THE USE AND AGRONOMIC EFFECTIVENESS OF KRAAL MANURES IN THE TRANSKEI REGION OF THE EASTERN CAPE, SOUTH AFRICA

BY

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A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Soil Science) in the Faculty of Agricultural and Environmental Sciences of the University of Fort Hare, Alice.

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DECLARATION

I declare that this dissertation describes my original work, except where due acknowledgement is made to the work of others.

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Z.Mkile

Dated this 10th day of April 2001

Place: Alice

DEDICATION

This piece of work is dedicated to my mother, the late Nontuthuzelo.

" A man had a fig tree planted in his vineyard; and he came looking for fruit on it and found none. So he said to the gardener, see here! For three years I have come looking for fruit on this fig tree and still I found none. Cut it down! Why should it be wasting the soil? He replied, Sir let it alone for one more year, until I dig around it and put **manure** *on it. If it bears fruit next year, well and good; but if not, you can cut it down." Luke 13:6-9.*

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ABSTRACT

The Transkei region of the Eastern Cape Province, South Africa has got a high agricultural potential. However, poor nutrient supply is known to be a major yield-limiting factor in this region which, is dominated by small-scale farmers. The main local source of nutrients available in the area is kraal manure, and a number of small-scale farmers are using this resource to address their soil fertility problems. However, the nutrient supply practices of the farmers and their effectiveness have hitherto not thoroughly been investigated. This study was undertaken to address this need, and to provide a basis for efficient and effective use of kraal manure for crop production by resource-poor farmers in the former Transkei. Consequently studies were carried out to: a) document manurial practices in selected districts of the former Transkei, namely Elliotdale, Umtata and Mt. Fletcher b) characterize the fertility status of soils in these three selected areas c) determine the chemical composition of selected kraal manures from the three districts d) determine the direct and residual agronomic effectiveness of selected kraal manure samples using maize as a test crop under glasshouse conditions, and e) determine an application rate of kraal manure which results in the optimization of maize yields.

The results of the investigation into farmers' nutrient supply practices and their perceptions about the use of chemical fertilizers and kraal manure revealed that farmers are keenly aware of the positive effects of supplying nutrients to their crops. They have developed practices that suit the properties of the fertilizers they have at their disposal, assigning particular uses to each, in ways where these complement each other. Of all the nutrient supply practices that have evolved, the application of a mixture of chemical fertilisers, crushed kraal manure, and the seed of beans and pumpkins in the planting furrow is considered to be the most ingenious. This practice, and others, are firmly rooted within the local farming culture, and farmers are convinced of their worth. However, the amounts of nutrients supplied through these practices do not adequately meet crop needs.

The fertility status of the soils in the study area varied between garden and field plots. The majority of the field plots were low in N, P, K, Ca and Zn. The fertility status of home-garden soils was much higher than that of field plot soils as most tested medium to high. This was attributed to the fact that garden plots receive better management attention due to their small size and proximity to homesteads. The pH of both garden and field soils was low (averages of 4.7 for gardens and 4.3 for fields, all measured in KCl), indicating the need for liming of the soils of in the study area for greater agronomic effectiveness.

The nutrient contents of the 105 manure samples collected during the study ranged from 9.9 – 16.7 g N kg^{-1}, 2.0 – 3.6 P kg^{-1}, and 17.2 – 23.7 g K kg^{-1}. The nutrient composition varied with livestock species, geographical location and mineral particle content. Goat manure had the highest N, P and K contents followed by sheep and cattle manure. All manures were low in P suggesting that their agronomic effectiveness could be enhanced by fortification with inorganic phosphates. Manures from Elliotdale had higher nutrient contents than those from Umtata and Mt. Fletcher, which suggested a possible relationship between altitude-related factors and manure quality.

A comparative glasshouse study of 16 selected manure samples applied at a single rate equivalent to 40 t ha^{-1} revealed that all 16 manures increased maize dry matter yields significantly, but response varied with the livestock species that produced the manure. The mean relative agronomic effectiveness (RAE) followed the order: sheep manure (102%)>goat manure (75%)> cattle manure (57%) and was related to the nutrients content of the manures, especially total nitrogen. This pattern of response was repeated in two subsequent residual trials conducted in the same pots. A subsequent pot trial with fewer manure samples, but with a wider range of application rates, revealed that at application rates less than 40t ha^{-1}, the manures produced comparable effects regardless of source animal or nutrient composition. Differences in response were observed only at rates of application greater than 20t ha^{-1} when sheep manure was superior in all cases. These results were confirmed by a field study in which a rate of 5t ha^{-1} manure, regardless of source animal or quality, was found to result in optimum maize yields in the study area. This rate of application could be easily be met with the manure reserves in the area that were estimated to range from 9.79 t to 44.29 t/homestead and to accumulate at an approximate annual rate of 21 t per homestead kraal.

Key words: Kraal manure, Organic wastes, Nutrients, Farmer perceptions, Transkei

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ACRONYMS

ANOVA	=	Analysis of Variance
ARDRI	=	Agricultural and Rural Development Research Institute
ARC	=	Agricultural Research Council
C/ ann.	=	Cycle/annum
DAP	=	Di-Ammonium Phosphate
DFID	=	Department For International Development
DM	=	Dry matter
DMY	=	Dry matter yield
EC	=	Eastern Cape
Exp.	=	Expenditure
FSSA	=	Fertilizer Society of South Africa
GI/cycle	=	Gross income/cycle
GTZ	=	Gesellschaft für Technische Zusammenarbeit
ha	=	hectare
HDRA	=	The Henry Doubleday Research Association
HOH	=	Head of household
ISCW-ARC	=	Institute for Soil, Climate and Water- Agricultural Research Council
L&APC	=	Land and Agricultural Policy Centre
MAP	=	Mono-Ammonium Phosphate
Mg	=	Mega grams or tons
NI/annum	=	Net income/annum
NRF	=	National Research Foundation

NUFU	=	Norwegian University Fund
OM	=	Organic matter
OC	=	Organic carbon
RCBD	=	Randomised Complete Block Design
t	=	ton
TBVC	=	Transkei Bophuthatswana Venda and Ciskei
TRC's	=	Transitional Rural Councilors
SASCP	=	South African Society of Crop Production
SOM	=	Soil organic matter
UOFS	=	University of Orange Free State
UK	=	United Kingdom

CHAPTER 1
INTRODUCTION

The agricultural potential of the Transkei region of the Eastern Cape, an area covering 4,37 million ha in the eastern part of the Province, is based on the region's favourable climatic conditions and abundant availability of water. However, its steep topography does not favour large-scale cultivation. African smallholders occupy 40% of the land in the Eastern Cape of which most is situated in the Ciskei and Transkei regions (Yoganathan and Van Averbeke, 1996). Many households in Transkei use their land allocations for agriculture. Usually, the residential site is large enough to accommodate a garden, in which vegetables and crops are grown. The fields are usually planted to summer crops, mainly maize, and the rangeland is used predominantly for the grazing of livestock (Lent, Scogings and Van Averbeke, 2000).

Most small-scale farmers in the Transkei region and the rest of the Eastern Cape practise mixed farming involving livestock keeping and maize production (Van Averbeke and De Lange, 1995). In 1995 the livestock population in Transkei was counted and found to consist of 1.58 million cattle, 2.99 million sheep and 1.85 million goats (Department of Agriculture, 1995). During the night, the small stock consisting of goats and sheep are usually kept in kraals (thorny pens) for security reasons (Bembridge, Coleman and Lategan, 1992). The confinement of cattle in kraals occurs mostly during winter except in the case of cows in milk, which may be kraaled throughout the year to enable milking (Masika, Sonandi, Van Averbeke and Goqwana, 1997). With time, the animals' excreta and urine accumulate in layers in the kraal, sometimes mixed with some fodder. Locally, this accumulated material is called kraal manure.

Maize in Transkei is produced mainly under rain-fed conditions on fields ranging in size from 1 to 4 ha. Harvesting of mature dry cobs is done during early winter, but the stover is usually left on the land for village livestock to graze. According to Sanford (1988), this system may remove up to 60% of the nutrients used by maize during its growth. This results in negative nutrient balances, as most local small-scale farmers are risk-adverse, and rarely spend money on fertilizers to replenish the nutrients lost from the soil through crop removal and other ways (Van Averbeke and De Lange, 1995). Manure contains N, P, K and micronutrients, which are essential for plant growth. The nutrient composition is, however, variable and depends on type of animal manure, the plane of nutrition of the animals that produce it, and environmental conditions during storage and handling.

Poor nutrient supply to arable lands is one of the critical factors limiting maize yields in the Transkei region (Bembridge, 1984). Programmes initiated during the 1980s to rectify the situation using chemical fertilizers supplied as part of production packages failed, however, due to poor recovery of loans from participating farmers (L&APC, 1995). As a result, the yield levels of all agronomic crops under traditional systems of agriculture are generally very low. This led to regional food shortages that were satisfied by importing food from the "white" farming areas of South Africa. Due to increasing demand for food, and the need to achieve regional food self-sufficiency, there is an urgent need to improve agronomic practices in African sma[illegible] areas. It is for this reason that available resources such as kraal manure, need to be utilized optimally to increase crop yields.

Farmers in the Eastern Cape try to address the problem of declining soil fertility by using kraal manure that is available in their homesteads (Bembridge *et al.*, 1992; Van Averbeke and De Lange, 1995). A recent survey of manuring practices in the Border and Ciskei regions of the Eastern Cape revealed that 54% of the responding owners of kraals used kraal manure as a fertilizer (Yoganathan and Van Averbeke, 1996). The effectiveness of the applications of manure were, however, doubtful as rates of application were found to vary widely among farmers and were without sound basis.

Experiences from Zimbabwe show that the quality of manure varies widely due to variations in chemical composition (Tanner and Mugwira, 1984). As a result recommended manure application rates in communal areas of Zimbabwe are also quite variable, ranging from 4.5 to 20 t ha^{-1}. Thus, for manure application to be effective, optimum rates of application need to be determined for each unique kraal manure. Information on the nutrient contents of kraal manures and optimum rates of application for cabbages produced under irrigated conditions is available for central Eastern Cape (Yoganathan, Sotana, Van Averbeke, Mandiringana, Materechera, Harris and Mnkeni, 1998), but not for the Transkei region, which differs from central Eastern Cape in terms of agro-ecology. The main objective of the study was therefore to generate information that would provide a basis for the effective use of kraal manure in crop production by resource-poor farmers in the former Transkei. The specific objectives of the study were:

(a) To document manurial practices in selected districts of the former Transkei.

(b) To characterize the fertility status of soils in selected communal areas of the former Transkei.

(c) To determine the chemical composition of selected kraal manures from three districts of the Transkei region of the Eastern Cape.

(d) To determine the agronomic effectiveness of selected kraal manure samples differing in chemical composition using maize as the test crop.

(e) To determine kraal manure application rates which result in optimum maize yields under glasshouse and field conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Historical overview of African farming in the Eastern Cape

According to Hammond-Tooke (1993) black people in South Africa belong to a group of Bantu-speaking tribes, of whom the Nguni settled along the East Coast. As the Nguni moved southwards into the Eastern Cape, they took over land occupied by the San (hunter-gathers) and the Khoikhoi (pastoral people), and assimilated these groups by way of trade and intermarriage (Bergh, 1984). The Nguni people can be subdivided into two large groups, namely the North Nguni (Zulu-speaking people) and the South Nguni (Xhosa-speaking people). The South-Nguni included the Mpondo, Mpondomise, Thembu and Xhosa tribes. Of the South-Nguni tribes, the Xhosa settled farthest south, and were most influenced by interactions with the Khoi. By 1686 Xhosa-speaking people had settled as far south as the Buffalo River, by 1736 they occupied all land northeast of the Keiskamma River, and by the end of the 18^{th} century they also held land west of the Great Fish River (Bergh, 1984).

The Xhosa settled mainly in the Coastal Belt and Coastal Plateau of the Eastern Cape. Their settlement pattern consisted of a disperse distribution of single homesteads (***umzi***), preferably situated on a slope about three to four hundred metres above a river. Distances that ranged from a few hundred metres to several kilometres separated homesteads from each other (Derricourt, 1974). A homestead consisted of several huts arranged around a kraal or byre made of brushwood similar to those found in the central and coastal parts of present-day Eastern Cape. Generally, homesteads were independent units of production that provided for their own subsistence (Bundy, 1979). The traditional Xhosa hut consisted of a wooden frame covered with thatch or grass mats. The opening of the kraal faced the hut of the homestead head, and cattle were returned to the kraal every night. According to Shaw (1974), the traditional fencing material for Nguni kraals was brushwood, or closely packed stacks. Among the South Nguni the gateway to the kraal has a special ritual significance, and among the Xhosa it faced the door of the main hut belonging to the male in authority of the homestead.

Before colonial times, the economies of African chiefdoms in the Eastern Cape were based on pastoralism, agriculture, hunting and gathering (Beinart and Bundy, 1980). There is not much information about Xhosa traditional cropping practices prior to the arrival of Europeans. It is generally accepted that the Xhosa were mainly pastoralists (Soga, 1931; Sobahle, 1982). The Xhosa farmed with cattle, and the herd was really a dairy herd. Sour milk constituted a major component of their diet (Hammond-Tooke, 1993). Slaughtering of cattle was reserved mainly for ceremonies, and meat was derived from hunting. Both hunting and handling of cattle were male domains.

The Xhosa also practised hoe-agriculture on small fields, planted a range of crops, including sorghum, pumpkins, gourds, calabashes, melons, wild peas, beans (several varieties), cocoyam, guavas, mangoes and tobacco (Bundy, 1979). Sorghum, the main grain crop, was gradually replaced by maize during the 18th and 19th century. Cultivation was the responsibility of women. Each married woman tended the crops on the field that had been allocated to her by the male head of the homestead. The number of fields cropped by a homestead was usually determined by the number of wives a man had (Bundy, 1979). The main tilling instrument was a primitive hoe or pointed spade (*ikhuba*), shaped out of hardwood (Bundy, 1979). When the soil in a field became exhausted a new and preferably forested piece of land was cleared. The men helped with the clearing of new land.

During the 19th century, African farming in the Eastern Cape became affected by the migration of European settlers, who moved from the Cape westwards in search of farmland. Conflicts between the two groups occurred towards the end of the 18th century and concerned control over the area situated between Bushmen River and Fish River, known as the Zuurveld (Van Averbeke, 2000). During the first half of the 19th century, military conflicts with white farmers and the British colonial powers caused Xhosas to be driven east, first from land west of the Fish River, thereafter from land west of Keiskamma River, and finally from land west of the Kei River (Thompson, 1991).

In the vacant Ciskei region, a group of African refugees (Fingos) were settled near Grahamstown in 1835, and later moved to Peddie (Bundy, 1979). They adopted many elements of the British culture, including religion, education and agricultural practices. In 1847, the land between the Fish and Kei river was annexed by the British, and turned into a new colony called 'British Kaffraria'. After Mlanjeni's war, which lasted for a period of three years (1850-1853), the resistance of the Xhosa against the invaders was broken completely. Soon thereafter, the Xhosas lost more than 80% of their animals due to lung sickness, a lethal cattle disease from Europe. In desperation, the Xhosas responded to a prophecy of Nongqawuse, who promised the demise of the European colonists if the Xhosa killed all their cattle and destroyed their granaries. The results were that a large number of Xhosas died of starvation. Many of those who survived became dependent on selling their labour on farms and in towns and villages (Bundy, 1979). During the rest of 19th century many Xhosas, especially men, became farm workers and ox-wagon drivers and entire Xhosa families resettled onto white-owned farms as sharecroppers and labour tenants. The old way of life of the Xhosa nation, which had its people relying on agri[illegible] their subsistence, was never to return.

During the 19th century many factors encouraged Africans in the Eastern Cape to change from pastoralists into cultivators. Loss of land to the colony rendered the remaining pasturage insufficient to support subsistence based on the pre-colonial farming system. Settlers from Europe, such as the 1820 British settlers and the 1858 German settlers, introduced new agricultural technology to the region, including new crops such as potatoes and small grains e.g. wheat, and new production technology such as the iron hoe, the plough, and animal draught, which made cultivation less labour intensive than before. Politically, the adoption of cultivation by Africans was also encouraged, especially during the 1850s, when Sir George Grey was the Governor of the Cape Colony (Crais, 1992).

From about 1830 onwards, the first African communities of cultivators developed in mission settlements in the Eastern Cape (Bundy, 1979; Crais, 1992). The Peddie Mfengu adopted cultivation as a dominant agricultural activity during the 1840s (Bundy 1979). During the 1860s, after the great cattle killing, a large number of Mfengu were moved from Peddie, and resettled on land around the town of Butterworth in Transkei from which the Xhosa had been evicted. The migration of the Mfengu to Transkei encouraged the transformation of agriculture in that region also (Sobahle, 1982). From about 1880 onwards, cultivation and the use of the plough became common among the Xhosa and large crops of grain became their staple food, thereby substituting milk to a large degree (Soga, 1931). African farmers were able to obtain larger crop yields than before, because the use of the plough enabled cultivation of much larger areas than was the case when wooden hoes were used (Brown, 1969). The shift from pastoralism to cultivation, and the adoption of new technology, also had an effect on gender relations. In the 1870s one thoughtful civil servant was overheard commenting that: "The more general use of the plough for gardening and other purposes by performing work which in former years was done solely by women, is everywhere observable, and may be regarded as a powerful ally in restricting the extension of polygamy, and obstructing if not entirely stopping its progress and advance. In former times when gardening and planting of all kinds was imposed upon women, the necessity of having more than one wife, if only for gardening purposes [illegible]nce felt, but the introduction of the plough has tended to remove this necessity." (Bundy, 1979 citing the Blue Book for the Cape Colony, 1875).

The period 1880 to 1910 became known as the boom period of African commercial farming, with many peasant farmers producing surplus for sale on the market (Bundy, 1979). After 1910, there was a sharp decline in African commercial farming. According to Bundy (1979) the land Act of 1913 was the main cause for this decline, because it limited access to agricultural land by Africans to designated native areas only. Bembridge (1984) suggested that land degradation and the depletion of soil fertility following decades of cultivation was another reason for the demise of African commercial agriculture in the Eastern Cape. Be that as it may, from 1910 onwards Africans in the Eastern Cape became heavily dependent on off-farm sources of income, mainly secured by men becoming migrant labourers during their most productive years. As a result, farming was left to women, old people and children (Van Averbeke, 2000).

The passing of the Native Land Act in 1936 saw the introduction of 'Betterment Planning' in an attempt to halt land degradation in the native reserves. The Act called for subdivision of land into designated functions (residential land, arable land and rangeland), and caused the 'villagisation' of the African areas of the Eastern Cape during the period 1940 to 1980. Generally, agricultural production in the African areas declined further. During the 1980s, when Ciskei and Transkei were independent homelands, there were attempts to revitalise African agriculture by means of subsidized development projects, but these proved not sustainable in most cases (Van Averbeke, 2000).

2.2. The present status of African agriculture in the Eastern Cape

Typically, a village settlement in the former Ciskei and Transkei has its own land resources attached to it. This land is usually held under some form of communal tenure. Most of the land in the two former homelands of Ciskei and Transkei was planned (Betterment Planning). This involved the subdivision of the land resources available to a group of people into three categories, namely residential land, fields for crop production, and rangeland. It also changed the settlement pattern from disperse clusters of homesteads to a concentrated village settlement (Van Averbeke, Gomm, Haas, Lohmeier and Sindinile, 2000).

Homesteads are situated on residential land. During the early phases of planning, residential sites were large, especially in Transkei where households were allocated sites of nearly 0.5 ha (70m x 70m). Besides providing space for the erection of a dwelling, such sites were large enough to accommodate a large home garden, and one or more kraals to pen livestock at night. When these sites got occupied, new residential land had to be excised from the rangeland to provide for new households. However, the size of new sites tended to get progressively smaller over time, and in some areas was limited to 0.09ha (30m x 30m), leaving very little space for a home garden (Van Averbeke *et al.*, 2000 a).

Traditionally, married men residing in a settlement would apply for a residential site and a field for crop production to the local authority (headman or chief). To acquire a residential site and access to the settlements' rangeland was usually not a problem, but obtaining a field became progressively more difficult as the arable land available for allocation ran out (Van Averbeke *et al.*, 2000a). For example, in the late 1940s nearly 30% of those eligible to hold land (married men and widows) in Chata (Keiskammahoek District) were considered landless, because they had no field of their own (Mills and Wilson, 1952).

In 1979, 32.0% of the households in Transkei had arable land holdings that exceeded 2 ha, 6.0% had holdings between 1 and 2 ha, 52.0% had holdings between 0.1 and 1 ha, and 10.0% were totally landless (Bembridge, 1984). According to Bembridge (1984) a household required 3.8 ha of arable land to meet its annual maize needs of about 1 ton of grain. Van Averbeke *et al.* (2000a) determined that in 1979, when the population of Transkei totalled about 2.5 million people, and consisted of approximately 416 700 households, at least 283 360 households (68%) had insufficient land to meet their subsistence needs for maize grain. Estimating the 1999 population of Transkei to total about 3,5 million people and 583 000 households, taking into account that very little additional land was made available to Transkei after 1980 and assuming that landholdings in communal areas are inherited by the eldest son, Van Averbeke *et al.* (2000a) estimated that during the period 1980-1999 an additional 166 300 households were added to the 1980 total of landless households. The estimated distribution of land holdings in Transkei, is shown in Table 2.1.

Most of the arable land that is cropped in Transkei is planted to maize, and in 1980, 88% of the area under food crops was planted to this crop (Bembridge, 1984). According to Bembridge (1984), there is strong evidence that maize yields in Transkei have declined since the 1930s, when the average yield for the period 1918 to 1927 was 636 kg ha^{-1}. During the period 1974 to 1980 the average yield had declined to 252 kg ha^{-1} (Bembridge, 1984) and in 1998 it was estimated to be 189 kg ha^{-1} (Andersson and Galt 1998). The main reasons for the general decline in maize yields appear to be soil erosion and nutrient depletion.

Table 2.1. Estimated distribution of arable landholdings in Transkei (1999).

Arable land holding	Number of households	Proportion of total number of households
>2ha	133 333	22.9%
1.01 – 2.0ha	25 000	4.1%
0.1- 1.0ha	216 667	37.2%
Landless	207 967	35.7%
Total	**582 967**	**100.0%**

Source: Van Averbeke *et al.*, 2000a

Apart from the decline in maize yields, there also appears to be a reduction in the area of arable land that is cultivated annually. No data on Transkei are available, but work conducted in two settlements in Ciskei by Van Averbeke, Harris, Mbuti, and Bennett, (1998) demonstrated that only a small proportion of the available land was under cultivation, and in both settlements more than 70% of the fields had not been cultivated for at least five years. Using observations and accounts of key informants as evidence, Van Averbeke *et al.*, (2000a) suggested that the abandonment of crop production on fields also occurs in Transkei. Reasons for the abandonment of field crop production are many, and include the lack of draught power, the risk of crops being damaged by livestock because of the deterioration of fences, lack of labour, and poor yields (Van Averbeke *et al.*, 2000a)

According to Van Averbeke *et al.*, (2000a) the agro-ecology of the Eastern Cape suits cattle and other animal production, because much of the land is suitable for use as rangeland only. They identified the enormous number of animals that are kept alive on the available land as one of the most intriguing aspects of livestock production in the former homelands. During this century, cattle numbers in Transkei have remained within a range of 1.1 and 1.5 million, sheep numbers increased from 1.9 million in 1964 to 2.8 million in 1970, and goat numbers increased from 1 million in 1952 to 1.3 million in 1970 (Bembridge, 1984). According to Van Averbeke *et al.*, (2000a) the latest livestock census conducted in March 1995 showed that the situation had not changed. They pointed out that contrary to expectations, cattle numbers had reached their historical maximum of 1.5 million, goat numbers had increased to 1,8 million and sheep numbers had remained close to their 1970 high of 2.8 million (Table 2.2).

Table 2.2. Livestock numbers in historical regions of the Eastern Cape (March, 1995) (from Van Averbeke *et al.*, 2000a).

Agricultural indicator	East Cape	Ciskei	Transkei	Eastern Cape
Land area (ha)	11 886 200	823 137	4 365 263	17 074 600
Land area as a proportion of Eastern Cape total	69.6%	4.8%	25.6%	100%
Cattle numbers	662 978	161 929	1 551 655	2 376 562
Cattle number as a proportion of Eastern Cape total	29.9%	6.8%	65.3%	100%
Sheep numbers	4 052 820	239 972	2 766 760	7 059 522
Sheep numbers as a proportion of Eastern Cape total	57.4%	3.4%	39.2%	100%
Goat numbers	1 185 485	249 991	1 847 440	3 282 916
Goat numbers as a proportion of Eastern Cape total	36.1%	7.6%	56.3%	100%
Large animal unit equivalents (LAU)	1 536 029	243 590	2 320 688	4 100 307
Large animal unit equivalents as a proportion of Eastern Cape total	37.5%	5.9%	56.6%	100%
Stocking density (ha/LAU)	11.12	3.38	1.88	4.16

The apparent increase in livestock numbers in Transkei over the past 20 years has not been explained, but it is likely that this is related to the abandonment of crop production, which made arable land available for grazing purposes.

As was indicated earlier, agriculture is not the mainstay of the rural population. The question arises where rural households in the former Ciskei and Transkei derive their income from? According to Van Averbeke *et al.*, (2000a) there is a dearth of household income studies in Transkei, but a few studies had been conducted in Ciskei. The results of a recent study in two villages in Ciskei are shown in Figure 2.1.

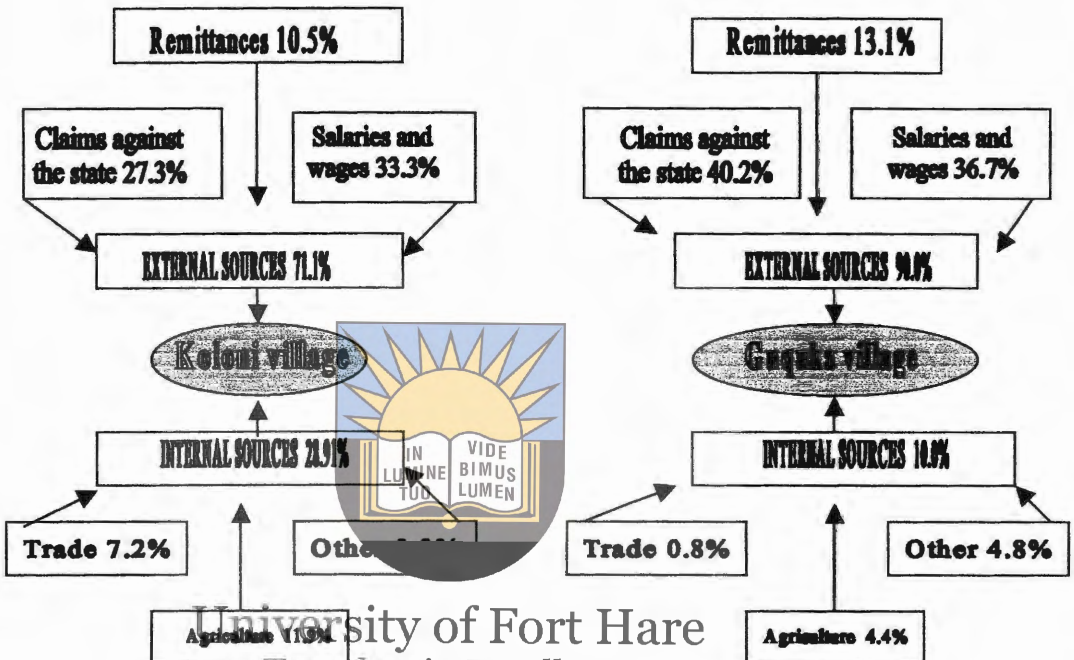

Figure 2.1. Sources of household income (in cash and kind) in Koloni, Middledrift District (n=55) and Guquka, Victoria East District (n =78) (from Van Averbeke *et al.*, 1998).

From Figure 2.1, it is evident that the income of rural households in the two settlements was derived largely from external sources. Local economic activities, including agriculture, trade, and locally supplied services, did not contribute much to average household income. According to Van Averbeke *et al.* (2000a) the same general picture is expected to apply to rural settlements in the former Transkei, but, because of the remoteness of much of Transkei, the contribution of remittances may be relatively more important and that of salaries and wages less important than in former Ciskei.

2.3. Soils of the Eastern Cape

2.3.1. *Soil Classification/groupings*

In the Eastern Cape soil water availability is a key factor to plant growth (Van Averbeke, Scogings, Bally and Van Averbeke, 2000). The soils of this province have aridic to ustic moisture regimes (Van Averbeke *et al*, 2000b cites Soil Survey Staff, 1975). These two water regimes are separated by the 600 mm mean annual rainfall isohyet. In the north west of the province, where mean annual rainfall is less than 400 mm, soils are usually poorly developed and calcareous because of lack of leaching. In the central part of the Eastern Cape where mean annual rainfall ranges from 400 to 600 mm, the soils have generally a neutral reaction, but lime may still be present in the sub-soil (Van Averbeke *et al.*, 2000b). Here, duplex soils (abrupt increase in clay content from surface horizon to sub-soil) and pseudo-duplex soils (gradual increase in clay in clay content from surface horizon to sub-soil) are common. Where mean rainfall exceeds 600 mm per annum, especially along the coast and in the east, soil acidity commonly occurs. Low infiltration rates, soil compaction, shallow rooting depth, phosphorus deficiency, soil alkalinity in the west and acidity in the east are the main factors that limit the potential of Eastern Cape soils (Van Averbeke *et al.*, 2000b).

The following soil forms are all found in the Eastern Cape:

(a) Smectite- rich black clays for example, Mayo soil form (Soil Classification Working Group, 1991) (Mollisols according to the USDA system of classification)

(b) Highly-weathered red and yellow-brown clays for example, Hutton, Clovelly, Avalon soil forms (Soil Classification Working Group, 1991) (Oxisols and Ultisols according to the USDA system of classification).

(c) Strongly-structured clays for example, Shortlands form (Soil Classification Working Group, 1991) (Alfisols according to the USDA system of classification).

(d) The soil forms common to Eastern Cape (and South African) wetlands are Katspruit and Sterkspruit soil forms (Soil Classification Working Group, 1991)

(Gleyosols and Ochric Solonetz, respectively according to the FAO system of classification).

(e) The soil forms predominantly occuring in the Eastern Cape (and South African) non-wetlands and are also found in temporary wetlands are Kroonstad, Westleigh and Longlands (Soil Classification Working Group, 1991) (Ochric lanosols, Plinthic Gleyosols, Plinthic Acrisols, respectively FAO Correlation).

(f) Oakleaf (Soil Classification Working Group, 1991) (Cambisols FAO Correlation), these are deep and well drained soil forms which in most cases are on the river banks and sometimes on highlands. These are the best soils for crop production.

The above listed soil forms are found both in the former Transkei and Ciskei, and former East Cape. In the Transkei region, most of the soils derived from Ecca and Beaufort sediments are duplex, for example Valsrivier, Kroonstad, Sterkspruit and Weisleigh soil forms, whereas some dolerite derived soil forms are deep for example Hutton (Transkei Agricultural Development Study, 1991). According to Laker (1978), medium-textured shallow, young soils, usually on shale or sandstone, predominate in Ciskei region. In this region, the main soil forms are Glenrosa, Mayo and Mispah, which is by far the most widespread soil form (Laker, 1978). The Hutton, Oakleaf, Westleigh soil forms, and to a lesser extent the Clovelly soil form are fairly deep and potentially productive soils. They occur in the Keiskamma, Stutterheim, Tyume, Debe, Frankfort, Smoordrift and Chalumna pedosystems, and to a lesser extent in the Salem and Mpekweni pedosystems (Laker, 1978).

2.3.2. *Soil fertility*

Brown (1969) found soils in Ciskei to be generally poor in soil fertility and ascribed this to the practices of monoculture and continuous cropping, which resulted in vast removal of nutrients with practically nothing being returned to the soil in the form of manures or chemical fertilizers. The most unfortunate part of this system was that the manure in the form of cattle dung was used for purposes other than soil fertility improvement (Brown, 1969). Bembridge (1984) also reported widespread poor-fertility of soils in Transkei, and attributed this to severe soil nutrient depletion caused by poor methods of cultivation. In a more recent study, local farmers in central Eastern Cape identified a decline in soil fertility to be responsible for low crop yields and explained the abandonment of crop production (Mei, Wotshela, Orei, Mdoda and Van Averbeke, 1995).

A study conducted in two villages (Guquka and Koloni) in the central region of Eastern Cape revealed that some soils in this region had very low P and organic carbon contents (Maqubela, 1999). For example, at Guquka, organic carbon was in the range of 0.5 to 1.4% and P in the range of 0.6 to 6.1 ppm, and at Koloni, organic carbon was in the range of 0.4 to 0.6% and P in the range of 3.9 to 5.6 ppm. The low values of P in both villages were attributed to poor supply of P in most soils (Van Averbeke and Yoganathan, 1997). Potassium was adequate in both villages (170- 272 ppm K for Guquka and 92- 216 ppm K for Koloni). Steyn (1988) found that farmers in Ciskei associated the condition or quality of their lands basically to the prevailing climatic conditions, and did not consider soil fertility as an important aspect.

2.4. Review of nutrient supply in African farming

2.4.1. Nutrient Management

2.4.1.1. Pre-colonial times: shifting cultivation

During the pre-colonial period African farmers practised shifting cultivation to maintain the fertility of their cultivated land. Land clearing occurred preferably in forested areas (Bundy, 1979). The dried brushwood was burnt, and the ash constituted a source of nutrients. The Xhosa maintained enclosures in which their livestock was kept during the night. Manure accumulated in these enclosures, but it was not used to fertilize the cropped land (Cole, 1961 as cited by Brown, 1969). The main reason for not using the manure as a fertilizer appeared to be that the Xhosa regarded the cattle kraal as the home of ancestral spirits, and the animals as the medium through which contact was established and maintained with the spirits (Brown, 1969; Shaw, 1974). The Xhosa did use a range of other practices to improve crop yields as reported by Soga (1931), Brown (1969) and Sobahle (1982). Many of these practices appear rooted in constructs (explanations) based on the worldview of the Xhosa about health and disease, and their agronomic value is certainly not beyond doubt. The following are practices that were recorded:

2.4.1.1.1. **Black sand practice (*__Intlabati__* *__emnyama__*)**

> The person 'doctoring' the fields walked around fields scattering handfuls of black sand at intervals until a circle was nearly formed. The reason for leaving the circle open (the 'gap') was to permit air to penetrate the growing crops and prevented the crops from being burnt up (Sobahle, 1982; Brown, 1969; Soga, 1931).

2.4.1.1.2. **The ant- bear practice (*I-Benxa*)**

The skin of the ant-bear (*I-Benxa*), an animal, was used for 'doctoring' poor yielding fields. It was believed to have a powerful influence on crop production. The skin of ant-bear was cut into strips and dried in the sun. The person who had the 'strips' was regarded as fortunate, and got paid for his 'strips' by the people who needed them. A 'strip' was burnt at the edge of the field so that the smoke passed over the field (Sobahle, 1982; Brown, 1969; Soga, 1931).

2.4.1.1.3. **Field / Plant Charm (*Isi-Sukulo*)**

A small shrub called *I-Todlwane* was planted at the bottom of a field for the purposes of assisting in the growth and abundance of crops (Sobahle, 1982; Brown, 1969; Soga, 1931).

2.4.1.1.1. **Incense (*Isi-Qumiso*)**

Several plants were used, for example the wild medlar (*um-Vilo*) (*Pachystigma macrocalyx*) and the wild fig tree (*um-Kiwane*) (*Ficus capensis*). The leaves were burnt and the smoke, which passed over growing crop, assured the owner of the multiplication in quantity of the meal (Sobahle, 1982; Brown, 1969; Soga, 1931).

According to Sobahle (1982), the Xhosa also had knowledge of the different soils that occurred in their environment, and about the characteristics and usefulness of these soils for agriculture. They identified black soil (*u-madakana*), usually found on the banks of rivers, as most suitable soil for agriculture. They also considered sour veld soil (*ijojo*) to be good for cultivation, but knew white soil (*umhlaba omhlophe*) to be poorly suited for production of crops.

It would be expected that African farmers adopted the use of animal manure as a fertilizer when they started using European implements and technology from about 1850 onwards, but generally this appeared not to have been the case. Soga (1931) described the introduction of European technology in Xhosa farming during the 19th century including the use of ploughs, planters, cultivators and 'new' crops, but made no mention of fertilization (organic or inorganic). Apparently, the use of fertilizers in African farming was still absent in 1930 as indicated by Soga's expression of hope that when land occupied by Africans would pass from communal to individual tenure, and owners would hold title to their property, some would manure their soils and practice crop rotation. According to Brown (1969), the ancient practice of selecting fertile sites in valleys and on hill-sides, where soil quality was superior to ensure good yields, persisted after 1930.

The use of fertilizers on cropped land by Africans appeared to have become fairly common after 1960. During the mid-1960s in greater Ciskei, Brown (1969) found that an average of 2.2% of the total ara[illegible] was fertilised with kraal manure, and 1.3% received additions of chemical fertilizers. During the early 1980s, Sobahle (1982) conducted research in Gqumahashe, Melani, Gildara and Roxeni in Ciskei, and reported that many farmers were fertilizing their fields, with the use of manure dominating the use chemical fertilizers. He indicated that farmers applied small quantities of fertilizers, because most mixed the manure with small amounts of chemical fertilizer, and applied this mixture using animal-drawn planters. Work conducted by Steyn (1988) in two locations in Peddie district (Ciskei), showed that 14% of farmers applied kraal manure to their lands during the 1983/84 growing season, and 18% during the 1984/85 growing season in Nyaniso location, which had implemented 'Betterment Planning'. On average, the application rate was less than 200 kg manure ha^{-1}, which was extremely low. In Lujiko location, where Betterment Planning was not implemented Steyn (1988) found that none of the farmers applied kraal manure to their fields during a three-year study period. Research conducted in 1995 in the Border Ciskei region by Yoganathan *et al.* (1998) involving eighty households in six villages, all in possession of one or more kraals on their residential sites, showed that 43 out of 80 used their kraal manure to fertilize their gardens or fields. The mean application rates in the six villages ranged between 2000 kg ha^{-1} and 18000 kg ha^{-1}, and the modal rate was 5000 kg ha^{-1}. Generally, these results indicated that the use of kraal manure to supply nutrients to crops was fairly common practice among present-day African farmers in the former Ciskei. The work by Yoganathan *et al.* (1998) also showed that many farmers applied kraal manure in quantities that were well below the amounts needed to meet the nutrient requirements of the crops they grew.

Not much is known about the utilization of fertilizers by African farmers in the Transkei region. A major study conducted in the Transkei region by Bembridge (1984) revealed that 26.1% of farmers applied kraal manure on their lands, but application rates were extremely low, with 65% of those applying manure on their lands limiting the rate to less than 500 kg ha^{-1}, and only 11% applying more than 1 ton ha^{-1}. Bembridge (1984) also reported that manure was often applied by means of a planter, limiting the amounts that could be applied at any one time.

2.5. Sources of plant nutrients in South Africa and Eastern Cape

2.5.1 Organic manures

In South Africa, three different types of farm manure have been identified and each type showed variability in composition (Malherbe, 1964). These can be differentiated as follows:

(i) Stable manure

Stable manure has large amounts of bedding and is not older than a year. It is found mainly in the winter-rainfall regions of the Western Cape Province (Malherbe, 1964). Thirty six years ago, the district of Malmesbury was a leader in the production and application of stable manure, with approximately 1 million ton of this manure being applied to fields and orchards (Malherbe, 1964).

(ii) Kraal manure

Kraal manure contains little, if any, bedding and has accumulated over a period of a year or slightly longer. It is found in the summer rainfall regions of South Africa for example, Orange Free State, Transvaal and Eastern Cape (Malherbe, 1964).

(iii) Karoo manure or dung

Karoo manure or dung is found in kraals in the arid sheep (or goat) areas. It is usually fairly old and contains no bedding material at all.

According to Yoganathan *et al.* (1998), the present manure application rates in Central Eastern Cape vary widely, ranging from 0.3 to 182 t ha^{-1}. The average amount of manure stored in kraals in six villages was found to range from 0.6 to 18.5 tons at Gxulu, 5.1 to 47.4 tons at Annshaw, 0.1 to 11.9 tons at Ngqele, 1.8 to 35.9 tons at Zalaze, 1.5 to 38.3 tons at Kubusi (Yoganathan *et al.*, 1998). It was found that rural farmers in the central Eastern Cape applied manure based on volumes e.g. wheelbarrows or animal- drawn carts, but available recommendations were usually mass-based (Yoganathan *et al.*, 1998). The frequency of manure application varied from annual to once in ten years (Yoganathan *et al.*, 1998). Only 35% of farmers applied manure every year, 28% in alternate years, and the rest applied once in a three to ten year cycle (Yoganathan *et al.*, 1998).

(a) Quality

According to Malherbe (1964), South African kraal manure differs from European farmyard manure (FYM), and this was attributed to the following reasons:

i. South African kraal manure contains high proportions of insoluble "ash", which is nothing else but very fine, earth or dust. This results in South African kraal manure having higher K content than FYM.
ii. South African kraal manure contains a high proportion of mineral "impurities", and this causes it to contain relatively little organic matter (OM) on dry matter basis when compared with European FYM..

Nitrogen, especially nitrate and ammonium ions are more susceptible to leaching by rain (Stevenson, 1986). This is common in uncovered kraals and the magnitude of nitrate leaching is difficult to estimate, since it depends on the quantity of nitrate available at a particular time, the amount and time of rainfall, and the infiltration and percolation rate of the manure (Stevenson, 1986). Seepage water from wet open kraals may contain water-soluble N compounds, P, K and humus (Malherbe, 1964). The more manure is subjected to leaching in open kraals, the higher will be the loss of plant nutrients. As a consequence such open kraals are expected to contain manure of low quality.

(b) Uses

In the Eastern Cape and some other parts of South Africa, kraal manure is the available resource used by resource-poor farmers in crop production and for other domestic purposes. Besides the use of dung as fuel, it is also used for plastering, floor cleaning, decoration and various medicinal purposes, e.g. treatment of sores (Bembridge *et al.*, 1992). In some rural areas, people collect cattle dung from the veld and fields for use as fuel, especially in areas where firewood is scarce. The actual amount of dung removed from rangelands was found to increase largely according to the cold factor, for example in Herschel, Glen Grey and Whittlesea Districts, between 50 and 60% of the available cattle dung was probably utilised for fuel, whereas in other areas approximately 5 to 10% was used (Schulze, 1968 as cited by Brown, 1969).

2.5.2. Chemical fertilizers

Chemical fertilizers commonly found in South Africa are either straight or compound solid fertilizers, or liquid fertilizers, which could also be straight or compound (FSSA, 1989). Straight fertilizers usually contain only one major plant nutrient, for example super-phosphate (10.5%P), urea (46% N), LAN (28% N). On the other hand, compound fertilizers are divided into two, there are those which contain two major plant nutrients (N and P) for example Mono-ammonium phosphate (MAP), Di-ammonium phosphate (DAP) and 3:2:0 (25), and those which contain three major plant nutrients (NPK) for example, 2:3:2(22), 2:3:2(30), 2:3:4(24), 2:3:4(30) and 3:2:1(25) (FSSA, 1989). Sometimes compound fertilizers contain a small proportion of micro-nutrients for example 0.5% zinc. Resource-poor farmers usually go for the cheapest type of fertilizer mixture (Sewanyana,pers. comm., 2000)[1].

2.5.3. Organic wastes in the Eastern Cape

A study conducted by Maqubela (1999), revealed sixteen sources of organic wastes in the Border region of the Eastern Cape. These are, hoof and horns, tobacco sticks and dust, sewage, pig waste, chicken manure, bone meal, carcass meal, sawdust, blood meal, pouch content, pineapple scales, coffee beans, tip-site waste and market waste. The last two wastes in this list contained foreign materials, and were rated as unsuitable to be used as fertilizer. Of the other fourteen organic wastes identified in the Border region, only tobacco sticks, dried sewage, pig waste and chicken manure were found to have potential for use as fertilizer (Maqubela, 1999).

2.6. Physical properties and chemical composition of organic manure

(i) *Physical properties*

According Malherbe (1964), the physical characteristics of manure vary with season. During wet seasons the manure in open kraals becomes wet and dark in colour. As water infiltrates the manure in open kraals, its density is increased. During dry seasons, the top layer of the manure dries out, allowing air to penetrate the manure, thus facilitating rapid decomposition.

Kraal manure in the central areas of the Eastern Cape was found to contain between 20 and 80% mineral soil particles by mass (Van Averbeke and Yoganathan, 1997). Manures in Zimbabwe were also found to contain mineral particles, but mineral content varied with time of year (Mugwira, 1987). Manures were found to contain an average of 59% sand (soil mineral particles) in December/January and 69% sand in September/October.

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[1] Miss P.T. Sewanyana is an Assistant Director and Head of Umtata dam Soil Analytical Laboaratory

However, some of the manures were found to contain as much as 80% sand (Mugwira, 1987). Apparently during the rainy season mud sticks on animals hoofs and is taken to the kraal thus contributing to increased soil mineral particles in manure. Lupwayi *et al* (2000) working in the Ethiopian highlands also reported incidences of high mineral particle content in manure. They attributed it to the fact that in areas characterized by sandy soils, livestock tend to eat large quantities of sand, resulting in manure consisting of a mixture of dung and sand.

(ii) *Chemical Composition of manures*

A study conducted by Malherbe (1964) showed that kraal manure in the summer rainfall areas of South Africa contained an average of 1.66% N, 0.31% P and 3.24%K when expressed on a total dry matter basis. Yoganathan *et al.* (1998) reported that on average kraal manure from Central Eastern Cape contained 3.8%N, 1.1%P and 5.8% K when expressed on a dry organic matter basis, or 1.9%N, 0.6%P and 2.9%K when expressed on a total dry matter basis. Thus the manures from central Eastern cape had relatively higher total N and total P contents but less total K when compared to the manures described by Malherbe (1964). However, the results of Yoganathan and Van Averbeke (1996) were in agreement with those of Malherbe (1964) with respect to the P content of kraal manures, which in both studies was found to be lower than the N and K contents. The low P content in kraal manure was ascribed to the low P content of the vegetation on which the livestock was subsisting. The low P content of the vegetation, in turn, was related to the general P deficiency of most South African soils reported by Laker (1976).

Yoganathan and Van Averbeke (1996) evaluated the effects of livestock species on the nutrient composition of kraal manures in the central Eastern Cape, and found no statistically significant effects. This was in contrast to findings by Follet, Murphy and Donahue (1981), who reported that the composition of domestic animal manure varied with kind and age of animal, feed consumed, bedding used, and the waste management system.

Work carried out in Zimbabwe on manure quality (Tanner and Mugwira, 1984), and on the effectiveness of manure as a source of plant nutrients (Mugwira and Mukurumbira, 1984) showed that manures from different communal areas were generally of low quality and varied widely in chemical composition, particularly in nitrogen and phosphorus. The average nutrient content of manures from communal areas in Zimbabwe was found to be 1.04% N, 0.15% P and 1.02% K per unit dry bulk kraal manure (Mugwira and Mukurumbira, 1984). It was noticed that P was especially low in manure samples from communal areas (Mugwira and Mukurumbira, 1984). Tanner and Mugwira (1984) concluded that poor grazing, storage and handling conditions in communal areas combined to produce manure with low P and N contents.

West African manures were reported to contain 0.89 – 2.5% N, 0.09 – 0.35 % P and 0.25 – 3.7% K (Williams, Powell and Fernandez-Rivera, 1995). Lupwayi, Girma and Haque (2000) found K to be the nutrient present in the highest concentration in manures from small-scale farming areas in the Ethiopian highlands. The N content of these manures ranged from 0.61 to 2.21 %.

2.7. Nutrient release from organic materials

Nutrient release from organic materials occurs through mineralization. Mineralization is the conversion of organic N, P and S to available mineral forms, i.e. NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}, which occurs through the activity of micro-organisms. It is influenced by factors affecting microbial activities (nutrient availability, temperature, moisture, pH, and others.), as well as by the C:N, C:P and C:S ratios of the decomposing plant residues (Stevenson, 1986). The mineralization process is nearly always accompanied by immobilization (the conversion of mineral forms of nutrients to organic forms) (Stevenson, 1986). Mineralization studies involving ten different organic manures showed that very old manure releases very little N. This was attributed to N immobilization during incubation (Castellanos and Pratt, 1981).

2.8. Agronomic evaluation of organic manures

2.8.1. *Livestock manures alone*

In a glasshouse study using two samples of kraal manure from Chiota Communal area in Zimbabwe, Mugwira, (1984) showed that the effectiveness of manure as a source of plant nutrients depended on the duration of its presence in the soil, and the rate and type of manure used. According to Murwira, Swift and Frost (1993), manure fertilization is a well-established practice in Zimbabwe, as it acts as a supplier of nutrients for low fertility soils (Table 2.3). It was found that the amount of chemical fertilizer used is generally small, and significantly below the levels recommended for the different agro-ecological regions of Zimbabwe (Murwira *et al* 1993).

Field experiments conducted by Yoganathan *et al.* (1998) showed that irrigated cabbage yield was increased by increasing the rate of manure application to 40 t ha^{-1}. No further yield response was observed when manure was applied at rates greater than 40t ha^{-1}. On the basis of the results obtained in their field experiments, Yoganathan *et al.* (1998) concluded that application of kraal manure at a rate of 20 t ha^{-1} per cropping season was adequate to maintain optimum yields of irrigated cabbages.

2.8.2. *Livestock manures in combination with chemical fertilizers*

According to Palm, Meyers and Nandwa (1997), organic fertilizers are often proposed as alternatives to chemical fertilizers. However, the traditional organic fertilizers such as crop residues and animal manures cannot meet crop nutrient demand over large areas, because of the limited quantities that are available, the low nutrient content of the materials, and the high labour demands of processing and application. Most farmers in Africa fall within the two extremes of the organic to inorganic fertilizer continuum, and use a combination of organic and inorganic fertilizers (Table 2.4).

Table 2.3. Recommended rates of manure application for arable cropping in communal areas of Zimbabwe.

Author	Experimental area and type of soil	Recommendation
Alvord (undated)	*	40 t ha^{-1} every 4 years
Cackett (1960)	Matopos-granite sandveld	15- 20 t ha^{-1} manure
Grant (1976;1981)	Kwekwe communal area - granite sandveld	10 t ha^{-1} manure+ 120 kg ha^{-1} N
Johnson (1962)	Chiweshe communal area - granite sandveld	5 t ha^{-1} manure + 191kg ha^{-1} urea at 6 weeks after planning
Rodel *et al.*(1980)	Hernderson Research Station – granite sandveld	4.5 t ha^{-1} manure + 70 kg ha^{-1} P_2O_5 +60 kg ha^{-1} K_2O

(from Murwira *et al.*, 1993)

* Original recommendation for the equivalent to the communal areas in colonial times.

Table 2 .4. The use of nutrient inputs at selected locations in sub-Saharan Africa.

Nutrient source	Location					
	Western Uganda†	Central Uganda†	Western Kenya†	Central Kenya†	Mutoko Zimbabwe*	Shurugwi Zimbabwe*
	---% of farmers---					
Fertilizer (inorganic)	3	4	54	83	98	40
Manures	29	31	79	98	86	65
Crop residues	4	83	72	98	77	-

Source: Palm *et al.*(1997) cite Bekunda and Woomer (1996) † and Murwira *et al.*(1995)*

In Tanzania, experiments investigating the use of combinations of organic manures and inorganic fertilizers showed that organic manures increased crop yields, but the highest yields were obtained by applying a combination of organic manure and inorganic fertilizers (Mnkeni, 1989). This was attributed to the effect of chemical fertilizers, which corrected imbalances of nutrients inherent in manures. In these studies, N was found to be insufficient in some of the organic manures. This was attributed to slow release of N from these manures, which, in most cases, had stayed in kraals for too long (Mnkeni, 1989).

2.9. Farmers' Perceptions

The majority (64%) of farmers in the former South African homelands (Bembridge *et al.*, 1992; Yoganathan *et al.*, 1998) and in India (>60%) (Motavalli, Singh and Anders, 1994) perceived the application of manure to improve crop yields and soil physical properties such as drainage and soil structure. Although some farmers in the former Ciskei perceived application of large quantities of manure to "burn" their crops and serving as a home for insects, which later attacked young growing plants, they credited manure for its long lasting action, and as a supplier of nutrients to crops (Sobahle, 1982; Bembridge *et al.*, 1992; Yoganathan *et al.*, 1998; and Maqubela, 1999).

2.10 Manurial practices

(i) Chemical fertilizers and manures

Bembridge (1984) reported that many small scale farmers (48%) had adopted the practice of applying chemical fertilizers, but the application rates maintained by farmers were far less than the standard recommendation for smallholder agriculture by the Department of Agriculture, i.e. 200 kg ha^{-1} of compound fertilizer. Similar low application rates of chemical fertilizers in small-holder areas have also been reported by Steyn (1988).

With respect to kraal manure application, Bembridge(1984) reported that on average the rates of application used by smallholders in the Transkei ranged between 260 and 530 kg ha^{-1}. Among smallholders in central Eastern Cape, Yoganathan et al (1998) found that 67% of farmers who applied manure as fertilizer did so at rates of 5 t ha^{-1} or less.

Among the reasons stated by farmers for not using kraal manure as a fertilizer were small number of cattle; lack of transport, financial constraints; and old age (Bembridge, 1984; Steyn, 1988; Transkei Agricultural Development Study, 1991;Yoganathan et al 1998).

(ii) Plant response to chemical fertilizers

According to Van Averbeke (1991) the data obtained from field experiments conducted at Potchefstroom during the years 1930 to 1940 showed a significant response of maize to the application of P and manure. Applications of P and manure increased yields by 41% and 48% respectively, and combining the two increased yields by 57% (Van Averbeke, 1991). The Potchestroom results from long-term experiments were so consistent that the standard for maize, not only in the western Transvaal where these results were obtained, but for maize growing areas in South Africa at large, became 10000 plants per morgen (approximately 12 000 plants per ha) fertilized with approximately 16 kg of P ha^{-1} (400 pounds of superphosphate per morgen) (Van Averbeke, 1991). However, in a field experiment conducted in 1951/52 at Frankenwald research station, maize responded to N when the planting density was increased from 12 to 36 000 plants per ha (Altona, 1980). The positive response obtained to the high rates of fertilizers when combined with an increase in plant density heralded a new era in fertilizer recommendations and fertilizer use, which largely persists to date.

It is evident from the above review that the type of agriculture practiced by the mostly black small-scale farmers in the Transkei region is mixed farming involving livestock keeping and crop production. Crop yields, are however, below potential due in part to poor nutrient supply. Programmes initiated during the 1980s to rectify the situation using chemical fertilizers supplied as part of production packages failed, however, due to poor recovery of loans from participating farmers. The review also indicates that proper utilization of the locally available kraal manure could result in improved nutrients supply and crop yields in the region. The studies that are reported in subsequent chapters were thus carried out to generate information that would hopefully contribute to the effective utilization of kraal manures in the Transkei.

CHAPTER 3
MATERIALS AND METHODS

3.1 Experimental area

Three districts in the former Transkei namely Elliotdale, Umtata and Mt. Fletcher were selected for this study to represent low (0-600 m above sea level), medium (700-1100 m above sea level), and high altitude (1500-3000 m above sea level) zones of the regions, respectively (Fig. 3.1). Two administrative areas were included in the study from each district. These were: Ncihana (Approximately 28^0 43^1 E and 31^0 59^1 S) and Ntlonyana (approximately 28^0 48^1E and 32^0 06^1S) in Elliotdale, Qweqwe (approximately 31^0 38^1S and 28^0 40^1E) and Qunu (approximately 31^0 47^1 S and 28^0 37^1E) in Umtata, and Bethania (approximately 30^0 38^1 S and 28^0 19^1E) and Chevychase (approximately 30^0 50^1 S and 28^0 39^1E) in Mount Fletcher. The physical characteristics of study areas are summarized in Table 3.1.

3.2 Soil fertility and nutrient supply practices survey

A purposeful type of sampling was used for this survey, which was conducted between July and September 1998. Twelve households were selected from each of the six administrative areas. To qualify for inclusion in the sample, farmers had to have one or more kraals on their residential sites, and had to be actively involved in crop production. As a result of the selection criteria used, the farmers who participated in this study could be regarded as the most influential or best resourced-farmers in their communities.

Information was collected from each household included in the sample on type and number of animals kept in the kraals; utilization of manure accumulated in the kraal, mode of manure transport to gardens and fields; as well as frequency, timing, rate, and method of manure application. The interview schedule used to collect this information is presented in appendix 1.

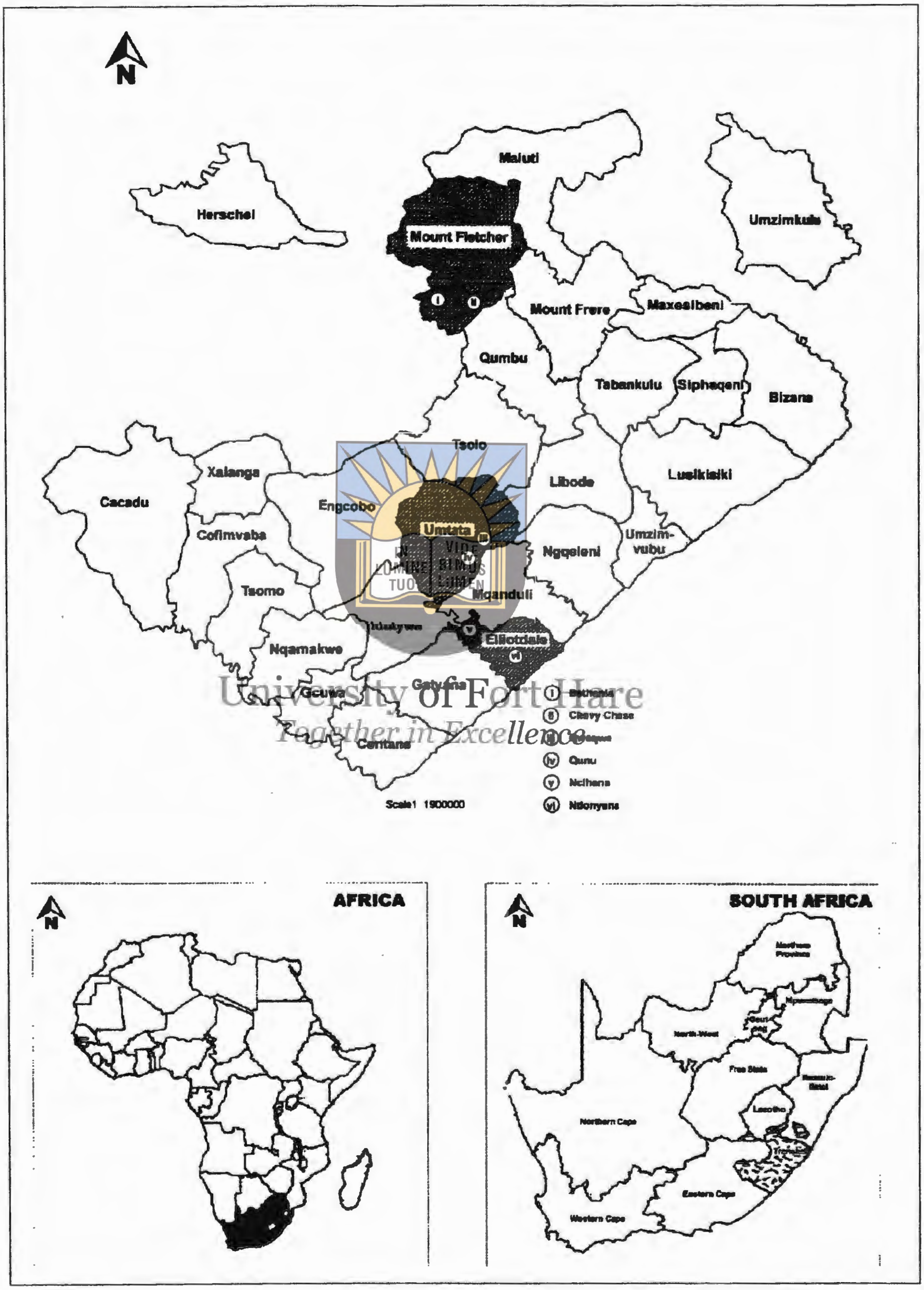

Figure 3.1 Location of the study areas in Africa, South Africa, Eastern Cape and former Tıanskei.

Table 3.1. The physical characteristics of the three study areas.

Districts	Physical factors					References
	Altitude	Rainfall	Temperature	Soils	Major vegetation and veld types	
Elliotdale	Coast 0-600 m above sea level (a.s.l.)	It ranges from 1 300 mm at the coast and decreases to 900 mm as inland is approached	Winter mean daily minimum temperatures range from 13 to 18°C and Summer mean maximum temperatures range from 22 to 25°C.	Soils have low fertility status especially P which is very low	Coastal forest and Thornveld	ARDRI (1989), Acocks (1988)
Umtata	700-1100 m a.s.l.	This district receives an average of 650 mm with maximum in March (100 mm) and minimum in June	Winter mean daily minimum temperatures range from 5 to 11 °C and Summer mean maximum temperatures range from 22 to 35°C.	Same as in Elliotdale	Döhne Sourveld and Valley Bushveld	Transkei Land Reform Research Group (1995), Department of Agriculture and Forestry Engineering Services, Transkei (1990) Acocks (1988)
Mount Fletcher	1500 – 3000 m a.s.l.	It ranges from 800 –900 mm at 1 500 m a.s.l. and from 600 to 700 mm at 1000 m a.s.l.	Variable	Same as other districts except that some soils in this district have leached bases like Mg and Ca	Highland Sourveld	Transkei Land Reform Research Group (1995); (Acocks, 1988) Transkei Agricultural Development Study (1991)

3.3 Soil and Manure sampling

After each interview the dimensions of the kraals including kraal manure depth, gardens and some fields were measured. A hole was dug through the manure layer in the kraal to the point of contact with the soil. Thereafter, a slice of manure was taken from the wall of the hole over the full depth of the manure layer. Manure from different layers was mixed in the kraal at the time of sampling. This was done to simulate the farmers' practice of mixing the manure layers when emptying their kraals. A total of 105 manure samples were collected in this manner for chemical analysis. The manure samples were separately collected from cattle, sheep and goat kraals or mixed kraals (goat and sheep). Top- soil samples (0-150 mm) for soil fertility status evaluation were collected from the gardens and fields during the same period.

3.4 Glasshouse studies

(a) Agronomic effectiveness of manures

The agronomic effectiveness of the manures as sources of nutrients was evaluated using a single manure rate experiment, followed by two residual experiments. The experimental soil was Phandulwazi fine sandy loam, of which the properties are shown in Table 3.2. This soil was used for the preliminary studies, because of its proximity to the University of Fort Hare, and because it is representative of many soils in the Eastern Cape, especially those found in areas where mean annual rainfall exceeds 600 mm.

Two pot experiments were conducted concurrently. One experiment was designed to determine the response of the experimental soil to inorganic fertilizers, whilst the other was designed to evaluate the agronomic effectiveness of the kraal manures. Treatments in the inorganic fertilizer trial included a control and six rates of compound fertilizer [2:3:2(22)+0.5% Zn] calculated to supply 12.5; 25; 37.5; 50; 100; 200 kg N ha^{-1}. In the manure trial a total of sixteen cattle, sheep and goat kraal manure samples selected from the 105 manure samples collected during the survey were used. The manures were selected to represent high, medium and low N categories on the basis of a criterion suggested by Tanner and Mugwira (1984). According to this criterion manures were rated as being of low, medium or high quality when their total N content was <0.90%, 0.90-1.20%, or >1.20%, respectively. The properties of these manures are shown in Table 3.3. A single manure rate of 40 t ha^{-1} was used. Each manure and fertilizer treatment was worked into 5 kg of air-dry potted Phandulwazi soil. The treatments were replicated three times and arranged in a randomised complete block design.

Maize (*Zea Mays L.*) cultivar PAN 6364 was planted on June 4, 1999. Seven maize seeds were planted and thinned to five plants per pot after emergence. The water content in each pot was brought to 80% of field capacity (FC) and maintained at this level by daily watering. Temperatures in the glasshouse were maintained at approximately 18^{0}C at night and 28^{0}C during the day.

On the 19th July 1999, after six weeks of growth, the above-ground plant material was harvested from each pot, dried to constant weight at 65^{0}C and dry matter yields determined using a scale with an accuracy of 0.001g. The samples were then finely ground in a stainless steel grinder and stored in plastic bottles for nutrient analysis as described in section 3.6.

The soil from the pots was allowed to air dry after harvest, before being pulverized, and re-potted after removing the coarse roots. One hundred grams of soil from each pot were collected and kept for analysis after mixing replicate samples of each treatment. A second crop was then established on the re-potted soils for evaluating the residual effects of the treatments.

Table 3.2. The chemical and physical characteristics of soil used for glasshouse studies (Phandulwazi fine sandy loam)

Chemical analysis of soil							
Total N (Kjeldahl) (mg N kg^{-1} soil)	P Bray 1	K	Ca	Mg	Na	pH (KCl)	%OC
	---------------------(mg kg^{-1})--------------------						
47.3	3.3	157	291	205	51	4.4	1.5

Mechanical analysis of soil

Coarse sand %	Medium sand %	Fine sand %	Silt %	Clay %
0.3	1.4	60.7	11	26.6

The residual experiments were conducted by following the same procedures as described for the first experiment, except that neither manure nor fertilizer was added. The pots were replanted with maize as in the first crop and measurements were taken and samples prepared for analysis as for the first crop. The first residual experiment was planted on the 2nd August 1999. This experiment was harvested on the 16th September 1999. The second residual experiment was planted on the 18th September 1999, following exactly the same procedure as for the first residual experiment. It was harvested on the 3rd December 1999.

On the basis of crop response to the 16 manures used in the first experiment and the fertility category of the manures, three manures [S_1H, S_1L and C_2M (Table 3.3)] were selected for a follow-up experiment (rate experiment) to study the effect of rate of manure application on nutrient supply. This experiment was planted on the 13th August 1999, using maize cultivar PAN 6364. Seven maize seeds were planted and thinned to five plants per pot after emergence. The treatments in the study were 0; 5; 10; 20; 40;

and 80 t ha^{-1} (equivalent to 0; 12.5; 25; 50; 100; and 200 g/5 kg potted soil) of kraal manure, and were replicated three times. The water content of each pot was brought to 80% of field capacity (FC) and maintained at this level by daily watering. Temperature in the glasshouse was maintained at approximately 18^0C at night and 28^0C during the day. This experiment was harvested on the 28th September 1999.

3.5 Field Experiment

The field study was conducted during 1999/2000 growing season on Qunu fine loam sand in Umtata district, in the Eastern Cape province of South Africa. This area receives summer rainfall with an annual mean of about 650 mm and is situated at about 700m above sealevel. About 70% of the annual precipitation falls between October and March and the mean maximum temperature varies from 22 to 35 ^{0}C in January while the mean minimum varies from 5 ^{0}C in July to 11 ^{0}C in January. The experimental site was located at Lwalweni location of Qunu Administrative Area at approximately 31^0 37^1S and 28^0 37^1E. It is relatively level, with slope ranging between 1 and 4% and the soil was somewhat poorly drained and classified as a Gleysol (according to the FAO classification).

The experimental design was a randomised complete block (RCBD) with three replications. Each plot was 10 m long and 10 m wide for a plot area of $100m^2$. Treatments consisted of sheep and cattle manures at rates of 0, 5, 10, 20 and 40 t ha^{-1} and a chemical fertilizer mixture 2:3:4(30) at a rate of 400 kg ha^{-1}. The manures were spread and incorporated into soil three days before planting using hand-hoes and spades. The chemical fertilizer was band-placed. Hybrid maize (*Zea Mays L.*) PAN 6480 was planted on the 27th December 1999 at a population of 40 000 plants ha^{-1}. The row and inter-row spacings were 1 m and 0.25 m, respectively.

Table 3.3. Chemical properties of sixteen selected manures used for glasshouse studies.

Treatment	Manure composition											
	(%)								(mg kg^{-1})			
	OC	N	P	K	Na	Ca	Mg	C:N	Cu	Zn	Fe	Mn
S_1H	36.3	2.1	0.2	3.0	2.7	2.4	0.6	17.5	28	106	2931	496
G_1H	32.5	2.2	0.1	1.0	0.5	0.7	0.3	14.7	21	85	10402	388
S_2H	24.2	1.8	0.1	1.4	0.8	2.1	0.5	13.5	33	178	11351	772
C_2L	32.5	0.9	0.1	1.0	0.2	0.6	0.2	34.9	23	67	7291	375
C_1H	30.4	1.9	0.2	2.1	1.2	2.3	0.5	16.2	36	100	10134	579
C_3H	24.2	1.9	0.2	1.7	1.8	1.5	0.5	13.1	28	116	3739	566
C_1M	17.9	1.7	0.2	1.6	0.4	2.3	0.5	10.4	33	105	5685	927
S_1M	26.3	1.6	0.3	2.7	0.5	1.7	0.6	16.5	31	84	5442	445
C_1L	23.5	1.4	0.1	0.9	0.6	1.2	0.3	17.0	26	92	6971	648
S_1L	30.7	0.8	0.1	0.8	0.2	0.8	0.2	37.0	24	82	6432	456
C_3L	28.8	1.0	0.1	0.6	0.4	0.7	0.2	30.5	26	77	9842	449
C_2H	18.8	1.0	0.1	0.8	0.2	1.0	0.3	18.1	27	79	9834	568
S_3H	31.9	2.2	0.2	1.8	0.3	1.4	0.5	14.8	36	93	6125	868
C_2M	34.4	1.8	0.3	1.4	0.7	1.7	0.5	19.7	41	91	11799	919
G_1L	9.3	0.6	0.3	3.0	1.5	3.4	0.3	15.3	38	137	8685	679
G_1M	19.8	1.4	0.2	1.4	1.2	1.4	0.4	14.5	29	99	7906	519

S= sheep, C= cattle and G=goat manures ; H= high, M=medium and L=low qualities and OC= organic carbon

Weeds were controlled manually using hand-hoes. The first weeding started five weeks after planting, while the second and last was done twelve weeks after planting. Stalk-borers were controlled by applying stalk-borer bait[active ingredient carbaryl (carbamate)] six weeks after planting.

In mid February 2000, (six weeks after planting) leaf and soil samples from each plot were collected and prepared for analysis. Topsoil (0-150 mm) was sampled randomly from each plot using a Beater soil sampler. Ten leaves were sampled randomly (one leaf per row) from each plot and brought to the laboratory where they were dried at 65^0C for 48 hours, weighed and analysed, following methods described in section 3.6.

Harvesting was done on the 9th June 2000. Grain yield was determined by harvesting and weighing all the cobs in each plot, while stover yield was determined by harvesting a 6 m^2 area at the centre of each plot. Guard and end rows were discarded. Grain sub-samples were taken for gravimetric moisture determination after being dried at 65^0C for 48 hours. The dried sub-samples were ground, passed through a 2 mm sieve, and used for nutrient content determination following procedures described under section 3.6.

3.6 Methods of Analysis

(a) Manures and soil samples

Air-dried kraal manure samples were analysed for P, Ca, Mg, K, Na, Zn, Mn and Fe content following the sulphuric acid wet digestion procedure described in the Official Method of Analysis of the AOAC, (1988) and (Okalebo, Gathua and Woomer, 1993). Phosphorus in the digest was determined colorimetrically, whilst the other nutrients were determined by atomic absorption spectro-photometry. Organic carbon and total N contents of the manure samples were determined using procedures described by Okalebo *et al.* (1993). The mineral soil particles content of 16 of the 105 the manure samples was determined by ashing the samples at 500°C, dissolving the soluble ash originating from the organic fraction, and equating the insoluble filtrate to mineral soil particle content.

(b) Plant and soil samples

Ground plant and grain samples were digested using a wet ashing technique followed by spectrometric analyses of total N (using an autoanalyzer), P, K, Ca, Mg, Na, pH and micro-nutrients (Official method of analysis of the AOAC, 1988; The Non-Affiliated Soil Analysis Working Committee (1990). Soil samples were analysed for total inorganic N(NH_4^++NO_2^-+NO_3^-), %OC, P, K, Ca, Mg, pH and Zn (Official method of analysis of the AOAC, 1988; The Non-Affiliated Soil Analysis Working Committee (1990).

3.7 *Statistical analyses*

The survey data were analysed using Microsoft Excel and STATISTICA soft wares. Cross tabulation was used to compare crop production and manurial practices from surveyed districts.

Glasshouse and field experimental data were analysed following the ANOVA procedures described by Gomez and Gomez (1984). Fisher's Least Significant difference (LSD) test was used for comparing differences between treatment means. The relative agronomic effectiveness (RAE) values were computed using dry matter yields from pot experiment. The formula used was described by Engelstad, Jugsujinda and de Datta (1974) as follows:

$$RAE = \frac{YM - YC}{YF - YC} \times 100$$

Where:

YF = yield due to references fertilizer

YM = yield due to tested source (Manure)

YC = yield in the control treatment.

CHAPTER 4

RESULTS AND DISCUSSION OF FARMER SURVEY

4.1. Introduction

In Chapter 3, it was indicated that farming households participating in the survey were selected purposefully. To be considered for inclusion in the sample, households had to own livestock and be actively involved in crop production. With reference to agricultural resources, these households were among the best resourced, because they held livestock, owned or accessed land, and were able to bring together the means to grow crops.

4.2 Characteristics of responding farmer households

During each interview, the heads of the farming households we interviewed identified themselves. Typically, heads of household were male (89 %), and older than 50 years (64%). There were few exceptions to this general observation (Table 4.1).

Table 4.1. Gender and age distribution of the heads of responding households interviewed in Elliotdale, Umtata, and Mount Fletcher (n=72; 1998).

Gender of head of households		**Age distribution of head of households**		
Male (%)	Female (%)	<50 years old (%)	50 – 70 years old (%)	>70 years old (%)
89	11	18	64	18

The size of the responding households is presented in Table 4.2. The overall mean household size was nine ranging between a mean of eight in Umtata, and a mean of 10 in both Elliotdale and Mount Fletcher. Overall, the average farming household was composed of four children (people aged less than 15 years), five active persons (people between the ages of 15 and 64), and one aged person (aged 65 or older) (Table 4.2).

Table 4.2. Family size and age composition in three districts of the former Transkei (n = 72; 1998)

	Districts			Overall		
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	Range	Mean	SD
Mean family size	10	8	10	4 – 17	9	3.54
<15 years	5	3	4	0 –14	4	2.59
15 – 64 years	5	4	6	0 - 13	5	2.56
65 years and older	1	1	1	0 – 2	1	0.67

* SD =standard deviation

The mean household size (9) was considerably higher than the means recorded for Ciskei and Transkei by other authors in the past (Table 4.3).

Table 4.3. Household size in different localities of the Eastern Cape.

District/ Region	Household size	Source
Peddie (Ciskei)	4.1 – 5.4	Steyn (1988)
Peddie (Ciskei)	5.1 – 6	Steyn (1988)
Zithulele (Transkei)	5.8	ARDRI (1989)
Wild Coast (Transkei)	5.8	Anderson and Galt (1998)
Engcobo (Transkei)	5.9	Rose (1987)
All former South African homelands combined	6.83	Bembridge *et al.* (1992)
Guquka & Koloni (Ciskei)	6.0	Van Averbeke *et al.* (1998)
Mgwalana (Ciskei)	7.6	Williams and Rose (1989)
Khambashe (Ciskei)	8.0	William and Ward (1989)

In a study of two settlements in former Ciskei, Van Averbeke, Bediako, Langeveld and Barrett (1998) identified four categories of rural African households on the basis of sources of income. One category of households referred to as welfare-assisted households was characterized by deriving their income from multiple sources including claims against the state. Households falling in this category were found to be significantly larger in size than those in other categories, because many incorporated three generations. They had a mean household size of 8.1 persons, compared to an overall mean household size of 6.0.

In Table 4.4, the income of responding households is presented for the three Districts included in the current study. The data exclude income derived from agriculture and other home or village-based income-generating activities.

Table 4.4. Mean household income (per month) of responding farmers in three districts of the former Transkei derived from external sources (n=72; 1998)

Districts	Sources of income		
	Remittances	Salaries	Claims against the State
	(R)	(R)	(R)
Elliotdale	491.67	575.00	482.50
Umtata	409.46	787.50	387.92
Mount Fletcher	1 023.82	0.00	326.67
Overall	**641.65**	**454.17**	**399.03**

Overall, remittances were the most important source of external income for the responding households, followed by salaries and claims against the State (Table 4.4). The situation in Mount Fletcher, which was the most remote of the three districts, differed from that in the other two districts. In Mount Fletcher remittances were much more important than in Umtata and Elliotdale, and none of the 24 households that were interviewed in Mount Fletcher derived income in the form of salaries or wages.

Thirty-seven of the 72 responding households (51%) derived income from claims against the state. Of these 37 households 29 had at least one other source of external income, suggesting that a considerable number (40%) had income characteristics similar to the welfare-assisted households identified by Van Averbeke *et al.*, (1998).

Overall, the 72 households that were interviewed contained 158 economically active persons (aged 15-64) who considered themselves as unemployed. This represents a mean of 2.2 persons per household, and 35% of the total economically active population contained in the sample. No questions were asked about the participation of the unemployed in on-farm activities, but it is expected that most participated in either farming or household activities, or both. The age and gender distribution of the unemployed is presented in Table 4.5.

Table 4.5. Age and gender distribution of economically active people who formed part of farming households group in three districts of the former Transkei and who were unemployed (1998).

District	Age distribution of unemployed group					
	15-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
Elliotdale	5	7	12	12	3	7
Umtata	7	10	10	15	2	5
Mt Fletcher	9	17	8	19	5	5
Total	**21**	**34**	**30**	**46**	**10**	**17**

From Table 4.5 it is evident that in terms of gender, unemployment was more prevalent among women than men. In terms of age, unemployment was more common among people in the age class of 30-49 than among people in the other two age classes.

4.3 Land holdings

In the review of literature it was explained that full land rights in areas where land is held communally means ownership of a residential site and one or more fields, and the right of access to the rangeland held by the community. Residential sites are usually large enough to allow for a home garden, especially those allocated long ago.

The results of the survey showed that all 72 households had a home garden, and six had two. All but one of the 72 households were growing crops in their garden. The sizes of the home gardens differed considerably among respondents in all districts (Table 4.6). On average, the total garden area held by respondents was 0.42 ha in Elliotdale, 0.51 ha in Umtata and 0.32 ha in Mount Fletcher. The overall mean size of the home garden was 0.416 ha per household.

Sixty-eight of the 72 households that were interviewed owned a field, and among these 68 there were 13 who held two fields. The size of the field area held by farmers also differed among districts and among respondents (Table 4.6). The mean size was 1.68 ha in Elliotdale, 3.67 ha in Umtata, and 2.43 ha in Mount Fletcher, and the overall mean was 2.59 ha. Field area calculations excluded the four households not holding fields.

In Transkei, residential sites are not equal in size. Generally, the size of residential sites allocated to people got smaller over time. Sites that were allocated long ago measured 70 m x 70 m, whilst those that were demarcated more recently tended to be smaller, often measuring 50 x 50m or even smaller. This was probably one of the factors that contributed to the observed differences in the size of the home gardens. One village included in the study, namely Bethania in Mount Fletcher was never subjected to planning. In the absence of planning, the size of gardens and fields was determined by the occupant's needs and other factors, but standard measurements as employed by planners did not apply. This was probably another factor causing variation in the size of residential sites, gardens, and fields.

Table 4.6. Size of land holdings of selected farmers in three districts of the former Transkei (n=72; 1998).

Districts	Size of land holdings			
	Total garden area		Total field area	
	Range	Mean	Range	Mean
	(ha)	(ha)	(ha)	(ha)
Elliotdale	0.096 - 1.00	0.42	1.0 – 3.42	1.68
Umtata	0.100-1.24	0.51	0.1 – 4.75	3.67
Mount Fletcher	0.078 - 1.02	0.32	1.0 – 4.05	2.43
All	**0.1 – 1.24**	**0.416**	**1.0 – 4.75**	**2.59**

Fields allocated as part of betterment planning were usually 2 ha to 4.5 ha in size. In Umtata, however, one field resembled a small garden. The owner explained that the field used to be an open space, which was granted to him by the community following his request to use the space as a field.

4.4. Crop production

The crops grown by responding farmers are shown in Table 4.7. Maize (*Zea mays*) was grown by all 72 farmers. Other common crops included pumpkins (curcubits), dry beans (*Phaseolus aureus*), potatoes (*Solanum tuberosum*), and cabbage (*Brassica oleracea*). Radish (*Rhaphanus sativus*), ryegrass (*Secale cereale*), and grain sorghum (*Sorghum bicolor*) were commonly grown by farmers in Mount Fletcher, but not by those in the other two districts.

Table 4.7. Crops grown by selected farmers in three districts of the former Transkei (n=72; 1998).

Crops	**Districts**			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	Total (%)
Maize	24 *	24	24	**100**
Cucurbits	24	23	23	**97**
Beans	21	23	20	**89**
Potatoes	14	17	20	**71**
Cabbage	15	13	12	**56**
Spinach	13	11	6	**42**
Carrots	6	7	5	**25**
Radish	0	0	15	**21**
Ryegrass	0	0	13	**18**
Grain sorghum	0	0	10	**14**
Beetroot	2	5	3	**14**
Peas	3	2	4	**13**
Onion	5	2	1	**11**
Tomatoes	2	1	5	**11**
Fruit	2	0	1	**4**
Turnip	0	0	2	**3**
Sweetpotato	1	0	0	**1**
Wheat	0	0	1	**1**

* number of selected farmers growing crops

4.5 Livestock holdings

(i) *Types of animals and size of herds*

Data on livestock holdings are presented in Table 4.8. In all three areas that were surveyed, the most common livestock species were cattle, sheep and goats. Among the 72 responding farmers combined, the mean herd size was 14 for cattle, 86 for sheep, and 24 for goats, but there were considerable differences among individual farmers and among district means (Table 4.8). In the three districts combined 68 of the 72 farmers owned cattle, 67 owned sheep and 54 farmers owned goats. Herd sizes in Mount Fletcher were larger than in the other two districts (see Table 4.8).

Table 4.8. Livestock holdings among selected farmers in three districts of the former Transkei (n = 72; 1998).

Districts	Livestock								
	Cattle			Sheep			Goats		
	Mean	Range	*SD	Mean	Range	SD	Mean	Range	SD
Elliotdale (n=24)	9	1-24	5	33	1-100	32	18	3-74	16
Umtata (n=24)	9	2-30	8	65	4-320	107	8	2-25	6
MtFletcher (n=24)	23	4-110	23	161	7-890	217	45	2-500	100

* SD = standard deviation

(ii) Kraaling Practices

The frequency of penning of livestock among responding farmers is presented in Table 4.9.

Table 4.9. Night-time penning practices in three districts of the former Transkei (n=72; 1998).

Livestock Species	Elliotdale n=24			Umtata n=24			Mount Fletcher n=24		
	Year-round	Occasional	Not	Year-round	Occasional	No	Year-round	Occasional	Not
Cattle	19	4	1	21	0	3	21	2	1
Sheep	18	5	1	22	0	2	20	2	2
Goats	15	3	6	14	1	9	19	1	4

Of the 72 responding farmers, 61 (85%) penned their cattle, 60 (83%) their sheep, and 48 (67%) their goats every night throughout the year (Table 4.9). These results suggest that year-round night-time penning of livestock is a practice that prevails among farmers in Transkei, especially with regard to cattle and sheep. By implication, it is expected that a considerable proportion of the manure excreted by livestock in Transkei gets deposited in kraals.

(iii) Types of kraals

During the survey four types of kraals were identified, and there were distinct regional differences. The *izinti* kraal was constructed by closely stacking thin tree trunks when building the kraal walls (Plate 4.1.). A fairly small opening is left in one wall to enable livestock to get in and out of the kraal. During the night, this opening is closed off by means of wooden or zink-iron gate. This type of kraal was found in all three districts.

Plate 4.1. The walls of an *izinti* kraal consist of closely stacked thin tree trunks.

The *corral* kraal was made of wooden poles, which were mostly made of gum trees. Long horizontal poles were attached to short vertical poles to form a fenced in enclosure (Plate 4.2.). The *corral* kraal was common in Umtata district.

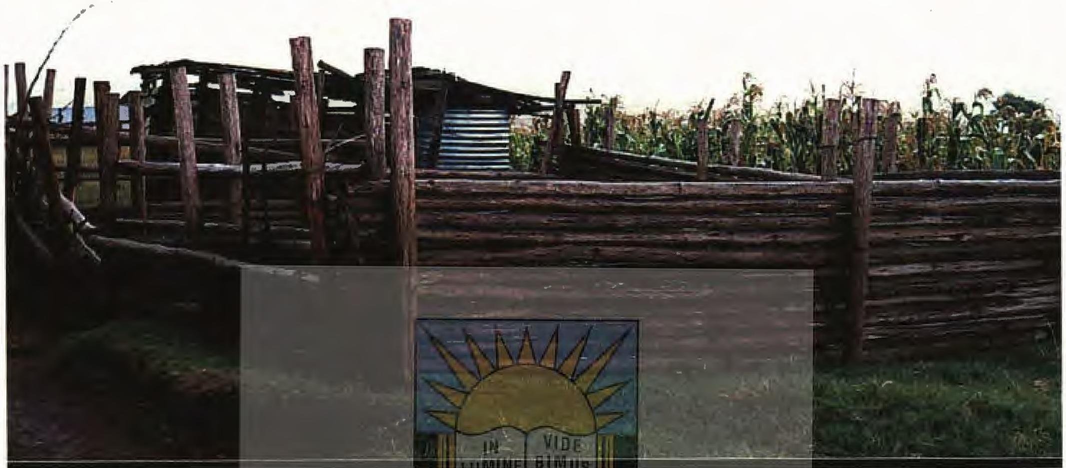

Plate 4.2. The *corral* kraal was constructed of wooden poles and was common in Umtata District.

The *stone-wall* kraal is an enclosure with walls made of dry-packed stones and boulders (Plate 4.3.). The *stone-wall* kraal was very common in Mount Fletcher, but was also found in Umtata.

The *corrugated-iron* kraal had walls made of corrugated iron sheets, usually old roof sheets, but new sheets were also used (Plate 4.4). The *corrugated-iron* kraal was common in Umtata District.

The *brushwood* kraal was constructed by combining thorny wood stems and branches and was typical for Ciskei and western Transkei (Plate 4.5). A fairly small opening is left in one wall to enable livestock to get in and out of the kraal. During the night, this opening is closed off by means of wooden or zink-iron gate.

In Mount Fletcher, Sotho-speaking communities had mainly *stone-wall* kraals, and Xhosa-speaking communities *izinti* and *corral* kraals. According to farmers in Umtata District, the use of *stone-wall, corral, and corrugated-iron* kraals was a response to an increasing scarcity of izinti, which used to be the traditional fencing material for Nguni kraals (Shaw 1974; Stuart and Malcolm, 1986).

Plate 4.3. The *stone-wall* kraal had walls made of dry-packed stones and boulders.

(iv) Sizes and shapes of kraals

In all three districts, the kraals were usually square or rectangular in shape, and very few were circular or oblong. In Mount Fletcher, farmers maintained two sets of kraals, one in the hills for use during summer, and one next to the homestead on the residential site for use during winter. The homestead kraals were also used sometimes to keep animals that were sick, and to contain sheep during shearing time.

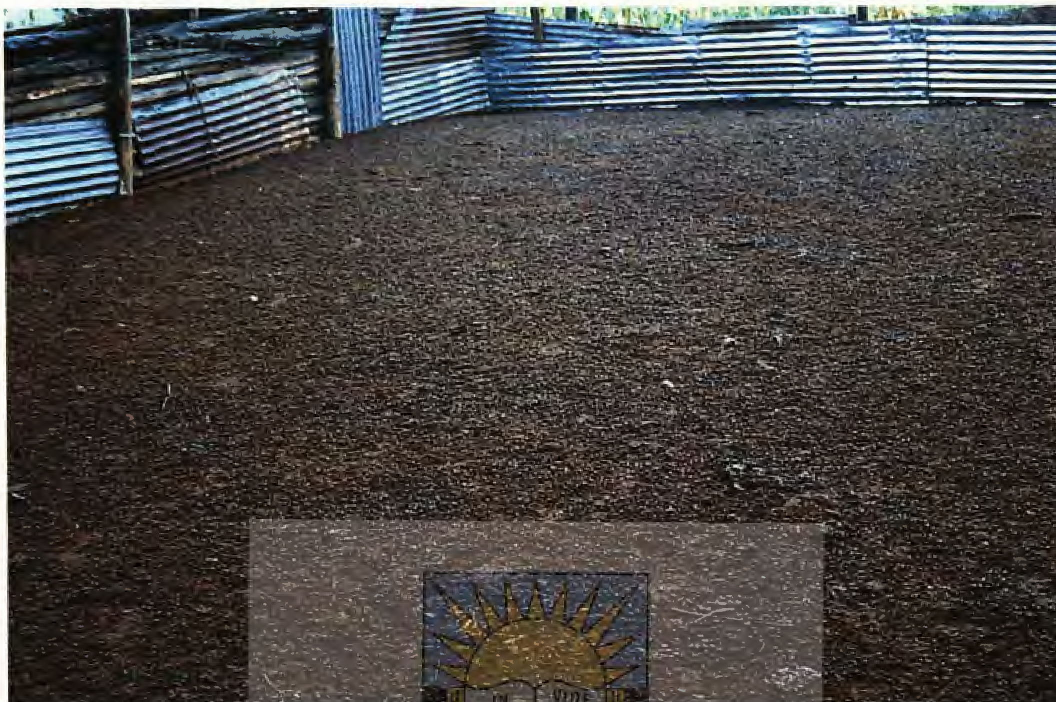

Plate 4.4. The walls of a *corrugated-iron* kraal are usually made of old roof sheets but some farmers purchase new sheets when building a kraal.

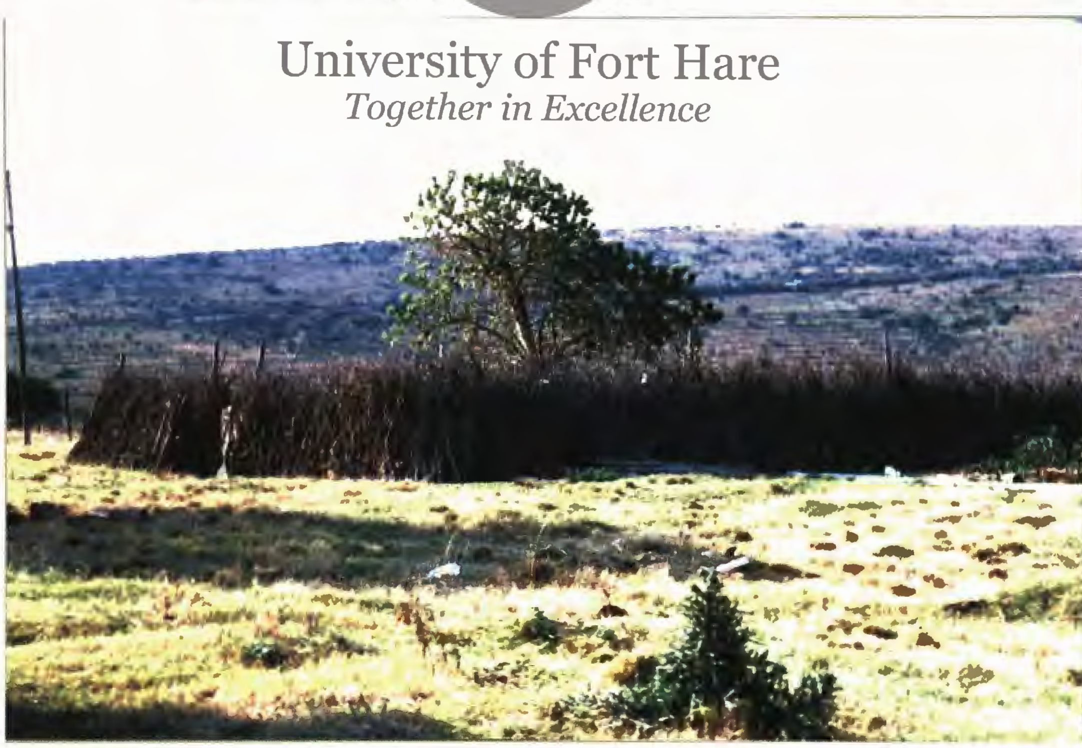

Plate 4.5. The walls of a *brushwood* kraal consists of closely stacked thorn wood

The largest of all kraals was a cattle kraal in Mount Fletcher. It covered an area of 2,500 m^2. It used to be the farmer's garden before it was transformed into a kraal to accommodate growth in the farmer's herd (Table 4.10.). The largest sheep kraal (370 m^2) was also in Mount Fletcher, and the largest goat kraal (370 m^2) in Elliotdale.

Next to many kraals in Umtata, there were cow dung structures shaped as beehives and plastered on the outside with fresh manure (Plate 4.6.). These were used to store manure for use as fuel.

Table 4.10. Size of kraals in three districts of the former Transkei (1998).

Districts	Kraal size (m^2)					
	Cattle		Sheep		Goats	
	Range	Mean	Range	Mean	Range	Mean
Elliotdale	56 - 231	110	7 – 159	57	16 – 71	34
Umtata	15 – 731	92	14 – 185	53	13 – 42	21
Mount Fletcher	15 - 2 500	314	6 – 370	107	6 – 29	26

(iv) Uses of kraals

In all three districts, it was general practice to kraal livestock every night throughout the year. However, after heavy rains when the floor of the kraal was wet, livestock was kept out of the kraal. When this happened, mature animals were left roaming on parts of the residential site, and lambs and calves were locked in a hut or kept under a roofed shed. Cows in milk were penned with other cattle, but the calves were kept separately, usually in a kraal used by sheep or goats.

The results of this study contrast with those of Bembridge *et al.*, (1992), who reported that only small stock (sheep and goats) were kept in kraals during the night. The results also differed from those reported by Masika *et al.*, (1997), for Ciskei, who found that the confinement of cattle in kraals occurred mainly during winter, except in the case of cows in milk, which were sometimes kraaled throughout the year to enable milking.

Plate 4.6. Cow dung heaps for use as fuel in Umtata (Transkei)

4.6. Handling of kraal manure

(i) Accumulation of manure in the kraals

In all the three districts the majority of farmers (73%) let manure accumulate in the kraals without intervention (Table 4.11). A few farmers (8%) fed their animals with crop residues in the kraals.

Table 4.11. Interventions by farmers in the process of accumulation of manure in livestock kraals in three districts of the former Transkei (n=72; 1998).

Farmer interventions	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mt Fletcher (n=24)	Total
				(%)
No intervention	18	16	18	73
Feeding of livestock in the kraal	1	2	3	8
Adding of bedding material	4	6	3	18
Adding of ash	1	0	0	1

Some farmers (18%) applied bedding materials, such as thatching grass, when the kraal floor turned soggy after heavy rain. One farmer in Umtata spread wood and cowdung ash on the floor of the kraal, because he believed this improved the quality of the manure when used as a fertilizer. In general, the results showed that most farmers did not make attempts to enrich manure in the kraals by adding organic or inorganic materials. This meant that manure accumulating in the kraals was in most cases derived solely from the excreta of the livestock kept in the kraals.

(ii) *Manure transport to the gardens and fields*

In Table 4.12 information on the mode of transport that farmers used to move manure from kraal to garden is presented. Overall, the majority of farmers (68%) used wheelbarrows to transport manure to their gardens (Table 4.12). Exceptions were one farmer in Elliotdale who used a sledge, three farmers in Umtata and one in Mount Fletcher, who used scotch carts, and three farmers in Elliotdale and two in Umtata, who transported the manure in 50 kg grain bags loaded onto carts or sledges. In each district there was one farmer who transported manure to the garden by means of a tractor-trailer combination.

Table 4.12. Mode of transport used by farmers to transport kraal manure to their gardens in three districts of the Transkei region (n=72; 1998).

Mode of transport	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All
				(%)
Sledge	1	0	0	1.4
Wheelbarrow	17	14	18	68.1
Tractor trailer	1	1	1	4.2
Scotch cart	0	3	1	5.6
Buckets	1	0	3	5.6
Bags (50 kg)	3	2	0	6.9
No response	1	4	1	8.2

The way manure was transported from kraal to field is shown in Table 4.13. Overall, about one out of three farmers (30.5%) transported manure to the fields using 50 kg bags loaded on donkey backs, in sledges, and or on animal-pulled carts. Others made use of tractor-trailers (22.2%), open or basket sledges (11%), animal–pulled carts (8.3%) and trucks (1.4% of farmers).

One farmer in Elliotdale was using a small van (LDV) to transport kraal manure to his field. The methods of manure transportation commonly used by farmers in Elliotdale were tractor-trailer combinations (ten farmers), and sledges (five farmers). In Umtata six farmers used 50 kg bags loaded onto animal–pulled carts or sledges, and five used a tractor-trailer combination. In Mount Fletcher 12 farmers used 50 kg bags loaded onto animal–pulled carts, sledges, or the back of donkeys.

Table 4.13. Mode of transport used by farmers to transport kraal manure to their fields in three districts of the Transkei region (n=72; 1998).

Mode of transport	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All
				(%)
Sledge	5	0	3	11.1
Wheelbarrow	2	0	0	2.8
Tractor trailer	10	5	1	22.2
Bakkie	1	0	0	1.4
Scotch cart	0	4	2	8.3
Truck	0	1	0	1.4
Bags (50 kg)	4	6	12	30.6
No response	2	8	6	22.2

From the results, it appeared that most of the available kraal manure found its way to gardens rather than fields. Farmers identified difficulties with transporting manure to fields, which in many cases were located considerably farther from the homestead than the garden, as the main reason why fields received less manure than gardens.

Interviews with farmers also confirmed that farmers who used manure to fertilize their fields expressed the amounts of manure in measures of volume, not mass, as was indicated by Van Averbeke and Yoganathan (1997).

4.7. Application of kraal manure in gardens and fields

In all three districts, farmers applied kraal manure to their soils in two ways. The first was to broadcast fairly large quantities of manure during the fallow period. The second was to air-dry and crush small quantities of kraal manure, mix these with equally small amounts of chemical or purchased organic fertilizer, and the seed of dry beans and/or pumpkins. This mixture was applied as a band application in the planting furrow at the time of planting maize. Band-placement of the fertilizer-seed mixture, and planting of maize seed occurred in a single operation. This was achieved by placing the mixture in a fertilizer bin and the maize pips in the seed bin of an animal-drawn single-furrow planter. One farmer in Umtata said that this practice was already in use during his grandfather's time, suggesting that in the Transkei region the use of kraal manure to supply nutrients to crops probably dates back to at least the late 1950s.

The type of seeds introduced into the mixture differed among farmers. Forty-three farmers combined the seed of dry beans and pumpkins; 12 used pumpkin seed only, and three the seed of dry beans only. On occasion, farmers deposited a mixture of small seeds of dry beans and maize in the seed bin of the planter, but in most cases dry bean seed formed part of a seed-fertilizer mixture applied through the fertilizer bin of the planter.

As with seed, farmers mixed the fertilisers that went into the band in different ways. In all districts combined, the majority of farmers (31) applied in their gardens a fertiliser mixture which consisted of crushed air-dry kraal manure and chemical fertilisers. Twelve used a mixture of Gromor, crushed air-dry kraal manure and chemical fertilizer. Three used a mixture composed of Gromor and chemical fertilizers, and two a mixture of Gromor and air dried kraal manure.

A study by Yoganathan *et al.* (1998) among farmers in the Border-Ciskei region of the Eastern Cape, situated west of the Kei River, made no mention of the practice of applying air-dry crushed kraal manure in the planting furrow as part of a fertilizer-seed mixture. Instead, they reported that farmers broadcasted kraal manure, or, when planting potatoes, deposited dollops of kraal manure below the seed.

The mean quantities of nitrogen, phosphorus and potassium applied by farmers in the planting furrow by adding Gromor and or chemical fertilizers to a mixture of seed and air-dry crushed kraal manure were calculated and are presented in Table 4.14.

Table 4.14. Mean annual amounts of nitrogen, phosphorus and potassium supplied to garden and field soils by farmers at planting by adding Gromor (17 farmers) and or chemical fertilizers to a mixture of seed and air-dry crushed kraal manure (Transkei, 1998).

Nutrients	Sources of nutrients					
	Gardens (n=52)			Fields (n=32)		
	Gromor	Fertilizer	All	Gromor	Fertilizer	All
	-----------------------		$kg\ ha^{-1}\ annum^{-1}$	-----------------------		
N	0.20	4.9	5.10	0.30	2.50	2.80
P	0.07	6.2	6.27	0.11	3.93	4.04
K	0.08	4.0	4.08	0.12	1.76	1.88

The results presented in Table 4.14. show that on average the quantities of N, P, and K supplied by adding organic (Gromor) or chemical fertilizer to a mixture of air-dry crushed kraal manure and seed, and applying this mixture in the furrow at planting, tended to be limited, but significant. In gardens a mean of 15.45 kg NPK ha^{-1} $annum^{-1}$ were applied. The average proportions in which the nutrients were supplied were approximately 7N: 8P: 5K. In fields, the quantities of N, P and K supplied as Gromor or chemical fertilizers was less than in gardens, amounting to a mean of 8.72 kg ha^{-1} $annum^{-1}$, and the average proportions in which the nutrients were supplied were approximately 3N: 5P: 2K.

The rates at which farmers applied kraal manure to garden soils are presented in Tables 4.15 and 4.16. Only farmers who applied manure (solely or as a mixture) were taken into account when calculating these rates. The amounts of manure applied at planting in the band were counted separately from those applied broadcast. The average nutrient content of manures was used when calculating the quantities of nutrients present in manure applications. The amounts of nutrients applied in the form of manure (mixed or not) are presented in Table 5.6. From the data presented in Table 4.15, it is evident that broadcasting of kraal manure was done at fairly substantial rates. For the combination of all districts, the mean rate at which farmers broadcasted kraal manure in their gardens was 6 t ha^{-1}, and the median and mode 5 t ha^{-1}.

Table 4.15. Application rates used by farmers when broadcasting kraal manure in home gardens (n = 71; 1998).

District	Administrative Area	No. of farmers	Amount applied	
			Mean	Range
			----(t ha^{-1})----	
Elliotdale	Ncihana	12	7.66	0.08 – 15.24
	Ntlonyana	12	3.59	0.03 - 7.14
Mount Fletcher	Bethania	12	1.97	1.92 - 2.02
	Chevychase	12	1.94	0.02 - 3.85
Umtata	Qweqwe	11	5.38	0.00 – 10.75
	Qunu	12	2.37	0.05 - 4.73

Contrary to the rates used when broadcasting kraal manure in gardens, rates of application in the band were very limited (Table 4.16). Over all districts, the mean application rate was 124 kg ha^{-1}, the median 120 kg ha^{-1}, and the mode 120 kg ha^{-1}.

Table 4.16. Application rates used by farmers who band-placed crushed kraal manure at planting of maize in gardens (n = 52; 1998).

District	Administrative Area	No. of farmers	Amount applied	
			Mean	Range
			----(kg ha^{-1})----	
Elliotdale	Ncihana	6	96.67	60-160
	Ntlonyana	9	144.44	60-200
Mount Fletcher	Bethania	11	136.36	60-380
	Chevychase	8	112.50	50-240
Umtata	Qweqwe	7	130.00	50-240
	Qunu	11	111.82	60- 20

In field production farmers used the same two ways of applying kraal manure to fertilize their crops as was the case in garden production. Rates of broadcasting and band-placed applications are presented in Tables 4.17 and 4.18, respectively. As was the case for rates applied in gardens, only those farmers who applied kraal manure were taken into account when calculating rates of application. The rates at which manure was broadcast in fields ranged between 0.5 and 25 t ha^{-1}. The mean was 8.4 t ha^{-1}, the median was 6.5 t ha^{-1}, and the mode was 14.0 t ha^{-1}.

Table 4.17. Application rates used by farmers who broadcast kraal manure in their fields (n = 20; 1998).

District	Administrative Area	No. of farmers	Amount applied	
			Mean	Range
			----(t ha^{-1})----	
Elliotdale	Ncihana	6	10.92	7 – 17
	Ntlonyana	2	7.50	5 – 10
Mount Fletcher	Bethania	2	6.50	1 – 12
	Chevychase	2	5.25	0.5 – 10
Umtata	Qweqwe	5	10.50	1– 25
	Qunu	3	3.67	2 – 6

Table 4.18. Application rates used by farmers when band-placing crushed kraal manure at planting of maize in fields (n = 32; 1998).

District	Administrative Area	No of farmers	Amount applied	
			Mean	Range
			----(kg ha^{-1})----	
Elliotdale	Ncihana	7	71.43	60 – 80
	Ntlonyana	7	78.57	30 – 140
Mount Fletcher	Bethania	9	112.22	50 – 180
	Chevychase	4	155.00	80 – 240
Umtata	Qweqwe	2	315.00	180 – 450
	Qunu	3	113.33	40 – 180

Band placing of manure as part of a fertilizer-seed mixture was done at rates similar to those in gardens. The range was 30 kg ha^{-1} to 450 kg ha^{-1}, the mean was 114 kg ha^{-1}, the median was 90 kg ha^{-1}, and the mode was 114 kg ha^{-1}.

Farmers who applied kraal manure did not necessarily do so every time they planted a crop. The frequency of band-placed and broadcast manure applications is presented in Table 4.19. for gardens and in Table 4.20. for fields.

Table 4.19. Frequency of manure application in gardens by farmers in three districts of the former Transkei (n=72; 1998)

Frequency	Band placement		Broadcast application	
	No. of farmers	(%)	No. of farmers	(%)
Every year	52	72.2	38	52.8
Once in 2 years	0	[illegible]	19	26.4
Once in 2-3 years	0	0	3	4.2
Once in 3 years	0	0	4	5.5
Once in 4 years	0	0	1	1.4
Once in 5 years	0	0	6	8.3
Never	0	0	1	1.4
No response	20	27.8	0	0.0

In home gardens, the majority of farmers (72.2%) band-placed air-dry crushed kraal manure every year at planting. Broadcasting of manure, on the other hand, tended to be done less frequently. Only about half of the farmers broadcast kraal manure annually in their gardens, whilst the others did so every second year or less frequently. In the fields, the trend was similar, except that the results were less conclusive, because of the large number farmers who did not respond to the question asking about frequency of manure application. The results also indicated that in contrast to home gardens, the practice of broadcasting kraal manure in fields on an annual basis was very rare. A possible reason for the difference in nutrient supply practices between home gardens and fields was that fields tended to be larger and located farther away from the residence and kraal than gardens, thus requiring considerably more effort to transport and spread the manure. This reason was also offered to explain differences in nutrient supply to gardens and fields by farmers in Kenya (Ellias, Morse and Belshaw, 1998).

Table 4.20. Frequency of manure application in fields by farmers in three districts of the former Transkei (n=72; 1998).

Frequency	Band-placed application		Broadcast application	
	No. of farmers	(%)	No. of farmers	(%)
Every year	31	43.0	3	4.2
Once in 2 years	1	1.4	5	6.9
Once in 2-3 years	0	0.0	0	0.0
Once in 3 years	0	0.0	4	5.6
Once in 4 years	0	0.0	3	4.2
Once in 5 years	0	0.0	5	6.9
Never	1	1.4	1	1.4
No response	39	54.2	51	70.8

Another possible reason for differences in nutrient supply between gardens and fields could be the difference in level of security. Most home gardens of farmers participating in the survey were fenced off securely. This limited the risk of crop damage by stray livestock. Moreover, gardens were usually situated next to the residence and enabled any entry of livestock to be noticed soon. This further reduced the risk of major damage by livestock. The same did not apply to the fields. Most fields were not fenced off individually, and they were often located out of sight of the residence. Several studies have identified the risk of livestock damage to crops as one of the key constraints in crop production in Transkei (Transkei Agricultural Development Study, 1991: Transkei Land Reform Research Group, 1995). This could explain the persistent calls made by farmers to government for fences. Given these circumstances, limiting efforts in field cropping, for example by limiting the frequency of broadcasting manure, can be interpreted as a way in which farmers reduce risk.

The results of this study showed that band-placing a fertilizer and manure combination at planting is a practice that is common and widespread in the region. Earlier it was explained that most farmers added other fertilizers to the crushed manure, be it in the form of other organic fertilizers (Gromor) or chemical fertilizers. The amounts of any of the components were found to be limited, but by combining the three, sufficient bulk material is obtained to apply some fertilizer over the full garden or field area.

The chemical component in the fertilizer mixtures deposited by farmers in the planting furrow, though relatively low (Table 4.14), had the advantage of being available immediately to the emerging seedling. The nutrients present in the organic fertilizers were expected to be released later in the season. It follows that this indigenous practice made a lot of sense agronomically, and should be seen as an ingenious adaptation to conditions of limited financial resources. These conditions were prevalent among the group investigated by this study, even though farmers in this group represented the best-resourced farming households in the region.

Using the results presented in Tables 4.17 to 4.20, the annual quantities of kraal manure applied to gardens and fields were calculated for band-placed (Tables 4.21 and 4.22) and broadcast (Tables 4.23 and 4.24) applications.

Table 4.21. Average annual band-placed amounts of kraal manure in gardens by farmers in former Transkei (n = 52; 1998)

District	No. of farmers	Amount applied	
		Mean	Range
		----(kg ha^{-1})----	
Elliotdale	15	127	60-200
Mount Fletcher	19	126	50-380
Umtata	18	116	50-320
Total and Mean	**52**	**123**	

* Twenty farmers did not respond and one farmer had never applied manure

Table 4.22. Average annual band-placed amounts of kraal manure in fields by farmers in former Transkei (n = 32; 1998).

District	No. of farmers	Amount applied	
		Mean	Range
		----(kg ha^{-1})----	
Elliotdale	14	75	30-140
Mount Fletcher	13	116	50-180
Umtata	5	194	40-450
Total and Mean	**32**	**128**	

* Thirty-nine farmers did not respond and one farmer had never applied manure

Table 4.23. Average annual broadcast amounts of kraal manure in gardens by farmers in former Transkei (n = 71; 1998).

District	No. of farmers	Amount applied	
		Mean	Range
		----($t\ ha^{-1}$)----	
Elliotdale	24	2.63	1.25 – 16.00
Mount Fletcher	24	2.96	1.00 – 5.00
Umtata	23	2.37	1.60 - 8.25
Total and Mean	71	2.65	

* One farmer had never applied manure

Table 4.24. Average annual broadcast amounts of kraal manure in fields by farmers in former Transkei (n = 20; 1998).

District	No. of farmers	Amount applied	
		Mean	Range
		----($t\ ha^{-1}$)----	
Elliotdale	8	3.37	1.00 – 8.50
Mount Fletcher	5	0.32	0.13 – 0.50
Umtata	7	1.85	0.30 – 5.00
Total and Mean	**20**	**1.85**	

*** A total of fifty-one farmers did not respond and one had never applied manure**

The results of this analysis showed that in the case of gardens, for which a substantial data set was available, most of the kraal manure was applied by broadcasting. Among those farmers who broadcasted manure, the average total annual amount applied was 2.77 $t\ ha^{-1}$, of which 2.65 $t\ ha^{-1}$ (96%) was applied by broadcasting, and 0.13 $t\ ha^{-1}$ (4%) was placed in the band at planting. In the case of field production, the data set was limited, and care should be exercised when considering the results . Be that as it may, the average annual application of kraal manure by those farmers who reportedly applied manure by broadcasting and in the band, was 1.98 t ha^{-1}, of which 1.85 t ha^{-1} (93%) was broadcast and 0.13 t ha^{-1} (7%) was placed in the band. The results suggested that on average gardens annually received about 0.8 t ha^{-1} more kraal manure than fields.

4.8 Farmer perceptions about kraal manure and chemical fertilizers

(i) *Kraal manure*

An enquiry into how farmers perceived the different types of fertilizers showed that the perceptions differed quite widely. The first issue that was investigated was the type of kraal manure farmers preferred. Here reference was made to the source of animals producing the manure. Farmers were also asked to explain their preference. The results are presented in Table 4.25.

Table 4.25. Preferred type of manure among farmers in three districts of the former Transkei (n=72; 1998).

Type of Manure	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All (n=72)
				(%)
Sheep	11	15	14	55.6
Cattle	6	3	2	15.3
Goat	0	0	1	1.4
Mixture of sheep and goat	2	3	2	9.6
No preference	1	0	0	1.4
Chicken	0	0	1	1.4
No response	4	3	4	15.3

Of the 72 farmers interviewed, 40 preferred sheep manure. All those who held this opinion were convinced that sheep manure was the most effective type of manure, and claimed that applying sheep manure resulted in a better crop response than was the case with other manures. They were convinced that when equal quantities of the manures of sheep, cattle and goats were applied, the crop fertilized with sheep manure would yield more than those fertilized with cattle or sheep manure. This perception suggested that sheep manure contained a higher nutrient concentration and/or demonstrated a higher nutrient mineralization rate than cattle or goat manure.

Farmers preferring cattle manure did so for reasons other than crop response. They motivated their choice by indicating that when compared to other types of manure, cattle manure was less compact, easy to crush, and easy to mix with chemical fertilizers. Clearly, the perceived advantages of cattle manure were related to the use of manure in fertilizer mixtures for band-placement at planting, and not to a superior crop response, as was the case with manure from sheep.

Farmers were asked what they perceived to be the main benefits derived from using kraal manure to fertilize their soils. Their responses are summarized in Table 4.26.

Table 4.26. Perceived benefits derived from the application of kraal manure among selected farmers in three districts of the former Transkei (n=72; 1998).

Perceived benefits	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All (n=72)
				(%)
Positive plant response **(a)**	8	12	10	41.6
Improved soil physical properties **(b)**	5	3	4	16.7
Saves money **(c)**	1	2	2	6.9
Benefits (a)+(b)	6	6	7	26.4
Benefits (b)+(c)	1	0	0	1.4
Benefits (a)+(b)+(c)	0	0	1	1.4
Benefits (a)+(c)	3	0	0	4.2
No response	0	1	0	1.4

The majority of farmers (53 out of 72) considered a positive plant response to be a benefit derived from fertilizing their soils with kraal manure. Farmers identified improved plant growth and higher yields as evidence of this positive crop response. Nearly half of responding farmers (33) indicated that applying kraal manure improved the physical properties of their soils. This included improvement in the rate at which water entered the soil, the general soil drainage, and the consistency of the soil, which made the soil easier to cultivate. Ten farmers also identified the use of kraal manure as a fertilizer to be a cheap way of applying soil nutrients. It enabled them to save money, which they would have to spend when purchasing commercial fertilizers, be they organic or chemical.

Farmers were also asked to identify the disadvantages of using kraal manure as a fertilizer. Their responses are presented in Table 4.27. Just over half of the responding farmers (38) were of the opinion that there were no disadvantages associated with the use of kraal manure as a fertilizer. Among the remaining 34 who did identify disadvantages, 22 were of the opinion that applying kraal manure on cropped land caused an increase in weeds. Farmers were of the opinion that this was caused by the presence of weed seeds in the manure.

The second most important disadvantage related to the observed effect of kraal manure on crop growth. Four farmers were of the opinion that a response by the crop to the supply of nutrients in the form of kraal manure was less evident than when using chemical fertilizers. Similarly, there were five farmers who were of the opinion that applying nutrients in the form of kraal manure instead of chemical fertilizers delayed crop response. Several other disadvantages were identified by one or two farmers only. These included the problem of crop-burn resulting from the application of manure, possibly caused by the high salt content of the manure applied. They also included the high labour requirement of using manure as a fertilizer, which involved emptying the kraal, transporting the manure, and the spreading of it over the field area. Two farmers claimed that applying kraal manure enhanced the rate of cutworm infestations, and one observed that the positive effect on crop growth of an application of manure was reduced over time.

Table 4.27. Disadvantages of kraal manure according to selected farmers in three districts of the former Transkei (n=72; 1998).

Disadvantages of kraal manure	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All (n=72)
				(%)
None identified	13	14	11	52.6
Introduces weeds (a)	7	2	8	23.6
Crop response is slow (e)	0	2	2	5.6
"Burns" the crops (c)	1	1	0	2.8
Increases rate of cutworm infestation (f)	1	1	0	2.8
High labour requirement (d)	0	0	1	1.4
Effect is reduced over time (g)	0	1	0	1.4
Yield response is less evident than when using chemical fertilizers (b)	1	0	0	1.4
Disadvantages (a)+(b)	0	3	0	4.2
Disadvantages (d)+(e)	1	0	0	1.4
Disadvantages (a)+(f)	0	0	2	2.8

(ii) Chemical fertilizers

The advantages and disadvantages of using chemical fertilizers as perceived by farmers are presented in Tables 4.28 and 4.29, respectively. The results of the investigation into the perceptions of farmers about benefits and disadvantages of using chemical fertilizers to supply nutrients to their crops demonstrated substantial awareness of the effects these compounds have on growing crops. Nearly half of responding farmers (33) indicated that the application of chemical fertilizers increased crop yields, and 12 stated that it hastened the rate of crop growth. It may be that an increase in nutrient supply does not increase the rate of physiological development of crops, but to the observing farmer the application of chemical fertilizers does appear to have such an effect. When supplied adequately with nutrients, plants grow rapidly, develop a large leaf area, and grow tall. When the supply of water during the season remains favourable, this also results in high yields. Eleven farmers were of the opinion that applying chemical fertilizers enhanced the positive effect of kraal manure applications on crop growth. Probably this observation related to the timing of availability of nutrients from the two types of fertilizers. Nutrients contained in chemical fertilizers are available immediately, whereas those present in the kraal manure may become available later in the season. This particular farmer observation may constitute one of the motivations of local farmers for applying a mixture of kraal manure and chemical fertilizers in the planting furrow. Seven farmers claimed that applying chemical fertilizers improved water supply to their crops. It is well known that the supply of nutrients to crops improves root ramification and possibly rooting depth. This would explain why some farmers perceive the supply of nutrients, both in chemical and organic form, to improve water supply to their crops. Five farmers identified the quick and positive response of crops after applying chemical fertilizers to be an advantage.

Most farmers (42) were of the opinion that chemical fertilizers had no disadvantages. Among the others, 15 farmers identified the high cost of these fertilizers to be a disadvantage. Four farmers, all from Mount Fletcher, claimed that chemical fertilizers resulted in poor crop yields during the dry seasons. When water supply during the season is limited, the supply of nutrients to a crop is expected to result in an early lush of growth, causing the available water to be depleted rapidly. As a result, the amount of water stored in the soil could end up being insufficient to support the plants during critical stages of growth, and consequently causing crop yield to be severely depressed (Van Averbeke and Marais, 1992).

As was the case with kraal manure, there were a few farmers (4), who thought that the application of chemical fertilizers burnt the young seedlings. Two farmers believed that applying chemical fertilizers introduced weeds into their lands. This could be an erroneous belief, but it probably emanates from the observation that supplying nutrients to a crop also has a positive effect on the growth rate of weeds. Observing the lush growth of weeds could leave the observer with the impression that there were more weeds than usual.

Table 4.28. Advantages of using chemical fertilizers identified by selected farmers in three districts of the former Transkei (n=72; 1998).

Advantages of chemical fertilizer	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All (n=72)
Increases crop yields	10	12	11	45.8
Hastens crop growth	3	3	6	16.7
Assists the action of kraal manure	4	5	2	15.3
Improves water supply to crops	1	2	4	9.7
Has immediate effect	3	1	1	6.9
None	3	1	0	5.6

Table 4.29. Disadvantages of chemical fertilizers according to selected farmers in three districts of the former Transkei (n=72; 1998)

Disadvantages of chemical fertilizers	Districts			
	Elliotdale (n=24)	Umtata (n=24)	Mount Fletcher (n=24)	All (n=72)
				(%)
No disadvantages identified	15	17	10	58.2
Are expensive	4	4	7	20.8
"Burn" crops	2	2	0	5.6
Cause poor plant response in dry seasons	0	0	4	5.6
Hasten the drying out of the soil	2	0	1	4.2
Introduce weeds	0	1	1	2.8
Crops on wet land do not respond to LAN	1	0	0	1.4
Are not always available in local stores	0	0	1	1.4

The results of the investigation into farmers' nutrient supply practices and farmers' perceptions about the use of chemical fertilizers and kraal manure demonstrated that farmers were keenly aware of the positive effects of supplying nutrients to their crops. They have had developed practices that suited the properties of the fertilizers they had at their disposal, assigning particular uses to each, in ways where these complemented each other.

Farming among African people in the Transkei region is subjected to a range of limitations and constraints. Also, it forms part of a much broader survival strategy, and needs to be viewed as a part-time activity. Incomes of farmer households in the region were limited, even among the best-resourced group, which formed the subject of this study. With reference to the supply of nutrients to crops, the financial constraints to which most responding farmers were exposed appeared to have encouraged the ingenious utilization of the limited resources. Of all the nutrient supply practices that have evolved, the application of a mixture of chemical fertilizers, crushed kraal manure, and the seed of beans and pumpkins in the planting furrow was considered the most ingenious. This practice, and others, are firmly rooted within the local farming culture,7 and farmers are convinced of their worth. Research and extension should avoid trying to convince farmers to abandon these indigenous practices, which are based on farmer-experimentation, and farmer-to-farmer extension. Instead, there is a need to build on and enrich current farmer knowledge. Several opportunities for improvements were identified. Perhaps the most important one is the addition of lime or other neutralizing substances to farmers' nutrient supply repertoire. The single farmer who was found to enrich his kraal manure by adding wood-ashes may be showing a way in which the development of such an intervention may be approached.

CHAPTER 5

EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Soil Fertility Status of Selected Farmers' Gardens and Plots

5.1.1 Introduction

The fertility status of soils in the former homelands of Ciskei and Transkei is generally very low (Laker, 1976). Phosphorus and nitrogen are specifically known to be the major factors limiting the productivity of soils in the sub-region (ARDRI, 1989). However, no specific information could be found on the fertility status of soils in the three districts of the former Transkei covered by the present study. Such information is, however, necessary for making informed recommendations on soil fertility management. The study reported below was carried out to address this need.

The study entailed the analysis of soils collected from garden and field plots from two administrative areas in each of the three districts covered by the study. The results obtained are shown in Table 5.1 and were used for rating the fertility status of the soils using a combination of criteria suggested by Fertilizer Society of South Africa (1989) and Landon (1991) summarized in Table 5.2.

5.1.2 Soil pH

The mean pH values of garden and field soils were 4.7 and 4.3, respectively, indicating that the soils were acidic. This was true in all districts as indicated by low mean pH values in each case (Table 5.1). However, the lowest pH values for garden and field soils were observed at Umtata. The low pH indicated that the soils are highly leached and this is confirmed by the Ca data, which revealed that a high proportion of the soils had low Ca levels. Generally, garden soils had relatively higher pH values and higher amounts of exchangeable bases.

Table 5.1. Chemical analysis of soils, expressed as averages and ranges, from three districts of the former Transkei.

Soil property	Elliotdale		Umtata		Mount Fletcher		Overall	
	Gardens							
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH (KCl)	4.4 – 5.1	4.8	3.8 – 4.9	4.2	3.8 – 5.5	5.0	3.8 - 5.5	4.7
% OC	1.4 – 5.8	3.2	1.4 – 5.2	3.9	0.3 – 3.3	1.2	0.3 – 5.8	2.8
P (mg kg^{-1})	10.6 – 46.4	23.0	5.0 – 39.7	16.8	7.0 – 29.3	17.4	5.0 – 46.4	19.0
K (mg kg^{-1})	88.5 – 602.3	317.5	73.5-1295.6	382.4	41.8 - 1117.5	230.7	41.8 – 1295.6	310.2
Ca (mg kg^{-1})	157.0 – 2184.0	983.5	94.0 - 2850	885.8	191.0 - 3552.5	919.5	94.0 – 3552.5	929.6
Mg (mg kg^{-1})	249.0 – 677.0	418.8	39.0 – 449.0	193.9	0 – 722.5	176.9	0 – 722.50	263.21
Zn (mg kg^{-1})	0.0 – 36.6	10.2	0 – 10.8	2.2	1.75 – 36.8	13.4	0 – 36.8	8.6
	Fields							
pH (KCl)	3.9 – 4.7	4.3	3.7 – 4.4	3.9	4.0 – 5.9	4.8	3.9 – 5.9	4.3
% OC	1.5 – 6.8	3.4	1.1 – 3.9	2.3	0.1 – 0.9	0.5	0.1 – 6.8	2.1
P (mg kg^{-1})	1.1 – 18.4	6.7	1.1 – 20.1	8.5	5.0 – 12.5	7.8	1.1 – 20.1	7.7
K (mg kg^{-1})	33.6 – 303.0	97.7	18.7 – 362.8	91.2	32.8 - 142.8	73.0	18.7 – 362.8	87.3
Ca (mg kg^{-1})	91.0 – 3085.0	975.9	0 – 1020.0	149.0	189.0 – 1290.0	533.0	0 – 3085.0	552.6
Mg (mg kg^{-1})	249.0 – 677.0	418.8	0 – 237.0	63.5	36 – 241.3	107.5	0 – 68.0	196.6
Zn (mg kg^{-1})	0.0 – 12.8	2.7	0 – 2.80	0.4	0 – 9.0	2.1	0 – 12.8	1.7

Table 5. 2. Limits for assessing the fertility status of soils according to individual chemical properties (Adapted from FSSA, 1989 and Landon, 1991)

Rating	pH(KCl)	%OC	P	K	Ca	Mg	Zn
			(mg kg^{-1})				
Low	<5	<1	<5	<80	<800	<40	<1.5
Medium	5 – 7	1 – 2	5 – 15	80 – 200	800-2000	40 – 80	1.5 – 3
High	>7	>2	>15	>200	>2000	>80	>3

5.1.3 Soil organic carbon

The organic carbon contents ranged from 0.3 to 5.8% in garden plots and 0.1 to 6.8% in field plots. The mean organic carbon values for the three districts showed that the lowest values were observed in Mount Fletcher for both gardens and fields (Table 5.1). This trend could be related to the steep and ragged terrain that characterizes the Mt. Fletcher district as well as to the relatively high rainfall experienced in the area. This combination of factors may have resulted in the erosion of the organic matter-rich topsoil. If this is indeed the case, these results indicate a strong need for soil conservation measures in the Mount Fletcher area in order to minimize soil erosion. Application of kraal manure, where available, is also recommended as one way of supplying nutrients and replenishing the dwindling soil organic matter levels in the area. Umtata and Elliotdale had reasonable organic matter levels in that a large proportion of soils from these areas had medium to high levels of organic carbon (Table 5.3). As in the case of soil pH, organic carbon levels were higher in gardens than the field plots.

5.1.4 Extractable phosphorus

Phosphorus levels ranged from 5 to 46.4 mg kg^{-1} in garden plots and 1.1 to 20.1 mg kg^{-1} in field plots. The lowest P values were observed in Elliotdale, where more than 50% of the field soils were rated as having low P (Table 5.3). A large proportion of Umtata field soils had low to medium levels of P. Although a sizeable proportion of the soils had medium to high levels of P, the rather low pH of the soils is likely to limit its availability to plants. The results of this study are consistent with those of Laker (1976), who reported that Eastern Cape (former homelands) soils, and those of South Africa in general, are low in P. As was the case with other parameters garden plots had higher P status than field soils.

5.1.5 Extractable potassium

Potassium levels ranged from 41.8 to 1295.6 mg kg^{-1} in garden plots and 18.7 to 362.8 mg kg^{-1} in field plots, with an overall mean of 310.2 mg K kg^{-1} for garden soils, and 87.3 mg K kg^{-1} for field soils (Table 5.1). Thus, garden soils were generally richer in K than field soils. In fact, 56% of the field soils were rated as having low K, while only 8% of the garden soils had low K (Table 5.3). The proportion of soils with low K varied from district to district. It was 62% for Elliotdale, 57% for Umtata and 50% for Mt. Fletcher. These results indicate that K was also a problem in many soils in the Transkei, and that it ought to be taken into consideration when making fertilizer recommendations. This is in contrast to a conclusion reached by La[illegible] stated that in general South African soils do not have K deficiency problems. The low K status of soils observed in the present study may be the result of nutrient mining which appears to be a common phenomenon in small-scale farming in the Eastern Cape.

5.1.6 Extractable calcium

As noted earlier, the Ca levels in all three districts were very low in both garden and field soils (Table 5.1). The mean Ca values of garden and field soils were 929.6 and 552.6 mg kg^{-1}, respectively. Overall, 80% of the field soils and 63% of the garden soils were low in Ca (Table 5.3). This explains the generally acidic nature of these soils observed earlier, and suggests that liming should be included in any soil fertility management programme to be considered for the area.

5.1.7 Extractable magnesium

Magnesium levels varied considerably across the three districts (Tables 5.1 and 5.3). The highest values were recorded in Elliotdale where 100% of the garden and field soils were rated as having high Mg levels (Table 5.3). The lowest Mg values were observed in Umtata where 57% of the field soils were categorized as being low in Mg (Table 5.3). Most Mount Fletcher field soils fell in the medium to high categories (Table 5.3). As observed for other parameters, the garden soils were higher in Mg than the field soils (Tables 5.1 and 5.3).

5.1.8 Extractable zinc

Zinc levels also varied considerably across the three districts (Tables 5.1 and 5.3). The differences were particularly striking in the field soils, where the proportion of soils having low Zn levels was found to be 62%, 86% and 50% in Elliotdale, Umtata and Mt. Fletcher, respectively. Thus, Zn deficiency could be limiting crop yields in most field soils in the Transkei, especially in the Umtata area, where 86% of the soils were low in Zn. These results confirmed earlier generalizations made by Laker (1976) that Zn was a potentially a major yield limiting factor in South Africa and Eastern Cape in particular. Garden soils in Elliotdale and Mt. Fletcher had relatively high levels of Zn compared to field soils (Table 5.3).

In general, the fertility status of home-garden soils, as judged by the properties reviewed above, was much higher than that of field soils, as most tested medium to high, except for pH, which still tested low in most cases. These results are consistent with observations made during the survey reported in Chapter 4, which showed that garden plots receive better management attention, probably because of their small size and proximity to homesteads. These plots received above average applications of kraal manure, and also ash produced at the homestead. For field soils, application of adequate quantities of kraal manure remains the number one option, given that farmers are generally poor and cannot afford expensive inputs. Supplementing kraal manure with inorganic fertilizers is another option that could be considered. In both cases research is required to establish rates of manure application and/or combination of kraal manure and inorganic fertilizers that result in the optimization of crop yields.

Table 5.3. Rated fertility status of garden and field soils from three districts of the former Transkei.

Parameter	Rating*	Districts							
		Elliotdale		Umtata		Mount Fletcher		Overall Mean	
		Proportion (%)							
		Gardens	Fields	Gardens	Fields	Gardens	Fields	Gardens	Fields
pH (KCl)	L	92	100	100	100	37	86	76	95
	M	8	0	0	0	63	14	24	5
	H	0	0	0	0	0	0	0	0
%OC	L	0	0	0	0	63	100	21	34
	M	33	31	7	57	26	0	22	29
	H	67	69	93	43	11	0	57	37
P	L	0	54	7	29	0	7	2	30
	M	25	15	50	50	42	93	39	53
	H	75	31	43	21	58	0	59	17
K	L	0	62	14	57	10	50	8	56
	M	25	38	14	29	68	50	36	39
	H	75	0	72	14	22	0	56	5
Ca	L	58	62	72	93	58	86	63	80
	M	33	15	14	7	31	14	26	12
	H	9	23	14	0	11	0	11	8
Mg	L	0	0	14	57	5	7	6	21
	M	0	0	7	14	10	36	6	17
	H	100	100	79	29	85	57	88	62
Zn	L	16	62	57	86	0	50	24	66
	M	0	15	21	14	10	36	11	22
	H	84	23	22	0	90	14	65	12

* L = Low, M=Medium, and H=High

5.2 Nutrient supply potential of kraal manures from the Transkei region of Eastern Cape Province.

5.2.1 Introduction

It was concluded in the previous section that the fertility status of field soils in the former Transkei was low, and that since most farmers in the area own livestock, one option of replenishing the fertility status of the soils was to use the locally available kraal manure. As was explained in Chapter 4, farmers in the area already used kraal manure in their gardens and fields, but rates of application were not based on the nutrient content or nutrient release properties of the manures. For this reason a study was undertaken to determine the nutrient contents of kraal manures from Transkei as a first step in estimating their nutrient supply potential. The results obtained are reported hereunder.

5.2.2 Nutrient contents of the manures

The nutrient contents of the manures varied considerably ranging from 9.9 to 16.7 g N kg^{-1}, 2.0 to 3.6 g P kg^{-1}, and 17.2 to 23.7 g K kg^{-1} (Table 5.4) for all administrative areas and summarized for the three districts in Figure 5.2.1. The values from the present study were within the nutrient content ranges reported for manures in several West African countries by Williams *et al* (1995) as cited by Lupwayi *et al.* (2000). West African manures were reported to contain 8.9 – 25.0 g N, 0.9 – 3.5 g P and 2.5 – 37.0 g K kg^{-1}. Potassium was the macro-nutrient, which was on average present in the highest concentration in the manures (20.4 g kg^{-1}) followed by N, Mg, P and Ca with 12.0, 3.1, 2.5 and 2.1 g kg^{-1}, respectively (Table 5.4). Lupwayi *et al.* (2000) also found K to be the nutrient present in the highest concentration in manures from small-scale farming areas in the Ethiopian highlands.

The nutrient content of the manures from the present study was higher than the one reported for manures from communal areas of Zimbabwe, which was 10.4 g N kg^{-1}, 1.6 g P kg^{-1} and 9.6 g K kg^{-1} (Tanner and Mugwira, 1984). The same was observed in the case of *boma* (small enclosure) manures from semi-arid Eastern Kenya, which had an average nutrient content of 4.8 g N kg^{-1}, 1.7 g P kg^{-1} and 8.8 g K kg^{-1} (Probert, Okalebo and Jones, 1995). These differences could be attributed to differences in vegetation, differences in the quality of the forage consumed by the animals, and/or differences in mineral soil particles content of the manures.

On-farm trials in West Africa revealed that in order to replenish the nutrients taken off the farm through crop removal, manures needed to be applied at rates of 3 – 7 t ha^{-1}. However, Lupwayi and Haque (1999) demonstrated in a two-year study that when manure is applied to soil, on average, 28% of the N, 19% of the P and 90% of the K were released into the soil in the first season. This implied that if the manures analysed in the present study were applied at 3t ha^{-1} as recommended for West Africa, they would release 8.3 – 14.0 kg N, 1 – 2 kg P and 46 – 64 kg K per hectare in the first season. The values for N and P are much lower than the 35 kg N and 24 kg P ha^{-1} required to produce a modest target maize yield of 3 t ha^{-1} on a sandy soil (Harry, 1978). This suggested a need for higher rates of manure application, preferably determined experimentally. The amount of K that can be potentially released by the manures is adequate to meet the maize K requirements, which amounted to only 18 kg K ha^{-1} for a target yield of 3 t ha^{-1}. Tanner and Mugwira (1984) also observed that low, medium and high quality manures in Zimbabwe were good suppliers of K under glasshouse conditions. The amount of P which could be potentially released by the manures (1 – 2 kg P/3 t) is, however, very low, suggesting that kraal manure will have to be applied at very high rates (36 to 72 t ha^{-1}) in order to meet crop P needs. The high rates of manure application could, however, be avoided by fortifying the kraal manure with experimentally determined amounts of phosphate rich inorganic fertilizer.

5.2.3 Influence of livestock species on kraal manure nutrient content

The nutrient contents of cattle, sheep and goat manures are shown in Table 5.4 for all administrative areas and summarized for the three districts in Figure 5.2.1. Goat manure had the highest N, P and K content followed by sheep and cattle manure. Thus, when applied on weight basis the manures were likely to release N, P and K nutrients into the soil in the order goat>sheep>cattle. This trend tends to agree with farmer perceptions captured during the survey, and reported on in Chapter 4, that small stock and in particular sheep manure was a more effective source of nutrients than cattle manure. The higher nutrient concentration of goat manure could be related to goats being both grazers and browsers, while sheep on the other hand are selective grazers. Sheep and goats select the best plant species, usually those richest in nutrients, such as nitrogen (Goqwana, pers comm., 1999).[2] On the other hand, cattle tend to be less selective grazers, and as a consequence their manure is low in N, P and K, because it is a product of poor quality forage. This possibility needs to be investigated in a systematic study examining the relationship between forage quality and kraal manure nutrient composition.

Table 5.4. Mean nutrient composition of cattle, sheep and goat kraal manure samples from administrative areas in three districts of the former Transkei.

Nutrient (%)	Elliotdale			Umtata			Mt. Fletcher			Overall mean
	Ncihana	Ntlonyana	Mean	Qweqw[illegible]	[illegible]u	Mean	Bethania	Chevy Chase	Mean	
					Cattle					
N	1.06	1.11	1.09	0.94	0.94	0.94	1.14	1.09	1.11	1.05
P	0.23	0.33	0.28	0.18	0.16	0.17	0.19	0.20	0.19	0.21
K	1.67	1.23	1.45	1.35	1.51	1.43	1.59	1.62	1.61	1.50
					Sheep					
N	1.69	1.82	1.76	1.21	1.11	1.16	1.51	1.17	1.34	1.42
P	0.35	0.40	0.38	0.25	0.28	0.27	0.26	0.19	0.23	0.29
K	2.41	2.41	2.41	2.56	2.46	2.51	2.03	2.02	2.02	2.31
					Goats					
N	1.58	2.12	1.85	0.82	0.97	0.89	1.28	2.14	1.71	1.63
P	0.36	0.35	0.35	0.21	0.30	0.26	0.44	0.33	0.39	0.33
K	3.14	2.25	2.69	2.77	1.41	2.09	3.21	3.46	3.34	2.71

The results of this study are in agreement with those of Follet, Murphy and Donahue (1981) who reported that the composition of domestic animal manure varied with kind of animal among other things. Results of Yoganathan and Van Averbeke (1996) were less consistent in this respect in that they observed no statistically significant differences in

[2] Mr W. M. Goqwana is a lecturer in the Department of Livestock and Pasture Sciences at the University Fort Hare, Alice.

the nutrient composition of manures from different animal species in central Eastern Cape. However, the N and P concentrations of sheep manure were consistently higher than those of cattle manure. These results thus in a way agree with those of the present study in that they show cattle manure to have lower nutrient concentrations than sheep and goat manures.

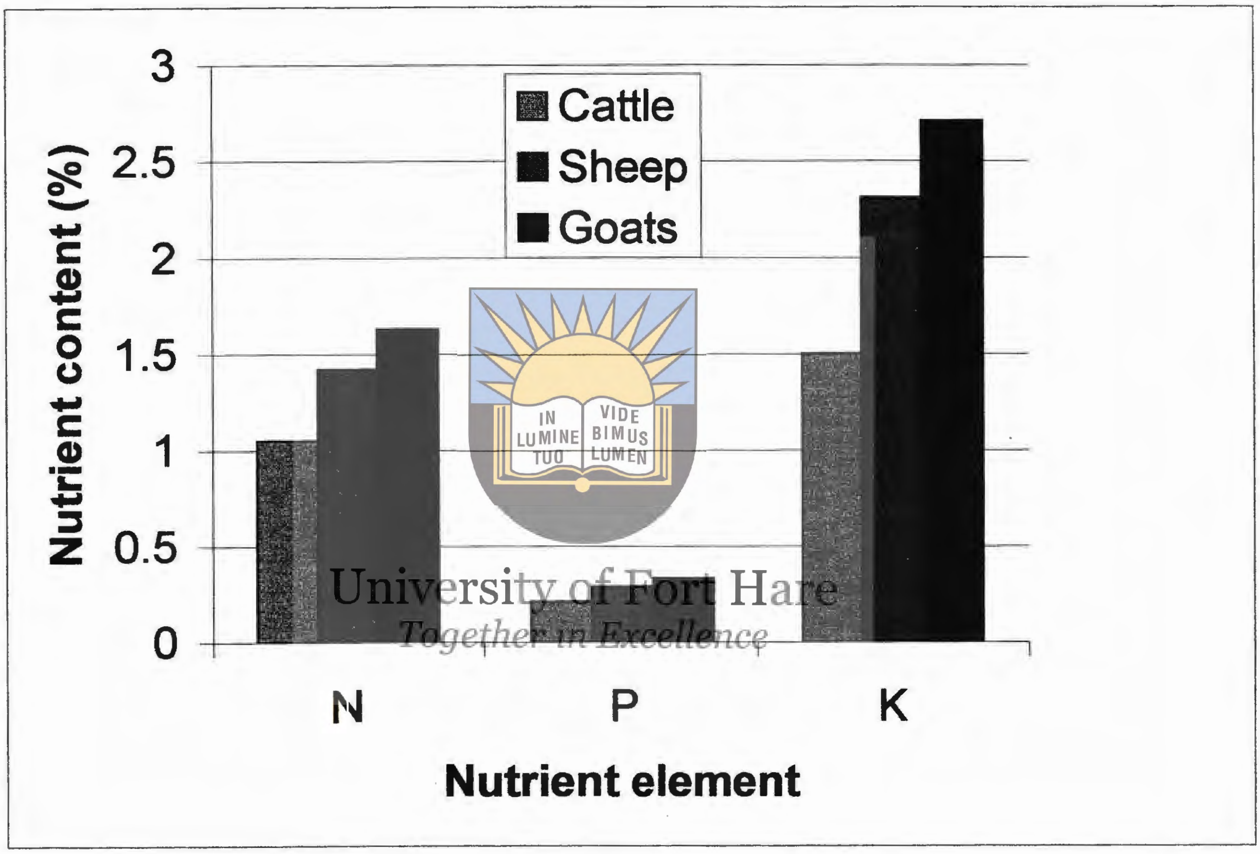

Figure 5.2.1: Mean N, P and K concentration of Cattle, Sheep and Goat kraal manures from the former Transkei.

5.2.4 Effect of location on manure nutrient content

The mean nutrient composition (N, P, K, Fe, Mg and Ca) of all manures are shown in Table 5.5 for all administrative areas, and are summarized for the three districts in Figure 5.2.2. The results showed that manures from Elliotdale had higher nutrient contents than those from Umtata and Mt. Fletcher. Manures from Umtata had more bases (K, Ca and

Mg) than those from Mt. Fletcher. This trend suggested a relationship between altitude-related factors (e.g. vegetation, temperature and rainfall) and nutrient content of the manures, with nutrient contents decreasing as altitude increased from Elliotdale located near the coast to Mt. Fletcher at the foot of the Drakensberg. One possible explanation is the difference in vegetation types. Coastal Forest and Thornveld dominate Elliotdale and Valley Bushveld is also found in other parts of this district (Acocks, 1988). These veld types have trees and bushes, which are rich in proteins, and thus good sources of nitrogen (Scogings, pers. Comm., 2000).[3] On the other hand Sourveld, which is poor in protein-rich trees and shrubs, dominated the Umtata and Mount Fletcher study areas (Acocks, 1988).

5.2.5 Effects of mineral particle content on kraal manure quality

The soil mineral particles content of the manures ranged from 21 to 68 % for 16 of the 105 manure samples whose soil mineral particle content was determined. These results were within the range of mineral particle content (20 to 80%) reported for central Eastern Cape by Van Averbeke and Yoganathan (1997). They were also comparable to those reported by Mugwira (1987) for manures from communal areas of Zimbabwe, which were found to contain as high as 80% sand. In the case of Zimbabwe, Mugwira (1987) suggested that most of the sand could have been introduced into the manure through cattle trampling manure into underlying soil in kraals. In contrast, Lupwayi *et al* (2000) suggested that mineral particles could also be introduced into manures through direct ingestion by the livestock. They observed, for example, that in areas dominated by sandy soils, livestock ingested large quantities of sand, resulting in manure that was a mixture of dung and sand. In the case of Transkei, it is possible that both trampling and ingestion contributed to the mineral particle content of the manures, because the soils of the area were generally sandy and the kraal floors were not made of concrete. Trampling is likely to play a major role in new kraals or kraals that have been recently emptied. Wind could also deposit sandy particles in open kraals.

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[3] Dr P. Scogings is a senior lecturer in the Department of Livestock and Pasture Sciences at the University Fort Hare, Alice.

Table 5.5. Mean nutrient composition of kraal manures in six administrative areas of three districts in Transkei.

Nutrient	Elliotdale			Umtata			Mt. Fletcher			Overall
	Ncihana	Ntlonyana	Mean	Qweqwe	Qunu	Mean	Bethania	Chevychase	Mean	Mean
	Nutrient content (g kg^{-1})									
N	14.8	16.7	15.7	10.2	9.9	10.0	11.4	12.2	11.7	12.0
P	3.1	3.6	3.3	2.1	2.0	2.1	2.3	2.1	2.2	2.5
K	23.7	19.9	22.0	23.0	17.2	20.3	18.4	19.6	18.9	20.4
Ca	2.4	2.6	2.5	2.6	1.9	2.2	1.6	1.3	1.5	2.1
Mg	3.7	4.4	4.0	3.2	2.7	2.9	2.3	2.2	2.3	3.1
Fe	13.6	9.8	11.9	7.6	10.8	9.1	11.4	8.6	10.1	10.1
Mn	0.52	0.60	0.56	0.46	0.60	0.53	0.43	0.56	0.50	0.52
Zn	0.12	0.12	0.12	0.10	0.09	0.09	0.06	0.10	0.08	0.10

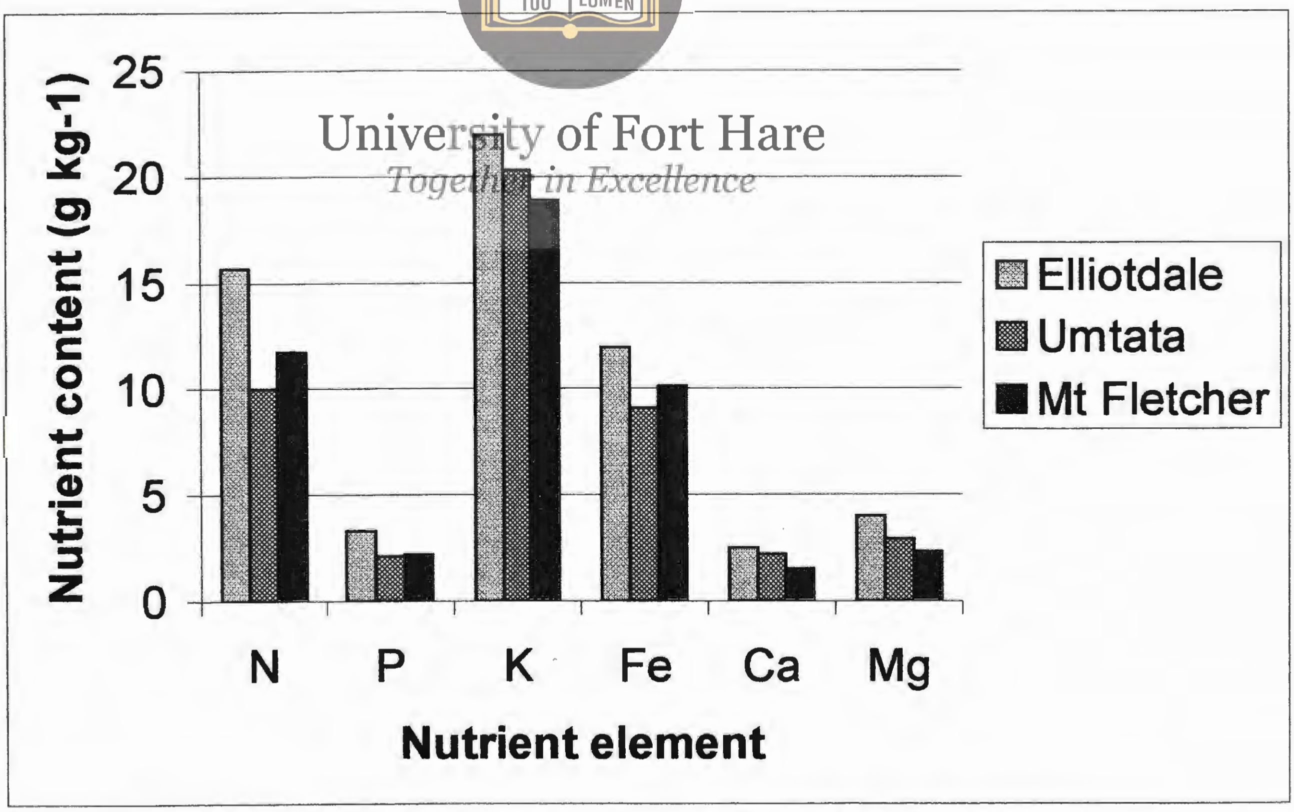

Figure 5.2.2: Mean nutrient composition of different kraal manure samples from three districts of the former Transkei

The fact that some manures had up to 68% sand suggested that mineral particles which were predominantly sand particles, may have played an important role in influencing the quality of the manures in this area. In fact a highly significant negative correlation (R^2=0.73) was observed between the N content of the manures and soil mineral particles content (Figure 5.2.3). Thus, when kraal manure recommendations are made, the mineral particle content of the manures in a particular area ought to be taken into consideration.

5.2.6 Total nutrient supply to gardens and fields in the study area

In chapter 4, information was presented and discussed on the nutrient supply practices of farmers in the Transkei, but the actual quantities of nutrients supplied by the different practices remained to be worked out. This information is provided in this section based on the nutrient composition of the manures.

The average annual nutrient supply from all types of fertilizers to farmers' gardens and fields is presented in Table 5.16. The average total annual N, P and K supplied to farmers' gardens were 38.38, 13.20 and 62.31 kg ha^{-1} respectively, while the supplies of the same to farmers' fields were 26.04, 8.99 and 43.42 kg ha^{-1}, respectively. The amounts of N and P supplied were less than the 70 kg N ha^{-1} and 47 kg P ha^{-1} recommended by FSSA (1989) for producing a target maize yield of 4 t ha^{-1}. The amounts of K supplied were, however, was more than the 43 kg K ha^{-1} recommended by FSSA (1989) for producing a target maize yield of 4 t ha^{-1}. Kraal manure was the largest supplier of both N and P to farmers' gardens and fields, and the smallest supplier of all nutrients was Gromor.

Generally, the contribution of nutrients from chemical fertilizers and Gromor was very small for gardens, and it was even smaller for fields. This could be attributed to the reluctance of farmers to purchase fertilizers due to financial constraints as highlighted in chapter 4, and as reported earlier by L&APC (1995). Kraal manure is, therefore, the main source of plant nutrients in the Transkei. Similar results were reported for central Eastern Cape by Yoganathan *et al.* (1996). The results of the present study,

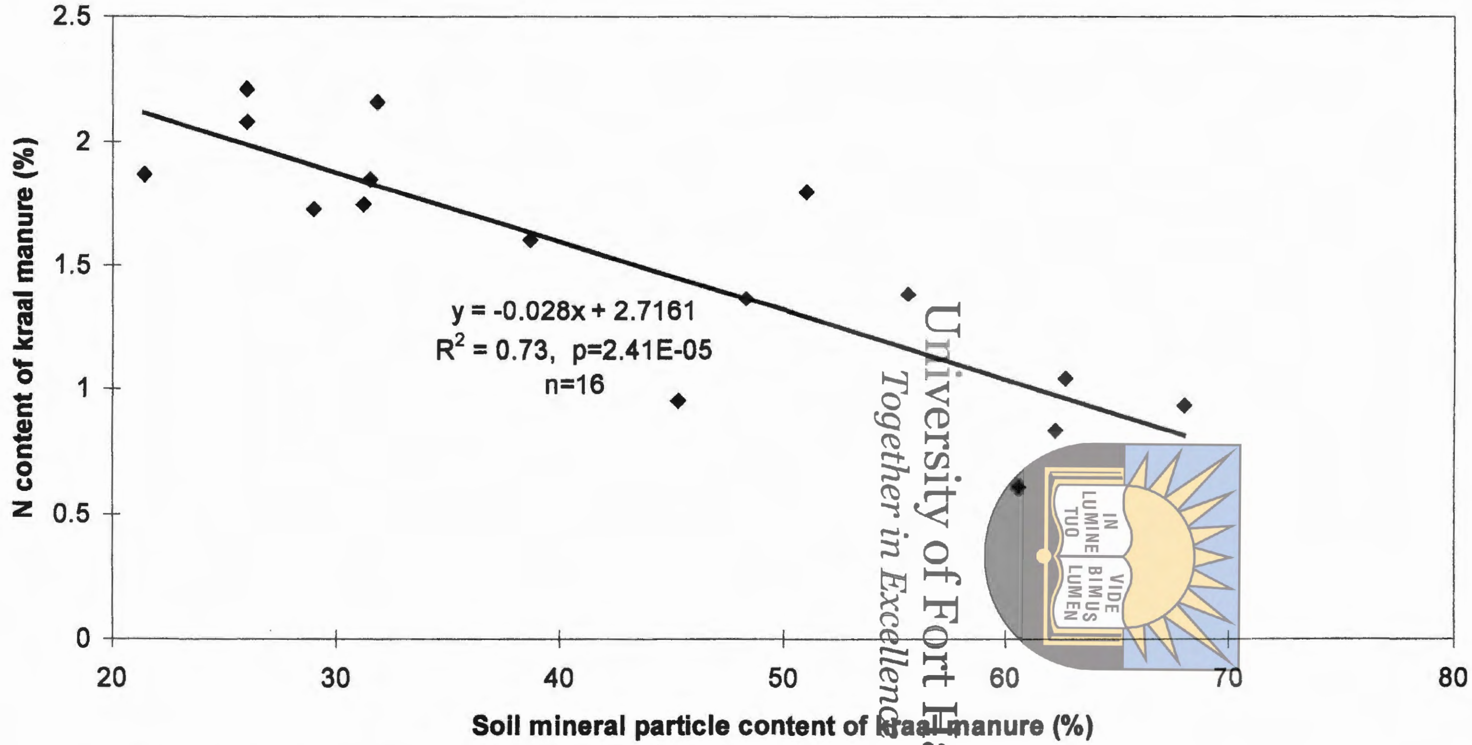

Figure 5.2.3: Relationship between the proportion of soil mineral particles in kraal manures and nitrogen content.

Table 5.6. The average annual nutrient supply from all types of fertilizers by farmers and their estimated nutrient contents (Transkei, 1998).

Nutrients	Sources of nutrients							
	Gardens		Fields		Gardens	Fields	Total Nutrient Supply in gardens	Total Nutrient Supply in Fields
	• Gromor	Fertilizer	Gromor	Fertilizer	Kraal Manure			
	------------(kg ha^{-1} annum^{-1})------------							
N	0.20	4.90	0.30	2.50	33.28	23.74	**38.38**	**26.50**
P	0.07	6.20	0.11	3.93	6.93	4.95	**13.20**	**8.99**
K	0.08	4.00	0.12	1.76	58.23	41.54	**62.31**	**43.42**

- Commercially available organic fertilizer

Average annual nutrient supply from manure (kg ha^{-1} annum^{-1}) = average yearly quantity of manure used x average nutrient content of manure
Average annual nutrient supply from chemical fertilizer (kg ha^{-1} annum^{-1}) = average yearly quantity of chemical fertilizer used x %individual nutrient as supplied by such fertilizer
Average annual nutrient supply from Gromor (kg ha^{-1} annum^{-1}) = average yearly quantity of Gromor used x %individual nutrient as supplied by Gromor
Average total nutrient supply (kg ha^{-1} annum^{-1}) = the sum of average annual nutrient supply from manure, Gromor and chemical fertilizer.
The average nutrient content of all the manures from Transkei was 1.2%N, 0.25%P and 2.04%K
The average nutrient content for Gromor was 3.0%N, 1.1%P and 1.2%K. Different chemical fertilizer supplied different amounts of nutrients depending on the concentration of individual nutrients e.g. 2:3:2(22) supplied 6.3 kg N, 9.4 kg P and 6.3kg K per 100kg and supers (10.5 %P) supplies 10.5 kg P per 100 kg

agree with McIntire, Bourzart and Pingali (1992) who reported that chemical fertilizer use in sub-Saharan Africa was typically less than 10 kg of nutrients per hectare of crop land.

Data on the average amount of manure (per household) stored in kraals in the surveyed areas together with their equivalent nutrient contents are presented in Table 5.7. The least amount of manure reserve of 9.79 t was found in Elliotdale while the highest amount (44.3 t) was recorded in Umtata. Overall, there were substantial amounts of manure reserves available for use as fertilizer in the study area, especially when considering that manure was estimated to accumulate in the kraals at a rate of 21 t/homestead kraal/year (Table 5.8). The chemical fertilizer equivalence of the manure reserves was estimated at four 50 kg bags of LAN (28%) and two 50 kg bags of single super-phosphate (10.5%P) for the smallest reserve amount of manure observed, and nineteen 50 kg bags of LAN (28%) and 10.5 bags (50kg) of single super-phosphate (10.5%P) for the largest. The highest mean manure reserve observed was comparable to the 38.3 tonnes observed by Yoganathan *et al.* (1998) in central Eastern Cape.

Table 5.7. The average amount of major nutrients stored per household kraal at the time of sampling in three districts of the former Transkei.

	Elliotdale		Mount Fletcher		Umtata	
	Ncihana	Ntlonyana	Bethania	Chevychase	Qweqwe	Qunu
Manure (t)	24.95	9.79	36.54	11.19	15.92	44.29
N (kg)	299.4	117.48	438.48	134.28	191.04	531.48
P (kg)	62.38	24.48	91.35	27.98	39.8	110.73
K(kg)	499	195	730	223.8	318.4	885.8

The results of the present study showed that not much of the nutrients were flowing from kraals to gardens and fields, and that lots of nutrients remained in kraals as reserves.

Table 5.8. Average herd size in the surveyed area and its manure production potential (on mass weight basis).

Livestock species	Average No. per herd	Estimated weight (kg)	Equivalent Large Stock Units (LSU)	Estimated manure production (t $year^{-1}$)
Cattle	14	6300	14.00	10.0
Sheep	86	5590	12.42	8.9
Goats	24	1320	2.93	2.1
Total		13210	29.35	21.0

<u>Assumptions:</u>

- Average weight of mature beef cattle = 450kg
- Average weight of a mature shee[illegible] kg
- Average weight of a mature goat = 55 kg
- 1 LSU = 450 kg
- 1 LSU produces approx. 7 tons wet manure/year (= 2.1 t/year on dry basis) when stabled through out the year.
- 1 LSU produces approx. 3 tons manure/year when stabled at night only (i.e. 40% of the manure is produced at night)
- 85 % of Livestock keepers in the Transkei stable their animals at night.

5.3 Effectiveness of kraal manures from the Transkei as sources of plant nutrients

5.3.1 Introduction

Chemical analysis of kraal manures from three magisterial districts in the former Transkei reported on in the previous section revealed that the manures varied widely in nutrient composition. This variability in nutrient composition indicated a need to experimentally establish the agronomic effectiveness of the manures. The study reported below was carried out to address this need using 16 kraal manures selected to include manures of each major livestock species from the magisterial districts covered by the study. The effectiveness of the manures was compared with that of an inorganic fertilizer in a glasshouse study that was followed by two residual experiments.

5.3.2 Response to inorganic fertilizers

Application of the inorganic compound fertilizer [2:3:2(22)] to the experimental soil resulted in improved maize growth at each level of application. The response observed was linear as reflected by a high positive correlation (R^2 =0.93) between DM yields and added nutrients (Figure 5.3.1). This indicated that the experimental soil was deficient in nutrients, consistent with the chemical analysis results of this soil reported in Table 3.2. The experimental soil was therefore ideal for evaluating the effectiveness of our manures as sources of plant nutrients.

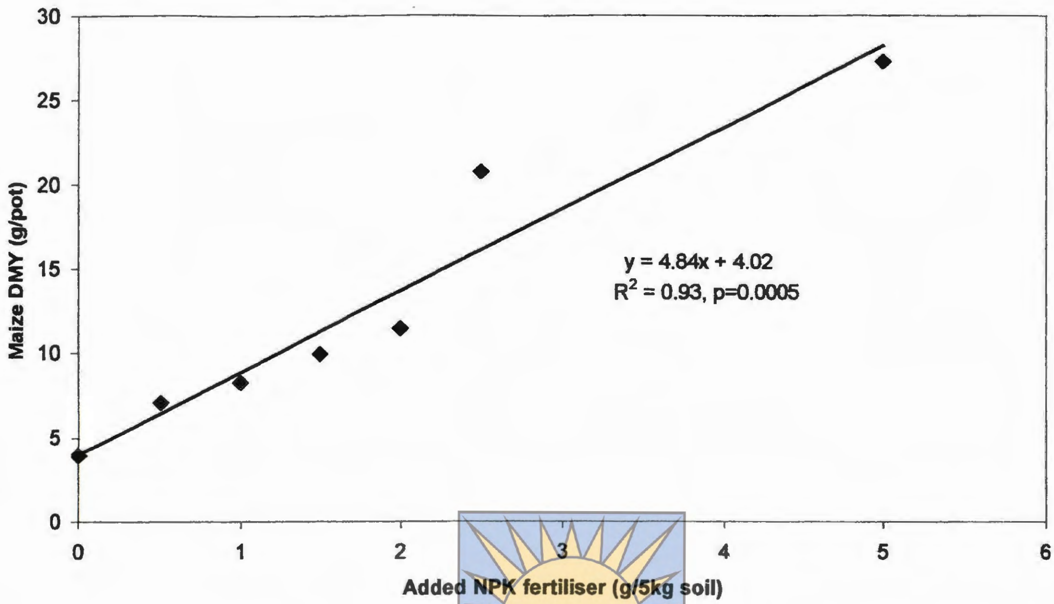

Figure 5.3.1: Relationship between added NPK[2:3:2(22)] fertiliser and the dry matter yield (DMY) of the first maize crop.

5.3.3 Response to added kraal manure

As indicated in section 3.4 manures used in this study were classified into quality categories based on their total nitrogen content as was proposed by Tanner and Mugwira (1984). They were rated as low, medium or high quality when their total N content was <0.90%, 0.90-1.20% or >1.20%, respectively. The results obtained showed that all the manures increased dry matter yields significantly relative to the control, though to different degrees (Table 5.9). Of the three major plant nutrients (N, P and K), only the nitrogen content of kraal manure was significantly correlated with DMY (R^2=0.31, P=0.03 (Figure 5.3.2)). The correlation coefficient was low but significant, and indicated the importance of using the total N content as one of the parameters for evaluating kraal manure quality. No significant relationship was observed between total P or total K content of manure with DMY. However, when results were considered separately for each livestock species, the responses were found to be in some cases inconsistent with the manure quality classifications suggested by Tanner and Mugwira (1984). This was particularly true for cattle manures, which regardless of their quality rating gave more or less the same yield responses (Table 5.9). In the case of sheep manures, medium and high rated manures gave more or less comparable responses that were significantly higher than the response obtained from the low quality manure (Table 5.9). In the case of goat manures, low and medium rated manures gave comparable responses that were significantly lower than that produced by the high quality goat manure (Table 5.9). These results indicated that nitrogen alone should not be used for rating the quality of manures from the Transkei. There is need to investigate other parameters that could be used with total N to develop a more reliable index of kraal manure quality.

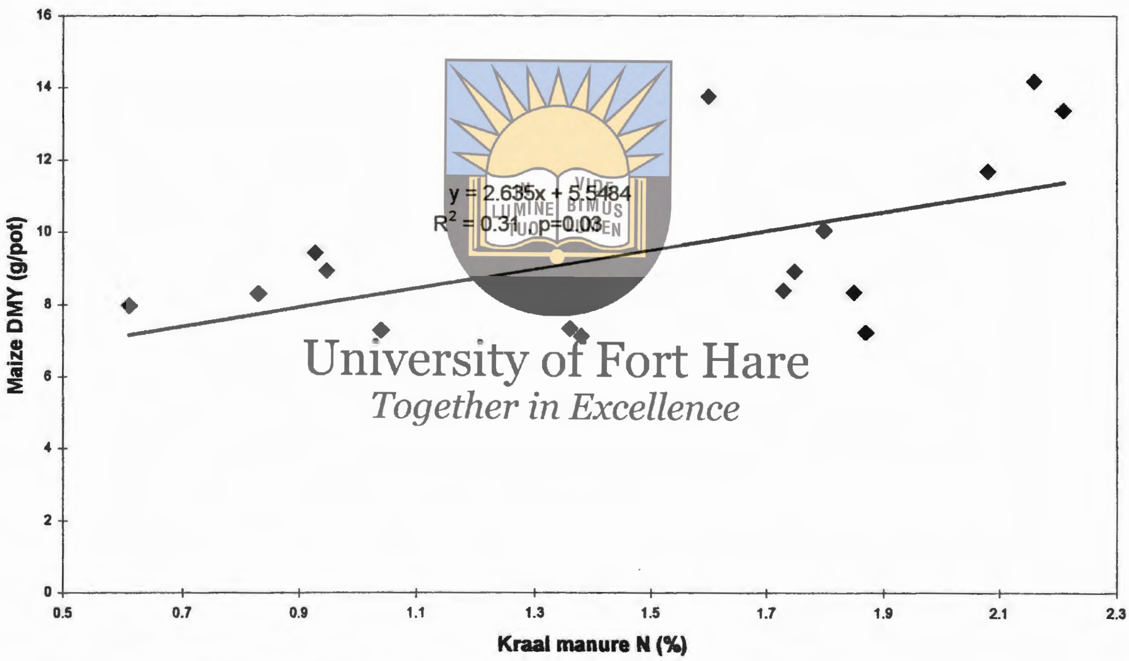

Figure 5.3.2: Relationship between kraal manure N and the dry matter yield (DMY) of the first crop of maize.

The relative agronomic effectiveness (RAE) of the manures calculated according to Engelstad *et al.*, (1974) ranged from 43 to 137% (Table 5.9). The mean RAE calculated for each livestock species followed the order: sheep manure (102%)>goat manure (75%)>cattle manure (57%). Thus sheep manure was almost twice as effective as cattle manure, and confirmed farmer perceptions captured during the survey that sheep manure is a superior fertiliser, and for this reason it is preferred to cattle manure.

Table 5.9. Effects of manures on dry matter yield (DMY), N uptake, P uptake and Relative Agronomic Effectiveness (RAE) of the first crop of maize grown in the glasshouse.

Treatment	DMY	N uptake	P uptake	RAE
	(g 5kg^{-1}pot)	*(mg 5kg^{-1}pot)*	*(mg 5kg^{-1}pot)*	(%)
Control	3.9g	32.7d	2.6h	-
S_1L	8.5de	85.4abcd	8.0ef	60
S_1M	13.8a	128.7ab	14.3ab	131
S_1H	11.7b	103.2abc	13.1b	103
S_2H	10.1c	68.4cd	10.3c	81
S_3H	14.2a	142.5a	13.8ab	137
G_1L	8.0ef	54.3cd	7.4fg	54
G_1M	7.3f	60.2cd	8.4def	45
G_1H	13.4a	111.8abc	15.1a	126
C_1L	7.1f	54.5cd	5.8g	43
C_1M	8.4e	69.5cd	9.3cde	59
C_1H	7.2f	69.1cd	7.5f	44
C_2L	9.4cd	87.2abcd	8.1ef	73
C_2M	8.9de	70.8bcd	8.2ef	67
C_2H	7.3f	65.8cd	8.8cdef	45
C_3L	8.9de	105.8abc	8.0ef	67
C_3H	8.3e	72.3bcd	10.1cd	59
$LSD_{0.05}$	0.98	57.99	1.66	
CV (%)	6.43	42.89	10.68	

Means within a column with similar letter(s) are not significantly different ($p < 0.05$) according to the LSD test.
C =Cattle, S= Sheep, G= goat. Subscripts denote location where manure was obtained. L, M and H denote Low, Medium and High quality manures, respectively.

All 16 manures increased the uptake of nitrogen and phosphorus (Table 5.9). This was consistent with the observed effects of these manures to increase soil levels of these nutrients (Table 5.10). The nutrient uptake patterns (Figure 5.3.3) were the same as that observed for dry matter yields with sheep manure resulting in the highest uptakes followed by goat and cattle manure. The mean dry matter yield and nutrient uptakes associated with the three livestock manures were a good reflection of the mean total nutrients supplied by the different manures (Table 5.11), which also followed the order: sheep > goat > cattle manure.

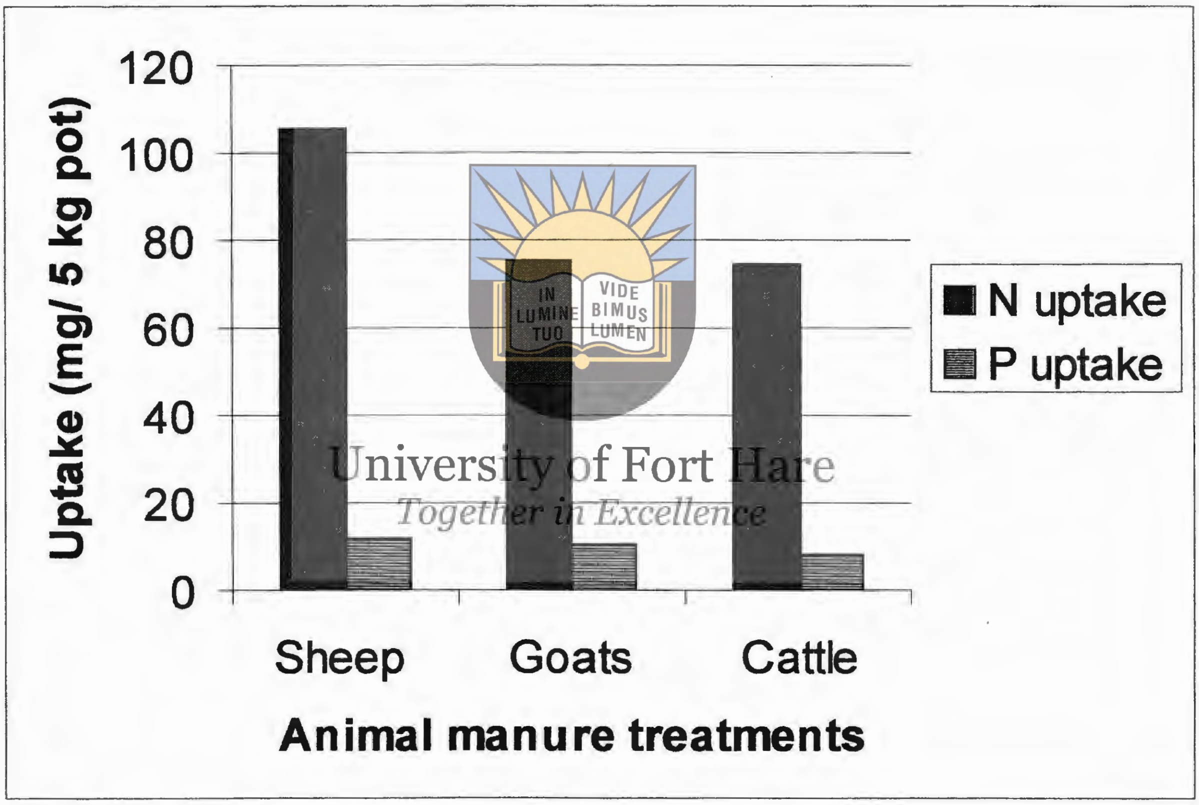

Figure 5.3.3 Nitrogen and P uptake from Phandulwazi soil amended with sheep, goat and cattle manure under glasshouse conditions.

5.3.4 Residual effects

Analytical results of treatment soils after the first crop are presented in Table 5.10. The results showed that except for P, nutrient levels in pots treated with chemical fertilizer were lower than or not different from those observed in control treatments, indicating that the plants had utilized most of the available nutrients from the fertilizer. In contrast, compared to the control, soils treated with kraal manure had higher levels of inorganic N, extractable P and exchangeable K (Table 5.10). The mean inorganic N (NH_4^+-NO_3^-N) values were 42.0, 46.2; 46.1, and 44.2 mg N kg^{-1} for control, sheep, goat, and cattle manure treatments, respectively. Extractable P values were 1.0, 12.0, 9.4 and 6.8 mg P kg^{-1}, for control, sheep, goat and cattle manure treated soil treatments, respectively. Corresponding values for K were 96, 161, 179 and 176 mg K kg^{-1}, respectively. It is noteworthy that the manures had such a dramatic influence on available P because the soils of the province are very deficient in P as reported by Laker (1976), and confirmed by the results of the present study. The equally dramatic increases of exchangeable K are consistent with the reports of other workers notably Tanner and Mugwira (1984) and Lupwayi *et al.* (2000), who stated that most livestock manures are good suppliers of K. Nevertheless, the results showed that after the first crop, the manures applied to soil still had potentially good residual fertilizer value while the chemical fertilizer had none. This was confirmed by the results of the residual experiments summarized in Figures 5.3.4 and 5.3.5. The dry matter yields for the two residual experiments summarized in these graphs show that the inorganic fertilizer treatments had less effect on the yields of the residual crops. By contrast, all manures resulted in yields higher than check treatments in both residual experiments (Figure 5.3.5).

Uniformly higher yields were obtained during the second residual experiment when compared to the first experiment. This could be attributed to the differences in day lengths and light intensities that prevailed during the different growing periods. The June/ July and August/September growing periods were in winter and had more or less the same day lengths and light intensities, but October/November was totally different. The October/November growing period had longer day lengths and higher light intensities than in winter resulting in greater accumulation of DM, even for the control treatment. However, even though these DM yields were higher, the general trend of treatment effects remained unaffected when compared to the first residual experiment (Figure 5.3.5).

Table 5.10. Chemical analyses of soils treated with manures and inorganic fertilizer after harvesting the first crop.

Treatment	Inorganic N (NH_4^+-NO_3-N) (mg N kg^{-1} soil)	P (Bray1) (mg kg^{-1})	K (Ammonium Acetate Extractable) (mg kg^{-1})
	Analysis of soil treated with 16 selected manures		
C_1H_1	43.8	7.4	132
C_2H_1	45.5	6.0	181
C_3H_1	50.8	11.2	218
C_1M_1	47.3	9.5	230
C_2M_1	43.8	6.0	223
C_1L_1	38.5	4.8	130
C_2L_1	42.0	4.5	162
C_3L_1	42.0	5.1	132
S_1H_1	43.8	9.3	189
S_2H_1	42.0	8.6	174
S_3H_1	50.8	8.0	125
S_1M_1	49.0	18.2	164
S_1L_1	45.5	15.2	154
G_1H_1	42.0	13.4	176
G_1M_1	56.0	8.6	127
G_1L_1	40.3	6.1	235
Control	42.0	1.0	96
	Analysis of soil treated with chemical fertilizer 2:3:2(22)		
12.5 kg N /ha	38.5	6.2	86
25 kg N /ha	38.5	5.2	88
37.5 kg N /ha	40.3	7.8	71
50 kg N /ha	40.3	8.6	67
100 kg N /ha	47.3	16.4	54
200 kg N /ha	38.5	16.0	54
Control	42.0	1.0	96

S= sheep, C= cattle and G=goat manures; H= high, M=medium and L=low qualities

Table 5.11. Total nutrients supplied by different types of manures used in the single rate (40 t ha^{-1}) glasshouse experiment.

Type of manure	Amount of nutrients (kg ha^{-1})		
	N	P	K
	Total	Total	Total
Sheep manures			
S_1H	840	80	1200
S_2H	720	40	560
S_3H	880	80	720
S_1M	640	120	1080
S_1L	320	40	320
Mean	**680**	**72**	**776**
Goat manures			
G_1H	880	40	400
G_1M	560	80	560
G_1L	240	120	1200
Mean	**560**	**80**	**720**
Cattle manures			
C_1H	760	80	840
C_2H	400	40	320
C_3H	760	80	680
C_1M	680	80	640
C_2M	720	120	560
C_1L	560	40	360
C_2L	360	40	400
C_3L	360	40	240
Mean	**575**	**65**	**505**

S= sheep, C= cattle and G=goat manures; H= high, M=medium and L=low qualities

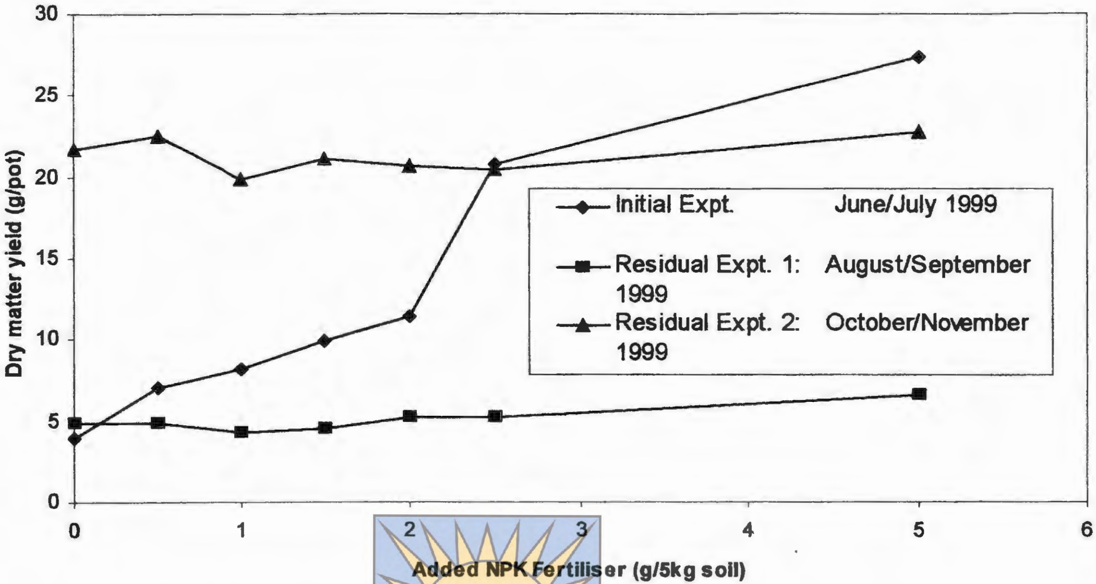

Figure 5.3.4: Initial and residual effectiveness of added NPK [2:3:2(22)] fertiliser on the growth of maize under glasshouse conditions

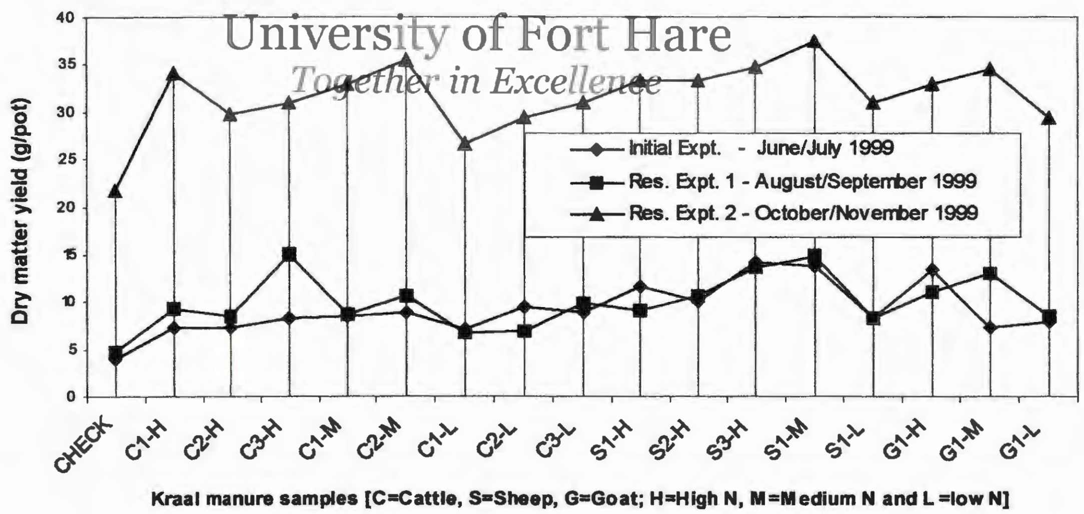

Figure 5.3.5: Initial and residual effectiveness of 16 different kraal manures on the growth of maize under glasshouse conditions.

5.4 Maize response to rate of manure application

5.4.1 Introduction

Results of the initial and residual glasshouse studies discussed under section 5.3 showed that all 16 manures studied improved maize growth during both the first and subsequent croppings. Since a single rate of 40 t ha^{-1} manure was used in the comparative studies it was not clear how maize would respond to lower or higher rates of manure application. The study reported in this section examined the effects of graded rates of selected manures under glasshouse and field conditions.

5.4.2 Glasshouse Studies

As indicated under materials and methods, the manures selected for this glasshouse study were C_2M (a medium fertility cattle manure), S_1H (a sheep manure of high nutrient status) and S_1L (a low nutrient status sheep manure). The results obtained are presented in Figures 5.4.1 and 5.4.2. All three manures increased dry matter yields relative to the control at all rates of manure application (Figure 5.4.1). At the 5 and 10 tonnes ha^{-1} rates of manure application all three manures increased yields to more or less the same extent regardless of their nutrient status. Thus at low rates of application, the manures were equally effective as sources of nutrients to the maize plants. Differences in growth response to the manures started to show at rates of application greater than 10 tonnes ha^{-1}. Each increment in the rate of application of manure resulted in improved growth for each manure, but the extent of response was greater with the high quality sheep manure. The DMY responses observed were linear for each manure (Figure 5.4.2). The growth response to the high quality sheep manure was particularly high (R^2=0.9959), suggesting the nutrients in it were as readily available as nutrients present in chemical fertilizers. The fact that differences in the agronomic effectiveness of manures became apparent only at high rates of manure application implies that if a low rate of application had been used in the comparative study reported under section 5.3, no differences in effectiveness would have been observed among the different livestock manures.

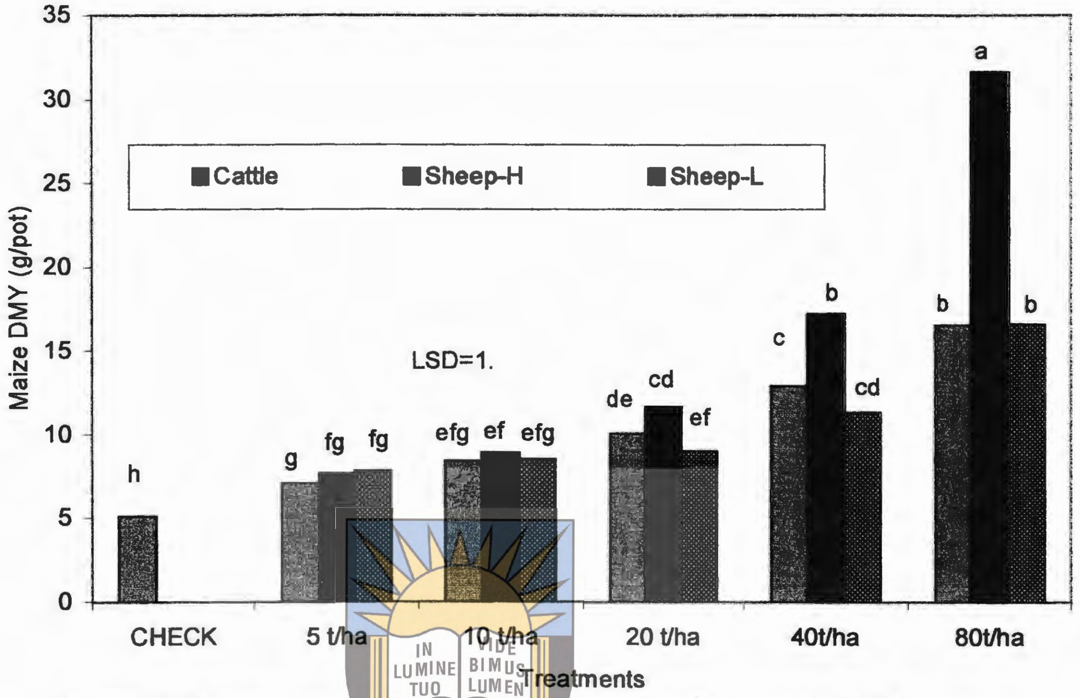

Figure 5.4.1: Response of maize to cattle and sheep kraal manure applied at different rates under glasshouse conditions. Bars with no common letter(s) are significantly different at 5% level.

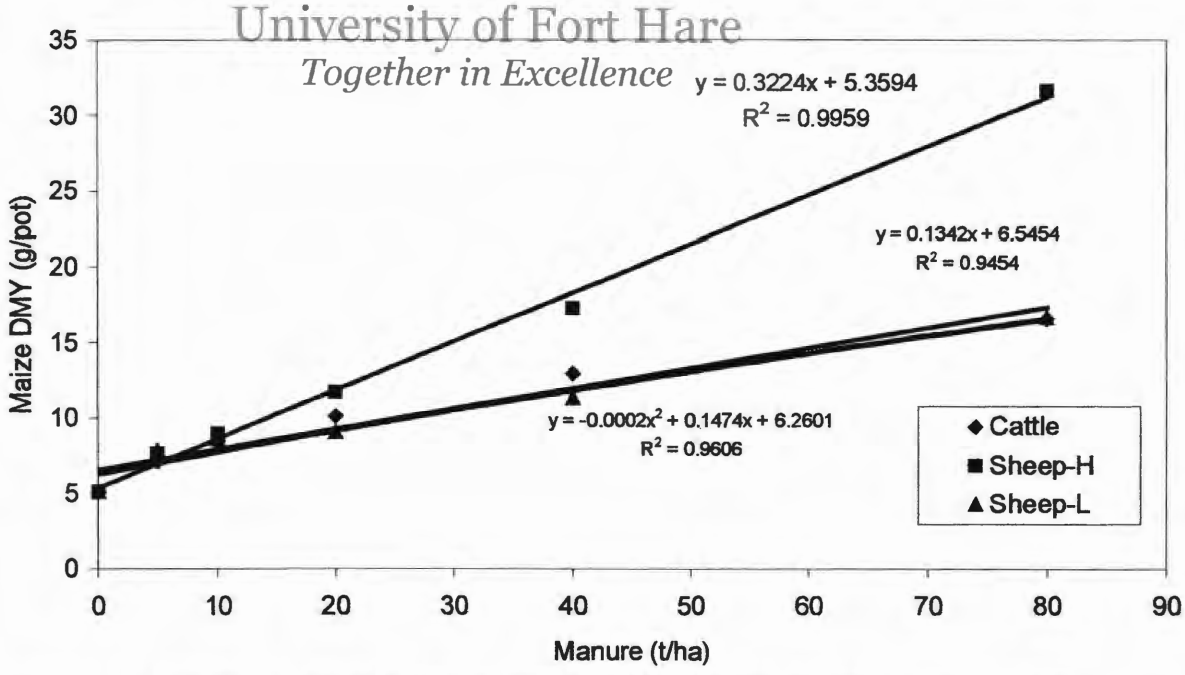

Figure 5.4.2: Response of maize to different rates of cattle and sheep manure application under glasshouse conditions

5.4.3 Field studies

The field studies were carried out at Lwalweni location in Qunu, Transkei following procedures described in section 3.5. Based on criteria discussed in section 5.1, the experimental soil whose properties are presented in Table 5.12 was acidic, low in Ca and Mg, and had medium levels of K and P. The kraal manure samples used were locally obtained in the Qunu area, and their properties are given in Table 5.13. Based on the classification criteria suggested by Tanner and Mugwira (1984), both manure samples were of high quality as their total nitrogen content was more than 1.2%.

5.4.3.1 Leaf dry matter yields, N and P uptakes

Above average rainfall was experienced in the experimental area during the 2000 growing season (Table 5.14). The mean monthly rainfall during the season was 114.24 mm, which was much higher than the monthly mean of 87.03 mm received during the 1998/99 growing season. The peak for the growing season was observed in March (172.55 mm) and was the highest amount of rainfall in four years. Excess rain caused water logging, which seriously affected the performance of the maize crop. This resulted in low and very variable grain and stover yields (Table 5.16). The leaf dry matter yields were taken at the end of February, two months after planting, which was before water logging affected the experiment. The leaf results are therefore considered more indicative of treatment effects than the grain yields.

The leaf dry matter yields are shown in Figure 5.4.3 and Table 5.15. Application of the recommended fertilizer for the area [400kg 2:3:4(30)/ha] increased the dry matter yields (DMY) of the leaves significantly ($P \leq 0.05$), confirming the need for nutrient supplementation of the experimental soil. Both cattle and sheep manure increased leaf DMY relative to the control at all rates of application. The yields obtained with 5, 10 and 20 t ha^{-1} manure were statistically comparable and on *par* with the yield obtained with the inorganic fertilizer. Only the 40 t ha^{-1} rate of manure application resulted in yield levels that were significantly higher than what was obtained with the inorganic fertilizer.

Table 5.12. Chemical and physical properties of the experimental soil at Lwalweni location, Qunu, Umtata.

Chemical analysis of soil							
Total inorganic N (mg N kg^{-1} soil)	P Bray 1	K	Ca	Mg	Na	pH (KCl)	%OC
----------------------	ppm	----------------------					
37.9	9	120	265	75	111	4.5	0.3

Mechanical analysis of soil				
Coarse sand %	Medium sand %	Fine sand %	Silt %	Clay %
0.1	9.4	[illegible]	4	9.8

Table 5.13. Chemical composition of manures used in the field experiment at Qunu.

Manure	Manure composition											
	(%)								(ppm)			
	OM	OC	N	P	K	Na	Ca	Mg	C:N	Cu	Zn	Fe	Mn
Cattle	30.99	18.02	1.78	0.41	2.88	2.03	2.24	0.55	10.12	38	130	5298	765
Sheep	19.47	11.32	1.66	0.42	2.84	2.31	2.90	0.65	6.82	38	112	5501	875

A similar response pattern was observed with nitrogen and phosphorus uptake (Table 5.15) indicating that the observed yield responses were largely the result of the treatments effects to improved nutrient uptake. These results confirm those observed under glasshouse conditions, which showed that when applied at rates lower than 20t ha^{-1}, kraal manures from Transkei, regardless of type or quality, had comparable effects on maize yields.

Table 5.14. Monthly rainfall at Cezu Station (± 11 km from Qunu) from 1996- May 2000 (ARC-ISCW, 2000).

Month	1996	1997	1998	1999	2000
	------------	------------	(mm)	------------	------------
January	142.5	87.0	105.3	80.5	129.2
February	93.5	72.5	141.5	101.5	138.1
March	100.5	104.5	104.5	88.0	172.6
April	***	113.5	49.0	55.0	76.9
May	***	18.5	6.5	24.5	37.2
June	0.0	***	***	18.0	0.0
July	26.0	20.0	8.5	0.0	-
August	6.0	***	54.5	***	-
September	0.0	34.5	***	5.0	-
October	88.5	42.0	***	***	-
November	180.5	91.5	134.0	64.0	-
December	74.0	34.0	172.7	131.5	-
Mean	**59.3**	**51.5**	**64.7**	**47.3**	

***** =missing data**

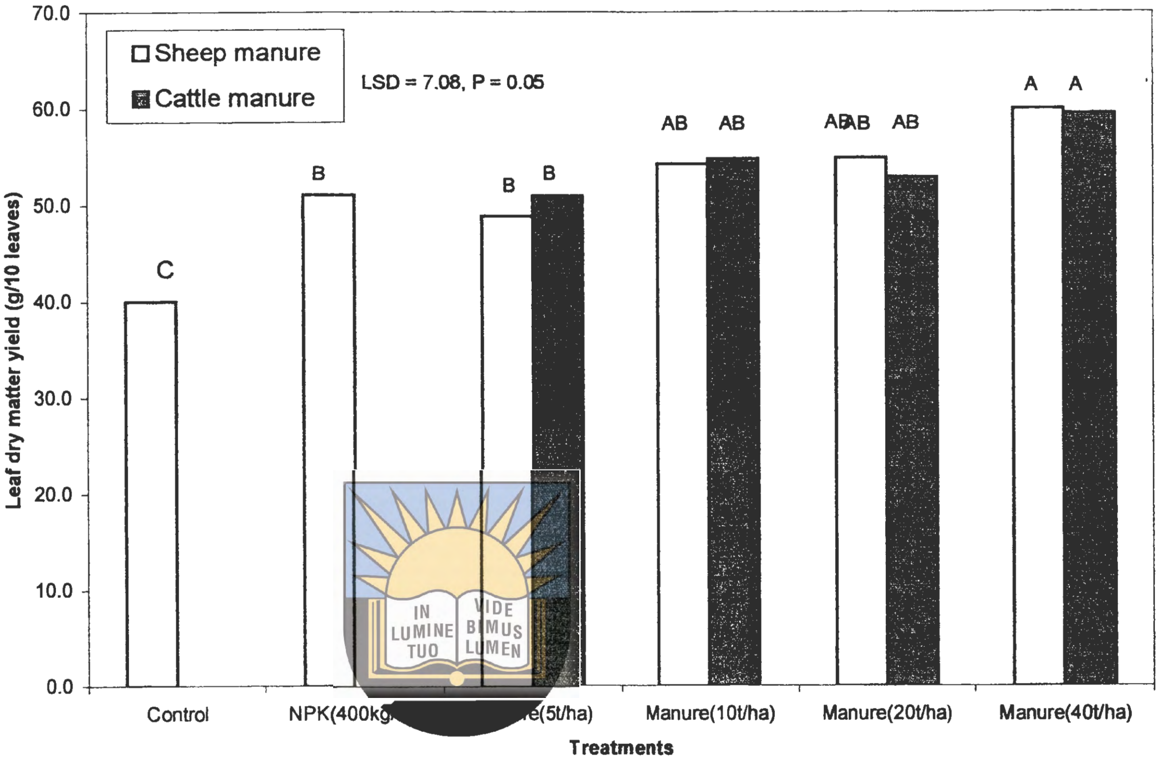

Figure 5.4.3: Leaf dry matter yield as affected by NPK fertilizer and different rates of sheep or cattle manure application. Bars bearing the same letter(s) are not significantly different from each other according to the LSD test (P<0.05).

5.4.3.2 Grain and stover yields

Grain and stover DM yields are shown in Table 5.16. As explained earlier, excess rain caused water logging that seriously affected the performance of the maize crop, resulting in low and very variable grain and stover yields. The grain yields ranged from 100 to 1340 kg ha^{-1} with a coefficient of variation (CV) of 52%. The high CVs of both the grain and stover yields and associated nutrient uptakes masked the statistical significance of some treatment differences that were observed. In spite of the low yields and high CVs observed, the results still revealed some discernible treatment differences worthy of highlighting. The recommended level of inorganic fertilizer increased both grain and stover yields significantly relative to the control (Table 5.16) consistent with its effect on leaf dry matter yields (Table 5.15). Similarly, both cattle and sheep manure treatments produced higher grain and stover yields than the control, though in certain cases these were not statistically significant due to high CVs.

Table 5.15. Effect of rate of application of cattle and sheep kraal manure on dry matteryield of leaves (DMY) and nitrogen and phosphorus uptake four weeks after planting.

Treatment[+]	DMY (g)	N uptake (mg/10 leaves)	P uptake (mg /10 leaves)
0	40.0 c	559.8c	62.7 d
2:3:4(30) 400kg ha^{-1}	51.1 b	786.2 abc	66.3 d
C5	51.0 b	620.5 c	82.8 cd
C10	54.8 ab	703.8 bc	82.9 cd
C20	53.0 ab	721.6 bc	89.6 bcd
C40	59.6 a	964.3 a	119.1 a
S5	48.9 b	735.6 abc	100.4 abc
S10	54.3 ab	796.2 abc	81.1 cd
S20	54.9 ab	668.7 bc	90.4 abcd
S40	60.0 a	901.2 ab	117.4 ab
$LSD_{0.05}$	7.1	236.5	29.0
CV	7.8%	18.5%	18.9%

[+] S= sheep and C= cattle (accompanying figure is the rate of manure application in Mg ha^{-1})
CV= coefficient of variation.
Values are means of three numbers; Means within a column followed by the same letter (s) are not significantly different ($p<0.05$) according to the LSD test.

Application of 5, 10 and 20 t ha^{-1} of both types of manures produced effects comparable to those observed with leaf yields and in the glasshouse study. As with leaf DM yields, only the 40 t ha^{-1} rate of application produced yields that were statistically higher than the reference fertilizer and the other rates of manure application (5, 10, and 20 t ha^{-1}). The amounts of potentially available nutrients supplied by the manures (Table 5.17) suggest that plant response to added manures at rates of application less than 40 t ha^{-1} could have been limited by available phosphorus. The estimated data show that the potentially available P values at rates of manure less than 40 t ha^{-1} were less than the 24 kg P ha^{-1} reported by Harry (1978) as necessary for producing a target yield of 3 t ha^{-1} maize on a sandy soil. Only rates of manure application more than 40 t ha^{-1} of both sheep and cattle manure could potentially supply an amount of available P more than 24 kg P ha^{-1}, and close to or more than what was provided by the recommended fertilizer (Table 5.17). On the other hand all rates of manure above 10 t ha^{-1} provided potentially available N and K levels well above levels supplied by the recommended fertilizer (Table 5.17). It is, thus possible that the greater response to manures observed at high rates of manure application could have been related to greater input of available P at these manuring levels. This implies that greater response to added manure at rates less than 40 t ha^{-1} could be obtained if the available P content of the manures can be boosted by the deliberate addition of inorganic P.

The above results confirm deductions made in *Section 5.2.2* that the effectiveness of kraal manures from the Transkei could be partly limited by their low P content. Thus, one possible way to improve their fertilizer value would be to mix them with inorganic phosphate fertilizer before application or simply band the P fertilizer separately at planting time. Because nitrogen is released slowly from manures, fortifying the manures with an N & P fertilizer mixture would be an ideal option. This would insure adequate nutrients to start off the crop, whose subsequent growth would be sustained by nutrients released from the decomposing manure. The exact amounts of N and P to be added as starter nutrients for different rates of manure application will have to be determined experimentally. No additional K would be necessary as the manures supplied more than adequate amounts of potassium. Each rate of manure application including the lowest (5 t ha^{-1}) could potentially supply more available K than the 53 kg K ha^{-1} provided by the reference fertilizer (Table 5. 17).

The results discussed above further showed that when kraal manure is applied alone at a rate of 5 t ha^{-1} as either cattle or sheep manure regardless of its nutrient quality, it produced yields that were statistically on *par* with those obtained with the recommended rate of inorganic fertilizer and with rates of manures up to 20 t ha^{-1}. It therefore seems logical at this stage to recommend an annual rate of 5 t ha^{-1} kraal manure applied by broadcasting for the study area. This rate of application should be reviewed when more information on optimising the effectiveness of kraal manure including the residual effectiveness of different rates of application becomes available. It was observed in Chapter 4 that farmers applied manure at frequencies that ranged from every year to once in two, three, four and five years, respectively (Tables 4.19 & 4.20). Information is thus required for optimum rates of kraal manure application at the different frequencies of application. The 5 t ha^{-1} rate of manure application, however, was within the range of manure reserves observed in the area which ranged from 9.79 to 44.29 t (Table 5.7). Thus the supply of manure was not a limiting factor for farmers who owned livestock, especially considering that based on the average herd size (29), the manure reserves in each homestead increased by about 21t year^{-1} (Table 5.8).

The practice of broadcasting kraal manure is already widely practiced on home gardens where 52% of the farmers reported applying an average of 1.94 to 7.66 t ha^{-1} to their home garden plots (Table 4.15). Broadcasting kraal manure to the larger fields plots was, however, practiced less frequently and by only a small proportion of farmers (Table 4.20). This was attributed to transport constraints and less incentive to invest due to risk of crop loss associated with the inadequate fencing of field plots and their distant location from the homesteads. While a few farmers broadcasted above optimum amounts of kraal manure (up to 25 t ha^{-1}) (Table 4.17), on average the annual rate of application by broadcasting was only 1.85 t ha^{-1} (Table 4.24) with no significant effects on crop performance. The amounts of manure applied by band application were even much less and averaged only 114 kg ha^{-1} (Table 4.18). Plate 5.1 shows a typical maize crop growing on a field plot in the study area. It compares favourably with the control plot of our field experiment (Plate 5.2) suggesting that this particular field received little or no fertilization of any kind. Since the study shows the local kraal manures to be relatively effective sources of plant nutrients, there is need to encourage farmers in the

Transkei to broadcast kraal manure to their field plots at rates that will optimise their crop yields. This may call for programmes to assist farmers to overcome the limiting circumstances that presently discourage optimum use of kraal manures. The practice of mixing manure with seed and applying by planter, though considered unique and ingenious, tended to limit the amount of manure that could be applied at any one time as also reported by Bembridge (1984). Farmers should thus be discouraged from continuing with this method of kraal manure application and consistently use broadcasting which is a proven and more effective method.

Table 5.16. Effect of rate of application of cattle and sheep manure on maize grain and stover yields and uptake of nitrogen and phosphorus.

Treatment[+]	Grain yield (kg ha^{-1} at 12.5g kg^{-1} H_2O)	DMY (stover) (t ha^{-1})	N uptake (grain) (kg ha^{-1})	P uptake (grain) (kg ha^{-1})
0	100 c	3.9 c	1.3 c	0.2 c
2:3:4 (30) 400kg ha^{-1}	1340 a	10.4 ab	16.3 a	2.3 ab
C5	450 bc	8.8 bc	5.6 bc	1.2 bc
C10	750 ab	9.39 abc	9.9 ab	2.0 ab
C20	590 bc	10.9 ab	8.4 abc	1.5 bc
C40	1260 a	13.4 ab	16.2 a	3.1 a
S5	760 ab	10.3 ab	9.4 abc	1.6 bc
S10	810ab	9.19 abc	10.4 ab	1.8 ab
S20	630 abc	9.9 abc	8.7 abc	1.8 ab
S40	970 ab	15.2 a	12.9 ab	2.5 ab
$LSD_{0.05}$	600	6.2	8.6	1.4
CV (%)	52	35	47	51

[+] S= sheep and C= cattle (accompanying figure is the rate of manure application in Mg ha^{-1})
CV= coefficient of variation.
Values are means of three numbers; Means within a column followed by the same letter (s) are not significantly different ($p<0.05$) according to the LSD test.

Table 5.17. Total* and potentially available+ nutrients supplied by manure and fertilizer treatments used in the field experiment.

Manure/ Fertilizer treatments	Rate of application t ha^{-1}/ kg ha^{-1}	Amount of nutrients (kg ha^{-1})					
		Nitrogen		Phosphorus		Potassium	
		Total	Potentially available	Total	Potentially available	Total	Potentially available
Cattle	5	89	24.9	20.5	3.9	144	130
	10	178	49.8	41	7.8	288	259
	20	356	99.6	82	15.6	576	518
	40	712	199.2	164	31.2	1152	1037
Sheep	5	83	23.2	21	4.0	142	128
	10	166	46.4	42	8.0	284	256
	20	332	92.8	84	16.0	568	511
	40	664	185.6	164	32.0	1136	1022
2:3:4 (30)	400	27	27	40	40	53	53

* Calculated from the total nutrient contents of the manures presented in Table 5.13.

+ The potentially available nutrients from manures were calculated based on findings of Lupwayi and Haque (1999) that on average manures release 28%, 19% and 90% of their total N, P and K contents, respectively during the first season.

Plate 5.1: Maize plants growing on a farmer's field-plot next to the field trial

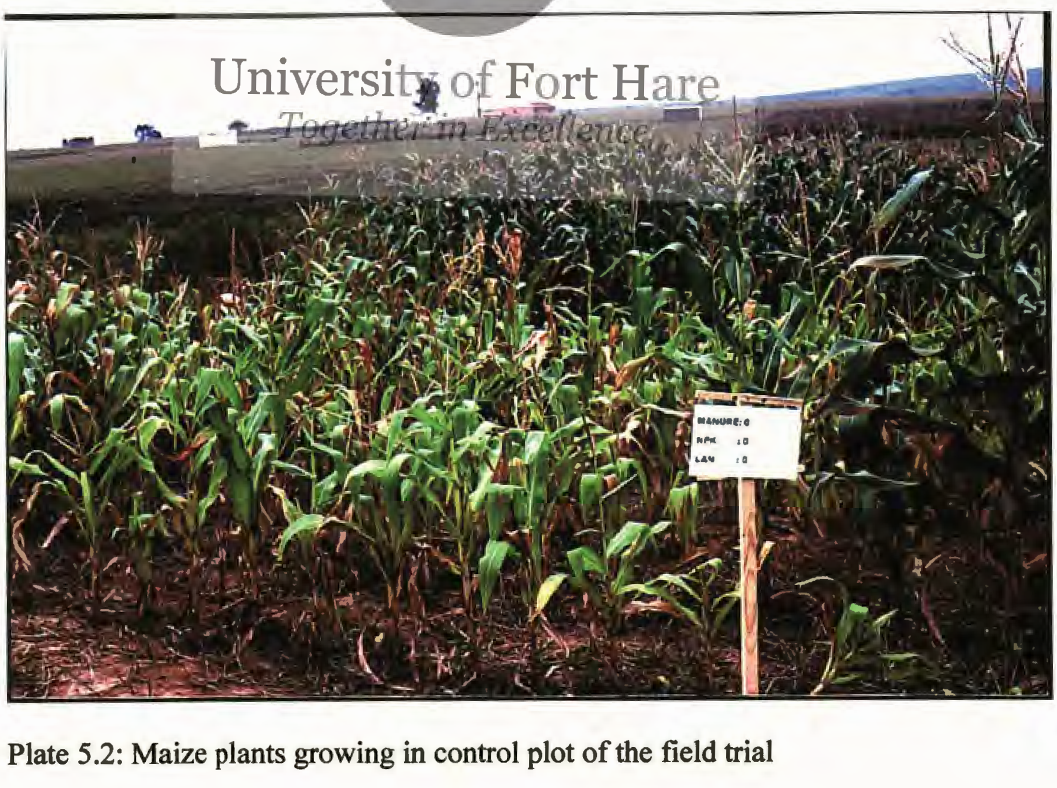

Plate 5.2: Maize plants growing in control plot of the field trial

CHAPTER 6

CONCLUSIONS

The results of the investigation into farmers' nutrient supply practices and their perceptions about the use of chemical fertilizers and kraal manure demonstrated that:

- Farmers are keenly aware of the positive effects of supplying nutrients to their crops, and have developed practices that suit the properties of the fertilizers they have at their disposal, assigning particular uses to each, in ways where these complement each other.
- Of all the nutrient supply practices that have evolved, the application of a mixture of chemical fertilizers, crushed kraal manure, and the seed of beans and pumpkins in the planting furrow is considered to be the most ingenious. This practice, and others, are firmly rooted within the local farming culture, and farmers are convinced of their worth. Research and extension should take into consideration these indigenous practices, which are based on farmer-experimentation and farmer-to-farmer extension, when conducting research and recommending changes.

The results of the study on the fertility status of the soils in three districts of the former Transkei revealed that:

- The fertility status of home-garden soils was higher than that of field plot soils. The garden plot soils tested medium to high in N, P, K, Ca and Zn contents, while most of the field-plot soils tested low in the same nutrients. This was attributed to garden-plots receiving better management attention due to their small size and proximity to homesteads.
- More than 50 % of the soils in the study area (62% for Elliotdale, 57% for Umtata and 50% for Mt. Fletcher) were low in K suggesting that potassium ought to be taken into consideration when making fertilizer recommendations in the Transkei.
- The pH of both garden and field soils was low and indicated the need to lime the soils of the study area in order to optimize crop yields.

The survey investigating kraal manure availability and the chemical analysis of manure samples collected from participating farmers in the three districts covered by the study revealed that:

- Manure reserves in the homesteads of participating farmers ranged from 9.79 to 44.29 tonnes and had the potential of accumulating at a rate of 21 t /year/homestead.
- The N, P, and K contents of kraal manures in Transkei ranged from 9.9 – 16.7 g N kg^{-1}, 2.0 – 3.6 P kg^{-1}, and 17.2 – 23.7 g K kg^{-1}. The concentration of P was lowest among the three nutrients, suggesting that it had the most limiting effect on the fertilizer value of the manures. Thus fortification of with phosphate fertilizer could increase the agronomic effectiveness of the kraal manures.
- The nutrient composition of the manures varied with livestock species. Goat manure had the highest N, P and K contents followed by sheep and cattle manure.
- The nutrient composition of the manures varied with geographical location. Manure from Elliotdale located along the coast had higher nutrient contents than those from Umtata and Mt. Fletcher, which were located at much higher altitudes. This suggested a possible relationship between altitude-related factors, such as vegetation type, and manure quality.

Glasshouse and field studies on the agronomic effectiveness of selected manures revealed that:

- All 16 manures compared in a glasshouse study at a single rate of application of 40 t ha^{-1} increased maize dry matter yields significantly relative to the control.
- The mean relative agronomic effectiveness of the manures followed the order: sheep manure (102%)>goat manure (75%)> cattle manure (57%), and was consistent with the nutrients which the manures supplied to the soils. Consequently, no major differences in crop response are to be expected from differences in the type of manure when application rate is of manure is based on nutrient content.

- All manures evaluated had residual fertilizer value, which confirmed their potential usefulness as slow release fertilizers.
- When only kraal manure is available, a rate of 5 t ha^{-1} manure, regardless of its source animal or quality, was found to result in optimum yields of maize. For the group of farmers who participated in this study, this rate of application could easily be met with the manure reserves stored in the kraals of their homesteads.

Recommendations for further work

1. Results of the present study revealed a trend suggesting that the nutrient content of kraal manures decreased with altitude. There is need for a more systematic study to examine the relationship between kraal manure nutrient composition and altitude, and factors that may be responsible for it.
2. It was observed that farmers applied manure at frequencies that ranged from every year to once in two, three, four and five years, respectively. Local studies are thus required to establish optimum rates of kraal manure application at the different frequencies of application.
3. Co-application of manure with phosphate rich inorganic fertilizers or fortifying manure with a mixed fertilizer high in P could substantially increase their agronomic effectiveness as the kraal manures were found to be consistently low in P. Local studies are therefore required to determine optimum combinations of kraal manures and inorganic fertilizers that would result in economically optimum yields.
4. Since a large proportion of soils in the Transkei are acidic, there is need to investigate the possibility of enhancing the effectiveness of kraal manure through liming.
5. Most farmers in the study area practice multiple cropping. Since the present study used sole maize as the test crop, there is need for other studies that will determine optimum kraal manure application rates under intercropping or multiple cropping situations.

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APPENDICES

APPENDIX 1

SURVEY ON SOIL FERTILITY MANAGEMENT IN THREE DISTRICTS OF THE TRANSKEI

ARDRI/Faculty of Agriculture
University of Fort Hare
July and September 1998

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1. District : 1. Elliotdale 2. Umtata 3. Mt. Fletcher

2. Name of Village: ____________________ Admin. Area ____________________
3. Name of Farmer: ____________________
4. **Demographic information**
   Please provide the following information about your household.
   [Place a tick next to the members participating in the interview]

	Relation to HOH	Age	Gender (M/F)	Marital Status	Highest educ. qual.	Employ. Status	Occup.	Sector	Time at home	Monthly cash contr. to HHI
4.1										
4.2										
4.3										
4.4										
4.5										
4.6										
4.7										
4.8										
4.9										
4.10										

5. Income from Agriculture :

	Source	Cycle	Exp./cycle	GI/cycle	C/ann .	NI/annum
5.1	Agriculture (Kind) : Crops					
5.2	Agriculture (Kind) : Animals					
5.3	Agriculture (Cash) : Crops					
5.4	Agriculture (Cash) : Animals					

6. How many of the following livestock do you keep? (tick)

Cattle ___ Sheep ___ Goats ___ Pigs ___
Horses ___ Donkeys ___ Poultry ___ Other (specify)_____

7. Do you pen your livestock? (Circle choice)

Yes No

8. Which animals do you pen? (tick)

Cattle ___ Sheep ___ Goats ___ Pigs ___
Horses ___ Donkeys ___ Poultry ___ Other (specify)_____

9. Describe your penning practices for the different types of animals, ask about seasonal differences, gender differences, lactating or pregnant animals, time of day, etc. (record practices in detail using opposite blank page when needed)

10. What soil type is dominant in garden 1?

Soil texture	Colour	Depth (cm)	Slope	Perceived Soil fertility
Sand	Red	Deep (>100 cm)	Steep	High
Loam	Yellow	Moderate (50-100 cm)	Gentle	Medium
Clay	Brown	Shallow (<50 cm)	Flat	Low
Other (specify)	Black	Other (specify)	Other (specify)	Other (specify)
	Grey			
	Other (specify)			

11. What soil type is dominant in garden 2?

Soil texture	Colour	Depth (cm)	Slope	Perceived Soil fertility
Sand	Red	Deep (>100 cm)	Steep	High
Loam	Yellow	Moderate (50-100 cm)	Gentle	Medium
Clay	Brown	Shallow (<50 cm)	Flat	Low
Other (specify)	Black	Other (specify)	Other (specify)	Other (specify)
	Grey			
	Other (specify)			

12. What soil type is dominant in field 1?

Soil texture	Colour	Depth (cm)	Slope	Perceived Soil fertility
Sand	Red	Deep (>100 cm)	Steep	High
Loam	Yellow	Moderate (50-100 cm)	Gentle	Medium
Clay	Brown	Shallow (<50 cm)	Flat	Low
Other (specify)	Black	Other (specify)	Other (specify)	Other (specify)
	Grey			
	Other (specify)			

13. What soil type is dominant in field 2?

Soil texture	Colour	Depth (cm)	Slope	Perceived Soil fertility
Sand	Red	Deep (>100 cm)	Steep	High
Loam	Yellow	Moderate (50-100 cm)	Gentle	Medium
Clay	Brown	Shallow (<50 cm)	Flat	Low
Other (specify)	Black	Other (specify)	Other (specify)	Other (specify)
	Grey			
	Other (specify)			

14. How do you treat manure in the kraal?

1. Let it accumulate without intervention Yes No
2. Feed animals in pen Yes No
3. Throw materials onto the manure Yes No

If feed or materials are added, specify practices.

15. Describe what you usually do when you empty the kraal up until planting (pay attention to timing of different operations)

16. Do you have a preference for a particular type of manure in terms of source animals?

Yes No

17. If Yes, why?

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18. Do you obtain manure from places other than your own kraal?

Yes No

19. If Yes from whom?

------

20. Do you pay for that manure?

Yes No

21. If Yes, how much? --

----

22. How do you apply manure?

Mixture	Tick	Type	Quantity
As is Alone			
Organic fertilizer (Gromor)			
Chemical fertilizer			
Gromor +chemical fertilizer			
Ash +chemical fertilizer			
Other(specify)			

23. Which crops do you usually grow immediately after applying manure and what are the subsequent crops?

Land	Crops
Garden 1	
Garden 2	
Field 1	
Field 2	

24a. According to your experience, what are the advantages of using kraal manure as a fertilizer?

24b. According to your experience, what are the disadvantages of using kraal manure as a fertilizer?

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25 Do you make use of chemical fertilizers?

Yes No

26. If Yes, where? (circle choice)

1. Garden 2. Fields 3. Both

27. According to your experience, what are the advantages of using chemical fertilizers?

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28. According to your experience, what are the disadvantages of using chemical fertilizers?

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29. When last did you apply chemical fertilizer in your garden(s)?

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30. When did you apply chemical fertilizer in your field(s)?

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31. How do you apply fertilizer to your garden(s)?

Method of application	Type of fertilizer	Amount applied (kg or bags)
Basal		
Basal + topdress		
Topdress only		
Other (specify)		

32.How do you apply fertilizer to your field(s)?

Method of application	Type of fertilizer	Amount applied (kg or bags)
Basal		
Basal + topdress		
Topdress only		
Other (specify)		

33. Have you ever applied lime to your garden(s)? Yes No

34. Have you ever applied lime to your field(s)? Yes No

35. Do you send soil samples for analyses? Yes No

36. Do you follow the recommendations by the advisor and apply fertilizers at the recommended rate?

Yes No

37. If not, why not?

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38. What type of seeds do you use in your garden(s)?

1. Farmer selected 2. Hybrid 3. Both

39. What type of seeds do you use in your field(s)?

1. Farmer selected 2. Hybrid 3. Both

40. Reason for seed preference?---

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41. Do you receive agricultural advisory services? Yes No
42. If Yes are the services adequate? Yes No

43. If Not, what is missing?---

Ask farmer to accompany you to the kraal, garden and fields.

44. Manure on hand (volume) _________ m^3

Calculated from

Size of kraal(s): Length _____ m x Width _____ m **OR** Radius _____ m

and Average depth of manure: _____ cm

45. What is the size of:

Land	**Area in farmer units**	**Area in m^2**
Garden 1		
Garden 2		
Field 1		
Field 2		

46. How much and how often do you apply manure to your lands?

Unit of measurement (measure the volume of the implement used)	Volume	Number	**Area Covered (measure + units)**			
			Garden 1	Garden 2	Field 1	Field 2
Wheelbarrow						
Scotch cart						
Tractor trailer						
Truck load						
Sledge						
Other (specify)						
Frequency of application						

APPENDIX 2

GLASSHOUSE STUDIES

Effectiveness of 16 kraal manures as sources of nutrients under controlled glasshouse conditions.

ANALYSIS OF VARIANCE FOR DMY OF THE FIRST CROP

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	0.86	0.431	1.23	0.3060
Treat	16	350.16	21.885	62.46	0.0000
Error	32	11.21	0.350		
Total	50	10.68	0.345		

Grand Mean = 9.207
LSD $_{0.05}$ = 0.984
Coefficient of Variance = 6.43%

ANALYSIS OF VARIANCE FOR DMY OF THE SECOND CROP

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	1.45	0.723	0.38	0.6880
Treat	16	389.61	24.351	12.74	0.0000
Error	32	61.15	1.911		
Total	50	452.21			

Grand Mean = 9.992
LSD $_{0.05}$ =2.299
Coefficient of Variance = 13.84%

ANALYSIS OF VARIANCE FOR DMY OF THE THIRD CROP

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	158.93	79.494	6.29	0.0050
Treat	16	630.71	39.419	3.12	0.0030
Error	32	404.37	12.636		
Total	50	1194.01			

Grand Mean = 31.545
$LSD_{0.05}$ = 5.912
Coefficient of Variance = 11.27%

Effects of rates of application of kraal manures on maize growth under controlled glasshouse conditions.

ANALYSIS OF VARIANCE FOR DMY OF MAIZE CROP FROM MANURE RATES EXPERIMENT.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	9.70	4.852	4.33	0.0217
Treat	16	3890.63	243.165	216.80	0.0000
Error	32	35.89	1.122		
Total	50	3936.23			

Grand Mean = 13.490
$LSD_{0.05}$ = 1.761
Coefficient of Variance = 7.85%

APPENDIX 3

FIELD STUDIES

Effects of rates of manure application on maize leaf weights

ANALYSIS OF VARIANCE FOR DMY OF MAIZE LEAF WEIGHTS (g/10 leaves)

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	191.47	95.734	5.68	0.0129
Treat	9	877.35	97.483	5.78	0.0010
Error	17	286.76	16.868		
Total	28	1355.57			

Grand Mean = 52.756
LSD $_{0.05}$ = 7.075
Coefficient of Variance = 7.79%

ANALYSIS OF VARIANCE FOR N UPTAKE (mg/10 LEAVES) FOR MAIZE PLANTS GROWN IN THE FIELD USING SHEEP AND CATTLE MANURE RATES.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	122.65	61.32	0	0.9968
Treat	9	404229.61	44914.40	2.36	0.0576
Error	18	342168.41	19009.36		
Total	29	746520.67			

Grand Mean = 745.77
LSD $_{0.05}$ = 236.509
Coefficient of Variance = 18.49%

ANALYSIS OF VARIANCE FOR P UPTAKE (mg/10 LEAVES) FOR MAIZE PLANTS GROWN IN THE FIELD USING SHEEP AND CATTLE MANURE RATES.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	1703.45	851.725	2.98	0.0765
Treat	9	9567.36	1063.04	3.71	0.0086
Error	18	5152.94	286.275		
Total	29	16423.75			

Grand Mean = 89.29
$LSD_{0.05}$ = 29.024
Coefficient of Variance = 18.95%

ANALYSIS OF VARIANCE FOR GRAIN YIELD ($t\ ha^{-1}$) OF MAIZE CROP FROM MANURE RATES FIELD EXPERIMENT.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	0.43	0.216	1.61	0.2308
Treat	8	2.51	0.314	2.34	0.0702
Error	16	2.15	0.134		
Total	26				

Grand Mean = 0.703
$LSD_{0.05}$ = 0.634
Coefficient of Variance = 52.14%

ANALYSIS OF VARIANCE FOR STOVER YIELD (t ha-[1]) OF MAIZE CROP FROM MANURE RATES FIELD EXPERIMENT.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	30.51	15.257	1.19	0.3295
Treat	8	236.17	29.521	2.30	0.0739
Error	16	204.99	12.812		
Total	26	471.67			

Grand Mean = 10.11
$LSD_{0.05}$ = 6.195
Coefficient of Variance = 35.40%

ANALYSIS OF VARIANCE FOR GRAIN N UPTAKE (kg ha-[1]) FOR MAIZE PLANTS GROWN IN THE FIELD USING SHEEP AND CATTLE MANURE RATES.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	33.04	16.52	0.66	0.5302
Treat	9	559.45	62.16	2.47	0.0487
Error	18	452.37	25.13		
Total	29	1044.86			

Grand Mean = 9.89
$LSD_{0.05}$ = 8.60
Coefficient of Variance = 50.67%

ANALYSIS OF VARIANCE FOR GRAIN P UPTAKE (kg ha-^{1}) FOR MAIZE PLANTS GROWN IN THE FIELD USING SHEEP AND CATTLE MANURE RATES.

Source	Degrees of freedom	Sum of Squares	Mean Square	F-value	Prob
Rep	2	3.75	1.875	2.65	0.0977
Treat	9	16.17	1.797	2.54	0.0439
Error	18	12.72			
Total	29	32.64			

Grand Mean = 1.789
$LSD_{0.05}$ = 1.442
Coefficient of Variance = 46.99%