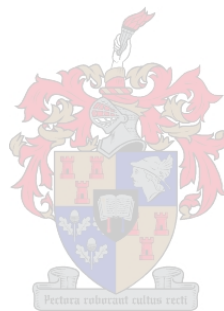


Applications of dairy wastewater as a fertilizer to agricultural land: an environmental management perspective.

by

Leigh Christine Torr

Thesis presented in partial fulfilment of the requirements for the degree of Master of Arts at the University of Stellenbosch.



Supervisor: BHA Schloms

Department of Geology, Geography and Environmental Studies
Faculty of Social Sciences
University of Stellenbosch

March 2009

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.



Signature

Leigh Christine Torr
Name in full

18 February 2009
Date

Abstract

As with any form of intensive agriculture, there are potential environmental impacts associated with the management and housing of livestock on dairy farms. Within the field of dairy farming, particular focus falls to the issue of environmental degradation of water resources, as this form of pollution is currently a major environmental issue around the world. Conventional agricultural practices involving the application of chemical fertilizers to land and crops are causing environmental problems as a result of poor management practices. Dairy wastewater and manures could however be a valuable resource for agricultural producers in the form of an alternate fertilizer for their crops. Waste application as a fertilizer is more environmentally friendly than chemical fertilizers, and could drastically reduce costs for farmers, whilst alleviating storage and management problems often associated with farmyard manures (FYM). The application of organic wastes, notably livestock manures, to land has historically been important for maintaining soil fertility on farms in terms of nutrient status and organic matter levels, as well as helping to reduce soil erosion and improve water-holding capacity. The research sought to investigate the environmental and economical feasibility of using dairy wastewater and manures as an alternative form of fertilizer within agriculture in South Africa.

Opsomming

Soos met enige vorm van intensiewe landbou is daar potensiële omgewingsimpakte betrokke by die bestuur en behuising van vee op 'n suiwelplaas. In die veld van suiwelboerdery is daar 'n sterk fokus op die agteruitgang van waterhulpbronne, aangesien hierdie vorm van besoedeling tans 'n belangrike omgewingsprobleem regoor die wêreld is. Konvensionele lanbougebruike wat die toediening van chemiese bemestingstowwe tot die grond en gewasse insluit, lei tot omgewingsagteruitgang as gevolg van swak bestuurspraktyke. Suiwel-afvalwater en mis kan egter 'n waardevolle bron van alternatiewe bemesting vir suiwelboere wees. Die toepassing van afval as bemesting is meer omgewingsvriendelik as chemiese bemesting en kan kostes drasties verminder. Terselfertyd kan dit die berging- en bestuursprobleme wat met die hantering van vee mis gepaard gaan, verminder. Die toediening van organiese afval, veral vee mis, tot landerye is 'n gevestigde praktyk om die vrugbaarheid van grond te behou. Die praktyk merk ook gronderosie teen en verhoog die waterhou-kapasiteit van die grond. Hierdie navorsing het 'n ondersoek ingestel na die lewens- en ekonomiese vatbaarheid van suiwel-afvalwater as 'n alternatiewe vorm van bemesting vir landbou in Suid Afrika.

Acknowledgements

I would like to thank the following persons for assisting me with this research report. Without their ongoing advice and support, this study would not have been possible.

- Mr. Bennie Schloms, my supervisor, for his encouragement, support, patience and much needed academic advice.
- The staff of the Department of Geology, Geography and Environmental Studies at Stellenbosch University for their keen interest and support.
- Marianne Cronje for her friendly smile, ever-helpful attitude, and patience.
- The Milk Producers Organisation (MPO) of South Africa (in particular, Dawie Maree, Mike Black and Tokkie Venter), Chris Burgess (Farmer's Weekly), Ainsley Moos, Lucille Botha and Johan Coetsee (Landbou Weekblad), Willemien von Solms and Liza Burger (Dairymail), Lizanne Slabbert (Agriconnect), and Joel Kotze and Hennie Maas (Radio Sonder Grense) for their help in publicising the research.
- All the respondents to the research questionnaires, who provided valuable insight for the study, as well as Mrs. S Blane, Mr. P Meade, Mr. C Muller, Mr. J Keane, Mr. D Greene, Mr. G Torr, Mr. R Stubbs, Mr. G Fourie, Mr. J Loubser, Mr. W Basson, Mr. K Strahlendorf, Mr. B Van Greunen, Mr. B Robertson, Mr. T Breytenbach, Mr. N Houart, Mr. G Muller, Mr. A Williams, and Mr. B Dixon for their contribution to the practical investigations.
- My good friends, Anita Adendorff, Jaco Kemp, and Garth Stephenson, for their editing, support, late night encouragements, and endless cups of coffee!
- My dearest friend, Dale Thomas for his love and motivation, and for believing in me.
- Most of all, my parents, for their interest, encouragement, patience and support, both emotionally and financially. Without your help, this would never have been possible. Thank you very much.

Table of Contents

| | |
|---|-------------|
| Declaration | ii |
| Abstract | iii |
| Opsomming | iv |
| Acknowledgements | v |
| Table of Contents | vi |
| Figures | ix |
| Tables | xii |
| Acronyms | xiii |
| Chapter 1 – INTRODUCTION | 1 |
| <i>1.1 Setting the scene</i> | <i>1</i> |
| <i>1.2 Motivation</i> | <i>2</i> |
| <i>1.3 Research Approach</i> | <i>3</i> |
| 1.3.1 Aim..... | 3 |
| 1.3.2 Research Question..... | 3 |
| 1.3.3 Objectives | 3 |
| 1.3.4 Research Design..... | 4 |
| 1.3.5 Study Area..... | 5 |
| 1.3.6 Methodology | 6 |
| Chapter 2 – LITERATURE REVIEW | 8 |
| <i>2.1 Agriculture in South Africa</i> | <i>8</i> |
| <i>2.2 Agriculture and pollution</i> | <i>13</i> |
| 2.2.1 Types of agricultural pollutants and their impact on the environment | 13 |
| 2.2.2 Mechanisms for pollution management and control within agricultural systems: Current and future strategies. | 17 |
| <i>2.3 Environmental management and legislation in South Africa</i> | <i>21</i> |
| 2.3.1 Environmental Management..... | 22 |
| 2.3.2 White Paper on Agriculture | 24 |
| 2.3.3 Conservation of Agricultural Resources Act (CARA) | 25 |

| | | |
|---|---|-----------|
| 2.3.4 | White Paper on Integrated Pollution and Waste Management for South Africa. | 25 |
| 2.3.5 | National Environmental Management Act (NEMA) | 26 |
| 2.3.6 | The National Water Act (NWA)..... | 28 |
| 2.3.7 | Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act..... | 29 |
| 2.3.8 | Legislation and waste management in South Africa | 30 |
| 2.4 | <i>The use of fertilizers in agriculture</i> | 32 |
| 2.4.1 | Chemical fertilizers: Definition and place in agriculture (storage, management, use, costs). | 33 |
| 2.4.2 | Advantages and disadvantages of chemical fertilizer utilization in agriculture | 36 |
| 2.4.3 | Dairy wastes: Definition and place in agriculture (storage, management, use, costs)..... | 38 |
| 2.4.4 | Advantages and disadvantages of manure utilization in agriculture | 45 |
| 2.4.5 | Manure vs. fertilizer – A comparison..... | 48 |
| 2.4.5.1 | Composition | 50 |
| 2.4.5.2 | Economical feasibility..... | 50 |
| 2.4.5.3 | Environmental feasibility | 51 |
| 2.4.5.4 | Management..... | 52 |
| 2.4.5.5 | Legislation..... | 52 |
| 2.5 | <i>Organic farming: Agriculture’s new ‘buzz word’</i> | 53 |
| 2.5.1 | What is organic farming?..... | 53 |
| 2.5.2 | Managing soil fertility in organic agriculture..... | 54 |
| 2.5.3 | The role that manure can play in organic agriculture | 55 |
| 2.5.4 | Organic vs. conventional agriculture | 55 |
| 2.6 | <i>Conclusion</i> | 60 |
| Chapter 3 – METHODOLOGY | | 62 |
| 3.1 | <i>Questionnaire</i> | 62 |
| 3.2 | <i>Interviews & farm visits</i> | 63 |
| Chapter 4 – RESULTS & DISCUSSION | | 65 |
| 4.1 | <i>Questionnaire results</i> | 65 |
| 4.2 | <i>Farmer’s comments</i> | 72 |
| 4.3 | <i>Interviews and farm visits</i> | 75 |
| 4.3.1 | KwaZulu-Natal region (23-26 September 2008). | 76 |
| 4.3.1 | KwaZulu-Natal region (23-26 September 2008). | 77 |
| 4.3.2 | Western Cape region (13-14 May, and 5-7 October 2008). | 89 |

| | |
|--|-----|
| <i>4.4 Discussion</i> | 98 |
| Chapter 5 – CONCLUSIONS & RECOMMENDATIONS | 103 |
| REFERENCES | 107 |
| APPENDICES | 115 |
| <i>Appendix A: Anaerobic Lagoon Design (Houart 2008, pers com)</i> | 115 |
| <i>Appendix B: Sediment Pit Design (Houart 2008, pers com)</i> | 116 |
| <i>Appendix C: Dairy wastewater management questionnaire</i> | 117 |

Figures

| | |
|---|--------------|
| Figure 1.1: Study area showing the KwaZulu-Natal and Western Cape regions of South Africa..... | 5 |
| Figure 2.1: The different agricultural sectors and their contribution to the economy in South Africa (2002)..... | 10 |
| Figure 2.2: Number of dairy cattle per province (2002)..... | 11 |
| Figure 2.3: Water pollution caused by wastewater run-off from dairy lagoons (point-source pollution)..... | 14 |
| Figure 2.4: Spreading waste onto cropland via a tanker..... | 17 |
| Figure 2.5: Course of action taken in the development of environmental management policies and systems in South Africa..... | 23 |
| Figure 2.6: Static irrigation line, centre pivot irrigation system, and granular fertilizer application..... | 34 |
| Figure 2.7: International price trends of fertilizers and raw materials (four-month moving average)..... | 35 |
| Figure 2.8: Net fertilizer prices (current price and 4-quarter moving average)..... | 35 |
| Figure 2.9: Waste storage methods commonly used in dairy farming..... | 40 |
| Figure 2.10: Waste application methods commonly used in dairy farming..... | 41-42 |
| Figure 2.11: Price comparison between applying organic fertilizer in the form of dairy slurry verses granular fertilizer..... | 51 |
| Figure 4.1: Herd management systems used by the sample..... | 65 |
| Figure 4.2: Crops grown by the sample group..... | 66 |
| Figure 4.3: Preferred methods of chemical fertilizer application in sample group..... | 66 |

| | |
|--|-----------|
| Figure 4.4: Percentage of crop growers and their seasonal preferences for fertilizer application..... | 67 |
| Figure 4.5: Percentage of farmers using various forms of dairy waste management..... | 69 |
| Figure 4.6: Waste application methods used by sample..... | 69 |
| Figure 4.7: Respondents' reaction to the question of whether their current dairy waste management poses an environmental threat on their farms..... | 70 |
| Figure 4.8: Classification of most beneficial organic farming characteristics according to sample..... | 71 |
| Figure 4.9: Study area showing the Western Cape and KwaZulu-Natal regions..... | 76 |
| Figure 4.10: KwaZulu-Natal region showing the distribution of visited farms..... | 78 |
| Figure 4.11: Ericsberg Farm system, showing separation of slurry using a rotary screen system and storage of liquid waste in a storage lagoon..... | 79 |
| Figure 4.12: Lamington Farm system, showing only agitation of slurry (no separation) and irrigation onto pastures through a dedicated line..... | 80 |
| Figure 4.13: Bromley Farm system, showing separation of slurry using a lagoon system, followed by application onto pastures using an applicator gun mounted on a centre pivot..... | 81 |
| Figure 4.14: Denleigh Farm system, showing agitation of slurry and subsequent application to pastures via umbilical pipes and a tractor mounted dribble bar..... | 82 |
| Figure 4.15: SlurryTech® waste application procedure..... | 83 |
| Figure 4.16: Kildare Farm system, showing removal of slurry from anaerobic lagoons and subsequent application onto cropping lands using specialized tankers..... | 84 |
| Figure 4.17: Dunira Farm system, showing separation of slurry using a screw auger system and subsequent application of liquids onto pasture using a traveling applicator gun..... | 85 |
| Figure 4.18: Mearns Farm system, showing agitation of slurry and subsequent application to pastures via both a pivot mounted gun applicator, as well as a travelling gun applicator..... | 86 |

| | |
|--|------------|
| Figure 4.19: Western Cape region showing the distribution of visited farms..... | 90 |
| Figure 4.20: Vyevelei system, showing a static screen separator and manure trailer, and smothering caused by the incorrect method of applying dairy waste to land..... | 91 |
| Figure 4.21: Fair Cape system, showing separation of slurry, recycling of liquids, and application of solids to pastures via a specialized tanker imported from Holland..... | 93 |
| Figure 4.22: Uilenkraal barn system, showing the use of recycled water in the wash down of barn feeding area, and the blocked sand traps that are overflowing..... | 94 |
| Figure 4.23: Uilenkraal dairy system, showing the use of a screw auger separator, recycled water storage for the wash down of holding area, the separated solids, and the new worm farm that is used in composting procedures..... | 95 |
| Figure 4.24: Tweerivier dairy system, showing the new sediment/sand trap and two irrigation ponds..... | 96 |
| Figure 4.25: Van Greunen farms, showing the sediment/sand trap, muck spreader, homemade agitator, and the application of waste to lands..... | 97 |
| Figure 4.26: Waste management strategy options currently prevalent in study area..... | 100 |
| Figure 5.1: Elements of dairy wastewater management that need to be considered when planning a site-specific management system..... | 104 |

Tables

| | |
|--|-----------|
| Table 2.1: Number of farming units and their gross income (2002)..... | 9 |
| Table 2.2: Number of milk producers per province Dec' 97- Jan '08..... | 11 |
| Table 2.3: Estimated waste generation in the RSA in million tons/annum..... | 22 |
| Table 2.4: Approximate percentages of ingested nitrogen, phosphorus and potassium excreted by cattle on pasture..... | 39 |
| Table 2.5: Approximate amounts of nitrogen, phosphorus and potassium excreted by a single dairy cow in a year, and their current fertilizer value..... | 44 |
| Table 2.6: Solid fertilizer equivalent and Rand value of effluent from 100 cows (pasture system)..... | 44 |
| Table 2.7: Comparison between organic and chemical fertilizers..... | 49 |
| Table 2.8: Overview of the absolute and relative environmental impacts of organic farming compared with conventional farming..... | 57 |
| Table 2.9: The benefits, opportunities and challenges for organic agriculture in the global arena..... | 59 |
| Table 3.1: Questionnaire Statistics..... | 63 |
| Table 4.1: Annual expenditure on fertilizers (p/ha)..... | 68 |

Acronyms

| | |
|-------------|--|
| CARA | Conservation of Agricultural Resources Act |
| DOA | Department of Agriculture |
| DWAF | Department of Water Affairs and Forestry |
| FSSA | Fertilizer Society of South Africa |
| FYM | Farmyard Manure |
| MEA | Millennium Ecosystem Assessment |
| MPO | Milk Producer's Organization |
| NEMA | National Environmental Management Act |
| NWA | National Water Act |
| RSG | Radio Sonder Grense |
| SSM | Site Specific Management |

Chapter 1 – INTRODUCTION

‘The tradition in agriculture has been to maximize production and minimize the cost of food with little regard to impacts on the environment and the services it provides to society. As the world enters an era in which global food production is likely to double, it is critical that agricultural practices be modified to minimize environmental impacts even though many such practices are likely to increase the costs of production.’

(Tilman, 1999)

1.1 Setting the scene

As with any form of intensive agriculture, there are potential environmental impacts associated with the housing of livestock on farms, and hence, environmental protection of agricultural resources is becoming more of a concern for farmers and consumers alike (Neményi, Mesterházi, Pecze & Stépán, 2003; Merrington, Winder, Parkinson & Redman, 2002a; DOA, 1998; Garnier, Lo Porto & Marini, 1998). Within the field of dairy farming, particular focus falls to the issue of dairy wastewater management, as diffuse pollution of water resources from agricultural sources is currently a major environmental issue around the world (Giupponi & Vladimirova, 2005). Wastewater from dairies has become a controversial topic in recent years as it increasingly presents a considerable problem in this regard (Healy, Rodgers & Mulqueen, 2004; Northcott, 2004; Garnier *et. al.*, 1998).

Even so, dairy wastewater and manures could also be a valuable resource for farmers in the form of a fertilizer for their crops. The application of organic wastes, notably livestock manures, to land has historically been important for maintaining soil fertility in terms of both nutrient status and organic matter levels, as well as helping to reduce soil erosion and improve water holding capacity (Merrington *et. al.*, 2002a; Fraisse, Campbell, Jones & Boggess, 1996). Rising fertilizer and food costs in 2007/2008 in South Africa (FSSA, 2008) have provided the necessity for investigation into more economically viable alternatives to chemical fertilizers. Dairy wastewater and/or manure applications as a fertilizer could drastically reduce fertilizer costs for farmers, whilst simultaneously alleviate storage and management problems often associated with such wastes on these dairy farms. There are numerous studies to date that have been conducted on the feasibility of ‘recycling’ or treating dairy wastewater so that it

can be reused in crop production practices (Gottschall, Boutin, Crolla, Kinsley & Champagne, 2007; Lansing & Martin, 2006; Feng, Letey, Chang & Campbell Mathews, 2005; McGarvey, Miller, Sanchez, Silva & Whitehand, 2005).

Wastewater application as a fertilizer to agricultural land is more environmentally friendly and economically beneficial than the application of chemical fertilizers. By alleviating costs, income to farmers and increased production could drastically benefit not only the farmer him/herself but also the consumer. Within agriculture, input costs such as transport, animal feeds and fertilizer play a large role in determining the success or failure of a farming enterprise and with the global increase in energy prices (FSSA, 2008), the future for farming in South Africa promises to be a challenging one.

For the purpose of this research, the different types of pollution resulting from agricultural practices will be explored. Additionally, South African legislation pertaining to environmental management and control of agricultural resources will also be investigated. Following this background research, an empirical investigation into the use of livestock manure as a feasible alternative to chemical fertilizers within the agricultural sector of South Africa will be conducted, one that could hopefully aid in the promotion of environmental sustainability within this sector in the long term.

1.2 Motivation

An increase in maize and fuel prices, along with a shortage of silage and other roughage, had a negative impact on the local dairy industry in 2007 (DOA, 2008b). With the rising costs of fertilizers and fuel, farmers are looking towards alternative fertilizer options, one being the utilization of farmyard manure (FYM) as an organic form of fertilizer for application to agricultural lands and crops.

Dairy wastewater in agriculture often poses a pollution threat on farms due to poorly managed or broken storage systems. Maintenance costs involved in proper storage of dairy wastes often result in illegal dumping of such wastes into rivers or onto lands. However, if managed properly, dairy wastewater could be beneficial to farmers by providing a cheap alternative to industrial fertilizer and/or a source of revenue through

composting. Nevertheless, the environmental feasibility of such activities needs to be investigated, and environmental legislation adhered to, before this ‘solution’ to dairy wastewater management can be declared a feasible management strategy within agricultural systems.

1.3 Research Approach

1.3.1 Aim

To explore the economical and environmental feasibility of using dairy wastewater as an alternative to industrial fertilizers for agricultural production systems in South Africa.

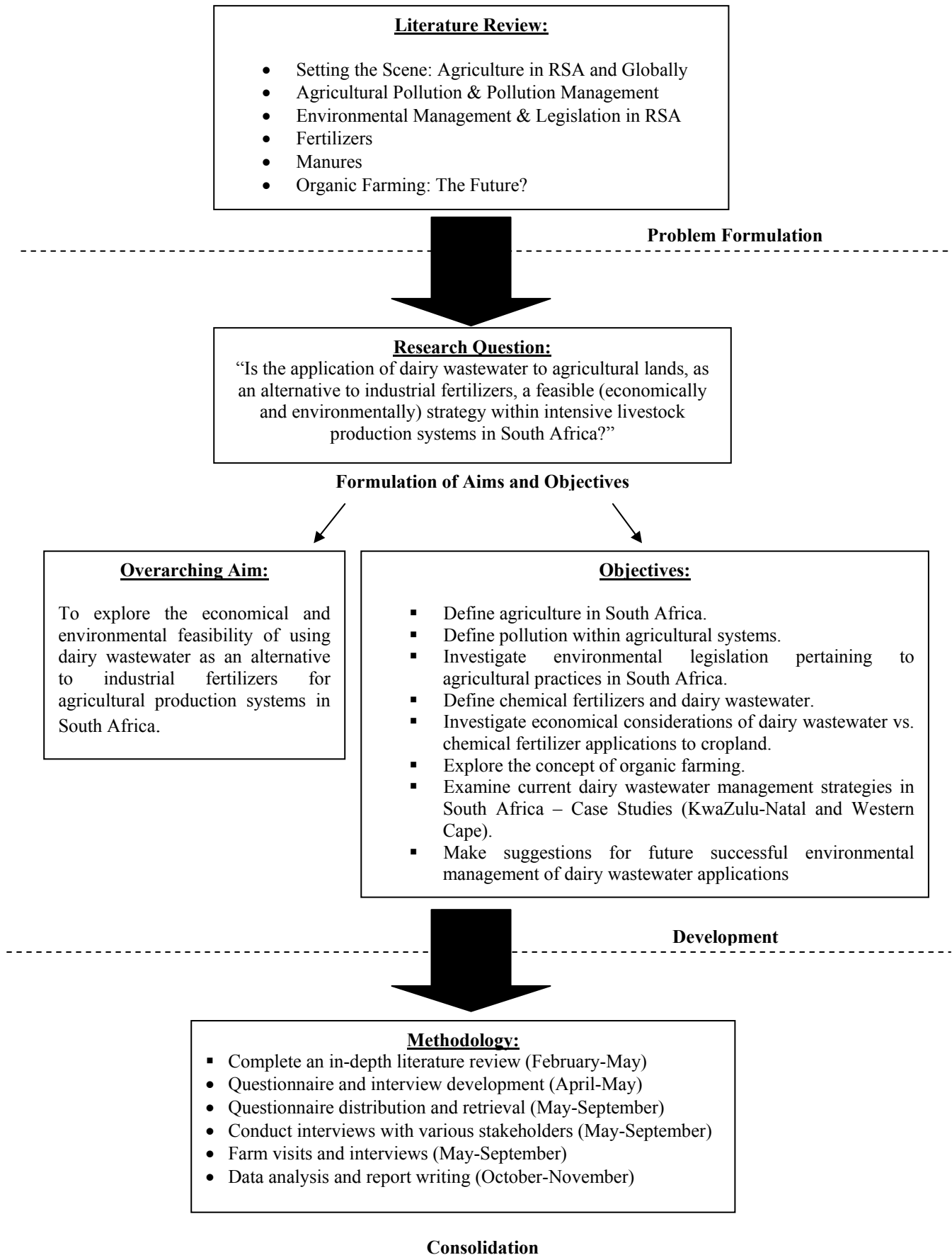
1.3.2 Research Question

Is the application of dairy wastewater to agricultural lands, as an alternative to industrial fertilizers, a feasible (economically and environmentally) strategy within intensive livestock production systems in South Africa?

1.3.3 Objectives

- Define agriculture in South Africa.
- Define pollution within agricultural systems.
- Investigate environmental legislation pertaining to agricultural practices in South Africa.
- Define chemical fertilizers and dairy wastewater.
- Investigate economical considerations of dairy wastewater vs. chemical fertilizer applications to cropland.
- Explore the concept of organic farming.
- Examine current dairy wastewater management strategies in South Africa – Questionnaire and farm visits (KwaZulu-Natal and Western Cape).
- Make suggestions for future successful environmental management of dairy wastewater applications

1.3.4 Research Design



1.3.5 Study Area

The study areas for the research included the KwaZulu-Natal and Western Cape provinces of South Africa. Reasons for choosing these two specific regions include the feedback from the questionnaires, climatic and seasonal differences in agricultural practices, and varying herd management practices, all of which play an important role in the consideration of crop and herd management strategies.

KwaZulu-Natal farmers receive their rainfall in the summer months of the year, and herd management practices in this province are mainly pasture-based. In contrast, the Western Cape regional farmers receive their rainfall in the winter months of the year, and the farms in this region are larger, feedpad-based systems. These differences are important considerations for the successful implementation of area-specific dairy wastewater management strategies, and thus it was necessary to investigate the different regions for the purpose of obtaining area-specific insight into such systems.

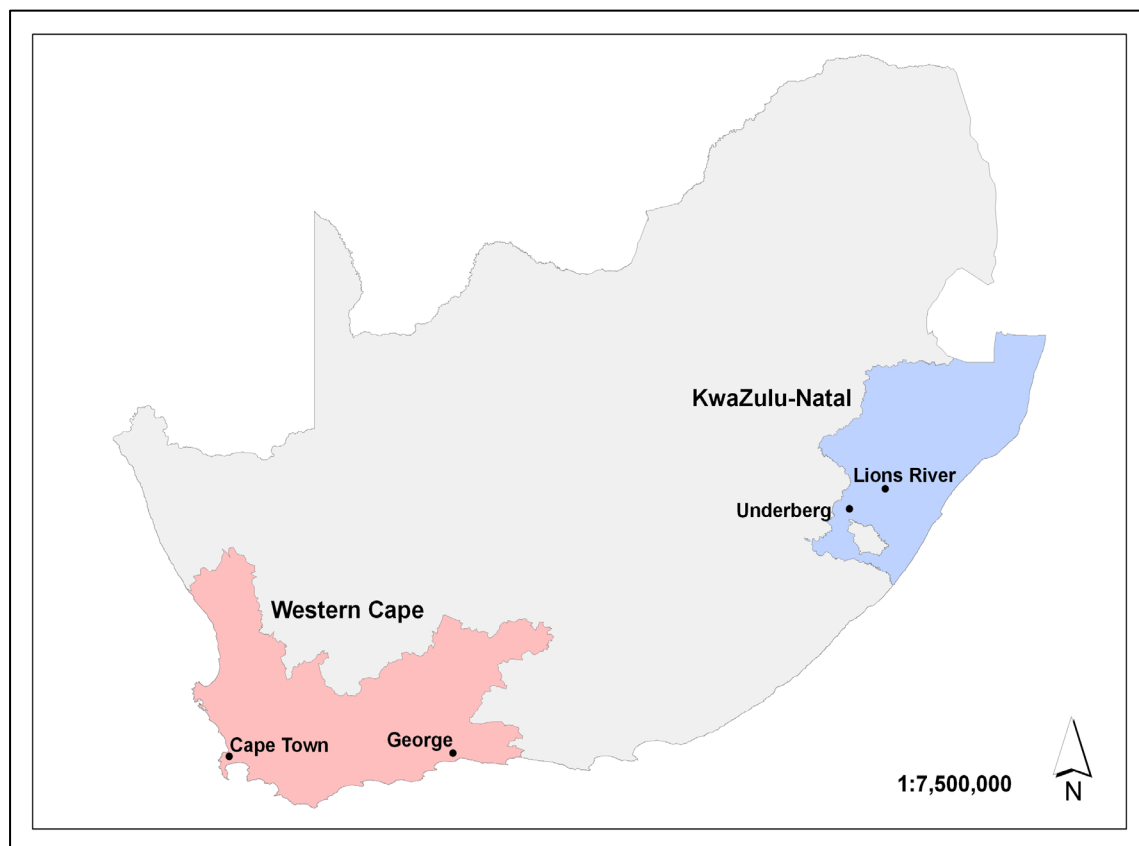


Figure 1.1: Study area showing the KwaZulu-Natal and Western Cape Regions of South Africa.

1.3.6 Methodology

The empirical research was conducted through the use of various data collection methods. These included a comprehensive literature study, a web-based questionnaire on dairy wastewater management in South Africa, and various interviews and farm visits with farmers in both the KwaZulu-Natal and Western Cape regions. The information gathered in the literature study provides a strong theoretical base from which the research can draw, whereas the questionnaire, interviews and farm visits helped to establish the current trends of wastewater management, and the problems that are encountered within such operations, throughout South Africa.

Literature Study

A solid theoretical background study of the topic was undertaken through an extensive investigation of both local and international literature on the topic of dairy wastewater management. This was achieved through the collection of information from:

- 1) *The GS Gericke Library, University of Stellenbosch*
 - International and local journal articles
 - Research papers
 - Books and book chapters
 - Proceedings of conferences, congresses, symposia, etc.
 - Magazine and newspaper articles and reports
- 2) *The Internet* – electronic sources
- 3) *Personal correspondence and interviews*

Questionnaire

In order to investigate the current wastewater management practices in South Africa, the research made use of an electronic questionnaire. This web-based questionnaire (see Appendix C), designed by Anita Adendorff of Inida Design (www.inidadesign.com), was made available to dairy farmers in South Africa via the following channels:

- 1) Regional Milk Producers Organizations (MPO's) of South Africa:
 - KwaZulu-Natal and Eastern Cape (tokkie@mpo.co.za)
 - Freestate and Northern Cape (mpovrystaat@ripplesoft.co.za)
 - Western Cape (dawie@mpo.co.za)
 - North (Limpopo, Mpumalanga, Gauteng) (lizedw@mpo.co.za)
- 2) Articles in three local journals/magazines:
 - The Landbou Weekblad (Botha, 2008)
 - The Farmer's Weekly (Torr L 2008, pers com)
 - The Dairymail (Dairymail, 2008)
- 3) A radio interview on Radio Sonder Grense (RSG) (Maas 2008, pers com)
- 4) A Web link to the questionnaire made available on the MPO and Dairymail WebPages (28 July – 15 September, 2008) Mailing lists of farmers obtained personally

The questionnaire was composed of 20 multiple choice type questions that addressed the topic of dairy wastewater management and sought to investigate current management strategies being employed by dairy farmers within South Africa. Furthermore, the survey examined the current management and costs involved concerning chemical fertilizer usage within the dairy sector of this country. Respondents were asked an assortment of questions pertaining to their current management of dairy wastewater, their use of chemical fertilizers, their opinions regarding using waste as a fertilizer on crops, as well as their views regarding 'organic farming'. In addition to the multiple-choice questions, respondents were asked to add any comments on the topic of the research. This allowed the researcher to gain both quantitative and qualitative data pertaining to the topic of dairy wastewater management in South Africa.

Interviews & farm visits

In addition to the questionnaire, empirical data was gathered personally through various interviews and farm visits that were conducted within the study areas.

Chapter 2 – LITERATURE REVIEW

2.1 Agriculture in South Africa

Agriculture can be defined as the science or practice of farming, including horticulture, fruit growing, crop cultivation, and dairy farming and livestock breeding (Hawker, 2006; Stephens, 1990; Grigg, 1984). In general, agriculture occupies 35% of the world's land surface, with 11% under direct cultivation and 24% managed as permanent pasture (Merrington *et. al.*, 2002a). It is one of the world's most important economic activities, occupying over a third of the world's surface area and employing around 45% of the working population - there are over 250 million farmers worldwide (Grigg, 1984). Out of the total land area used for agriculture, the Commonwealth of Independent States, Latin America, and sub-Saharan Africa are the three largest agricultural regions in the world, comprising roughly half of the total agricultural land area on the planet (Tanji & Enos, 1994). Furthermore, in many developing countries, over half the population is dependent on agriculture for a living, and it is often the most important contributor to the national income in such regions (Grigg, 1984).

South Africa possesses a dual agricultural economy, comprising a large commercial, together with a substantial subsistence sector. Agricultural activities in the country range from intensive crop production and mixed farming, to cattle and sheep farming (DOA, 2008b; South Africa Info, 2008; DOA, 1998). Almost 80% of the land in South Africa is suitable for extensive livestock farming, of which an area of 590 000 km² (half of all agricultural land in the country) is used for cattle, sheep, and goat farming (DOA, 2008b).

Differences in physical environment are an important factor that determines the spatial variations in agricultural activity. Ecosystem differences (e.g.: climate and soil) from place to place can give rise to distinctive agricultural regions or types of farming areas within a province or country (Grigg, 1984). Reciprocally, agricultural activities can have significant implications for wild species of flora and fauna. Agricultural activities that have an impact on natural ecosystems include tillage, drainage, intercropping, rotation, grazing and extensive usage of pesticides and

fertilizers (McLaughlin & Mineau, 1995). South Africa is divided up into several agricultural regions according to climate, natural vegetation types, soil types, and farming practices (South Africa Info, 2008). According to the South African Department of Agriculture (DOA, 2008b), 86% of South Africa's total surface area is used for agriculture - 74% being natural veld and pastures and 14% available for cropping purposes. Of this 14%, only 22% can be classified as arable land, with about 1,3 million square kilometres of this land under irrigation. Rainfall in the country is generally low, erratic, unevenly distributed and unreliable, and therefore nearly 91% of the country is arid, semi-arid and dry sub-humid. As a result, almost half of South Africa's fresh water is utilized for agricultural purposes. Consequently, the most important limiting factor to agriculture in this country is water availability, which poses a major drought threat to many a South African farmer (DOA, 2008b; South Africa Info, 2008; DOA, 1998). In a water-scarce country like South Africa, it is important that water resources be used with great care, and in this regard, all role players need to promote farming methods that enhance soil and water conservation.

In 2002 there were approximately 45 818 active commercial farming units in South Africa (Table 2.1), a decrease of 12 162 from the 57 980 farming units that were acknowledged in 1993. The total contribution of these units to the South African economy at this point in time was around R50 billion (Lehohla, 2005). Overall, primary agriculture in South Africa contributes 2.6% to the Gross Domestic Product (GDP) and 9% of formal employment in the country (DOA, 2008b).

Table 2.1: Number of farming units and their gross farming income (2002)
(Lehohla, 2005).

| Province | Farming Units | Gross Farming Income (R '000) |
|---------------------|---------------|-------------------------------|
| Eastern Cape | 4376 | 3 213 986 |
| Free State | 8531 | 9 125 579 |
| Gauteng | 2206 | 3 962 582 |
| KwaZulu-Natal | 4038 | 6 429 273 |
| Limpopo | 2915 | 4 577 904 |
| Mpumalanga | 5104 | 6 186 402 |
| North West | 5349 | 5 125 343 |
| Northern Cape | 6114 | 3 578 025 |
| Western Cape | 7185 | 11 129 958 |
| South Africa | 45 818 | 53 329 052 |

As rainfall plays an important role in the availability of fodder and grazing for intensive livestock production systems, coastal areas are favoured for their mild temperatures and good rainfall (DOA, 2008b). The main dairy cattle farming provinces in South Africa are the Western Cape, Eastern Cape, KwaZulu-Natal, and the Free State. The total number of dairy cattle in South Africa is around 713 557. The provincial breakdown of this number is shown in Figure 2.1.

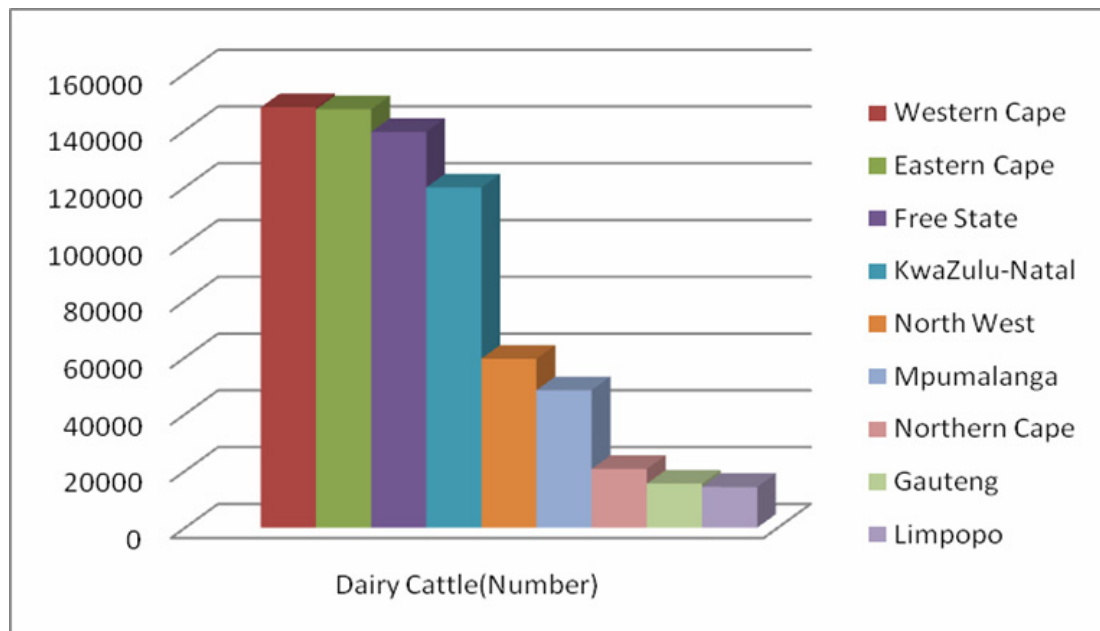


Figure 2.1: Number of dairy cattle per province (2002) (Lehohla, 2005).

With specific regard to dairy farming, milk consumption in South Africa is steadily increasing; a growing middle class and higher per capita disposable income is fuelling the demand (MPO, 2008). South African milk production accounts for a very small percentage of world production (0.5%) but is the fourth largest agricultural sector in the country (Figure 2.2). The country produces around 2.37 billion litres of milk annually (MPO, 2008; Lehohla, 2005). However, the total number of milk producers in the country has decreased from 7077 in December 1997 to only 3 665 in January 2008, a loss of an astounding 3412 producers (48%) (Table 2.2). This drastic drop in dairy farmers is mainly a result of the higher costs involved in successful farming these days (e.g. fertilizer, fuel and grain prices) (FSSA, 2008).

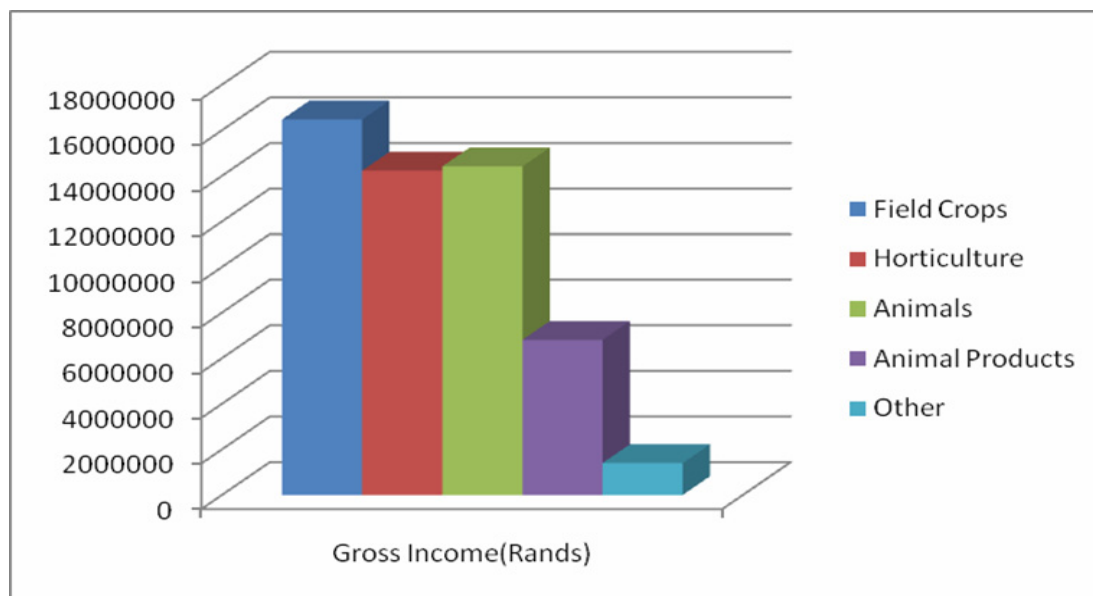


Figure 2.2: The different agricultural sectors and their contribution to the economy in South Africa (2002) (Lehohla, 2005).

Table 2.2: Number of milk producers per province Dec' 97- Jan '08 (MPO, 2008).

| Province | Number of producers per province | | | | % Change 1997-2008 |
|---------------|----------------------------------|-------------|-------------|-------------|--------------------|
| | Dec ' 97 | Jan ' 06 | Jan ' 07 | Jan ' 08 | |
| Western Cape | 1577 | 878 | 827 | 815 | -48.30% |
| Eastern Cape | 717 | 422 | 420 | 407 | -43.20% |
| Northern Cape | 133 | 39 | 37 | 34 | -74.40% |
| KwaZulu-Natal | 648 | 402 | 385 | 373 | -42.40% |
| Free State | 1204 | 1067 | 987 | 919 | -23.70% |
| North West | 1502 | 649 | 596 | 549 | -63.40% |
| Gauteng | 356 | 275 | 245 | 228 | -36% |
| Mpumalanga | 866 | 407 | 357 | 302 | -65.10% |
| Limpopo | 74 | 45 | 45 | 38 | -48.60% |
| Total | 7077 | 4184 | 3899 | 3665 | -48.20% |

With regard to cropping, maize is the most prolifically grown crop in South Africa (accounting for 25-33% of total agricultural production – about R12 billion), followed by wheat, oats, sugar cane and sunflowers (Lehohla, 2005; DOA, 1998). South Africa is the main maize producer amongst the SADC countries, producing an average of 8.8 million tonnes annually (South Africa Info, 2008). Crops are grown for a variety of purposes, including exports, food production, and as a fodder for animals. Within the dairy industry, many farmers grow maize that is harvested to form silage, and this is used as fodder for their animals during the dry seasons.

In recent years, agriculture in South Africa has undergone some radical changes. Main policy shifts include:

- 1) liberalisation of agricultural trade and deregulation of the market,
- 2) the implementation of land-reform policies and programmes,
- 3) abolishment of tax concessions and the reduction of subsidisation, and
- 4) the introduction of minimum wage for farm workers.

(DOA, 2008b; DOA, 1998).

Such changes have resulted in an increased intensity within farming practices, as farmers actively attempt to supply an ever increasing demand, whilst at the same time, try to benefit and profit from their agricultural businesses in the process. As a result of this intensification in farming practices countrywide, interest has turned to the sustainability and environmental implications thereof. The following sections will explore the effects that agriculture can have on the environment, as well as discuss various policies and legislation that are geared towards ensuring sustainable agricultural practices in South Africa.

2.2 Agriculture and pollution

International concern surrounding the growth of pollution worldwide has intensified over the past twenty years and even more so in the last decade (Merrington *et. al.*, 2002a; South Africa, 2000; DOA, 1998; Garnier *et. al.*, 1998). Pollution can be defined as ‘*the introduction into the environment of any substance that has, or results in, direct harmful effects to humanity or the environment, or that makes the environment less fit for its intended use*’ (South Africa, 2000:1). Intensive agricultural systems can be the cause of various types of pollution, including air, soil, and water pollution. Agricultural pollutants have the potential to impact heavily on the environment - from the immediate on-farm environment, to agricultural food products (such as beef and dairy), and from local surface and groundwaters, to the very air that we breathe (Merrington *et. al.*, 2002a). Hence, agriculture is continually under growing pressure to meet public demands for accountability of quality and safety of agricultural inputs and products, improved environmental performance, and traceability of practices (Ancev, Whelan & McBratney, 2005).

2.2.1 Types of agricultural pollutants and their impact on the environment

The increased intensity of production on modern day farms due to a fuelled demand for agricultural products worldwide has had exacerbating effects on agricultural and livestock pollution problems (Kristiansen, Taji & Reganold, 2006; Leigh, 2004). In other words, an increase in population has resulted in an increase in the demand for food, putting greater pressure on agricultural producers, who in turn put greater pressure on their immediate environment in order to reap better returns (Feng *et. al.*, 2005; Milne, 2005; Chadwick & Chen, 2002; Giasson, Bryant & Bills, 2002; Merrington *et. al.*, 2002a; Owen, 1994).

Whatever the cause, pollution from agricultural livestock systems can have adverse effects on the atmosphere, water supplies, and the food chain, by both the direct and indirect transmission of toxins and disease through animal products and emissions (Liu, Liao, Zhang Z, Zhang H, Wang & Meng, 2007; Chadwick & Chen, 2002; Merrington *et. al.*, 2002a; Rejesus & Hornbaker, 1999; Carpenter, Caraco, Correll,

Howarth, Sharpley & Smith, 1998; Owen, 1994). Pollution of the food chain has become a major issue in the 21st century, partly because of the fears that the consumer has about real and/or imagined risks associated with the consumption of animal products such as meat and dairy products (Owen, 1994).

When discussing agricultural pollutants, it is first important to define the term. A pollutant is any substance that:

- 1) is deliberately introduced into the environment (e.g.: pesticides and fertilizers);
- 2) is produced by agricultural processes as wastes (e.g.: farmyard manure (FYM) and slurry); or
- 3) is produced by the enhancement of natural processes in the course of agricultural activity (e.g.: nitrous oxide from cultivated soils and methane from livestock).

(Merrington *et. al.*, 2002a)

The most common forms of pollutants that can occur in agricultural systems include nitrates and phosphates in fertilizers (also K, Ca, Mg, and Na), organic matter, pesticides, heavy metals and pathogens (Chadwick & Chen, 2002; Merrington *et. al.*, 2002a; Sharpley, 2002; Butler, Wooding & Myers, 1978). In terms of dairy farming systems, pollution is often said to result from poor waste storage and/or management.



Figure 2.3: Water pollution caused by wastewater run-off from dairy lagoons (point-source pollution) (Researcher's own photographs).

‘Waste’ is a term used to describe those by-products of livestock farming which cannot normally be sold. These include: slurries, wastewaters, solid manures, and

silage effluent (Nicholson, 1994). Mismanagement of these agricultural wastes can result in both point source and non-point source transfers of nutrients and organic matter to water sources (Carpenter *et. al.*, 1998). **Point source pollution** (Figure 2.3) happens via leakages and spills from poorly managed waste storage facilities, whereas **non-point source pollution** occurs via run-off waters from fertilized lands and irrigation channels (Chadwick & Chen, 2002; Carpenter *et. al.*, 1998). Although point source pollution is relatively easy to recognise and control (e.g. tends to be continuous, little variability), non-point source pollution is difficult to measure and regulate as it is derived from activities scattered over a large area and these inputs can often vary over time and space due to factors such as seasonality and weather patterns (Carpenter *et. al.*, 1998).

The two most common agricultural pollutants are Nitrogen (N) and Phosphorus (P), which are universally applied to soils and crops as fertilizers (Almasri, 2007; Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998). These nutrients can find their way into water sources causing dangerous pollution, including toxic algal blooms, hypoxia (depletes dissolved oxygen available to marine life), and loss of biodiversity (Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998; Butler *et. al.*, 1978). Nitrates, in large doses, are also toxic to human children and can cause methaemoglobinaemia (“Blue Baby Syndrome”), as well as stomach cancer in adults (Leigh, 2004; Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998). Pollution occurs when fertilizers are applied in excess of the crops’ requirements of nutrients, or when fertilizers are applied at times of the year when little or no crop growth occurs and the risk of run-off is heightened (Almasri, 2007; Webb & Archer, 1994). N and P fertilizer application from agricultural production not only exceeds outputs in produce, but is also the largest contributor to agricultural non-point source nitrate pollution in the USA, as well as many other countries (Almasri, 2007; Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998).

In modern intensive livestock farming, the storage and disposal of large amounts of wastes is of great relevance and concern to farmers as such wastes contain large amounts of N, P and K. Merrington *et. al.* (2002a) found that, out of all the different forms of agricultural pollutants, organic pollutants accounted for almost 90% of all farm pollution incidents recorded in the UK, with dairy farming causing more

incidents than all other agricultural sources combined. Adjacent studies have found that the most common causes of such pollution include: 1) poor containment of wastes, 2) the discharge of untreated dairy washings, and 3) surface run-off of slurries following application to land (Hoffman, Harris & Mazac, 2001; Danalewich, Papagiannis, Belyea, Tumbleson & Raskin, 1998).

Typical dairy wastewater comprises a combination of runoff from feedlot areas, silage pads, holding areas, and milking centre wastewater (a mixture of manure, milk residue, and food grade cleansers) (Northcott, 2004). These wastes that are flushed out in the rinsing phase of dairy parlour cleaning process, along with elements (e.g. N and P) present in the detergents used in cleaning processes, are leading contributors to eutrophication of surface and groundwaters on dairy farms and their surrounding areas (Danalewich *et. al.*, 1998). Such eutrophication manifests itself as toxic algal blooms in water sources, presenting a significant health hazard in being poisonous to both livestock and humans (Chadwick & Chen, 2002).

As the intensity of dairy farming operations increases (e.g. the occurrence of larger numbers of animals on single farms), attention has shifted to manure management and the possible environmental degradation it can cause on farms (Giasson, Bryant & Bills, 2002). Nicholson (1994), through his research on systems of storage and disposal of livestock wastes, found that many pollution incidents occur because waste storage facilities are often improperly managed, and are inadequate in terms of their size, construction or location. Hence, all watercourses adjacent to areas of production, storage or application of agricultural wastes are potentially at risk of point source pollution (Merrington *et. al.*, 2002b).

Livestock wastes can be used as fertilizers for both grassland and certain crops (Figure 2.4) due to the fact that they contain useful amounts of nutrients. The application of such organic wastes and manures to land has historically been important for maintaining soil fertility in terms of nutrient status and organic matter levels, as well as helping to reduce soil erosion and improve water holding capacity (Merrington *et. al.*, 2002b; Fraisse *et. al.*, 1996).



Figure 2.4: Spreading waste onto cropland via a tanker (Researcher's own photograph).

However, the nutrient content of FYM is frequently overlooked or underestimated, and the application of organic wastes to land is often mistakenly regarded as an 'easy' form of waste disposal (Webb & Archer, 1994), which can lead to dumping of wastes onto lands without correct waste analysis and planning. This is a very real problem that is occurring in South Africa as this is being written, which is contributing significantly to environmental pollution of many water sources.

2.2.2 Mechanisms for pollution management and control within agricultural systems: Current and future strategies.

Pollution incidences in agriculture are often the result of poor waste management. Inadequate storage facilities, over-application of nutrients and fertilizers to land, and spills and leakages from storage systems are only a few of the ways in which harmful agricultural substances can enter the environment (Merrington *et. al.*, 2002a). Hence, it is important to address pollution within agricultural systems through correct management practices and mechanisms.

Pollution management can successfully be achieved in two ways (Merrington *et. al.*, 2002a). Firstly, we can attempt to 'cure' the problem by acting against pollutants that are already present in agricultural systems (e.g. using water treatment facilities to clean polluted water). Secondly, we can take an active role and try to 'prevent' the

problem by addressing the underlying causes of pollution in these systems. Five common pollution control principles that encompass this form of management are identified below:

- 1) Reducing the **intensity** of agricultural production (e.g. organic farming);
- 2) **Recycling**/management of wastes (e.g. anaerobic digestion, litter);
- 3) **Tailoring** fertilizers and feed to avoid excess nutrients;
- 4) Defining **thresholds** and source area delineation for fertilizer application; and
- 5) **Transport** and **storage** management.

(Carpenter *et. al.*, 1998; Owen, 1994)

Alternative management systems have become increasingly inviting over the last few years as farmers have begun to investigate farming practices that reduce the intensity of agricultural production and promote a positive relationship between agriculture and the environment (University of Illinois, 2008; Rodrigues, Pereira, Cabanas, Dias, Pires & Arrobas, 2006; Edmeades, 2003; McLaughlin & Mineau, 1995). Such farming practices can be termed ‘organic’ or ‘biodynamic’ farming, and are based on the principles that they are more environmentally benign and promote environmental friendly practices such as limiting or even prohibiting the use of chemical fertilizers (Edmeades, 2003).

The recycling of nutrients in manures and wastes could significantly contribute to alleviating waste storage issues in agriculture (Webb & Archer, 1994). By re-using wastes to fertilize lands, together with or entirely in place of chemical fertilizers, farmers can save money as well as promote environmental practice within their agricultural systems. If waste is applied as fertilizers, then storage space and period is reduced, decreasing the likelihood that such stored waste could pose a threat to the environment. Correct management of waste applications is vital to the success of such a venture and the extent to which nutrients can be recycled from wastes is dependent on factors such as the amount of waste necessary for a certain area of land, the timing of the application, and the form of the waste being used (Matsi, Lithourgidis & Gagianas, 2003; Ap Dewi, 1994; Webb & Archer, 1994).

By tailoring fertilizers (organic or chemical) in order to ensure that they meet specific crop nutrient requirements, farmers can ensure that there are little or no excess nutrients that can run-off into water sources (Tagg, 2007; Merrington *et. al.*, 2002b; Rejesus & Hornbaker, 1999). This principle is based on the fact that the farmer should only apply the amount of fertilizer absolutely necessary to meet the crops' needs (i.e. the crop threshold). Coupled to this approach is a form of precision farming that could aid in the management of nitrogen and phosphorus pollution known as site-specific management (SSM), which is based on 'taking advantage of productivity differences between different soil types, or other sources of spatial variation, and targeting the optimal application levels of fertilizers consistent with the productivity characteristics and/or other spatial characteristics of soil specific to a particular area' (Rejesus & Hornbaker, 1999). In this way, the farmer can reduce surplus N run-off by making certain that N-applications are precisely matched to specific soil N requirements, thereby ensuring that there is no excess N that could run into water sources or leach through the soil into ground water supplies (Rejesus & Hornbaker, 1999; Owen, 1994).

However, the most effective way of reducing point source pollution is to upgrade waste storage facilities, which are often the leading causes of water pollution in agriculture (Webb & Archer, 1994). Inadequate storage facilities can result in spills and leakages of wastes that inevitably end up in water sources such as dams or rivers. By calculating the storage requirements for slurry and wastewater, and thus ensuring that there is enough space for one's waste, farmers can greatly minimize their pollution risk. Furthermore, if one is to make use of such wastes in irrigation or land applications, it is essential that correct transport equipment be utilized (Butler *et. al.*, 1978). Adequate pumps and pipelines are essential, and it is paramount that such systems are assembled correctly in order to avoid leakages, and that they are maintained on a regular basis.

To conclude, all farming systems need some means of maintaining the soil's plant nutrients. Without this, continuous cultivation of crops could eventually lead to detrimental environmental effects such as erosion and loss of biodiversity, to name only two. Thus, even though fertilizers and wastes are the leading cause of diffuse water pollution worldwide, they are an essential component of successful agricultural

practice. It is therefore imperative that farmers employ well planned management strategies when working with these substances in order to prevent further environmental degradation within agricultural systems. Because of the effects that increased intensification in agricultural practices can have on agricultural ecosystems, it is necessary that such practices are controlled, especially in such a way that promotes the conservation of natural resources that are used for agriculture. Such “control methods” are discussed in the following section on legislation and policies in South Africa that are geared towards ensuring environmental sustainability within agricultural systems.

2.3 Environmental management and legislation in South Africa

With pollution an ever-increasing problem worldwide, South Africa has a growing obligation to meet international commitments and to be a globally responsible country (South Africa, 2000). As a result, South African leaders need to investigate improved means of pollution and waste management if they want the country to become fully integrated into the global community (South Africa, 2000). With the introduction of mandatory environmental impact assessments in 1997, a significant shift was made towards attaining sustainable development within the country (Hoogervorst, Rosenberg & Kemm, 1999). Furthermore, the development of environmental legislation, together with the environmental rights included within the Constitution of the Republic of South Africa Act, 108 of 1996, has resulted in a very comprehensive framework of environmental laws that are applicable to South Africa. However, to date, these laws have been poorly enforced and this situation is in need of immediate rectification (Hoogervorst *et. al.*, 1999).

Intensification in agriculture countrywide requires the guidance of environmental policies and legislation if agricultural activities in the country are to contribute to the sustainability of agriculture within South Africa as a whole. In particular, the environmental management of agricultural waste products is of growing concern. In the South African White Paper on Integrated Pollution and Waste Management (2000) waste is defined as:

“...an undesirable or superfluous by-product, emission, or residue of any process or activity which has been discarded, accumulated or been stored for the purpose of discharging or processing. It may be gaseous, liquid or solid or any combination thereof and may originate from a residential, commercial or industrial area. This definition includes industrial wastewater, sewage, radioactive substances, mining, metallurgical and power generation waste.”

(South Africa, 2000:1)

The estimated total waste generation in South Africa in the year 1999 is illustrated in Table 2.3.

Table 2.3: Estimated waste generation in the RSA in million tons/annum (Theron, 1999).

| Source | QTY | % of Total | Hazardous Portion (tons) |
|------------------|------------|------------|--------------------------|
| Mining | 377 | 80,3 | 1,05 |
| Industrial | 22 | 4,7 | 0,81 |
| Power generation | 20 | 4,3 | 0,01 |
| Agriculture | 20 | 4,3 | 0,13 |
| Domestic & trade | 18 | 3,8 | 0,13 |
| Sewage Sludge | 12 | 2,6 | 0,13 |
| Total | 469 | 100 | 2,26 = +/- 0,5% |

The White Paper on Integrated Pollution and Waste Management (2000) gave rise to the formulation of a National Waste Management Strategy and Action Plans (Theron, 1999). A few of the many separate acts included in this strategy and directing agricultural waste management in South Africa include:

- The White Paper on Agriculture
- The White Paper on Integrated Pollution and Waste Management, 2000
- The National Environmental Management Act, 1998 (Act 107 of 1998)
- The National Water Act, 1998 (Act 36 of 1998)
- The Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983)
- The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947).

The following sub-sections will explore the concept of environmental management, as well as the core policies and legislation documents applicable to the agricultural sector in South Africa, that seek to promote the sustainable use of natural resources within our borders in order to ensure a sustainable future for all south Africans.

2.3.1 Environmental Management

Environmental management is a deliberate, multidisciplinary process that requires careful preparation and planning. It can be defined as *‘management that has as its objective the protection of human health and well being, and the protection*

(*preservation and conservation*) of life forms, and their habitats' (Dupont, Baxter & Theodore, 1998:1). This process includes the gathering of information, by a company or organisation, on natural and human activities, processes and systems, decisions surrounding plans and procedures, the drawing up of documents and the implementation of various management systems (Hoogervorst *et. al.*, 1999). This type of planning and decision-making should be carried out in a participative manner to ensure that all stakeholders and interested and affected parties understand the purpose, manner and form in which it is to be applied, as well as to ensure that corrective action, auditing and review activities are all undertaken, in order to guarantee that specific company/organisation targets are achieved (Smith & Scott, 2002; Hoogervorst *et. al.*, 1999). Figure 2.5 indicates an environmental management plan that is currently being used by policy makers in South Africa.

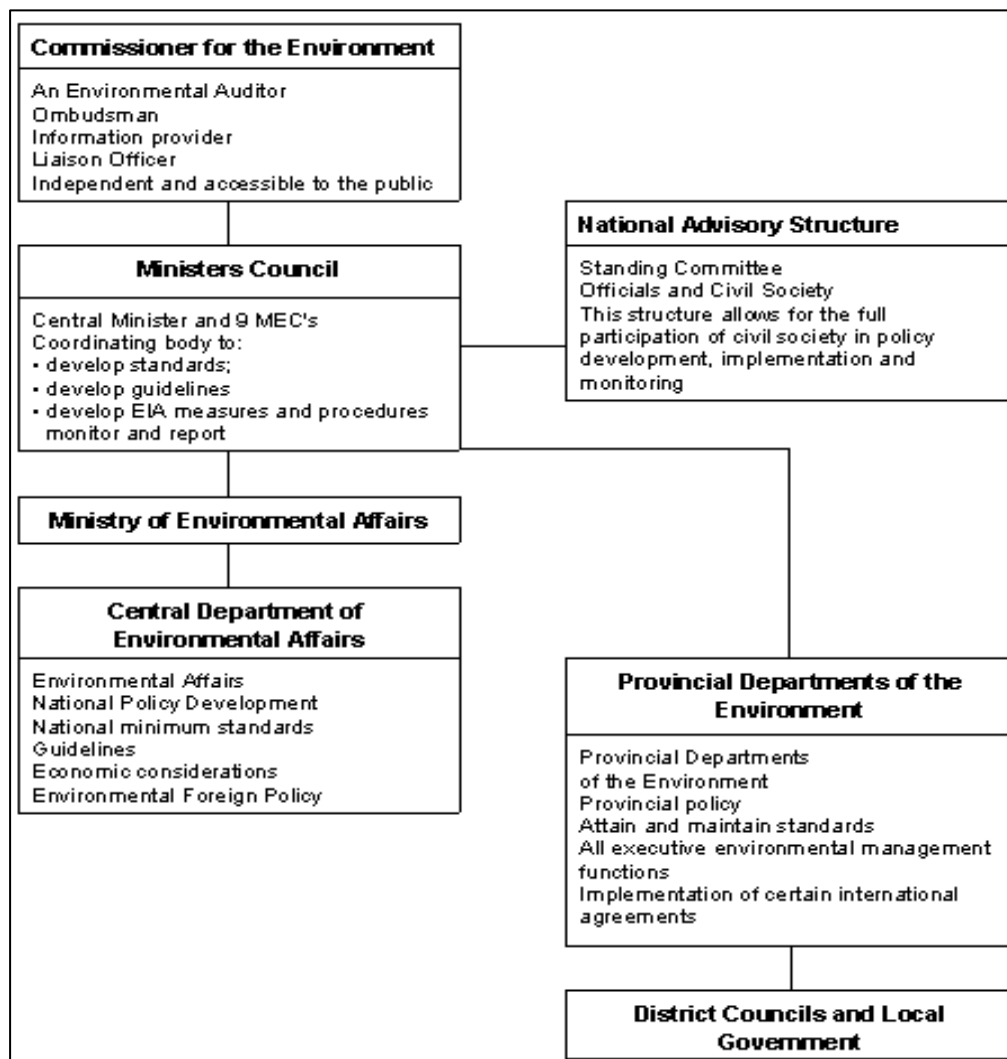


Figure 2.5: Course of action taken in the development of environmental management policies and systems in South Africa (DOA, 1998).

When developing an environmental management strategy, various legal documents need to be consulted. Sections 2.3.2 to 2.3.7 will discuss some of the Acts that are relevant to agricultural resource management in South Africa, with particular focus on the management of agricultural waste products.

2.3.2 White Paper on Agriculture

The White Paper on Agriculture is a policy document that was drawn up by the South African Department of Agriculture in 1995, with the intent of providing concerned parties with essential basic principles for successful and sustainable agriculture. This policy is aimed at *‘ensuring equitable access to agriculture and promotes the contribution of agriculture to the development of all communities, society at large and the national economy, in order to enhance income, food security, employment and quality of life in a sustainable manner’* (DOA, 2008a: 1). The following basic principles regarding sustainable agricultural practice in South Africa are outlined:

- All South Africans are custodians of and should accept responsibility for the country’s natural resources;
- **All farmers must be made aware of and accountable for the sustainable utilisation of natural agricultural resources;**
- South Africa’s productive agricultural land should be retained for agricultural use;
- **Land users’ responsibility towards the land will include the rehabilitation of mismanaged natural agricultural resources;**
- The government recognises its responsibility to provide assistance and law enforcement for the appropriate management of the natural agricultural resources while maintaining a balance between the basic needs of people and the promotion of an all-inclusive environmental ethic;
- Natural resources (e.g. water) constituting the agricultural potential of land are national assets.

(DOA, 2008a)

By placing the responsibility of sustainability in the hands of consumers as well as producers, government is creating a positive environment where cooperation is essential to the success of agricultural sustainability in the country. The relationship between the environment and humankind is promoted due to the responsibility that all South Africans are given regarding the control over natural resources. Here, ownership creates a feeling of responsibility in all shareholders, and that

responsibility involves the conservation of the environment and its various resources. Furthermore, the Act stipulates that the rehabilitation of mismanaged land is the responsibility of the landowners, and this fact should encourage farmers to exercise sustainable, environmentally friendly farming practices so as to avoid reciprocation from the law.

2.3.3 Conservation of Agricultural Resources Act (CARA)

The Conservation of Agricultural Resources Act No. 43 of 1983, allows the National Department of Agriculture to exercise control over the utilisation of South Africa's national agricultural resources (South Africa, 1983). The intention of the act is stated as being:

'To provide for control over the utilization of the natural agricultural resources of the Republic in order to promote the conservation of the soil, the water sources and the vegetation and the combating of weeds and invader plants; and for matters connected therewith.'

(South Africa, 1983:1)

In the act, natural agricultural resources are defined as '*soil, water sources and vegetation, excluding weeds and invader plants*' (South Africa, 1983:2). Through the control of these resources, the government is able to ensure the conservation of South Africa's biological heritage, and in the process, promote sustainable practices and use of such resources in agriculture.

In a similar attempt at sustainable management of national resources, authorities have drawn up the White Paper on Integrated Pollution and Waste Management for South Africa, a document that once again emphasizes the importance of involving various stakeholders at grass-roots level in policy development and implementation.

2.3.4 White Paper on Integrated Pollution and Waste Management for South Africa.

Different approaches to integrated pollution and waste management are explored in this policy document, focusing on a shift away from an attitude of 'solution' to one of

‘prevention’ (South Africa, 2000). It identifies the following key problems surrounding pollution and waste management in South Africa:

- **Lack of priority afforded to waste management;**
- Fragmented legislation and ineffective enforcement;
- Unacceptable safety, health and environmental practices for pollution and waste management;
- The absence of integrated waste management options; and
- Insufficient involvement and empowerment of people.

(South Africa, 2000)

The paper identifies various strategic goals for policy implementation, and emphasizes the roles that need to be undertaken by various stakeholders involved, including the government itself. The stress here is strongly on the involvement of people in pollution prevention. Furthermore, the way forward for pollution and waste management in the country is stated, and involves administrative actions, the integration of the National Waste Management Strategy, and legislative amendments and implementation of legislation (South Africa, 2000). Problems surrounding policy implementation and lack of priority afforded to pollution and waste management are cited as being the main culprits contributing to poor decisions in the past. A movement away from previous management based on finding a ‘solution’ to pollution incidents, towards a more ‘prevention’ oriented approach, ensures that government can crack down more strictly on offenders who are polluting the environment.

2.3.5 National Environmental Management Act (NEMA)

The National Environmental Management Act (NEMA) No. 107 of 1998, further seeks to uphold sustainable development in South Africa through ‘*the integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that development serves present and future generations*’ (South Africa, 1998a: 2). The preamble to the act states the intention of the act as being:

‘To provide for co-operative, environmental governance by establishing principles for decision-making on matters effecting the environment, institutions that will promote

co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith.'

(South Africa, 1998a: 2)

Furthermore, it is stated within the act that everyone has the right to '*have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that: prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development*' (South Africa, 1998a: 2).

The act focuses largely on sustainable use of natural resources, and is therefore a key piece of legislation in agriculture due to the fact that agricultural resources are regarded as natural resources and are therefore worthy of conservation. In addition, the duty of care provisions included in both the National Water Act and the National Environmental Management Act create a public consciousness not to pollute and to remediate where pollution has been caused. These acts go on to describe national environmental management principles, and strongly emphasize the fact that natural resources should be made available to all citizens of the country as part of their national heritage (South Africa, 1998a).

With special reference to the purpose of this research, the act also addresses the theme of environmental degradation, and states with no ambiguity that '*the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment*' (South Africa, 1998a: 14). This sentence alone identifies the importance of environmental management within agriculture for the farmers themselves, as failure to follow laws and regulations of this nature could result in severe fines and punishments.

2.3.6 The National Water Act (NWA)

The National Water Act (NWA) No. 36 of 1998, provides for the protection and integrated management of the quality of water resources in South Africa. The purposes of the NWA include the meeting of basic human needs of present and future generations, as well as the redressing of the results of past racial and gender discrimination (South Africa, 1998b). The Department of Water Affairs and Forestry (DWAF) is the primary agency responsible for water resources management, and in exercising its mandate, DWAF must reconcile, integrate and coordinate diverse and often conflicting interests of different stakeholders, within the framework of sustainable and equitable utilizations of South Africa's water resources (South Africa, 1999).

The NWA defines waste as including *'any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted'* (South Africa, 1998b: 16). The Act recognises that water is a natural resource that belongs to all people and that the national government, through the Minister of Water Affairs and Forestry, is acting as the public trustee for the people. As such, he must *'ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefits of all persons and in accordance with its constitutional mandate'* (South Africa, 1998b: 14). The Act goes on to stipulate the different forms of waste disposal that constitute pollution of water resources, and the legal ramifications of such actions. Like the NEMA, the NWA puts a responsibility on the person who owns, controls, occupies or uses the land from where the water is polluted to take measures to prevent and/or rectify pollution. If s/he does not take these measures, the Catchment Management Agency (CMA) may do what is necessary to remedy the situation and recover the cost from the person that is responsible (South Africa, 1999; South Africa, 1998b). The Act states that these CMA's are responsible for *'developing catchment management strategies and are required to set principles for allocating water to existing and prospective users, taking into account all matters relevant to the protection, use,*

development, conservation, management and control of water resources' (South Africa, 1998b: 24).

Furthermore, a number of offences are listed in the NWA related to non-compliance with directives and requirements of the Act. These include:

- Failure to register water use;
- Unlawfully and intentionally or negligently committing any act or omission which detrimentally affects or is likely to affect a water source; and
- Failure to provide access to any books, accounts, documents or assets required under the Act.

(South Africa, 1998b)

A person guilty of an offence is liable to a fine and/or imprisonment. The offender may also be liable for damages, for the loss or harm suffered by others, as well as for remedial measures (South Africa, 1998b).

2.3.7 Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act

The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act no. 36 of 1947, is aimed at regulating the sale and use of the above mentioned substances. The preamble to the act states the intention of the act as being:

'To provide for the appointment of a Registrar of Fertilizers, Farm Feeds and Agricultural Remedies; for the registration of fertilizers, farm feeds, agricultural remedies, stock remedies, sterilizing plants and pest control operators; to regulate or prohibit the importation, sale, acquisition, disposal or use of fertilizers, farm feeds, agricultural remedies and stock remedies; to provide for the designation of technical advisors and analysts; and to provide for matters incidental thereto.'

(South Africa, 1947:1)

Such an act is necessary in regulating fertilizer practices within the country. Advisers and controllers are in place to ensure that fertilizers are obtained and utilized in the most environmentally friendly way possible. Without an act like this one, dangerous chemicals could be introduced into the environment and would be a serious threat to

the natural resource base, as well as pose a dangerous hazard to humans. The act is thus in place to regulate the use of fertilizers, farm feeds, and agricultural and stock remedies in order to benefit the consumer, the farmer and the natural environment.

2.3.8 Legislation and waste management in South Africa

As can be seen from the above discussion, various legislations and policies are applicable to agricultural producers in South Africa. Currently, environmental protection is a growing concern for farmers and consumers worldwide (Merrington, Winder, Parkinson & Redman, 2002b; DOA, 1998; Garnier *et. al.*, 1998). Together with increasing economic development accompanying the rise in world population, there comes an ever increasing potential for environmental pollution and degradation of natural resources used in agricultural systems (Owen, 1994). As noted in sections 2.3.2 to 2.3.7, it is evident that the South African government is gearing towards involving as many stakeholders as possible in the promotion of agricultural and environmental sustainability within our borders. Such an approach is essential if a symbiotic relationship between the environment and agriculture is to exist. Farmers need to recognise the importance of sustainable agricultural practice, and it is therefore imperative that they are aware of and incorporate environmental policy into their businesses. Through successful integration and management of such legislation, environmental degradation can be managed, and even eradicated, from agricultural systems.

With regard to dairy wastewater management, farmers need to be aware of the legal implications of disposing of these wastes in a non-environmentally sound manner. Although enforcement of legislation in the past has been poor, it is evident that government is rectifying this situation and will be a force to deal with in the near future. As a result, in a more recent movement aimed at reducing the pollution potential of their cropping practices, farmers are exploring the option of recycling their dairy wastewater and manure and using this as a fertilizer for crops. However, if wastes are to be utilized in this way, it is necessary that we understand their place in agriculture, their composition, and the pros and cons of using them in the place of conventional fertilizers such as urea/nitrogen (N), phosphorus (P) and

potash/potassium (K). A comparison between organic wastes/manures and chemical fertilizers is therefore essential before a conclusion can be made about the feasibility of manure applications in agriculture. The following section will seek to define fertilizers, aiming to compare similarities and discrepancies between chemical and organic fertilizers with regard to their positive and negative impacts on the environment. Following this, a discussion focusing on manure vs. chemical fertilizer applications as a whole will be conducted.

2.4 The use of fertilizers in agriculture

All agricultural systems depend on the maintenance of soil fertility in order to achieve environmental and economic sustainability (Davis & Abbott, 2006). In any biological system, plants require up to sixteen different chemical elements for successful growth and development, of which nitrogen, phosphorus and potassium are the most important (Grigg, 1984). Because of this, farmers need to make use of some manual means of maintaining the soil's plant nutrients, without which, the continuous cultivation of crops would ultimately lead to soil exhaustion and erosion, and result in a decline in crop yields (Grigg, 1984). This form of maintenance in agricultural systems is achieved through the application of fertilizers to soils and crops.

Fertilizers are organic and/or inorganic compounds that are applied to soils and crops in order to promote growth, yield, quantity and nutritive value of agricultural produce (Herren & Donahue, 1991; Stephens, 1990; Somani & Tikka, 1983). They can be organic (composed of organic matter, i.e. manure and composts) or inorganic (made of simple inorganic chemicals or minerals, i.e. N, P, and K) and typically provide the following nutrients to crops and soils:

- 1) three major plant nutrients (nitrogen, phosphorus, potassium: N-P-K);
- 2) secondary plant nutrients (sulphur, magnesium and calcium); and
- 3) trace elements (or micronutrients) that play a role in plant nutrition: boron, chlorine, manganese, iron, zinc, copper, and molybdenum.

(Encyclopaedia Britannica, 2007; Herren & Donahue, 1991).

The next sub-section will explore the definitions of both organic and inorganic fertilizers, as well as highlight the pros and cons associated with their management, storage and use in agricultural systems.

2.4.1 Chemical fertilizers: Definition and place in agriculture (storage, management, use, costs).

Definition

Farmers utilize chemical fertilizers in order to replace the chemical components that are taken from the soil through the cultivation of various crops in agriculture (Stephens, 1990). However, they are also designed to improve the production potential of soil and create a better growing environment than natural soil for the cultivation of agricultural crops.

Chemical fertilizers are manufactured industrially and include **nitrogen fertilizers** (containing mainly nitrate and ammonium), **compound fertilizers** (supplying two or more nutrients), and **liquid fertilizers** (solution of materials used in chemical fertilizers) (Stephens, 1990). Such fertilizers are typically made from three major nutrients, namely nitrogen, phosphorus and potassium (N, P and K). **Nitrogen (N) fertilizers** are obtained from synthetic ammonia (NH_3) that is converted from a gas or liquid form into salts such as ammonium sulphate, ammonium nitrate, and ammonium phosphate for use on soils and crops (FSSA, 2008; Encyclopaedia Britannica, 2007). Rocks and bones are used to derive calcium phosphates, otherwise known as **Phosphorus (P) fertilizers**, and **Potassium (K) fertilizers** (potassium chloride, potassium sulphate and potassium nitrate) are commonly mined from potash deposits (Encyclopaedia Britannica, 2007).

Storage and Management

As with any foreign substance being introduced into an ecosystem, proper management of chemical fertilizers is essential for ensuring that they do not become an environmental hazard within agricultural systems. The Fertilizer Society of South Africa (FSSA, 2005) identifies the following steps in proper storage and management of these chemical compounds:

- not to be compacted, and should be kept at a constant, allowable humidity;
- stored in piles no higher than 2 metres, never outdoors without protection;
- kept in their original, waterproof packaging;
- ammonium nitrate (explosive) should be kept separate, and liquid fertilisers are to be stored with leakage collection containers; and

- fertilizer spreading machines are not to be washed in/near water sources.
(FSSA, 2005)

If managed correctly, fertilizers are a very useful method of nutrient supplementation for agricultural soils, and can contribute towards the maintenance of soil fertility and minimise the degradation of the soil. Positive fertilizer application considers the following factors:

- what nutrients are required by the crop/soil (what are adequate quantities of fertilizer);
- what type of fertilizer to use (considering soil type, soil chemistry, climatic conditions, crop type);
- when are the most suitable application periods (seasonality); and
- what the best application techniques are (efficiency).

(FSSA, 2005; Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998)

Application techniques used by farmers utilizing chemical fertilizers in South Africa include liquid irrigation (“fertigation”) and granular spreading (Figure 2.6). Fertigation is achieved through either static irrigation lines (sprinklers) or a centre pivot system.



Figure 2.6: Static irrigation line, centre pivot irrigation system, and granular fertilizer application.

Cost

The South African fertilizer industry is exposed to world market forces and therefore operates in a totally deregulated environment with no import tariffs or government sponsored support measures (FSSA, 2006). Hence, there are four main driving forces that influence the demand, and consequent price, of chemical fertilizers in South Africa. These are: the price of oil, the exchange rate of the Rand, the low production

of cereal crops, and high crop prices (FSSA, 2007). Because nitrogen fertilizers are made using natural gas, the significant increase in the oil price at the end of 2007 impacted heavily on the price of these fertilizers in South Africa (Figure 2.7).

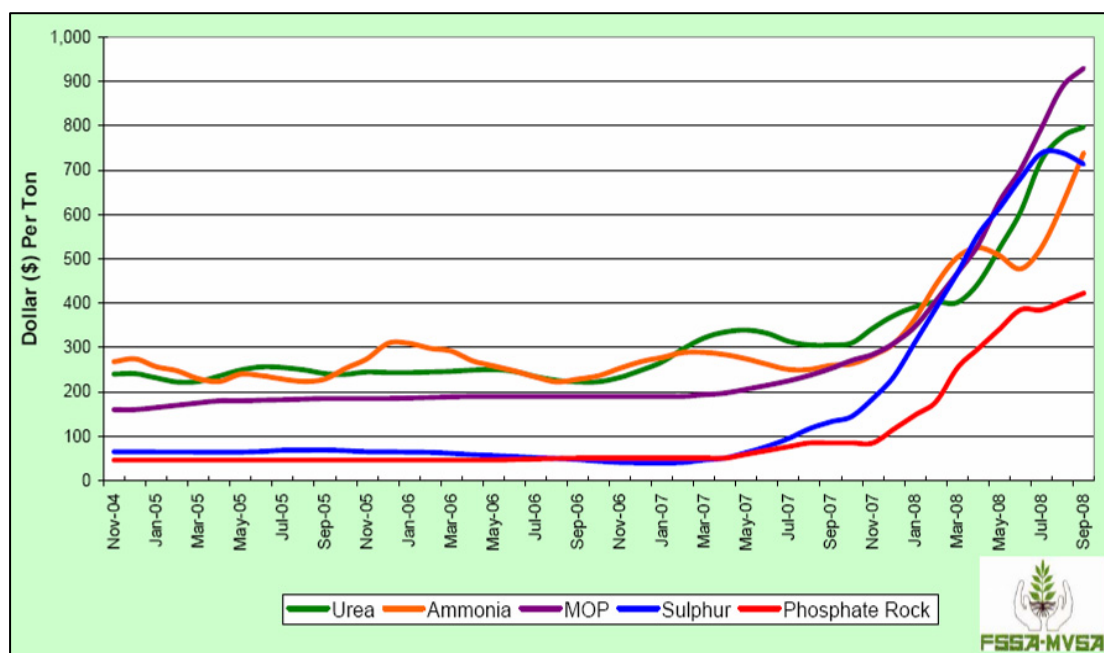


Figure 2.7: International price trends of fertilizers and raw materials (four-month moving average) (FSSA, 2008).

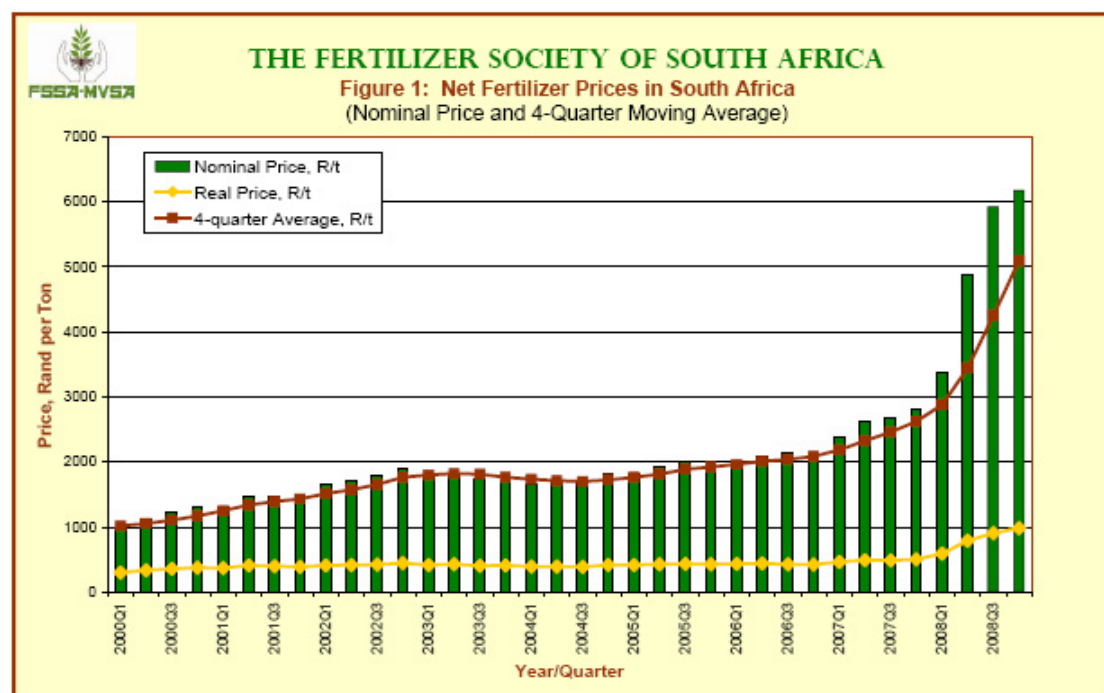


Figure 2.8: Net fertilizer prices (current price and 4-quarter moving average) (FSSA, 2008).

The price of chemical fertilizers tends to vary with their chemical composition, demand and supply, and is currently sitting around R4500 a ton (Figure 2.8) (FSSA,

2008). The average amount being spent by farmers on fertilizers currently is around R 2650 p/ha in preparation for planting crops, and a further R1700 p/ha used in top-dressing, a total of R4350 p/ha/yr (Dixon 2008, pers com). Fertilizer equipment is also not cheap. According to Prins (2008, pers com), the cost of an irrigation system would roughly be around R 18 000 p/ha (static line irrigation) and R31 000 p/ha (centre pivot irrigation). For both systems, the addition of a central fertigation set-up (tank, pump, etc) would cost around R20 000 (Prins 2008, pers com).

2.4.2 Advantages and disadvantages of chemical fertilizer utilization in agriculture

A distinct advantage of chemical fertilizers is that they release their nutrients immediately when applied to soils or crops; in other words, there is no time required for the breakdown and release of nutrients, and they are immediately available to the plants (Keithlow, 2008). Additionally, chemical fertilizers can be tailored to meet the specific needs of crops, reducing the threat of over-fertilization. Proper fertilization results in higher crop quality in terms of mineral, protein and vitamin contents, and contributes significantly to the maintenance and improvement of soil fertility that is inherent to sustainable agriculture (FSSA, 2008).

Mismanagement of chemical fertilizers, however, can result in the loss of farm profitability, the loss of soil fertility, reduced crop yields, and environmental degradation (including surface- and groundwater pollution) (FSSA, 2008; Encyclopaedia Britannica, 2007; FSSA, 2005). Agriculture is the leading source of N and P pollution in aquatic systems worldwide (Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998), which ultimately results in problems such as:

- hypoxia (depletion of oxygen in water and the resultant death of marine life),
- eutrophication (toxic algal blooms),
- loss of biodiversity,
- health risks to both humans and animals (methaemoglobinaemia – “blue baby syndrome”, stomach cancer).

(Almasri, 2007; Leigh, 2004; Rejesus & Hornbaker, 1999; Carpenter *et. al.*, 1998)

The fact that fertilizers are polluting water sources means that there is an excess of nutrients being applied to soils/crops that is not being absorbed by the plants and

therefore are running off into water sources (FSSA, 2005). Environmental pollution from chemical fertilizers is almost always as a result of human negligence and/or inadequate storage facilities (FSSA, 2005; Hoffman *et. al.*, 2001; Danalewich *et. al.*, 1998).

In addition to water pollution, environmental problems that can result from poor fertilizer management include soil erosion, loss of soil fertility, increased mechanisation, threats to biodiversity, and denitrification (FSSA, 2005; Leigh, 2004). Most N-fertilizers acidify soils, but this can be corrected with proper soil liming practices whereby lime is added to agricultural lands to maintain a desired pH (FSSA, 2008). Industrial fertilizer production also involves the consumption of large amounts of energy (e.g. fossil fuels) in the form of natural gas. According to some studies, it takes about ten to fifteen times as much energy to produce food using fertilizers than is actually contained in the food itself (Leigh, 2004; Carpenter *et. al.*, 1998). Thus the question is raised as to whether it is sustainable to continue to produce chemical fertilizers when the environmental costs appear to be overriding the benefits.

Worldwide, more farmers are seeking alternatives to industrially produced fertilizers. The high costs involved in the production, transport and storage of chemical fertilizers, as well as an increase in intensity of agricultural practices, has led many farmers to explore more economically sustainable alternatives. Amongst these alternate strategies is the application of farmyard wastes onto agricultural lands. The following sub-section will explore this concept in further detail.

2.4.3 Dairy wastes: Definition and place in agriculture (storage, management, use, costs).

Definition

Dairy Wastes can generally be defined as those by-products of livestock farming which cannot normally be sold, such as slurries, wastewaters, solid manures, and silage effluent (Nicholson, 1994). These wastes can be classified into three main types:

- **Liquid wastes** – material containing <10% solids which can be conveyed through piping systems and is treated in oxidation ponds;
- **Slurry** – contains between 10-20% solids and will flow; and
- **Sludge** – waste exceeding 20% total solids that will not flow and requires mechanical spreading equipment.

(Dexcel, 2007; Encyclopaedia Britannica 2007;
Ap Dewi, 1994; Herren & Donahue, 1991; Stephens, 1990).

Up to now, farmers in South Africa have underestimated the nutrient value of their wastes, and consequently may have managed them inefficiently, thereby increasing their risk of contributing to environmental pollution (Smith & Chambers, 1993). This is noted by Mkhabela and Materechera (2003) in their research on factors influencing the utilization of cattle and chicken manure for soil management in the Midlands of KwaZulu-Natal:

‘The FSSA estimated that in 1989, approximately 3 million tonnes of manure was available in South Africa from various feedlots. The value of this manure calculated in terms of N, P and K was R29.7 million. It was also estimated that the manure was sufficient to meet 13.3%, 9.9% and 27.6% of the country’s requirements of N, P, and K respectively. However, only 25% of this 3 million tonnes was being used in soil fertility management – 75% was mostly wasted, with a small proportion used for heating’

(Mkhabela & Materechera, 2003)

However, the newly discovered value of organic matter to the structure of some soils, as well as high fertilizer costs, have been prompting many farmers to re-consider the use of organic fertilizers on their crops (McLaughlin & Mineau, 1995). The use of manure as a fertilizer in agriculture dates back to the stone age, when manure and dung were used in agriculture to improve soil quality, soil organic material and water

holding capacity, and to recycle nitrogen, phosphorus and carbon (Alvarenga, Palma, Goncalves, Fernandes, Cunha-Queda, Duarte & Vallini, 2007; Sager, 2007; FSSA, 2005; Merrington *et. al.*, 2002b). When recycled back onto the land, dairy wastes offer a source of N, P and K that enhances pasture and crop production, and can help to drastically reduce fertilizer expenditure (Dexcel, 2007). Manure from livestock production is a valuable form of organic fertilizer, as farm animals use only a small proportion of the nutrients in what they eat to produce milk and meat, the rest being excreted as dung and urine (Table 2.4) (Encyclopaedia Britannica, 2007; Miles 2007).

Table 2.4: Approximate percentages of ingested nitrogen, phosphorus and potassium excreted by cattle on pasture (Miles, 2007).

| Nutrient | Beef | Dairy |
|----------------|------|--------|
| Nitrogen (N) | 96% | 85% |
| Phosphorus (P) | 88% | 70-75% |
| Potassium (K) | >95% | >95% |

Storage and Management

As with chemical fertilizers, proper management of manures is essential if they are to be a sustainable resource to farmers. Factors such as the nutrient content of waste, method and rate of application, land accessibility, topography, soil properties, groundwater, and seasonal and climatic factors all need to be considered when planning a dairy waste application scheme (Dexcel, 2007; Ap Dewi, 1994).

Farm wastes can be stored using different systems, dependant on the specific needs of individual farms in terms of their capacity and annual waste production. Some farms irrigate with their effluent directly from the dairy to pastures on a daily basis. Nevertheless, this is an exercise that is not very flexible, requires labour and maintenance, and can also be prone to system failure. Direct application is therefore not recommended without some form of back-up storage facility (Dexcel, 2007). Adequate waste storage facilities are an essential part of waste management, as they enable effluent to be applied to land at only the most beneficial times of the year, and can aid the farmer during crises when he lacks staff or time to deal with direct land

applications. Figure 2.9 shows the most commonly used systems of waste storage currently utilized in dairy farming.

Small concrete sump only, no storage capacity

Disadvantages

- No storage capacity- leads to increased risk of ponding, leaching and run-off
- No stone-trap - increases system wear and tear
- Hard on pump due to starting and stopping and solids content
- No flexibility – labour required on a daily basis.



Concrete stone trap and box sump, no storage capacity

Advantages

- Effective stone trap reduces wear and tear on pumps
- Easy to construct
- Doesn't require a large area
- High nutrient value in effluent

Disadvantages

- Prone to crusting
- Pump hard to service
- Prone to float switch issues due to crusting
- No storage capacity or flexibility - increased risk of ponding, leaching and run-off



Effluent saucer with concrete stone trap

Advantages

- Some storage capacity (from 80m³ up to 200m³)
- Less crusting (no crusting if stirrer is installed)
- Less build up of solids
- Easy to service
- Cost per m³ of storage is very low
- High nutrient value in effluent

Disadvantages

- 3 to 5 days maximum storage capacity.



Pond/Lagoon system

Advantages

- Large storage capacity
- Able to use existing two-pond system
- Can irrigate when conditions are suitable and beneficial
- Less risk of waterway contamination
- Reduced pressure on time and grazing management
- Medium nutrient value.

Disadvantages

- Prone to crusting, needs stirring before pumping out
- Care required with desludging if clay or plastic liner present
- Possible problems with odour if long storage period.



Figure 2.9: Waste storage methods commonly used in dairy farming (Adapted from Dexcel, 2007).

Whether wastes are stored or applied to agricultural land directly is largely dependent on an individual farmer's needs. The different application methods for wastes in agriculture are shown in Figure 2.10.

Centre pivot

Nozzles, droppers or guns attached to the side of the center pivot irrigator. Moves around with the pivot, and can be shifted along as required.

Advantages

- Easy to shift, quick to set up
- No need for additional underground pipes and hydrants
- Can deliver low application rates
- Unlimited carrying capacity.

Disadvantages

- During periods when not irrigating, requires the entire pivot to move just to shift the waste applicator gun
- Waste is often applied to soils that have just received irrigation water, increasing run-off potential
- Lack of control over distribution pattern
- Waste solids can cause nozzles to block, thus separation is needed to prevent such blockages (more equipment, maintenance)
- Inappropriate nozzle size and / or distribution patterns can cause ponding.



Traveling irrigator

Small irrigator specifically for dairy waste uses pressure from pumped waste to rotate boom with a nozzle at each end. Drags along by a winch and cable mechanism at a rate set by the operator.

Advantages

- Common, easy to use, reasonably priced option
- Can deliver low application rates if set up and run correctly
- Unlimited carrying capacity
- Mobile, flexible.

Disadvantages

- Often requires high levels of maintenance
- Labour intensive to shift
- Uneven application
- Require regular checking to ensure pipes are not leaking
- Creates significant ponding in event of cable break or winch failure.
- Separation is needed to prevent blockages (more equipment, maintenance)



Mainline injection

Injection of waste into irrigation mainline and discharge with irrigation water.

Advantages

- Waste is diluted prior to disposal
- Only maintaining one irrigation system
- May be able to reach larger/further areas of the farm
- Unlimited carrying capacity.

Disadvantages

- If the irrigation water is sourced from a groundwater well, or direct from surface water, back flow prevention will be required to be installed to avoid effluent entering the irrigation bore or surface water
- Waste still needs to be spread when there is no irrigation Occurring



- All irrigation water becomes contaminated. Therefore separation distances to wells and surface water applies, and any runoff is required to be controlled
- Separation is needed to prevent blockages (more equipment, maintenance)

Dedicated irrigation line

A separate irrigation line is set up to deal solely with the irrigation of waste material.

Advantages

- Waste is diluted prior to disposal
- Separate irrigation system to the mainline system, thus no contamination of regular irrigation water
- Can reach larger/further areas of the farm
- Unlimited carrying capacity.

Disadvantages

- Expensive to install – laying of pipes, pump
- Checking and maintenance of equipment needs to be done on a regular basis
- Limited areas of application



Waste Tanker

Slurry is pumped from storage ponds into specialized tankers that then spread the waste onto the lands.

Advantages

- Waste does not need to be separated
- Can reach further areas of the farm.

Disadvantages

- Compaction of the land due to heavy machinery
- Increased pollution potential if spread too thickly
- Equipment is expensive
- Labour intensive
- Limited carrying capacity
- Slurry needs to be worked into the land, therefore won't work for no-till systems.



Umbilical Cord system

Pump situated on storage pond wall pumps slurry directly through umbilical pipes which are attached to a tractor mounted dribble bar.

Advantages

- Waste does not need to be separated
- Can reach further areas of the farm.

Disadvantages

- Compaction of the land due to heavy machinery
- Increased run-off pollution potential for steep areas
- Equipment is expensive
- Labour intensive
- Taint (cows won't eat grass)



Figure 2.10: Waste application methods commonly used in dairy farming (adapted from Dexcel, 2007).

As can be seen from the above, many application strategies are reliant on the separation of waste prior to application. Solid material is separated from liquids, ensuring that there will be no blockages of the irrigation equipment when wastewater is applied to lands. The solids are then either applied directly to cropping or pastoral land, or are composted for future application. In South Africa, there are three common

separators used by dairy farmers, namely the rotary screen, static screen, and screw auger systems.



The **rotary screen** separator consists of a revolving perforated drum (like a sieve) that rotates over a catchment tray. As dairy waste is pumped into the rotating drum, liquids fall through the perforations and run via gravity through a pipe and into a settlement/holding pond. The solids are expelled from the drum and are removed and spread on nearby lands or composted for future use.

The **static screen** separator works on a similar principle. Dairy waste is pumped onto a sloping screen that is also perforated and the liquids seep through and move into storage ponds, while the solids fall into a trailer for removal. Unlike the rotary screen, there are no moving parts in a static screen, and the device is therefore stationary during the separation process.



Lastly, the **screw auger** separator draws waste up a pipe using an auger, where it is pressed and the liquids are expelled via a pipe into a settlement/holding pond. The solids continue along the auger and are expelled into a holding pit where they can later be removed and used for land application or composting.

Cost

The average dairy cow excretes approximately 50 litres of waste per day, which works out to be about R2400 worth of nutrients per cow per year. In a herd of 500 dairy cows, this means that approximately R1, 2 million worth of plant nutrients are cycling through the animals yearly (Robertson 2008, pers com; Miles, 2007). The amount of money that farmers can save on fertilizing by utilizing dairy waste is further illustrated in Tables 2.5 and 2.6.

Table 2.5: Approximate amounts of nitrogen, phosphorus and potassium excreted by a single dairy cow in a year, and their current fertilizer value (Miles, 2007).

| Nutrient | Amount Excreted | Fertilizer Equivalent | Fertilizer Value |
|----------------|-----------------|-------------------------|------------------|
| Nitrogen (N) | 150 kg | 6,5 bags urea | R1252 |
| Phosphorus (P) | 12 kg | 2,3 bags superphosphate | R250 |
| Potassium (K) | 140 kg | 5,6 bags potash | R866 |
| | | Total | R2388 |

Table 2.6: Solid fertilizer equivalent and Rand value of effluent from 100 cows (pasture system) (Adapted from Miles, 2007).

| Nutrient | Amount Excreted/100 cows | Value |
|------------------|--------------------------|-----------------|
| N | 15t of urea | R125 200 |
| P | 1.2t of superphosphate | R25 000 |
| K | 14t of MoP | R86 600 |
| Total Rand Value | | R238 800 |

However, manure storage, treatment and handling equipment is relatively expensive. For example, to set up an anaerobic lagoon system for a 500 cow dairy will set you back as much as R90 000, with an additional R80 000 for a separator and R75 000 for the construction of a housing for the equipment – a total of R245 000 set-up cost (Houart 2008, pers com). Appendices A and B illustrate plans for an anaerobic lagoon and sediment pit respectively (Houart 2008, pers com). Further expenses to take into consideration include labour, running costs (electricity, water, and diesel/petrol) and maintenance.

2.4.4 Advantages and disadvantages of manure utilization in agriculture

Organic fertilizers are becoming popular worldwide due to the fact that they are readily available on farms, are easy to transport and have great precision and effectiveness (McLaughlin & Mineau, 1995). In terms of alleviating storage issues regarding dairy wastes and manures, waste application to lands holds the advantage that readily available nutrients in effluent are supplied directly to the plant-soil system allowing for less time spent in storage where such wastes are prone to leakages and resultant environmental pollution (Zaman, Cameron, Di & Inubushi, 2002). Furthermore, waste that is stored in ponds or lagoons changes in nutrient composition and value, as the surface liquid is highly diluted when compared with the more concentrated slurry at the bottom of the pond (Dexcel, 2007). By reducing nutrient losses in this way during storage, handling and application, a significant contribution can be made to improve efficiency in agricultural practices (Ap Dewi, 1994).

Organic manures contain N-rich materials such as organic matter and humus, which are slow releasing under the action of soil micro organisms and which can significantly raise soil fertility and can greatly improve the soil's capacity to absorb and store water, thus preventing erosion in the medium and long-term (McLaughlin & Mineau, 1995). However, per unit, manure is less rich in nutrients than chemically produced fertilizers, and it is therefore necessary to apply much greater quantities of this organic fertilizer than its chemical cousin. Volumes and nutrient concentrations of dairy waste are dependent on the following factors:

- Stocking rate and amount of fertilizer applied to grazed pastures;
- Pasture fed – quality and quantity
- Supplements fed – type and quantity
- Wash down system and technique in dairy parlours
- Frequency of milking
- Storage and pre-treatment of effluent
- Area that effluent is collected from
- Time the herd spends in holding yard/feed pad and frequency of wash downs
- Herd management and handling while in the yards

(Dexcel, 2007)

Another advantage of using manure as a fertilizer for crops is its affordability. Manure is cost-effective, readily available on dairy farms, and relatively cheap to transport. It can be applied directly to lands or converted into compost, depending on the farmers'

specific requirements. Such compost can even be sold, providing a small extra-income to farmers.

In addition to manure's value as a fertilizer, it can also be utilized for the production of energy in the form of biogas (Sager, 2007). Biogas digesters are becoming a popular way in which farmers can utilize their waste to produce fuel and electricity, and thereafter apply the by-products as fertilizers to crops, as they retain a lot of nutrients even after the process of biodigestion. However, with a test run on a 300 cow dairy in South Africa, biodigestion of wastes only produced about 15 kilowatts at peak, and with the costs of the digester in the order of R3 to R4 million, biodigestion is not economically viable at this small scale level of dairy farming (Westfall 2008, pers com). Biogas viability only starts to become feasible with a minimum of 1000 cows, where one could produce 45 kilowatts at peak output. A more feasible alternative is composting, which is an aerobic process as opposed to the anaerobic process of biogas production. This would incorporate the separation of solids and liquids from dairy waste - the former going to the composter and the latter into several dams for processing, and later irrigation. The sun's ultraviolet radiation would assist in breaking down the odours so that what is put onto the lands is pure nutrients (Westfall 2008, pers com).

Furthermore, Ceotto (2005) identifies the substitution of organic wastes for chemical fertilizers as a revolutionary step in combating global warming. The application of dairy wastes to agricultural lands aids in the practice of **carbon sequestration**, a process by which atmospheric CO₂ is trapped underground in the humic content of the soil (Canarache, Vintila & Munteanu, 2006; Ceotto, 2005). Thus, dairy wastes are viewed as having the following advantages with regard to the world's energy sources:

- fulfilment of nutrient requirements of crops growing in non-limiting conditions;
- the chance of reducing the use of fossil energy (production and transport) and hence reducing the output of CO₂ into the atmosphere ; and
- the possibility of enhancing carbon sequestration in agricultural soils by application of FYM to optimised cropping systems.

(Ceotto, 2005)

However, as with chemical fertilizers, there are also problems often associated with the use of organic manures in agriculture. With the increasing intensification of livestock production systems, farmers are faced with growing numbers of animals concentrated in relatively small areas, resulting in the production of larger volumes of waste (Merrington *et. al.*, 2002b; Zaman *et.al.*, 2002; Smith & Chambers, 1993). Storage of such large amounts of waste can become a serious problem on farms, and inadequate facilities and leakage often result in non-point source pollution of surface- and groundwaters (Smith & Chambers, 1993). Other problems associated with organic wastes include:

- Physical effects (i.e. smothering and scorching, taint, odour)
 - Losses following application (N leaching, NH₄ volatilization, denitrification)
 - Nutrient composition of manure (question of quality)
 - Manure application (time, transport, cost, machinery, etc)
 - Growth of weeds after manure application
 - Introduction of disease (pathogens in manure)
- (Mkhabela & Materechera, 2003; Smith & Chambers, 1993)

Excessive loadings of cattle manure on lands can cause an increase in soil salinization and NO₃⁻ contamination of adjacent water sources (Matsi *et. al.*, 2003). Livestock wastes also contain many pathogenic microorganisms, including bacteria, viruses and protozoa, which can be harmful to both humans and livestock (Mawdsley, Bardgett, Merry, Pain & Theodorou, 1995).

Potential solutions to these problems include various management strategies that incorporate the following considerations into comprehensive planning of manure applications to agricultural land:

- Application timing (crop uptake at a maximum)
 - Application policy (manure comprises 50-60% of application)
 - Soil mineral nitrogen measurements (quantifies crop-available nitrogen supply following manure applications)
 - Good Agricultural Practice (GAP) (250kg/ha/yr as a maximum application)
- (Smith & Chambers, 1993)

Hence, although manures hold certain advantages over chemical fertilizers, both of these forms of applications require strict strategic planning and responsible management. Before it can be said that one form of fertilizer is better than the other, it is essential that a comparative analysis be done between the two, so as to decide which would be the more sustainable option in the long-term.

2.4.5 Manure vs. fertilizer – A comparison

It has been argued thus far that chemical fertilizers and manures are generally equally effective and have similar and noticeable effects on the long-term productivity of soils, and addition of nutrients in either form must be regarded as essential for the maintenance of soil quality (Edmeades, 2003). Therefore, dependent on individual farming scenarios, it is important that the farmer consider the advantages and disadvantages of both organic and chemical fertilizers before choosing which type would best suit his particular business. This chapter will seek to compare the two types, listing their various advantages and disadvantages. Table 2.7 summarizes the main advantages and disadvantages of both forms of fertilizer with regard to their composition, cost, environmental benefits and risks, health risks, management and legislation.

Table 2.7: Comparison between organic and chemical fertilizers.

| | Organic Fertilizer/Manures | Inorganic/Chemical Fertilizer |
|-------------------------------|---|---|
| Composition (N, P, K) | Varies with type of manure, mainly N & K. | Contains all three, can be tailored to suit specific crop requirements. |
| Cost | <ul style="list-style-type: none"> - High initial cost of setting up application system (storage, transport, treatment). - Low management costs (if using on-farm manure). | <ul style="list-style-type: none"> - High cost (manufacturing, transport, storage, application). |
| Environmental Benefits | <ul style="list-style-type: none"> - Improvements in soil structure and organic content, and reduction in soil erosion. - Maintenance of soil biodiversity. - Slow release of nutrients. - Aid in CO₂ sequestration. - Organic produce benefits. | <ul style="list-style-type: none"> - Immediate release of nutrients to soil/crop. - Can be tailored to suit specific crops, therefore minimising risk of over-application. - Higher crop quality in terms of mineral, protein and vitamin contents. |
| Environmental Risks | <ul style="list-style-type: none"> - Losses following application. - Plant damage (smothering, scorching) - Taint. - Weeds. - Odour. - Quality of manure (questionable). | <ul style="list-style-type: none"> - Losses following application. - Hypoxia (depletion of oxygen in water and resultant death of marine life). - Eutrophication (toxic algal blooms). - Loss of biodiversity. - Soil erosion. - Loss of soil fertility. - Increased mechanisation. - Denitrification. - Consumption of large amounts of energy (e.g. fossil fuels). |
| Health Risks | Parasites and disease (pathogens). | Methaemoglobinaemia (“blue baby syndrome”), Stomach cancer. |
| Management | <ul style="list-style-type: none"> - nutrients required by the crop/soil (what = adequate quantities of fertilizer)? - type of fertilizer (considering soil type, climatic conditions, crop type)? - when are the most suitable application periods (seasonality)? - what are the best application techniques (efficiency)? | |
| Legislation | <ul style="list-style-type: none"> - White Paper on Agriculture. - White Paper on Integrated Pollution and Waste Management for South Africa. - NEMA. - Conservation of Agricultural Resources Act. | <ul style="list-style-type: none"> - White Paper on Agriculture. - Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act. - NEMA. - Conservation of Agricultural Resources Act. |

2.4.5.1 Composition

Chemical fertilizers contain all three nutrients essential to sustainable agricultural production (N, P and K), whereas manures often have high levels of one or low levels of all three (Keithlow, 2008). In this regard, chemical fertilizers can be tailored to meet specific crop requirements, whereas manures cannot. Additionally, manures contain significant amounts of carbon (C) whereas chemical fertilizers do not. Furthermore, manures supply a small amount of nutrients (which vary from load to load) per unit in comparison to chemical fertilizers, thus requiring a higher rate of application and therefore a greater risk to the environment (22.7kg of chemical fertilizer = one tonne of manure) (Keithlow, 2008).

2.4.5.2 Economical feasibility

Although they have a high initial cost (setting up application system, storage, transport, treatment, etc), manures are cheaper and more cost effective than industrial fertilizers. The primary advantage that they hold over chemical fertilizers is that they are produced on site, and therefore require minimum transport, whereas chemical fertilizers must be purchased and transported to the farm (high costs involved in chemical fertilizer production, transport and storage). Furthermore, manures are slow-release fertilizers allowing for less risk of over-fertilization (Keithlow, 2008), while chemical fertilizers can contain acids and their quick release of nutrients often results in high soil acidity and over-fertilization (Keithlow, 2008). The use of manure as a fertilizer has been employed in organic agriculture all over the world, where miscellaneous organic materials, including animal manure, sewage sludge, compost, grass turf (green manure), straw, and other crop residues, are applied to fields to improve both soil structure and moisture-holding ability and to nourish soil life (Encyclopaedia Britannica, 2007).

According to Williams (2008, pers com), who runs an independent slurry contracting business in the Natal midlands, farmers can save up to R635/ha if they fertilize with dairy wastewater (R1400/ha) as opposed to traditional chemical fertilizers (R2035/ha) (Figure 2.11).



Figure 2.11: Price comparison between applying organic fertilizer in the form of dairy slurry versus granular fertilizer (Williams 2008, pers com).

In addition, manure application is more economical in the sense that it cuts out the cost of waste storage. If one has an efficient management system in place, the money saved through the alleviation of storage problems can be spent on the application of wastes.

2.4.5.3 Environmental feasibility

Although chemical fertilizers have numerous advantages (immediate release of nutrients to soil/crop, can be tailored to suit specific crops, higher crop quality in terms of mineral, protein and vitamin contents), their environmental risks heavily outweigh these benefits. Probably the most relevant disadvantage for this research is that chemical fertilizer production and management requires the consumption of large amounts of energy, a problem that has resulted in fuel and food price hikes in South Africa, if not around the world. Additionally, losses following application to lands often result in non-point source pollution that has devastating toxic effects on both humans and livestock (i.e. hypoxia, eutrophication, Methaemoglobinaemia and Stomach cancer), as well as the actual land where the fertilizer is being applied (loss of biodiversity, soil erosion, loss of soil fertility, increased mechanisation, and denitrification).

In comparison, the environmental benefits of organic fertilizers appear to equal, if not outweigh, their risks. Although there are several disadvantages (i.e. losses following application, plant damage, taint, weeds, manure quality, and odour), they are minor in comparison to those of chemical fertilizers, and can be more readily corrected. Furthermore, the benefits of organic wastes (i.e. improvements in soil structure and organic content, reduction in soil erosion, maintenance of soil biodiversity, and organic produce benefits) are more environmentally beneficial than those associated with chemical fertilizers, which tend to benefit the farmer's pocket more than the natural environment.

2.4.5.4 Management

In either case, whether utilizing organic or chemical fertilizers, it is essential that the management of such substances is properly planned and employed in order to avoid environmental pollution. Essential questions that need to be asked include:

- what nutrients are required by the crop/soil (what are adequate quantities of fertilizer for specific crops/areas)?
- what type of fertilizer to use (considering soil type, climatic conditions, crop type)?
- when are the most suitable application periods (seasonality)?
- what are the best application techniques (efficiency)?

Included in management strategies is the issue of storage. It is essential that fertilizers are kept away from surface waterways and contained in facilities that are specifically designed for such purposes. More often than not, pollution from agricultural systems is as a result of poorly constructed or maintained storage facilities.

2.4.5.5 Legislation

The legislation discussed in chapter 2.3 covers both chemical fertilizer use and waste management in agricultural production systems. A large problem is that, although there is a law regarding chemical fertilizer composition and application strategies, there is no specific policy regarding the composition or application of livestock wastes to agricultural land. This is definitely an area where there is room for future development.

2.5 Organic farming: Agriculture's new 'buzz word'

2.5.1 What is organic farming?

Organic farming can be defined as 'natural production management systems that promote and enhance biodiversity, soil biological activities, and biological cycles' (Akinyemi, 2007). It is based on management practices that restore, maintain, or enhance ecological harmony, and has the primary goal of optimising the health and productivity of interdependent communities of social life, plants, animals and people (Delate, 2008). Essentially, organic farming employs biological methods of fertilization and pest control as substitutes for chemical fertilizers and pesticides (such products are regarded by proponents of organic farming as a health risk to humans and the environment and unnecessary for successful cultivation) (Encyclopaedia Britannica, 2007).

The key characteristics of a utopic organic farming scenario would include the following:

- protection of long-term soil fertility by maintaining organic matter levels and promoting soil biological activity;
- provision of crop nutrients indirectly using relatively insoluble nutrient sources which are made available to crops by the action of soil micro-organisms;
- nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials, including crop residues and livestock manures;
- weed, disease and pest control controlled primarily through crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited (preferably minimal) thermal, biological and chemical intervention;
- the extensive management of livestock (evolutionary adaptations, behavioural needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing); and
- careful attention to the impact of the farming system on the wider environment and the conservation of wildlife and natural habitats.

(Institute of Rural Sciences, 2008)

Organic agriculture boomed in the 1980's, with the intensification of agriculture becoming a political issue, fuelled by public concerns such as the increasing

destruction of valued features of the farmed landscape, the intensification of livestock production, and food scares (Kristiansen *et. al.*, 2006). Increasing wealth and disposable income in some developed countries resulted in organic food becoming highly 'fashionable' among higher socio-economic groups, and its popularity has continued to grow since then (Kristiansen *et. al.*, 2006). In fact, organic agriculture is one of the fastest growing agribusiness sectors in the world; there are approximately 26 million hectares of organic farmland currently under cultivation and the global market value of organic goods in 2003 was US\$25 billion per year (Willer & Yussefi, 2005).

To ensure that organic agriculture actually works towards sustainable practices, it has to be adapted to local farming, social, geographical and climatic factors (Kristiansen *et. al.*, 2006). The principles of organic agriculture are therefore guides that should be used in tailoring organic practices to suite each individual farming scenario.

2.5.2 Managing soil fertility in organic agriculture

A key feature of organic farming systems is that they are very dependent on soil biological fertility, which in turn influences aspects of chemical and physical fertility (Davis and Abbott, 2006). To achieve the long-term goal of sustainability, organic farming systems aim to be self-sufficient for nutrients and organic matter by producing and reusing various materials in the on-farm environment (Davis & Abbott, 2006). The management of soil fertility is thus characterized by mixed livestock-arable systems, crop rotations, legume cultivation, organic matter inputs and the use of certain organic fertilizers (Akinyemi, 2007; Stockdale, Shepherd, Fortune & Cuttle, 2001). Such systems emphasize frequent additions of diverse sources of organic matter such as catch crops, crop residues, manures, some forms of organic fertilizers and perennial crops (Drinkwater, Wagoner & Sarrantonio, 1998; Reginold, Papendick & Parr, 1990).

Fertilizers that are permitted in organic farming are restricted by organic certification standards that divide them into two categories:

- 1) **Naturally occurring geological resources** (lime, gypsum, rock phosphate, guano, elemental sulphur, dolomite, and various silicate minerals); and
- 2) **Organic materials** (green manure, animal manure and compost, fish-, blood- and bone-meal, seaweed extracts, and microbial products).

(Davis & Abbott, 2006)

2.5.3 The role that manure can play in organic agriculture

Livestock can directly improve soil chemical and biological fertility by introducing organic matter and nutrients in the form of manure and urine into the soil (Watson, Atkinson, Gosling, Jackson & Rayns, 2002). It is likely that manures will have a greater effect on soil organic matter and related soil properties than fertilizers when applied at the same nutrient inputs because they introduce an additional exogenous source of organic matter to the soil/crop (Edmeades, 2003). The use of such material helps to achieve the aim of self-sufficiency in nutrients and organic matter, but it is not always available in large quantities and its management during storage and handling needs to minimise leaching losses of nutrients in order for these fertilizers to perform optimally (Condrón, Cameron, Di, Clough, Forbes, McLaren & Silva, 2000; Lampkin 1990). The use of manure/compost and cover crops on farmland additionally reduces soil erosion losses and increases water holding capacity, soil porosity, and aeration (Akinyemi, 2007).

2.5.4 Organic vs. conventional agriculture

Although agriculture and food production in the modern world has successfully increased overall yields and overcome many biophysical limitations, it has also been a destructive force for the environment (MEA, 2005), excessively consuming key resources (soil and water), under utilising 'waste' streams and thus polluting other resource bases. Many governments today have accepted the arguments that there are problems associated with conventional farming practices and that organic agriculture offers a viable solution to many of these (Kristiansen *et. al.*, 2006). Some key findings from scientific research on organic farming have shown that:

- Yields equivalent to or better than conventional agriculture may be achieved, although often they are not;

- Yields decrease during conversion but then improve afterwards;
- Organic farms have higher levels of soil biological activity and biodiversity;
- Weeds can have major impact on yield in cropping systems, and specific pests and diseases can be problematic in their host crops and animals;
- Some nutrients may have negative budgets for certain organic crops, depleting soil reserves of that nutrient;
- Organic agriculture causes less pesticide contamination in food, people and the environment; and
- The beneficial effects of organic agriculture in food quality are unconfirmed.

(Mendoza, 2002; Stonehouse, Clark & Ogini, 2001; Wynen, 1994)

Table 2.8 highlights the absolute and relative environmental impacts of organic farming compared with conventional farming as observed by Davis & Abbott (2006) in their work on the topic. The column 'absolute' refers to the impact of organic farming on the environment, and the 'relative' column refers to the relative environmental impact in comparison with conventional forms of agriculture.

Table 2.8: Overview of the absolute and relative environmental impacts of organic farming compared with conventional farming.

| Area | Aspect | Environmental Impact | |
|---------------------------------|--|----------------------|----------|
| | | Absolute | Relative |
| Biodiversity | Genetic diversity | + | + |
| | Floral diversity | + | ++ |
| | Faunal diversity | + | +++ |
| | Habitat diversity | +? | + |
| Landscape | Landscape structures and aesthetic value | +? | + |
| Soil | Organic matter and acidity | ? | ++ |
| | Biological activity | +? | +++ |
| | Soil structure | ? | + |
| | Erosion | - | ++/- |
| | Desertification | + | + |
| Ground and Surface Water | Nutrient use and balance | - | ++ |
| | Nitrate leaching | - | ++/? |
| | Phosphorus | 0 | +? |
| | Pesticides | - | +++ |
| | Pathogens | - | -? |
| Climate and air | Carbon dioxide | +? | +? |
| | Nitrous oxide | - | +/-? |
| | Methane | - | ? |
| | Ammonia | - | +/-? |
| Energy | Intensity of energy use | n/a | ++/- |
| | Efficiency of energy use | n/a | +? |

+ = Slightly better; ++ = Better; +++ = Substantially better;

++/- = Better with some aspects that are negative; +? = Better with some uncertainties; +/-? = Partly better and partly worse with some uncertainties;

? = Unclear; - = Negative impact; 0 = No impact or change; n/a = Not applicable

(Source: Davis & Abbott, 2006)

Through previous research, it has been found that organic agriculture provided several environmental benefits, including lower pesticide pollution, enhanced biodiversity and ecological services, improved soil health, and strong links between organic

farmers and nature conservation activities (Akinyemi, 2007; Davis & Abbott, 2006; Grigg, 1984).

Could organic farming therefore be the future of agriculture? With a society that is increasingly concerned with the well being of our planet, such an environmentally friendly approach to food production could provide sustainable solutions to food security and agricultural pollution issues worldwide. Nevertheless, the future of such an endeavour is heavily dependent on the education of people regarding the importance of environmentally friendly and sustainable agricultural practices.

The following table (Table 2.9) identifies the benefits and opportunities for organic agriculture, as well as the challenges it faces in the current agricultural setting as identified by Kristiansen *et. al.* (2006), in their book '*Organic Agriculture: a global perspective*'.

Table 2.9: The benefits, opportunities and challenges for organic agriculture in the global arena.

| Benefits and opportunities for organic agriculture |
|--|
| • Provision of ecological services (Crop protection; Yield stability; System resilience) |
| • Reduced chemical residues in food and the environment |
| • Few strongly negative environmental impacts |
| • Economic performance is often equivalent to conventional farming |
| • High standards of animal welfare |
| • Reliable and credible standard-setting processes and certification schemes |
| • Dynamic review of policies and standards |
| • Strong consumer demand and brand recognition |
| • Indigenous knowledge is valued |
| • Potential for cooperative rural and regional development |
| Challenges for organic agriculture |
| • Maintaining sustainability in the global economy: balancing organic principles with commercial imperatives |
| • Maintaining flexible organic standards and certification processes to address issues such as: Nature conservation and regeneration; Equitable, affordable and flexible access to certification services; Responsible labour relations and land tenure arrangements; Animal welfare; New inputs such as ‘natural’ biocides, soil amendments and GMO’s; and incomplete or unscientific basis for including/excluding materials from organic standards. |
| • Pursuing international harmonisation of standards and certification |
| • Developing locally applicable agronomic solutions to production constraints, such as weeds, animal health and soil fertility |
| • Expanding research activities in many disciplines and foster the integration of knowledge |
| • Preserving food quality while trying to increase productivity |
| • Educating and training at all levels to build capacity, infrastructure and networks |
| • Inadequacies in regulatory and marketing structures (e.g. labelling) |
| • Excessive consumer prices and inconsistent quality and availability |
| • Establishing and maintaining credibility and professionalism |

(Source: *Kristiansen et. al., 2006*)

Therefore, by providing the necessary tools to farmers, organic agriculture seems to be the most environmentally feasible project for modern agricultural production. Not only can farmers conserve the environment, but also, through the use of organic fertilizers, they could profit immensely from branding their merchandise as 'organic' produce. There is, however, no room for chemical fertilizers in organic farming. Thus, in order for farmers to become a part of the 'organic' community, it is essential that they begin to see the important role that manure and other organic fertilizers can play in agricultural sustainability.

2.6 Conclusion

An increased intensity within farming practices, as farmers actively attempt to supply an ever-increasing global demand for agricultural produce, has led to intensification in farming practices countrywide. As a result of this intensification, interest has turned to the sustainability and environmental implications thereof. The two most common agricultural pollutants are Nitrogen (N) and Phosphorus (P), which are universally applied to soils and crops as fertilizers. In modern intensive livestock farming, the storage and disposal of large amounts of wastes are of great relevance and concern to farmers as such wastes contain large amounts of N, P and K. Although organic wastes definitely possess the potential to pollute the environment, the ways in which they may do so are far more subtle and avoidable than the problems associated with chemical fertilizer pollution. For the aim of this research, this is an infallible point. Therefore, although there are many advantages to chemical fertilizers and the fact that they are necessary in a lot of countries in order to deal with food shortages, organic fertilizers possess a distinct environmental advantage over inorganic compounds. Employing dairy wastes on agricultural land as a fertilizer for crops is a more environmentally feasible method of crop management than the utilization of chemical fertilizers. The recycling of nutrients in manures and wastes could significantly contribute to alleviating waste storage issues in agriculture, and by re-using wastes to fertilize lands, together with or entirely in place of chemical fertilizers, farmers can save money as well as promote environmental practice within their agricultural systems

Intensification in agricultural practices countrywide requires the guidance of environmental policies and legislation if these activities in the country are to contribute to the sustainability of agriculture within South Africa as a whole. South Africa has a growing obligation to meet international commitments and to be a globally responsible country with regards to environmental sustainability, and as a result, South African leaders are investigating improved means of pollution and waste management in order to become fully integrated into the global community. The South African government is gearing towards involving as many stakeholders as possible in the promotion of agricultural and environmental sustainability, and such an approach is essential if a symbiotic relationship between the environment and agriculture is to exist.

All of the above information is all very convincing in theory, but what are the actual practical implementations of such proposed dairy waste management on farms in South Africa? The following two chapters (Chapters 3 and 4) will investigate, through the use of a questionnaire and various farmer interviews, the current trends in wastewater management amongst dairy farmers in South Africa. This investigation will seek to develop a broader understanding of the importance of the management of nutrients on farms, be it through either chemical or organic fertilization of crops and pastures, as well as to establish current trends of dairy wastewater management in South Africa.

Chapter 3 – METHODOLOGY

3.1 Questionnaire

The questionnaire used in the research process was an on-line questionnaire consisting of a series of closed questions pertaining to agricultural waste management on dairy farms in South Africa. The intent of the questionnaire was to establish current trends of dairy wastewater management within the South African dairy farming community. This questionnaire was made available via the Milk Producer's Organisation (MPO) who sent out a general email to all dairy farmers in South Africa, as well as through a web page link on the Dairymail website (www.dairymail.co.za), where farmers could click on a link that would take them directly to the web page containing the research questionnaire. Furthermore, details of the research were also placed in articles in the following national agricultural magazines/journals:

- Dairymail,
- Farmers Weekly, and
- Landbou Weekblad.

This method of data gathering was decided upon due to previous experience with questionnaire analysis. The use of paper questionnaires for an honours study yielded poor results as many farmers stated their annoyance for "junk mail" and questionnaires that took up too much time. The use of the on-line questionnaire ensured that minimum input was needed on the farmer's behalf (hence the use of closed questions), yet answers were sufficient enough for the construction of a comprehensive database pertaining to wastewater management practices in South Africa.

Although the questionnaire was made available through these various public channels, and the target group was initially intended to be of a national scale, the feedback was regrettably disappointing. A mere total of fifty-seven (N=57) questionnaires were obtained nationally; 41 from KwaZulu-Natal, 7 from the Western Cape, and 3 each from the Freestate, Eastern Cape, and Northern Provinces (Limpopo, Mpumalanga,

Gauteng). Reasons for this poor response rate are uncertain, but as a result of this unequal distribution, it was decided that an analysis of the ‘national’ trend would be biased, and therefore, the questionnaire results analysis will only take into account the KwaZulu-Natal questionnaires. Hence, the questionnaire analysis has been converted from a national study to a KwaZulu-Natal Case Study. Table 3.1 indicates some of the questionnaire statistics:

Table 3.1: Questionnaire Statistics

| | |
|---|-------------------|
| Number of questionnaires retrieved: | 41 |
| Average size of farming land: | 337 ha |
| Average size of dairy herd: | 450 |
| No. of farms using pasture-based MS | 38 (93%) |
| No. of farmers who grow crops principally for fodder | 40 (98%) |
| No. of farmers who grow crops for other purposes | 3 (7%) |
| No. of farms with WMSs: | 40 (98%) |
| No. of farmers who consider waste to be a problem on their farms | 7 (17%) |
| No. of farmers that have considered using waste as fertilizer | 39 (95%) |
| No. of farmers currently using waste as fertilizer | 35 (85%) |
| Average amount spent on chemical fertilizer annually | R2001-4000 |
| No. of farmers spending > R10 000 average annual expenditure for fertilizer | 8 (20%) |
| No. of farmers that believe being classified ‘organic’ has value | 13 (32%) |
| No. of farmers who would classify their operations as ‘organic’ | 3 (7%) |

MS – Management System; WMS – Waste Management Strategy

3.2 Interviews & farm visits

In addition to the questionnaire, farm visits and various interviews were conducted in the KwaZulu-Natal and Western Cape regions. The area of the Western Cape is included for comparison, as the agricultural practices vary greatly between these two regions, KwaZulu-Natal being a summer rainfall, pasture-based management system, whereas the Western Cape being a winter rainfall, feed pad-based system. The differences between these two regions illustrates the applicability of different systems to distinct areas in South Africa, as well as demonstrates the importance of management and planning that is tailored to one’s specific scenario. These visits and

interviews allowed for the researcher to obtain valuable insight into, and observation of, the different waste management strategies currently in use in these areas, and for the collection of photographic and qualitative data pertaining to these management practices.

Interviews were conducted in a casual, open-ended, face-to-face manner during farm visits, with interviewees being selected from the questionnaire sample following recommendations from various agricultural authorities in the areas. These interviews were conducted using a snowballing effect of question construction, i.e.: the farmers' answers determined the line of questioning. Questions were specifically directed at the management of dairy wastewater on these farms, and each farmer was asked a similar set of questions pertaining to their waste management practices. Farmers lacking any form of waste management on their farms are included in the questionnaire results analysis, but it was not necessary to interview these farmers as their answers to the questionnaire yielded sufficient information. Additional interviews were also conducted with various key stakeholders in the field of agricultural management in both the KwaZulu-Natal and Western Cape Regions.

Chapter 4 – RESULTS & DISCUSSION

4.1 Questionnaire results

The total number of questionnaires returned from the KwaZulu-Natal region was 41 (N=41). Of these farmers, the majority are involved in pasture-based herd management (Figure 4.1). The average milking herd size in the sample is 450 cows, with a range from 72 animals on the smallest farm to 1300 animals on the largest. Average farm size was 337 hectares.

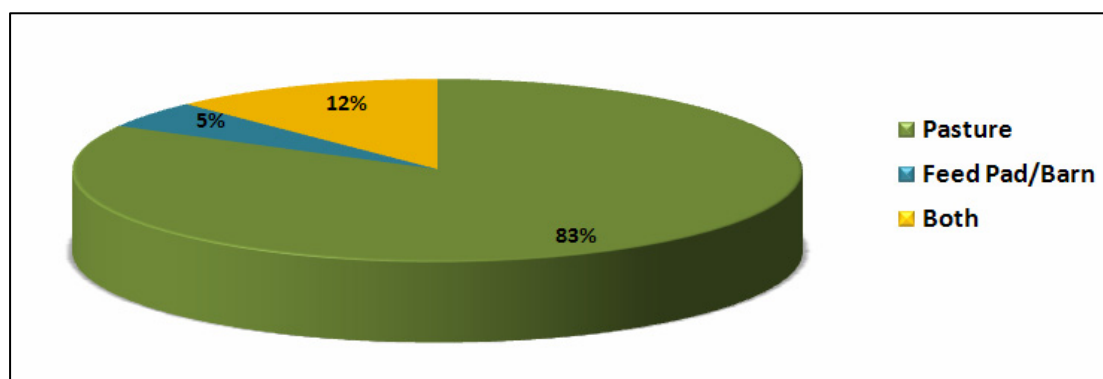


Figure 4.1: Herd management systems used by the respondents.

With an average herd size of 450 milking cows, and an average farm size of 337 hectares, the KwaZulu-Natal dairy farmers are clearly engaged in a highly intensive form of agriculture. With one cow per 0.75 hectares of arable land, it is evident that these farmers need to make certain that their lands bear optimum yields in order to ensure that their animals are fed well enough to produce sufficient amounts of milk annually. Thus, farmers' livelihoods are heavily dependent on various calculations of carrying capacity and crop requirements.

With regards to such crop management, the majority of respondents (97.6%) grow their crops principally for fodder (e.g. silage). A breakdown of the crops grown in the sample area is given in Figure 4.2. As can be distinguished from the graph, maize is the predominantly grown grain (although it is grown for fodder purposes), and nearly all of the farmers (N=39) grow pastures in order to feed their cattle. The 'other' types of crops grown included sugar cane, veld grass, dryland rye grass, Rhodes grass, Millet, green feed, and hay.

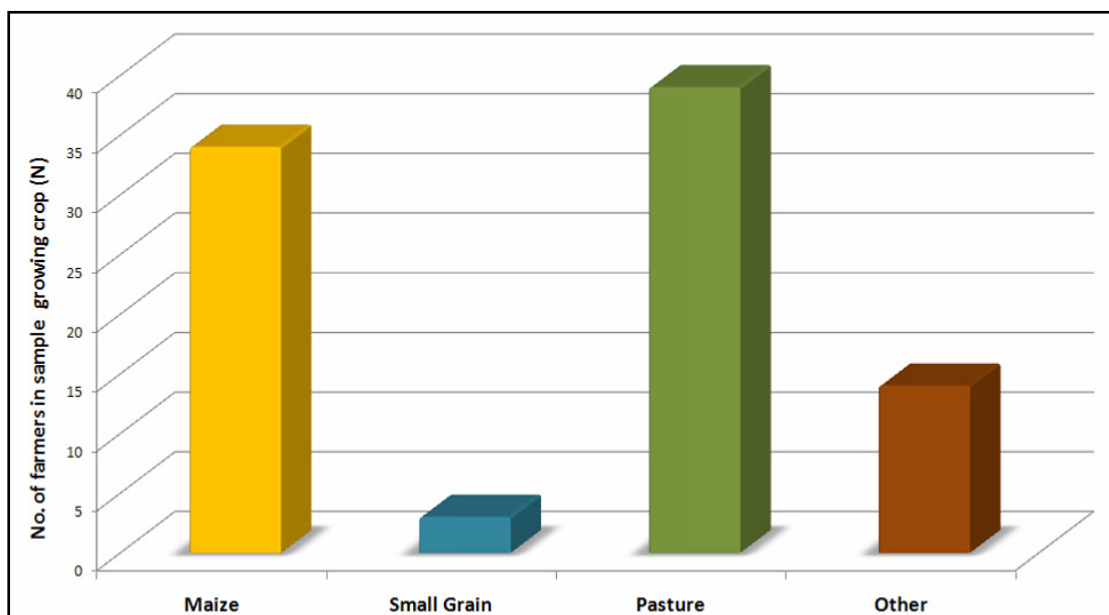


Figure 4.2: Crops grown by the sample group.

In 73.2% of cases, farmers are employing chemical fertilizers for the fertilization of their crops. The remaining 26.8% make use of both chemical and organic fertilizers, but the larger portion of this mix is still chemical fertilizer. None of the respondents reported the use of purely organic fertilizers in the management of their crops.

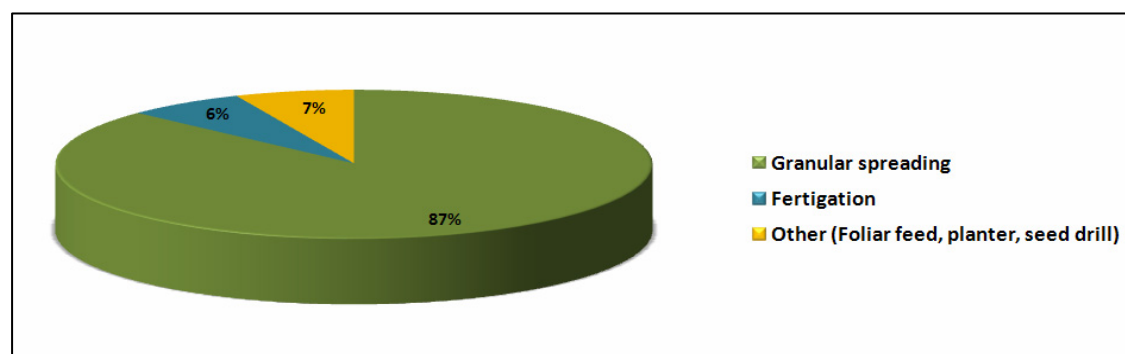


Figure 4.3: Preferred methods of chemical fertilizer application in sample group.

The preferred method for the application of these chemical fertilizers is granular spreading (87%). Fertigation (6%) and other methods (7%) are employed to a lesser extent, with such 'other' methods including foliar feeding, seed drilling, and application by planter (Figure 4.3). These results imply that farmers are currently highly mechanized in terms of their crop management. Such mechanization is often heavily labour intensive, as well as being environmentally detrimental. Hence, chemical fertilizers themselves are not only wounding farmers' agricultural

environments, but are also denting their budgets in terms of machinery and labour requirements.

Maize is the dominant grain crop grown in KwaZulu-Natal, with 83% of respondents managing this crop on their farms for use as fodder. Other crops include pastures (95%), veld (9%), small grain (7%), sugar cane (4%) and various dryland pasture grasses. Figure 4.4 shows the percentage of each crop grower's seasonal preference for fertilizing their crops. From this illustration it can be noted that farmers who plant pastures fertilize them year round, whereas maize and small grain farmers fertilize predominantly during spring and summer, which is the principal growing period for these crop types. Such practices are very important in ensuring the sustainability of soils. If managed correctly, fertilizers can boost soil fertility, but if managed poorly, they can have the completely opposite effect and damage the environment through the leaching of excess nutrients into surface and groundwaters (eutrophication). The KwaZulu-Natal farmers appear to be well informed as to the regional and seasonal requirements of their crops, and hence should have no difficulty with implementing sustainable waste management strategies.

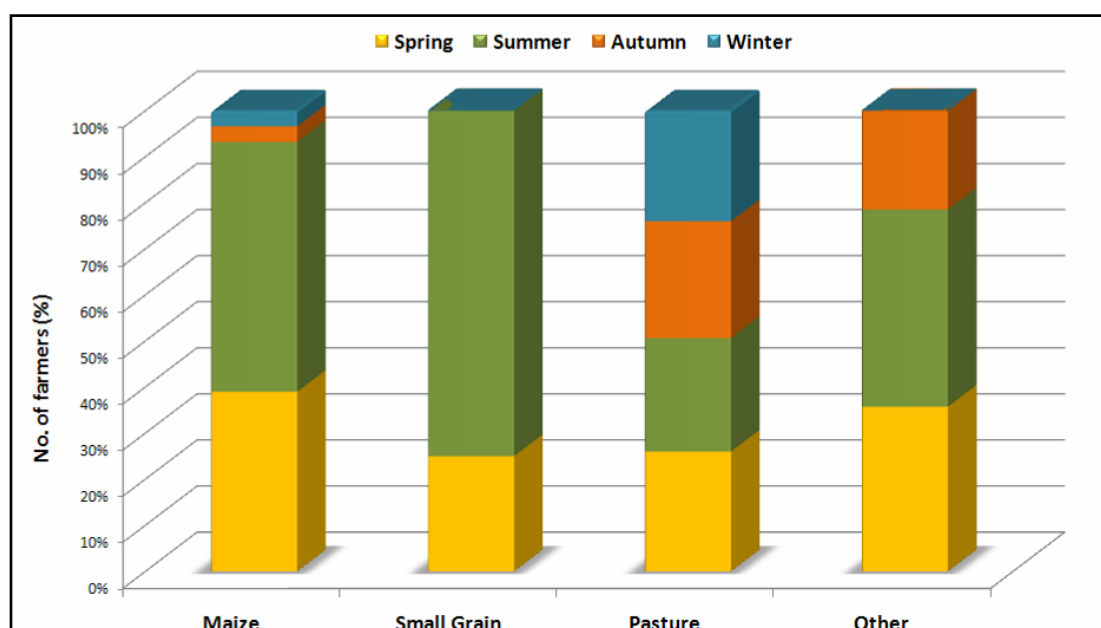


Figure 4.4: Percentage of crop growers and their seasonal preferences for fertilizer application.

Respondents were also asked to give an idea of how much they spend annually on fertilizing their crops. Table 4.1 illustrates the differences in annual fertilizer expenditure per hectare for each crop type as indicated by the sample group. The crop

that is most prolifically grown in the sample, and that tends to be the most expensive crop to fertilize as can be seen from the table, are pastures. This is mainly due to the fact that these crops are fertilized all year round, whilst the other crops are only fertilized at particular times of the year (see Figure 4.4).

Table 4.1: Annual expenditure on fertilizers (p/ha).

| (R) | Percentage of crop growers spending (R) amount per hectare to fertilize the following crops: | | | |
|-------------|--|-------------|----------|-------|
| | Maize | Small Grain | Pastures | Other |
| < R2000 | 8% | 66% | 2% | 12% |
| R2001-4000 | 28% | 33% | 20% | 25% |
| R4001-6000 | 24% | - | 12% | 25% |
| R6001-8000 | 11% | - | 18% | 12% |
| R8001-10000 | 5% | - | 18% | 25% |
| >10000 | 24% | - | 30% | - |

Pasture-based herd management systems are highly intensive due to the fact that farmers are constantly fertilizing their pastures in order to provide fodder for their animals. In a pasture-based management system such as that which is dominant in the sample group, pasture health and growth are essential elements in the production of food for cows, and subsequently, the production of quality dairy produce. An important question that can be asked at this stage then is how can farmers cut back on their fertilizer costs involved in crop management without affecting the yield of their crops and subsequent milk production?

In connection with this problem, respondents were then asked how they are currently managing their dairy wastes, as wastes can be used in the fertilization of crops and pastures. There are several types of waste management systems currently in use in South Africa, the most popular of which is the anaerobic lagoon system. A summary of the systems employed by the sample group is shown in Figure 4.5.

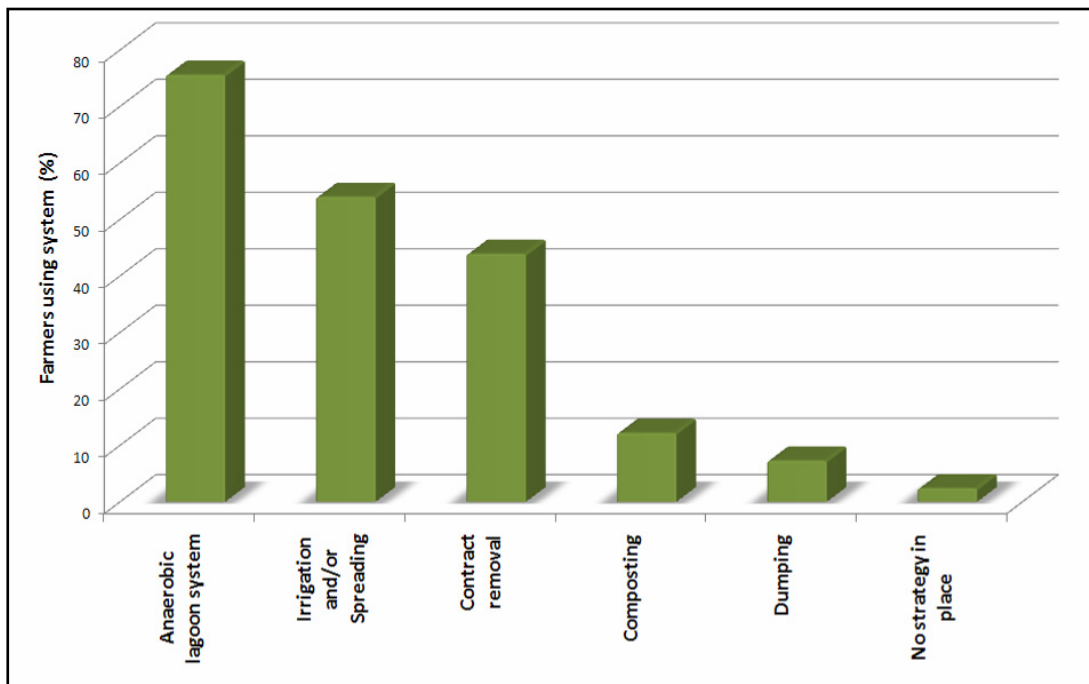


Figure 4.5: Percentage of farmers using various forms of dairy waste management.

Following the establishment of these waste management trends, respondents were then asked whether they had ever thought of using their dairy waste as a fertilizer for their crops.

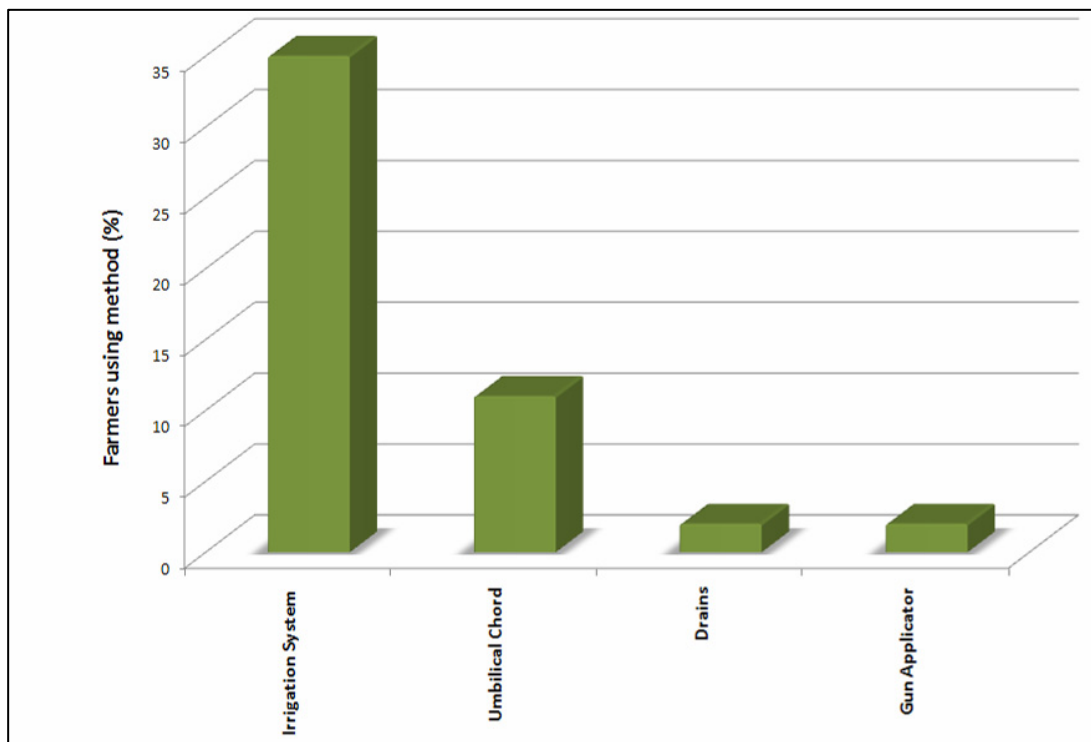


Figure 4.6: Waste application methods used by sample.

A resounding 95% of farmers said that they had, and a large portion of them (35 out of the total 41 farmers in the sample) are actually currently applying their waste to their lands. Waste application methods in use for waste disposal by the sample group are shown in Figure 4.6. In connection with these management strategies, the sample was then asked whether dairy waste management was a problem on their farms. A significant 17.1% of respondents agreed that it was. A further 42% stated that it wasn't a problem, but it could do with an upgrade, and a reassuring 41% stated that waste management on their farms was under control (Figure 4.7).

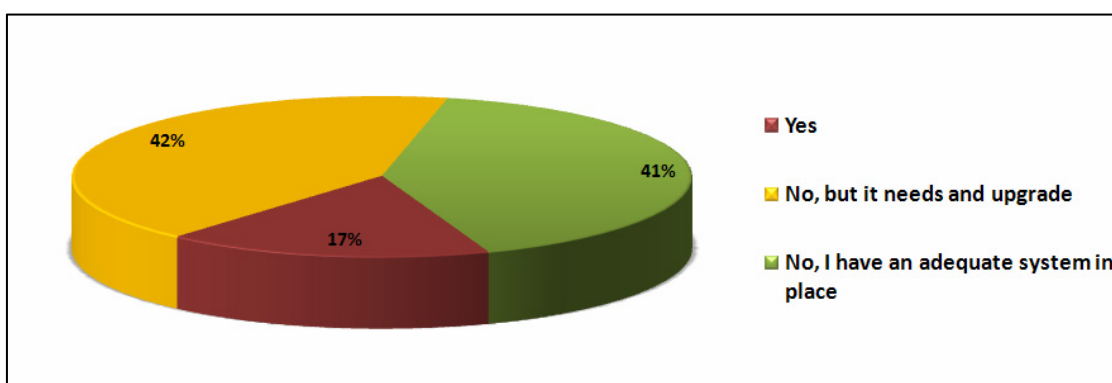


Figure 4.7: Respondents' reaction to the question of whether their current dairy waste management poses an environmental threat on their farms.

These results are indicative of a positive attitude towards waste management in South Africa. Farmers were willing to admit that their systems were inadequate, indicating that they have identified the area to be a problem on their farms, and are openly receptive to any suggestions for improvement.

An area where respondents were not very receptive, however, was when questioned about their opinions on organic farming. When asked whether they thought being classified as an organic farmer was valuable, respondents varied in their responses. An equal number of farmers believe that it is definitely valuable (31%), but also that conventional farming is just as profitable (31%). A slight majority, however, feel that organic farming is just a marketing ploy and carries no distinctive advantages over conventional farming methods (36%). (The following section on farmers' opinions of organic farming will delve into this question in greater detail). However, those respondents who were open to organic farming were asked to rate different characteristics of this form of agriculture that they found to be most advantageous. These results are shown in Figure 4.8.

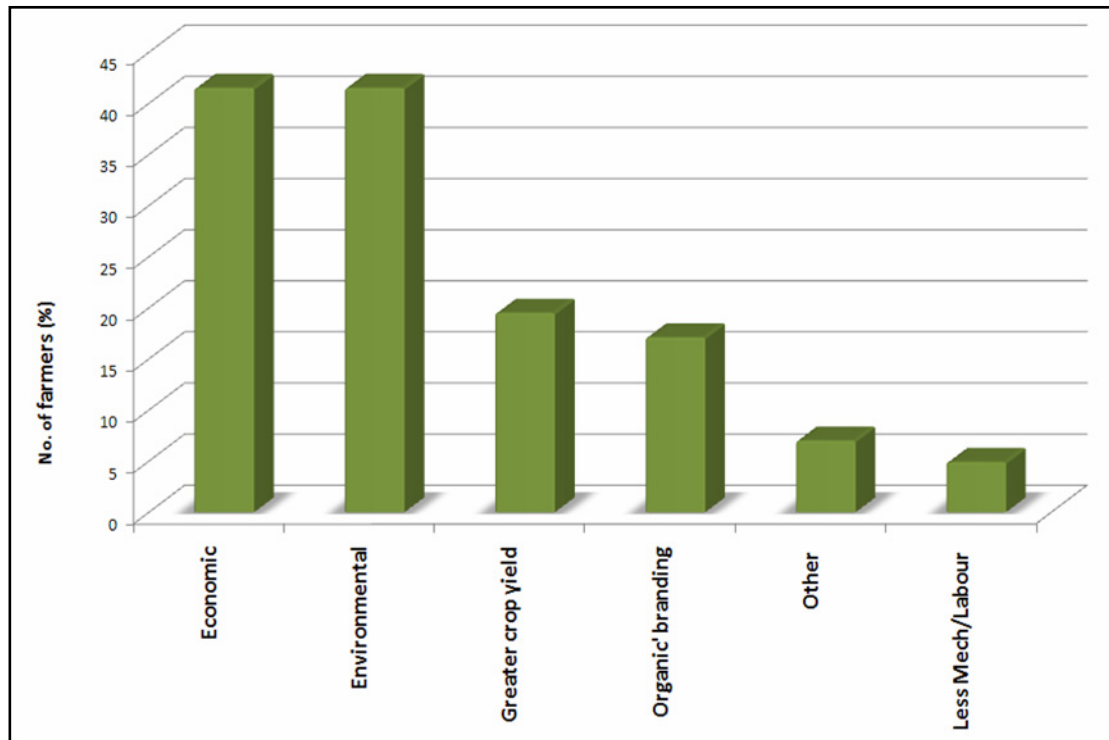


Figure 4.8: Classification of most beneficial organic farming characteristics according to sample.

A majority of 38 out of the 41 farmers in the sample group would not classify their farms as organic. Therefore, although there is slight interest in the concept, it has clearly not been put into practice in the region. Those farmers who do classify themselves as ‘organic’ are using raw manure (N=5), compost (N=2), and certified organic fertilizers (N=1) for their pasture management. This makes sense as organic produce has strict rules as to the conditions under which it must be grown.

The following section explores the opinions stated by farmers on the topics of dairy wastewater management and organic farming. These comments are important to the research as they provide valuable insight into the reasons behind farmers’ answers to the questions posed in the questionnaire.

4.2 Farmer's comments

Respondents to the questionnaires were also given the option to add any further comments pertaining to their dairy wastewater management practices and problems, as well as their opinions on organic farming in South Africa. These are included below.

“There is a definite need for an economical, management friendly dairy slurry system for fertilizer saving and to be more environmentally responsible.”

Brett Andrew, eMoyeni, KwaZulu-Natal

“With the high cost of fertilizer, we intend making more efficient use of our waste from the lagoon dam in the future.”

R. Oldfield, Carwin, KwaZulu-Natal

“I think a combination of the two systems is required.”

Goxhill, KwaZulu-Natal

“With the prohibitive cost of chemical fertilizers many farmers are being forced into alternate ways of fertilizing. Dairy wastewater has always been an issue and now is the time for farmers to clean up their act and utilise their waste water for the good of the ground water and environment, and with the bonus of saving partially on chemical fertilizers applied.”

R. Stapylton-Smith, Eastwolds, KwaZulu-Natal

“As far as using dairy waste as a form of fertilizer is concerned, it has a role to play, but we do not produce a sufficient amount to be able to use it as a regular substitute for chemical fertilizers.”

AAD Taylor, The Banks, KwaZulu-Natal

“We need to find an economical and practical method of getting waste onto the lands without the use of expensive tractors/machinery or fancy separators (i.e. local manufactured).”

Gerrard Torr, Kildare, KwaZulu-Natal

“We do pump waste from our lagoons. After soil sampling, there has been no improvement in N, P, and K. We are sure there is a long-term benefit to spreading waste on lands. We would not get the yields that we do if we used only waste. However, we treat waste as a "bonus" to the soil.”

Paddy Carr, Netherby,

KwaZulu-Natal

We see in the future ... to install a Bio-Digester, for the use of methane harvesting and powering an on farm electrical power plant. At that time, we would gain the best use of manure waste for organic fertilizer. The reason for this is that the processed waste from the bio-digester has very little water content and the spreading application becomes more economical. Although we make use of slurry when we can, it is still regarded as a booster on top of our chemical fertilizer programme. However we are using CMS (molasses) where possible, although the growth response is poorer where the soil has depleted spots of fertility.

“Since Summer 2007, I wasn't going to apply chemical nitrogen to my maize crop. I did spray biological compounds as well as small amounts of calcium and potassium nitrates. This was a late program given to me by Dr Adriaan Wiechers. Fertilizer representatives said I would benefit for only 1 year as there were old nitrogen levels left in the soil. So I took fright and applied 46kg N/ha onto the silage lands by plane later in the maize season before they started to tassel and nothing on grain lands where I've reaped 6tons/ha. In March 2008 my slurry ponds were upgraded and I started applying slurry onto pastures by irrigation and tankers. The dams were so old and caked up that it took some work. Now they are aerobically active and I have a cheap efficient system in place. I am in the process of making compost with as much old veld and maize stova hay by laying it down where cows come into and out of the milking parlour to dung on it, and then gathering the bedding and moving it onto compost heaps with chicken litter and lime. Slurry is pumped onto the heaps and they are turned once a week. Hopefully there should be sufficient compost to apply 2 tons/ha by autumn 2009 onto my pastures. It's a big job. I am extremely keen on this type of farming because, with further increases of chemical fertilizers, farming is not going to be profitable at all if prices continue to increase. Our soils have been messed up over all these years so it will take time.”

Graham Caldecott, The Plains, KwaZulu-Natal

“We already pump our dairy waste & wash down water from an anaerobic lagoon system through the pivot onto ~75ha of pastures. Our concern is the eventual build up of P & K to toxic levels. I would like to use the lagoon for biogas production too.”

Rob Walker, Watermead, KwaZulu-Natal

“I think you could go further by looking at the nutrient balance of both slurry and chemical fertilizer and look at the possible economic benefits to proper slurry management and the resulting nutrient substitution and savings derived from effective slurry management.”

Ren Stubbs, Denleigh, KwaZulu-Natal

“With the current input and fertilizer increases, we definitely need to look at & utilise alternative forms of fertilizer. We are currently looking at upgrading our lagoons and using a contractor to come in and spread our waste on our lands and I think most dairy farmers are trying to minimise slurry wastes which could harm the environment.”

Dylan Eagleston, Stockton, KwaZulu-Natal

“Although my farm could not be classified as organic because I use some chemical fertilizers, I have cut out all weed killers and pesticides for some years now. This is mainly because I no longer plant any maize.”

Nigel Ralfe, Doornkop, KwaZulu-Natal

“I believe organic farming is the environmentally and ecologically correct way to go, but it has to be economically viable.”

Les Francis, Fernhurst, KwaZulu-Natal

“Dairy waste can and should be used as a fertilizer. It can only compliment chemical fertilizers. Organic farming is a pipe dream because it can only support a fraction of the world's population.”

L.G. Lettenga, Coniston, KwaZulu-Natal

“The opportunity in Organic Farming lies in the marketing of the finished product to the consumer. As per the current value chain any benefit that is received from the marketing of an "Organically" labelled product accrues to the secondary and tertiary industry, not to the primary producer. Although there is economic benefit to utilizing more organic materials as fertilizer (especially with current fertilizer prices) it is unlikely that a full conversion to an organic system would be viable. The other element of organic farming to consider is that it is all in "the definition" for example the pasture system that is used in the KZN Midlands would be classified as "organic" in some states in the USA but "organic" definitions from Europe are much more stringent and we would not comply.”

Turner Family, Kingussie, KwaZulu-Natal

“Although we’re moving to organic farming, there is little value in South Africa but for the saving in fertilizer.”

Willie Pretorius, Brigadoon, KwaZulu-Natal

“There is great value in dairy slurry if used properly on a commercial farm. You must not get confused between organic farming and the use of slurry. Organic farming will most probably never succeed in Africa because the yields are too low and the price too high.”

F Williams, Glen Gowrie, KwaZulu-Natal

“With regard to "Organic Dairy farming" Firstly with the increase in all our input costs ... people are already complaining about all the food increases, why are they then going to spend even more on organic milk? ... Secondly, unlike vegetable or chicken farming, I really don't see how it could be economically viable for a commercial dairy farmer. If you have 80 or 100 cows running on a small scale you could maybe do it. On a large-scale operation grass = food for cows = production from cow. If we had to stop fertilizing our pastures I think our grass growth would drop by 50-60%, the cows would be very short of food. We could have a 100% drop in milk production (say 20 l/cow to 10 l/cow). I'm not even looking at the financial loss of yield in maize and/or pastures by not spraying chemicals. I think the milk price we would have to get to sustain and justify going organic would have to be huge. We are currently getting around R3.15/l, so best case scenario if milk dropped by half, I would need to get minimum R6.30/l, not taking into account any other organic practices/expenses I would have to follow. I think to summarise, on our operation we would need a milk price of R8 to justify this and no one is going to pay this. Consumers are already resistant to milk on the shelf... imagine how much it would have to sell in shop for us to get R8/ltr! Hopefully you have some answers to my limited knowledge of organic dairy farming but these are a few of my views from a farmers angle.”

Dylan Eagleston, Stockton, KwaZulu-Natal

4.3 Interviews and farm visits

In addition to the questionnaires, farm visits were conducted in the Western Cape and KwaZulu-Natal regions of South Africa (Figure 4.9). These visits enabled the researcher to conduct various interviews with stakeholders within the dairy industry, and also allowed for the identification of the various management systems currently in use in these areas. The reasons for choosing the Western Cape and KwaZulu-Natal areas specifically include accessibility, climatic and seasonal variations, cropping variations, and herd management variations.

With regard to accessibility, the researcher is currently based in the Western Cape, but lives in KwaZulu-Natal. Thus the KwaZulu-Natal data was gathered during the term break period, and the Western Cape data was gathered during the term period.

KwaZulu-Natal enjoys wet, warm summers and cold, dry winters. Alternatively, the Western Cape is accustomed to harsh, dry summers and cold, wet winters. These climatic differences are very important when considering the use of wastewater as a fertilizer application, as optimal application relies on several factors such as run-off potential (e.g. from rainfall) and optimum crop growth period. The fact that these two regions vary greatly in regard to their climates also means that there are different types of crops grown in each area. In KwaZulu-Natal, the dominant crops include maize, pastures and sugar cane, whereas the Western Cape farmers grow various forms of small grain as their principal crops. Different crops require different nutrients, therefore it is important to understand the different requirements of each scenario when working in the field of dairy wastewater research.

Whilst the majority of farmers in KwaZulu-Natal manage their dairy cattle on pastures, the majority of their Western Cape contemporaries manage their animals in either barn or feed lot systems. These barn/feed lot systems are more intensive and produce greater amounts of waste than the pasture-based management systems. The following section includes various interviews with dairy industry stakeholders, as well as the discussion of fourteen farm visits that were conducted in the study areas over a period of six months.

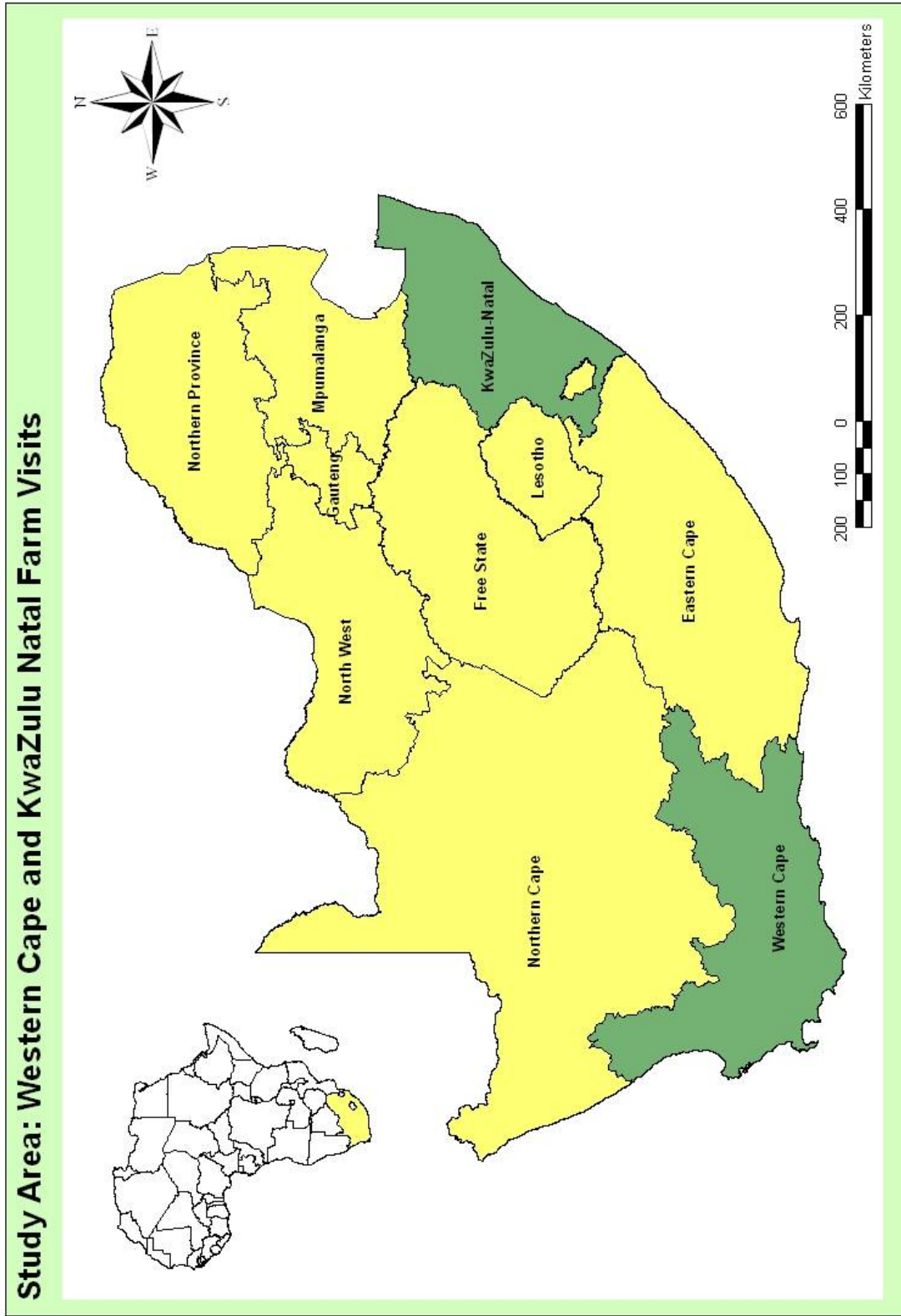


Figure 4-9: Study area showing the Western Cape and KwaZulu-Natal regions.

4.3.1 KwaZulu-Natal region (23-26 September 2008).

Seven farms in total were visited in the KwaZulu-Natal region, in two municipal districts, namely District 43 (Underberg) and District 22 (Lions River). Figure 4.10 shows the farm distribution within the study area.

The Underberg farms consisted of:

- Ericsberg (owned by Mr. B. Hein),
- Lamington (owned by Mr. G. Pitt) and
- Bromley (owned by Mr. A. Massey).

The Lions River farms consisted of:

- Dunira (owned by Mr. D. Greene),
- Kildare (owned by Mr. G. Torr),
- Mearns (owned by Mr. J. Keane) and
- Denleigh (owned by Mr. R. Stubbs).

In addition to these farm visits, five interviews were conducted in this region, which are as follows:

- 1) Mr. Gerhard Fourie: *Owner, G4 Irrigation, Underberg, KwaZulu-Natal* (23 September) (Fourie 2008, pers com).
- 2) Mr. Bruce Dixon: *Fertilizer Consultant, KwaZulu-Natal Midlands* (17 September) (Dixon 2008, pers com).
- 3) Mr. Andrew Williams: *Owner, SlurryTech[®], KwaZulu-Natal* (24 September) (Williams 2008, pers com).
- 4) Mr. Noel Houart: *Civil Engineer, Agri. Design and Civils, Howick, KwaZulu-Natal* (25 September) (Houart 2008, pers com).
- 5) Mr. Graham Muller: *Irrigation Consultant, Howick, KwaZulu-Natal* (25 September) (Muller 2008, pers com).

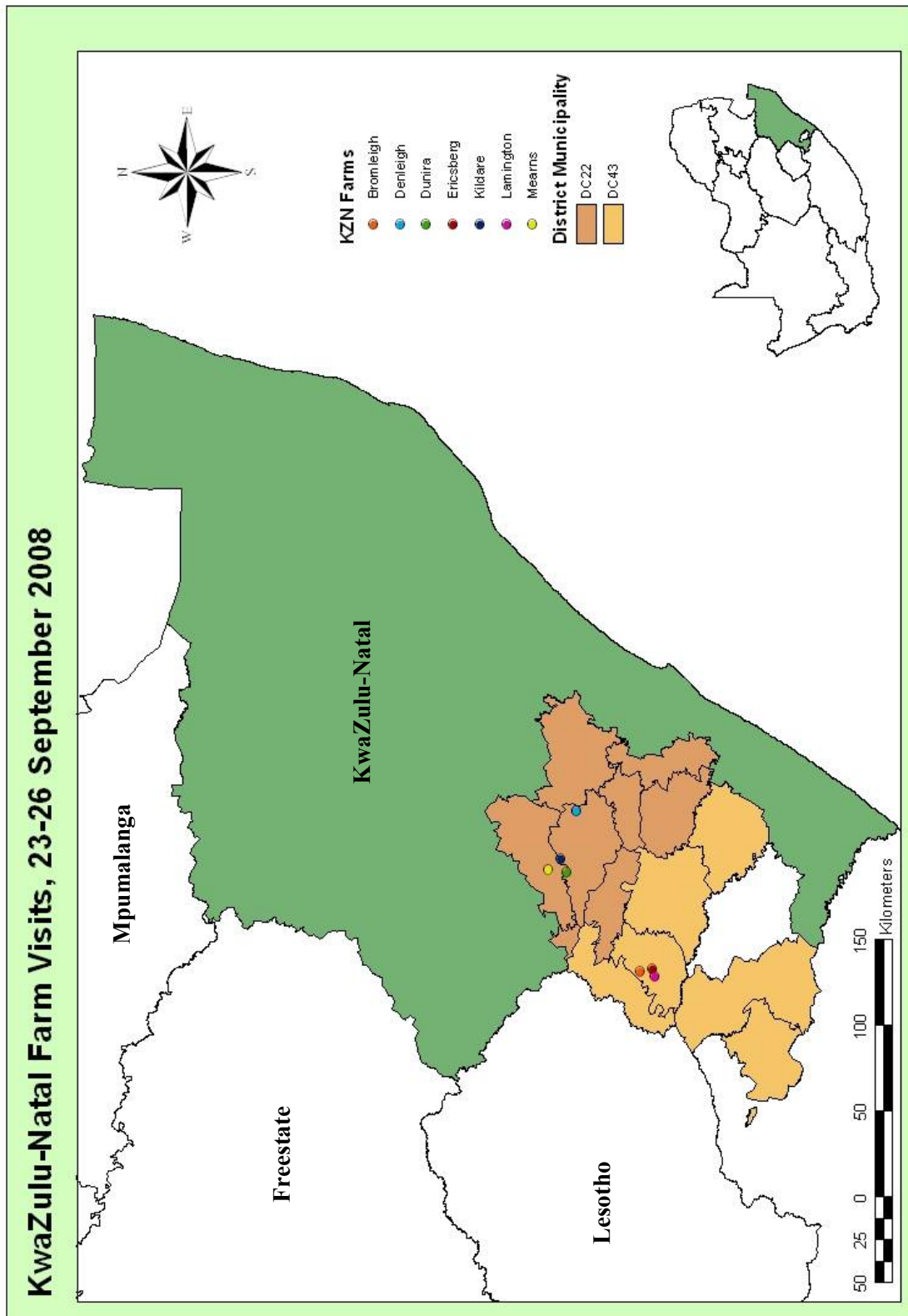


Figure 4.10: KwaZulu-Natal region showing the distribution of visited farms.

Underberg region

With the successful broadcast of the RSG interview (Maas 2008, pers com), a meeting was arranged with Mr. Gerhard Fourie, a self-employed irrigation equipment supplier in Underberg, to undertake farm visits in this region. Through various correspondences via email and telephone, a visit to the Underberg area was arranged in order to view three local farms, each operating a different waste management strategy. Mr. Fourie's extensive knowledge of irrigation equipment ensures that he has worked with many types of systems, and he is hence often called upon by farmers in the area for advice regarding the implementation of waste management systems that involve the use of irrigation equipment.

The first farm visited, Ericsberg owned by Mr. B. Hein, showed the use of a rotary screen separator (Figure 4.11). In this system, dairy wastewater flows into a basic storage pond where it is agitated (1) and pumped through a rotary screen (2). The screen separates liquid from solid waste, and the liquid flows into a large storage lagoon (3 & 4). From here, liquids are irrigated onto pastures through a dedicated irrigation line, and solids are stored and later applied to croplands as an additional fertilizer.



Figure 4.11: Ericsberg Farm system, showing separation of slurry using a rotary screen system and storage of liquid waste in a storage lagoon.

The system on the second farm that was visited, Lamington Farm owned by Mr. G. Pitt (Figure 4.12), was similar, but lacked any form of separation. Wastes were simply agitated before being pumped directly onto pastures.

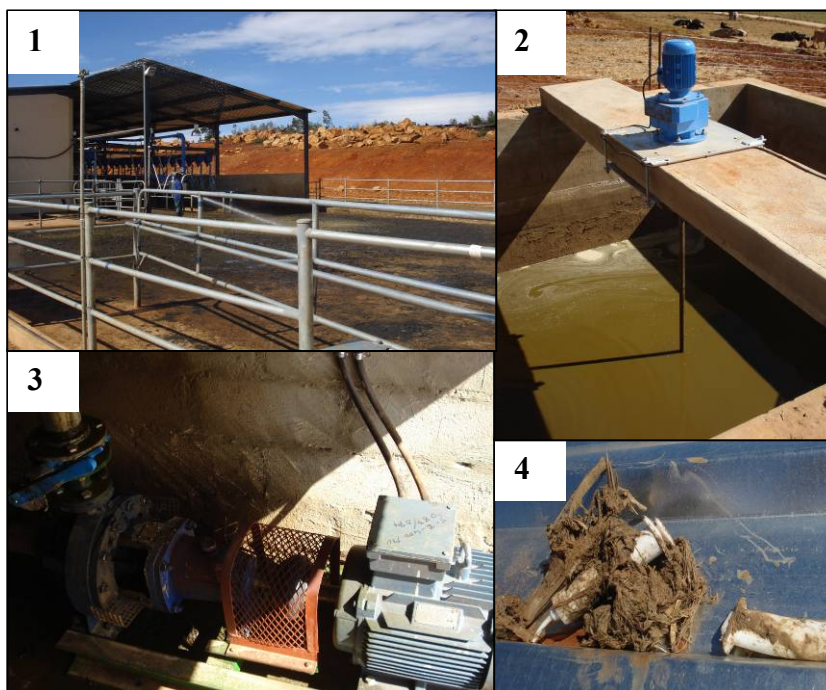


Figure 4.12: Lamington Farm system, showing only agitation of slurry (no separation) and irrigation onto pastures through a dedicated line.

On Lamington, dairy waste flows into a small storage pond from the holding yard (1) where an agitator (2) is used to ensure that the solids are held in suspension before they are pumped (3) through a dedicated line onto pastures. A large problem associated with this system, as indicated to me by Mr. Fourie, is that the pump can get blocked with foreign objects from the dairy parlour, such as mastitis syringes (4) and plastic bags, etc. This can result in a suspension of irrigation, and the storage pit can overflow, increasing the risk of environmental pollution.

The last farm visited in the Underberg region was Bromley Farm owned by Mr. A. Massey (Figure 4.13), where the farmer is busy installing a new 100-berth dairy and adjacent slurry system. With this new system in place, Mr. Massey will be milking around 900 cows twice a day. This guarantees that a large volume of waste will be produced daily, and therefore the farmer has ensured that a dairy wastewater management system has been developed for his specific needs.



Figure 4.13: Bromley Farm system, showing separation of slurry using a lagoon system, followed by application onto pastures using an applicator gun mounted on a centre pivot.

In this particular scenario, wastes are being pumped through a centre pivot irrigation system onto pastures. The wastes flow from the dairy holding yard (1 & 2) into a small holding pond (3). From here, they are pumped (4) through a dedicated line to a centre pivot, where they are irrigated via an irrigation gun (5) that is mounted on the centre pivot (Fourie 2008, pers com).

Mr. Fourie is becoming more intensively involved in the field of dairy waste management systems, as the demand for adequate and sustainable systems is growing due to the increase in fuel and subsequent petrol prices in South Africa.

“Farmers are feeling the pinch and have started looking into using their waste as fertilizer in order to save money” (Fourie 2008, pers com). Furthermore, Mr. Fourie feels that there is a huge demand for a cost effective, low maintenance system for the disposal of wastes from the dairy parlour, and if someone can come up with a good plan then “...he will be a millionaire!” (Fourie 2008, pers com).

Lions River region

The first farm visited in the Lions River region, Denleigh Farm owned by Mr. R. Stubbs (Figure 4.14) was visited in the Karkloof area. Here the farmer employs contractors to manage his dairy wastes that are the result of milking 700 cows. He believes that waste management on his farm is under control, and that he has adequate facilities and management strategies in place to avoid any environmental problems associated with dairy waste management in general (Stubbs 2008, pers com). During this particular contacting session, a tractor-mounted agitator was first used to stir the storage ponds (1), ensuring that the solids were brought to the surface and held in suspension. The waste was then pumped from the lagoon (2) through a long umbilical chord pipe (3) attached to a tractor mounted dribble bar. The tractor then spread the waste (4) by driving up and down the land and ensuring an even distribution pattern.



Figure 4.14: Denleigh Farm system, showing agitation of slurry and subsequent application to pastures via umbilical pipes and a tractor mounted dribble bar.

In this instance, SlurryTech[®] contractors of Rosetta, owned by Mr. A. Williams, were utilized to spread waste on lands adjacent to the dairy parlour. SlurryTech[®] is a slurry contracting company based in Rosetta. This father and son business imported the only umbilical slurry pumping and slurry application system available in South Africa.

This system is contracted out to local farmers as a means of spreading their slurry, and the operation is charged on a per m³ basis (R14.00 p/m³ = R1400 p/ha)(Williams 2008, pers com).

Mr. Williams makes use of the following equipment during contracting:

- Lay flat umbilical pipes and dribble bar mounted on tractor
- Slurry Stirrer and tractor
- Stand-alone 81 kilowatt diesel slurry pump with in-built chopper

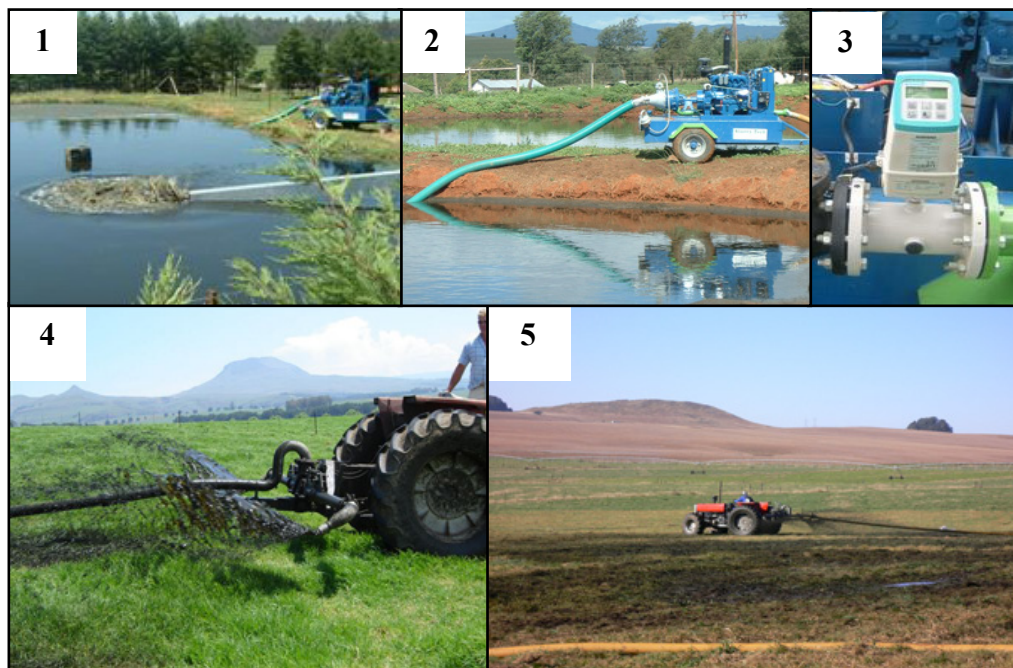


Figure 4.15: SlurryTech[®] waste application procedure (Williams 2008, pers com).

The procedure is as follows (Figure 4.15). The slurry stirrer is lowered into the pond and continues to stir at the same time as the pump is operating (1). Stirring is an essential part of the procedure as it reduces the settling of the large particles present in the dams. Without this part of the operation, the storage ponds could eventually become completely solid due to the practice of only removing the very liquid slurry from the top layer of the ponds. The stand-alone 81-kilowatt diesel slurry pump with an in-built chopper (2) is positioned on the dam wall. A pipe is then lowered into the dam ready for pumping. A digital flow meter (3) built into the pump records each m³ as it is expelled through the pipes. The lay flat umbilical pipes are reeled out and laid across the fields to which the slurry is to be applied. One end is attached to the pump and the other to the slurry applicator (dribble bar) on the tractor (4). The tractor carrying the slurry applicator starts on one side of the field, much like someone would

do when using an electric lawnmower and its cord, and travels up and down spreading the slurry while also drawing the umbilical pipes behind it (5). Soil compaction is negligible as the tractor never travels the same track twice, and there is no expensive turnaround time as the slurry applicator is continuously linked to the pump at the dam via the umbilical pipes (Williams 2008, pers com).

The second farm in the Lion's River area to be visited, Kildare owned by Mr. G. Torr (Figure 4.16), is situated in Nottingham Road. This farm is currently housing about 600 animals, and milking around 320 of these.



Figure 4.16: Kildare Farm system, showing removal of slurry from anaerobic lagoons and subsequent application onto cropping lands using specialized tankers.

As can be seen in the diagram, Mr. Torr's slurry dams are overgrown and in desperate need of attention (1). Currently he is pumping out as much liquid slurry as he can from these dams (2) and applying it to his cropland using specialized tankers (3, 4 & 5) that he has contracted from a company in the nearby town of Mooi River. His plan is to plough the applied waste into the soil in preparation for the planting season. His one lagoon, that is too solid to be pumped (6), will be excavated using a TLB, and the solids will then be used to make compost, which the farmer intends to use on smaller plots of land, as well as to sell for a marginal income (Torr G 2008, pers com).

A second farm in the Nottingham Road area also visited, Dunira Farm owned by Mr. D. Greene (Figure 4.17), shows an entirely new type of system. In this system, dairy waste flows into a small collection pond (1) where it is agitated (2) and pumped through a separator (3). The liquid waste runs into a lagoon (4) from where it is irrigated onto pastures through a dedicated line and gun applicator. The solid waste is stored in a concrete pit (5) and is later used as an organic application to cropping lands (6).

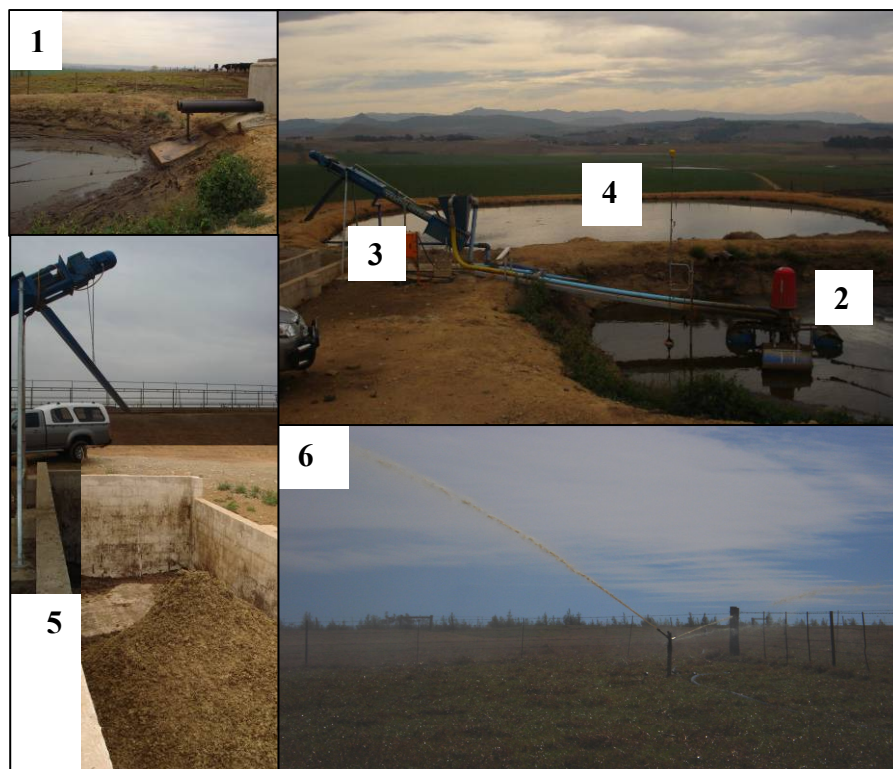


Figure 4.17: Dunira Farm system, showing separation of slurry using a screw auger system and subsequent application of liquids onto pasture using a traveling applicator gun.

This particular visit was conducted with the aid of Mr. G. Muller, an irrigation consultant from Howick, who is also the representative for different types of slurry equipment in the area. He makes various forms of separators himself through knowledge gained from numerous visits to New Zealand and Australia. He is also a representative for slurry equipment that is imported from these two countries. The entire system at Dunira was imported from New Zealand and thus was quite expensive to set up. However, after the initial costs, management of such a system is minimal, as this particular set-up runs almost entirely autonomously. The separator is linked to a sensor on the agitator that only switches on when the collection pond contains a specific amount of wastewater. Similarly, when the pond level drops below a certain point, the separator automatically switches itself off. These levels can be set by the operator and ensure that the risk of the pond overflowing is minimized, and that the separator does not run unnecessarily (Muller 2008, pers com).

The last visit in this region was to Mearns Farm in Rosetta, owned by Mr. J. Keane (Figure 4.18).



Figure 4.18: Mearns Farm system, showing agitation of slurry and subsequent application to pastures via both a pivot mounted gun applicator, as well as a traveling gun applicator.

This system is similar to Bromley Farm's scenario, whereby wastes are caught in a small pond (1), agitated, and pumped via a dedicated line to a gun applicator (2) mounted on his centre pivot 1.5 kilometres away. This gun is interchangeable, and can be moved to different centre pivots around the farm, within the limit of the dedicated line. The farmer also makes use of a travelling gun that he imported from New Zealand (3). Although expensive, the farmer insists that the gun was worth the cost and that it is an efficient way in which to irrigate slurry (Keane 2008, pers com).

The last two interviews conducted were with Mr. Bruce Dixon (a fertilizer consultant for Profert[®], a fertilizer company based in the midlands area of KwaZulu-Natal) and Mr. Noel Houart (a civil engineer specializing in the construction of dairy parlours in South Africa and Namibia).

According to Mr. Dixon, the average amount of money currently being spent by farmers on fertilizers is sitting around R4350/ha - R 2650/ha for planting, and an additional R1700/ha in top-dressing the crops. In KwaZulu-Natal, the best time for fertilizer application of maize is in October (planting), and top dressing should occur around mid-summer (December).

When asked about what the biggest concerns were for farmers surrounding chemical fertilizer applications, Mr. Dixon mentioned the high costs, the efficiency of applications, and the utilization of all available N. He added that, in his business, soil sampling and management models are strictly employed when tailoring fertilizers to suit individual farmers' needs, so as to ensure the maximum utilization of N by crops and pastures. He also stated that legislation is very often involved in the decision making process with regards to his business. All of the consultants/scientists must pass an examination before being legally permitted to sell agricultural fertilizers (South Africa, 1947). However, when asked about the other types of legislation available surrounding the issue of dairy waste management, Mr. Dixon stated that he has not seen any governmental regulation on farms so far, and that many waste management systems in the area are in dire need of attention.

Lastly, Mr. Dixon was asked about his opinion on organic farming and fertilizers. He stated that there is not enough money in it currently, and that it is not worth his while

to market organic fertilizers as there is no proven economical benefit to farmers (Dixon 2008, pers com).

Mr. Houart showed interest in the research after reading the Dairymail article (Dairymail, 2008) and organized a meeting to be held on the 25 September at his offices in Howick, KwaZulu-Natal. From here, Mr. Houart runs a civil engineering company that specializes in the design and construction of dairy parlours countrywide. His interest in the research is based on the intention of developing a generic dairy waste management system to complement his dairy designs. Currently he is working on design principles modified from New Zealand and Australian scenarios (Houart 2008, pers com). A good insight into the structural and cost requirements of building a dairy and the associated waste management system for such a building was obtained (see Appendices A and B). For example, to set up an anaerobic lagoon system for a 500 cow dairy will set you back as much as R90 000, with an additional R80 000 for a separator and R75 000 for the construction of a housing for the equipment – a total of R245 000 set-up cost (Houart 2008, pers com). This information is valuable to the research as it provides insight into the cost requirements involved in the design and development of adequate dairy waste management systems.

4.3.2 Western Cape region (13-14 May, and 5-7 October 2008).

Seven farms in total were visited in the Western Cape region, in three municipal districts, namely DC 2 and 4 (West Coast and George respectively) and the Cape Town District. Figure 4.19 shows the farm distribution within the study area.

The seven farms consisted of:

- Vyevelei (owned by Mr. N. Neethling),
- Fair Cape (owned by the Loubser family),
- Uilenkraal (owned by Mr. W. Basson),
- Tweerivier (owned by Mr. B. Robertson),
- Jonkershoek (owned by the Van Greunen family),
- Werde (owned by the Van Greunen family) and
- Bossie Alleen (owned by the Van Greunen family).

In addition to these farm visits, two interviews were conducted in this region, which were as follows:

- 1) Mr. Theuns Breytenbach: *Civil Engineer, Department of Agriculture, Western Cape* (3 October) (Breytenbach 2008, pers com).
- 2) Mr. Kurt Strahlendorf: *Consultant, Streamline Milking Services (SMS), Malmesbury, Western Cape* (13 May) (Strahlendorf 2008, pers com).

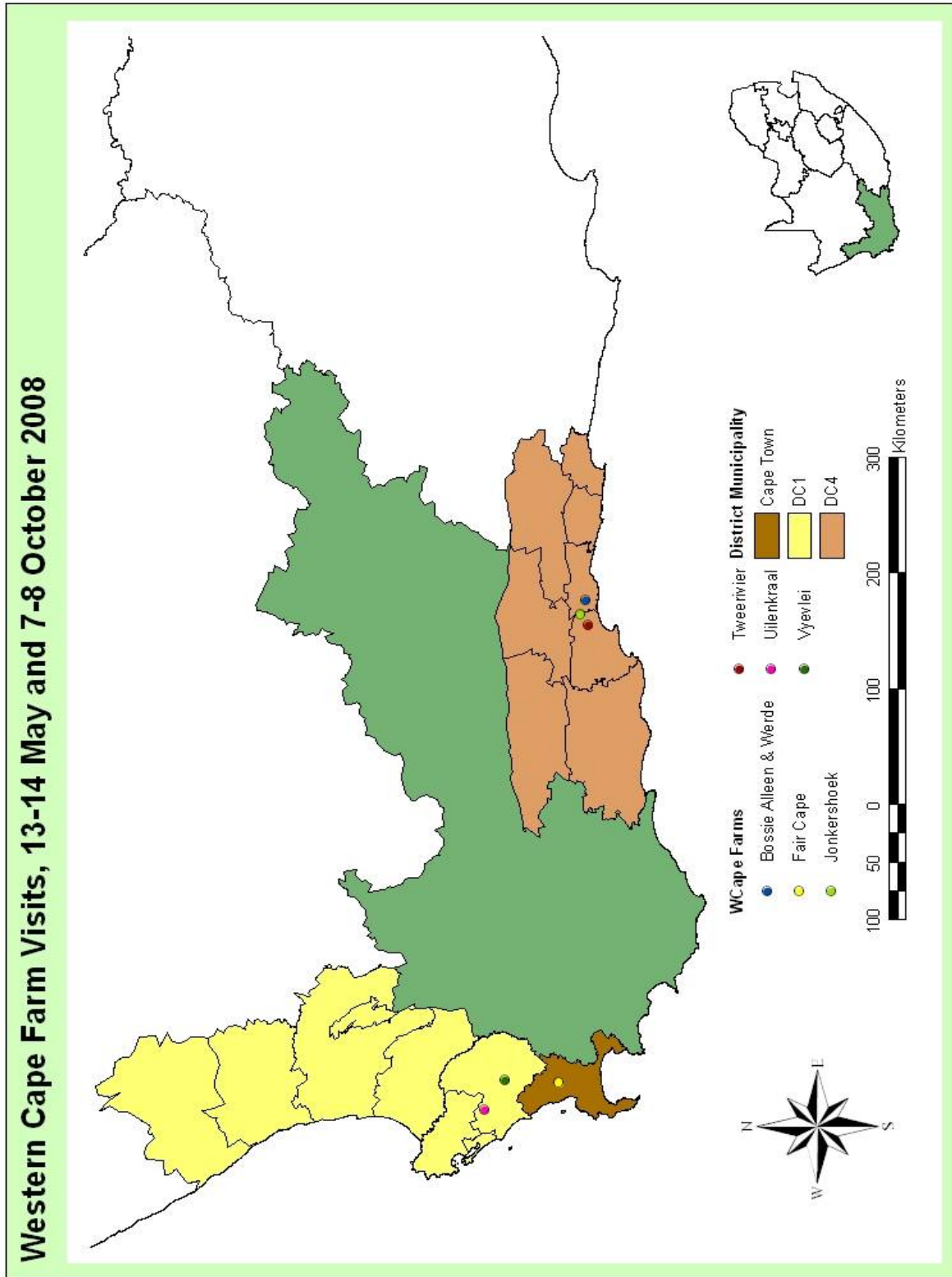


Figure 4.19: Western Cape region showing the distribution of visited farms.

Cape Town region

In the beginning of 2008, a visit to Vyevelei farm in Malmesbury was organised through Mr. Kurt Strahlendorf, a consultant for Streamline Milking Services (SMS) in Malmesbury, Western Cape. At the time, Mr Strahlendorf was looking into effluent management on farms, with a keen interest in composting of solid dairy wastes.

Vyevelei farm has 2500 milking cows being managed using a barn-fed/feed-pad system. Dairy waste management on the farm is comprised of a static manure screen that sits over a tractor-drawn manure trailer (Figure 4.20). Dairy waste from the milking parlour and holding yards is pumped over the static screen, where the liquids are then separated from the solid manure, and are stored in holding tanks before being pumped to a larger holding dam. Solids are collected in the manure trailer and are later transported onto a field area where they are stored (along with used bedding from the barns) in large heaps. These solids are later applied onto land as fertilizers, where there was evidence of smothering (Figure 4.20). The liquids that are stored in the dam are used in irrigation.



Figure 4.20: Vyevelei system, showing a static screen separator and manure trailer, and smothering caused by the incorrect method of applying dairy waste to land.

The importance of separation and agitation of slurry has, according to Mr Strahlendorf, so far been underestimated in South Africa. The question arose whether compost has a better nutrient content than straightforward manure, and hence whether farmers should be exploring this as a feasible management strategy with regards to their dairy wastes. According to Mr. Strahlendorf, the annual cost of spreading

manure on a 600 cow dairy farm is roughly around R300 000-R400 000 (Strahlendorf 2008, pers com). He believes that the future in dairy waste management is the biodigestion and subsequent composting of dairy wastes, as this would provide the most cost effective and economical solution to the farmer (Strahlendorf 2008, pers com).

Fair Cape dairy (Figure 4.21), the second farm to be visited in this area earlier in the year (14 May), was started in 1995 by the five Loubser brothers. The farm houses a total of 2433 cows on 2000 ha of prime agricultural land in the Malmesbury area of the Western Cape. The herd management system is based on an Israeli design (due to the Western Cape's Mediterranean climate) and is a barn-fed/feed-pad system. Crops grown on the farm include wheat, oats and canola.

Mr. J. Loubser is a firm believer in sustainability. Water used in the daily cleaning procedures at his dairy is around 120 000 litres, all of which is recycled from the dairy wastewater (Figure 4.21). Cow manure and wastewater from the barns and holding areas is collected and separated using a static screen **(1)**. The separated liquids run into a small holding pond **(2)** (40 000 litres capacity) from where they are pumped into a larger holding pond known as a settling lagoon **(3)**. From here, the liquid waste is aerated via agitation **(4)** (oxygenation kills any odour and pathogens) and ultimately pumped into a large storage tank **(5)** where it is then used after the next milking session to clean the holding yard, walkways and barns **(6)**. The solid material obtained via daily extraction from the housing stalls and the solid manure from the separated material (13 tonnes daily) is spread using a specialized spreading trailer **(7)** imported from Holland. This material is comprised of 12% dry matter, and the speed of the tractor determines the thickness of waste material applied to the land, usually 20 tonnes/ha **(8)**. Mr Loubser strongly believes that the application of such wastes to agricultural land encourages organic material and micro organism action in soil **(9)** (e.g. earthworms) therefore promoting the cooling of upper levels of the soil in which the organisms grow and work to ultimately enhance the soil's properties. His ultimate aim is to reduce the farms' carbon footprint as much as possible, hoping eventually to add to his recycling system with the addition of a bio-digester. He believes that Fair Cape will have self-sufficiency within the next 5 years (Loubser 2008, pers com).

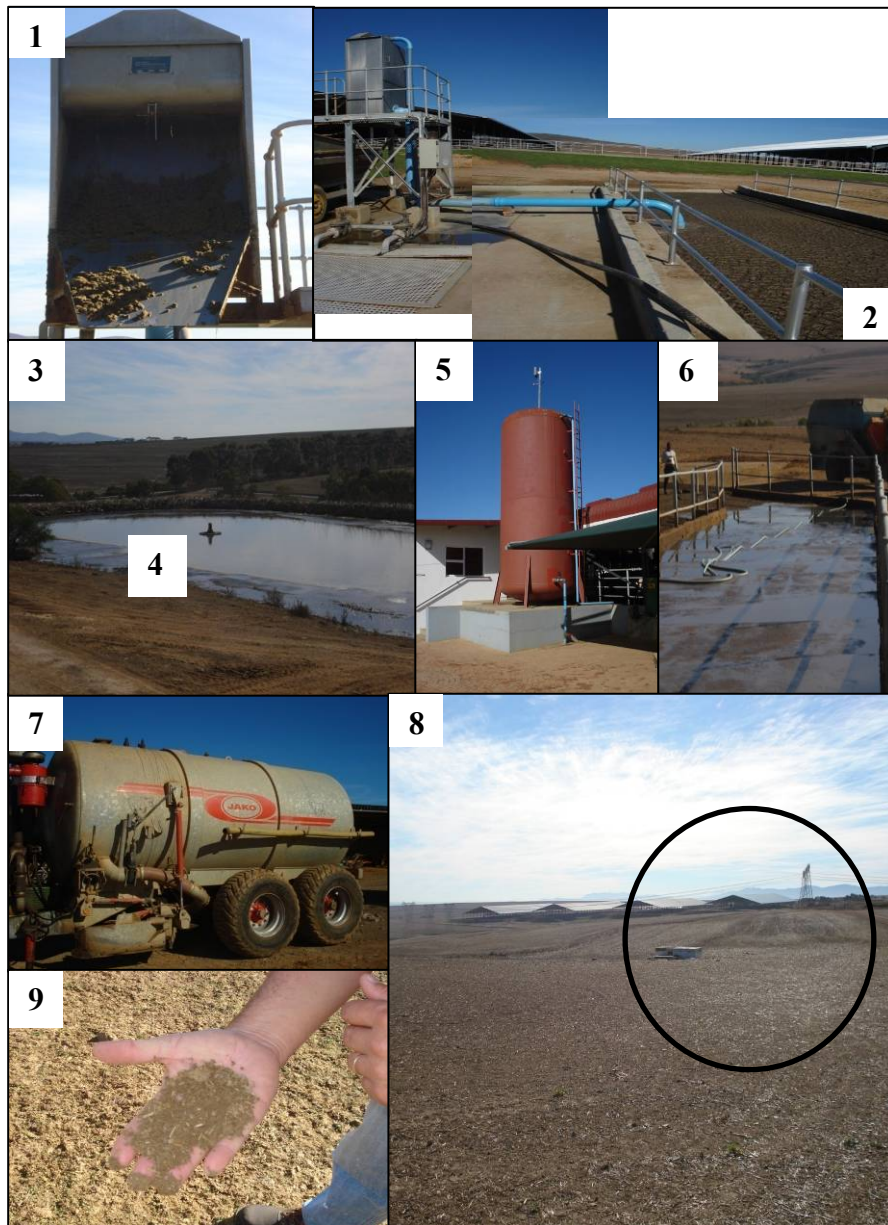


Figure 4.21: Fair Cape system, showing separation of slurry, recycling of liquids, and application of solids to pastures via a specialized tanker imported from Holland.

Later on in the year, a meeting was arranged with Mr. Theuns Breytenbach from the Department of Agriculture, Elsenburg, to discuss the issue of dairy wastewater management, as this topic greatly interested him with regards to its groundbreaking status. According to him, this type of research, specific to South Africa, has been given very little attention until now (Breytenbach 2008, pers com). His insight into the field was centered round his vocation as a civil engineer, and the discussion revolved around specific techniques involved in dairy waste separation and application (specifically irrigation). The different methods of separation, as previously

discussed in this report, were mentioned and acknowledged by Mr. Breytenbach as being the principle methods of dairy waste separation that he has witnessed in South Africa (Breytenbach 2008, pers com). A trip to see these different techniques in operation in the Western Cape was then organized. This took place on the 6th and 7th of October, where four farms in the Cape Town and George areas were visited in order to investigate their current waste management strategies.

The first of these, Uilenkraal Farm, is owned by Mr. W. Basson (Figure 4.22) and is situated in the Darling area of the Western Cape. Working with a barn-fed/feed-pad herd management system similar to that used at Fair Cape, Mr. Basson is currently milking 770 cows and admits that there is a problem with his barn slurry management system (Basson 2008, pers com).

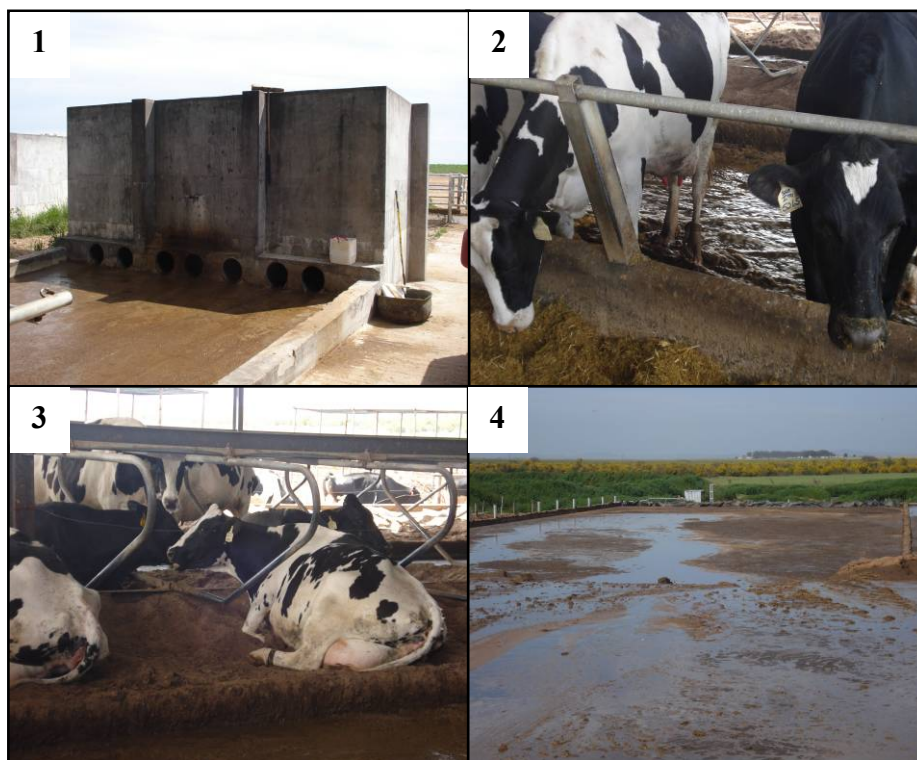


Figure 4.22: Uilenkraal barn system, showing the use of recycled water in the wash down of barn feeding area, and the blocked sand traps that are overflowing.

The barn slurry management system is comprised of an anaerobic lagoon system, headed by two sand/sediment traps. The barn that houses Mr. Basson's dairy cows (Figure 4.2.12) is continually flushed with recycled dairy wastewater (1 & 2) in order to keep the walkways clear of effluent. However, because he uses sand as bedding (3) in his barn, the sand traps at the entrance to his slurry ponds are full of sediment and

overflowing (4), causing run-off in the direction of his marshlands. He acknowledges this problem and is currently trying to correct it, as the presence of high water tables and underground aquifers on the farm is a cause for concern. At the milking parlour (Figure 4.23), Mr. Basson is making use of a screw auger separator (5) to manage the waste coming from the dairy holding yard. The liquids that are separated in this procedure are pumped into a storage tank (6) alongside the parlour and recycled for use in daily wash down procedures of the holding yard. The solids (7) are stored and later will be used in composting. The farmer has converted his old dairy parlour into a worm farm (8), where he is using the solid waste material to make compost for his crops. The earthworms act on the waste to remove heavy metals and neutralize the pH. Mr. Basson states that no matter what pH the solid material is at when placed in the worm farm, the pH will come out neutral (between 6.2 and 6.5) every time (Basson 2008, pers com).



Figure 4.23: Uilenkraal dairy system, showing the use of a screw auger separator, recycled water storage for the wash down of holding area, the separated solids, and the new worm farm that is used in composting procedures.

George region

Mr. Breytenbach also managed to arrange a visit to two farms in the George area of the Western Cape. The first farm, Tweerivier (Figure 4.24) is owned by Mr. B. Robertson who has just installed a new dairy. His herd management system is pasture based. He calculated that if each cow is excreting 50 litres of waste a day, that equates to R137 worth of nutrients being excreted per cow per day, a total of R2400 per cow per year (Robertson 2008, pers com). With a herd of approximately 400 cattle, this could mean a substantial amount of R960 000 annually. Because of this calculation, Mr. Robertson has installed a brand new slurry management system to go with his new dairy. The system is comprised of a sediment/sand trap settlement pond (1) that runs into two storage lagoons (2). The idea is that the solids will separate out of the holding yard waste, accumulating in the sand trap, from where they can be removed and spread onto cropland using a tanker. The liquids from the dams are to be recycled in wash down procedures, as well as irrigated, as the availability of water on the farm is not good due to its elevation. The farmer will therefore be saving money as he will not have to pump as much water from the river, which has to be lifted over 100 metres to the dairy parlour (Robertson 2008, pers com).

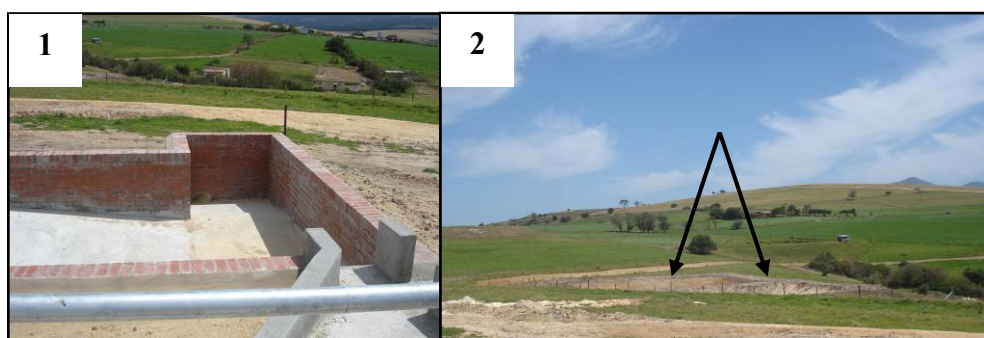


Figure 4.24: Tweerivier dairy system, showing the new sediment/sand trap and two irrigation ponds.

The last visit in the Western Cape was to the three farms owned by the Van Greunen brothers, namely Jonkershoek, Werde and Bossie Alleen. All three of these farms are run on a pasture-based herd management system. Apart from Jonkershoek (where waste runs directly into a settlement pond from where it is irrigated directly onto croplands) the Van Greunen brothers make use of a similar system (Figure 4.25) to that of Mr. Robertson. Both systems are characterized by the presence of a sediment/stone trap (1), which allows for solids and sand to fall out of suspension,

allowing the liquid wastewater to continue on to two storage ponds. The water is then used for irrigation, whilst the solid waste is collected and spread on the lands. The Van Greunens have their own muck spreader that they imported from Holland (2). This is used to apply both dairy and chicken manure to their croplands and pastures. It is also used to apply slurry, as the dams need to be emptied regularly due to the buildup of solid material. This requires the use of a homemade agitator (3) to mix the liquids and solids together, ensuring that the solids are in suspension before being pumped into the tanker, and subsequently applied to agricultural land (4). This system has been successfully in place for 10 years, and the Van Greunens are adamant that their slurry is working for them (Van Greunen 2008, pers com). The one problem that they do have is that they are irrigating their wastewater through the same irrigation lines as their ordinary irrigation. They therefore have to alternate waste application and normal irrigation, often depending on where their herd is at the time.

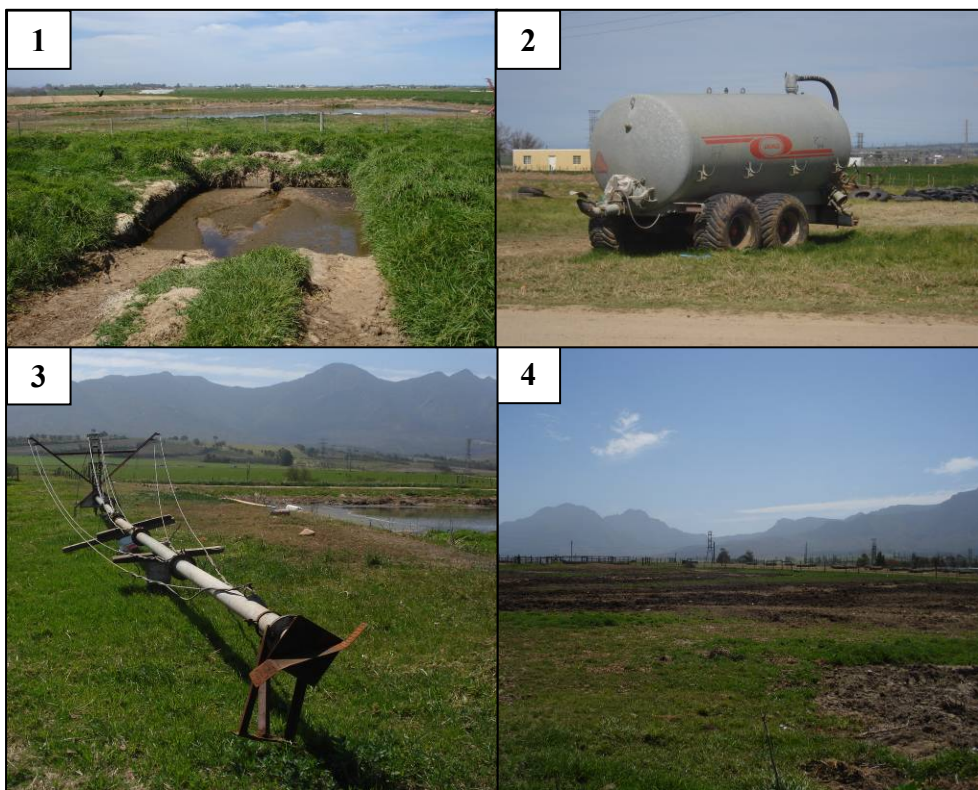


Figure 4.25: Van Greunen farms, showing the sediment/sand trap, muck spreader, homemade agitator, and the application of waste to lands.

4.4 Discussion

The intention of the questionnaire, interviews and farm visits was to identify the existing dairy wastewater management systems in use amongst a portion of dairy farmers in South Africa, as well as to explore whether these systems are environmentally and economically viable options for wastewater management in general.

The most noticeable trend that is identifiable at the beginning of the results analysis is that all respondents from the KwaZulu-Natal region are managing highly intensive livestock production operations. With an average carrying capacity of 0.75 hectares per cow, this is unquestionable. What is questionable is how they are managing these systems. Thus, the question to ask is - are the current wastewater management trends in South Africa sustainable in the long term?

In general, both the KwaZulu-Natal sample group (including farm visits) as well as the Western Cape farmers visited seem to understand the value that wastes have as fertilizer for their crops and pastures. This is evident not only in the number of questionnaire respondents who are already involved in some form of waste application to their lands (85%) as well as those who have entertained the idea of using their waste in the future (95%), but also from the individuals interviewed during the farm visits that took place. The point that has been stressed by farmers in both cases is that waste should not be used exclusively, but rather together with chemical fertilizers. Considering that none of the respondents to the questionnaire, nor the farmers who were interviewed during the farm visits, are making use of their dairy waste as the **only** form of fertilizer for their crops, it can be assumed that this is not a feasible option to them. The reasons for this were demonstrated in the section on farmers' comments, where both operation size and crop requirements were two areas that were presented as limiting factors. However, with the high costs involved in chemical fertilizer utilization, farmers are definitely seeking out better methods for waste utilization within their operations.

In connection with current trends in waste management, there appear to be two distinct routes that have been taken with regards to the South African scenario.

Firstly, waste can be collected and applied directly to lands as sludge, or secondly, waste is first separated before being utilized. In a separation system, the farmer not only needs a separator, but also a means by which to manage his separated liquid and solid waste. This could be through the use of a tanker, contractors, or an irrigation system. Alternatively, direct application of slurry to lands does not require three separate facets, but either an irrigation set-up or a tanker/muck spreader. Both methods are being employed in South Africa, and which one is preferred is heavily dependent on an individual's requirements and budget.

There are three methods of separation currently in use that were identified by the research, namely rotary screen separation, static screen separation, or screw auger separation. Those farmers who made use of rotary screen (N=1), static screen (N=2) and screw auger (N=2) separators were generally the larger businesses who were operating mainly on barn/feed-pad herd management systems (e.g. Vyevelei, Fair Cape and Uilenkraal). A reason that was repeatedly stated for the majority decision to apply wastes directly onto land and crops rather than make use of separation, was the high costs involved in the separation of slurry, and in particular, the cost of the equipment. Dairy waste storage facilities alone are already expensive, and separation equipment adds quite significantly to this figure.

Out of the total farms visited for the research (N=14), the majority of farmers (N=9, 64%) opted for the first option of applying their slurry directly to lands. The sludge that is applied directly to lands is done so by either tanker/muck spreader, dedicated irrigation line, umbilical chord contracting, or through the main line irrigation system. However, the most commonly used method stated by respondents to the questionnaire is via tanker (43.9%). During the farm visits, the most frequently used method of direct application was also via tanker (50%), although a new form of separation also emerged. This involves the use of a rudimentary sediment/sand trap facility that is designed to be a filtration system for the liquid dairy waste. As the waste from the milking parlour leaves the holding yard, it runs into this sediment/sand trap where any solids are allowed to settle out of solution. From here on, liquids flow into storage dams and are used in irrigation. Therefore, a large percentage (36%) of the farmers visited make use of both tankers and irrigation methods of waste application; tankers to spread the solids that they extract from these traps and the storage ponds, whilst the

liquids are irrigated onto lands and pastures. Figure 4.26 illustrates the different routes of waste management that are presently operating in the KwaZulu-Natal and Western Cape areas.

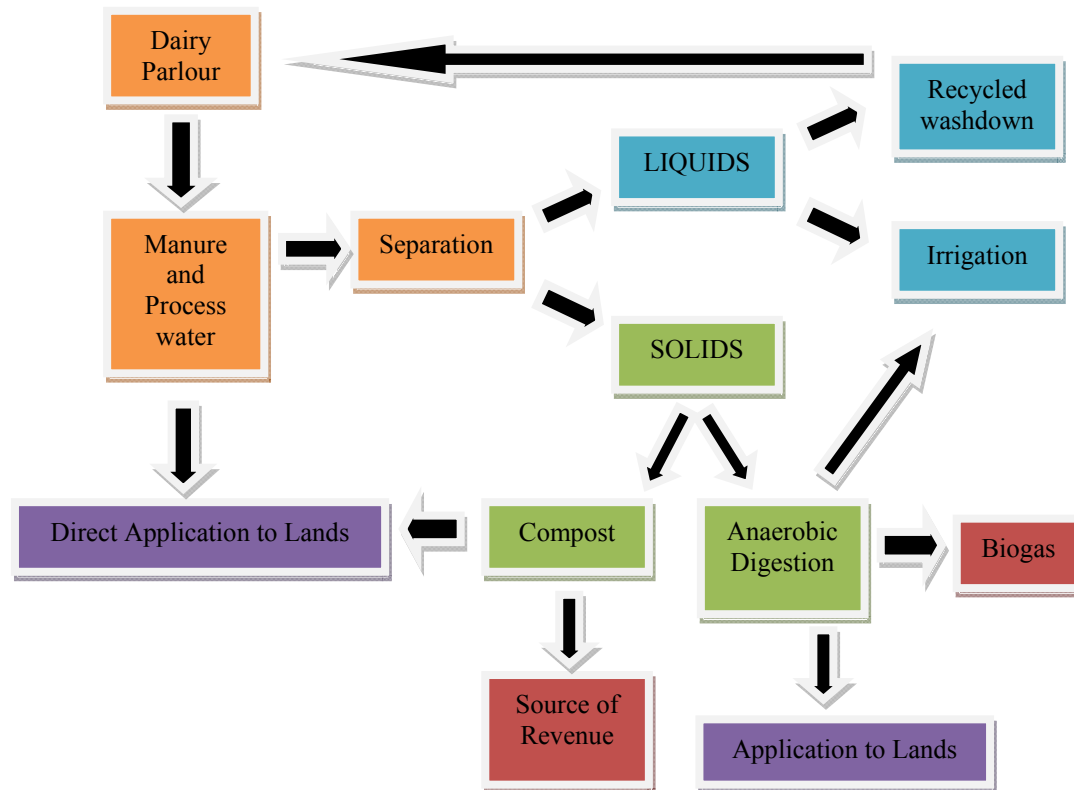


Figure 4.26: Waste management strategy options currently prevalent in study area.

There are, however, environmental and economical problems associated with the use of tankers. These include compaction of the soil, limited transport capacity (resulting in frequent trips to and from the storage facility), the need for labour, and high running costs (diesel, time, maintenance). Hence, most of the farmers interviewed would prefer to run a dedicated irrigation line from their waste storage facilities, as such a system would not require any form of labour. This method poses a series of new problems, such as the need for installing underground pipes, the question of distance (how far can one pump the waste?) and the need for and running of various pumps. Thus, there appears to be an ongoing search for the most efficient, environmentally and economically viable solution to wastewater application on dairy farms. Farmers want a system that requires the least amount of capital and maintenance, namely one that runs autonomously, only needing to be maintained every other month. The most economically and environmentally viable solution seems to be the utilization of a dedicated irrigation line for liquid wastewater and/or slurry

application. This ensures that the wastewater is not being fed through the mainline irrigation, which could result in pollution of borehole and groundwaters through backflow of applicants. In many scenarios, the mainline irrigation is also responsible for watering the herd, and if wastes are pumped through this system it could have effects on the taste of the cows' drinking water. Additionally, if the farmer has a separation system, and needs to dispose of solid as well as liquid waste products, results suggest that solids are most effectively composted and later spread manually using a tractor and trailer. This system appears to require the least amount of financial input and is relatively easy to maintain.

Either way, dairy waste management requires some form of storage facility. All farmers that participated in the questionnaire and farm visits have some form of storage for their wastes, but in some cases reported by the questionnaire, these facilities are inadequate (17%) or in need of an upgrade (42%). In general, farmers are good conservationists, and are aware of the problems associated with wastewater management, and they are actively involved in minimizing the pollution risk of their operations. There appears to be very minimal regulation of wastewater management by the government to correct such problems. Therefore farmers do not feel pressured by legislation or policies to improve their systems, but rather see the economic value in doing so, and hence embark on exploring such principles on their own accord. In this regard, farmers have come to the realisation that if they can cut down on their chemical fertilizer costs, the money which they save can be used in the application of their wastes, which would subsequently alleviate their storage problems and pollution risks. Organic fertilizer is just as effective as chemical fertilizer, and although both methods involve high costs, the added advantage of storage problem alleviation associated with the utilization of wastewater on farms is paramount.

With regards to organic farming, there does not seem to be any real interest in the concept amongst all the farmers who were interviewed. The general feeling is that they stand nothing to benefit from the endeavour, and that there is no real demand for organic milk produce in South Africa at the moment, with only 17% of questionnaire respondents stating that 'organic branding' was a distinct advantage of organic over conventional produce. Although positive about the utilization of their wastes as fertilizer, farmers are not linking this management principle to the idea of organic

farming. Their main priority at this stage is to save as much money as they can, and converting to organic farming does not appear to be a viable option at this stage. Perhaps in the future, when waste utilization has yielded promising results, will farmers then look to benefiting from organic farming methods. Currently, there is not enough evidence to suggest that organic farming is a more viable method of cultivation than conventional farming practices, as very little research has been done in this regard in South Africa.

Chapter 5 – CONCLUSIONS & RECOMMENDATIONS

As the world population grows, so does the demand for food security. This demand has fuelled an increase in the intensity of livestock production systems worldwide, and has thus resulted in an increase of environmental problems associated with these systems. Therefore, if we are to ensure that agriculture remains sustainable in the long term, it is important that farmers become aware of the environmental risks associated with intensive production practices.

Although chemical fertilizers can be harmful to the environment, they are an essential factor in the production of food, and are thus used worldwide in the production of grain and cereal crops. However, an increase in the cost of such chemical fertilizers, as a result of increasing global energy prices, has been extremely hard on the world's farmers. As a result, farmers are looking into alternate methods of gaining the essential nutrients needed for crop production, one of which is the utilization of livestock wastes as an organic fertilizer for agricultural land.

Research shows that dairy wastes have been used as fertilizers and composts in agriculture dating back to the Stone Age. The fact that such wastes are often a storage issue on dairy farms, promotes the idea of alleviating storage problems by applying these wastes as fertilizers to land. Not only can this organic approach to crop production alleviate the environmental issues associated with poor waste management, but it can also aid in reducing the cost of chemical fertilizer usage, thus benefiting the farmer both economically and environmentally.

Another economical advantage associated with the utilization of waste materials in agricultural production systems is the marketing benefit of 'organic produce' branding. Organic farming is a movement that is strongly against any introduction into the environment of non-organic substances for agricultural management. The use of organic compounds and manures is, however, accepted in this form of agriculture, and can benefit the farmer in two ways: environmentally (healthy soils and plants) and economically (organic branding of produce).

In terms of all of the above, this research sought to identify current trends of dairy wastewater management in South Africa, and forthwith, to establish whether the application of dairy wastes to agricultural land is an environmentally and economically feasible option for farmers in this country. In conclusion, it can be said that dairy wastewater utilization as a fertilizer in agricultural production systems is a feasible management strategy, both environmentally and economically. However, the general finding is that such wastes should be used in conjunction with their chemical counterparts rather than as a complete replacement for these fertilizers. In addition, although the utilization of wastes can be beneficial over chemical fertilizers, this is only the case when they are properly managed and utilised.

Elements that need to be taken into consideration during planning of wastewater management facilities include the production, collection, storage, processing and utilization of dairy wastewater. These are summarized in Figure 5.1.

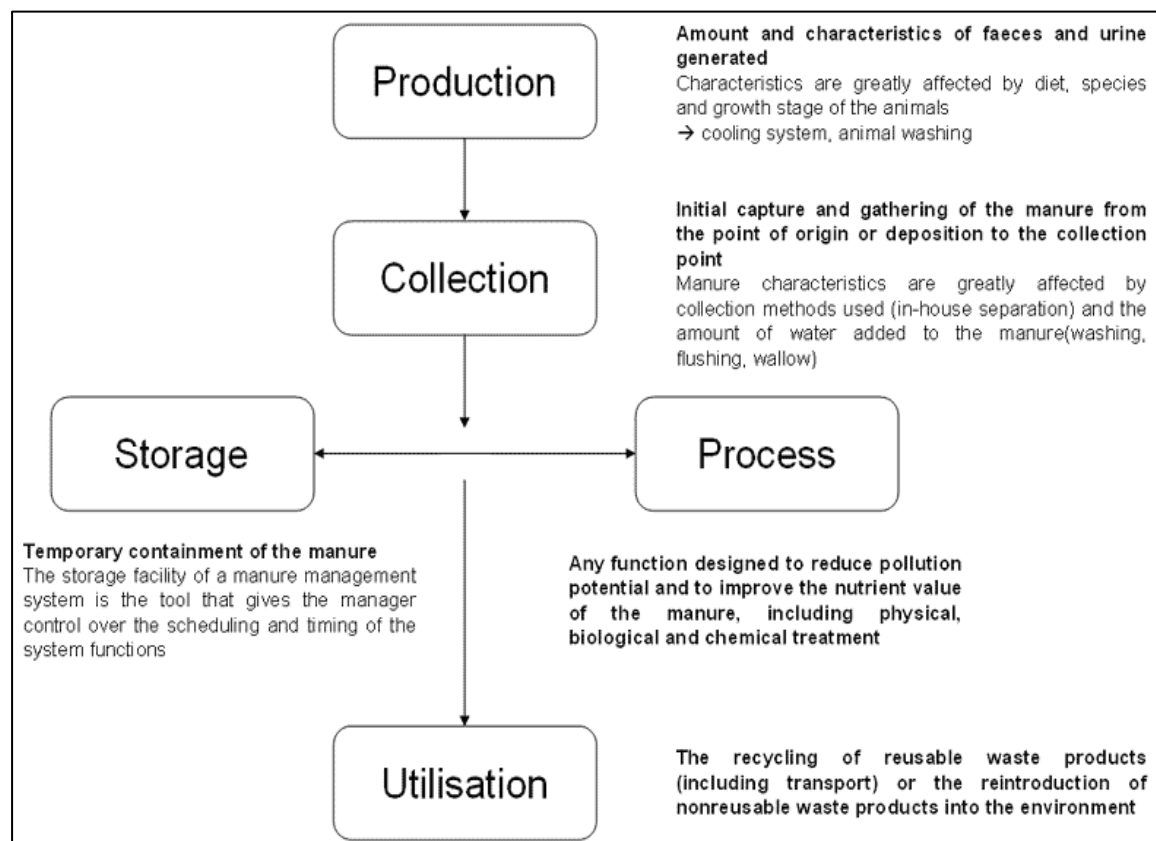


Figure 5.1: Elements of dairy wastewater management that need to be considered when planning a site-specific management system (Dexcel, 2007).

Knowledge gained through the research suggests that the most economically and environmentally viable solution to wastewater utilization is, in effect, the operation of

a dedicated irrigation line for wastewater and/or slurry application. In addition, if the farmer has a separation system, solids are most effectively composted and later spread manually using a tractor and trailer system. This approach appears to require the least amount of financial input and is relatively easy to maintain.

Whichever method is eventually chosen for wastewater management, the importance of proper planning and execution cannot be stressed enough. Various elements need to be taken into consideration and a suitable management system devised for individual agricultural settings. It must be noted that there is no general model that can be applied across the board; wastewater management is very scenario-specific, and there cannot be one solution applicable to all cases.

Environmental legislation needs to be consulted and adhered to in order to avoid heavy penalties and/or fines. With more farmers around the country becoming interested in the utilization of their on-farm dairy wastes as a fertilizer to the crops, it is essential that some form of legislation or policy document be drafted in order to regulate these specific activities. The government needs to get involved in ensuring that these practices are not going to cause further problems in terms of environmental pollution. Farmers are generally willing to cooperate if they are provided with the necessary information and means by which they can become more compliant.

In closing, organic farming is, although incorporating the use of wastes as fertilizers, according to the results obtained in the research, not a feasible option for dairy farming in South Africa at this stage. Reasons for this include the high costs involved in converting to this method of cultivation, as well as the perceived low demand for organically branded milk produce which is a result of current food and fuel hikes in the country. Further limitations include the size of farming operations and outputs, low yields, and a restricted consumer base.

The recommendation of the researcher is that further research needs to be conducted on the actual composition of dairy wastes (e.g. nutrient content) so as to optimise the use of these wastes as fertilizers in conjunction with chemical fertilizers in agricultural production systems, and also to prevent further environmental degradation of the natural resource base. Furthermore, governmental authorities

involved in the environmental sector of South Africa need to be more strict in their implementation of various policies and legislations pertaining to agricultural practices if they are intent on 'preventing' rather than 'curing' future environmental pollution from the agricultural sector. It does not help to have a system in place if there is no formal implementation of policies and/or prosecution of defectors. A stricter approach to policy and legislation adherence is a necessity for the symbiotic coexistence of the environmental and agricultural sectors of South Africa.

REFERENCES

- Akinyemi OM 2007. *Agricultural production: organic and conventional systems*. United States of America: Science Publishers.
- Almasri MN 2007. Nitrate contamination of groundwater: A conceptual management framework. *Environmental Impact Assessment Review* 27: 220-242.
- Alvarenga P, Palma P, Goncalves AP, Fernandes RM, Cunha-Queda AC, Duarte E & Vallini G 2007. Evaluation of chemical and ecotoxicological characteristics of biodegradable organic residues for application to agricultural land. *Environmental International* 33: 505-513.
- Ancev T, Whelan B & McBratney A 2005. Evaluating the benefits from precision agriculture: the economics of meeting traceability requirements and environmental targets. In Stafford J (ed) *Precision agriculture '05*, 985-992. Wageningen: Wageningen Academic Publishers.
- Ap Dewi I, Axford RFE, Marai IFM & Omed H 1994. *Pollution in Livestock Production Systems*. London, CAB International.
- Ap Dewi I 1994. Chapter 17: The use of animal waste as a crop fertilizer. In Ap Dewi I, Axford RFE, Marai IFM & Omed H 1994. *Pollution in Livestock Production Systems* 309- 331. London: CAB International.
- Basson W 2008. Farm owner, Uilenkraal. Darling. Interview on 7 October about dairy waste management on his farm.
- Breytenbach T 2008. Civil Engineer, Western Cape Department of Agriculture. Elsenberg. Interview on 3, 6 and 7 October to discuss dairy waste management in the western cape and visit farmers.
- Botha L 2008. Navorsing oor afval op melkplase. *Landbou Weekblad* 4 July 2008: 91.
- Butler RM, Wooding NH & Myers EA 1978. *Spray-irrigation disposal of wastewater*. Special Circular 185. The Pennsylvania State University, College of Agriculture Extension Service, University Park, Pennsylvania.
- Canarache A, Vintila I & Munteanu I (eds) 2006. *Elsevier's Dictionary of Soil Science*. Elsevier.
- Carpenter SR, Caraco NF, Correll DL, Howarth RW, Sharpley AN & Smith VH 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 8,3: 559-568.
- Ceotto E 2005. The issues of energy and carbon cycle: new perspectives for assessing the environmental impact of animal waste utilization. *Bioresource Technology* 96: 191-196.

- Chadwick & Chen 2002. Chapter 3: Manures. In Haygarth PM & Jarvis SC (eds) *Agriculture, hydrology and water quality*, 57-82. United Kingdom: Cromwell Press.
- Condron LM, Cameron KC, Di HJ, Clough TJ, Forbes EA, McLaren RG & Silva RG 2000. A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. *New Zealand Journal of Agricultural Research* 43: 443-466.
- Dairymail 2008. Put waste water to use. *Dairymail* 15,8: 116.
- Danalwich JR, Papagiannis TG, Belyea RL, Tumbleson ME & Raskin L 1998. Characterization of dairy waste streams, current treatment practices, and potential for biological nutrient removal. *Water Research* 32,12: 3555-3568.
- Davis J & Abbott L 2006. Chapter 2: Soil fertility in organic farming systems. In Kristiansen P, Taji A & Reganold J (eds) *Organic Agriculture: A Global Perspective* 25-45. United Kingdom: CABI Publishing.
- Delate K 2008. *What is organic agriculture?* [online]. Iowa State University. Available from: <http://extension.agron.iastate.edu/organicag/whatis.html> [Accessed 13 March 2008].
- DOA (Department of Agriculture, South Africa) 1998. *Agricultural Policy in South Africa* [online]. Available from www.nda.agric.za/docs/policy98.html [Accessed 21 July 2007].
- DOA (Department of Agriculture, South Africa) 2008a. *White Paper on Agriculture* [online]. Available from: <http://www.nda.agric.za/docs/WHITEPAPER.htm> [Accessed 13 March 2008].
- DOA (Department of Agriculture, South Africa) 2008b. *Trends in the agricultural sector 2007*. Pretoria: Department of Agriculture.
- Dexcel 2007. *A guide to managing farm dairy effluent: Canterbury* [online]. DairyNZ, New Zealand. Available from: <http://www.dairynz.co.nz/page/pageid/2145836756#EffluentManagement> [Accessed 24 July 2008].
- Dixon B 2008. Fertilizer consultant, Profert®. Howick. Interview on 23 September concerning current fertilizer costs and the resultant concerns amongst farmers.
- Drinkwater LE, Wagoner P & Sarrantonio M 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262-265.
- Dupont RR, Baxter TE & Theodore L 1998. *Environmental Management: Problems and Solutions*. Florida: CRC Press.
- Edmeades DC 2003. The long-term effects of manures and fertilizers on soil productivity and quality: a review. *Nutrient Cycling in Agroecosystems* 66: 165-180.
- Encyclopaedia Britannica 2007. *The New Encyclopaedia Britannica: Fifteenth Edition*. London: Encyclopaedia Britannica, Macropaedia.

- Feng GL, Letey J, Chang AC & Campbell Mathews M 2005. Simulating dairy liquid waste management options as a nitrogen source for crops. *Agriculture, Ecosystems and Environment* 110: 219-229.
- Fourie G 2008. Owner, G4 Irrigation. Underberg. Interview on 23 September to discuss and visit various dairies in the Underberg region of KwaZulu-Natal, in order to gain information concerning current trends in dairy wastewater management in this region.
- Fraisse CW, Campbell KL, Jones JW & Boggess WG 1996. GIDM: A GIS-based model for dairy waste management analysis. AWRA Symposium on GIS and Water Resources, September 22-26, 1996. Florida: Fort Lauderdale.
- FSSA (Fertilizer Society of South Africa) 2005. AB De Villiers: Fertilisers, Food Production and the Environment. 46th Annual Congress of the FSSA, Pretoria. (English in English)
- FSSA (Fertilizer Society of South Africa) 2006. GJ van der Linde & MA Pitse: The South African Fertiliser Industry. AFA Conference, Cairo, Egypt. (English in English)
- FSSA (Fertilizer Society of South Africa) 2007. Alfred Pitse: President's Report. 48th Annual Congress of the FSSA, Durban. (English in English)
- FSSA (Fertilizer Society of South Africa) 2008. Fertilizer Society of South Africa [online]. Available from: <http://www.fssa.org.za> [Accessed 13 March 2008].
- Garnier M, Lo Porto A & Marini R 1998. Integrated use of GLEAMS and GIS to prevent groundwater pollution caused by agricultural disposal of animal waste. *Environmental Management* 22,5: 747-756.
- Giasson E, Bryant RB & Bills NL 2002. Environmental and economic optimization of dairy manure management: a mathematical programming approach. *Agronomy Journal* 94: 757-766.
- Giupponi C & Vladimirova I 2005. Ag-PIE: A GIS-based screening model for assessing agricultural pressures and impacts on water quality on a European scale. *Science of the Total Environment* 359: 57-75.
- Gottschall N, Boutin C, Crolla A, Kinsley C & Champagne P 2007. The role of plants in the removal of nutrients at a constructed wetland treating agricultural (dairy) wastewater, Ontario, Canada. *Ecological Engineering* 29: 154-163.
- Grigg D 1984. *An introduction to agricultural geography*. Essex: Hutchinson & Co. (Publishers) Ltd.
- Hawker S (ed) 2006. *Oxford English Dictionary*. 9th Edition. London: Oxford University Press.
- Haygarth PM & Jarvis SC (eds) *Agriculture, hydrology and water quality*. Wallingford, OXON: CABI Publishing.

- Healy MG, Rodgers M & Mulqueen J 2004. Re-circulating sand filters for treatment of synthetic dairy parlour washings. *Journal of Environmental Quality* 33,2: 713-718.
- Herren RV & Donahue RL 1991. *The Agriculture Dictionary*. New York: Delmar Publishers Inc.
- Hoffman DW, Harris BL & Mazac FJ 2001. *Reducing contamination by improving milking centre wastewater treatment* [online]. Texas: Texas Department of Agriculture. Available from <http://waterhome.brc.tamus.edu/texasyst/milking.html> [Accessed 24 July 2007].
- Hoogervorst A, Rosenberg E & Kemm K 1999. *The Enviropaedia*. South Africa, Simonstown: Eco-Logic Publishing.
- Houart N 2008. Civil Engineer, Agri. Design and Civils. Howick. Interview on 25 September concerning the cost of implementing specific waste management strategies in South Africa.
- Institute of Rural Sciences 2008. *What is organic farming?* [online]. Aberystwyth University, Ceredigion. Available from: <http://www.wirs.aber.ac.uk/research/organics/define.html> [Accessed 14 March 2008].
- Keane J 2008. Farm owner, Mearns. Rosetta. Interview on 26 September about dairy waste management on his farm.
- Keithlow S 2008. *Chemical versus natural fertilizers* [online]. Available From: http://ezinearticles.com/?expert=Scotie_Keithlow [Accessed 14 March 2008].
- Kristiansen P, Taji A & Reganold J (eds) 2006. *Organic agriculture: a global perspective*. United Kingdom: CABI Publishing.
- Lampkin N 1990. *Organic Farming*. Ipswich: Farming Press Books.
- Lansing SL & Martin JF 2006. Use of an ecological treatment system (ETS) for removal of nutrients from dairy wastewater. *Environmental Engineering* 28: 235-245.
- Lehohla PJ 2005. *Census of commercial agriculture, 2002: Financial and production statistics*. (Report No 11-02-01). Pretoria: Statistics South Africa.
- Leigh GJ 2004. *The world's greatest fix: a history of nitrogen and agriculture*. New York: Oxford University Press Inc.
- Liu J, Liao W, Zhang Z, Zhang H, Wang X & Meng N 2007. Effect of phosphate fertilizer and manure on crop yield, soil P accumulation, and the environmental risk assessment. *Agricultural Sciences in China* 6,9: 1107-1114.
- Loubser J 2008. Farm owner, Fair Cape Dairies. Malmesbury. Interview on 14 May about dairy waste management on his farms.
- Maas H 2008. Radio Sonder Grense (RSG) interview. 8 July 2008: 4:45am.

- Matsi T, Lithourgidis AS & Gagianas AA 2003. Effects of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. *Agronomy Journal* 95: 592-596.
- Mawdsley JL, Bardgett RD, Merry RJ, Pain BF & Theodorou MK 1995. Pathogens in livestock waste, their potential for movement through soil and environmental pollution: A review. *Applied Soil Ecology* 2: 1-15.
- McGarvey JA, Miller WG, Sanchez S, Silva CJ & Whitehand LC 2005. Comparison of bacterial populations and chemical composition of dairy wastewater held in circulated and stagnant lagoons. *Journal of Agricultural Management* 99: 867-877.
- McLaughlin A & Mineau P 1995. The impact of agricultural practices on biodiversity. *Agriculture, Ecosystems and Environment* 55: 210-212.
- Mendoza TC 2002. Comparative productivity, profitability and energy use in Organic, LEISA and Conventional rice production in the Philippines. *Livestock Research for Rural Development* 14:6.
- Merrington G, Winder L, Parkinson R & Redman M 2002a. Chapter 1: Agriculture and pollution. In Merrington G, Winder L, Parkinson R & Redman M (eds) *Agricultural Pollution*, 1-11. New York: Spon Press.
- Merrington G, Winder L, Parkinson R & Redman M 2002b. Chapter 5: Organic Wastes. In Merrington G, Winder L, Parkinson R & Redman M (eds) *Agricultural Pollution*, 93-134. New York: Spon Press.
- MPO (Milk Producers Organisation, South Africa) 2008. Statistics: a service to the dairy industry by the Milk Producer's Organisation (MPO). *Lactodata March 2008* 11,1: 1-15.
- Miles N 2007. Nitrogen: don't forget your animals. *Farmer's Weekly* 23 November: 24-26.
- MEA (Millenium Ecosystem Assessment) 2005. *Millenium Ecosystem Assessment Synthesis Report*. Washington DC: Island Press.
- Milne JA 2005. Societal expectations of livestock farming in relation to environmental effects in Europe. *Livestock Production Science* 96: 3-9.
- Mkhabela TS & Materechera SA 2003. Factors influencing the utilization of cattle and chicken manure for soil fertility management by emergent farmers in the moist Midlands of KwaZulu-Natal Province, South Africa. *Nutrient Cycling in Agroecosystems* 65: 151-162.
- Muller G 2008. Irrigation specialist. Howick. Interview on 25 September concerning the cost of implementing specific waste management strategies in South Africa, as well as the current trends surrounding waste management in the KwaZulu Natal area.
- Neményi M, Mesterházi PA, Pecze Z & Stépán Z 2003. The role of GIS and GPS in precision farming. *Computers and Electronics in Agriculture* 40: 45-55.

- Nicholson RJ 1994. Chapter 21: Systems of storage and disposal of livestock wastes. In Ap Dewi I, Axford RFE, Marai IFM & Omed H (eds) *Pollution in Livestock Production Systems* 385- 402. London: CAB International.
- Northcott W 2004. *Managing dairy wastewater using an innovative treatment and disposal system* [online]. Michigan State University. Available from www.egr.msu.edu/age/aenewsletter/1_july_aug_04/northcott7_04.htm [Accessed 20 July 2007].
- Owen JB 1994. Chapter 1: Pollution in livestock production systems: an overview. In Ap Dewi I, Axford RFE, Marai IFM & Omed H (eds) *Pollution in Livestock Production Systems* 1-18. London: CAB International.
- Prins C (cedricp@elsenburg.com) 2008. RE: Dairy wastewater research. E-mail to L. Torr (leightorr@sun.ac.za) (13 October).
- Reginold JP, Papendick RI & Parr JF 1990. Sustainable Agriculture. *Scientific American* 262: 112-120.
- Rejesus RM & Hornbaker RH 1999. Economic and environmental evaluation of alternative pollution-reducing nitrogen management practices in central Illinois. *Agriculture, Ecosystems and Environment* 75: 41-53.
- Robertson B 2008. Farm owner, Tweerivier, George. Interview on 6 October about dairy waste management on his farm.
- Rodrigues MA, Pereira A, Cabanas JE, Dias L, Pires J & Arrobas M 2006. Crops use-efficiency of nitrogen from manures permitted in organic farming. *European Journal of Agronomy* 25: 328-335.
- Sager M 2007. Trace and nutrient elements in manure, dung and compost samples in Austria. *Soil Biology and Biochemistry* 39: 1383-1390.
- Sharpley AN 2002. Introduction: Agriculture as a potential source of water pollution. In Haygarth PM & Jarvis SC (eds) *Agriculture, Hydrology and Water Quality* 4-5. New York: CABI Publishing.
- Smith KA & Chambers BJ 1993. Utilizing the nitrogen content of organic manures on farms – problems and practical solutions. *Soil Use and Management* 9,3: 105-112.
- Smith PG & Scott JS 2002. *Dictionary of water and waste management*. London: IWA publishing.
- Somani LL & Tikka SBS (eds) 1983. *Dictionary of Agriculture*. New Delhi: Agricole Publishing.
- South Africa Info 2008. *South African Agriculture* [online]. International Marketing Council of South Africa, Big Media Publishers (Pty) Limited. Available from: <http://www.southafrica.info/doingbusiness/economy/keysectors/agricultural-sector.htm> [Accessed 18 March 2008].

- South Africa (Republic of) 1947. Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, Act 36 of 1947. *Government Gazette of South Africa* 36, 1.6.1948.
- South Africa (Republic of) 1983. Conservation of Agricultural Resources Act, Act 43 of 1983. *Government Gazette of South Africa* 43, 25.5.1984: 1048.
- South Africa (Republic of) 1998a. National Environmental Management Act, Act 107 of 1998. *Government Gazette of South Africa* 401, 27.11.1998: 19519.
- South Africa (Republic of) 1998b. National Water Act, Act 36 of 1998. *Government Gazette of South Africa* 398, 26.08.1998:19182
- South Africa (Republic of) 1999. *A framework for implementing non-point source management under the National Water Act: A Discussion Paper*. WRC Report # TT 115/99. Pretoria: Water Research Commission.
- South Africa (Republic of) 2000. White Paper on Integrated Pollution and Waste Management for South Africa. *Government Gazette of South Africa* 227, 17.3.2000: 20978.
- Stafford JV (ed) 2005. *Precision agriculture '05: European Conference on Precision Agriculture, Upsala, Sweden*. Wageningen, Netherlands: Wageningen Academic Publishers.
- Stephens A (ed) 1990. *Dictionary of Agriculture*. Middlesex: Peter Collin Publishing.
- Stockdale EA, Shepherd MA, Fortune S & Cuttle S 2001. Soil fertility in organic farming systems – fundamentally different? *Soil Use and Management* 18,3[Supplement]: 301-308.
- Stonehouse DP, Clark EA & Ogini YA 2001. Organic and conventional dairy farming comparisons in Ontario, Canada. *Biological Agriculture and Horticulture* 19,2: 115-125.
- Strahlendorf K 2008. Consultant, Streamline Milking Services (SMS). Malmesbury. Interview on 13 May concerning farmers' current waste management practices.
- Stubbs R 2008. Farm Owner, Denleigh. The Karkloof. Interview on 24 September about dairy waste management on his farm.
- Tagg F 2007. The importance of getting it right. *Dairy Exporter* December 2007: 67-68.
- Tanji KK & Enos CA 1994. Chapter 1: Global water resources and agricultural use. In Tanji KK & Yaron B (eds) *Advanced Series in Agricultural Sciences (vol. 22): Management of water use in agriculture* 3-23. Berlin: Springer-Verlag.
- Theron PF 1999. Waste Management in South Africa. In Hoogervorst A, Rosenberg E & Kemm K *The Enviropaedia*, 201-204. South Africa, Simonstown: Eco-Logic Publishing.

- Tilman D 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences of the United States of America* 96, 11: 865-872.
- Torr G 2008. Farm owner, Kildare. Nottingham Road. Interview on 24 September about dairy waste management on his farm.
- Torr L 2008. Letter to Farmers Weekly magazine entitled: Fertilizer Research. *Farmers Weekly* 25 July 2008: 8.
- University of Illinois 2008. *As fertilizer prices rise, the manure option is looking better* [online]. Illinois, University of Illinois. Available from: <http://web.extension.uiuc.edu/state/discover.cfm?DiscoverID=24> [Accessed 11 March 2008].
- Van Greunen B 2008. Farm owner, Bossie Alleen, Werde and Jonkershoek. George. Interview on 6 October about dairy waste management on his farms.
- Watson CA, Atkinson D, Gosling P, Jackson LR & Rayns FW 2002. Managing soil fertility in organic farming systems. *Soil Use and Management* 17: 263-268.
- Webb J & Archer JR 1994. Chapter 11: Pollution of soils and watercourses by wastes from livestock production systems. In Ap Dewi I, Axford RFE, Marai IFM & Omed H (eds) *Pollution in Livestock Production Systems* 189-204. London: CAB International.
- Westfall B (BWestfall@arc.agric.za) 2008. RE: Dairy wastewater research. E-mail to L. Torr (leightorr@sun.ac.za) (27 August).
- Willer H & Yussefi M (eds) 2005. *The world of organic agriculture 2005 – Statistics and emerging trends*. International Federation of Organic Agriculture Movements: Bonn.
- Williams A 2008. Owner of SlurryTech®. Rosetta. Interview on 24 September concerning his slurry contracting business in the KwaZulu Natal midlands.
- Wynen E 1994. Economics of organic farming in AQustralia. In Lampkin NH & Padel S (eds) *The Economics of Organic Farming: An International Perspective* 185-199. Wallingford: CAB International.
- Zaman M, Cameron KC, Di HJ & Inubushi K 2002. Changes in mineral N, microbial biomass and enzyme activities in different soil depths after surface applications of dairy shed effluent and chemical fertilizer. *Nutrient Cycling in Agroecosystems* 63: 275-290.

APPENDICES

Appendix A: Anaerobic Lagoon Design (Houart 2008, pers com).

NOTES:

12m³ slurry/cow/90 day retention period
 Bank slopes at 2:1 (can be 1:1 for upper bank in good soil conditions)
 Crest: min of 4m
 Base Square: min 10x10m
 Free Depth: min 3.5m
 Free board = 500mm
 Pumping Lagoon: min. fluid depth of 2.5m at all times length same as width of anaerobic lagoon

V = Volume = herd size x 12m³/cow/90 day retention period
 D = depth = fluid depth (min. of 3.5m - effective digestion)
 L = length = length of fluid surface
 W = width = width of fluid surface

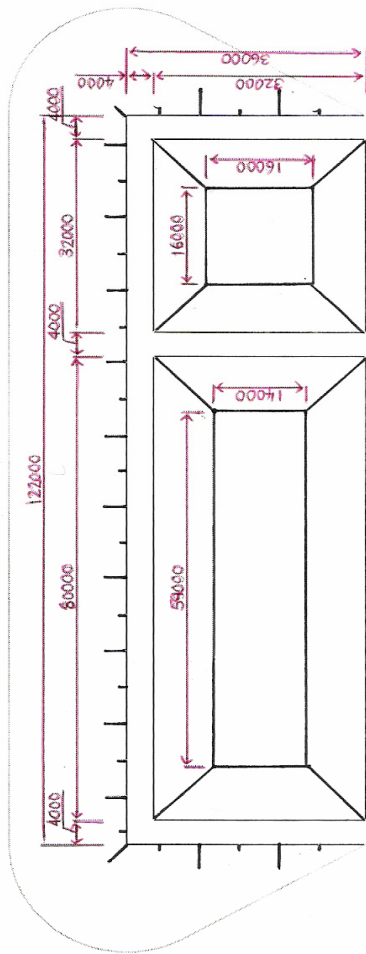
480 Cow Milking Herd:

Anaerobic Lagoon:

V = 5500m³
 D = 4m
 L = 77m
 W = 30m

Pumping Lagoon:

V = 1852m³
 D = 3.5m
 L = 30m
 W = 30m

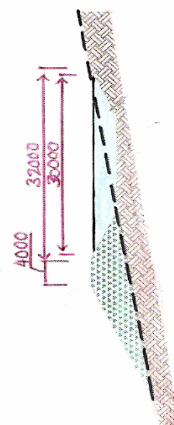


ANAEROBIC LAGOON

V = 5500m³

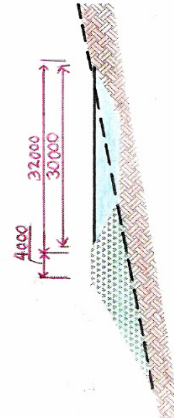
PUMPING LAGOON

V = 1852m³



PUMPING LAGOON SECTION

D = 3.5m



ANAEROBIC LAGOON SECTION

D = 4m

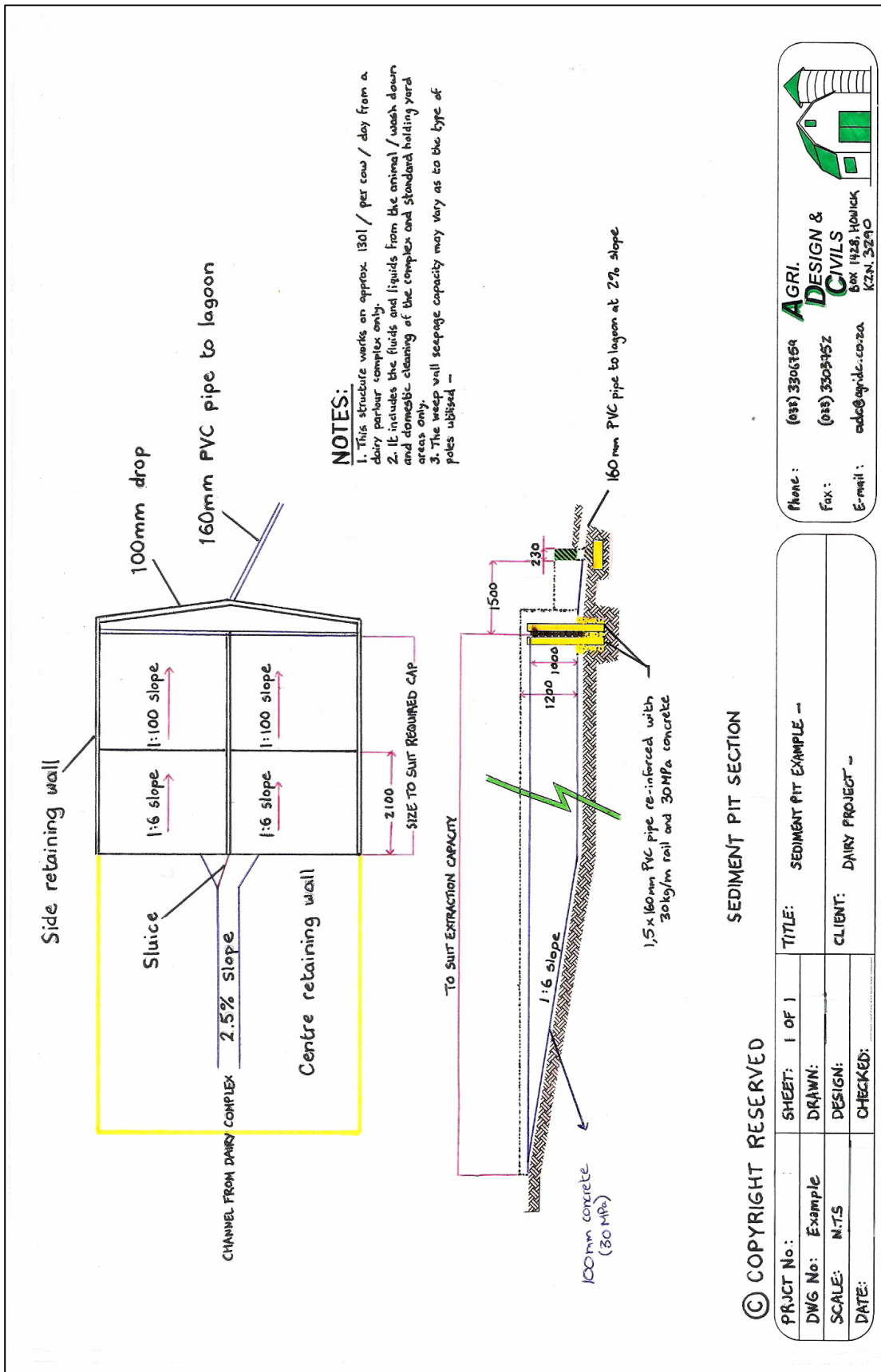
© COPYRIGHT RESERVED

| | | |
|--------------------|---------------|--|
| PRJCT No: EXAMPLE | SHEET: 1 OF 1 | TITLE: SLURRY LAGOON DESIGN FOR 480 COW HERD |
| DWG No: 480(B)Herd | DRAWN: | CLIENT: DAIRY PROJECT - |
| SCALE: N.T.S | DESIGN: | |
| DATE: | CHECKED: | |

Phone: (083) 3504159
 Fax: (083) 3503952
 E-mail: odc@agri-design-civils.co.za

AGRI. DESIGN & CIVILS
 BOX 1428 HOUTKOP
 K.Z.A. 3210

Appendix B: Sediment Pit Design (Houart 2008, pers com).



© COPYRIGHT RESERVED

| | | | |
|--------------|---------------|----------|------------------------|
| PROJECT No.: | SHEET: 1 OF 1 | TITLE: | SEDIMENT PIT EXAMPLE - |
| DWG No.: | Example | DRAWN: | |
| SCALE: | M:T:S | DESIGN: | |
| DATE: | | CHECKED: | |
| | | CLIENT: | DAIRY PROJECT - |

Phone: (081) 3306164

Fax: (081) 3305452

E-mail: info@agrilc.co.za

AGRI. DESIGN & CIVILS

Box 1428, HOLLICK KZN, 3290

Appendix C: Dairy wastewater management questionnaire



UNIVERSITEIT · STELLENBOSCH · UNIVERSITY
jou kennisvenoot · your knowledge partner

Dairy wastewater as fertilizer for agricultural land: **Questionnaire**

This questionnaire forms part of a Masters thesis investigating the feasibility of using dairy wastewater as an alternative to chemical fertilizers in the field of dairy farming. The information provided by you in answering this questionnaire will remain confidential and shall not be used for purposes other than the research specified. For more information feel free to contact Miss Leigh Torr at leightorr@sun.ac.za or project supervisor Mr. Schloms at (021) 808 3218 during office hours.

- Please complete all questions.
- In some instances, where a drop-down box is not provided, multiple answers are available.
- Please click on the **submit** button once you have completed the questionnaire. This step will ensure that the questionnaire is transferred automatically.

- 1) Name of owner:
- 2) Name of your farm(s):
- 3) In which province is/are your farm(s) located?
 - a) Eastern Cape
 - b) Free State
 - c) KwaZulu-Natal
 - d) Northern Cape
 - e) Northern Provinces (Limpopo, Mpumalanga, North West)
 - f) Western Cape
- 4) Approximate area of arable land on your farm(s):
- 5) Size of your dairy herd:
 - a) Milking
 - b) Dry
- 6) Is your herd management based on an intensive or pasture system?
 - a) intensive
 - b) pasture
 - c) both

- 7) Type of crops grown on your farm(s) and their area(ha):
- Maize
 - Small Grain
 - Pastures
 - Other – Specify
- 8) Crops are principally grown as:
- Fodder for cows (silage)
 - Grain
 - Cash crop
 - Bedding
 - Other - specify
- 9) What form of fertilizer(s) do you use for crop management?
- Chemical fertilizers (N,P,K)
 - Organic fertilizers (manures, compost)
 - Both chemical and organic fertilizers, but more chemical fertilizers
 - Both chemical and organic fertilizers, but more organic fertilizers
 - I don't use fertilizers

- 10) Fertilizer application period(s) (Tick appropriate boxes):

| | Spring | Summer | Autumn | Winter |
|----------------|--------|--------|--------|--------|
| a) Maize | | | | |
| b) Small grain | | | | |
| c) Pastures | | | | |
| d) Other | | | | |

- 11) If you make use of chemical fertilizer, how do you apply this fertilizer to your lands?
- Liquid Irrigation (Centre Pivot, sprinkler system)
 - Fertigation
 - Granular spreading
 - Other – specify
 - Not applicable (I don't use chemical fertilizers)
- 12) If you make use of your waste as a fertilizer, how do you apply this waste to your lands?
- Irrigation System (Centre Pivot, sprinkler system)
 - Using a tanker
 - Manually
 - Other – Specify
 - Not applicable (I don't use my waste as fertilizer)

- 13) Approximately how much do you spend on fertilizers for the following crops (annually, R/ha)(tick appropriate boxes):

| | <R2000 | R2000-4000 | R4001-6000 | R6001-8000 | R8001-10 000 | > 10 000 |
|----------------|--------|------------|------------|------------|--------------|----------|
| a) Maize | | | | | | |
| b) Small grain | | | | | | |
| c) Pastures | | | | | | |
| d) Other | | | | | | |

- 14) Is dairy waste management a problem on your farm?
- Yes, I don't have enough space/proper storage facilities for my waste
 - Not a big problem, but it could do with an upgrade
 - No, I have adequate facilities and management strategies in place
- 15) Would/Have you ever considered using your dairy waste as a fertilizer?
- Yes
 - I hadn't really thought about it
 - No
- 16) How do you currently manage your dairy waste?
- Anaerobic lagoon system
 - Removal by contractors
 - Irrigation/spreading onto crops and land
 - Composting
 - Dumping
 - Biodigestion
 - I don't currently have a management strategy
 - Other – specify

Organic farming refers to natural production management systems which promote and enhance biodiversity, soil biological activities, and biological cycles, and are based on management practices that restore, maintain, or enhance ecological harmony. Essentially, organic farming employs biological methods of fertilization and pest control as substitutes for chemical fertilizers and pesticides (such products are regarded as a health risk to humans and the environment and unnecessary for successful cultivation).

- 17) Do you see any value in being classified as an 'organic' farmer?
- Yes, definitely.
 - I don't think so, conventional farming is just as profitable as 'organic' farming.
 - No, it's just a marketing ploy.

- 18) If you answered yes to question 16, which of the following would you say are the most important advantages of organic farming that are applicable to your business?
- a) Economically beneficial
 - b) Environmentally friendly
 - c) Less mechanised/labour intensive
 - d) Greater crop yields
 - e) 'Organic' branding
 - f) Other – specify
- 19) Would you classify your farm as an 'organic' farming system?
- a) Yes
 - b) No
- 20) If yes to the above, what form of fertilizer do you utilize on your crops?
- a) Raw manure (slurry, liquid and solid manure)
 - b) Compost made from dairy manure
 - c) I buy certified organic fertilizers
 - d) I don't use fertilizers
 - e) Other – Specify

Thank you for your time!