THE PRACTICE, CONSTRAINTS AND PERCEPTIONS OF IMPROVING SOIL QUALITY THROUGH MANURE APPLICATION: A CASE STUDY OF THREE SMALLHOLDER FARMER GROUPS

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March 2009

Submitted in partial fulfillment of the degree of
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ABSTRACT

Land degradation and soil nutrient depletion have become serious threats to agricultural productivity in sub-Saharan Africa. Soil fertility depletion in smallholder areas has been cited as the fundamental biophysical cause of declining per-capita food production in Africa. Manure application is a well established and known practice, but not effectively used among South African smallholders. This study investigated the practice, constraints and perceptions of improving soil quality through manure application through a case study of three smallholder farmer groups.

Three groups from rural areas of KwaZulu-Natal (Mkhambatini, Mooi River and Richmond) were selected to participate in the study. Participatory methodologies were used to identify and clarify the study problem. Three participatory focus group discussions, one per area, were conducted with farmers at the study sites to discuss farming methods, experience and perceptions of manure use, manure management practices and constraints farmers experience with manure use. Force Field Analysis was used for each group to explore for forces against and in support for manure use. Random soil and manure samples were collected for laboratory analysis to determine fertility levels.

Some farmers indicated that soil fertility was low. However, half the sample perceived the land to be productive to some extent. The study showed that 40 per cent of farmers reported improved soil fertility following the application of manure. Due to the limited availability of livestock manure, farmers prefer to use both livestock manure and commercial fertilisers. Furthermore, the study found that except for young farmers (20 per cent of the sample), farmers had not received formal training and very limited extension advice on composting and manure use and management.

The study participants were aware of the consequences of declining soil fertility and were attempting to improve soil quality. However, low livestock numbers and poor management led to inadequate amounts of manure, and, limited access to information on manure and compost use. Unless better knowledge of optimal soil nutrient management

practice is acquired by the farmers, soil fertility levels will continue to decline, further reducing production potential and rural household food security.

Government needs to revisit extension support to meet the needs of smallholders and offer training on sound soil management, sustainable production methods, composting and livestock management. A handbook with graphic detail should be accompanied to provide smallholders with information and advice on how to manage soil fertility.

DECLARATION

I KD Naidoo declare that:

- The research reported in this mini-dissertation, except where otherwise indicated, is my original research
- This mini-dissertation has not been submitted for any degree or examination at any other university
- This mini-dissertation does not contain other persons' data, picture, graphs or other information, unless specifically acknowledged as being sourced from those persons
- This mini-dissertation does not contain other authors' writing, unless specifically acknowledged as being sourced from other authors. Where other written sources have been quoted then:
  - Their words have been re-written but the general information attributed to them has been referenced;
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Signed: ……………………………………………………………………………

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As Research Supervisor, I agree to submission of this mini-dissertation for examination.

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Dr JM Chitja **Date**

As Research Co-supervisor, I agree to submission of this mini-dissertation for examination.

Signed

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Professor SL Hendriks **Date**

ACKNOWLEDGEMENTS

The following people and organizations, without whom this study would not have been possible, are thanked for their contribution to this study:

My supervisor, Dr JM Chitja, who allowed me the opportunity to take the next step in my education to do my masters. She allowed me the scope to follow my thoughts and develop my research skills, whilst always being available to provide guidance and discussion whenever it was needed; for this I am very grateful.

My co-supervisor Prof SL Hendriks. I am certain that having supervisors such as these were instrumental to my completion of this dissertation.

The three farmer groups that allowed me to interview them, especially Maureen Magubane, Senior Manager for Inyamvubu Cooperative, who gave me so much important information; Mr Bheko Sithole from Ingwe Family Project who was willing to help me answer all my questions without hesitation; and Mrs Jabu Hlela from Umphumela Cooperative who also contributed some useful comments during my data collection. I also thank all the respondents for participating.

Financial support received from the National Research Foundation, the Archbishop Denis Hurley Scholarship Fund and the Ernst and Ethel Eriksen Trust.

My family, for their love and support throughout my life. I also wish to thank my mother, Jennifer, and my sister Morganie for their support and understanding during my study.

My dear friends Kitso Maragelo, Nonkululeko Mthembu, Mduduzi Ndlovu, Thulile Dlamini, Milane Selwe, Shana Govender and Wayne Naidoo and my peers from the African Centre for Food Security for being there for me when things got tough. God Almighty, thanks and praise for your constant love and compassion for keeping me steadfast in the completion of this journey.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACFS	African Centre for Food Security
Ca	Calcium
Cu	Copper
KZN DAEA	KwaZulu-Natal Department of Agriculture & Environmental Affairs
DoA	Department of Agriculture
DLRC	Department of Land Resources Conservation
FAO	Food and Agriculture Organisation
FFA	Force Field Analysis
Fe	Iron
FSSA	Fertilizer Society of South Africa
IDP	Integrated Development Plan
ISFM	Integrated Soil Fertility Management
K	Potassium
LMU	Land management unit
Mg	Magnesium
Mn	Manganese
MOFFEA	Ministry of Forestry, Fisheries and Environmental Affairs
N	Nitrogen
Na	Sodium
P	Phosphorus
SSA	Sub-Saharan Africa
S	Sulphur
TCEQ	Texas Commission on Environmental Quality
TLC	Transitional Local Councils
Zn	Zinc

CHAPTER 1
THE RESEARCH PROBLEM AND ITS SETTING

1.1 Introduction

In many small-scale farming areas of Africa, poor soil fertility is one of the major causes of low agricultural production and productivity (Bationo & Mokwunye, 1991). In sub-Saharan Africa, land degradation and soil nutrient depletion have become serious threats (Bekele, 2003). Most arable land has been affected by degradation, reducing agricultural productivity (Bekele, 2003) that leads to poverty and food insecurity among populations that depend on agriculture for their livelihoods (Bunderson & Hayes, 1995).

Poverty is largely a rural phenomenon - and the poor predominantly reside in rural areas (Tropical Soil Biology and Fertility Programme, 2002). Agriculture is the primary sector upon which the rural populations depend for their livelihoods. Rural poverty leads to food insecurity (Tropical Soil Biology and Fertility Programme, 2002). Traditional land tenure systems constrain agricultural production and investment in rural areas (Lyne & Nieuwoudt, 1991). The majority of farmers in South Africa lack access to credit and collateral which places financial constraints on acquisition of inputs, including fertilisers (Amin & van Schalkwyk, 1996).

Productivity improvements are required to meet the food and income requirements of the poor. This is unlikely to happen without concerted effort to improve and build sustainable soil fertility. Compost and manure and could play a vital role in the transformation of smallholder agriculture in South Africa through improving soil fertility (Mkhabela, 2006). Studies have shown that application of cow manure can significantly improve soil conditions; increasing the pH, water holding capacity, hydraulic conductivity and infiltration rate and decrease the bulk density (Lungu *et al.*, 1993). Manure is the preferred source of nutrients to increase soil fertility (Nambiar & Ambrol, 1989) over commercial fertilisers as manure provides the full range of nutrients required for optimal plant growth including trace elements.

The Fertiliser Society of South Africa estimated in 1989 that approximately three million tons of manure was available in South Africa from various feedlots (FSSA, 1997). The value of this manure calculated in terms of nitrogen, phosphorous and potassium was R29.7 million. It was also estimated that the manure was sufficient to meet 13.3%, 9.9% and 27.6% of the N, P and K requirements, respectively. However, it was estimated that only 25% of the three million tonnes of available manure was being used for soil fertility management. The remaining 75% of the available manure was mostly wasted, with a small portion used as energy for heating. According to FSSA (1997) the tonnes of manure available in South Africa are not expected to have changed much between 1997 and 1989.

The use of compost and manure for soil-fertility maintenance and crop production is influenced by a host of factors. Farm-level decisions concerning the use of manure are governed by socio-economic and institutional factors such as agronomic and ecological concerns (Williams, 1999). Factors such as herd size, farm size, distance of farm plots from source of manure, and knowledge of manure composition have been reported to influence the use of manure by smallholders for soil fertility (Williams, 1999; Corales & Serrano, 1999).

One problem that confronts farmers is that insufficient manure is available to meet the nutrient requirements (Probert *et al.*, 1995; du Toit & du Preez, 1995). The quantity of manure available on large farms is usually insufficient to fertilise all the land that is being planted to crops. However, when cropping a small area only, which is typical among smallholders, the available supply of manure may be adequate for sustainable production (van Averbeke & Yoganathan, 2003). Manure is sourced from livestock such as sheep, goats and cattle, poultry manure and green manure are could also be used.

1.2 Importance of the study

Solving complex agricultural problems, such as how to improve productivity with regard to manure management systems, requires strong trans-disciplinary research where farmers and scientists come together to apply adaptive, collaborative approaches to problem solving. Available literature on the use of manure for soil fertility shows that manure is a good source for plant nutrients (Mkhabela, 2006). The use of manure is an old technology that is appropriate for smallholders in South Africa because most smallholders practice mixed livestock and crop farming. Despite the use of manure dating back many years, smallholders in South Africa are not fully exploiting the available manure for replenishing soil fertility.

Studies of the soil nutrient balance in Africa have shown evidence of widespread nutrient mining, leading to severe nutrient deficiencies across ecological zones (Enyong *et al.,* 1999). Smallholder soil fertility problems in the midlands of KwaZulu-Natal (KZN) and the province of KZN in particular, are no exception. Most soils in the midlands of KwaZulu-Natal are highly weathered and inherently deficient in plant nutrient and soil organic matter (Farina & Channon, 1991). This study will contribute to literature on manure use among smallholders in three areas of KwaZulu-Natal found in Mkabathini, Mooi River and Richmond.

1.3 Statement of the problem

This study set out to investigate the practice, constraints and perceptions of improving soil quality through manure application.

1.4 Sub-problems

- Sub-problem one: To explore farmer practices with regard to manure application.
- Sub-problem two: To explore the perceived benefits and what motivates farmers to apply manure.
- Sub-problem three: What constraints are perceived by farmers?

1.5 Limits of the study

The study focused on three smallholder farmer groups in KwaZulu-Natal. These farmer groups are not representative of the total population of smallholder farmers in the province. Therefore, the results of this study cannot be generalized to the wider population. The study did not investigate the impact of manure on the final produce. To account for seasonal variations, soil samples were collected at approximately the same time each year. However due to the nature and objective of this study the researcher did not investigate the seasonal variations in soil quality and so repeated samples were not taken over seasons due to resource constraints. The results of the analysis are therefore not generalisable over all seasons.

1.6 Assumptions

It was assumed that the farmers were willing to participate and that information provided by participants was reliable and true, and that members did not withhold vital information that may have affected the findings. It was further assumed that the analysis of the manure and soil samples would be accurate as this was outsourced to the KwaZulu-Natal Department of Agriculture and Environmental Affairs' Soil Fertility and Analytical Services.

1.7 Structure of the mini-dissertation

The mini-dissertation is organised into six chapters. Chapter one presents an introduction to the study, the importance of this study, sub-problems, study limits and assumptions. The second chapter presents a review of literature on the contribution of manure use on soil fertility to increase food production and improve the food security situation of smallholders. The descriptive characteristics of participating farmers are presented in chapter three. The fourth chapter describes the methodology used to collect data and analyse data. The results and discussions are presented in chapter five. Finally, a summary of results, conclusions and recommendations is presented in chapter six.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Introduction

Smallholder agricultural production in sub-Saharan Africa is threatened by declining soil fertility (Scoones & Toulmin, 1999). Population growth, increasing land scarcity and inappropriate land-use practices are seen as the main contributing factors to reduced soil fertility (Scoones & Toulmin, 1999). Soils are subject to continuous and intensive cultivation by smallholders with nutrient withdrawal rates exceeding nutrient inputs, threatening the sustainability of farming systems (Mkhabela, 2006). Addressing declining soil fertility calls for adoption of an all-encompassing strategy to manage soil fertility in efficient ways and to develop practical, appropriate technologies for farmers in specific and yet diverse settings (Altieri *et al.,* 1997).

Manure has been used for centuries as a fertiliser, as it is rich in nitrogen and other nutrients that facilitate plant growth (Johannsen *et al.*, 2005). Fertilisation with manure is appropriate for smallholders, who typically have mixed livestock and crop systems (Mkhabela, 2006). A number of studies (van Averebeke & Yoganathan, 2003; Mkahabela, 2006; Prudencio, 1993) have validated the value of manure as a means of enhancing soil fertility. Cattle and chicken manure have been shown to improve soil conditions, increasing the pH, water-holding capacity, hydraulic conductivity and infiltration rate and decreasing the bulk soil density (Lungu *et al.,* 1993). Structural deterioration of soils can be reversed with the application of organic matter from manure. Soil fertility can be restored with organic matter as microbes in the manure metabolise the organic matter, turning it into humus. This process replenishes and maintains long term soil fertility by providing optimal conditions for beneficial soil biological activity (Lungu *et al.*, 1993).

There is a need for research to improvement soil fertility within the broader framework of rural livelihoods and to identify development initiatives. This is needed because manure could contribute to improved soil fertility, increasing food production and contributing to food security among smallholders. Therefore, choice of intervention options and the design of strategies for improved production need to take cognisance of the factors and resources (e.g. status of natural resource such as soil and social capital such as farmer networks that promote better learning and sharing of ideas). This will provide livelihood options and trade-offs that directly or indirectly influence soil fertility management (Pretty & Buck, 2002). Human resources (e.g. level of farmer knowledge and skills) and physical resources (e.g. transport, shelter and communication) are also important to ensure that soil fertility levels are improved. Before any attempt is made to design new strategies of soil fertility management, there is a need for an inventory to evaluate existing resources and options that impact on agricultural productivity and soil fertility management in general. Human resource capacity problems and limited knowledge and skills of soil fertility management can impact negatively on soil fertility improvement efforts.

This literature review presents a body of information relating to issues of manure use by smallholders, which will aim to investigate soil fertility determinants and what options are available for smallholders to improve soil quality.

2.2. Soil fertility

Soil is not only the major natural resource on which human beings depend for production of food, feed, fibre, renewable energy and raw material, but also plays a key role in maintaining complex terrestrial ecosystems and climate systems (Chen *et al.*, 2002). Recent rapid increases in the human population are placing considerable strain on the world's resources. Intensive agricultural activity and land overuse has led to soil degradation through water and wind erosion; chemical and physical degradation and deterioration of biological activity (Scherr, 1999). Soil degradation is significantly increasing the challenge to feed a growing population due to diminishing land area of declining quality, resulting in food insecurity.

Soil fertility degradation has been described as the single most important constraint to food security in Africa (Tropical Soil Biology and Fertility Programme, 2002). Depletion of soil fertility, particularly of nitrogen, phosphorus and potassium over the last 30 years

(Sanchez *et al.,* 1997) has been a major cause of low per capita food production in Africa (Pinstrup-Anderson, 1994). Over decades, smallholders have mined large quantities of nutrients from their soils without replenishment with manure, compost and fertiliser. Unsustainable land practices contribute to massive erosion and deforestation. The urgency to restore soil fertility in Africa stems from the fact that more than three-quarters of the farmland in sub-Saharan Africa has been depleted of basic nutrients, reducing crop yields and food security (Tropical Soil Biology and Fertility Programme, 2002). Soils which are low in organic matter and have poor water holding capacity. Until these conditions are reversed, food production in Africa will remain inadequate to feed its growing population. The present soil fertility problems affect future production prospects (Bekele, 2003).

South Africa is dominated by shallow soils with extremely delicate structures that lack resilience compared to soils in temperate areas due to South Africa's thin, vulnerable and unstable mantle (Mills & Fey, 2003). This is a result of a combination of hard rock parent materials and very low, inefficient rainfall that limits soil formation. Large parts of the country are covered by sandy soils, with severe inherent limitations. In most parts of the country with between 500 and 700 mm annual rainfall, where crop production could theoretically be important, poor quality, unstable soils prohibit this. The poor quality of these soils is due to the influence of the parent materials from which they formed (Laker, undated). Ongoing policy measures to control erosion in many parts of the country began in 1923. One aspect that stands out in the policy is the conservation and replenishment of nitrogen to maintain soil fertility (Laker, undated). However, decades of discrimination against smallholders during the apartheid regime, resulted in smallholders being extremely neglected by policy and extension services (Mkhabela & Materechera, 2003). Until recently, national agricultural programmes and policies were largely oriented to large scale commercial sectors (Mkhabela, 2003; Aliber *et al.,* 2006). However, since 1994 there has been an attempt to re-orient agricultural policies to accommodate smallholders in the rural and peri-urban areas of South Africa (Mkhabela, 2003).

The shift of emphasis to smallholder agriculture by government has resulted in a marked surge in the numbers of emergent farmers without secure access to land for residential and agricultural purposes (Amin & van Schalwyk, 1996). Most are part-time farmers who produce mainly for subsistence and sell produce when there is a surplus (Ngqangwenil *et al.,* 1999). In South Africa, as is the case in many developing countries, smallholders represent a very large proportion of the country's population and have the potential to become important contributors to household and national food security (Fertiliser Society of South Africa, 1997). Therefore, rectifying land degradation and enhancing productivity through soil fertility management and conservation could play a major role in achieving food security.

Soil fertility problems among smallholder farming in KwaZulu-Natal are common (Mkhabela, 2006). Most soils in the midlands of KwaZulu-Natal are weathered and inherently deficient in plant nutrients and organic matter (Farina & Channon, 1991). These deficiencies inevitably affect the yield and productivity of soils. Seventy five percent of the approximately 1.6 million people in the KwaZulu-Natal midlands are engaged in agriculture, which could have a negative impact on soil quality due to intensive agricultural practices (Mkhabela & Materechera, 2003).

According to Manson (1996), there is adequate manure in the midlands to increase soil fertility for sustainable food production as there are many intensive and commercial poultry and feedlot units that have increased in the area. Although the general perception among the people in the area is that manure is beneficial for soil fertility, experience has shown that the use of manure by farmers is relatively limited (Letty *et al*., 1999). The limited manure use may be attributed to resource constraints such as lack of transportation and labour (Miles & Manson, 2005). Furthermore, farmers are less inclined to use manure in their fields due to the lack of training and sufficient information on manure use and management. However, smallholders are knowledgeable about their own situations, their resources, what works and what does not work, and how one change impacts other parts of their system. The need for action and collaborative efforts of stakeholders such as government, non-governmental organisations and initiatives emphasising agricultural development, particularly in areas of soil fertility is paramount to ensuring sustainable food production and increased food security.

2.3 Synthetic fertiliser versus manure

Most commonly commercial fertilisers add nutrients to soil, without anything else. Plants needs more than just nutrients to survive. They also need organic matter and living organisms for physical, chemical and biological processes. Many of these functions interact. For example, the high cation exchange properties of organic matter are a major means by which organic matter is able to bind soil particles together in a more stable structure.

Alternatives to the use of commercial fertilisers exist. One alternative is animal manure. According to van Averbeke & Yoganathan (2003), before the introduction of commercial fertilisers, farmers all over the world, including those in South Africa, made use of manure to restore soil fertility of their lands. Commercial fertilisers do not fully support microbiological life in soil. The application of a commercial fertiliser kills a significant percentage of beneficial microorganisms. The wrong application of a commercial fertiliser kills a significant percentage of beneficial microorganisms. These tiny creatures are responsible for breaking down organic matter into a stable amendment for improving soil quality and fertility. Some even convert nitrogen from the air into a plant useable form (Fertilizer Society of South Africa, 1997).

The constraint faced by smallholders are well documented. They include transport, finance to buy commercial fertiliser and technology. Synthetic fertilisers are bulky and heavy which increase the cost of transport. Getting these from town to village or farm is cumbersome incurring transport costs for resource-poor farmers. Commercial fertilisers are also too expensive for many smallholder farmers. However, manure is also bulky and would require extra transportation if fetched from far.

Due to inadequate availability and competing uses for fodder and fuel, organic fertilisers such as manure often need to be supplemented with synthetic fertilisers to sustain the levels of productivity and production required to feed Africa's rapidly growing population. Improving soil productivity in Africa will, therefore, require the increased use of commercial fertilisers. A study conducted in Zimbabwe investigating the profitability of manure use on maize in the smallholder sector indicated that the use of manure with smaller quantities of commercial mineral fertilisers offers much larger productivity gains compared to using synthetic fertilisers alone or manure alone (Mutiro & Murwira, undated). The study further concluded that a combination of commercial fertilisers and manure generally resulted in better yields. Furthermore, it was indicated that the application of commercial fertiliser with manure can reduce the risk of economic losses and increase the probability of higher financial returns that could trigger rural and national economic development, achieving long term food security and improve smallholder's standard of living, while mitigating environmental degradation. The economic contribution of farm manures can be considerable due to the benefit of soil–organic matter build-up, resulting in enhanced soils structure, better diversity and activity of soil organisms (Magdoff & van Es, 2000). The quantity of manure available on large farms is usually inefficient to fertilize all the land that is being cultivated. However, when cropping a small area, the available supply of manure may be adequate and the work involved with transporting manure to the lands may be feasible.

Most KwaZulu-Natal soils are very deficient in phosphorus. Large amounts of phosphorus fertiliser are often necessary for satisfactory yields and most large-scale farmers use synthetic fertilisers (Magdoff & van Es, 2000).

Mkhabela (2006) also found that 69% of farmers who used manure to manage soil fertility indicated improved soil conditions, crop growth and yields after applying manure. The findings also found that plants looked healthier, and produced higher yields than those without manure. Mkhabela’s study showed that manure could be used to manage soil fertility and ensure sustainable food production and increased food security. The following section will discuss manure in more detail, as the study focus is investigating the contribution of manure to soil quality.

2.4 Soil fertility improvement methods used by smallholders

Soil fertility improvement technologies (including manuring, composting, intercropping and vermin composting) are being promoted by governments in order to improve agricultural sustainability and livelihood security (Akinnifesi & Kwesinga, 2002). Manure has long been recognised as a soil "builder" because of its contributions to improving soil quality (Magdoff & van Es, 2000). With food shortages looming and soil quality declining rapidly, techniques for effective manure use are needed to make farming more productive and sustainable to achieve food security. Environmental benefits are possible from manure application if recommended rates are applied and timing and replenishment follows best management practices. Magdoff & van Es (2000) state that: "manure properly applied to land has the potential to provide environmental benefits such as reduced soil erosion; reduced leaching and increased soil carbon". If properly handled, manure can serve as a valuable renewable source of nutrients. Therefore, if properly applied, manure could increase soil fertility thereby rectifying land degradation, and enhancing food productivity. In America, manure is one of the most important plant foods used by organic farmers (Walz, 2004).

In the past, the use of manure was widely practiced in Asia in irrigated rice, but interest in its use has declined in the last few decades with increases in cropping intensity and readily available synthetic fertilisers. With energy shortages, rising fertiliser costs, deterioration in soil health and environmental concerns, the use of manure has again become important (Yaduvanshi, 2002). Manures are vital resources not only for supplying plant nutrients, but also for replenishing organic matter and increasing soil fertility.

High potential arable lands in the highlands of east and central Africa provide sustainance to millions of households, cultivating farms of less than one hectare (Lekasi *et al*., 2001). With high population densities, more than 800 persons/km^2 in some areas, and a corresponding high demand for food, soils are now subject to continuous and intensive cultivation. Soil fertility status has been declining in a number of areas, presenting a serious threat to food security (Lekasi *et al*., 2001). Studies in Malawi have shown that livestock ownership, besides the obvious role of producing milk for home consumption and sale, is highly valued for the production of manure (MOFFEA, 1998). Livestock ownership is important for smallholders in Africa and South Africa where the purchases of commercial fertilisers are extremely limited because of cost (Lekasi *et al.*, 2001). The search for sustainable soil fertility replenishment techniques is therefore an urgent need. One of the key resources in this respect is animal manure.

Studies have indicated that the application of manure improved crop yields and soil fertility which may be are equivalent or superior to those attainable with synthetic fertilisers (Singh *et al.*, 1988; Hue & Amein, 1989). If manures are managed properly, they can save farmers money and be an environmentally safe means of waste disposal (Harris, 2001). Application rates could be devised to provide enough but not excessive nutrients for growing a crop and increasing soil fertility. The timing of manure application is important, as it affects the availability of nutrients required at various plant growth stages (Magdoff *et al*., 2000). Nutrient from manure are available after three months. Therefore, this should be timed with planting season due to a decomposition process that must take place to be available in the required organic form.

Manure is organic material consisting of the residues of plants digested by animals. Keeping the animals in an enclosure (kraal) over night reduces the labour involved in collecting manure and provides protection against theft and wild animals. The excrement and livestock urine accumulate on the kraal floor, forming a layer of manure. Kraal manure is often good quality, relatively cheap and easy to obtain, making it eminently accessible to smallholders. According to Mkhabela & Materechera (2003), a number of farmers regard the use of kraal manure as a practice that is tedious and introduces weeds. However, those that have applied manure properly realise that once properly applied, manure nourishes the soil for many years, reducing the need for commercial fertiliser application.

2.4.1 Composting to increase soil fertility

Composting is a traditional practice for the improvement of soil fertility and structure that allows farmers to enhance and make better use of available resources In addition, composting is controlled decomposition, the natural breakdown process of organic residues (Smith & Hughes, 2001). Composting transforms raw organic waste materials such as animal manure into biologically stable, humic substances that make excellent soil amendments. Compost is easier to handle than manure and other raw organic materials, stores well and is odour-free (Rynk, 1992). Composting is an ancient technology, practised today at every scale from the backyard compost pile to large commercial operations. There are Roman and biblical references to composting (Cooperband, 2002). Farmers have been aware for centuries of its impact on crop yields, soil structure and fertility, crop growth and vigour (Diop, 1999; Onduru *et al.*, 1999). Composting animal manures can also be a solution to manure management on the farm. Most importantly, the final product is a valuable soil resource. Compost can replace materials like peat and topsoil as seed starters, container mixes, soil amendments, mulches and natural fertilisers in commercial greenhouse production, farms, landscaping, turf and land remediation (Cooperband, 2002).

Compost is affordable and easy to make. For example, maize stalks and other biodegradable substances that are found in great abundance by smallholders can be used to make compost. The use of compost can help soils retain water and nutrients and is hence, an alternative to commercial fertilisers. The most common practice for composting involves the use of pits, which are dug at 1 meter deep and 1.5 meters in width (Figure 2.1). Composting material, including crop residue, dry leaves and manure is moistened and left in a pit for varying lengths of time to allow for decomposition. Composting times vary from three to six months before the compost is mature and ready to use. Factors that could influence the varying time are temperature, water, decomposition level of microorganism and type of organic material. However, farmers are reluctant to wait for long periods before they can use the compost.

Figure 2.1: Manure beds where thousands of earthworms are quietly toiling to turn ordinary manure into high quality compost (Agrelek, undated).

Another example of composting that appears to be increasing is vermi-composting. Vermi-composting or worm composting is different to traditional composting in that it is a process that uses red earthworms (also commonly called redworms). These redworms consume organic waste, producing an odour-free compost product casting for use as mulch, soil conditioner and as topsoil additive (Tripp, 2006). One worm weighs approximately 0.5g to 0.6 g, eats waste equivalent to its own body weight per day and produces casts of the same weight per day. It is estimated that 1000 tonnes of moist organic matter can be converted by earthworms into 300 tonnes of compost (Butterworth *et al.,* 2003). The casts of earthworms are rich in nutrients such as nitrogen, phosphorous, potassium, calcium and magnesium, and also in bacterial and actinomycete population. The production of vermin-composting is becoming a popular activity for non-governmental organisations (NGOs) in India and elsewhere (Butterworth *et al.*, 2003).

In South Africa, vermi-composting is practised in areas such as Potchefstroom where worms are introduced into horse and cattle manure for organic compost. This has led to a lucrative composting business (Agrelek, undated). The advantages of and disadvantages are shown in table 2.1. To construct composting beds with sides it is preferable to use bricks or concrete to contain the worms. The bed is filled with layers of leaves, decomposed manure and other organic matter with the finer material near the top. The bed may be covered with plastic or banana leaves. Once the worms are introduced, the bed must be watered carefully and the worms must be protected from various predators. Organic matter is periodically added to the bed and the vermi-compost is ready within three to six months (Tripp, 2006).

To make the compost, the manure is spread in special beds in layers of 20cm. Then the earthworms are added. One requires approximately 1000 worms for each cubic metre of compost. To create the ideal conditions for breeding and processing, the manure must have a moisture level of between 60-70% (Agrelek, undated).

Table 2.1: Advantages and disadvantages of vermi-composting (Mukhtar, 2003)

Advantages	Disadvantages and constraints
Improved yield and better quality produce that keeps well	Some hard work is needed to make and harvest beds
No weeding problems	Requires careful management
Improved moisture retention	Worms need care, food, heat and moisture
Expenditure savings on synthetic fertilisers, and reduced dependence on others for money to buy synthetic fertilisers	Requires lime to stabilize pH (acidity)
Waste is utilized productively	

Composting has received relatively little attention in low-input agriculture projects (Watson *et al.*, 2006). This may be attributed to its association with former top-down extension approaches and little attention by researchers (Tripp, 2006). Much of the available literature tends to be written from a purely developed world, technical perspective (Tripp, 2006). Little consideration has been given to the benefits and constraints of promoting manure use in smallholder agriculture.

One of the major problems associated with compost and manure use is high labour requirements (Onduru *et al*., 1999), particularly for women undertaking some of the heavier tasks involved in composting, such as preparing compost pits (Diop, 1999). For example, Briggs & Twomlow (2002) found that poor households in Uganda did not make compost at all because of the labour and time requirements. Transporting and moving biomass (waste plant and animal material) and compost is also problematic, particularly considering that resource–poor smallholder farmers require relatively large amounts to make a difference to their farming operations. Composting may sometimes be constrained by a lack of water (Apiradee, 1988; Diop, 1999), which is needed for decomposition, and, a lack of tools can also place constraints on production (Ouedraogo *et a*l., 2001).

Prior to planting or sowing crops, crop residues are often removed from fields and community gardens and thrown away, further depleting the soil nutrients and organic matter. However, large quantities of biomass are required for composting. Obtaining this biomass is problematic for small farmers, especially where there are competing demands for resources such as for mulching, fuel and/or fodder (Onduru *et al.*, 1999). Nevertheless, some production systems are capable of producing relatively large quantities of biomass. Briggs & Twomlow (2002) found that smallholders in Uganda produced 40kg of fresh organic waste per day, 25% of which was used to make compost, with the rest either fed directly to livestock or applied directly to household plots.

An example of the use of compost in small-scale agriculture is provided by extensive work done by the Rodale Institute, which has been working with farmers in the Peanut Basin region of Senegal since 1987 in an attempt to mitigate the rising costs of fertiliser due to the removal of subsidies in Senegal (Diop, 1999). Composting is not a new technique in Senegal, so research has focused on attempting to improve existing techniques involved in its production and use. Farmers are encouraged to collect crop residues for compost making rather than burning them and to incorporate the resulting compost in the soil rather than leaving it on the surface. This method of producing compost requires that the compost be turned every 15 days, and the product is ready within 45 days. Pit composting is also being developed in project areas. These pits are about one meter deep, lined with cement and bricks, and covered to prevent contamination from wind-blown sand. This method does not require turning and rainfall in the wet seasons helps the degradation processes. However, during the dry months, water is added manually when the compost humidity drops below a certain level. Yield of groundnuts and millet have tripled through the application of two tones of compost per hectare (Diop, 1999).

In India, manure composting is widely practised. In any village in dry-land India, one cannot fail to spot rows of heaps along the roadside, in the backyards of houses and in specially enclosed 'kallam' or compost yards (Butterworth, 2003). Composting has been increasingly recognised as an economical alternative for livestock waste management in Hong Kong (Wong *et al.*, 1999) and increased livestock production has led to an increase in the use of compost for organic farming.

Composting is not commonly practiced in many South African rural communities although there is a great need to increase food production and focus on soil conservation. However, considered by many smallholders to be a complicated process that requires specific machinery and is very labour intensive (Smith & Hughes, 2002). It is therefore necessary to demonstrate that compost of high quality can be produced with minimal requirements in terms of mechanisation and labour for this practice to be successfully integrated into production systems (Smith & Hughes, 2002).

Composting is likely to provide only a partial solution to the problem of declining soil fertility and poor soil structure in small-scale agriculture, but should be an important component in the options a farmer could apply to improve production.

2.5. Manure use among smallholders

In developing countries, increasing prices of synthetic fertilisers, coupled with growing concerns for sustaining soil productivity have led to a renewed interest in the use of manure for soil fertility (Sankaram, 1996). Manure is a vital resource for supplying plant nutrients and replenishing the organic matter content of most agricultural soils, particularly in the tropics. Generally, smallholders use resources that are easily available at farm level as farm inputs. These resources include green manure, farm yard manure and compost (Kihanda & Gichuru, 1999).

Studies have shown that large herd sizes can influence manure use (MOFFEA, 1998). However, farmers with few animals may be less willing to use manure, especially if their farm size is large and/or if labour availability for collection and spreading of manure is limited (Williams, 1999). Mkhabela & Materechera (2003) found that land tenure also influences the use of manure by smallholder farmers. Land tenure and the nature of this access influences investment in soil fertility improvement and maintenance. Due to apartheid laws, which existed in South Africa before 1994, many black smallholders did not have secure access to productive land for farming, cultivating communal land without title deeds. Land under communal ownership is held in trust by traditional leaders for the community and allocated by the chief (van Rooyen & Nene, 1997). Research has shown that farmers who cultivate both borrowed (leased) and owned fields consistently divert manure towards the latter (Gavian & Fafchamps, 1996).

A study conducted by Mkhabela & Materechera (2003) in the KwaZulu-Natal Midlands identified problems associated with manure use. The major problems faced by respondents/farmers with regard to utilisation of manure were mostly technical. For example, rate of application and the offensive smell were cited. Another problem identified was the bulkiness of manure, implying increased transportation costs and the growth of weeds after application. A study conducted in the Vhembe district of Limpopo South Africa, indicated that transportation was the main constraint regarding manure use, as a result impacting on the quantity of manure applied would be very low (Odhiambo & Magandini, 2008).

Mkhabela & Materechera (2003) reported that farmers claim that manure, especially kraal manure from cattle that graze on communal land encourages weeds and diseases. The amount of manure available is controlled by the number of livestock and fodder resources (Williams, 1999). However, at household level, this will depend on socio-economic factors such as resources and assets, for example, livestock holdings.

Farmers in sub-Saharan Africa often complain of a shortage of organic material for composting and manuring, exacerbated by the shortage of fodder for livestock (Turner, 1995). In terms of fodder, these resources are dependent upon rainfall, which is extremely variable over a season. Shortages of manure are aggravated by drought cycles, which affect productivity and herd numbers (Williams, 1999). Smallholder farmers are resource poor and cannot afford costly fertilizers, as a result, they turn to manure. Smallholder farmers often face problems such as lack of sufficient knowledge of handling and storage of manure. In addition, due to the limited number of animals kept by smallholder farmers, the amount of manure produced is never sufficient.

2.5.1 Manure quantity

Several researchers have calculated the amount of manure required to replace the nutrients removed from fields by cropping, and have tried to calculate the number of livestock required to produce this and the rangeland required to feed the animals (Turner, 1995). The general conclusion is that cropping intensity and extent compete for available land for grazing animals to produce manure. The rangeland to cropland ratio depends on rangeland productivity (Harris, 2001). When the ratio falls below the threshold, farmers can no longer rely on manure supplies to replenish soil nutrient losses. Pilbeam *et al.,* (1999) illustrate the previous point further. For example, a household with one hectare of agricultural land in the mid-hills of Nepal, requires 1.8 tonnes of feed per year per live weight beast of 250kg. To balance soil organic matter losses, this would mean that one and a half cows are required per hectare in semi-arid regions (assuming that nearly 100% of the consumed biomass passes through the animals (Lekasi *et al.*, 2001). A study conducted by (Thamaga-Chitja, 2008) showed the current rate of manure application by the Mbumbulu farmers (EFO) was 8998.716 kg/ha or 120 wheelbarrow loads per hectare per annum. In contrast, one needed comparatively less commercial fertiliser to produce one ton of a crop. For example, 3.34kg of N is required to produce one ton of cabbage compared to 334 wheelbarrow loads of manure per hectare (Thamaga-Chitja, 2008). The study found that organic production based on manure as the source of nutrients would be difficult to maintain and crops would perform poorly. The study also found, the least number of wheelbarrow loads required to grow crops on the predetermined list was 29 wheelbarrows per hectare. The farmers suggested that even this relatively low number of wheelbarrow loads would be difficult to obtain due to limited animal livestock. Manure produced from one cow amounts to only 7.92 wheelbarrow loads per annum (USDA, 1996). Evidently, it was not possible for the farmers to have an adequate load of manure given their current livestock level because the mean wheelbarrow loads were low.

Such biomass requirements are rough guides, but serve to show that the quantity of animal manure needed to maintain soil physical characteristics and nutrient levels effectively are high. In most cases, it is unlikely that resource-poor or smallholder farmers would have access to on-farm sources of manure in sufficient quantities to supply the total requirements of their cropped land, particularly as there are competing demands for its use, such as for building material or fuel. In such cases, reliable access to off-farm land for fodder collection will be a major requirement for the use of animal manure. Several authors argue that there is never enough manure available to maintain soil fertility (de Ridder & van Keulen, 1990).

Although it could be assumed that expansion of cropping would result in a reduction in livestock numbers due to diminished rangelands, several researchers in West Africa have shown that livestock numbers do not decrease in intensively farmed areas, and may even increase (de Leeuw *et al.*, 1995). As farmers integrate crop and livestock production systems and use crop residue to feed livestock, the number of small ruminants increases relative to the number of cattle. In areas such as Kano, a close-settled zone in Nigeria, and the Kisii district in Kenya, there is no rangeland or fallow land, yet farmers still obtain manure from livestock (Harris, 2002). In these regions, an integrated crop-livestock farming system where farmers rely on crop residues to provide fodder for livestock is prevalent. Livestock may also graze on crop residues in fields during dry seasons.

Therefore, the quantity of biomass available to smallholder farmers, either from plant or animal manure, is likely to constrain the degree to which soil fertility can be maintained or even improved through the use of manure.

2.5.2 Manure quality

Manure quality can be simply defined as the value of manure in improving soil properties and enhancing crop yields. Scientists have used laboratory analysis for nutrient content. The perception has been that the higher the nutrient levels, the better the manure quality. More recently, the use of nutrient release patterns has been considered a better measure of manure quality following laboratory incubations of manure and investigations into how nutrient release is synchronised with crop uptake (Kimani & Lekasi, undated). Farmers have traditionally used their own yardsticks to determine manure quality (such as dark manure suggests better quality) (Mkhabela, 2006). The challenge is, therefore, to match the scientific facts and farmer perceptions for simple decision making tools for defining manure quality without expensive laboratory analysis.

Table 2.2 Nutrient content of farmyard manure sample (Kihnada & Gichuru, 1999)

Nutrient content (%) of farmyard manure sample					
Country	**Nitrogen**	**Phosphorous**	**Potassium**	**Calcium**	**Magnesium**
United Kingdom	1.76	0.24	1.29	0.74	0.34
Kenya	0.20-2.2	0.08-0.95	1.34	0.26	0.26
Zimbabwe	0.80	0.20	0.85	0.25	0.15
Madagascar	1.10	0.80	0.86	0.85	0.40

An example of laboratory analysis for manure quality determination is given in Table 2.2. While the values given are means, the range is quite variable and wide. For instance, nitrogen (N) content for cattle manure from Kenya ranges from 0.20 to 2.2%, while phosphorous (P) content ranged from 0.08 to 0.95%.

Farmers in central Kenya use texture, longevity of composting, homogeneity and the presence of fungal spores/hyphae as some of the quality characteristics for manure (Lekasi *et al.,* 2001; Wanjekeche *et al.*, 1999). In Ethiopia's Tigray region, farmers distinguish between two types of manure, the 'husse' and 'aleba', based on the degree of decomposition. The 'husse' is well-decomposed and rich in plant nutrients while 'aleba' is less decomposed and has fewer nutrients (Kihanda & Gichuru, 1999). Table 2.3 shows indicators of manure quality as determined by farmers in West Pokot district, Northern Kenya.

Table 2.3: **Indicators of good quality manures used by farmers in Cheptuya village, West Pokot district, northern Kenya** (Wanjekeche *et a*l., 1999)

Indicator	**Frequency of farmers**
Fine soil-like texture	10
Black-grey colour	12
Longer time of composing	3
Appearance of white caterpillars	5
Lack of heat in the manure	2

Studies conducted indicate that the variations in chemical composition of cattle manure are large, influenced by a number of factors such as the quality of feed, age of the animal, storage conditions, treatment and handling conditions (Murwira *et al*., 1993). For example, in the KwaZulu-Natal Midlands region, a study conducted by Mkhabela & Materechers (2003) found that manure quality was affected by herd management. Cattle that were pen-fed with crop residue in the kraal, may produce manure of higher quality than those that relied on extensive grazing of poor quality. This could be attributed to the difference in management of cattle such as feed is often of better quality and can be monitored, also the method by which manure is stored and treated may also affect its composition and value.

2.6 Manure management by smallholders

The last 50 years have seen a rapid expansion of cultivated area under production in semi-arid areas of Africa. This has precipitated a change from traditional fallowing to more pro-active soil fertility management techniques (Harris, 2001). Manure management relates to the appropriate use of animal manure according to each farm's capabilities and goals to enhance soil quality, crop nutrition and farm profits (Nowak *et al*., 1998). Manure management requires decision making to maximize profitable agricultural production with minimal nutrient losses through careful combination of faeces, feed waste and urine (Brandjes *et al*., 1996). Extensive surveys of management and quality on farms in central Kenya indicated that the quality of manure produced on many of the farms was poor (Onduru *et al*., 1999). When the study included maize trials, manure produced by local farmers gave a grain yield of only 2.3 tonnes per hectare - little more than half that obtained from the same nutrient application of well managed manure. It was therefore, concluded that the maize production doubled through careful management of manure on many small farms in the area.

2.6.1 Manure collection and storage

The management of manure is extremely important to ensuring quality, as storage methods affect nutrient content. Muwira *et al.* (1995) maintain that the greatest nutrient losses occur prior to application of dung and manure, when urine is lost, or during anaerobic decomposition of dung and manure.

A limitation of manure collection and storage is that it encourages loss of nitrogen, mainly through volatilisation where evaporation occurs. Harris (2001) working with smallholder farmers in Kenya, found that there were substantial losses of nutrients from cattle dung through leaching, volatilisation of ammonia and de-nitrification from manure and dung. Kwakye (1980) found that in Ghana, up to 59% of nitrogen was lost after a storage period of three months.

In the South African context, the manure gathered by smallholder farmers is mostly stored under aerobic conditions where manure decomposition takes place only in the presence of oxygen. In KwaZulu-Natal, manure is typically spread on the fields during the dry season (Mkhabela, 2003). In extensive systems where animals graze freely, manuring occurs *in situ* as the animals graze. The conventional way of storage involves digging manure out of the kraal and heaping it beside the kraal for three months (Mutiro & Murwira, undated). Where animals are housed overnight in a kraal, the manure usually comprises of feaces only. The dung is heaped beside the kraal throughout the year. This system is common among smallholders in Kenya and some parts of South Africa (Harris, 2001). Lekasi *et al.,* (2001) found that larger farms stored manure for longer, allowing for better maturity before application. In Zimbabwe, most smallholder farmers store their manure for at least three months before application in the field. In the Kenyan highlands smallholders store manure in heaps and pits. Smallholders also cover their manure to speed decomposition, conserve nutrients (Lekasi *et al*., 2001) and loss of moisture (Table 2.4). Storage periods are short on small farms but longer on larger farms. This may indicate the intensity of manure use on small farms but could also be a factor of limited storage and or proximity to land requiring manure on small farms.

Table 2.4: Manure storage practices in the Kenya Highlands (Lekasi *et al*., 2001)

	Why do you cover manure?				**How long do you store? (months)**		
Farm size	Speed de-composition	Conserve/ improve Nutrient status	Stop evaporation of moisture	Prevent excessive wetting	0-2	3-6	>6
Small	60	36	28	7	65	1	-
Medium	55	-	-	-	67	33	-
Large	33	33	52	24	20	50	30

2.6.2 Manure application

Most farmers believe that manure affects soil physical and chemical properties for more than only the season in which it is applied (Harris & Yusuf, 2001). Nutrients from manure help build and maintain soil fertility. Manure can also improve soil tilth, which is the state of aggregation of soil and its condition for supporting plant growth, increase water-holding capacity, lower wind and water erosion, improve aeration, and promote the activity of beneficial organisms.

Mkhabela & Materechera, (2003) state that in order to adequately replenish the annual removal of plant nutrients from the soil by crops, manure has to be applied at adequate rates and frequency. The rates of manure application observed in a study conducted in the midlands area of KwaZulu-Natal ranged from 2 to 100 tonnes per hectare (mean = 7.5 t/ha) for most crops such as maize, potatoes and vegetables across in study area (Mkhabela & Materechera, 2003). The frequencies of manure application in the study area were annual (51%), biannual (35%), once every three to five years (28%) and cycle longer than 5 years (19%). Farmers reported that there were no guidelines available with regard to the use and management of manure.

Studies of nitrogen (N) and phosphorous (P) mineralisation in soil are useful because they help develop efficient manure management practices. To quantify the residual effects of organic inputs in the soil, the quantitative contribution of manure to soil nitrogen (N) and the interaction between soil nitrogen (N) and manure needs to be known (Murwira *et al.*, 1995). In animal manure management, phosphorus (P) is the nutrient of major concern in soils with low phosphorus levels. Frequent application of manure and other organic inputs can satisfy or exceed crops nitrogen needs. Excessive application of phosphorus affects soil fertility. Although phosphorus (P) is essential for plant growth, mismanagement of soil phosphorus (P) can pose a threat to water quality. Figure 2.2 illustrates the phosphorus cycle in soils.

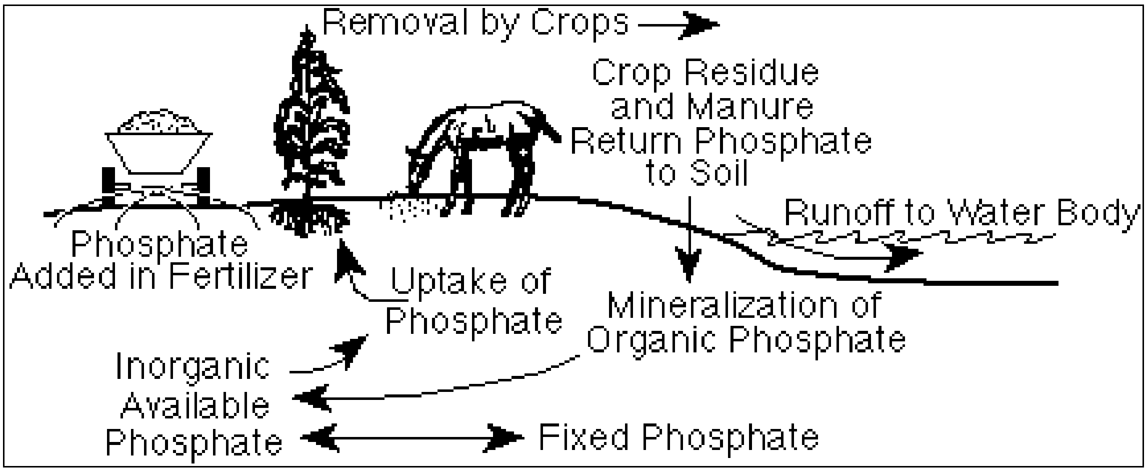

Figure 2.2: The phosphorus cycle (Busman *et al.,* 2002).

Phosphate is taken up by plants from soils, utilised by animals that consume plants, and returned to soils as organic residues (Figure 2.2). Much of the phosphate metabolised by living organisms becomes incorporated into organic compounds. When plant materials are returned to the soil, this organic phosphate will slowly be released as inorganic phosphate or be incorporated into more stable organic materials and become part of the soil organic matter. The release of inorganic phosphate from organic phosphates is called mineralisation and is caused by micro-organisms breaking down organic compounds. The activity of micro-organisms is highly influenced by soil temperature and soil moisture. The process is most rapid when soils are warm and moist but well drained. Phosphate can potentially be lost through soil erosion and, to a lesser extent, to water running over or through the soil (Lowell *et al*., 2002).

Phosphorus applied to fields as manure or synthetic fertiliser can move into bodies of water during erosion and run-off events, and is largely responsible for the accelerated eutrophication or depletion of oxygen in water sources. Phosphorous accumulates in soils and, if applied in quantities greater than those removed by crops, can result in pollution problems in water used for drinking, fisheries, recreation, and industrial uses.

To maximize the benefits of manure, it needs to be applied at the onset of rain. This time for manure application is ideal due to the manure's slow rate of nutrient release and also the improvement of synchrony with plant intake and minimisation losses through leaching (Singh *et al*., 1991).

Table 2.5: Application rates of kraal manure recommended for low and high target yields of some garden and field crops (van Averbeke & Yoganathan, 2003)

Crop	Target yield t/ha		Application rate of kraal manure wheelbarrows/ha
Maize and sorghum	Low	2	100
	High	5	200
Potatoes and cabbage	Low	30	300
	High	40	400
Peas	Low	2	150
	High	3	200
Dry beans	Low	1	100
	High	2	150
Cucurbits, beetroot and onion	Low	20	200
	High	30	300
Tomatoes	Low	30	225
	High	40	300
Spinach	Low	10	550
	High	15	850

Tables 2.5 and 2.6 illustrate recommended application rates for manure for frequently planted garden and field crops. Table 2.5 is most useful when one intends producing a

field crop and Table 2.6 is designed for use in home gardens. For each crop or group of crops, two target yields are presented, namely a low and a high yield target. Application rates of manure recommended for the low target yield should be used when farming in an area where the rainfall tends to be low and unreliable. When farming in areas with high rainfall, or when irrigation water is available, one should use the application rates of kraal manure recommended for high target yields

Table 2.6: Recommended area of land to be fertilized with one wheelbarrow load of kraal manure (van Averbeke & Yoganathan, 2003)

Crop	**Area to be fertilised with one wheelbarrow load of kraal manure (m^2)**	
	Low target yield	**High target yield**
Maize, sorghum and peas	100	50
Dry beans	30	60
Cucurbits, beetroot tomato and onion	50	30
Potato and cabbage	33	25
Spinach	15	10

To ensure that recommended application rates are effective, effective farmer technology adoption is needed (Magdoff & van Es, 2000). However, most studies conducted by researchers often deal with the adoption of external technologies (Becker *et al.*, 1995).

Technology characteristics play a role in influencing the diffusion process and farmers' decision making with regard to technology adoption (Vedeld & Krogh, 2001) and their resources and capability to manage technology. Therefore, the adoption potential, from a farmer's perspective can be considered to have three components namely feasibility, profitability and acceptability (Swinkles & Franzel, 1997). Using appropriate farmer technology could improve soil fertility and trigger rural development, achieving long-term food security and improved smallholder standard of living, while mitigating environmental degradation. The farmer should have the required information and resources to maintain the soil fertility improvement.

2.7 Training for smallholders to increase soil fertility

Farmers require soil fertility management training to improve their knowledge and capacity to observe and experiment, and is an extremely important element in technology adoption (Graves *et al.*, 2004). It is also important to build local systems of knowledge, relating to specific locations, based on experience and understanding of local conditions of production (Mkhabela & Materechera, 2003).

Farmers lack information about innovations (Rogers, 1995). A model such as decision making tool for determining suitable application rates for specific sites, based on soil condition, plant growth and climate for farmers should be made available through workshops to demonstrate how the tool works. .Sometimes agricultural innovations fail to generate expected benefits due to poor implementation, especially if farmers do not understand how the technology works. It is important that policies and technical support services by extension personnel encourage the use of available manure and other techniques for soil fertility management. For over a decade agriculture and as small farmers have been neglected. Governments should therefore invest in small farmers, in environmental programmes that focus on soil fertility and better ways to increase soil quality. The availability of personnel suitably trained in the appropriate techniques is essential for sustainable agricultural development and research to ensure long term soil fertility improvement for food production through training and information campaigns.

Manure will remain an important component of soil fertility management strategies for the foreseeable future. In order to improve farming in Africa and, more specifically, South Africa, farmers need to make the most of this resource. This chapter showed that manure can help farmers to improve their current soil management practices. Research has allowed for a better understanding of diverse conditions where soil fertility management options can help benefit the rural poor. Investment in farmer-centred soil fertility research is an integral part of rural development. The goal for future research is to create a system to empower farmers to sustainably manage their soils.

CHAPTER 3
STUDY BACKGROUND AND CHARACTERISTICS OF THE PARTICIPATING GROUPS

Farming forms an important part of livelihood strategies for most rural communities in South Africa (Delgado, 1999). Agriculture is promoted widely as a strategy to overcoming poverty and food insecurity in South Africa, and the KwaZulu-Natal province in particular (Hendriks, 2005). Moreover, organic production relies heavily on compost and manure for soil fertility and is promoted as a means of income generation among smallholders in the province (Vezi, 2005).

This chapter outlines the selection of the participating farmer groups, provides background information regarding the location and agro-ecological situation for each area and describes the groups' aims and member profiles.

3.1 Group selection

Historically, most smallholders in South Africa are found in rural areas with less favourable agricultural potential (Hendriks & Lyne, 2003). These groups of farmers are located in rural areas of South Africa, farm on less than two hectares of land and are often not engaged in the market. These areas often have harsh climates, poor soils and low rainfall. In addition, such smallholders are often resource poor. Unless they are beneficiaries of the smallholder irrigation schemes of the former homelands (Aliber *et al.*, 2006), smallholder farmers lack supplementary irrigation. Farming under such conditions makes it difficult for them to succeed (Thamaga-Chitja & Hendriks, 2008).

The groups included in this study needed to show an interest in the application of manure/compost in small scale production. It was deemed important to have three groups for comparison of practices. Three KwaZulu-Natal farmer groups located in Mkhambatini, Mooi River, and Richmond participated in the study. The three distinct agro-ecological zones had varying agricultural potential (Fig 3.1). In Table 3.1, a basic climatic comparison of the three areas is presented. The three groups operated at varying levels of organisational formalisation. The following section discusses the characteristics of the farmers and their geographical location.

3.2. Characteristics of the farmer groups and their location

Figure 3.1: Map of Umgungundlovu showing research sites of Mkhambatini, Mooi Mpofana and Richmond (University of KwaZulu-Natal Cartographic Unit, 2007).

3.2.1 Mooi River (Inyamvubu Co-operative)

Mpofana Municipality is located approximately 40 km west of Pietermaritzburg and falls within the uMgungundlovu District in the KwaZulu-Natal Midlands. It is bound by three municipalities, namely, uMngeni in the south, uMshwathi in the east, and Impendle in the west. The former Mooi River Transitional Local Council (TLC) area, with its immediate outer areas of Bruntville and Rosetta is a hub of economic, commercial and social activities. The peripheral areas included in Mpofana during the delimitation of new municipal boundary are rural (ward four) in nature and sparsely populated. The predominant land use is commercial agriculture. The Mpofana Municipal boundary covers an area of approximately 181 000 hectares.

Mpofana Municipality is a new entity of which large parts, especially the rural areas, are severely underdeveloped. In terms of the 2001 census data 52% of the population in Mpofana Municipal area is male. The Municipality has a population of 24 785, 45% of whom fall into the 0-19 age bracket, with a further 19% between 20-29 figure 3.2. The current employment rate is believed to be around 50%, raising concerns over prevalent poverty.

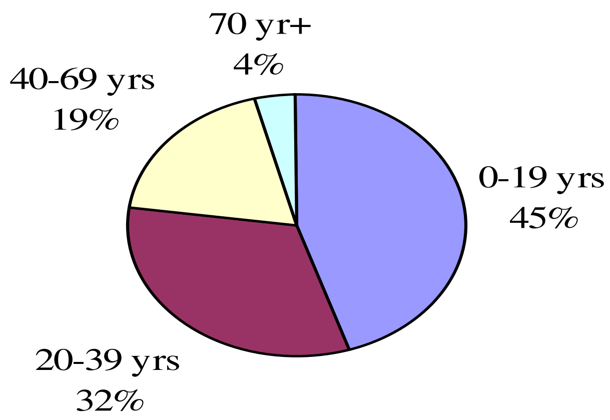

Figure 3.2: Age distribution in the Mpofana Municipality (Mpofana Integrated Development Plan Review Report 2007/2008).

Agriculture forms an important source of livelihood for the people of the Mpofana Municipality as the agricultural sector employs an average 4274 individuals (17 % of population) ranging from 15-65 years. More than 70% of the total population have not acquired matriculation certificates, while 20.8% of the population have no education at all (Mpofana IDP Review Report 2007/2008).

Table 3.1: Comparative climatic data for Mkhambatini, Mooi River and Richmond

Area	**Annual average rainfall (mm)**	**Mean minimum temperature (degree Celcius)**	**Mean maximum temperature (degree Celcius)**
Mkhambatini	956	18.6	24
Mooi River	706-838	17.2	20.8
Richmond	781-1017	14.2	27

The Inyamvubu Co-operative has been in existence since 2004 and operates as a community based cluster project. Since 2004, the cooperative received assistance from the owner of Burnwood farm. The initial assistance was with a craft center. During the latter part of 2003, the owner of Burnwood farm left the farm, leading to the establishment of a community trust to take care of the property, whereafter small-scale agricultural activity began. The group is comprised of 72 permanent members and six part-time members (12 males and 66 females). The average age of the group members was 45 years at the time of the study. The youngest member was 24 years and the oldest was 80. The majority of the women in the group are grandmothers with the responsibility of raising their grandchildren due to death of the children's parent/s. The grandmothers also acted as child minders for sons/daughters who had migrated to bigger towns in search of jobs to secure their livelihood and left their children in the rural area.

Thirty three percent of the group members (elderly) had low education levels, while most youngsters had formal education with a grade twelve certificate. Currently the members are actively involved in agriculture. Thirteen percent young members have attended training courses in agricultural practices at the Midlands College that was established by the KwaZulu-Natal Department of Agriculture and Land Affairs.

The co-operative also makes and sells crafts such as bead work/crafts, carved wood products, traditional thongs (*imbadada*), walking sticks, among others. The co-operative has a full-time manager who is responsible for the daily operation of the business, while other aspects of the business are shared by co-operative members. The manager reports directly to the co-operative committee, which consists of five office bearers and two additional members.

3.2.2 Richmond (Ingwe Family Co-operative)

The Richmond Municipality is located in the uMgungundlovu District Municipality in the KwaZulu-Natal Midlands. The northern boundary of the Municipality is located approximately ten kilometers from the N3 highway. The Mkomazi river represents the southern boundary. The Municipal centre, Richmond Village, is situated about 38 km south-west of Pietermaritzburg.

The Richmond Municipality had a population of approximately 62108 people during the time of the study, of whom 53% are female (Richmond Municipality IDP, 2007). Another significant socio-economic factor is that 47% of the inhabitants were between the ages of 0-19, and a further 20% between 20-29 in 2007. The implications for planning include pressure on the Municipality to provide more educational, recreational and social facilities.

The rate of unemployment in Richmond is 38% which means that for those employed, the ratio of dependency is eight people dependent on every earner (Richmond Municipality IDP, 2007). This situation also affects household incomes, with 77% of households subsisting on less than R1500 a month in 2007.

Economic development in Richmond is regarded as the potential driver of future growth. The Municipality is well situated on major routes to key development nodes of Durban and Pietermaritzburg, has high agricultural potential with the farming industry employing about 4996 people, and already has a number of manufacturing and production facilities, some of these catering for the export market.

Richmond has mild climate (14.2°c min-27°c max) with good soils and adequate rainfall at an average of 781-1017 mm annually (Richmond Municipality IDP, 2007). It is regarded as the fruit and vegetable basket of the province, as virtually all varieties of fruit and vegetable are grown in the area. The main agricultural activities are the cultivation of timber, sugarcane, tea, citrus, peaches, maize, market vegetables, dairy, poultry, pigs and cattle and game farming. At present, agricultural activity contributes more than 50% in terms of gross geographic product and employment to Richmond's economy (Richmond Municipality IDP, 2007). One of the objectives of the municipality is to establish an agricultural development programme aimed at providing support services both to establish emerging small farmers, and to integrate all farming activities.

The Ingwe Family Co-operative is situated in a community called Nhluzuka on the outskirts of Richmond (Figure 3.1). Ingwe Family group has been in existence since 2005. Initially the group started with three people with Mr Bheko Sithole heading the initiative. Mr Sithole donated the use of his land to the co-operative. Currently, the group consists of seven permanent members (two males and five females). Female members are featured in Figure 3.3. The group also has three school boys who assist with the gardens in the afternoons. The average group age of members ranged between 15-55 years. The women are wives, mothers and caregivers, who have given their skills and time to ensure the success of their co-operative.

Figure 3.3: Some of the members from Ingwe Family Co-operative, December 2007.

This group is characterised by low education levels. Three of the members have no formal education, while two have less than a grade nine education. The aim for Ingwe Family co-operative is to fight poverty and provide good food for the families so as to decrease dependency on family members employed in Richmond The current members have joined the co-operative due to the high levels of unemployment in the area.

Average rainfall in the Nhluzuka area of 781-1017mm is adequate for supplementary irrigation as illustrated in Figure 3.4. The farmers explained that rural smallholder activities are traditionally dominated by women. The group farms as a collective but members also have smaller homesteads units where they farm as individuals. The mixed production homestead unit is mainly for household consumption. The joint farms are for large-scale, commodity-based production and produce such as green pepper, cabbage green beans among others is sold at the Housewives Markets at the Bluff and Mkhondeni, while chillies are sold in Richmond. Most of the farms are on steep slopes making farming difficult and farmers are often only able to cultivate manually due to the steep slopes. Farmers are able to adjust their farm boundaries and this decision is mainly determined by the importance of the crop to be planted and quantity of seeds available given the current trend in the markets at the time (Mkhambathini Municipality IDP 2006/2007; Fischer 2005).

Figurer 3.4: Water harvesting and irrigation, December 2007.

3.2 3 Mkhbamthini (Umphumela Co-operative)

Mkhambathini local municipality lies between Ethekwini metropolitan and Pietermaritzburg (Mkhambathini local municipality Integrated Development Plan (IDP), 2003/2004). There are six tribal authorities within Mkhambathini municipality namely: Maphumalo, Manyavu, Ebmothimoni, Kwanyathi, Vumukwenze and Umacala. The area Umphumela, where the study was conducted, falls under the Manyavu tribal authority. Population of Mkhambathini municipality was estimated at 59067 individuals or 12551 households in 2007 of which the majority of the people live in rural areas under traditional authorities (Mkhambathini Municipality IDP, 2006/2007; 2000).

Mkhambathini Municipality is mainly characterised by undulating escarpments and steep slopes. Land use patterns depict the apartheid past. Fertile soils and gentle sloping land above escarpment is dominated by commercial farms, mainly owned by white farmers while the traditional authority areas are mainly located below the escarpment on the northern part of the Municipality (Mkhambathini Municipality IDP, 2006/2007).

The area is characterised by humid temperatures (18.6°c min-24°c max) with wet summer seasons and dry winters. Umphumela Co-operative operates within ward 8, which receives a great share of annual rainfall (Mkhambathini Municipality IDP, 2006/2007). Agricultural activities within this municipality are characterised by apartheid based inequalities, manifested in the dichotomy between the well developed white owned farms and the underdeveloped and resource poor farmers in wards 1, 2, 5, 6 and 7. The majority of farmers in these areas are small scale or subsistence farmers and do not farm as large-scale commercial farmers (Mkhambathini Municipality IDP, 2006/2007). Small scale or subsistence are characterized as resource poor and farm on farm size of not more than two hectares.

Umphumela farming group farm on communal land which is 2.5 hectares. Presently the group is made up of eight females members from one family. The group has been in existence since 2005. The group started with 3 farmers (all family members).

Figure 3.5: Some of the members from Umphumela co-operative, December 2007.

The average age of the members was 55 years. The youngest member was 30 years. The interviewed farmers were all married women. The average education level of this group was grade 10. Only one of the members (who works on the farm part-time) has a grade 12 education. The farmers hope to make a better living through their involvement in agriculture. The lack of water and other resources demotivates the group. The river from which water is sourced is far from the farm plots.

These farmers produce food crops based on extensive indigenous agricultural knowledge and current market demand for organic produce. They do not apply external inputs like commercial fertilisers (Fischer 2005). Manure is readily available, and is obtained from commercial and semi-commercial farmers in the area.

3.3 Group institutional arrangements and activities

The levels of success and stage of establishment of the three co-operatives were different. The co-operatives share some differences and similarities in terms of productivity, marketing organisation and size yet, the management structures of the co-operatives are similar. All three co-operatives were managed by one person and committees were elected annually through a democratic process. The Inyamvubu group is managed by an annually elected committee, which includes a chairperson, a treasurer and a secretary. Inyamvubu has a well-developed constitution that details the role of the internal approval committee, which reviews applications from prospective members and makes decisions. The constitution sets out the role of the internal control system and determines the ramifications for Inyamvubu members who violate the rules. Administration work is carried out in an office environment and data capturing of records are carried out electronically since the office has a computer.

The Umphumela and Ingwe family groups have an elected leadership, and elect a committee every year, but they do not have an elaborate constitution, as does Inyamvubu. However, Umphumela do have basic constitutions and rules of engagement. The chairpersons of both groups provide leadership and serve as the contact person for stakeholders. In contrast, Umphemela formalised itself as a collective of people who share or were motivated by a common issue or interest, because they saw a need in the community for people to be self sustaining. More importantly, they have become aware of the importance of organic agriculture and the growing demand for produce of this nature. Ingwe Family Co-operative formalised because they saw a growing need in the community to have people involved in projects that will generate income for their families, since the community has low levels of poverty. Inyamvubu and Umphumela are registered as co-operatives. Ingwe Family co-operative were in the process of registering the co-operative.

The current production methods are quite similar and based on traditional farming methods similar to organic production methods. However, only Ingwe used conventional farming methods on a very small scale with the integration of livestock manure (also known as kraal manure or 'mqhuba') as a fertiliser on one of the fields that produce peppers. The three groups farm on communally owned land held in trust by the Inkosi (Traditional Authority Chief). Due to communal tenure and weak traditional institutions, there is no land rental market. Unlike commercial farmers, who traditionally farm privately-owned land, smallholder farmer members in these areas cannot use their land to secure finance/loans (Thamaga-Chitja, 2008). The implication for these farmers is that land can be taken away at anytime due to no security of tenure.

Inyamvubu appears to be the most developed group of the three, because it has access to formal markets and has exhausted all the resources available to co-operatives including government funding. The aim of Inyamvubu is to demonstrate the importance of agriculture to the community and encouraging rural dwellers and emerging entrepreneurs to start businesses, thereby creating rural development and employment in the area. Inyambvubu has since expanded into other enterprise areas such as crafts, which they export overseas. They sell agricultural produce to markets in Mooi River and assist a school feeding scheme with provision of fresh produce. The Ingwe Family group sells to housewives' markets in Mkhondeni and the Bluff, while chillies are sold in Richmond. Umphumela was new and had not yet accessed markets.

CHAPTER 4
RESEARCH METHODOLOGY

The purpose of this chapter is to outline the qualitative and quantitative methodology used in the study. Participatory methodologies were used to identify and clarify the study problem, which was to investigate the contribution of manure to soil quality among three smallholder organic farmer groups in the area of KwaZulu-Natal, South Africa.

4.1 Research design

The study was conducted with smallholder farmers in KwaZulu-Natal with an interest in organic farming to understand the contribution of manure to soil quality

Three participatory focus group discussions were conducted with farmers, one at each study site, by the researcher and a research assistant using a question guide relating to farming methods, farmers' experience and perceptions of manure use, manure management and constraints farmers experience with manure use. The qualitative approach gathered information through semi-structured face-to-face interviews and focus group discussions.

The purpose of a qualitative study is to "accumulate sufficient knowledge to lead to understanding of a phenomenon''. This is further validated by Silverman (2000) who states that the aim of qualitative research is to describe in detail what is happening in a group, in a community or in a conversation. Data collected through qualitative methods is very difficult to generalise to the entire population and samples do not necessarily represent the population (Sarantakos, 1998).

4.2 Group selection

In each of the three areas, an informant i.e., a lead farmer was identified, contacted and met to make arrangements to meet other farmers. The identification of participating groups depended not only on the willingness of farmers to be part of the study but also on meeting the selection criteria namely practicing "organic farming" agriculture and applying manure to their fields. Although these groups were not certified as organic producers they described themselves as organic due to the low commercial fertiliser use and following ethnic ways of farming. Data was obtained from sample farmers using interviews and structured questionnaires. The focus group discussions were undertaken during the month of December 2007, during a single visit. Data collected during the focus group included information on farmers' socio-economic circumstances and soil fertility management practices.

4.3 Data collection

Focus group discussions conducted with farmer groups were an important part of the study as they provided opportunities to investigate critical issues as perceived by farmers (Lewis, 1995). Data was collected through focus group discussions; soil and manure collection; and semi-structured interviews. Intra-method triangulation was used to obtain a range of information on the same issue, achieve a higher degree of validity and reliability and overcome the deficiencies of single method studies. Triangulation ensures the strengths of one method can overcome the deficiencies of another method (de Vos, 1998; Sarantakos, 1998) and reach consensus.

Focus groups are considered the most appropriate method for undertaking a study of this nature, because during discussions, rich and insightful information can be provided, and when used as a post research method, this can explain trends and variances, reasons and causes through the views of the respondents (Fern, 2001; Sarantakos, 1998). In focus groups, discussions are limited to the specific theme under investigation, and can be referred to as purposive discussions of a specific topic or related topic. Eight to twelve individuals with similar backgrounds or common interests are included in the discussion (de Vos, 1998; Sarantakos, 1998). For the purpose of this study, the following structure and processes were followed during focus group discussions.

Three participatory focus group discussions, one in each of the study areas, were conducted with farmers at their sites by the researcher, using a question guide. Questions were posed to the group and answers were recorded after consensus was reached among the farmers. Occasionally, it was necessary to encourage or facilitate further discussion among farmers in order to reach consensus. If there was no consensus after further discussion, more than one answer was recorded.

The three main areas of the focus group questionnaire guide (Appendix A) related to farming methods, experience and perception of manure use and manure management. According to de Vos (1998), focus groups can be used for a variety of reasons, including exploration and confirmation of issues. The questionnaire guide ensured that the same questions were used for all three groups. Due to the fact that the questionnaire guide consisted of many open-ended questions, the respondents had room to explain and elaborate on their responses. In this study, the researcher guided the participants throughout the discussions to make it easier for participants to recall information. The researcher also paid attention to controversial responses given to questions and requested clarity before recording the responses. The extension officer for Mooi River was involved in meeting the group members. The extension officer for the Richmond and Mkhambatini areas were unable to meet with the researcher.

Questions were repeated and clarified when requested to ensure that all the respondents understood them. At times, respondents helped to re-phrase questions when these were not understood by fellow farmers. The researcher ensured that the meaning was not lost during re-phrasing by being attentive, while giving space to farmers to assist one another. Data collection was done in isiZulu with a Zulu speaking research assistant.

Force Field Analysis is a management and analysis tool that uses a creative process for forcing agreement about facets of any desired change (Lewin, 2005). Issues identified during focus group sessions were brainstormed into two categories as the driving and restraining forces pertaining to manure use. Driving forces included elements such as skills, equipment, procedures and culture that facilitate movement towards the goal, whereas restraining forces inhibit achievement of the desired goals. In this case, the aim was to identify forces for and against manure use. An example of a Force Field Analysis is presented in Figure 4.1. Once the farmers had listed the positive and negative forces for manure use, these were ranked from strongest to weakest in terms of supporting manure use. The strongest negative force was placed first in the negative force box. The strongest positive force was placed first in the positive box.

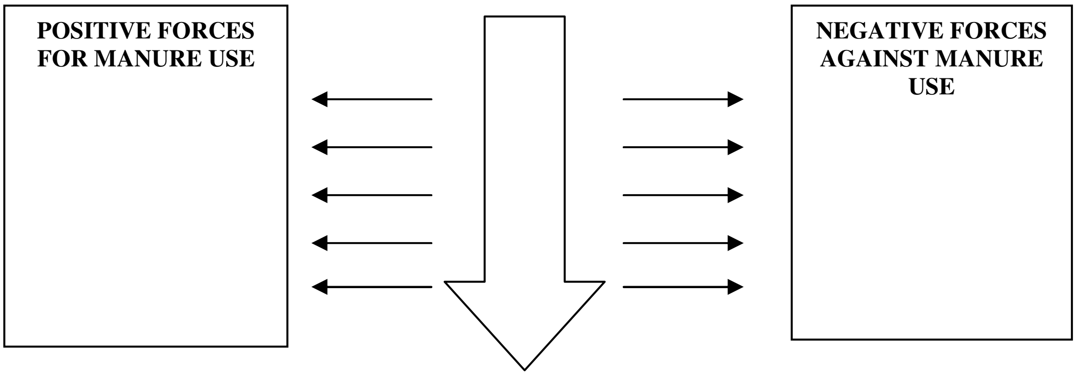

Figure 4.1: Outline of Force Field Analysis (Montgomery, 1995).

Both methodologies (focus groups and Force Field Analysis) were participatory, enabling farmers to engage actively in clarifying problems and finding solutions to problems relating to manure use. These methodologies helped prioritise key problems and develop and prioritise possible solutions to common problems.

4.3.1 Soil and manure sample collection

During visits, soil and manure samples were collected for laboratory analysis. Samples were only collected once at each study site. The sampling soil is essential to determine soil fertility levels and make good nutrient management decisions.

Manure testing is the process of evaluating manure nutrient content to provide specific agronomic and environmental recommendations for manure use (Klienman *et al.*, 2003). Manure nutrient composition varies widely between farms due to differences in animal species and management and manure storage and handling. Therefore, sampling and laboratory analysis is the only method for determining the actual nutrient content of manure.

Soils were sampled at various plowing depths (0-20 cm) using a soil auger from plots of two hectares because studies have found that the average farm size for smallholder farmers in South Africa is generally two hectares (Naledzani, 1988). Each soil auger's precisely angled cutting blades pull the auger into the soil approximately 2.54 cm with every revolution of the handgrip. These blades cut a hole slightly larger than the auger barrel for easy retraction of the auger and sample. The sample is easily removed by just inverting the auger and a thump handgrip on the ground. Three soil samples per plot were bulked and mixed thoroughly and a sub sample (1kg) was taken for laboratory analysis to KwaZulu-Natal Department of Agriculture and Environmental Affairs: Soil Fertility and Analytical Services in Cedara. The researcher used simple random sampling methods for collecting sub-samples to form the composite sample from the land management unit (LMU) as indicated in Figure 4.2.

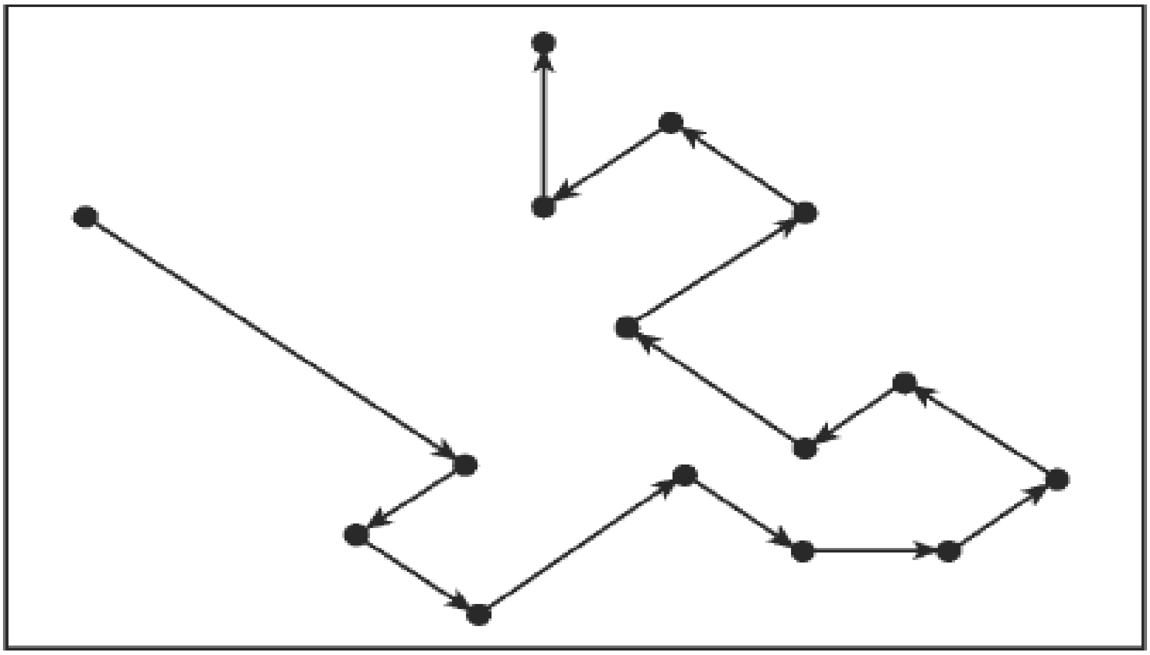

Figure 4.2: Using simple random sampling to locate sub samples on a land management unit (Texas Commission on Environmental Quality, 2003).

Simple random sampling relies on the experience and knowledge of the soil sampler. In this case, the researcher selected the soil sample locations on the basis that manure was the only fertiliser applied to the plots. With a simple random system each soil core was selected separately, randomly and independently of previously drawn units. Soil samples were taken within the root zone or approximately 20 cm away from the plant roots respectively for cabbage, butternuts and green beans. The samples were transported to the KwaZulu-Natal Department of Agriculture and Environmental Affairs: Soil Fertility and Analytical Services at Cedara laboratories. All soil samples were taken according to the simple random sampling protocol described by Tan (2005), and are considered to be representative of the environment from where they come from. Soil samples for the three research sites were collected during December 2007. Soil and manure analysis were conducted to establish the current soil fertility and to show if the manure used for field application was of good quality.

The soil analysis investigated the availability of nutrients. The soil sample tests and sample acid saturation reflected in the soils were also tested. Soil fertility fluctuates throughout the growing season each year. The quantity and availability of mineral nutrients are altered by the addition of fertilisers and manure among others. Furthermore, a large quantity of mineral nutrients is removed from soils as a result of plant growth and development, and the harvesting of crops. The soil tests determine the current fertility status. It also provides the necessary information needed to maintain the optimum fertility year after year.

An indication of the soil's nitrogen supplying capacity and organic matter content can be obtained from the carbon-nitrogen ratio through analyses for total nitrogen and organic carbon content. The required levels of lime required to decrease soil acidity saturation was also estimated. The analyses provided nutrient and lime recommendations, management guidelines and fertiliser options. The soil's acidity and salinity was also analyzed to determine if pH was too "acid" (low pH) or "alkaline" (high pH), nutrients present in the soil become locked-up or unavailable.

Depending on the size of the manure pile, as indicated in Figure 4.3, the researcher took at least three samples, each consisting of five sub-samples from one manure pile as farmers did not have extra loads during the time of the study. Soils collected to form composite samples from a single source from several depths thoroughly mixing this material until the pile looked uniform and then took a sample. The sub-sample was mixed by placing it in a pile and repeatedly shoveled. Plastic gloves were used to take smaller samples for analysis, placing the mixture in a heavy weight plastic freezer bag. The bag was squeezed to remove the air, and then placed the bag in a second freezer bag to prevent leakage. Samples were analysed at the Plant Laboratory at Cedara for pH, total ash, organic matter, nitrogen, phosphorous, potassium, calcium and magnesium as described by in Anderson and Ingram (1993).

Figure 4.3: Manure pile, Inyamvubu, 2007.

4.4 Data analysis

Content analysis refers to the contextual investigation of verbal data through inference of data by identifying categories and themes that best represent the data trends (Shaughnessy & Zechmeister, 1997; Silverman, 2000). Themes and patterns are identified from this data. Where the words were similar or carried the same meaning, the researcher exercised judgment and put them together into one category. Categories were accurate, exhaustive and mutually exclusive and clearly defined. Responses were categorised due to similarities and a theme developed from similar responses. Themes, relationships and associations were identified to make sense of these relationships. Tape recordings of the focus groups conducted in isiZulu were transcribed. The notes that had been taken by the research assistants were also consulted.

Qualitative data analysis is a reasoning strategy with the objective of taking a complex whole and separating it into parts. Since qualitative data is in crude form, separating data into parts allows the researcher to identify units that are of similar features and these are in turn coded. The results are presented in the following chapter.

CHAPTER 5
RESULTS AND DISCUSSION

This study focused on the contribution of manure to soil quality on non-certified smallholder organic farmers in three areas of KwaZulu-Natal. Kraal manure is the only fertiliser option these farmers have due to the inaccessibility and high cost of commercial fertilisers. However, it must be noted that some farmers in this study have used commercial fertiliser where possible. This will be discussed later in this chapter. Based on participatory interviews and focus group discussions with farmers from three groups, a general picture of the use of manure has been obtained. Moreover, through the analysis of soil and manure samples, the current fertility status of the soils and the relative value of manure as fertiliser were determined. The positive effect of manure on soil fertility as perceived by farmers is clearly shown in this study.

5.1 Current interventions to improve soil conditions

The Ingwe Family Project, based in Richmond, was the only group to use commercial fertiliser on designated plots. Commercially available fertilisers have immediate benefit for crop production. Twenty three percent (23%) of the farmers used commercial fertilisers in combination with manure. Participants from Inyamvubu and Umphumela indicated that they never used commercial fertilisers as they typically applied indigenous knowledge in current farming practices. Commercial fertilizers applied were 2:3:2 and 2:3:4 (N:P:K), limestone ammonium nitrate (LAN) and potassium chloride (KCl). Urea and LAN contain nitrogen and KCl contains potassium.

As indicated, the respondents in Richmond used commercially manufactured fertiliser in combination with manure. These farmers practice organic farming, however, are not certified organic farmers, hence the occasional use of fertiliser. The reason given for this practice was that manure was in short supply. The logistics, cost and availability of vast quantities of manure make its sole use impractical. However, the Richmond farmers explained the benefits of using manure, and of supplementing commercial fertiliser application with manure. They explained that manure improved the organic content of the soil and increased the water holding capacity, improving soil structure.

Only Inyamvubu farmers used composted manure as a tool for soil fertility improvement. The farmers complained that using composted manure required considerable time to produce (3-6 months) and labour time to make adequate amounts. However, when applied, they did notice changes in the soils such as increase moisture absorption that improved production levels. Figure 5.1 shows a compost heap belonging to Inyamvubu members. Some farmers from Inyamvubu have been trained by the Department of Agriculture in compost making. As a result, they illustrated and described how the compost was made, based on the model that the Department of Agriculture taught.

Figure 5.1: Compost heap, Inyamvubu

One of the farmers from Inyamvubu who was trained explained how he understood compost was made. Firstly, the compost heap must be under a leafy tree as this will prevent sun and wind from drying out the layers of the heap. The size of the heap should be (2mx2m). The use of coarse material such as twigs should form the base of the compost heap as this will allow for aeration. The farmers suggested the layer should be two hand width or 20cm deep. Following the base, a layer of plant material such as grass and leaves are placed. Kraal manure was then spread over the first layer, after which, the third layer, a thin layer of soil was added as organisms in the soil, earthworms in particular, will help in the rotting process and mix the material to increase air flow. The farmers stated the layers are repeated depending on the individual preference. The last layer should be dry grass or leaves to keep the smells in and to repel flies. Straw was used to keep the moisture and heat contained as is helped to decompose plant and animal material and destroys weeds.

Umphumela and Richmond farmers attribute their non-practice of composting to a lack of knowledge, and explained that compost making and distribution is bulky, requiring labour and transportation. Therefore, distance to farming plots is an important aspect in use of compost. Farmers could use green manure for soil improvements and soil protection.

5.2 Experience and perception of manure use

In order to improve agricultural production and food security with regard to the existing soil fertility problem, farmers have adopted manure use (for soil fertility improvements). All farmers involved in this study used livestock manure in varying degrees. Due to the limited availability of livestock manure, farmers preferred to integrate livestock manure with other fertilisers. The Ingwe Family Project has limited livestock so manure is gathered from neighbours and is supplemented with commercial fertilisers on plots with cabbage and green pepper. Green beans were fertilized with manure only. The Inyamvubu group tends to use livestock manure as a compost booster that stabilises nutrients and reduces bad odours, as well as to make compost to increase the quality of manure for soil fertility. The composted manure is then applied at each planting pocket (digging out a space for a plant, filling the area with as much good soil/compost as one can, being sure to mix at least some of the original soil) and sprinkled around plants to avoid heat burn. The Umphumela group also used livestock manure. However, manure is sourced from the nearby dairy farm. Often transport problems are an issue, which also has an influence on whether to or not use manure. Although these farmers view transport as a constraint they were adamant to farm organically, they need to apply manure.

Table 5.1 illustrates the activities carried out by each of the three groups. The points discussed in the table explain issues such as what they do, how and where they get manure, when is manure applied, and the required amount of manure to use. Answering these questions may give a clearer picture of farmers' perceptions of manure use and soil fertility.

Table 5.2 indicates farmer responses to experience and perception of manure use. Although all participating farmers were still using manure for soil fertility management, some farmers indicated that they had used manure on household plots in the past. The reason for abandoning the use of manure included a lack of transport and labour to haul and apply manure in the fields, low crop yields, low nutrient content of manure, the fact that manure encourages weed growth and has a bad smell, and lack of appropriate technical information on manure management.

Umphumela members indicated that transport was not the major factor constraining manure use but labour availability was a major issue for these farmers. They indicated that some members were employed in other jobs during the week, creating farm labour shortages. The Inyamvubu members indicated that manure kept the soil more moist for longer. All participants indicated that manure was cheap and mostly available. Members of all three groups' complained that manure encouraged weed growth. Weed growth may occur although properly managed, however, weed growth may be relatively low.

Table 5.1: Summary table of responses to questions addressing the subproblems

	Inyamvubu	Umphumela	Ingwe Family

What activities do they do?	Inyamvubu members practise irrigated small scale agriculture on three fields of four hectares. Fields are ploughed using hand hoes and garden forks. These smallholders have been farming as a group for two years. A lack of finances led to the use of manure as a traditionally used fertiliser. The main crops were cabbage, onion and butternut. Surpluses are sold at the Mooiriver market and the group supplies vegetables to a feeding scheme at a local school.	Like Inyamvubu, Umphumela members practise smallscale farming. Farming activities take place on a field of two and a half hectares. A hired tractor is used to plough the fields but planting is manual. Umphumela members have been farming as a group for the past two years. Farming is mainly rain fed. There is a river from which water can be drawn, but it is far from the fields. The use of manure was motivated by the interest in organic farming. Crops grown were butternut, pumpkin and green beans.	The Ingwe family practice smallscale agriculture on a two hectare field. They have been farming as a group for three years. Mr Sithole, the leader of the co-operative owns a tractor, which saves time and money in land preparation. Farming is both rain fed and irrigated. The farmers used manure as they believed that some crops are suited to manuring. They grow sweet potatoes, cabbage, green beans, spinach and amadumbe. Produce is sold at the local vegetable market in Richmond and the Housewives' Market in Mkondeni, Pietermaritzburg.

How and where do you get manure?	Manure is reportedly always available from a nearby dairy farmer. Manure is usually stored in heaps on nearby lands to allow for decomposition to take place, and for ease of field application and spreading. The group does not have proper storage facilities, but did not express concerns over this. Farmers stored manure in heaps.	Manure is obtained from a commercial farmer and collected from neighbours. Transport is often a problem, as Umphumela members do not a vehicle. Often a vehicle is hired and at times it is not available. These farmers do not store manure due a lack of storage space. The fields are far from the homestead, making management of plots difficult.	Ingwe members used manure because it was a cheap option to fertilise crops. Manure is gathered from neighbours, but there is not enough available. Manure is stored in heaps.
When is manure applied?	Manure application takes place during the winter season, as it provides farmers enough time for the manure to take effect on the soil before planting. During the growing season manure is sprinkled around plants to avoid heat burn.	Manure is applied during winter and is sprinkled in lines before planting. Ridge furrows are formed after which manure is applied by hand.	Manure is hand spread over fields, stretching available labour. Manure is applied close to planting time.
How do you decide how much manure to apply?	Inyamvubu farmers have no set method of deciding how much manure to apply to their fields and rely on indigenous wisdom. Some members have received training on manure use	Members do not know how much manure is required for field application. Farmers use indigenous knowledge and experience in farming. They have not received any training on manure use	Members do not know how much manure is required and so are also guided by indigenous knowledge and farming experience. They have not received any training on manure use

Table 5.2: Experience and perception of manure use among participating farmers (n=30)

	Frequency of manure use	Percentage of manure use	Inyamvubu	Ingwe Family Project	Umphumela
A. Experience with manure use					
Never used	0	0	-	-	-
Used but discontinued	0	0	-	-	-
Still using	30	100	✓	✓	✓
B. Positive attributes					
Better crop growth	15	50	x	✓	✓
Kept soil moisture longer	15	50	✓		
Cheap and always available	30	100	✓	✓	✓
Other (specify)					
C. Negative attributes					
Demand labour and transport	22	73	✓	✓	x
Low nutrient content	0	0	-	-	-
Utilization requires technical information	0	0	-	-	-
Its performance is slow	5	16.6	x	x	✓
Encourage weed growth	30	100	✓	✓	✓

The findings of this study are consistent with those of Enyong *et al.,* (1999) who reported that farmers are, in general, risk averse when confronted with technology that involves substantial tradeoffs. They suggested that farmers adopt a technology only when they are convinced it will bring about higher levels of success (yields in this case). Half of farmers who applied manure indicated that they observed improved soil conditions, crop growth and yields after applying manure. It was claimed that the plants where manure was applied looked healthier and greener, and produced higher yields than those without manure. All farmers were not concerned about low nutrient content of manure. Additionally, some farmers indicated manure performance is slow this may be attributed to lack of labour and transport which may affect the application rate.

5.3 Manure quality

The effectiveness of animal manure depends on the nutrient composition such as levels and availability of nitrogen, phosphorous and potassium. Table 5.3 shows the summary of manure analysis. At the time of manure collection, there was no manure in stock for the third group for the researcher to sample and compare with the soil analysis. Soil analyses were based on two crops cabbage and green beans from the study areas indicated above. The composition for the Ingwe Family Project and Inyamvubu samples varied slightly. Table 5.4 shows soil analysis results from two areas (Ingwe and Inyamvubu

The results suggest that manure is deficient in nutrients. It was assumed that the reason for low nitrogen, phosphorous and potassium could be attributed, quality of feed, age, and storage. Tanner *et* al, (1993) found that the chemical composition of cattle manure is influenced by a number of factors such as quality of feed, age, storage and handling conditions. Phosphorous content was low (0,22%) compared most commercial fertilisers that contain between 20 and 30% of nitrogen, phosphorous and potassium nutrients per 100kg of fertiliser (van Averbeke and Yoganathan, 2003). The results of the current study concur with those of Mkhabela's (2006) study in the KwaZulu-Natal Midlands that found the nutrient content of manure to be 2% nitrogen, 1.5% phosphorous and 2% potassium.

This suggests that the farmers would have to apply 10 times more to match commercial fertiliser. These fertiliser applications will also be affected by crop type which, have different nutrient requirement needs. The soils in Mooi River were more deficient in nitrogen and phosphorous at the time of sampling, possibly due to the fact that Richmond farmers reported the use of commercial fertilisers in the past.

The soil analysis results indicate that 3.5 tonnes and 2.0 tonnes of lime are required per hectare (Table 5.4). These requirements suggest that the soils are acidic due to leaching of nutrients with high rainfall (Mooi River-706-838 mm; Richmond-781-1017 mm) and organic matter decay. Soil acidity renders nutrients unavailable, so plants are not able to absorb them (Averbeke & Yoganathan, 2003).

Table 5.3: Summary of manure analysis 100% dry matter basis

Sample ID	Nitrogen %	Calcium %	Magnesium %	Potassium %	Sodium mg/kg	Zinc mg/kg	Copper mg/kg	Manganese mg/kg	Iron mg/kg	Phosphorus %	Al mg/kg	Moist %	pH
Ingwe (Richmond)	0.81	0.691	0.20	0.64	80.5	249	15.7	83	9203	0.22	3018	35.74	9.42
Inyamvubu (Mooi River)	0.82	0.53	0.17	0.56	80.7	165	12.1	452	8184	0.19	2728	35.85	9.47

Table 5.4: Soil analysis results for samples from Inyamvubu and Ingwe farmers

	NITROGEN			PHOSPHORUS			POTASSIUM			LIME			ZINC
	Yield Target t/ha	Req. Nitrogen Kg/ha	Sample Soil test mg/L	Target soil test mg/L	Req. Phosphorous mg/L	Sample soil test mg/L	Target soil test mg/L	Req. potassium kg/ha	Sample acid sat. %	PAS %	Req. Lime t/ha	Lime type	Zinc Fertiliser required
Inyamvubu (Mooi River)	100.0 cabbage	200	20	33	115	230	200	0	10	1	3.5	Dol/ Calc	No
Ingwe (Richmond)	optim	100	4	27	100	161	100	0	20	5	2.0	Dol	No

The application of manure to acid soils will not increase crop yields but the nutrients released from the manure will be fixed in the soil but unavailable for plant growth requirements. Reducing soil acidity will require large quantities of lime (3.5 and 2.0 tonnes in Iyamvubu and Ingwe respectively), which is expensive for resource-poor farmers who live in remote areas. However, any intervention must take into account the soil type, crop type and current availability of minerals. For example, in clay soils, soil phosphorous is not available to plants, even when levels are high (FAO, 1992). Farmers need access to an extension officer to interpret soil test results and assist them in designing appropriate soil nutrition improvement plans. These plans may include crop rotation and the use of compost.

5.4 Factors influencing farmers' use of manure

The use of manure will undoubtedly persist because; with increasing cost of commercial fertiliser manure will remain the best possible means by which farmers can fertilise their soils. Furthermore, this impacts on the use of commercial fertiliser. The distance from markets drives smallholders to use manure as fertiliser. The table below reports socio-economic factors that have influenced manure use by farmers in the three groups.

Table 5.5: Socio-economic factors influencing farmers use of manure, among three groups

	Ingwe Family Project	**Inyamvubu**	**Umphumela**
Socio-economic factors			
Lack of resources	✓	✓	✓
Lack of farmer support	✓	✓	✓
Limited financial capacity	✓	x	x
Increased crop production	x	✓	✓

Lack of resources is a common problem in small-scale agriculture (Mkahbela, 2007). The Inyamvubu farmers were relatively well resourced in terms of transport, and labour is better organised compared to farmers in the other two groups as they were also involved in bead work and crafts. The members of the Ingwe Family Project indicated that the use manure was due to limited financial capacity to purchase fertiliser although they had used commercial fertiliser albeit in insufficient amounts.

Crop production is major source of income for the Inyamvubu and Umphumela farmers. Declining soil fertility would significantly affect their livelihoods. The Umphumela farmers indicated that demand for organic produce was growing and fertilisation with manure would enable them to sell organic produce. However, organic niche markets are relatively small (but growing) and the farmers would need help accessing these markets.

5.5 Farmers perception of soil fertility problems

Understanding soil fertility problems from the farmers' points of view is crucial in the analysis of the contribution of manure to soil quality. Farmers over forty years were identified based on the membership records from each group as experience shows that the more mature age groups are the ones participating in agriculture compared to youth. Eighty percent of the total sample farmers described soil fertility levels as low as compared to 10 years ago. About 40% of farmers said soil fertility levels improved with the introduction of manure.

Table 5.6: Farmer' perceptions of soil fertility, in Inyamvubu, Igwe & Uphumela (December, 2007) n=30

Good soil	**Inyamvubu**	**Ingwe Family Project**	**Umphumela**
Black soil colour	✓	✓	✓
Good crop performance	✓	✓	✓
Presence/ vigorous growth of certain plants	✓	x	x
Abundance of earth worms	✓	✓	✓
Poor soil			
Yellow and red colour soil	✓	x	✓
Compacted soil	✓	✓	✓
Stunted plant growth	✓	✓	✓
Reduced vegetative cover	x	✓	x
Increased change of natural habitat	x	✓	✓
Presence of rock and stones	x	x	x

The most common local indicators of soil fertility that distinguish between good and poor soils are indicated in the previous Table 5.6. Soil related indicators include soil colour, presence of worms, sand and gravel and drying up characteristics. Vegetation related indicators include dominance of types of plants and crop performance.

Farmers attributed changes in soil fertility to a number of factors including the social and economic changes. These factors include population growth over the years, declining land size resulting in impossible fallowing.

Twenty three percent of farmers indicated that they have used synthetic fertiliser to increase agriculture production to meet their consumption need and the demand for produce in their respective areas. The Ingwe Family Project indicated the use of synthetic fertiliser. However, due to price increase of fertilisers over the last years, it has become difficult for these farmers to apply fertiliser at the recommended rate and at the appropriate time. Therefore, the Ingwe Family Project farmers continue to cultivate plots without soil nourishments, leading to a decline in soil fertility. These farmers also claimed that continued use of synthetic fertiliser reduced soil fertility and agriculture production. Smaling (1993) also states that the use of fertiliser under small-scale conditions can make this technology risky and difficult by farmers in this sector. It is important that the all three farmer groups investigate and exploit the benefits of manure use further. The majority of Inyamvubu and Umphumela farmers were aware that soil fertility was low. Inyamvubu farmers believe that the soil was productive to a satisfactory level, whilst Umphumela perceived their farms to be highly productive. However, the improved manure and compost use can improve productivity (Mkhabela *et al.*, 2003).

Umphumela farmers have access to manure. Animals were kept overnight in a kraal close to the household, making accessibility to farming plots manageable. This means that more time could be spent on the fields to achieve the desired outcome. These farmers had opportunities to expand production and there was still land available for expansion of production. Kraal manure that was accumulated throughout the year was collected and applied to the field by Nyamvubu. The study suggests that, manure stock may not be adequate for acceptable commercial yield. A study by Thamaga-Chitja (2008) shows that for a common crop such as cabbage 334 wheelbarrow loads of manure are required for nitrogen which illustrates that manure was not enough. In most cases, the manure was broadcasted and ploughed before planting.

Continuous cropping with little or no commercial fertiliser inputs was suggested as one of the causes for declining soil fertility by Ingwe Family Project members. Some farmers (for example Inyamvubu members) have been cultivating on the same farm land continuously for years without practicing fallowing techniques, mining essential nutrients, resulting in declining crop yields.

Table 5.7: Indicators of good quality manure expressed by three farmer groups

Name of farmer group	Responses
Inyamvubu (Mooi River)	Manure must resemble sand meaning that manure is fully decomposed then ready for the field. The manure must be black in colour.
Umphumela (Mkhabatini)	It must be fully decomposed. The quality is only known by the crop growth. The appearance should be black in colour.
Ingwe Family Project (Richmond)	Quality of manure depends on the quality of the produce.

Table 5.7 indicates a range of responses by farmers in the three study areas when asked what the indicators of good quality manure were. These responses indicate that these farmers have had different experiences with manure use, but most importantly experience based on their indigenous knowledge. In addition, their responses are indicative of the agro-ecological area because of ecological principals in different agricultural zones are not the same; therefore farmers would experience different issues such as weather pattern, soil structure and numerous other qualities and their experiences with small-scale farming. The responses also suggest some overlap, which indicates that farmers experience in relation to small-scale farming and manure use do share a common trend.

5.6 Manure management practices

The study found that except for a group of young Inyamvubu farmers, most farmers had not received formal training related to the use and management of manure table 5.1. This finding suggests that many farmers in the study area were using manure but without the necessary technical information for its efficient use and management. Most farmers cited lack of knowledge and information about optimum use and management of manure as an important factor deterring efficient manure use. Farmers did not have knowledge regarding optimum application rates, application methods and the best time to apply manure. The farmers indicated that they had access to extension services and personnel but the staff were extremely busy.

Extension officer occasionally interacted with farmers. The Inyamvubu group was assisted in areas of composting making; on the other hand, Uphumela and Ingwe Family Project, contact with the extension officer was non-existent during the time research was conducted. Although, extension support was minimal, farmers made use of their indigenous knowledge, skills and peer to peer support in relation to manure management. For example Ingwe Family Project had not been for training in composting, however, they were practising some elements of composting by default.

The output of Figure 4.1 was used to understand the challenges farmers faced. A number of constraints were listed by the farmers. Although the respondents continue to use manure, they indicated some challenges, such as difficulty in application and the offensive smell. The bulkiness and weed growth after application initially deterred some farmers from using manure. The results of the Force Field Analysis (FFA) are presented in Appendix B. A comparison of manure use constraints identified from the Force Field analyses among the three groups are presented in table 5.8.

Table 5.8: A comparison of manure use constraints identified from Force Field Analyses, December 2007

	Ingwe Family Project	Inyamvubu	Umphumela
Experience			
Difficulty in application (required rate, labour, and equipment)	✓	✓	✓
Insufficient manure available	✓	✓	✓
Offensive smell	✓	✓	✓
Encouraged the growth of weeds	✓	✓	✓
Resources			
Transport costs to transport manure	✓	✓	✓
Equipment for haulage of manure	✓	x	✓
Skills			
Lack technical information	✓	x	✓
Lack of training extension service to advice farmers.	✓	✓	✓

All three groups stated that there was a shortage of manure due to low herd sizes in the community to supplement their own supplies, supporting William's (1999) findings. It was suggested that manure, especially kraal manure from cattle that grazed on communal land, encouraged the flourishing of weeds. Farmers from Inyamvubu and Umphumela collected manure from dairy farms in their respective regions. It was not clear which manure source encouraged weed growth.

Ingwe Family Project, Inyamvubu and Umphumela farmers listed increased transport costs and the time required to load and transport manure from external sources as a constraint. The group of Umphumela did not have any means of transport, occasionally manure was transported to the farm by neighbours with appropriate vehicles, compared to Ingwe Family Project and Inyamvubu members. Although the Ingwe Family Project members had a vehicle to transport manure, they were faced with other challenges such as location and road accessibility to transport manure. The Ingwe Family Project is located in a mountainous area, making the transportation difficult. In addition, bad weather conditions affected road accessibility and it was not possible to use the roads during rainy weather.

Smallholders are resource-poor, so equipment is a constraint. All three farmer groups stated that the application rate would be affected due to lack of equipment. The Ingwe Family Project had a tractor to plough the land so could plant larger plots. The Inyamvubu members rented a tractor from the local chief who was granted permission by the Department of Agriculture to maintain the tractor. The Umphumela farmers had to physically plough and weed the land with hand a hoe which was time consuming.

The Ingwe Family Project and Umphumela members expressed concern about their poor knowledge and lack of technical information on manure use and soil fertility practices. Although some Inyamvubu members have undergone training, there is a need for further training. The Ingwe Family Project and Umphumela members stressed the lack of compost-making skills was a constraint because compost has shown to improve soil properties. It is paramount that farmers have access to appropriate information and technical skills relating to manure use and management. Most respondent farmers shared the opinion that it was necessary to introduce technologies that reduce weed growth and the poor smell from manure, proper storage and composting of manure.

The farmers indicated that covering manure heaps would speed up decomposition, conserve nutrients and prevent evaporation. The farmers cited the importance of storing manure in a heap as a means to reduce weed germination later. The farmers expressed ignorance of other manure storage methods. The manure heap in Figure 5.2 is structured with branches placed at the bottom of the heap followed by hay and manure. The farmers in Inyamvubu indicated that this method allowed for aeration to prevent the compost heap from rotting. The manure heap was turned periodically.

Figure 5.2: Heap manure storage December (2007).

Manure quality may simply be defined as the value of manure in improving soil properties and enhancing crop yields. Scientists have used laboratory analysis for nutrient contents as a measure of quality. However, farmers have traditionally used their own yardsticks to determine the quality of their manure (Kimani & Lekasi, undated).

The results from the FFA and priorities indicated in Table 5.9 show a common trend through each of the solutions for the constrained issues. The theme focuses on the need for training, knowledge and skills development. The most important constraining element indicated by all farmer groups was the lack of extension service and training. If farmers are adequately trained on manure use, management and manure application, the other constraining elements in the FFA could have limited impact on the use of manure.

Table 5.9: Results of the FFA (Appendix B) and ranked priorities with Inyamvubu, Ingwe Family project and Umphumela groups, December 2007

Constraining element	Solution
1. Lack of extension service and training	The farmers expressed that selected individuals could attend training provided by extension officers, thereafter come back to the community to teach other farmers what was learnt. Non-Governmental organisations could also conduct training for farmers within their communities.
2. Lack of sufficient manure	The farmers also expressed that knowledge of how to store manure is needed, and interventions on how to improve the quality of manure such as composting could assist in this respect.
3. Difficulty in manure application	Workshops by technical experts on manure use and application such as non-governmental organisations that focus on agricultural practices, apart from extension support needs to be investigated further, as extension officers are few between districts.
4. Transport costs	The community can pool resources and pay or barter with community in exchange for produce.
5. Lack of equipment to spread manure	Equipment was least important as farmers have been farming in the past without the necessary equipment for manure use. However, it is necessary as it will save time and allow more time on priority areas.

Table 5.3 reflects the soil analysis to determine the NPK requirement for cabbage in Inyamvubu. The recommended rate for nitrogen was set at (200 kg/ha), phosphorous (115 kg/ha) and potassium (0 kg/ha). A study conducted by Thamaga-Chitja (2008) shows the NPK requirements for optimum growth (withdrawal norms) versus equivalent from manure. The findings suggest that the nitrogen withdrawal norm on commercial fertiliser for cabbage is 3.3 kg/ton, while the number of wheelbarrow loads of manure 334. The model developed in the same study suggests that manure produced by one cow and one sheep/goat can total 8.85 wheelbarrows per annum. Large amounts of manure

would be required to obtain better yields. This may pose a real challenge for farmers who do not have livestock, as is the case with many smallholder farmers. Even those with livestock will require unrealistically large amounts of manure to meet yield demands. Farina (2005) further argues that it is barely possible for farmers to make up their nitrogen inputs using only organically-acceptable manures or compost.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

In many developing countries, the smallholder sector represents a very large proportion of the country's population and has the potential to become an important contributor to household food security. Small-scale crop production systems in South Africa and other countries in sub-Saharan Africa involve a mixture of both crop and livestock farming. However, one of the most important threats to the sustainability of smallscale crop production system is the decline in soil fertility. Declining soil fertility has been described as an important constraint to food security in sub-Saharan Africa (SSA). The shortage of land as well as land degradation have led to a decline in traditional soil fertility management practices, affecting soil fertility unless farmers actively manage soil fertility for long term sustainable production. Manure could play a vital role in the maintenance in soil fertility under smallscale agriculture in South Africa and elsewhere. Engaging in soil fertility maintenance may lead to greater food availability and economic growth opportunity for smallholders. This study set out to investigate the practice, constraints and perceptions of improving soil quality through manure application.

A qualitative, participatory approach was used to engage with the farmers and gather information. Three participatory focus group discussions were conducted with farmers, one at each study site, using a question guide relating to farming methods, farmers experience and perception of manure use, manure management and constraints farmers experience with manure use. Force Field Analysis was used to identify forces for and against manure use. During research visits, soil and manure samples were collected for laboratory analysis to determine soil fertility and manure quality. A simple random sampling method for collecting soil samples to form the composite sample from the land management unit was used.

The study has shown that the three farmer groups are applying manure to their fields, but at varying time rates. For two farmer groups (Inyamvubu and Umphumela), manure application takes place during the winter season, as it allows enough time for the manure to take effect on the soil before planting. During the growing season, manure is sprinkled by hand around plants to avoid heat burn. For Ingwe farmers, manure was hand spread requiring considerable labour. Manure was applied close to planting time by Ingwe members. Indigenous knowledge and wisdom played a significant role in how much manure was required for field application, as all farmers in the study had no clear idea of the appropriate manure application rate.

The majority of farmers who applied manure observed improved soil conditions, crop growth and yields. Farmers claimed that plants where manure was applied looked healthier and greener, and produced higher yields than those without manure. A lack of resources, farmer support and financial resources and a desire for increased crop production led to the use of manure.

Evidence from this study suggests that available manure is currently being used, but insufficient quantities are available and applied. Most farmers did not have experience and technical information regarding the use and management of manure. Some indicated that they had used manure before but had stopped for various reasons such as difficulty in application, transport costs and a lack of technical information. Appropriate storage and management strategies will need to be promoted in order to improve the efficiency of manure use.

6.1 Conclusions

The case study has shown that three smallholder groups use manure, but not effectively due to insufficient quantities of available manure. Most farmers have no ready supply of manure, which may be needed at rates beyond what the farmers can supply. These farmers perceived manure to have benefits such as increasing yields and better looking plants. Nevertheless, farmers expressed concerns that included poor extension, insufficient manure, lack of improved technology on manure application and composting, lack of equipment to spread manure and transport to assist with manure collection from diary farmers. The logistics, cost and even availability of such vast quantities of material make their sole use difficult for these smallholder farmers.

6.2 Policy implications and recommendations for improving the contribution of manure to soil quality

This study has shown that manure is currently of variable quality, but that better knowledge of practices with regard to manure application could enable farmers to improve the value of manure and better understand application methods. Even though manure use has been around for a long time, it never really evolved into a sustainable concept due to a number of factors, some of those studied in this research. Manure use is seen as only one measure to manage soil fertility, so government programmes and training should include this and other alternative soil fertility practices.

Given the nature of soil fertility challenges among smallholder farmers outlined in the study, farmers who used manure to manage soil fertility indicated improved soil conditions and crop growth. Government needs to develop programmes that would provide training and technical information that would focus on possible intervention to improve current soil conditions among smallholder farmers such as composting and vermi-composting. Workshops in the area of compost and vermi-composting need to be conducted, as farmer groups indicated a lack of understanding on techniques that would improve the quality of manure. Non governmental organisation (NGO's) have an instrumental role to play in providing and outsourcing the capacity to ensure that small farmers are not neglected. This will need partnerships between government and NGO's to work together to ensure the small farmers are getting all the technical expertise they require. In addition, Community Based Organisations (CBO's) do also provide support to farmers willing to farm organically or on small holdings. This will compliment the efforts of government i.e. KZNDAEA or extension service. A handbook with graphic detail should be accompanied to provide farmers with information and advice on how to manage soils. Farmers are willing to invest in soil fertility management techniques to improve agricultural production but the lack of follow-up and understanding of the needs of farmers by extension work is a problem.

6.3 Recommendations for improvement of the study

Manure has been recognised as a good soil amendment that can be used as an organic fertiliser, providing plant macro- and micronutrients to improve crop production. If manure is applied according to soil tests and crop nutrient requirements, it can optimise soil nutrient availability. The use of manure as a source of fertiliser could be a feasible option to solving smallholder soil fertility problems. This study could have investigated the agronomic and environmental effects of manure on this agroecosystem, to develop comprehensive recommendations for manure use. The study overlooked the number of livestock farmers to determine the quantity of manure they were able to supply. Additionally, optimal manure application rates were not determined. The study could have entailed regular soil analysis during its duration.

6.4 Recommendations for further research

Future research needs to be multi-disciplinary as issues on water use/hydrology; agronomic practices, socio-economic factors or social facilitation, and institutional development all play a role in optimising the use of manure in improving soil fertility, thus crop production and ultimately household income.

Organic farming is a knowledge intensive production system. Farmers require support with regard to manure use, production knowledge and continued updating of this knowledge. Appropriately trained extension personnel, plus knowledge and information-sharing with other smallholder farmers are important elements that can be facilitated at a local level. The growth of organic farming in South Africa and in Africa requires intensive training to capacitate farmers' new production knowledge that replaces synthetic input driven agriculture. Information gathering and building on local knowledge systems is important for productivity. Information sharing could be linked to innovative rural information technology centres such as those used in rural India.

There needs to be an optimum and balanced use of the nutrients in any farming system if sustainable agricultural practices are to be established. Long-term studies are needed involving manure from different sources and forms, different soil types, different crops, and variable environmental conditions. Studies to evaluate the long-term effects of repeated manure applications on various aspects of soil quality should be considered. This would include examining the effect of several manure applications on soil microbial populations, soil physical properties such as structure, chemical properties including nutrient load, salinity, and sodality as well as hydrological properties such as water infiltration. There is a need to take physical response data (i.e. yield increases) associated with application of manure nutrients observed in field trials, and apply economic analyses to determine the net benefits of manure application.

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APPENDICES

Appendix A: Questionnaire

AN INVESTIGATION ON THE CONTRIBUTION OF MANURE TO SOIL QUALITY AMONG NON-CERTIFIED SMALL-SCALE ORGANIC FARMERS IN THE UMGUNGUNDLOVU DISTRICT OF KWAZULU-NATAL.

1. **Location Characteristics**
   Farm Location_________________________________
   Name of Farm organisation______________________

2. **Farm Characteristics**
   Size of farm (hectares)__________________________
   Number of years cultivated _______________________
   How do you prepare the area for cultivation?

____
____
____
____

Does farmer cultivate other land parcels apart from this farm? Yes_____ No_____
If yes does______hectares distance from homestead_______Kms.

3. **Farming Methods**
3.1 How long have you been involved in farming?
3.2 Type of farming practice? rain fed farming ________ irrigated farming_________
3.3 Which methods do you practice? Manure______fertiliser______
3.4 What are the reasons for using these methods of farming practice?
3.5 What type of crops are grown?

Tubers	Legumes	Grains	Leafy vegetables

4. **Experience and perception of manure use**
4.1 Experience with manure utilization
a) never used b) used but discontinued c) still using

4.2 Positive attributes
a) better crop growth b) kept soil moisture longer c) cheap and always available e) other (specify)

4.3 Negative attributes
a) demands labour& transport b) low nutrient content c) utilization requires technical information d) its performance is slow e) encourage weed growth f) other (specify)

4.4 What factors influenced your decision to use manure?

5. Manure Management

5.1 How do you manage your manure on a short term basis?

5.2 Management of manure on a medium term

5.3 How do you store the manure?

a) Heap stored b).pit stored c) under plastic

d) In a shed e) cover with layer of soil e) other (specify)

5.4 Why do you store manure?

a) to decompose b) to accumulate: before use c) other (specify)

5.5 How long do you need to store the manure before it is applied to the field?

5.6 Which inorganic fertilisers do you add to manure?

Synthetic fertilisers added	Reason for addition

5.7 Can you comment on whether you have used manure or chemical fertiliser alone and what was the difference between the two?

5.8 What have been some of the benefits using manure alone, chemical fertiliser alone and using them together?

____
____

5.9 Do you mix manure from different animals or do you handle them separately? Yes/No
If yes, which ones?
a) cattle manure+poultry b) cattle manure+sheep c) cattle manure +goats
c) all these manures together

5.10 Can you explain and demonstrate the methods used to apply manure to your fields?

____
____
____
____

5.11 If you need more manure, how would you increase it?
a) ________ b) ________ etc.

5.12 How would you improve the quality of your manures?
a) ________ b) ________ etc.

What are the indicators of good quality manure before application?
____
____
____

5.14 Do you normally make compost? Yes/No
If yes, how often do you make it? Can you demonstrate how you make compost?
a) throughout the year b) just before every season
c) other (specify).

____
____
____

5.15 Where did you learn about composting?
a)__________ b) ________etc.

____
____
____
____

5.16 What are the major constraints of using compost?

____
____
____
____
____

5.17 Do you know of any additional techniques that other farmers use to manage their manures?
a) ________ b) ________etc.

Appendix B: Force Field Analysis Results

Ingwe Family Project

POSITIVE FORCES FOR ORGANIC FARMING

- Improved supply of technical information 2
- Composting 3
- Training 1

NEGATIVE FORCES FOR ORGANIC FARMING

- Difficulty in application 4
- Insufficient manure 3
- Growth of weeds 5
- Increased transport cost 8
- Equipment 7
- Lack of technical information 6
- Lack of training and extension service 1
- Location 2

Inyamvubu

POSITIVE FORCES FOR ORGANIC FARMING

- Improved supply of technical information 2
- Composting 3
- Proper storage 4
- Training 1

NEGATIVE FORCES FOR ORGANIC FARMING

- Difficulty in application 3
- Insufficient manure 4
- Growth of weeds 5
- Increased transport cost 7
- Equipment 1
- Lack of technical information 6
- Lack of training and extension service 2

Umphumela

POSITIVE FORCES FOR ORGANIC FARMING

- Improved supply of technical information 3
- Training 1
- Transport 2

NEGATIVE FORCES FOR ORGANIC FARMING

- Difficulty in application 6
- Insufficient manure 4
- Growth of weeds 7
- Increased transport cost 3
- Equipment 5
- Lack of technical information 2
- Lack of training and extension service 1

Appendix C: Soil sample analysis

Page 1

FERTILIZER ADVISORY SERVICE

KZN Department of Agriculture and Environmental Affairs; Soil Fertility and Analytical Services; Private Bag X9059, Pietermaritzburg 3200. Tel : 033-3559194. Fax : 033-3559454. Enquiries:Ruby Punwasi

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SUMMARY OF ANALYTICAL RESULTS

(These results may not be used in litigation)

Batch : 130 Year : 2008 Printed : 2008/02/28

Your sample ID	Lab number	Sample density g/mL	P mg/L	K mg/L	Ca mg/L	Mg mg/L	Exch. acidity cmol/L	Total cations cmol/L	Acid sat. %	pH (KCl)	Zn mg/L	Mn mg/L	Cu mg/L	MIR clay %	MIR org. C %	MIR N %
1	F2721	1.13	13	453	1242	761	0.10	13.72	1	5.52	4.4	3	5.0	26	2.5	0.29
2	F2722	1.07	20	230	785	318	0.76	7.88	10	4.14	5.8	13	9.7	> 60	3.2	0.24
3	F2723	1.18	5	342	924	278	0.09	7.86	1	4.78	2.0	8	2.7	38	1.8	0.15
4	F2724	1.29	4	161	192	74	0.51	2.49	20	4.14	1.6	6	0.4	14	1.6	0.12

Comments:

(1) Recommended rates of fertilizer and lime for the relevant crops are reported on the following pages. No recommendation will be given for crops not entered on the submission form.
(2) Recommendations are not provided for subsoil samples.
(3) It is assumed that samples submitted for crops and for the establishment of pastures were taken from the top 15 cm of soil. For the maintenance of established pastures, a sampling depth not exceeding 10 cm is assumed.
(4) It is assumed that the lime to be used has a neutralising value equal to 75% of that of pure calcium carbonate. Dolomitic lime is recommended if soil Mg levels are low, and calcitic lime, if soil Mg exceeds 0.6 x soil Ca. Where Mg is sufficient, but not excessive, either type of lime may be used. If lime is not necessary, but the soil Mg level is suboptimal for the intended crop, this is indicated under the "Lime type" heading with the comment "low Mg". Consult your advisor for the most cost-effective method of improving Mg status.
(5) Phosphorus recommendations are based on a water-soluble P source.
(6) The recommendations are based on the assumption that the soil sample is trully representative of the land and that other growth factors are not limiting.
(7) Organic carbon, total nitrogen and clay percentage, estimated by mid-infrared (MIR) spectroscopy, is given for most samples. MIR measurements should be viewed as reasonably reliable estimates. Actual C, N and clay percentages (as well as S concentrations) can be determined (at extra cost) on request.

Fertrec 6 ..... Naidoo Denvei / Naidoo Denvei

NUTRIENT AND LIME RECOMMENDATIONS

Cabbage; irrigated

Sample ID	Lab Num	NITROGEN		PHOSPHORUS			POTASSIUM			LIME				ZINC
		Yield target t/ha	Req. N kg /ha	Sample soil test mg/L	Target soil test mg/L	Req. P kg/ha	Sample soil test mg/L	Target soil test mg/L	Req. K kg/ha	Sample acid sat. %	PAS %	Req. Lime t/ha	Lime type	Zinc fert. reqd.?
2	F2722	100.0	200	20	33	115	230	200	0	10	1	3.5	Dol/Calc	No

Sample soil test and sample acid saturation reflect the soil test values of the sample submitted. Required P and required K (coloured red) are the amounts of P and K required to raise the soil test to the target value. Lime required (coloured red) is the amount of lime needed to decrease the soil acid saturation to the permissable acid saturation (PAS).

MANAGEMENT GUIDELINES

(1) LIME, IF REQUIRED, SHOULD BE APPLIED AT LEAST ONE TO TWO MONTHS BEFORE PLANTING. It is assumed that the lime will be incorporated to a depth of 20 cm. Thorough incorporation is essential: discing followed by ploughing is recommended.

(2) Where P levels are considered adequate, but are less than 120 mg/L, an application of 40 kg P/ha has been recommended to ensure adequate growth.

(3) Where the soil P test of a sample is abnormally high (>120 mg/L), a response to P fertilizer is unlikely. However, P fertilizer may be applied to ensure that adequate P is available over the entire area to be cropped.

(4) Apply 65% of the recommended N at planting of seedlings and the remainder four weeks after planting.

(5) Nitrogen recommendations given above should be used as a guideline only as there are many situations where lower N rates are more cost-effective. Details are given in the leaflet "Nitrogen fertilization: Allowing for N mineralization and residual N" which is available from Alan Manson (033-3559100).

(6) To ensure high yields, it is recommended that 60 kg/ha of sulphur be applied at establishment or soon thereafter.

(7) Consult your adviser on the use of micronutrients such as zinc, boron and molybdenum.

FERTILIZER OPTIONS

The following are fertilizer options (given in bags/ha) using DAP, MAP, Double Supers, 2:3:4(38), KCl, LAN and urea. Your local fertilizer adviser can provide additional fertilizer options. The quantities recommended are those for a complete growing season and the management guidelines on the previous page/s should be considered when scheduling applications.

Sample F2722 Yield target (t/ha) 100.0

(1) 11.5 bags/ha DAP; 6.9 bags/ha LAN or 4.2 bags/ha urea.

(2) 10.5 bags/ha MAP; 10.2 bags/ha LAN or 6.2 bags/ha urea.

(3) 11.5 bags/ha Double Supers or Maxifos; 14.3 bags/ha LAN or 8.7 bags/ha urea.

(4) 18.1 bags/ha 2:3:4(38); 8.9 bags/ha LAN or 5.4 bags/ha urea. The 2:3:4 would supply more than sufficient K.

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Fertrec 6 ..... Naidoo Denvei / Naidoo Denvei

NUTRIENT AND LIME RECOMMENDATIONS

Green bean; dryland

Sample ID	Lab Num	NITROGEN		PHOSPHORUS			POTASSIUM			LIME				ZINC
		Yield target t/ha	Req. N kg /ha	Sample soil test mg/L	Target soil test mg/L	Req. P kg/ha	Sample soil test mg/L	Target soil test mg/L	Req. K kg/ha	Sample acid sat. %	PAS %	Req. Lime t/ha	Lime type	Zinc fert. reqd.?
3	F2723	optim.	100	5	22	105	342	100	0	1	5	0	-	No
4	F2724	optim.	100	4	27	100	161	100	0	20	5	2.0	Dol	No

Sample soil test and sample acid saturation reflect the soil test values of the sample submitted. Required P and required K (coloured red) are the amounts of P and K required to raise the soil test to the target value. Lime required (coloured red) is the amount of lime needed to decrease the soil acid saturation to the permissable acid saturation (PAS).

MANAGEMENT GUIDELINES

(1) LIME, IF REQUIRED, SHOULD BE APPLIED AT LEAST ONE TO TWO MONTHS BEFORE PLANTING. It is assumed that the lime will be incorporated to a depth of 20 cm. Thorough incorporation is essential: discing followed by ploughing is recommended.
(2) Where P levels are considered adequate, but are less than 120 mg/L, an application of 40 kg P/ha has been recommended to ensure adequate growth.
(3) Where the soil P test of a sample is abnormally high (>120 mg/L), a response to P fertilizer is unlikely. However, P fertilizer may be applied to ensure that adequate P is available over the entire area to be cropped.
(4) To ensure high yields, it is recommended that 30 - 40 kg/ha of sulphur be applied at establishment or soon thereafter.
(5) Consult your adviser on the use of micronutrients such as zinc, boron and molybdenum.

FERTILIZER OPTIONS

The following are fertilizer options (given in bags/ha) using DAP, MAP, Double Supers, 2:3:4(38), KCl, LAN and urea. Your local fertilizer adviser can provide additional fertilizer options. The quantities recommended are those for a complete growing season and the management guidelines on the previous page/s should be considered when scheduling applications.

Sample F2723 optimum yield
(1) If DAP was used, too much nitrogen would be supplied.
(2) If MAP was used, too much nitrogen would be supplied.
(3) 10.5 bags/ha Double Supers or Maxifos; 7.1 bags/ha LAN or 4.3 bags/ha urea.
(4) If 234 was used, too much nitrogen would be supplied.

Sample F2724 optimum yield
(1) If DAP was used, too much nitrogen would be supplied.
(2) 9.1 bags/ha MAP; 3.6 bags/ha LAN or 2.2 bags/ha urea.
(3) 10.0 bags/ha Double Supers or Maxifos; 7.1 bags/ha LAN or 4.3 bags/ha urea.
(4) If 234 was used, too much nitrogen would be supplied.

Printed 2008/02/28 Page 4

Fertrec 6 ..... Naidoo Denvei / Naidoo Denvei

NUTRIENT AND LIME RECOMMENDATIONS

Pumpkin; irrigated

Sample ID	Lab Num	NITROGEN		PHOSPHORUS			POTASSIUM			LIME				ZINC
		Yield target t/ha	Req. N kg /ha	Sample soil test mg/L	Target soil test mg/L	Req. P kg/ha	Sample soil test mg/L	Target soil test mg/L	Req. K kg/ha	Sample acid sat. %	PAS %	Req. Lime t/ha	Lime type	Zinc fert. reqd.?
1	F2721	optim.	100	13	31	130	453	135	0	1	5	0	-	No

Sample soil test and sample acid saturation reflect the soil test values of the sample submitted. Required P and required K (coloured red) are the amounts of P and K required to raise the soil test to the target value. Lime required (coloured red) is the amount of lime needed to decrease the soil acid saturation to the permissable acid saturation (PAS).

MANAGEMENT GUIDELINES

(1) LIME, IF REQUIRED, SHOULD BE APPLIED AT LEAST ONE TO TWO MONTHS BEFORE PLANTING. It is assumed that the lime will be incorporated to a depth of 20 cm. Thorough incorporation is essential: discing followed by ploughing is recommended.

(2) Where P levels are considered adequate, but are less than 120 mg/L, an application of 40 kg P/ha has been recommended to ensure adequate growth.

(3) Where the soil P test of a sample is abnormally high (>120 mg/L), a response to P fertilizer is unlikely. However, P fertilizer may be applied to ensure that adequate P is available over the entire area to be cropped.

(4) To ensure high yields, it is recommended that 30 - 40 kg/ha of sulphur be applied at establishment or soon thereafter.

(5) Consult your adviser on the use of micronutrients such as zinc, boron and molybdenum.

FERTILIZER OPTIONS

The following are fertilizer options (given in bags/ha) using DAP, MAP, Double Supers, 2:3:4(38), KCl, LAN and urea. Your local fertilizer adviser can provide additional fertilizer options. The quantities recommended are those for a complete growing season and the management guidelines on the previous page/s should be considered when scheduling applications.

Sample F2721 optimum yield

(1) If DAP was used, too much nitrogen would be supplied.

(2) If MAP was used, too much nitrogen would be supplied.

(3) 13.0 bags/ha Double Supers or Maxifos; 7.1 bags/ha LAN or 4.3 bags/ha urea.

(4) If 234 was used, too much nitrogen would be supplied.

Appendix D: Manure sample analysis

PLANT LABORATORY

Soil Fertility and Analytical Services
KZN Department of Agriculture, Private Bag X9059, Pietermaritzburg, 3200
Telephone: 033 3559 448/515 (Margaret Parker) Fax: 033 3559 263

CLIENT DETAILS:

Denver Naidoo,23 Ishwariv
Rd,Raistope

ADVISER DETAILS:

Samples 2
Code 81
Sample receipt date: 2008/02/19

AS-IS results

Summary of analytical results- may not be used in litigation

Sample ID	Lab ID	C %	S %	N %	Ca %	Mg %	K %	Na mg/Kg	Zn mg/Kg	Cu mg/Kg	Mn mg/Kg	Fe mg/Kg	P %	Al mg/Kg	B mg/Kg	Ash %	Moist %	pH
Sample 5	P497			0.52	0.39	0.13	0.41	51.72	160	10.1	310	5914	0.14	1939			35.74	9.42
Sample 6	P498			0.52	0.34	0.11	0.36	51.78	106	7.8	290	5250	0.12	1750			35.85	9.47

PLANT LABORATORY

Soil Fertility and Analytical Services
KZN Department of Agriculture, Private Bag X9059, Pietermaritzburg, 3200
Telephone: 033 3559 448/515 (Billy Zondi) Fax: 033 3559 236

CLIENT DETAILS:

Denver Naidoo,23 Ishwariv
Rd,Raistope

ADVISER DETAILS:

samples 2
Code 81
Sample receipt date: 2008/02/19

100% Dry Matter Basis

Summary of analytical results- may not be used in litigation

Sample ID	Lab ID	C %	S %	N %	Ca %	Mg %	K %	Na mg/Kg	Zn mg/Kg	Cu mg/Kg	Mn mg/Kg	Fe mg/Kg	P %	Al mg/Kg	B mg/Kg	Ash %	Moist %	pH
Sample 5	P497			0.81	0.61	0.20	0.64	80.5	249	15.7	483	9203	0.22	3018			35.74	9.42
Sample 6	P498			0.82	0.53	0.17	0.56	80.7	165	12.1	452	8184	0.19	2728			35.85	9.47