.

Maps of pesticide use could however be improved through an updated census of crop production statistics in magisterial districts of South Africa. It is further recommended that pesticide use maps are regularly updated and disseminated when new data (e.g. pesticide use and crop census) becomes available, thus ensuring the availability of up to date information for use in design of monitoring programmes and risk assessment studies in South Africa. It should be noted that pesticide use, while an important input in exposure assessment in risk assessment, is not the sole indicator of exposure. Pesticide physicochemical properties and geographical (e.g. slope, soil type, hydrological network) and weather (e.g. rainfall) data also significantly influence the behaviour and movement of pesticides in the environment. The pesticide use maps produced in this project, together with other relevant data sources (which are readily available in South Africa, e.g. WR2005) therefore provide an ideal opportunity to perform spatially explicit risk assessments of pesticide use in the country, allowing for the identification of hotspot aquatic environments or human communities at greatest risk of exposure.

Given the limitations of the data used to derive the maps, the following disclaimer is recommended to precede the use of pesticide use maps developed in this project:

DISCLAIMER

The pesticide use maps developed in this project show the average annual pesticide use intensity expressed as average weight (kilograms) of a pesticide applied to each hectare of agricultural land in a magisterial district. Use estimates are based on 1) the spatial distribution of crops at a magisterial district level as reported by STATSSA in the Census of Agricultural Provincial Statistics (2002), and 2) national estimates of pesticide use rates for individual crops as compiled by the market research company GfK Kynetec. The area of mapped agricultural land for each magisterial district was obtained from the 2009 National Land Cover (NLC 2009) produced by the South African National Biodiversity Institute (SANBI).

The key limitations of the data used to produce these maps include the following:

1. The magisterial district coverage is based on the 2002 Census of Agricultural Provincial Statistics and did not represent all total coverage as accurate statistics were dependent

on farmers that responded to the census. Data was therefore normalised to reflect actual crop coverage as reported by the FAO (i.e. the area of each crop type in a magisterial district was multiplied by the ratio of total national area reported by STATSSA to total national area reported by the FAO);

2. The methodology assumes that a specific pesticide was evenly distributed to a specific crop regardless of the magisterial district the crop was produced in. Pesticide use data as displayed in the maps may therefore not reflect the local variability of pesticide management practices found within a magisterial district;
3. Due to the fact that the agricultural land cover does not discriminate between different crop types, pesticide use was aggregated up to a magisterial district level and assumed to be distributed across all agricultural land within a magisterial district. All agricultural land cover that fell within a magisterial district was therefore assigned a pesticide use category for the pesticide in question;
4. Crop production statistics may not have been available for all magisterial districts where a pesticide may have been applied to agricultural land, and therefore, are not displayed on the maps;
5. Pesticide use estimates are based on market research data for the year 2009;
6. Agricultural land cover used to display pesticide use rates is for the purpose of providing an indication of the spatial distribution of pesticide application and is not representative of actual agricultural land area used in the calculation of pesticide use rates.

The maps provide a relative indication of likely pesticide application at the national scale. Please refer to Identifying and Assessing the Source Agricultural Chemicals in South African Water Resources for a detailed discussion of how the pesticide use data were developed.

2.6 SOFTWARE

All pesticide use data and maps have been included on a CD attached to this report. The following data can be accessed through an Excel application (MAPestSA.xls):

- Maps of estimated use (kg/ha) of 206 active ingredients in South Africa (access to the maps is dependent on the installation of ArcReader.
- Maps of crop area per magisterial district (displayed as a percentage of the national area covered by the crop).
- Summaries of active ingredient application (as kg and as a percentage) per crop (users can identify active ingredients applied to a crop by selecting a crop or alternatively the crops to which an active ingredient is applied can be identified by selecting an active ingredient of interest).
- Raw pesticide use data supplied by GfK Kynetec
- Estimated application (kg) of 206 active ingredients per Magisterial District.
- Estimated application rate (kg/ha) of 206 active ingredients per Magisterial District.
- Estimated application (kg) of 206 active ingredients per Province.
- Estimated national application (kg and kg/ha) of 206 active ingredients.

2.6.1 Installation Requirements

The spreadsheet can be accessed directly from the CD or alternatively copy the entire folder (including all of its contents) to a suitable location on your hard drive and open the Excel application from this location.

The maps require ArcReader to be installed. This programme has been included on the attached CD. To install: copy the ArcReader101Windows.zip to a suitable location on your hard-drive, unzip the file, then double-click the Setup (.exe) application file to start the install process.

ArcReader can also be obtained free of charge at the following website:

http://www.esri.com/software/arcgis/arcreader (please note that users will have to register an account with Esri in order to download the software).

2.6.2 Metadata

The shapefiles created to produce the maps are available on the attached CD:

PestAppRate_2009.shp: Shapefile containing data on estimated application rate (kg/ha) of 206 active ingredients applied in South African agriculture (displayed as application on agricultural land cover per magisterial district in South Africa).

PestUse_2009.shp: Shapefile containing data on estimated application (kg) of 206 active ingredients applied in South African agriculture (displayed as application per magisterial district in South Africa).

2.7 REFERENCES

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APPENDICES

APPENDIX 1:

PESTICIDE USE, HUMAN HEALTH AND PHYSICOCHEMICAL DATA

All data collected and produced during the course of this project is available from the CSIR, Natural Resource and Environment (Building 33, Meiring Naude Rd., Brummeria, Pretoria. 0001. Tel: (012) 841 4783; Email: jdabrowski@csir.co.za)

Table A1: National pesticide use data for South Africa for the year 2009 (Data Source: Gfk Kynetec: www.gfk.com/gfk-kynetec)

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
2.4-D	11.67	0.90	10.5
2.4-D-amine	741.02	0.48	355.102
2.4-DB	0.43	0.80	0.346
2.4-D-ester	47.29	0.52	24.375
2.4-DP	31.38	0.04	1.19
Abamectin	1368.35	0.00	3.383
Acephate	16.02	0.54	8.65
Acetamiprid	16.43	0.23	3.697
Acetochlor	524.67	1.25	656.545
Acrinathrin	1.5	0.06	0.09
Alachlor	188.4	1.52	287.044
Aldicarb	51.33	2.05	105
Alphacypermethrin	711.59	0.01	6.922
Al-phosphide	0.21	5.57	1.169
Ametryn	65.06	1.23	79.81
Atrazine	1026.93	0.99	1014.42
Azinphos-m	126.99	0.44	55.365
Azoxystrobin	160.89	0.08	13.425
Benfuracarb	8.24	0.20	1.644
Benomyl	72.42	0.42	30.547
Bentazone	38.15	1.20	45.84
Betacyfluthrin	73.82	0.01	1.078
Betacypermethrin	74	0.01	0.74
Bifenthrin	7.58	0.02	0.15
Bitertanol	2.41	0.16	0.39
Boscalid	91.41	0.09	7.984
Bromacil	3.73	2.57	9.6
Bromoxynil	214.26	0.31	66.48

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
Bupirimate	6.84	0.28	1.906
Buprofezin	3.63	0.73	2.65
Captan	16.48	1.50	24.648
Carbaryl	25.99	0.57	14.758
Carbendazim	143.53	0.11	15.114
Carbofuran	19.53	1.71	33.444
Carbosulfan	0.08	7.53	0.602
Cartap	37.04	0.50	18.48
Chlorantraniliprole	9.07	0.02	0.153
Chlorfenapyr	6.67	0.76	5.04
Chloridazon	1.56	1.63	2.535
Chlorimuron-e	87.4	0.01	0.905
Chlormequat-chloride	7	1.58	11.025
Chlorothalonil	152.06	0.92	140.007
Chlorpyrifos	165.38	0.29	48.102
Chlorpyrifos-e	206.28	0.49	100.368
Clodinafop	61	0.05	2.928
Copper	67.44	0.79	53.116
Copper-carbonate	39.93	3.72	148.725
Copper-hydroxide	194.18	0.91	177.561
Copper-oxychloride	261.57	4.69	1225.806
Copper-sulphate	29.27	1.65	48.433
Cyanamide	41.98	4.84	203.252
Cycloxydim	46.4	0.10	4.64
Cydia pomonella GV	1.4	2.64	3.697
Cymoxanil	76.61	0.12	9.094
Cypermethrin	2365.89	0.02	58.468
Cyproconazole	107.11	0.04	3.92
Deltamethrin	257.81	0.01	3.822
Demeton-S-m	7.78	0.19	1.493
Diazinon	1.01	0.83	0.837
Dicamba	0.67	0.16	0.107
Dichlorvos(DDVP)	10.63	0.53	5.673
Difenoconazole	38.8	0.06	2.363
Dimethenamid-P	84.67	0.54	45.72
Dimethoate	117.93	0.30	35.38
Dimethomorph	36.98	0.18	6.656
Dinocap	3.27	0.29	0.942
Diquat	67.82	0.21	14
Dithianon	24.31	0.15	3.647
Diuron	43.37	2.21	96
Emamectin	42.59	0.01	0.27

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
Endosulfan	32.88	0.38	12.37
Epoxiconazole	230.51	0.08	18.864
EPTC	73.27	2.44	178.43
Esfenvalerate	14.01	0.01	0.21
Ethephon	60.56	0.68	40.915
Ethoprophos	0.09	4.89	0.44
Ethylene-dibromide	6.97	36.22	252.486
Famoxadone	28.75	0.12	3.358
Fenamiphos	58.82	1.77	103.88
Fenarimol	39	0.05	1.872
Fenbuconazole	3.3	0.10	0.33
Fenbutatin-oxide	29.5	0.12	3.448
Fenoxaprop-P-e	9.63	0.10	0.924
Fenoxycarb	33.33	0.04	1.25
Fenpyroximate	44.32	0.19	8.25
Fenthion	2.19	0.78	1.7
Fipronil	59.27	0.03	1.677
Fluazifop-P-b	17.85	0.33	5.928
Fludioxonil	1400	0.00	0.875
Flufenoxuron	2.3	0.30	0.69
Flumetsulam	41.68	0.02	1
Flurochloridone	1.18	0.80	0.94
Flusilazole	58.33	0.10	6
Flusulfamide	0.5	0.22	0.11
Folpet	59.96	0.11	6.74
Fosetyl-Al	15.2	2.03	30.924
Fosthiazate	15.93	3.28	52.2
Gamma-cyhalothrin	186.06	0.00	0.438
Gibberellic-acid	48.47	0.04	1.723
Glufosinate-ammonium	6.54	1.50	9.8
Glyphosate	3796.57	0.98	3720.799
Glyphosate-trimesium	47.97	1.66	79.85
Guazatine	3.26	0.80	2.604
Halosulfuron-m	6.5	0.08	0.488
Haloxyfop-r-m	31	0.16	5.022
Hexaconazole	20.63	0.02	0.319
Hexazinone	32.31	2.62	84.607
Imazalil	2.44	0.78	1.908
Imazamox	41.17	0.27	11.044
Imazapyr	19.5	0.02	0.293
Imazethapyr	167.17	0.05	7.7
Imidacloprid	849.95	0.30	252.167

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
Indoxacarb	34.63	0.06	1.95
Iodosulfuron-methyl-sodium	63	0.01	0.63
Ioxynil	12.95	0.20	2.55
Iprodione	17.92	0.71	12.635
Iprovalicarb	76.8	0.02	1.344
Isoxadifen-e	35.83	0.03	0.903
Kresoxim-m	52.39	0.10	5.293
Lambda-cyhalothrin	2807.04	0.00	12.637
Linuron	0.44	1.25	0.55
Lufenuron	22.46	0.03	0.656
Malathion	1.7	1.59	2.707
Mancozeb	1249.31	2.28	2849.02
Maneb	83.09	0.65	53.878
MCPA	350.25	0.81	284.6
Mefenpyr-diethyl	63	0.03	1.89
Mepiquat-chloride	20	0.01	0.25
Mesotrione	1117.12	0.08	92.446
Metalaxyl	30.01	0.16	4.911
Metalaxyl-M	1683.71	0.01	14.156
Metaldehyde	13.1	0.67	8.743
Metazachlor	8.64	0.62	5.39
Methamidophos	84.86	0.32	27.166
Methidathion	7.48	1.16	8.644
Methiocarb	7.66	0.21	1.606
Methomyl	69.24	0.44	30.38
Metiram	15.83	1.38	21.81
Metolachlor	418.7	1.06	443.707
Metrafenone	15.2	0.13	1.9
Metribuzin	80.67	1.31	106.08
Metsulfuron-m	136.67	0.01	0.758
Mevinphos	0.34	0.06	0.02
Mineral-oil	17.87	47.78	853.755
MSMA	111.24	2.20	245.108
Nicosulfuron	154.5	0.05	6.953
Omethoate	100	0.06	6.4
Oxadiazon	1.98	1.30	2.575
Oxamyl	49.25	0.86	42.246
Paraquat	653.98	0.53	345.127
Parathion-e	49.33	0.32	16
Parathion-m	12.41	0.56	6.982
Penconazole	21.91	0.02	0.4
Pencycuron	0.29	2.48	0.718

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
Pendimethalin	14	1.05	14.648
Petroleum-oil	178.51	20.09	3586.666
Pirimicarb	11	0.50	5.5
Potassium-phosphite	87.76	2.69	236.154
Prochloraz	0.32	0.50	0.16
Procymidone	1.23	0.25	0.302
Profenofos	75.82	0.42	32.1
Prohexadione-Ca	1.9	0.20	0.38
Propamocarb-HCl	0.49	8.80	4.313
Propaquizafop	37.18	0.07	2.788
Propargite	0.28	0.59	0.166
Propiconazole	346.64	0.11	36.44
Propineb	128.05	0.64	81.624
Propoxur	0.75	0.40	0.3
Propyzamide	1.07	0.56	0.6
Prothioconazole	197.73	0.01	2.3
Pymetrozine	9.25	0.11	1
Pyraclostrobin	276.97	0.07	19.018
Pyrimethanil	18.07	0.29	5.206
Pyriproxifen	24	0.15	3.6
Quaternary-Ammonium-salts	13	0.13	1.639
Quinalphos	8.78	0.04	0.329
Quinoxyfen	20	0.06	1.25
Rimsulfuron	6	0.03	0.15
Simazine	98.88	0.84	83.253
s-metolachlor	134.52	0.84	113.317
Spinosad	3.33	0.07	0.24
Spirodiclofen	40	0.01	0.48
Spiroxamine	68.89	0.22	15.5
Sulcotrione	67.44	0.31	21.075
Sulfosulfuron	65	0.02	0.975
Sulphur	555.46	4.21	2337.28
Tartar-emetic	3.2	4.78	15.28
Tau-fluvalinate	15.33	0.22	3.312
Tebuconazole	461.44	0.07	32.735
Tembotrione	35.83	0.05	1.806
Tepraloxydim	44	0.05	2.2
Terbufos	81.56	1.41	114.75
Terbuthylazine	775.41	0.87	674.413
Tetradifon	29.88	0.23	6.752
Thiabendazole	93.75	0.04	3.75
Thiacloprid	28	0.07	2.016

Active Ingredient	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (x 10^3 kg or L)
Thiamethoxam	496.54	0.05	22.8
Thifensulfuron-m	20	0.00	0.042
Thiodicarb	26.25	0.16	4.1
Thiophanate	0.36	5.07	1.824
Thiram	25.4	1.83	46.566
Tralomethrin	10	0.01	0.108
Triadimefon	12.73	0.13	1.684
Triadimenol	51.95	0.02	1.213
Triasulfuron	53.33	0.01	0.6
Tribenuron-m	116.67	0.01	1.313
Trichlorfon	46	0.10	4.37
Trifloxystrobin	50.66	0.08	3.8
Triflumuron	2.63	0.38	1.008
Trifluralin	253.89	0.63	160.416
Triticonazole	22.65	0.06	1.3
Uniconazole-P	0.09	1.50	0.135
Zineb	2.81	1.72	4.844
Trifluralin	253.89	0.63	160.416
Triticonazole	22.65	0.06	1.3
Uniconazole-P	0.09	1.50	0.135
Zineb	2.81	1.72	4.844

Table A2: Summary of active ingredient use for agricultural crops in South Africa for the year 2009 (Data Source: GfK Kynetec: www.gfk.com/gfk-kynetec)

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Bananas	Bananas	Insecticides	Carbaryl	13.00	4.90	0.93	0.400	0.370
Bananas	Bananas	Insecticides	Chlorpyrifos-e	13.00	4.90	6.67	0.360	2.400
Bananas	Bananas	Insecticides	Fenamiphos	13.00	4.90	0.32	7.188	2.300
Bananas	Bananas	Insecticides	Metaldehyde	13.00	4.90	1.13	0.529	0.595
Bananas	Bananas	Insecticides	Methiocarb	13.00	4.90	0.20	0.100	0.020
Bananas	Bananas	Insecticides	Oxamyl	13.00	4.90	0.13	0.600	0.075
Bananas	Bananas	Fungicides	Mancozeb	13.00	3.04	2.80	1.875	5.250
Bananas	Bananas	Fungicides	Petroleum-oil	13.00	3.04	2.40	4.130	9.912
Bananas	Bananas	Fungicides	Prochloraz	13.00	3.04	0.07	0.675	0.048
Bananas	Bananas	Fungicides	Triadimefon	13.00	3.04	0.40	0.038	0.015
Bananas	Bananas	Herbicides	Fluazifop-P-b	13.00	11.00	0.15	0.300	0.045
Bananas	Bananas	Herbicides	Glyphosate	13.00	11.00	13.17	1.135	14.940
Bananas	Bananas	Herbicides	Glyphosate-trimesium	13.00	11.00	0.08	1.250	0.100
Bananas	Bananas	Herbicides	Paraquat	13.00	11.00	12.50	0.400	5.000
Cereals	Barley	Insecticides	Dimethoate	68.00	10.34	10.34	0.300	3.102
Cereals	Barley	Fungicides	Carbendazim	68.00	68.00	57.94	0.093	5.392
Cereals	Barley	Fungicides	Cyproconazole	68.00	68.00	33.33	0.036	1.200
Cereals	Barley	Fungicides	Epoxiconazole	68.00	68.00	62.31	0.092	5.744
Cereals	Barley	Fungicides	Propiconazole	68.00	68.00	85.24	0.120	10.238
Cereals	Barley	Fungicides	Pyraclostrobin	68.00	68.00	13.00	0.063	0.813
Cereals	Barley	Fungicides	Tebuconazole	68.00	68.00	76.00	0.118	9.002
Cereals	Barley	Fungicides	Triadimefon	68.00	68.00	1.22	0.125	0.153
Cereals	Barley	Herbicides	Bromoxynil	68.00	68.00	40.00	0.338	13.500

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Cereals	Barley	Herbicides	Diquat	68.00	68.00	2.00	0.120	0.240
Cereals	Barley	Herbicides	Glyphosate	68.00	68.00	26.09	0.552	14.400
Cereals	Barley	Herbicides	Iodosulfuron-methyl-sodium	68.00	68.00	3.50	0.010	0.035
Cereals	Barley	Herbicides	MCPA	68.00	68.00	129.17	0.480	62.000
Cereals	Barley	Herbicides	Mefenpyr-diethyl	68.00	68.00	3.50	0.030	0.105
Cereals	Barley	Herbicides	Metsulfuron-m	68.00	68.00	66.67	0.003	0.200
Cereals	Barley	Herbicides	Paraquat	68.00	68.00	13.33	0.282	3.760
Cereals	Barley	Herbicides	Tribenuron-m	68.00	68.00	66.67	0.011	0.750
Cereals	Barley	Herbicides	Trifluralin	68.00	68.00	23.33	0.720	16.800
Cereals	Barley	Seed dressing	Prothioconazole	68.00	68.00	72.73	0.011	0.800
Cereals	Barley	Seed dressing	Tebuconazole	68.00	68.00	62.34	0.003	0.180
Cereals	Barley	Seed dressing	Triadimenol	68.00	68.00	12.12	0.025	0.300
Cereals	Barley	Seed dressing	Triticonazole	68.00	68.00	11.82	0.055	0.650
Cereals	Wheat-winter	Insecticides	Betacyfluthrin	748.00	485.00	2.33	0.015	0.035
Cereals	Wheat-winter	Insecticides	Chlorpyrifos	748.00	485.00	15.40	0.240	3.696
Cereals	Wheat-winter	Insecticides	Chlorpyrifos-e	748.00	485.00	50.67	0.360	18.240
Cereals	Wheat-winter	Insecticides	Cypermethrin	748.00	485.00	53.63	0.016	0.858
Cereals	Wheat-winter	Insecticides	Deltamethrin	748.00	485.00	1.60	0.025	0.040
Cereals	Wheat-winter	Insecticides	Demeton-S-m	748.00	485.00	7.78	0.192	1.493
Cereals	Wheat-winter	Insecticides	Dimethoate	748.00	485.00	107.59	0.300	32.278
Cereals	Wheat-winter	Insecticides	Lambda-cyhalothrin	748.00	485.00	81.61	0.025	2.040
Cereals	Wheat-winter	Insecticides	Methomyl	748.00	485.00	18.40	0.450	8.278
Cereals	Wheat-winter	Insecticides	Mevinphos	748.00	485.00	0.33	0.030	0.010
Cereals	Wheat-winter	Insecticides	Omethoate	748.00	485.00	100.00	0.064	6.400

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Cereals	Wheat-winter	Insecticides	Parathion-e	748.00	485.00	46.77	0.325	15.200
Cereals	Wheat-winter	Fungicides	Carbendazim	748.00	267.70	72.83	0.107	7.786
Cereals	Wheat-winter	Fungicides	Cyproconazole	748.00	267.70	57.78	0.036	2.080
Cereals	Wheat-winter	Fungicides	Epoxiconazole	748.00	267.70	40.83	0.113	4.594
Cereals	Wheat-winter	Fungicides	Fenbuconazole	748.00	267.70	3.30	0.100	0.330
Cereals	Wheat-winter	Fungicides	Flusilazole	748.00	267.70	30.00	0.100	3.000
Cereals	Wheat-winter	Fungicides	Hexaconazole	748.00	267.70	7.23	0.020	0.145
Cereals	Wheat-winter	Fungicides	Propiconazole	748.00	267.70	185.80	0.121	22.502
Cereals	Wheat-winter	Fungicides	Tebuconazole	748.00	267.70	88.00	0.165	14.508
Cereals	Wheat-winter	Fungicides	Triadimefon	748.00	267.70	5.44	0.125	0.681
Cereals	Wheat-winter	Herbicides	2.4-D-amine	748.00	700.00	90.00	0.960	86.400
Cereals	Wheat-winter	Herbicides	2.4-D-ester	748.00	700.00	27.29	0.600	16.375
Cereals	Wheat-winter	Herbicides	Bromoxynil	748.00	700.00	113.33	0.338	38.250
Cereals	Wheat-winter	Herbicides	Clodinafop	748.00	700.00	61.00	0.048	2.928
Cereals	Wheat-winter	Herbicides	Diquat	748.00	700.00	12.00	0.120	1.440
Cereals	Wheat-winter	Herbicides	Fenoxaprop-P-e	748.00	700.00	9.63	0.096	0.924
Cereals	Wheat-winter	Herbicides	Glyphosate	748.00	700.00	26.09	0.552	14.400
Cereals	Wheat-winter	Herbicides	Iodosulfuron-methyl-sodium	748.00	700.00	59.50	0.010	0.595
Cereals	Wheat-winter	Herbicides	MCPA	748.00	700.00	173.00	0.902	156.000
Cereals	Wheat-winter	Herbicides	Mefenpyr-diethyl	748.00	700.00	59.50	0.030	1.785
Cereals	Wheat-winter	Herbicides	Metolachlor	748.00	700.00	6.80	1.440	9.792
Cereals	Wheat-winter	Herbicides	Metsulfuron-m	748.00	700.00	70.00	0.008	0.558
Cereals	Wheat-winter	Herbicides	Paraquat	748.00	700.00	25.33	0.243	6.160
Cereals	Wheat-winter	Herbicides	Sulfosulfuron	748.00	700.00	65.00	0.015	0.975

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Cereals	Wheat-winter	Herbicides	Thifensulfuron-m	748.00	700.00	20.00	0.002	0.042
Cereals	Wheat-winter	Herbicides	Triasulfuron	748.00	700.00	53.33	0.011	0.600
Cereals	Wheat-winter	Herbicides	Tribenuron-m	748.00	700.00	50.00	0.011	0.563
Cereals	Wheat-winter	Herbicides	Trifluralin	748.00	700.00	50.00	0.720	36.000
Cereals	Wheat-winter	Growth regulators	Chlormequat-chloride	748.00		7.00	1.575	11.025
Cereals	Wheat-winter	Growth regulators	Ethephon	748.00		1.90	0.480	0.911
Cereals	Wheat-winter	Seed dressing	Imidacloprid	748.00	347.00	15.63	0.168	2.625
Cereals	Wheat-winter	Seed dressing	Prothioconazole	748.00	347.00	125.00	0.012	1.500
Cereals	Wheat-winter	Seed dressing	Tebuconazole	748.00	347.00	166.67	0.003	0.525
Cereals	Wheat-winter	Seed dressing	Thiamethoxam	748.00	347.00	12.25	0.143	1.750
Cereals	Wheat-winter	Seed dressing	Triadimenol	748.00	347.00	16.67	0.027	0.450
Cereals	Wheat-winter	Seed dressing	Triticonazole	748.00	347.00	10.83	0.060	0.650
Citrus	Citrus	Insecticides	Abamectin	55.03	55.00	1,066.48	0.001	1.557
Citrus	Citrus	Insecticides	Aldicarb	55.03	55.00	14.00	1.500	21.000
Citrus	Citrus	Insecticides	Alphacypermethrin	55.03	55.00	5.00	0.010	0.050
Citrus	Citrus	Insecticides	Buprofezin	55.03	55.00	3.33	0.750	2.500
Citrus	Citrus	Insecticides	Carbaryl	55.03	55.00	0.04	1.000	0.040
Citrus	Citrus	Insecticides	Chlorfenapyr	55.03	55.00	6.67	0.756	5.040
Citrus	Citrus	Insecticides	Ethoprophos	55.03	55.00	0.09	5.000	0.440
Citrus	Citrus	Insecticides	Fenamiphos	55.03	55.00	0.79	6.082	4.820
Citrus	Citrus	Insecticides	Fenbutatin-oxide	55.03	55.00	26.00	0.097	2.513
Citrus	Citrus	Insecticides	Fipronil	55.03	55.00	26.58	0.046	1.223
Citrus	Citrus	Insecticides	Fosthiazate	55.03	55.00	3.20	4.500	14.400
Citrus	Citrus	Insecticides	Imidacloprid	55.03	55.00	81.11	2.120	171.917

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Citrus	Citrus	Insecticides	Malathion	55.03	55.00	1.70	1.595	2.707
Citrus	Citrus	Insecticides	Metaldehyde	55.03	55.00	0.34	0.353	0.120
Citrus	Citrus	Insecticides	Methamidophos	55.03	55.00	1.34	0.293	0.393
Citrus	Citrus	Insecticides	Methidathion	55.03	55.00	7.48	1.155	8.644
Citrus	Citrus	Insecticides	Methiocarb	55.03	55.00	0.30	0.100	0.030
Citrus	Citrus	Insecticides	Methomyl	55.03	55.00	49.83	0.441	21.974
Citrus	Citrus	Insecticides	Mevinphos	55.03	55.00	0.01	0.750	0.010
Citrus	Citrus	Insecticides	Mineral-oil	55.03	55.00	2.29	16.880	38.655
Citrus	Citrus	Insecticides	Parathion-e	55.03	55.00	2.56	0.313	0.800
Citrus	Citrus	Insecticides	Petroleum-oil	55.03	55.00	159.08	20.024	3,185.525
Citrus	Citrus	Insecticides	Profenofos	55.03	55.00	22.00	0.568	12.500
Citrus	Citrus	Insecticides	Pyriproxifen	55.03	55.00	24.00	0.150	3.600
Citrus	Citrus	Insecticides	Spirodiclofen	55.03	55.00	40.00	0.012	0.480
Citrus	Citrus	Insecticides	Tartar-emetic	55.03	55.00	3.20	4.775	15.280
Citrus	Citrus	Insecticides	Terbufos	55.03	55.00	0.35	40.500	14.250
Citrus	Citrus	Insecticides	Tetradifon	55.03	55.00	2.40	0.400	0.960
Citrus	Citrus	Insecticides	Trichlorfon	55.03	55.00	46.00	0.095	4.370
Citrus	Citrus	Insecticides	Triflumuron	55.03	55.00	2.50	0.384	0.960
Citrus	Citrus	Fungicides	Benomyl	55.03	55.00	6.35	2.250	14.297
Citrus	Citrus	Fungicides	Carbendazim	55.03	55.00	3.64	0.200	0.729
Citrus	Citrus	Fungicides	Copper-oxychloride	55.03	55.00	6.67	10.200	68.000
Citrus	Citrus	Fungicides	Fosetyl-Al	55.03	55.00	0.02	13.600	0.204
Citrus	Citrus	Fungicides	Guazatine	55.03	55.00	3.26	0.800	2.604
Citrus	Citrus	Fungicides	Imazalil	55.03	55.00	2.44	0.782	1.908

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Citrus	Citrus	Fungicides	Kresoxim-m	55.03	55.00	0.21	0.700	0.150
Citrus	Citrus	Fungicides	Mancozeb	55.03	55.00	285.92	3.097	885.598
Citrus	Citrus	Fungicides	Maneb	55.03	55.00	3.10	2.175	6.735
Citrus	Citrus	Fungicides	Metalaxyl	55.03	55.00	2.53	0.075	0.190
Citrus	Citrus	Fungicides	Metalaxyl-M	55.03	55.00	12.12	0.317	3.840
Citrus	Citrus	Fungicides	Petroleum-oil	55.03	55.00	13.33	24.780	330.400
Citrus	Citrus	Fungicides	Potassium-phosphite	55.03	55.00	2.92	11.200	32.736
Citrus	Citrus	Fungicides	Prochloraz	55.03	55.00	0.14	0.450	0.064
Citrus	Citrus	Fungicides	Pyraclostrobin	55.03	55.00	56.00	0.125	7.000
Citrus	Citrus	Fungicides	Quaternary-Ammonium-salts	55.03	55.00	6.50	0.126	0.819
Citrus	Citrus	Fungicides	Thiabendazole	55.03	55.00	93.75	0.040	3.750
Citrus	Citrus	Fungicides	Thiophanate	55.03	55.00	0.36	5.040	1.824
Citrus	Citrus	Fungicides	Triadimefon	55.03	55.00	3.64	0.165	0.601
Citrus	Citrus	Fungicides	Zineb	55.03	55.00	0.04	0.980	0.042
Citrus	Citrus	Herbicides	Bromacil	55.03	55.00	0.40	4.000	1.600
Citrus	Citrus	Herbicides	Diquat	55.03	55.00	2.33	0.240	0.560
Citrus	Citrus	Herbicides	Fluazifop-P-b	55.03	55.00	0.75	0.300	0.225
Citrus	Citrus	Herbicides	Glyphosate	55.03	55.00	17.58	4.320	75.960
Citrus	Citrus	Herbicides	Glyphosate-trimesium	55.03	55.00	2.40	2.500	6.000
Citrus	Citrus	Herbicides	Oxadiazon	55.03	55.00	0.12	1.500	0.175
Citrus	Citrus	Herbicides	Paraquat	55.03	55.00	82.36	0.654	53.860
Citrus	Citrus	Herbicides	Simazine	55.03	55.00	3.89	0.900	3.500
Citrus	Citrus	Growth regulators	2.4-DP	55.03	37.73	31.38	0.038	1.190
Citrus	Citrus	Growth regulators	Gibberellic-acid	55.03	37.73	6.34	0.091	0.577

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Maize	Maize	Insecticides	Alphacypermethrin	2,750.00	2,500.00	322.06	0.009	3.016
Maize	Maize	Insecticides	Al-phosphide	2,750.00	2,500.00	0.21	5.622	1.169
Maize	Maize	Insecticides	Benfuracarb	2,750.00	2,500.00	0.49	0.196	0.096
Maize	Maize	Insecticides	Betacyfluthrin	2,750.00	2,500.00	37.08	0.008	0.283
Maize	Maize	Insecticides	Betacypermethrin	2,750.00	2,500.00	37.00	0.010	0.370
Maize	Maize	Insecticides	Bifenthrin	2,750.00	2,500.00	2.00	0.005	0.010
Maize	Maize	Insecticides	Carbaryl	2,750.00	2,500.00	1.50	0.850	1.275
Maize	Maize	Insecticides	Carbofuran	2,750.00	2,500.00	14.66	1.660	24.340
Maize	Maize	Insecticides	Carbosulfan	2,750.00	2,500.00	0.08	7.200	0.602
Maize	Maize	Insecticides	Chlorpyrifos	2,750.00	2,500.00	19.37	0.191	3.696
Maize	Maize	Insecticides	Cypermethrin	2,750.00	2,500.00	705.26	0.021	14.887
Maize	Maize	Insecticides	Deltamethrin	2,750.00	2,500.00	118.11	0.012	1.386
Maize	Maize	Insecticides	Endosulfan	2,750.00	2,500.00	29.05	0.309	8.970
Maize	Maize	Insecticides	Esfenvalerate	2,750.00	2,500.00	5.08	0.015	0.075
Maize	Maize	Insecticides	Fenpyroximate	2,750.00	2,500.00	9.43	0.175	1.650
Maize	Maize	Insecticides	Imidacloprid	2,750.00	2,500.00	62.69	0.195	12.215
Maize	Maize	Insecticides	Lambda-cyhalothrin	2,750.00	2,500.00	1,917.21	0.004	6.710
Maize	Maize	Insecticides	Propargite	2,750.00	2,500.00	0.14	0.600	0.083
Maize	Maize	Insecticides	Quinalphos	2,750.00	2,500.00	8.78	0.038	0.329
Maize	Maize	Insecticides	Terbufos	2,750.00	2,500.00	77.58	1.238	96.000
Maize	Maize	Insecticides	Thiodicarb	2,750.00	2,500.00	23.25	0.149	3.475
Maize	Maize	Insecticides	Tralomethrin	2,750.00	2,500.00	10.00	0.011	0.108
Maize	Maize	Fungicides	Azoxystrobin	2,750.00	161.83	6.00	0.100	0.600
Maize	Maize	Fungicides	Benomyl	2,750.00	161.83	6.00	0.500	3.000

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Maize	Maize	Fungicides	Carbendazim	2,750.00	161.83	8.20	0.125	1.025
Maize	Maize	Fungicides	Cyproconazole	2,750.00	161.83	16.00	0.040	0.640
Maize	Maize	Fungicides	Difenoconazole	2,750.00	161.83	9.91	0.087	0.863
Maize	Maize	Fungicides	Epoxiconazole	2,750.00	161.83	112.70	0.067	7.588
Maize	Maize	Fungicides	Propiconazole	2,750.00	161.83	16.00	0.125	2.000
Maize	Maize	Fungicides	Pyraclostrobin	2,750.00	161.83	104.00	0.063	6.500
Maize	Maize	Fungicides	Tebuconazole	2,750.00	161.83	14.66	0.123	1.796
Maize	Maize	Fungicides	Trifloxystrobin	2,750.00	161.83	13.33	0.075	1.000
Maize	Maize	Herbicides	2.4-D-amine	2,750.00	2,500.00	469.28	0.452	211.946
Maize	Maize	Herbicides	2.4-D-ester	2,750.00	2,500.00	20.00	0.400	8.000
Maize	Maize	Herbicides	Acetochlor	2,750.00	2,500.00	450.16	1.235	556.151
Maize	Maize	Herbicides	Alachlor	2,750.00	2,500.00	79.00	1.513	119.520
Maize	Maize	Herbicides	Atrazine	2,750.00	2,500.00	951.89	0.936	890.981
Maize	Maize	Herbicides	Bentazone	2,750.00	2,500.00	1.70	1.129	1.920
Maize	Maize	Herbicides	Bromoxynil	2,750.00	2,500.00	50.67	0.225	11.400
Maize	Maize	Herbicides	Dicamba	2,750.00	2,500.00	0.67	0.160	0.107
Maize	Maize	Herbicides	Dimethenamid-P	2,750.00	2,500.00	84.67	0.540	45.720
Maize	Maize	Herbicides	EPTC	2,750.00	2,500.00	45.28	2.160	97.812
Maize	Maize	Herbicides	Flumetsulam	2,750.00	2,500.00	11.67	0.024	0.280
Maize	Maize	Herbicides	Glyphosate	2,750.00	2,500.00	3,087.41	0.794	2,451.259
Maize	Maize	Herbicides	Glyphosate-trimesium	2,750.00	2,500.00	23.50	1.000	23.500
Maize	Maize	Herbicides	Halosulfuron-m	2,750.00	2,500.00	6.50	0.075	0.488
Maize	Maize	Herbicides	Isoxadifen-e	2,750.00	2,500.00	35.83	0.025	0.903
Maize	Maize	Herbicides	MCPA	2,750.00	2,500.00	18.00	1.000	18.000

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Maize	Maize	Herbicides	Mesotrione	2,750.00	2,500.00	1,083.79	0.068	73.696
Maize	Maize	Herbicides	Metolachlor	2,750.00	2,500.00	277.90	0.942	261.651
Maize	Maize	Herbicides	Nicosulfuron	2,750.00	2,500.00	154.50	0.045	6.953
Maize	Maize	Herbicides	Paraquat	2,750.00	2,500.00	53.88	0.623	33.580
Maize	Maize	Herbicides	Simazine	2,750.00	2,500.00	69.32	0.819	56.753
Maize	Maize	Herbicides	s-metolachlor	2,750.00	2,500.00	89.52	0.597	53.469
Maize	Maize	Herbicides	Sulcotrione	2,750.00	2,500.00	64.07	0.313	20.021
Maize	Maize	Herbicides	Tembotrione	2,750.00	2,500.00	35.83	0.050	1.806
Maize	Maize	Herbicides	Terbuthylazine	2,750.00	2,500.00	712.64	0.873	621.787
Maize	Maize	Seed dressing	Fludioxonil	2,750.00	2,500.00	1,400.00	0.001	0.875
Maize	Maize	Seed dressing	Imidacloprid	2,750.00	2,500.00	661.79	0.044	28.953
Maize	Maize	Seed dressing	Metalaxyl-M	2,750.00	2,500.00	1,400.00	0.000	0.350
Maize	Maize	Seed dressing	Thiamethoxam	2,750.00	2,500.00	440.00	0.044	19.250
Cotton	Cotton	Insecticides	Abamectin	58.00	58.00	183.67	0.006	1.043
Cotton	Cotton	Insecticides	Acetamiprid	58.00	58.00	16.43	0.225	3.697
Cotton	Cotton	Insecticides	Alphacypermethrin	58.00	58.00	305.00	0.010	3.050
Cotton	Cotton	Insecticides	Betacyfluthrin	58.00	58.00	6.00	0.005	0.030
Cotton	Cotton	Insecticides	Bifenthrin	58.00	58.00	1.25	0.040	0.050
Cotton	Cotton	Insecticides	Carbaryl	58.00	58.00	1.00	0.850	0.850
Cotton	Cotton	Insecticides	Cypermethrin	58.00	58.00	280.00	0.020	5.600
Cotton	Cotton	Insecticides	Deltamethrin	58.00	58.00	62.00	0.025	1.550
Cotton	Cotton	Insecticides	Dichlorvos(DDVP)	58.00	58.00	1.28	0.013	0.016
Cotton	Cotton	Insecticides	Esfenvalerate	58.00	58.00	1.67	0.015	0.025
Cotton	Cotton	Insecticides	Fenamiphos	58.00	58.00	0.31	1.500	0.460

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Cotton	Cotton	Insecticides	Lambda-cyhalothrin	58.00	58.00	34.00	0.005	0.170
Cotton	Cotton	Insecticides	Profenofos	58.00	58.00	0.71	0.700	0.500
Cotton	Cotton	Insecticides	Propargite	58.00	58.00	0.08	0.600	0.050
Cotton	Cotton	Insecticides	Pymetrozine	58.00	58.00	3.00	0.250	0.750
Cotton	Cotton	Insecticides	Tetradifon	58.00	58.00	24.00	0.160	3.840
Cotton	Cotton	Insecticides	Thiodicarb	58.00	58.00	1.00	0.375	0.375
Cotton	Cotton	Herbicides	Acetochlor	58.00	34.23	2.19	1.800	3.942
Cotton	Cotton	Herbicides	MSMA	58.00	34.23	4.00	2.160	8.640
Cotton	Cotton	Herbicides	Pendimethalin	58.00	34.23	0.40	1.250	0.500
Cotton	Cotton	Herbicides	Trifluralin	58.00	34.23	27.67	0.720	19.920
Cotton	Cotton	Growth regulators	Mepiquat-chloride	58.00	6.67	20.00	0.013	0.250
Cotton	Cotton	Seed dressing	Thiamethoxam	58.00	7.62	7.62	0.046	0.350
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Alphacypermethrin	54.00	54.00	4.00	0.010	0.040
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Betacyfluthrin	54.00	54.00	0.33	0.015	0.005
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Carbofuran	54.00	54.00	0.51	2.500	1.270
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Cypermethrin	54.00	54.00	110.64	0.026	2.829
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Deltamethrin	54.00	54.00	0.80	0.025	0.020
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Fenamiphos	54.00	54.00	2.38	2.622	6.240
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Fenpyroximate	54.00	54.00	6.60	0.250	1.650
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Lambda-cyhalothrin	54.00	54.00	39.60	0.005	0.198
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Oxamyl	54.00	54.00	0.49	1.178	0.577
Groundnuts/peanuts	Groundnuts/peanuts	Insecticides	Terbufos	54.00	54.00	0.48	1.238	0.600
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Azoxystrobin	54.00	36.65	3.99	0.145	0.580
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Benomyl	54.00	36.65	21.20	0.250	5.300

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Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Bitertanol	54.00	36.65	0.31	0.195	0.060
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Chlorothalonil	54.00	36.65	9.76	0.799	7.800
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Difenoconazole	54.00	36.65	2.22	0.113	0.250
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Mancozeb	54.00	36.65	13.20	1.875	24.750
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Propiconazole	54.00	36.65	0.60	0.125	0.075
Groundnuts/peanuts	Groundnuts/peanuts	Fungicides	Tebuconazole	54.00	36.65	5.00	0.125	0.625
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Acetochlor	54.00	54.00	9.03	1.587	14.337
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Alachlor	54.00	54.00	1.11	1.728	1.920
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Bentazone	54.00	54.00	0.40	1.200	0.480
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Fluazifop-P-b	54.00	54.00	0.15	0.300	0.045
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Flumetsulam	54.00	54.00	15.42	0.024	0.370
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Imazethapyr	54.00	54.00	22.00	0.050	1.100
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Metazachlor	54.00	54.00	4.15	0.650	2.695
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Metolachlor	54.00	54.00	32.25	1.112	35.863
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Propaquizafop	54.00	54.00	2.38	0.075	0.178
Groundnuts/peanuts	Groundnuts/peanuts	Herbicides	Trifluralin	54.00	54.00	42.67	0.360	15.360
Other Fruits	Mangoes	Insecticides	Esfenvalerate	7.90	7.90	0.25	0.040	0.010
Other Fruits	Mangoes	Insecticides	Fenamiphos	7.90	7.90	0.03	8.000	0.220
Other Fruits	Mangoes	Insecticides	Fenthion	7.90	7.90	0.13	1.875	0.250
Other Fruits	Mangoes	Insecticides	Fipronil	7.90	7.90	28.28	0.010	0.283
Other Fruits	Mangoes	Insecticides	Methamidophos	7.90	7.90	1.34	0.293	0.393
Other Fruits	Mangoes	Insecticides	Triflumuron	7.90	7.90	0.13	0.384	0.048
Other Fruits	Mangoes	Fungicides	Bupirimate	7.90	7.90	0.24	0.375	0.092
Other Fruits	Mangoes	Fungicides	Copper-carbonate	7.90	7.90	10.13	4.958	50.236

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Other Fruits	Mangoes	Fungicides	Copper-hydroxide	7.90	7.90	0.00	1.076	0.004
Other Fruits	Mangoes	Fungicides	Copper-oxychloride	7.90	7.90	11.72	11.828	138.571
Other Fruits	Mangoes	Fungicides	Copper-sulphate	7.90	7.90	1.33	2.550	3.400
Other Fruits	Mangoes	Fungicides	Hexaconazole	7.90	7.90	0.20	0.045	0.009
Other Fruits	Mangoes	Fungicides	Kresoxim-m	7.90	7.90	0.03	0.700	0.019
Other Fruits	Mangoes	Fungicides	Mancozeb	7.90	7.90	4.40	5.625	24.750
Other Fruits	Mangoes	Fungicides	Propiconazole	7.90	7.90	20.00	0.025	0.500
Other Fruits	Mangoes	Fungicides	Sulphur	7.90	7.90	2.15	24.865	53.460
Other Fruits	Mangoes	Fungicides	Triadimefon	7.90	7.90	0.01	0.375	0.005
Other Fruits	Mangoes	Fungicides	Triadimenol	7.90	7.90	0.13	0.188	0.025
Other Fruits	Mangoes	Herbicides	Glyphosate	7.90	2.77	3.42	4.320	14.760
Other Fruits	Mangoes	Herbicides	Glyphosate-trimesium	7.90	2.77	0.46	2.500	1.150
Other Fruits	Mangoes	Herbicides	Paraquat	7.90	2.77	1.67	0.600	1.000
Other Fruits	Pineapple	Insecticides	Diazinon	11.00	6.05	1.01	0.825	0.837
Other Fruits	Pineapple	Insecticides	Fenamiphos	11.00	6.05	0.26	2.500	0.640
Other Fruits	Pineapple	Insecticides	Oxamyl	11.00	6.05	9.74	1.178	11.470
Other Fruits	Pineapple	Fungicides	Cymoxanil	11.00	11.00	0.18	0.150	0.028
Other Fruits	Pineapple	Fungicides	Fosetyl-Al	11.00	11.00	1.26	4.000	5.040
Other Fruits	Pineapple	Fungicides	Mancozeb	11.00	11.00	3.50	2.102	7.349
Other Fruits	Pineapple	Fungicides	Metalaxyl	11.00	11.00	4.56	0.188	0.858
Other Fruits	Pineapple	Fungicides	Metalaxyl-M	11.00	11.00	8.01	0.320	2.560
Other Fruits	Pineapple	Fungicides	Potassium-phosphite	11.00	11.00	9.74	5.600	54.561
Other Fruits	Pineapple	Herbicides	Bromacil	11.00	8.15	3.33	2.400	8.000
Other Fruits	Pineapple	Herbicides	Fluazifop-P-b	11.00	8.15	3.25	0.300	0.975

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Other Fruits	Pineapple	Herbicides	Glyphosate	11.00	8.15	2.33	2.160	5.040
Other Fruits	Pineapple	Herbicides	Glyphosate-trimesium	11.00	8.15	0.80	1.250	1.000
Other Fruits	Pineapple	Growth regulators	Ethephon	11.00	7.33	7.33	1.440	10.560
Peas/beans	Beans	Insecticides	Alphacypermethrin	79.00	70.00	10.00	0.020	0.200
Peas/beans	Beans	Insecticides	Betacyfluthrin	79.00	70.00	0.33	0.015	0.005
Peas/beans	Beans	Insecticides	Chlorpyrifos	79.00	70.00	9.70	0.480	4.656
Peas/beans	Beans	Insecticides	Cypermethrin	79.00	70.00	63.33	0.060	3.800
Peas/beans	Beans	Insecticides	Deltamethrin	79.00	70.00	1.20	0.025	0.030
Peas/beans	Beans	Insecticides	Esfenvalerate	79.00	70.00	1.00	0.005	0.005
Peas/beans	Beans	Insecticides	Fenpyroximate	79.00	70.00	9.43	0.175	1.650
Peas/beans	Beans	Insecticides	Lambda-cyhalothrin	79.00	70.00	65.00	0.005	0.325
Peas/beans	Beans	Insecticides	Terbufos	79.00	70.00	0.24	1.238	0.300
Peas/beans	Beans	Fungicides	Bitertanol	79.00	70.00	1.33	0.135	0.180
Peas/beans	Beans	Fungicides	Chlorothalonil	79.00	70.00	13.75	0.400	5.500
Peas/beans	Beans	Fungicides	Copper-oxychloride	79.00	70.00	20.89	3.825	79.900
Peas/beans	Beans	Fungicides	Mancozeb	79.00	70.00	19.20	1.875	36.000
Peas/beans	Beans	Fungicides	Maneb	79.00	70.00	64.51	0.522	33.673
Peas/beans	Beans	Fungicides	Procymidone	79.00	70.00	0.16	0.375	0.061
Peas/beans	Beans	Fungicides	Tebuconazole	79.00	70.00	8.00	0.125	1.000
Peas/beans	Beans	Herbicides	Bentazone	79.00	70.00	16.00	1.200	19.200
Peas/beans	Beans	Herbicides	Fluazifop-P-b	79.00	70.00	0.55	0.300	0.165
Peas/beans	Beans	Herbicides	Flumetsulam	79.00	70.00	10.42	0.024	0.250
Peas/beans	Beans	Herbicides	Imazethapyr	79.00	70.00	52.00	0.050	2.600
Peas/beans	Beans	Herbicides	Metolachlor	79.00	70.00	10.42	0.756	7.875

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Peas/beans	Beans	Herbicides	Pendimethalin	79.00	70.00	0.80	1.250	1.000
Peas/beans	Beans	Herbicides	Trifluralin	79.00	70.00	9.33	0.720	6.720
Peas/beans	Beans: Dried Edible	Insecticides	Alphacypermethrin	44.00	40.00	10.59	0.010	0.106
Peas/beans	Beans: Dried Edible	Insecticides	Betacypermethrin	44.00	40.00	37.00	0.010	0.370
Peas/beans	Beans: Dried Edible	Insecticides	Carbaryl	44.00	40.00	0.40	0.536	0.213
Peas/beans	Beans: Dried Edible	Insecticides	Chlorpyrifos	44.00	40.00	7.71	0.480	3.702
Peas/beans	Beans: Dried Edible	Insecticides	Deltamethrin	44.00	40.00	8.97	0.005	0.045
Peas/beans	Beans: Dried Edible	Insecticides	Dichlorvos(DDVP)	44.00	40.00	5.66	0.500	2.828
Peas/beans	Beans: Dried Edible	Insecticides	Lambda-cyhalothrin	44.00	40.00	201.25	0.005	1.033
Peas/beans	Beans: Dried Edible	Fungicides	Copper-hydroxide	44.00	13.33	13.33	0.807	10.760
Peas/beans	Beans: Dried Edible	Fungicides	Flusilazole	44.00	13.33	13.33	0.113	1.500
Peas/beans	Beans: Dried Edible	Herbicides	Imazethapyr	44.00	40.44	15.00	0.033	0.500
Peas/beans	Beans: Dried Edible	Herbicides	Metazachlor	44.00	40.44	4.49	0.600	2.695
Peas/beans	Beans: Dried Edible	Herbicides	Metolachlor	44.00	40.44	16.20	1.440	23.328
Peas/beans	Beans: Dried Edible	Herbicides	Propaquizafop	44.00	40.44	4.75	0.075	0.356
Pome/stone Fruit	Apples	Insecticides	Abamectin	39.00	39.00	51.83	0.004	0.196
Pome/stone Fruit	Apples	Insecticides	Acephate	39.00	39.00	0.27	1.125	0.300
Pome/stone Fruit	Apples	Insecticides	Azinphos-m	39.00	39.00	45.27	0.419	18.965
Pome/stone Fruit	Apples	Insecticides	Betacyfluthrin	39.00	39.00	1.76	0.017	0.030
Pome/stone Fruit	Apples	Insecticides	Carbaryl	39.00	39.00	0.01	1.000	0.010
Pome/stone Fruit	Apples	Insecticides	Chlorantraniliprole	39.00	39.00	9.07	0.017	0.153
Pome/stone Fruit	Apples	Insecticides	Chlorpyrifos	39.00	39.00	16.20	0.240	3.888
Pome/stone Fruit	Apples	Insecticides	Chlorpyrifos-e	39.00	39.00	72.00	0.180	12.960
Pome/stone Fruit	Apples	Insecticides	Cydia pomonella GV	39.00	39.00	1.40	2.650	3.697

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Apples	Insecticides	Deltamethrin	39.00	39.00	0.81	0.037	0.030
Pome/stone Fruit	Apples	Insecticides	Emamectin	39.00	39.00	27.59	0.004	0.120
Pome/stone Fruit	Apples	Insecticides	Esfenvalerate	39.00	39.00	0.83	0.030	0.025
Pome/stone Fruit	Apples	Insecticides	Fenbutatin-oxide	39.00	39.00	0.53	0.500	0.267
Pome/stone Fruit	Apples	Insecticides	Fenoxycarb	39.00	39.00	33.33	0.038	1.250
Pome/stone Fruit	Apples	Insecticides	Flufenoxuron	39.00	39.00	1.67	0.300	0.500
Pome/stone Fruit	Apples	Insecticides	Gamma-cyhalothrin	39.00	39.00	15.00	0.014	0.216
Pome/stone Fruit	Apples	Insecticides	Imidacloprid	39.00	39.00	1.40	10.500	14.700
Pome/stone Fruit	Apples	Insecticides	Indoxacarb	39.00	39.00	2.67	0.225	0.600
Pome/stone Fruit	Apples	Insecticides	Metaldehyde	39.00	39.00	0.69	0.219	0.150
Pome/stone Fruit	Apples	Insecticides	Methiocarb	39.00	39.00	0.68	0.100	0.068
Pome/stone Fruit	Apples	Insecticides	Parathion-m	39.00	39.00	12.41	0.563	6.982
Pome/stone Fruit	Apples	Insecticides	Petroleum-oil	39.00	39.00	3.10	11.542	35.779
Pome/stone Fruit	Apples	Insecticides	Tau-fluvalinate	39.00	39.00	13.33	0.216	2.880
Pome/stone Fruit	Apples	Insecticides	Tetradifon	39.00	39.00	2.13	0.640	1.360
Pome/stone Fruit	Apples	Insecticides	Thiacloprid	39.00	39.00	28.00	0.072	2.016
Pome/stone Fruit	Apples	Insecticides	Thiamethoxam	39.00	39.00	30.00	0.025	0.750
Pome/stone Fruit	Apples	Fungicides	Bupirimate	39.00	39.00	5.92	0.275	1.628
Pome/stone Fruit	Apples	Fungicides	Captan	39.00	39.00	13.07	1.500	19.608
Pome/stone Fruit	Apples	Fungicides	Copper-oxychloride	39.00	39.00	12.17	5.100	62.050
Pome/stone Fruit	Apples	Fungicides	Dinocap	39.00	39.00	2.67	0.275	0.732
Pome/stone Fruit	Apples	Fungicides	Dithianon	39.00	39.00	24.31	0.150	3.647
Pome/stone Fruit	Apples	Fungicides	Fenarimol	39.00	39.00	39.00	0.048	1.872
Pome/stone Fruit	Apples	Fungicides	Kresoxim-m	39.00	39.00	21.15	0.190	4.019

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Apples	Fungicides	Mancozeb	39.00	39.00	100.01	3.337	333.709
Pome/stone Fruit	Apples	Fungicides	Metiram	39.00	39.00	3.75	2.800	10.500
Pome/stone Fruit	Apples	Fungicides	Penconazole	39.00	39.00	10.77	0.013	0.140
Pome/stone Fruit	Apples	Fungicides	Pyraclostrobin	39.00	39.00	24.31	0.050	1.216
Pome/stone Fruit	Apples	Fungicides	Quaternary-Ammonium-salts	39.00	39.00	3.25	0.126	0.410
Pome/stone Fruit	Apples	Fungicides	Thiram	39.00	39.00	0.04	1.800	0.066
Pome/stone Fruit	Apples	Fungicides	Triadimefon	39.00	39.00	0.50	0.050	0.025
Pome/stone Fruit	Apples	Herbicides	Diquat	39.00	39.00	11.67	0.240	2.800
Pome/stone Fruit	Apples	Herbicides	Fluazifop-P-b	39.00	39.00	0.35	0.300	0.105
Pome/stone Fruit	Apples	Herbicides	Glufosinate-ammonium	39.00	39.00	0.67	1.500	1.000
Pome/stone Fruit	Apples	Herbicides	Glyphosate	39.00	39.00	35.33	2.320	81.990
Pome/stone Fruit	Apples	Herbicides	Glyphosate-trimesium	39.00	39.00	1.56	2.500	3.900
Pome/stone Fruit	Apples	Herbicides	Haloxyfop-r-m	39.00	39.00	2.67	0.162	0.432
Pome/stone Fruit	Apples	Herbicides	MCPA	39.00	39.00	2.20	2.000	4.400
Pome/stone Fruit	Apples	Herbicides	Oxadiazon	39.00	39.00	0.03	1.500	0.050
Pome/stone Fruit	Apples	Herbicides	Paraquat	39.00	39.00	72.82	0.532	38.710
Pome/stone Fruit	Apples	Herbicides	Simazine	39.00	39.00	0.45	1.100	0.500
Pome/stone Fruit	Apples	Growth regulators	Carbaryl	39.00	23.45	2.45	0.960	2.352
Pome/stone Fruit	Apples	Growth regulators	Cyanamide	39.00	23.45	3.52	4.459	15.680
Pome/stone Fruit	Apples	Growth regulators	Mineral-oil	39.00	23.45	15.58	52.306	815.100
Pome/stone Fruit	Apples	Growth regulators	Prohexadione-Ca	39.00	23.45	1.90	0.200	0.380
Pome/stone Fruit	Apricots	Insecticides	Azinphos-m	4.80	2.39	5.00	0.700	3.500
Pome/stone Fruit	Apricots	Insecticides	Betacyfluthrin	4.80	2.39	0.27	0.019	0.005
Pome/stone Fruit	Apricots	Insecticides	Fenamiphos	4.80	2.39	0.20	3.000	0.600

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Apricots	Insecticides	Fenthion	4.80	2.39	0.20	1.000	0.200
Pome/stone Fruit	Apricots	Insecticides	Petroleum-oil	4.80	2.39	0.60	41.750	25.050
Pome/stone Fruit	Apricots	Fungicides	Bitertanol	4.80	4.80	0.31	0.195	0.060
Pome/stone Fruit	Apricots	Fungicides	Copper-oxychloride	4.80	4.80	3.50	5.100	17.850
Pome/stone Fruit	Apricots	Fungicides	Mancozeb	4.80	4.80	2.00	2.250	4.500
Pome/stone Fruit	Apricots	Fungicides	Thiram	4.80	4.80	4.09	1.650	6.750
Pome/stone Fruit	Apricots	Herbicides	Diquat	4.80	4.80	1.00	0.240	0.240
Pome/stone Fruit	Apricots	Herbicides	Fluazifop-P-b	4.80	4.80	0.10	0.300	0.030
Pome/stone Fruit	Apricots	Herbicides	Glufosinate-ammonium	4.80	4.80	0.53	1.500	0.800
Pome/stone Fruit	Apricots	Herbicides	Glyphosate	4.80	4.80	5.33	4.320	23.040
Pome/stone Fruit	Apricots	Herbicides	Glyphosate-trimesium	4.80	4.80	0.60	2.500	1.500
Pome/stone Fruit	Apricots	Herbicides	Haloxyfop-r-m	4.80	4.80	0.20	0.162	0.032
Pome/stone Fruit	Apricots	Herbicides	Paraquat	4.80	4.80	4.50	0.391	1.760
Pome/stone Fruit	Apricots	Growth regulators	Cyanamide	4.80	0.13	0.13	2.940	0.392
Pome/stone Fruit	Avocados	Insecticides	Betacyfluthrin	7.30	0.60	1.20	0.025	0.030
Pome/stone Fruit	Avocados	Insecticides	Buprofezin	7.30	0.60	0.30	0.500	0.150
Pome/stone Fruit	Avocados	Fungicides	Copper-hydroxide	7.30	4.94	0.02	1.076	0.017
Pome/stone Fruit	Avocados	Fungicides	Copper-oxychloride	7.30	4.94	8.21	12.333	101.235
Pome/stone Fruit	Avocados	Fungicides	Fosetyl-Al	7.30	4.94	0.89	9.000	8.000
Pome/stone Fruit	Avocados	Fungicides	Metalaxyl-M	7.30	4.94	3.03	0.317	0.960
Pome/stone Fruit	Avocados	Herbicides	Fluazifop-P-b	7.30	5.55	0.10	0.300	0.030
Pome/stone Fruit	Avocados	Herbicides	Glyphosate	7.30	5.55	0.83	4.320	3.600
Pome/stone Fruit	Avocados	Herbicides	Glyphosate-trimesium	7.30	5.55	0.10	2.500	0.250
Pome/stone Fruit	Avocados	Herbicides	Paraquat	7.30	5.55	10.00	0.400	4.000

Crop group	**Crop**	**Sector**	**Active Ingredient (AI)**	**Crop area (x 10^3 ha)**	**Base area (x 10^3 ha)**	**AI Area Treated (x 10^3 ha)**	**AI dose rate (kg or L/ha)**	**AI volume (10^3 kg or L)**
Pome/stone Fruit	Avocados	Growth regulators	Uniconazole-P	7.30	0.09	0.09	1.500	0.135
Pome/stone Fruit	Peaches/nectarines	Insecticides	Acephate	11.46	11.46	2.33	0.900	2.100
Pome/stone Fruit	Peaches/nectarines	Insecticides	Azinphos-m	11.46	11.46	11.76	0.595	7.000
Pome/stone Fruit	Peaches/nectarines	Insecticides	Betacyfluthrin	11.46	11.46	0.27	0.019	0.005
Pome/stone Fruit	Peaches/nectarines	Insecticides	Carbaryl	11.46	11.46	0.08	0.800	0.060
Pome/stone Fruit	Peaches/nectarines	Insecticides	Chlorpyrifos-e	11.46	11.46	5.42	0.576	3.120
Pome/stone Fruit	Peaches/nectarines	Insecticides	Cypermethrin	11.46	11.46	53.33	0.030	1.600
Pome/stone Fruit	Peaches/nectarines	Insecticides	Deltamethrin	11.46	11.46	0.17	0.060	0.010
Pome/stone Fruit	Peaches/nectarines	Insecticides	Fenamiphos	11.46	11.46	0.31	3.000	0.920
Pome/stone Fruit	Peaches/nectarines	Insecticides	Fenthion	11.46	11.46	0.19	1.300	0.250
Pome/stone Fruit	Peaches/nectarines	Insecticides	Metaldehyde	11.46	11.46	0.08	1.200	0.090
Pome/stone Fruit	Peaches/nectarines	Insecticides	Pirimicarb	11.46	11.46	11.00	0.500	5.500
Pome/stone Fruit	Peaches/nectarines	Insecticides	Tetradifon	11.46	11.46	1.12	0.400	0.448
Pome/stone Fruit	Peaches/nectarines	Fungicides	Bitertanol	11.46	11.46	0.46	0.195	0.090
Pome/stone Fruit	Peaches/nectarines	Fungicides	Copper-oxychloride	11.46	11.46	27.86	5.950	165.750
Pome/stone Fruit	Peaches/nectarines	Fungicides	Iprodione	11.46	11.46	0.67	1.530	1.020
Pome/stone Fruit	Peaches/nectarines	Fungicides	Mancozeb	11.46	11.46	28.33	2.250	63.750
Pome/stone Fruit	Peaches/nectarines	Fungicides	Procymidone	11.46	11.46	0.16	0.188	0.030
Pome/stone Fruit	Peaches/nectarines	Fungicides	Sulphur	11.46	11.46	2.80	4.000	11.200
Pome/stone Fruit	Peaches/nectarines	Fungicides	Thiram	11.46	11.46	17.08	1.800	30.750
Pome/stone Fruit	Peaches/nectarines	Herbicides	Diquat	11.46	11.46	2.00	0.240	0.480
Pome/stone Fruit	Peaches/nectarines	Herbicides	Fluazifop-P-b	11.46	11.46	0.90	0.300	0.270
Pome/stone Fruit	Peaches/nectarines	Herbicides	Glufosinate-ammonium	11.46	11.46	0.80	1.500	1.200
Pome/stone Fruit	Peaches/nectarines	Herbicides	Glyphosate	11.46	11.46	11.42	4.320	49.320

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Peaches/nectarines	Herbicides	Glyphosate-trimesium	11.46	11.46	1.30	2.500	3.250
Pome/stone Fruit	Peaches/nectarines	Herbicides	Haloxyfop-r-m	11.46	11.46	4.00	0.162	0.648
Pome/stone Fruit	Peaches/nectarines	Herbicides	MCPA	11.46	11.46	0.20	2.000	0.400
Pome/stone Fruit	Peaches/nectarines	Herbicides	Oxadiazon	11.46	11.46	0.05	1.500	0.075
Pome/stone Fruit	Peaches/nectarines	Herbicides	Paraquat	11.46	11.46	18.80	0.485	9.120
Pome/stone Fruit	Pears	Insecticides	Acephate	13.40		0.07	1.125	0.075
Pome/stone Fruit	Pears	Insecticides	Azinphos-m	13.40		48.33	0.420	20.300
Pome/stone Fruit	Pears	Insecticides	Betacyfluthrin	13.40		0.33	0.030	0.010
Pome/stone Fruit	Pears	Insecticides	Carbaryl	13.40		0.06	1.000	0.060
Pome/stone Fruit	Pears	Insecticides	Chlorpyrifos-e	13.40		16.00	1.200	19.200
Pome/stone Fruit	Pears	Insecticides	Deltamethrin	13.40		0.81	0.037	0.030
Pome/stone Fruit	Pears	Insecticides	Esfenvalerate	13.40		0.33	0.030	0.010
Pome/stone Fruit	Pears	Insecticides	Flufenoxuron	13.40		0.63	0.300	0.190
Pome/stone Fruit	Pears	Insecticides	Imidacloprid	13.40		0.33	10.500	3.500
Pome/stone Fruit	Pears	Insecticides	Metaldehyde	13.40		0.06	1.500	0.090
Pome/stone Fruit	Pears	Insecticides	Tau-fluvalinate	13.40		2.00	0.216	0.432
Pome/stone Fruit	Pears	Insecticides	Tetradifon	13.40		0.23	0.640	0.144
Pome/stone Fruit	Pears	Fungicides	Copper-oxychloride	13.40	13.40	5.50	3.400	18.700
Pome/stone Fruit	Pears	Fungicides	Iprodione	13.40	13.40	2.67	1.500	4.000
Pome/stone Fruit	Pears	Fungicides	Kresoxim-m	13.40	13.40	0.97	0.190	0.185
Pome/stone Fruit	Pears	Fungicides	Mancozeb	13.40	13.40	42.00	2.250	94.500
Pome/stone Fruit	Pears	Fungicides	Metiram	13.40	13.40	2.08	2.800	5.810
Pome/stone Fruit	Pears	Fungicides	Penconazole	13.40	13.40	4.00	0.025	0.100
Pome/stone Fruit	Pears	Fungicides	Procymidone	13.40	13.40	0.16	0.188	0.030

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Pears	Fungicides	Quaternary-Ammonium-salts	13.40	13.40	3.25	0.126	0.410
Pome/stone Fruit	Pears	Herbicides	Diquat	13.40	13.40	4.33	0.240	1.040
Pome/stone Fruit	Pears	Herbicides	Fluazifop-P-b	13.40	13.40	0.15	0.300	0.045
Pome/stone Fruit	Pears	Herbicides	Glufosinate-ammonium	13.40	13.40	0.27	1.500	0.400
Pome/stone Fruit	Pears	Herbicides	Glyphosate	13.40	13.40	10.17	4.320	43.920
Pome/stone Fruit	Pears	Herbicides	Glyphosate-trimesium	13.40	13.40	1.00	2.500	2.500
Pome/stone Fruit	Pears	Herbicides	Haloxyfop-r-m	13.40	13.40	3.33	0.162	0.540
Pome/stone Fruit	Pears	Herbicides	MCPA	13.40	13.40	1.40	2.000	2.800
Pome/stone Fruit	Pears	Herbicides	Paraquat	13.40	13.40	17.13	0.465	7.960
Pome/stone Fruit	Pears	Herbicides	Simazine	13.40	13.40	0.42	1.200	0.500
Pome/stone Fruit	Pears	Growth regulators	Gibberellic-acid	13.40	2.50	2.50	0.031	0.078
Pome/stone Fruit	Plums	Insecticides	Azinphos-m	4.30	4.30	3.13	0.560	1.750
Pome/stone Fruit	Plums	Insecticides	Betacyfluthrin	4.30	4.30	0.27	0.019	0.005
Pome/stone Fruit	Plums	Insecticides	Carbaryl	4.30	4.30	0.03	1.000	0.034
Pome/stone Fruit	Plums	Insecticides	Chlorpyrifos-e	4.30	4.30	1.04	0.600	0.624
Pome/stone Fruit	Plums	Insecticides	Cypermethrin	4.30	4.30	12.00	0.050	0.600
Pome/stone Fruit	Plums	Insecticides	Fenamiphos	4.30	4.30	0.19	3.000	0.560
Pome/stone Fruit	Plums	Insecticides	Indoxacarb	4.30	4.30	13.33	0.045	0.600
Pome/stone Fruit	Plums	Insecticides	Metaldehyde	4.30	4.30	0.03	1.500	0.051
Pome/stone Fruit	Plums	Insecticides	Methamidophos	4.30	4.30	2.69	0.293	0.786
Pome/stone Fruit	Plums	Fungicides	Bupirimate	4.30	4.30	0.18	0.344	0.061
Pome/stone Fruit	Plums	Fungicides	Captan	4.30	4.30	3.27	1.500	4.902
Pome/stone Fruit	Plums	Fungicides	Copper-oxychloride	4.30	4.30	2.50	5.100	12.750
Pome/stone Fruit	Plums	Fungicides	Hexaconazole	4.30	4.30	0.13	0.045	0.006

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Pome/stone Fruit	Plums	Fungicides	Iprodione	4.30	4.30	0.10	1.500	0.150
Pome/stone Fruit	Plums	Fungicides	Mancozeb	4.30	4.30	4.17	6.293	26.239
Pome/stone Fruit	Plums	Fungicides	Propiconazole	4.30	4.30	35.00	0.025	0.875
Pome/stone Fruit	Plums	Fungicides	Thiram	4.30	4.30	4.17	1.800	7.500
Pome/stone Fruit	Plums	Herbicides	Diquat	4.30	4.30	1.33	0.240	0.320
Pome/stone Fruit	Plums	Herbicides	Fluazifop-P-b	4.30	4.30	0.15	0.300	0.045
Pome/stone Fruit	Plums	Herbicides	Glufosinate-ammonium	4.30	4.30	0.40	1.500	0.600
Pome/stone Fruit	Plums	Herbicides	Glyphosate	4.30	4.30	2.08	4.320	9.000
Pome/stone Fruit	Plums	Herbicides	Glyphosate-trimesium	4.30	4.30	0.22	2.500	0.550
Pome/stone Fruit	Plums	Herbicides	Haloxyfop-r-m	4.30	4.30	1.47	0.162	0.238
Pome/stone Fruit	Plums	Herbicides	Paraquat	4.30	4.30	7.73	0.476	3.680
Pome/stone Fruit	Plums	Growth regulators	Cyanamide	4.30	0.33	0.33	2.940	0.980
Potatoes	Potatoes	Insecticides	Abamectin	51.00	51.00	8.83	0.009	0.079
Potatoes	Potatoes	Insecticides	Acephate	51.00	51.00	0.87	0.433	0.375
Potatoes	Potatoes	Insecticides	Aldicarb	51.00	51.00	37.33	2.250	84.000
Potatoes	Potatoes	Insecticides	Alphacypermethrin	51.00	51.00	1.43	0.007	0.010
Potatoes	Potatoes	Insecticides	Azinphos-m	51.00	51.00	12.50	0.280	3.500
Potatoes	Potatoes	Insecticides	Betacyfluthrin	51.00	51.00	5.33	0.015	0.080
Potatoes	Potatoes	Insecticides	Bifenthrin	51.00	51.00	1.00	0.030	0.030
Potatoes	Potatoes	Insecticides	Carbofuran	51.00	51.00	0.64	2.500	1.610
Potatoes	Potatoes	Insecticides	Cartap	51.00	51.00	5.65	0.750	4.240
Potatoes	Potatoes	Insecticides	Chlorpyrifos	51.00	51.00	26.20	0.240	6.288
Potatoes	Potatoes	Insecticides	Cypermethrin	51.00	51.00	26.81	0.016	0.429
Potatoes	Potatoes	Insecticides	Deltamethrin	51.00	51.00	13.83	0.013	0.183

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Potatoes	Potatoes	Insecticides	Esfenvalerate	51.00	51.00	0.22	0.023	0.005
Potatoes	Potatoes	Insecticides	Ethylene-dibromide	51.00	51.00	6.84	36.000	246.348
Potatoes	Potatoes	Insecticides	Fenamiphos	51.00	51.00	26.78	1.634	43.760
Potatoes	Potatoes	Insecticides	Fenbutatin-oxide	51.00	51.00	2.97	0.225	0.668
Potatoes	Potatoes	Insecticides	Fosthiazate	51.00	51.00	12.73	2.970	37.800
Potatoes	Potatoes	Insecticides	Gamma-cyhalothrin	51.00	51.00	24.00	0.003	0.072
Potatoes	Potatoes	Insecticides	Indoxacarb	51.00	51.00	0.96	0.188	0.180
Potatoes	Potatoes	Insecticides	Lambda-cyhalothrin	51.00	51.00	60.71	0.004	0.250
Potatoes	Potatoes	Insecticides	Lufenuron	51.00	51.00	9.85	0.033	0.321
Potatoes	Potatoes	Insecticides	Methamidophos	51.00	51.00	57.44	0.354	20.311
Potatoes	Potatoes	Insecticides	Methomyl	51.00	51.00	0.80	0.080	0.064
Potatoes	Potatoes	Insecticides	Oxamyl	51.00	51.00	6.18	1.422	8.784
Potatoes	Potatoes	Insecticides	Profenofos	51.00	51.00	21.87	0.375	8.200
Potatoes	Potatoes	Insecticides	Terbufos	51.00	51.00	2.91	1.238	3.600
Potatoes	Potatoes	Fungicides	Azoxystrobin	51.00	51.00	42.77	0.140	5.970
Potatoes	Potatoes	Fungicides	Boscalid	51.00	51.00	45.33	0.076	3.427
Potatoes	Potatoes	Fungicides	Bupirimate	51.00	51.00	0.50	0.250	0.125
Potatoes	Potatoes	Fungicides	Captan	51.00	51.00	0.14	1.000	0.138
Potatoes	Potatoes	Fungicides	Chlorothalonil	51.00	51.00	77.12	0.984	75.918
Potatoes	Potatoes	Fungicides	Copper	51.00	51.00	33.72	0.788	26.558
Potatoes	Potatoes	Fungicides	Copper-hydroxide	51.00	51.00	23.33	0.807	18.830
Potatoes	Potatoes	Fungicides	Copper-oxychloride	51.00	51.00	16.40	4.250	69.700
Potatoes	Potatoes	Fungicides	Cymoxanil	51.00	51.00	34.31	0.134	4.596
Potatoes	Potatoes	Fungicides	Difenoconazole	51.00	51.00	26.67	0.047	1.250

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Potatoes	Potatoes	Fungicides	Dimethomorph	51.00	51.00	0.08	0.180	0.014
Potatoes	Potatoes	Fungicides	Famoxadone	51.00	51.00	22.00	0.125	2.750
Potatoes	Potatoes	Fungicides	Hexaconazole	51.00	51.00	0.50	0.030	0.015
Potatoes	Potatoes	Fungicides	Mancozeb	51.00	51.00	238.17	1.841	438.371
Potatoes	Potatoes	Fungicides	Metalaxyl	51.00	51.00	11.70	0.200	2.341
Potatoes	Potatoes	Fungicides	Metalaxyl-M	51.00	51.00	7.60	0.096	0.730
Potatoes	Potatoes	Fungicides	Pencycuron	51.00	51.00	0.29	2.500	0.718
Potatoes	Potatoes	Fungicides	Potassium-phosphite	51.00	51.00	49.12	2.586	127.033
Potatoes	Potatoes	Fungicides	Prochloraz	51.00	51.00	0.11	0.450	0.048
Potatoes	Potatoes	Fungicides	Procymidone	51.00	51.00	0.32	0.188	0.061
Potatoes	Potatoes	Fungicides	Propineb	51.00	51.00	13.28	1.750	23.240
Potatoes	Potatoes	Fungicides	Pyraclostrobin	51.00	51.00	45.33	0.038	1.741
Potatoes	Potatoes	Fungicides	Tebuconazole	51.00	51.00	6.44	0.186	1.199
Potatoes	Potatoes	Fungicides	Trifloxystrobin	51.00	51.00	37.33	0.075	2.800
Potatoes	Potatoes	Fungicides	Zineb	51.00	51.00	0.04	0.980	0.042
Potatoes	Potatoes	Herbicides	Acetochlor	51.00	51.00	31.13	1.200	37.354
Potatoes	Potatoes	Herbicides	Alachlor	51.00	51.00	14.73	1.486	21.888
Potatoes	Potatoes	Herbicides	Bentazone	51.00	51.00	0.60	1.200	0.720
Potatoes	Potatoes	Herbicides	EPTC	51.00	51.00	25.99	2.880	74.858
Potatoes	Potatoes	Herbicides	Fluazifop-P-b	51.00	51.00	0.30	0.300	0.090
Potatoes	Potatoes	Herbicides	Flurochloridone	51.00	51.00	0.47	0.800	0.376
Potatoes	Potatoes	Herbicides	Linuron	51.00	51.00	0.32	1.250	0.400
Potatoes	Potatoes	Herbicides	MCPA	51.00	51.00	3.00	1.600	4.800
Potatoes	Potatoes	Herbicides	Metolachlor	51.00	51.00	2.51	1.400	3.520

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Potatoes	Potatoes	Herbicides	Metribuzin	51.00	51.00	10.56	0.864	9.120
Potatoes	Potatoes	Herbicides	Paraquat	51.00	51.00	46.73	0.742	34.681
Potatoes	Potatoes	Herbicides	Propaquizafop	51.00	51.00	3.17	0.075	0.238
Potatoes	Potatoes	Herbicides	Rimsulfuron	51.00	51.00	3.00	0.025	0.075
Potatoes	Potatoes	Growth regulators	Gibberellic-acid	51.00	5.63	5.63	0.003	0.014
Potatoes	Potatoes: Seed	Insecticides	Acephate	10.00	10.00	0.37	0.409	0.150
Potatoes	Potatoes: Seed	Insecticides	Azinphos-m	10.00	10.00	1.00	0.350	0.350
Potatoes	Potatoes: Seed	Insecticides	Betacyfluthrin	10.00	10.00	1.00	0.015	0.015
Potatoes	Potatoes: Seed	Insecticides	Bifenthrin	10.00	10.00	0.33	0.030	0.010
Potatoes	Potatoes: Seed	Insecticides	Cypermethrin	10.00	10.00	20.00	0.020	0.400
Potatoes	Potatoes: Seed	Insecticides	Deltamethrin	10.00	10.00	3.33	0.015	0.050
Potatoes	Potatoes: Seed	Insecticides	Esfenvalerate	10.00	10.00	0.22	0.023	0.005
Potatoes	Potatoes: Seed	Insecticides	Fenamiphos	10.00	10.00	3.10	1.485	4.600
Potatoes	Potatoes: Seed	Insecticides	Imidacloprid	10.00	10.00	2.00	2.450	4.900
Potatoes	Potatoes: Seed	Insecticides	Lambda-cyhalothrin	10.00	10.00	32.62	0.004	0.135
Potatoes	Potatoes: Seed	Insecticides	Methamidophos	10.00	10.00	14.00	0.209	2.925
Potatoes	Potatoes: Seed	Insecticides	Oxamyl	10.00	10.00	1.01	1.674	1.695
Potatoes	Potatoes: Seed	Insecticides	Profenofos	10.00	10.00	2.67	0.375	1.000
Potatoes	Potatoes: Seed	Fungicides	Azoxystrobin	10.00	10.00	0.60	0.500	0.300
Potatoes	Potatoes: Seed	Fungicides	Chlorothalonil	10.00	10.00	21.50	1.000	21.500
Potatoes	Potatoes: Seed	Fungicides	Copper-carbonate	10.00	10.00	14.40	3.305	47.592
Potatoes	Potatoes: Seed	Fungicides	Copper-oxychloride	10.00	10.00	12.80	4.250	54.400
Potatoes	Potatoes: Seed	Fungicides	Cymoxanil	10.00	10.00	2.00	0.150	0.300
Potatoes	Potatoes: Seed	Fungicides	Mancozeb	10.00	10.00	62.00	1.875	116.250

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Potatoes	Potatoes: Seed	Fungicides	Propineb	10.00	10.00	2.96	1.750	5.180
Potatoes	Potatoes: Seed	Fungicides	Tebuconazole	10.00	10.00	10.93	0.188	2.050
Potatoes	Potatoes: Seed	Herbicides	Alachlor	10.00	7.00	2.53	1.667	4.224
Potatoes	Potatoes: Seed	Herbicides	EPTC	10.00	7.00	2.00	2.880	5.760
Potatoes	Potatoes: Seed	Herbicides	Fluazifop-P-b	10.00	7.00	0.15	0.300	0.045
Potatoes	Potatoes: Seed	Herbicides	Linuron	10.00	7.00	0.12	1.250	0.150
Potatoes	Potatoes: Seed	Herbicides	Metribuzin	10.00	7.00	1.67	0.864	1.440
Potatoes	Potatoes: Seed	Herbicides	Rimsulfuron	10.00	7.00	1.00	0.025	0.025
Small Grains	Sorghum	Insecticides	Alphacypermethrin	87.00	87.00	19.58	0.008	0.160
Small Grains	Sorghum	Insecticides	Benfuracarb	87.00	87.00	7.75	0.200	1.548
Small Grains	Sorghum	Insecticides	Betacyfluthrin	87.00	87.00	1.00	0.015	0.015
Small Grains	Sorghum	Insecticides	Carbofuran	87.00	87.00	2.57	1.300	3.344
Small Grains	Sorghum	Insecticides	Cypermethrin	87.00	87.00	305.80	0.022	6.829
Small Grains	Sorghum	Insecticides	Deltamethrin	87.00	87.00	4.30	0.008	0.036
Small Grains	Sorghum	Insecticides	Esfenvalerate	87.00	87.00	2.08	0.012	0.025
Small Grains	Sorghum	Insecticides	Fenpyroximate	87.00	87.00	18.86	0.175	3.300
Small Grains	Sorghum	Insecticides	Lambda-cyhalothrin	87.00	87.00	81.96	0.004	0.353
Small Grains	Sorghum	Insecticides	Thiodicarb	87.00	87.00	2.00	0.125	0.250
Small Grains	Sorghum	Herbicides	2.4-D-amine	87.00	87.00	23.41	0.960	22.471
Small Grains	Sorghum	Herbicides	Alachlor	87.00	87.00	20.21	1.433	28.954
Small Grains	Sorghum	Herbicides	Atrazine	87.00	87.00	20.42	2.106	43.015
Small Grains	Sorghum	Herbicides	Bentazone	87.00	87.00	0.25	1.920	0.480
Small Grains	Sorghum	Herbicides	Bromoxynil	87.00	87.00	2.53	0.284	0.720
Small Grains	Sorghum	Herbicides	MCPA	87.00	87.00	8.13	0.960	7.800

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Small Grains	Sorghum	Herbicides	Metolachlor	87.00	87.00	9.80	1.440	14.112
Small Grains	Sorghum	Herbicides	s-metolachlor	87.00	87.00	11.67	0.308	3.598
Small Grains	Sorghum	Herbicides	Terbuthylazine	87.00	87.00	12.87	1.399	18.001
Small Grains	Sorghum	Seed dressing	Imidacloprid	87.00	6.69	6.69	0.385	2.577
Soybeans	Soybeans	Insecticides	Alphacypermethrin	164.00	120.00	4.00	0.010	0.040
Soybeans	Soybeans	Insecticides	Betacyfluthrin	164.00	120.00	1.00	0.015	0.015
Soybeans	Soybeans	Insecticides	Chlorpyrifos	164.00	120.00	24.40	0.240	5.856
Soybeans	Soybeans	Insecticides	Cypermethrin	164.00	120.00	108.12	0.028	3.029
Soybeans	Soybeans	Insecticides	Deltamethrin	164.00	120.00	4.43	0.010	0.046
Soybeans	Soybeans	Insecticides	Lambda-cyhalothrin	164.00	120.00	74.50	0.005	0.373
Soybeans	Soybeans	Fungicides	Benomyl	164.00	31.10	10.60	0.250	2.650
Soybeans	Soybeans	Fungicides	Epoxiconazole	164.00	31.10	13.00	0.063	0.813
Soybeans	Soybeans	Fungicides	Flusilazole	164.00	31.10	15.00	0.100	1.500
Soybeans	Soybeans	Fungicides	Pyraclostrobin	164.00	31.10	13.00	0.063	0.813
Soybeans	Soybeans	Herbicides	2.4-DB	164.00	160.00	0.43	0.800	0.346
Soybeans	Soybeans	Herbicides	Acetochlor	164.00	160.00	27.67	1.350	37.354
Soybeans	Soybeans	Herbicides	Alachlor	164.00	160.00	28.45	1.481	42.136
Soybeans	Soybeans	Herbicides	Bentazone	164.00	160.00	18.00	1.200	21.600
Soybeans	Soybeans	Herbicides	Chlorimuron-e	164.00	160.00	79.41	0.010	0.765
Soybeans	Soybeans	Herbicides	Fluazifop-P-b	164.00	160.00	0.45	0.300	0.135
Soybeans	Soybeans	Herbicides	Flumetsulam	164.00	160.00	4.17	0.024	0.100
Soybeans	Soybeans	Herbicides	Glyphosate	164.00	160.00	357.00	0.810	289.170
Soybeans	Soybeans	Herbicides	Imazethapyr	164.00	160.00	78.17	0.045	3.500
Soybeans	Soybeans	Herbicides	Metolachlor	164.00	160.00	53.02	1.385	73.454

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Soybeans	Soybeans	Herbicides	Metribuzin	164.00	160.00	4.44	0.864	3.840
Soybeans	Soybeans	Herbicides	Paraquat	164.00	160.00	6.67	0.828	5.520
Soybeans	Soybeans	Herbicides	Pendimethalin	164.00	160.00	1.60	1.250	2.000
Soybeans	Soybeans	Herbicides	Propaquizafop	164.00	160.00	2.38	0.075	0.178
Soybeans	Soybeans	Herbicides	Trifluralin	164.00	160.00	1.33	0.720	0.960
Soybeans	Soybeans	Seed dressing	Metalaxyl-M	164.00	164.00	164.00	0.003	0.431
Sugar Cane	Sugar Cane	Herbicides	2.4-D	430.00	430.00	11.67	0.900	10.500
Sugar Cane	Sugar Cane	Herbicides	2.4-D-amine	430.00	430.00	10.90	0.960	10.464
Sugar Cane	Sugar Cane	Herbicides	Acetochlor	430.00	430.00	4.49	1.651	7.407
Sugar Cane	Sugar Cane	Herbicides	Alachlor	430.00	430.00	13.13	1.871	24.576
Sugar Cane	Sugar Cane	Herbicides	Ametryn	430.00	430.00	65.06	1.227	79.810
Sugar Cane	Sugar Cane	Herbicides	Atrazine	430.00	430.00	50.12	1.515	75.924
Sugar Cane	Sugar Cane	Herbicides	Chlorimuron-e	430.00	430.00	7.99	0.018	0.140
Sugar Cane	Sugar Cane	Herbicides	Diquat	430.00	430.00	7.50	0.160	1.200
Sugar Cane	Sugar Cane	Herbicides	Diuron	430.00	430.00	43.37	2.213	96.000
Sugar Cane	Sugar Cane	Herbicides	Fluazifop-P-b	430.00	430.00	0.24	0.750	0.180
Sugar Cane	Sugar Cane	Herbicides	Glyphosate	430.00	430.00	85.67	3.136	268.650
Sugar Cane	Sugar Cane	Herbicides	Glyphosate-trimesium	430.00	430.00	6.75	2.000	13.500
Sugar Cane	Sugar Cane	Herbicides	Hexazinone	430.00	430.00	32.31	2.618	84.607
Sugar Cane	Sugar Cane	Herbicides	Ioxynil	430.00	430.00	11.67	0.150	1.750
Sugar Cane	Sugar Cane	Herbicides	Mesotrione	430.00	430.00	33.33	0.563	18.750
Sugar Cane	Sugar Cane	Herbicides	Metribuzin	430.00	430.00	63.33	1.440	91.200
Sugar Cane	Sugar Cane	Herbicides	MSMA	430.00	430.00	107.24	2.205	236.468
Sugar Cane	Sugar Cane	Herbicides	Paraquat	430.00	430.00	85.94	0.481	41.310

Crop group	**Crop**	**Sector**	**Active Ingredient (AI)**	**Crop area (x 10^3 ha)**	**Base area (x 10^3 ha)**	**AI Area Treated (x 10^3 ha)**	**AI dose rate (kg or L/ha)**	**AI volume (10^3 kg or L)**
Sugar Cane	Sugar Cane	Herbicides	s-metolachlor	430.00	430.00	33.33	1.688	56.250
Sugar Cane	Sugar Cane	Herbicides	Sulcotrione	430.00	430.00	3.37	0.313	1.054
Sugar Cane	Sugar Cane	Herbicides	Terbuthylazine	430.00	430.00	33.33	0.169	5.625
Sugar Cane	Sugar Cane	Herbicides	Trifluralin	430.00	430.00	5.22	0.864	4.512
Sugar Cane	Sugar Cane	Growth regulators	Ethephon	430.00	38.36	37.10	0.720	26.712
Sugar Cane	Sugar Cane	Growth regulators	Fluazifop-P-b	430.00	38.36	1.26	0.671	0.843
Sunflower	Sunflower	Insecticides	Betacyfluthrin	554.00	98.91	0.33	0.015	0.005
Sunflower	Sunflower	Insecticides	Carbofuran	554.00	98.91	0.51	2.500	1.270
Sunflower	Sunflower	Insecticides	Cypermethrin	554.00	98.91	89.67	0.054	4.829
Sunflower	Sunflower	Insecticides	Deltamethrin	554.00	98.91	3.90	0.007	0.026
Sunflower	Sunflower	Insecticides	Lambda-cyhalothrin	554.00	98.91	4.50	0.035	0.158
Sunflower	Sunflower	Fungicides	Benomyl	554.00	10.60	10.60	0.250	2.650
Sunflower	Sunflower	Herbicides	Alachlor	554.00	155.02	28.64	1.490	42.674
Sunflower	Sunflower	Herbicides	Flurochloridone	554.00	155.02	0.59	0.800	0.470
Sunflower	Sunflower	Herbicides	Imazamox	554.00	155.02	19.50	0.033	0.644
Sunflower	Sunflower	Herbicides	Imazapyr	554.00	155.02	19.50	0.015	0.293
Sunflower	Sunflower	Herbicides	Metolachlor	554.00	155.02	9.80	1.440	14.112
Sunflower	Sunflower	Herbicides	Paraquat	554.00	155.02	4.18	0.568	2.375
Sunflower	Sunflower	Herbicides	Trifluralin	554.00	155.02	92.31	0.624	57.600
Sunflower	Sunflower	Seed dressing	Imidacloprid	554.00	93.51	16.67	0.147	2.450
Sunflower	Sunflower	Seed dressing	Metalaxyl-M	554.00	93.51	70.18	0.030	2.100
Sunflower	Sunflower	Seed dressing	Thiamethoxam	554.00	93.51	6.67	0.105	0.700
Tomatoes	Tomatoes	Insecticides	Abamectin	11.20	11.20	55.25	0.009	0.501
Tomatoes	Tomatoes	Insecticides	Acephate	11.20	11.20	2.21	0.592	1.307

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Tomatoes	Tomatoes	Insecticides	Acrinathrin	11.20	11.20	1.50	0.060	0.090
Tomatoes	Tomatoes	Insecticides	Alphacypermethrin	11.20	11.20	12.00	0.010	0.120
Tomatoes	Tomatoes	Insecticides	Betacyfluthrin	11.20	11.20	2.33	0.015	0.035
Tomatoes	Tomatoes	Insecticides	Bifenthrin	11.20	11.20	3.00	0.017	0.050
Tomatoes	Tomatoes	Insecticides	Cartap	11.20	11.20	25.00	0.400	10.000
Tomatoes	Tomatoes	Insecticides	Chlorpyrifos	11.20	11.20	20.80	0.240	4.992
Tomatoes	Tomatoes	Insecticides	Cypermethrin	11.20	11.20	80.00	0.030	2.400
Tomatoes	Tomatoes	Insecticides	Deltamethrin	11.20	11.20	17.50	0.007	0.125
Tomatoes	Tomatoes	Insecticides	Emamectin	11.20	11.20	15.00	0.010	0.150
Tomatoes	Tomatoes	Insecticides	Endosulfan	11.20	11.20	1.87	0.750	1.400
Tomatoes	Tomatoes	Insecticides	Esfenvalerate	11.20	11.20	0.33	0.030	0.010
Tomatoes	Tomatoes	Insecticides	Ethylene-dibromide	11.20	11.20	0.03	45.000	1.530
Tomatoes	Tomatoes	Insecticides	Fenamiphos	11.20	11.20	15.71	1.338	21.020
Tomatoes	Tomatoes	Insecticides	Gamma-cyhalothrin	11.20	11.20	147.06	0.001	0.150
Tomatoes	Tomatoes	Insecticides	Lambda-cyhalothrin	11.20	11.20	84.50	0.003	0.238
Tomatoes	Tomatoes	Insecticides	Lufenuron	11.20	11.20	5.75	0.020	0.115
Tomatoes	Tomatoes	Insecticides	Methamidophos	11.20	11.20	1.34	0.293	0.393
Tomatoes	Tomatoes	Insecticides	Methomyl	11.20	11.20	0.21	0.300	0.064
Tomatoes	Tomatoes	Insecticides	Oxamyl	11.20	11.20	9.44	0.629	5.943
Tomatoes	Tomatoes	Insecticides	Profenofos	11.20	11.20	5.13	0.613	3.150
Tomatoes	Tomatoes	Insecticides	Propargite	11.20	11.20	0.06	0.600	0.033
Tomatoes	Tomatoes	Insecticides	Spinosad	11.20	11.20	3.33	0.072	0.240
Tomatoes	Tomatoes	Fungicides	Benomyl	11.20	11.20	17.67	0.150	2.650
Tomatoes	Tomatoes	Fungicides	Boscalid	11.20	11.20	11.33	0.076	0.857

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Tomatoes	Tomatoes	Fungicides	Chlorothalonil	11.20	11.20	25.72	0.951	24.459
Tomatoes	Tomatoes	Fungicides	Copper-carbonate	11.20	11.20	15.40	3.305	50.897
Tomatoes	Tomatoes	Fungicides	Copper-hydroxide	11.20	11.20	10.00	1.076	10.760
Tomatoes	Tomatoes	Fungicides	Copper-oxychloride	11.20	11.20	64.83	2.557	165.750
Tomatoes	Tomatoes	Fungicides	Copper-sulphate	11.20	11.20	0.35	1.700	0.595
Tomatoes	Tomatoes	Fungicides	Cymoxanil	11.20	11.20	5.02	0.123	0.618
Tomatoes	Tomatoes	Fungicides	Iprodione	11.20	11.20	5.00	0.510	2.550
Tomatoes	Tomatoes	Fungicides	Mancozeb	11.20	11.20	120.95	2.338	282.736
Tomatoes	Tomatoes	Fungicides	Metalaxyl	11.20	11.20	4.15	0.168	0.696
Tomatoes	Tomatoes	Fungicides	Metalaxyl-M	11.20	11.20	6.76	0.061	0.413
Tomatoes	Tomatoes	Fungicides	Procymidone	11.20	11.20	0.24	0.125	0.030
Tomatoes	Tomatoes	Fungicides	Propamocarb-HCl	11.20	11.20	0.01	72.200	0.866
Tomatoes	Tomatoes	Fungicides	Propineb	11.20	11.20	7.40	1.400	10.360
Tomatoes	Tomatoes	Fungicides	Pyraclostrobin	11.20	11.20	11.33	0.038	0.435
Tomatoes	Tomatoes	Fungicides	Sulphur	11.20	11.20	0.35	18.000	6.300
Tomatoes	Tomatoes	Fungicides	Tebuconazole	11.20	11.20	3.40	0.250	0.850
Tomatoes	Tomatoes	Fungicides	Zineb	11.20	11.20	0.63	1.680	1.050
Tomatoes	Tomatoes	Herbicides	Glyphosate	11.20	11.20	0.56	3.240	1.800
Tomatoes	Tomatoes	Herbicides	Glyphosate-trimesium	11.20	11.20	0.05	2.000	0.100
Tomatoes	Tomatoes	Herbicides	Metribuzin	11.20	11.20	0.67	0.720	0.480
Tomatoes	Tomatoes	Herbicides	Paraquat	11.20	11.20	30.27	0.408	12.350
Tomatoes	Tomatoes	Herbicides	Propaquizafop	11.20	11.20	3.17	0.075	0.238
Tomatoes	Tomatoes	Herbicides	Rimsulfuron	11.20	11.20	2.00	0.025	0.050
Tomatoes	Tomatoes	Herbicides	Trifluralin	11.20	11.20	0.80	0.720	0.576

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Vines/grapes	Grapes-table	Insecticides	Betacyfluthrin	23.00	23.00	0.33	0.015	0.005
Vines/grapes	Grapes-table	Insecticides	Carbaryl	23.00	23.00	0.74	0.800	0.594
Vines/grapes	Grapes-table	Insecticides	Chlorpyrifos	23.00	23.00	6.60	0.480	3.168
Vines/grapes	Grapes-table	Insecticides	Cypermethrin	23.00	23.00	30.00	0.020	0.600
Vines/grapes	Grapes-table	Insecticides	Deltamethrin	23.00	23.00	1.20	0.025	0.030
Vines/grapes	Grapes-table	Insecticides	Dichlorvos(DDVP)	23.00	23.00	0.15	3.750	0.566
Vines/grapes	Grapes-table	Insecticides	Esfenvalerate	23.00	23.00	0.50	0.010	0.005
Vines/grapes	Grapes-table	Insecticides	Fenamiphos	23.00	23.00	0.09	3.617	0.340
Vines/grapes	Grapes-table	Insecticides	Metaldehyde	23.00	23.00	1.59	0.666	1.061
Vines/grapes	Grapes-table	Insecticides	Methiocarb	23.00	23.00	0.85	0.100	0.085
Vines/grapes	Grapes-table	Insecticides	Profenofos	23.00	23.00	7.14	0.280	2.000
Vines/grapes	Grapes-table	Insecticides	Propoxur	23.00	23.00	0.19	0.400	0.075
Vines/grapes	Grapes-table	Insecticides	Sulphur	23.00	23.00	2.42	4.000	9.660
Vines/grapes	Grapes-table	Fungicides	Azoxystrobin	23.00	23.00	24.29	0.053	1.282
Vines/grapes	Grapes-table	Fungicides	Boscalid	23.00	23.00	8.92	0.146	1.300
Vines/grapes	Grapes-table	Fungicides	Carbendazim	23.00	23.00	0.46	0.200	0.091
Vines/grapes	Grapes-table	Fungicides	Copper-oxychloride	23.00	23.00	3.25	3.400	11.050
Vines/grapes	Grapes-table	Fungicides	Copper-sulphate	23.00	23.00	11.18	1.445	16.150
Vines/grapes	Grapes-table	Fungicides	Cymoxanil	23.00	23.00	4.50	0.113	0.510
Vines/grapes	Grapes-table	Fungicides	Dimethomorph	23.00	23.00	7.90	0.180	1.422
Vines/grapes	Grapes-table	Fungicides	Dinocap	23.00	23.00	0.10	0.350	0.035
Vines/grapes	Grapes-table	Fungicides	Famoxadone	23.00	23.00	3.25	0.090	0.293
Vines/grapes	Grapes-table	Fungicides	Folpet	23.00	23.00	14.47	0.121	1.745
Vines/grapes	Grapes-table	Fungicides	Fosetyl-Al	23.00	23.00	1.89	1.452	2.750

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Vines/grapes	Grapes-table	Fungicides	Hexaconazole	23.00	23.00	1.26	0.012	0.014
Vines/grapes	Grapes-table	Fungicides	Iprodione	23.00	23.00	2.19	0.529	1.157
Vines/grapes	Grapes-table	Fungicides	Iprovalicarb	23.00	23.00	32.80	0.018	0.574
Vines/grapes	Grapes-table	Fungicides	Kresoxim-m	23.00	23.00	6.68	0.031	0.210
Vines/grapes	Grapes-table	Fungicides	Mancozeb	23.00	23.00	32.87	1.772	58.249
Vines/grapes	Grapes-table	Fungicides	Maneb	23.00	23.00	7.74	0.870	6.735
Vines/grapes	Grapes-table	Fungicides	Metalaxyl	23.00	23.00	2.61	0.110	0.288
Vines/grapes	Grapes-table	Fungicides	Metiram	23.00	23.00	3.00	0.550	1.650
Vines/grapes	Grapes-table	Fungicides	Metrafenone	23.00	23.00	3.20	0.125	0.400
Vines/grapes	Grapes-table	Fungicides	Potassium-phosphite	23.00	23.00	12.99	0.840	10.912
Vines/grapes	Grapes-table	Fungicides	Procymidone	23.00	23.00	0.06	0.500	0.030
Vines/grapes	Grapes-table	Fungicides	Propineb	23.00	23.00	34.16	0.194	6.624
Vines/grapes	Grapes-table	Fungicides	Pyraclostrobin	23.00	23.00	3.00	0.050	0.150
Vines/grapes	Grapes-table	Fungicides	Pyrimethanil	23.00	23.00	2.09	0.288	0.603
Vines/grapes	Grapes-table	Fungicides	Quinoxyfen	23.00	23.00	10.00	0.063	0.625
Vines/grapes	Grapes-table	Fungicides	Spiroxamine	23.00	23.00	13.33	0.225	3.000
Vines/grapes	Grapes-table	Fungicides	Sulphur	23.00	23.00	27.10	9.644	261.340
Vines/grapes	Grapes-table	Fungicides	Tebuconazole	23.00	23.00	1.00	0.025	0.025
Vines/grapes	Grapes-table	Fungicides	Triadimefon	23.00	23.00	0.46	0.165	0.075
Vines/grapes	Grapes-table	Fungicides	Triadimenol	23.00	23.00	1.50	0.025	0.038
Vines/grapes	Grapes-table	Herbicides	Diquat	23.00	23.00	10.33	0.240	2.480
Vines/grapes	Grapes-table	Herbicides	Fluazifop-P-b	23.00	23.00	0.40	0.300	0.120
Vines/grapes	Grapes-table	Herbicides	Glufosinate-ammonium	23.00	23.00	1.20	1.500	1.800
Vines/grapes	Grapes-table	Herbicides	Glyphosate	23.00	23.00	4.50	4.320	19.440

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Vines/grapes	Grapes-table	Herbicides	Glyphosate-trimesium	23.00	23.00	0.60	2.500	1.500
Vines/grapes	Grapes-table	Herbicides	Haloxyfop-r-m	23.00	23.00	2.00	0.162	0.324
Vines/grapes	Grapes-table	Herbicides	Oxadiazon	23.00	23.00	0.03	1.500	0.050
Vines/grapes	Grapes-table	Herbicides	Paraquat	23.00	23.00	24.20	0.438	10.600
Vines/grapes	Grapes-table	Herbicides	Simazine	23.00	23.00	10.47	1.003	10.500
Vines/grapes	Grapes-table	Herbicides	Terbuthylazine	23.00	23.00	5.43	1.750	9.500
Vines/grapes	Grapes-table	Herbicides	Trifluralin	23.00	23.00	0.18	3.840	0.672
Vines/grapes	Grapes-table	Growth regulators	Cyanamide	23.00	23.00	38.00	4.900	186.200
Vines/grapes	Grapes-table	Growth regulators	Ethephon	23.00	23.00	14.23	0.192	2.732
Vines/grapes	Grapes-table	Growth regulators	Gibberellic-acid	23.00	23.00	34.00	0.031	1.054
Vines/grapes	Grapes-wine	Insecticides	Carbaryl	97.00	97.00	4.75	0.800	3.800
Vines/grapes	Grapes-wine	Insecticides	Chlorpyrifos	97.00	97.00	15.00	0.480	7.200
Vines/grapes	Grapes-wine	Insecticides	Chlorpyrifos-e	97.00	97.00	17.50	1.920	33.600
Vines/grapes	Grapes-wine	Insecticides	Cypermethrin	97.00	97.00	110.00	0.040	4.400
Vines/grapes	Grapes-wine	Insecticides	Deltamethrin	97.00	97.00	0.79	0.025	0.020
Vines/grapes	Grapes-wine	Insecticides	Dichlorvos(DDVP)	97.00	97.00	0.15	3.750	0.566
Vines/grapes	Grapes-wine	Insecticides	Esfenvalerate	97.00	97.00	0.50	0.010	0.005
Vines/grapes	Grapes-wine	Insecticides	Fenamiphos	97.00	97.00	0.83	3.639	3.020
Vines/grapes	Grapes-wine	Insecticides	Metaldehyde	97.00	97.00	8.85	0.737	6.520
Vines/grapes	Grapes-wine	Insecticides	Methiocarb	97.00	97.00	5.30	0.258	1.370
Vines/grapes	Grapes-wine	Insecticides	Profenofos	97.00	97.00	12.00	0.250	3.000
Vines/grapes	Grapes-wine	Insecticides	Propoxur	97.00	97.00	0.56	0.400	0.225
Vines/grapes	Grapes-wine	Insecticides	Sulphur	97.00	97.00	2.42	4.000	9.660
Vines/grapes	Grapes-wine	Fungicides	Azoxystrobin	97.00	97.00	83.24	0.056	4.693

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Vines/grapes	Grapes-wine	Fungicides	Boscalid	97.00	97.00	25.83	0.093	2.400
Vines/grapes	Grapes-wine	Fungicides	Carbendazim	97.00	97.00	0.46	0.200	0.091
Vines/grapes	Grapes-wine	Fungicides	Copper	97.00	97.00	33.72	0.788	26.558
Vines/grapes	Grapes-wine	Fungicides	Copper-hydroxide	97.00	97.00	80.00	0.807	64.560
Vines/grapes	Grapes-wine	Fungicides	Copper-oxychloride	97.00	97.00	37.75	3.400	128.350
Vines/grapes	Grapes-wine	Fungicides	Copper-sulphate	97.00	97.00	15.50	1.700	26.350
Vines/grapes	Grapes-wine	Fungicides	Cymoxanil	97.00	97.00	30.60	0.099	3.042
Vines/grapes	Grapes-wine	Fungicides	Dimethomorph	97.00	97.00	29.00	0.180	5.220
Vines/grapes	Grapes-wine	Fungicides	Dinocap	97.00	97.00	0.50	0.350	0.175
Vines/grapes	Grapes-wine	Fungicides	Famoxadone	97.00	97.00	3.50	0.090	0.315
Vines/grapes	Grapes-wine	Fungicides	Folpet	97.00	97.00	45.49	0.110	4.995
Vines/grapes	Grapes-wine	Fungicides	Fosetyl-Al	97.00	97.00	10.94	1.344	14.710
Vines/grapes	Grapes-wine	Fungicides	Hexaconazole	97.00	97.00	11.31	0.012	0.130
Vines/grapes	Grapes-wine	Fungicides	Iprodione	97.00	97.00	6.09	0.517	3.146
Vines/grapes	Grapes-wine	Fungicides	Iprovalicarb	97.00	97.00	44.00	0.018	0.770
Vines/grapes	Grapes-wine	Fungicides	Kresoxim-m	97.00	97.00	23.35	0.030	0.710
Vines/grapes	Grapes-wine	Fungicides	Mancozeb	97.00	97.00	248.24	1.503	373.009
Vines/grapes	Grapes-wine	Fungicides	Maneb	97.00	97.00	7.74	0.870	6.735
Vines/grapes	Grapes-wine	Fungicides	Metalaxyl	97.00	97.00	4.46	0.121	0.538
Vines/grapes	Grapes-wine	Fungicides	Metiram	97.00	97.00	7.00	0.550	3.850
Vines/grapes	Grapes-wine	Fungicides	Metrafenone	97.00	97.00	12.00	0.125	1.500
Vines/grapes	Grapes-wine	Fungicides	Potassium-phosphite	97.00	97.00	12.99	0.840	10.912
Vines/grapes	Grapes-wine	Fungicides	Procymidone	97.00	97.00	0.06	0.500	0.030
Vines/grapes	Grapes-wine	Fungicides	Propineb	97.00	97.00	70.25	0.516	36.220

Crop group	Crop	Sector	Active Ingredient (AI)	Crop area (x 10^3 ha)	Base area (x 10^3 ha)	AI Area Treated (x 10^3 ha)	AI dose rate (kg or L/ha)	AI volume (10^3 kg or L)
Vines/grapes	Grapes-wine	Fungicides	Pyraclostrobin	97.00	97.00	7.00	0.050	0.350
Vines/grapes	Grapes-wine	Fungicides	Pyrimethanil	97.00	97.00	15.98	0.288	4.603
Vines/grapes	Grapes-wine	Fungicides	Quinoxyfen	97.00	97.00	10.00	0.063	0.625
Vines/grapes	Grapes-wine	Fungicides	Spiroxamine	97.00	97.00	55.56	0.225	12.500
Vines/grapes	Grapes-wine	Fungicides	Sulphur	97.00	97.00	514.40	3.753	1,930.760
Vines/grapes	Grapes-wine	Fungicides	Tebuconazole	97.00	97.00	14.00	0.025	0.350
Vines/grapes	Grapes-wine	Fungicides	Triadimefon	97.00	97.00	0.79	0.121	0.095
Vines/grapes	Grapes-wine	Fungicides	Triadimenol	97.00	97.00	14.50	0.014	0.200
Vines/grapes	Grapes-wine	Herbicides	Diquat	97.00	97.00	13.33	0.240	3.200
Vines/grapes	Grapes-wine	Herbicides	Fluazifop-P-b	97.00	97.00	3.55	0.300	1.065
Vines/grapes	Grapes-wine	Herbicides	Glufosinate-ammonium	97.00	97.00	2.67	1.500	4.000
Vines/grapes	Grapes-wine	Herbicides	Glyphosate	97.00	97.00	69.17	4.320	298.800
Vines/grapes	Grapes-wine	Herbicides	Glyphosate-trimesium	97.00	97.00	7.12	2.500	17.800
Vines/grapes	Grapes-wine	Herbicides	Haloxyfop-r-m	97.00	97.00	17.33	0.162	2.808
Vines/grapes	Grapes-wine	Herbicides	MCPA	97.00	97.00	10.40	2.000	20.800
Vines/grapes	Grapes-wine	Herbicides	Oxadiazon	97.00	97.00	0.15	1.500	0.225
Vines/grapes	Grapes-wine	Herbicides	Paraquat	97.00	97.00	58.13	0.468	27.200
Vines/grapes	Grapes-wine	Herbicides	Simazine	97.00	97.00	14.33	0.802	11.500
Vines/grapes	Grapes-wine	Herbicides	Terbuthylazine	97.00	97.00	11.14	1.750	19.500
Vines/grapes	Grapes-wine	Herbicides	Trifluralin	97.00	97.00	0.18	3.840	0.672

Table A3: Toxicity and half-life scores and calculated indices (Toxicity Potential – *TP*; Environmental Exposure Potential – *EEP*; Hazard Potential – *HP*; Quantity Index – *QI* and Weighted Hazard Potential) for active ingredients used in South Africa

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
2,4-D	Possible	6	possible	6	No	0	Yes	4	Yes	4	10	1	21	1	21	10.50	19024	0.0006	**0.0116**
2,4-D-amine	Possible	6	No Data	4	No Data	2	No Data	1	No Data	1	10	1	15	1	15	355.10	19024	0.0187	**0.2800**
2,4-DB	No	0	possible	6	Possible	4	No	0	No	0	16	2	11	2	22	0.35	19024	0.0000	**0.0004**
2,4-D-ester	Possible	6	No Data	4	No	0	No Data	1	No Data	1	10	1	13	1	13	24.38	19024	0.0013	**0.0167**
Abamectin	No	0	No	0	No	0	Yes	4	No	0	30	3	5	3	15	3.38	19024	0.0002	**0.0027**
Acephate	Possible	6	Yes	8	No	0	No Data	1	Yes	4	3	1	20	1	20	8.65	19024	0.0005	**0.0091**
Acetamiprid	No	0	No Data	4	No Data	2	No Data	1	No	0	3	1	8	1	8	3.70	19024	0.0002	**0.0016**
Acetochlor	Possible	6	possible	6	Yes	6	Yes	4	No	0	14	1	23	1	23	656.55	19024	0.0345	**0.7938**
Acrinathrin	Possible	6	No	0	No Data	2	Possible	2	Possible	2	39.2	3	13	3	39	0.09	19024	0.0000	**0.0002**
Alachlor	Possible	6	possible	6	No	0	Possible	2	No	0	14	1	15	1	15	287.04	19024	0.0151	**0.2263**
Aldicarb	Possible	6	Yes	8	No	0	Possible	2	Possible	2	10	1	19	1	19	105.00	19024	0.0055	**0.1049**
Alpha-cypermethrin	No Data	3	Possible	6	No Data	2	No Data	1	No Data	1	35	3	14	3	42	6.92	19024	0.0004	**0.0153**
Al-phosphide	No Data	3	No Data	4	No	0	Possible	2	No Data	1	0.2	1	11	1	11	1.17	19024	0.0001	**0.0007**
Ametryn	No Data	3	No Data	4	No	0	No Data	1	No Data	1	37	3	10	3	30	79.81	19024	0.0042	**0.1259**
Atrazine	Possible	6	possible	6	No	0	Possible	2	Possible	2	75	4	17	4	68	1,014.42	19024	0.0533	**3.6260**
Azinphos-methyl	No	0	No	0	No	0	No Data	1	Yes	4	10	1	6	1	6	55.37	19024	0.0029	**0.0175**
Azoxystrobin	No	0	No Data	4	No Data	2	Possible	2	No	0	70	4	9	4	36	13.43	19024	0.0007	**0.0254**
Benfuracarb	No	0	No	0	No Data	2	Possible	2	Possible	2	0.5	1	7	1	7	1.64	19024	0.0001	**0.0006**
Benomyl	Possible	6	Possible	6	Yes	6	Yes	4	No Data	1	180	4	24	4	96	30.55	19024	0.0016	**0.1541**
Bentazone	No	0	No	0	No Data	2	No	0	No	0	13	1	3	1	3	45.84	19024	0.0024	**0.0072**
Beta-cyfluthrin	No	0	No Data	4	No Data	2	Possible	2	Yes	4	13	1	13	1	13	1.08	19024	0.0001	**0.0007**
Beta-cypermethrin	Possible	6	Possible	6	No Data	2	No Data	1	No	0	10	1	16	1	16	0.74	19024	0.0000	**0.0006**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
Bifenthrin	Possible	6	Yes	8	Possible	4	Possible	2	Possible	2	95	4	23	4	92	0.15	19024	0.0000	**0.0007**
Bitertanol	No	0	No	0	Possible	4	Possible	2	No	0	23	2	7	2	14	0.39	19024	0.0000	**0.0003**
Boscalid	Possible	6	No	0	No Data	2	Possible	2	No	0	150	4	11	4	44	7.98	19024	0.0004	**0.0185**
Bromacil	Possible	6	No Data	4	No	0	No	0	No	0	60	4	11	4	44	9.60	19024	0.0005	**0.0222**
Bromoxynil	Possible	6	Yes	8	No Data	2	Possible	2	No	0	1	1	19	1	19	66.48	19024	0.0035	**0.0664**
Bupirimate	No	0	No	0	No Data	2	Possible	2	No	0	79	4	5	4	20	1.91	19024	0.0001	**0.0020**
Buprofenzin	Possible	6	No	0	No Data	2	Possible	2	No	0	50	3	11	3	33	2.65	19024	0.0001	**0.0046**
Captan	Yes	8	No	0	No	0	No Data	1	No	0	0.8	1	10	1	10	24.65	19024	0.0013	**0.0130**
Carbaryl	Possible	6	Yes	8	No	0	No Data	1	Possible	2	16	2	18	2	36	14.76	19024	0.0008	**0.0279**
Carbendazim	Possible	6	Possible	6	No Data	2	Yes	4	No	0	22	2	19	2	38	15.11	19024	0.0008	**0.0302**
Carbofuran	No	0	Yes	8	No	0	Yes	4	Possible	2	29	2	15	2	30	33.44	19024	0.0018	**0.0527**
Carbosulfan	No	0	No	0	No Data	2	Possible	2	No	0	21	2	5	2	10	0.60	19024	0.0000	**0.0003**
Cartap	No	0	No Data	4	No Data	2	No Data	1	No	0	3	1	8	1	8	18.48	19024	0.0010	**0.0078**
Chlorantraniliprole	No	0	No	0	No Data	2	No	0	No	0	210	4	3	4	12	0.15	19024	0.0000	**0.0001**
Chlorfenapyr	Possible	6	No Data	4	No Data	2	No	0	No	0	0	1	13	1	13	5.04	19024	0.0003	**0.0034**
Chloridazon	No	0	No Data	4	No Data	2	No	0	No	0	31	3	7	3	21	2.54	19024	0.0001	**0.0028**
Chlorimuron-ethyl	No	0	No Data	4	No Data	2	Possible	2	No	0	40	3	9	3	27	0.91	19024	0.0000	**0.0013**
Chlormequat-chloride	No	0	No Data	4	No Data	2	Yes	4	Possible	2	10	1	13	1	13	11.03	19024	0.0006	**0.0075**
Chlorothalonil	Possible	6	No	0	No	0	No Data	1	No	0	22	2	8	2	16	140.01	19024	0.0074	**0.1178**
Chlorpyrifos	No	0	Possible	6	No	0	Yes	4	No	0	50	3	11	3	33	148.47	19024	0.0078	**0.2575**
Clodinafop	No Data	3	No Data	4	No Data	2	No Data	1	No Data	1	12	1	12	1	12	2.93	19024	0.0002	**0.0018**
Copper	No	0	Yes	8	Possible	4	Possible	2	No	0	100000	4	15	4	60	53.12	19024	0.0028	**0.1675**
Copper hydroxide	No	0	No	0	No Data	2	No Data	1	No	0	100000	4	4	4	16	177.56	19024	0.0093	**0.1493**
Copper oxychloride	No Data	3	No Data	4	No Data	2	No Data	1	No Data	1	100000	4	12	4	48	1,225.81	19024	0.0644	**3.0929**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	***WHP***
Copper sulphate	No	0	No	0	Yes	6	Possible	2	No	0	100000	4	9	4	36	48.43	19024	0.0025	**0.0917**
Copper-carbonate	No	0	No	0	No Data	2	No Data	1	No	0	100000	4	4	4	16	148.73	19024	0.0078	**0.1251**
Cyanamide	Possible	6	No	0	No Data	2	Possible	2	No	0	1	1	11	1	11	203.25	19024	0.0107	**0.1175**
Cycloxydim	No	0	No Data	4	No Data	2	Possible	2	No	0	5	1	9	1	9	4.64	19024	0.0002	**0.0022**
Cymoxanil	No	0	No Data	4	No Data	2	Yes	4	No	0	0.7	1	11	1	11	9.09	19024	0.0005	**0.0053**
Cypermethrin	Possible	6	Possible	6	No	0	Possible	2	No	0	60	4	15	4	60	58.47	19024	0.0031	**0.1844**
Cyproconazole	Possible	6	No Data	4	No Data	2	Possible	2	No	0	114	4	15	4	60	3.92	19024	0.0002	**0.0124**
Deltamethrin	Possible	6	Yes	8	No	0	Possible	2	Yes	4	13	1	21	1	21	3.82	19024	0.0002	**0.0042**
Demeton-S-methyl	No	0	No	0	Yes	6	Possible	2	Yes	4	2.7	1	13	1	13	1.49	19024	0.0001	**0.0010**
Diazinon	No	0	Possible	6	Possible	4	Possible	2	Yes	4	9.1	1	17	1	17	0.84	19024	0.0000	**0.0007**
Dicamba	No	0	No Data	4	No	0	Possible	2	No	0	14	1	7	1	7	0.11	19024	0.0000	**0.0000**
Dichlorvos	Possible	6	Possible	6	Yes	6	No Data	1	Yes	4	2	1	24	1	24	5.67	19024	0.0003	**0.0072**
Difenoconazole	Possible	6	No Data	4	No Data	2	Possible	2	No	0	120	4	15	4	60	2.36	19024	0.0001	**0.0075**
Dimethenamid-P	Possible	6	No Data	4	No Data	2	No Data	1	No	0	11	1	14	1	14	45.72	19024	0.0024	**0.0336**
Dimethoate	Possible	6	Possible	6	No	0	Yes	4	No	0	2.6	1	17	1	17	35.38	19024	0.0019	**0.0316**
Dimethomorph	Possible	6	Possible	6	No	0	Yes	4	No	0	57	3	17	3	51	6.66	19024	0.0003	**0.0178**
Dinocap	No	0	No Data	4	No Data	2	Yes	4	No	0	5	1	11	1	11	0.94	19024	0.0000	**0.0005**
Diquat	No	0	No Data	4	No Data	2	No	0	No	0	3450	4	7	4	28	14.00	19024	0.0007	**0.0206**
Dithianon	No	0	No Data	4	No Data	2	No	0	No	0	21	2	7	2	14	3.65	19024	0.0002	**0.0027**
Diuron	Possible	6	possible	6	No	0	Possible	2	No	0	75.5	4	15	4	60	96.00	19024	0.0050	**0.3028**
Emamectin	No	0	No Data	4	No	0	Possible	2	No Data	1	300	4	8	4	32	0.27	19024	0.0000	**0.0004**
Endosulfan	Possible	6	Possible	6	Yes	6	No Data	1	Yes	4	50	3	24	3	72	12.37	19024	0.0007	**0.0468**
Epoxiconazole	Possible	6	No Data	4	No Data	2	Possible	2	No	0	354	4	15	4	60	18.86	19024	0.0010	**0.0595**
EPTC	No	0	No Data	4	No	0	Possible	2	Yes	4	6	1	11	1	11	178.43	19024	0.0094	**0.1032**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
Esfenvalerate	No	0	Possible	6	No	0	Possible	2	No	0	44	3	9	3	27	0.21	19024	0.0000	**0.0003**
Ethoprophos	Possible	6	No Data	4	No Data	2	No Data	1	Yes	4	17	2	18	2	36	0.44	19024	0.0000	**0.0008**
Ethylene-dibromide	Yes	8	Possible	6	No Data	2	Yes	4	Possible	2	100	4	23	4	92	252.49	19024	0.0133	**1.2210**
Famoxadone	No	0	No Data	4	No Data	2	Possible	2	Yes	4	6	1	13	1	13	3.36	19024	0.0002	**0.0023**
Fenamiphos	No	0	No Data	4	No	0	No Data	1	Yes	4	0.85	1	10	1	10	103.88	19024	0.0055	**0.0546**
Fenarimol	No	0	Yes	8	No Data	2	Possible	2	No	0	250	4	13	4	52	1.87	19024	0.0001	**0.0051**
Fenbuconazole	Possible	6	No Data	4	No Data	2	Possible	2	No	0	60	4	15	4	60	0.33	19024	0.0000	**0.0010**
Fenbutatin-oxide	No	0	No Data	4	No Data	2	Yes	4	No	0	365	4	11	4	44	3.45	19024	0.0002	**0.0080**
Fenoxaprop-P-ethyl	No Data	3	No Data	4	No Data	2	Possible	2	No Data	1	0.5	1	13	1	13	0.92	19024	0.0000	**0.0006**
Fenoxycarb	Possible	6	Yes	8	No	0	No Data	1	Possible	2	25	2	18	2	36	1.25	19024	0.0001	**0.0024**
Fenpyroximate	No	0	No Data	4	No Data	2	Yes	4	No	0	37	3	11	3	33	8.25	19024	0.0004	**0.0143**
Fenthion	Possible	6	No Data	4	No	0	No	0	Possible	2	22	2	13	2	26	1.70	19024	0.0001	**0.0023**
Fipronil	Possible	6	Possible	6	No Data	2	No Data	1	Yes	4	142	4	20	4	80	1.68	19024	0.0001	**0.0071**
Fluazifop-P-butyl	No	0	No	0	No	0	Possible	2	No	0	28	2	3	2	6	5.93	19024	0.0003	**0.0019**
Fludioxonil	Possible	6	No Data	4	No Data	2	Possible	2	No	0	125	4	15	4	60	0.88	19024	0.0000	**0.0027**
Flufenoxuron	Possible	6	Possible	6	No	0	No Data	1	No Data	1	42	3	15	3	45	0.69	19024	0.0000	**0.0016**
Flumetsulam	No	0	No Data	4	No Data	2	No Data	1	No	0	45	3	8	3	24	1.00	19024	0.0001	**0.0013**
Flurochloridone	No Data	3	No Data	4	No Data	2	Yes	4	No	0	92	4	14	4	56	0.94	19024	0.0000	**0.0027**
Flusilazole	Possible	6	No Data	4	No Data	2	Yes	4	No	0	300	4	17	4	68	6.00	19024	0.0003	**0.0214**
Flusulfamide	No Data	3	No Data	4	No Data	2	No Data	1	No Data	1	0	1	12	1	12	0.11	19024	0.0000	**0.0001**
Folpet	Yes	8	No Data	4	Possible	4	No Data	1	No	0	4.7	1	18	1	18	6.74	19024	0.0004	**0.0064**
Fosetyl-Al	Possible	6	No Data	4	No Data	2	No	0	Possible	2	0.1	1	15	1	15	30.92	19024	0.0016	**0.0244**
Fosthiazate	No	0	No Data	4	No Data	2	Possible	2	No	0	13	1	9	1	9	52.20	19024	0.0027	**0.0247**
Gamma-cyhalothrin	No	0	Possible	6	No Data	2	Possible	2	Yes	4	0	1	15	1	15	0.44	19024	0.0000	**0.0003**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
Glufosinate-ammonium	No	0	No	0	No Data	2	Yes	4	Yes	4	7.4	1	11	1	11	9.80	19024	0.0005	**0.0057**
Glyphosate	No	0	No Data	4	No	0	No	0	No	0	12	1	5	1	5	3,720.80	19024	0.1956	**0.9779**
Glyphosate-trimesium	No	0	No Data	4	No	0	No	0	No	0	17	2	5	2	10	79.85	19024	0.0042	**0.0420**
Guazatine	Possible	6	No Data	4	No Data	2	Possible	2	No Data	1	500	4	16	4	64	2.60	19024	0.0001	**0.0088**
Halosulfuron-m	No	0	No Data	4	No Data	2	No	0	No	0	55	3	7	3	21	0.49	19024	0.0000	**0.0005**
Haloxyfop-r-m	No	0	No Data	4	No Data	2	No	0	No	0	0.5	1	7	1	7	5.02	19024	0.0003	**0.0018**
Hexaconazole	Possible	6	No Data	4	No Data	2	No Data	1	No	0	122	4	14	4	56	0.32	19024	0.0000	**0.0009**
Hexazinone	No	0	No Data	4	No	0	Possible	2	No	0	105	4	7	4	28	84.61	19024	0.0044	**0.1245**
Imazalil	Possible	6	No	0	No	0	Yes	4	No	0	50	3	11	3	33	1.91	19024	0.0001	**0.0033**
Imazamox	No	0	No Data	4	No Data	2	Possible	2	No	0	25	2	9	2	18	11.04	19024	0.0006	**0.0104**
Imazapyr	No	0	No Data	4	No Data	2	No	0	No	0	11	1	7	1	7	0.29	19024	0.0000	**0.0001**
Imazethapyr	No	0	No Data	4	No	0	No	0	No	0	51	3	5	3	15	7.70	19024	0.0004	**0.0061**
Imidacloprid	No	0	No Data	4	Possible	4	Yes	4	Possible	2	191	4	15	4	60	252.17	19024	0.0133	**0.7953**
Indoxacarb	No	0	No Data	4	No Data	2	No	0	Yes	4	17	2	11	2	22	1.95	19024	0.0001	**0.0023**
Iodosulfuron-m-Na	No	0	No Data	4	No Data	2	No Data	1	Yes	4	8	1	12	1	12	0.63	19024	0.0000	**0.0004**
Ioxynil	No	0	Yes	8	No Data	2	Possible	2	No	0	6	1	13	1	13	2.55	19024	0.0001	**0.0017**
Iprodione	Yes	8	Possible	6	No Data	2	No Data	1	No	0	84	4	18	4	72	12.64	19024	0.0007	**0.0478**
Iprovalicarb	Yes	8	No Data	4	No Data	2	No Data	1	No	0	15.5	2	16	2	32	1.34	19024	0.0001	**0.0023**
Kresoxim-methyl	Possible	6	No Data	4	No Data	2	No	0	No	0	16	2	13	2	26	5.29	19024	0.0003	**0.0072**
Lambda-cyhalothrin	No Data	3	No Data	4	No	0	No	0	No Data	1	25	2	9	2	18	12.64	19024	0.0007	**0.0120**
Linuron	Possible	6	possible	6	No	0	Yes	4	No	0	48	3	17	3	51	0.55	19024	0.0000	**0.0015**
Lufenuron	No	0	No	0	No Data	2	Possible	2	No	0	16.3	2	5	2	10	0.66	19024	0.0000	**0.0003**
Malathion	Possible	6	Possible	6	Possible	4	Possible	2	Yes	4	0.18	1	23	1	23	2.71	19024	0.0001	**0.0033**
Mancozeb	Yes	8	Possible	6	Possible	4	Yes	4	No	0	0.1	1	23	1	23	2,849.02	19024	0.1498	**3.4445**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	***WHP***
Maneb	Possible	6	Possible	6	No	0	Yes	4	No	0	5	1	17	1	17	53.88	19024	0.0028	**0.0481**
MCPA	Possible	6	No	0	Possible	4	Possible	2	No	0	15	2	13	2	26	284.60	19024	0.0150	**0.3890**
Mefenpyr	No	0	No Data	4	No Data	2	No	0	No	0	17.5	2	7	2	14	1.89	19024	0.0001	**0.0014**
Mepiquat-chloride	No	0	No Data	4	No Data	2	No	0	No	0	26	2	7	2	14	0.25	19024	0.0000	**0.0002**
Mesotrione	No	0	No Data	4	No Data	2	No	0	No	0	5	1	7	1	7	92.45	19024	0.0049	**0.0340**
Metalaxyl	No	0	No Data	4	No	0	No	0	No	0	42	3	5	3	15	4.91	19024	0.0003	**0.0039**
Metalaxyl-M	No	0	No Data	4	No	0	No	0	No	0	39	3	5	3	15	14.16	19024	0.0007	**0.0112**
Metaldehyde	No	0	No Data	4	Possible	4	Possible	2	No	0	4.4	1	11	1	11	8.74	19024	0.0005	**0.0051**
Metazachlor	No	0	No Data	4	No Data	2	No Data	1	No	0	77	4	8	4	32	5.39	19024	0.0003	**0.0091**
Methamidophos	No	0	No Data	4	Yes	6	Possible	2	Yes	4	3	1	17	1	17	27.17	19024	0.0014	**0.0243**
Methidathion	Possible	6	No data	4	No	0	Possible	2	Yes	4	10	1	17	1	17	8.64	19024	0.0005	**0.0077**
Methiocarb	No	0	No Data	4	No Data	2	No Data	1	Yes	4	1.4	1	12	1	12	1.61	19024	0.0001	**0.0010**
Methomyl	No	0	Possible	6	No	0	Possible	2	Possible	2	7	1	11	1	11	30.38	19024	0.0016	**0.0176**
Metiram	Yes	8	Possible	6	No	0	No Data	1	No	0	1	1	16	1	16	21.81	19024	0.0011	**0.0183**
Metolachlor	Possible	6	possible	6	No	0	No Data	1	No	0	20	2	14	2	28	443.71	19024	0.0233	**0.6531**
Metrafenone	Possible	6	No Data	4	No Data	2	No	0	No	0	250.6	4	13	4	52	1.90	19024	0.0001	**0.0052**
Metribuzin	No	0	possible	6	No	0	Yes	4	No Data	1	11.5	1	12	1	12	106.08	19024	0.0056	**0.0669**
Metsulfuron-methyl	No	0	No Data	4	No	0	No	0	No	0	10	1	5	1	5	0.76	19024	0.0000	**0.0002**
Mevinphos	No	0	Yes	8	No Data	2	No Data	1	Yes	4	1.2	1	16	1	16	0.02	19024	0.0000	**0.0000**
MSMA	Possible	6	No Data	4	No Data	2	No Data	1	No	0	200	4	14	4	56	245.11	19024	0.0129	**0.7215**
Nicosulfuron	No	0	No Data	4	No	0	No Data	1	No	0	26	2	6	2	12	6.95	19024	0.0004	**0.0044**
Omethoate	No	0	No Data	4	No Data	2	No	0	Yes	4	14	1	11	1	11	6.40	19024	0.0003	**0.0037**
Oxadiazon	Possible	6	No Data	4	No Data	2	Yes	4	No	0	135	4	17	4	68	2.58	19024	0.0001	**0.0092**
Oxamyl	No	0	No Data	4	No	0	No Data	1	Yes	4	7	1	10	1	10	42.25	19024	0.0022	**0.0222**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
Paraquat	Possible	6	No	0	Yes	6	No	0	No	0	3000	4	13	4	52	345.13	19024	0.0181	**0.9434**
Parathion	No	0	Possible	6	No	0	No	0	No	0	49	3	7	3	21	16.00	19024	0.0008	**0.0177**
Parathion-methyl	Possible	6	Possible	6	No	0	No Data	1	Yes	4	12	1	18	1	18	6.98	19024	0.0004	**0.0066**
Penconazole	No	0	No Data	4	No Data	2	Yes	4	No	0	197	4	11	4	44	0.40	19024	0.0000	**0.0009**
Pencycuron	No	0	No Data	4	No Data	2	Possible	2	No	0	64	4	9	4	36	0.72	19024	0.0000	**0.0013**
Pendimethalin	Possible	6	Yes	8	No	0	No Data	1	No	0	90	4	16	4	64	14.65	19024	0.0008	**0.0493**
Pirimicarb	Possible	6	No Data	4	No Data	2	No	0	Yes	4	86	4	17	4	68	5.50	19024	0.0003	**0.0197**
Potassium-phosphite	No	0	No Data	4	No Data	2	No Data	1	No Data	1	157	4	9	4	36	236.15	19024	0.0124	**0.4469**
Prochloraz	Possible	6	Possible	6	No Data	2	No Data	1	No Data	1	120	4	17	4	68	0.16	19024	0.0000	**0.0006**
Procymidone	Yes	8	Yes	8	No Data	2	Yes	4	No Data	1	7	1	24	1	24	0.30	19024	0.0000	**0.0004**
Profenofos	No	0	No Data	4	No Data	2	No	0	Yes	4	7	1	11	1	11	32.10	19024	0.0017	**0.0186**
Prohexadione-Ca	No	0	No Data	4	No Data	2	Yes	4	No	0	0.7	1	11	1	11	0.38	19024	0.0000	**0.0002**
Propamocarb HCL	No Data	3	No Data	4	No Data	2	No Data	1	Possible	2	39.3	3	13	3	39	4.31	19024	0.0002	**0.0088**
Propaquizafop	Possible	6	No Data	4	No Data	2	Possible	2	No	0	17.5	2	15	2	30	2.79	19024	0.0001	**0.0044**
Propargite	Possible	6	No Data	4	No Data	2	Possible	2	No Data	1	56	3	16	3	48	0.17	19024	0.0000	**0.0004**
Propiconazole	Possible	6	No Data	4	No Data	2	No Data	1	No Data	1	214	4	15	4	60	36.44	19024	0.0019	**0.1149**
Propineb	No	0	No Data	4	No Data	2	Possible	2	No	0	3	1	9	1	9	81.62	19024	0.0043	**0.0386**
Propoxur	Possible	6	No Data	4	No	0	No Data	1	Possible	2	79	4	14	4	56	0.30	19024	0.0000	**0.0009**
Propyzamide	Possible	6	No Data	4	No Data	2	No	0	No	0	47	3	13	3	39	0.60	19024	0.0000	**0.0012**
Prothioconazole	No	0	No Data	4	No Data	2	Possible	2	No Data	1	0.8	1	10	1	10	2.30	19024	0.0001	**0.0012**
Pymetrozine	Yes	8	No Data	4	No Data	2	Possible	2	No Data	1	14	1	18	1	18	1.00	19024	0.0001	**0.0009**
Pyraclostrobin	No	0	No Data	4	No Data	2	Possible	2	No	0	32	3	9	3	27	19.02	19024	0.0010	**0.0270**
Pyrimethanil	No	0	Possible	6	No Data	2	No	0	No	0	55	3	9	3	27	5.21	19024	0.0003	**0.0074**
Pyriproxifen	No	0	No Data	4	No Data	2	No	0	No	0	#N/A	1	7	1	7	3.60	19024	0.0002	**0.0013**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Potential	Score	Days	Score	*TP*	*EEP*	*HP*	*QI*	Qtotal	*QI*/Qtotal	*WHP*
Quinalphos	No	0	No Data	4	No Data	2	Possible	2	Yes	4	21	2	13	2	26	0.33	19024	0.0000	**0.0004**
Quinoxyfen	No	0	No Data	4	No Data	2	No	0	No	0	97	4	7	4	28	1.25	19024	0.0001	**0.0018**
Rimsulfuron	No	0	No Data	4	No Data	2	No	0	No	0	24.3	2	7	2	14	0.15	19024	0.0000	**0.0001**
Simazine	Possible	6	Possible	6	No	0	Possible	2	No Data	1	90	4	16	4	64	83.25	19024	0.0044	**0.2801**
s-metolachlor	Possible	6	Possible	6	No Data	2	No	0	No Data	1	15	2	16	2	32	113.32	19024	0.0060	**0.1906**
Spinosad	No	0	No	0	No Data	2	No Data	1	No	0	14	1	4	1	4	0.24	19024	0.0000	**0.0000**
Spirodiclofen	Possible	6	No Data	4	No Data	2	Possible	2	Possible	2	7	1	17	1	17	0.48	19024	0.0000	**0.0004**
Spiroxamine	No	0	No Data	4	No Data	2	No	0	No	0	25	2	7	2	14	15.50	19024	0.0008	**0.0114**
Sulcotrione	Possible	6	No Data	4	No Data	2	Possible	2	No Data	1	25	2	16	2	32	21.08	19024	0.0011	**0.0355**
Sulfosulfuron	Possible	6	No Data	4	No Data	2	No Data	1	No	0	24	2	14	2	28	0.98	19024	0.0001	**0.0014**
Sulphur	No	0	No Data	4	No Data	2	No	0	No	0	30	3	7	3	21	2,337.28	19024	0.1229	**2.5801**
Tau-fluvalinate	No	0	Yes	8	No	0	Possible	2	No Data	1	4	1	12	1	12	3.31	19024	0.0002	**0.0021**
Tebuconazole	Possible	6	No Data	4	No Data	2	Yes	4	No	0	62	4	17	4	68	32.74	19024	0.0017	**0.1170**
Tembotrione	Possible	6	No Data	4	No Data	2	Possible	2	No Data	1	30	3	16	3	48	1.81	19024	0.0001	**0.0046**
Tepraloxydim	Possible	6	No Data	4	No Data	2	No Data	1	No Data	1	10	1	15	1	15	2.20	19024	0.0001	**0.0017**
Terbufos	No	0	No Data	4	No	0	No Data	1	Yes	4	8	1	10	1	10	114.75	19024	0.0060	**0.0603**
Terbuthylazine	Possible	6	No Data	4	No Data	2	Possible	2	No Data	1	45	3	16	3	48	674.41	19024	0.0355	**1.7016**
Tetradifon	No	0	No	0	No Data	2	No Data	1	No	0	112	4	4	4	16	6.75	19024	0.0004	**0.0057**
Thiabendazole	Possible	6	No Data	4	No	0	Possible	2	No	0	500	4	13	4	52	3.75	19024	0.0002	**0.0103**
Thiacloprid	Possible	6	No Data	4	No Data	2	No Data	1	No Data	1	15.5	2	15	2	30	2.02	19024	0.0001	**0.0032**
Thiamethoxam	Possible	6	No	0	No Data	2	No	0	No	0	50	3	9	3	27	22.80	19024	0.0012	**0.0324**
Thifensulfuron-methyl	No	0	No	0	No Data	2	No	0	Yes	4	4	1	7	1	7	0.04	19024	0.0000	**0.0000**
Thiodicarb	Yes	8	No Data	4	No Data	2	No Data	1	Yes	4	0.67	1	20	1	20	4.10	19024	0.0002	**0.0043**
Thiophanate	Possible	6	No Data	4	Yes	6	Yes	4	No Data	1	0.6	1	22	1	22	1.82	19024	0.0001	**0.0021**

Active Ingredient	Carcinogenicity		EDC		Mutagenicity		Teratogencitiy		Neurotoxicity		Half-life		Prioritisation Indices						
	Potential	**Score**	**Potential**	**Score**	**Potential**	**Score**	**Potential**	**Score**	**Potential**	**Score**	**Days**	**Score**	***TP***	***EEP***	***HP***	***QI***	**Qtotal**	***QI*/Qtotal**	***WHP***
Thiram	Possible	6	Possible	6	Possible	4	Possible	2	No Data	1	15.2	2	20	2	40	46.57	19024	0.0024	**0.0979**
Tralomethrin	No	0	No Data	4	No Data	2	Possible	2	No	0	3	1	9	1	9	0.11	19024	0.0000	**0.0001**
Triadimefon	Possible	6	Possible	6	No	0	Yes	4	Possible	2	26	2	19	2	38	1.68	19024	0.0001	**0.0034**
Triadimenol	No	0	Yes	8	No Data	2	Yes	4	Possible	2	250	4	17	4	68	1.21	19024	0.0001	**0.0043**
Triasulfuron	No	0	No Data	4	No Data	2	Possible	2	No Data	1	23	2	10	2	20	0.60	19024	0.0000	**0.0006**
Tribenuron-methyl	Possible	6	No Data	4	No Data	2	No	0	No	0	14	1	13	1	13	1.31	19024	0.0001	**0.0009**
Trichlorfon	Possible	6	Possible	6	Yes	6	Possible	2	Yes	4	18	2	25	2	50	4.37	19024	0.0002	**0.0115**
Trifloxystrobin	No	0	No Data	4	No Data	2	Yes	4	No	0	7	1	11	1	11	3.80	19024	0.0002	**0.0022**
Triflumuron	No	0	No	0	No Data	2	No	0	No	0	22	2	3	2	6	1.01	19024	0.0001	**0.0003**
Trifluralin	Possible	6	Yes	8	No	0	Yes	4	No Data	1	181	4	20	4	80	160.42	19024	0.0084	**0.6746**
Triticonazole	N\ o Data	3	No Data	4	No Data	2	No Data	1	No Data	1	237	4	12	4	48	1.30	19024	0.0001	**0.0033**
Uniconazole-P	Possible	6	No Data	4	No Data	2	No Data	1	No Data	1	100	4	15	4	60	0.14	19024	0.0000	**0.0004**
Zineb	Possible	6	Possible	6	Possible	4	Yes	4	No Data	1	30	3	22	3	66	4.84	19024	0.0003	**0.0168**

APPENDIX 2:

CAPACITY BUILDING AND KNOWLEDGE DISSEMINATION

CAPACITY BUILDING

MSc Dissertations:

The student and dissertation listed below contributed directly to the objectives of the project.

Shadung JM (Graduated 2014):

Prioritizing pesticides in South Africa based on their environmental mobility and potential to cause human health effects.

Department of Zoology, University of Johannesburg.

KNOWLEDGE DISSEMINATION

Papers accepted for publication:

Dabrowski, J.M., Shadung J. and Wepener, V. (2014) Prioritizing agricultural pesticides used in South Africa based on their environmental mobility and potential human health effects. *Environment International* **62**: 31-40.

Dabrowski, J.M. (2015) Development of pesticide use maps for South Africa. *South African Journal of Science*. **111**:1-7.

Poster Conference Presentations:

Dabrowski, J.M. and Shading, J.M. (2014) Prioritizing agricultural pesticides used in South Africa based on their environmental mobility and potential human health effects. *IUPAC 14th International Congress on Pesticide Chemistry. 10 -14 August, 2014, San Francisco, USA.*

Other:

The priority list of pesticides produced as part of this report, in combination with the mobility index has been used to identify pesticides for inclusion into the development of risk based water quality guidelines for irrigation (WRC Project No. K5/2399/4 – Revision of the 1996 South African water quality guidelines: development of risk-based approach using irrigation water use as a case study).

MSc Dissertation Abstract

PRIORITIZING PESTICIDES IN SOUTH AFRICA BASED ON THEIR ENVIRONMENTAL MOBILITY AND POTENTIAL TO CAUSE HUMAN HEALTH EFFECTS

Justinus Madimetja Shadung

Promoter:	Prof. Victor Wepener
Department:	Zoology
Faculty:	Faculty of Science
University:	University of Johannesburg
Degree:	Master of Science

Pesticides are used intensively in South Africa and many studies have identified the widespread occurrence of a number of different agricultural chemicals in water resources of the intensively farmed areas in particular. Of major concern is the fact that humans and animals living in most rural and some urban areas are still dependent on untreated water for drinking. This study identified priority pesticides in terms of quantity of usage, toxicity and persistence as well as the crops they are applied to. Many pesticides which were applied in high quantities and highly toxic were identified as well as the specific crops these priority pesticides were applied to. Furthermore, two indicator models which require only two environmental fate properties (Koc and half-life) were used to determine the potential of pesticides to move from source to water resources. Based on the movement rating of each pesticide, almost two-third of pesticides have the potential to reach water resources (surface and groundwater resources). The information about the priority pesticides of concern was integrated based on pesticides usage, toxicity and physicochemical properties (environmental fate properties) so as to indicate which of the larger number pesticides used pose the greatest potential risk to human health. Thus, pesticides which put human health at more risks are those pesticides which have high weighted toxic potential (WTP) and are highly mobile. The more the pesticide is used in high quantities, the higher the WTP score. Subsequently, linking priority pesticides to specific crops produced in South Africa gave an indication of which area or communities are at risk of pesticides exposure. Results of this research help in the future in terms of monitoring programs, pollution preventative measures and policy making.