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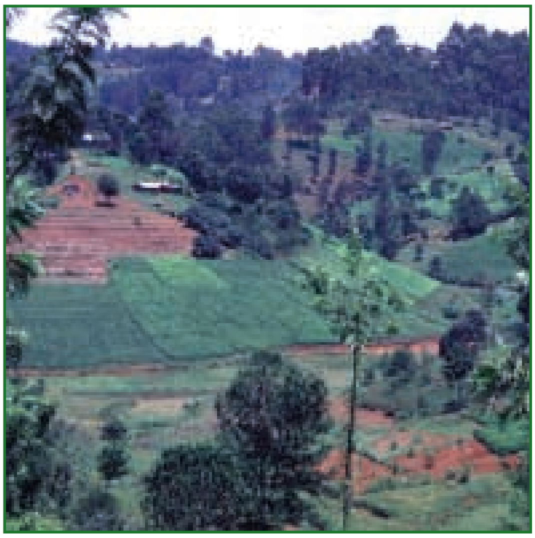
Manure Management in the Kenya Highlands: Practices and Potential

Second Edition



JK Lekasi, JC Tanner, SK Kimani, PJC Harris

HDRA the organic organisation

ILRI

KARI

HDRA - the organic organisation

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for

High Potential Production System Portfolio of
the Natural Resources Systems Programme
Renewable Natural Resources Knowledge Strategy
Department for International Development

2001

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OTHER PUBLICATIONS

A further output from Project R6731 summarises additional survey data and experimental studies to evaluate manure management options that could best conserve nutrients and improve manure quality:

Lekasi, J.K., Tanner, J.C., Kimani, S.K. & Harris, P.J.C. (2001). Managing Manure to Sustain Smallholder Livelihoods in the East African Highlands. HDRA, Ryton-on-Dunsmore. ISBN 0 905343

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CONTENTS

SUMMARY

High potential arable land in the highlands of East and Central Africa provides sustenance to millions of households cultivating farms of less than 1 ha. With high population densities, more than 800 persons/km^2 in some areas, hence a high demand for food, soils are now subject to continuous and intensive cultivation. Soil fertility status has been observed to be in decline in a number of areas presenting a serious threat to food security.

Livestock ownership is widespread amongst households in the high potential areas with between 77 and 85% of households keeping dairy cattle. Smallholder dairying makes an important contribution to household income in the poorest farm households, particularly those 25% which are headed by females in Kiambu District. It is also becoming apparent that smallholder dairy is a significant employer of non-family labour providing an income for itinerant labourers and landless members of rural communities.

This study shows that, besides the obvious role of producing milk for home consumption and sale, dairy cattle and other livestock are highly valued for the production of manure. This is a vital role on many farms where the purchase of artificial fertilisers is extremely limited because of cost. A survey of 60 farmers cultivating high potential land in Kiambu and Murang'a Districts of Central Province, Kenya, representative of other East African highland areas, shows that dairy cattle, kept traditionally in permanent confinement throughout the year, produce considerable quantities of high quality manure. Livestock not only accelerate nutrient turnover but are also the major conduit for import of external nutrients since many farms purchase forage, cereal milling by-products and minerals as feed.

Stall-feeding permanently confined stock should permit the collection of all excreta produced and in many cases maximum accumulation of solid waste material is achieved. Urine, containing nitrogen and almost all the potassium excreted, is less often managed so as to minimise the losses of these nutrients. In many cases this valuable resource is lost to the production system.

Of particular importance is the finding that, since livestock (cattle) herd sizes are largely independent of farm size, the high stocking rate on the smallest, poorest farms are such that solid manures from ruminant livestock could sustain the nutrient extraction rates required by intensive cropping, assuming that farmers will continue to purchase feeds off-farm.

Techniques for more effective capture and use of urine are urgently required to maximise returns from the purchase of off-farm nutrients and further underpin the sustainability of high intensity farming.

Farmers revealed an impressive range of ideas for the better management of solid manures. While a number actually put theory into practice, and it is clear that management was having an impact upon manure quality, too few were using quality enhancement techniques, particularly urine conservation. This may be related to the fact that knowledge concerning visual assessment of manure quality was lacking on all farms.

The price set on livestock-derived manures is high, at approximately five times the price which can be calculated from the content of nutrients alone (artificial fertiliser-equivalent price), indicating the value farmers place on the physical benefits to soil quality to be derived from using manure. On the poorest farms, annual manure value is equivalent to between 200 and 260 days labour (daily agricultural wage rate at between Kenya Shillings 70 and 90 per day).

As farms intensify and become smaller through intergenerational sub-division, the need to enhance nutrient turnover will become more important. The overall impression from the survey was that the small farms in the sample already had a greater knowledge base than the larger farms about improving efficiency of manure management.

The study raises a number of researchable issues:

(1) If small farms do produce considerable quantities of manure, quite apart from addition of fodder refusals and bedding, why do these farmers perceive that supply is too low?

(2) If urine makes a difference to manure quality, how can it best be captured?

(3) What is the scale of nutrient passage through livestock? Very few organic amendments are made directly to the soil. All exogenous and endogenous nutrients on the farm pass through livestock, either through the digestive tract or the housing unit. How efficient is this routing? Losses of dry matter and other nutrients through this route must be measured and compared with direct application of organic materials to soils.

(4) How do farmers perceive manure quality? The survey indicated that some farmers have perceptions/measures of quality and suggested management techniques to improve the quality. However, further investigation into the basis of quality ranking is warranted especially to test if these criteria influence application rates.

(5) What is the impact (cost/benefit) of the farmer-suggested improved manure storage methods on manure quality?

Outputs of current and future research should provide tools to permit farmers to make better assessments of manure quality, match those with crop nutrient requirements and also provide simple criteria to enable farmers to meet manure nutrient deficiencies with strategic use of inorganic fertilisers.

1.0 INTRODUCTION

There is great concern over soil fertility decline on arable land in the East African Highlands (Swift *et al*, 1994). In Kenya, it is estimated that 64% of the population resides in the highlands with population densities in these areas of over 1000 persons/km^2 (Braun *et al*, 1997). Losses of N and P were estimated at 42 and 3 kg/ha/yr respectively in the period 1982 to 1984 (Stoorvogel *et al*, 1993). The long-term decline is, in part, related to increased cropping intensity on shrinking smallholder farms (most households subsist on less than 1 ha) and to the limited use of inorganic fertiliser. Smaling *et al* (1992) estimated N and P fertiliser use in Kenya was only 6 and 3 kg/ha/yr in 1981.

Use of inorganic fertilisers on smallholdings in the Kenya Highlands has been reducing steadily since the 1960s when heavy promotion and subsidisation of fertiliser coincided with the release of improved maize varieties and the creation of co-operatives such as the Kenya Grain Growers Co-operative Union (Smaling *et al*, 1992).

In recent years, with increasing cost of inorganic fertilisers, scientific interest has turned towards the evaluation of organic fertilisers based on locally-available resources including green manures and mulches (Reijntjes *et al*, 1992). Research has focused on the quality, quantity and methods of application of biological materials (Myers *et al*, 1994). These studies now complement a wealth of research conducted over the last half century in East Africa demonstrating the positive responses of crops to livestock manure (eg Pereira & Jones, 1954).

From the 1960s, when the use of organic fertilisers, particularly livestock manure, might be considered to be at a nadir, manure is now used by over 95% of all smallholder farmers in the Kenya Highlands (Karanja *et al*, 1997; Harris *et al*, 1997). Manure is highly valued and its price is increasing as the cost of inorganic fertilisers rises and the long-term (residual) benefits of using manure are realised by farmers. The survey by Harris *et al* (1997) gained the impression from farmers that inorganic fertiliser is for feeding plants (ie short term response) but manure is required to feed the soil (long term sustainability). The term manure in this report refers to a mixture of animal faeces, urine and plant material.

The objectives of the present study in the high potential areas of Central Kenya were to:

- estimate the potential for ruminant livestock to supply manure;
- gain an appreciation of farmers' perceptions of the value of manure;
- assess the potential for improving manure supply and quality.

2.0 METHODOLOGY

2.1. Survey site description

The study, a structured survey of 60 mixed farms (crop/dairy) in February 1997, was conducted in Kiambu and Murang'a Districts, Central Province, Kenya (Figure 1). Most of the land area in these districts is described as having high agricultural potential and is agroecologically representative of much of Kenya's other high potential land areas (Jaetzold & Schmidt, 1983). The general characteristics of these districts are described in Table 1.

2.2 Survey design

Sixty households were selected, 30 in Kiambu District and 30 in Murang'a District. The households were selected at random from lists of farms known to be operating dairy/arable farms. Their geographical location with respect to agroecological zone is shown in Figure 2 and a listing of names and administrative location in Appendix 3.

The survey was implemented by staff of the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) in conjunction with front-line extension staff from the Ministry of Agriculture. The survey took place over a period of three weeks in February 1997.

The survey instrument took the form of a questionnaire directed at the household head taking 1.5 h to administer in the local language, Kikuyu. The survey relied upon the farmer's capacity to recall farm productivity (crop yields, animal numbers etc) for 1996. It should be noted that 1996 was a year of prolonged drought. The survey questions can be found in Appendix 2.

2.3 Classification of manures

Manures were classified on the basis of the animal(s) producing them. The major groups of animals encountered during the survey were, cattle, sheep, goats, rabbits, poultry (local, layers and broilers) and pigs. It was often found that cattle and goat or sheep manures were stored/mixed together. Cattle manure was further classified according to the state in which it was taken to the field. Some farmers would apply it as fresh dung, others as slurry and others as a manure based compost, a composted mixture of dung, urine, feed refusals and bedding.

2.4 Manure sampling and analysis

On each farm visited heaps of manure were identified, where present, that were thought by the farmer to be 'mature', that is ready to be applied to the field. Manure was scooped from four random spots on the heap to a depth of about 30 cm. The four samples were mixed together and a subsample of approximately 1 kg was taken and stored in plastic bags. The manures were air dried and then ground to pass through 2 mm screen openings.

Table 1. General characteristics of high potential areas in Kiambu and Murang'a Districts, Central Kenya

District	Annual rainfall range (mm)	Mean annual temp (°C)	Main soil type	Main land-use systems	Overall population density (person/km^2)*	Market access
Kiambu	1000 - 1800	18 - 19	Nitisol	Tea/dairy; Coffee/dairy; Marginal coffee/maize	353	Good
Murang'a	1000 - 1800	18 - 19	Nitisol	Tea/dairy; Coffee/dairy; Marginal coffee/maize	340	Medium

**CBS, 1995. Note that this population density includes people in the lower potential areas in each District. Recent figures for the high potential areas of Embu District give a population density of 800 persons/km^2(Imbernon, 1997) whereas CBS (1995) gives 132 persons/km^2 for overall Embu District. (Table source: Jaetzold & Schmidt, 1983)*

Carbon was analysed by the loss on ignition technique described by Okalebo *et al* (1993). A 10 g sample was taken and ignited at 550 °C for 8 h and the ash weighed on a fine balance. The percent organic matter content was converted to total C by dividing by 1.74 (Stevenson, 1986). Total nitrogen was analysed by the modified Kjeldahl oxidation method where salicylic acid is added during digestion so as to include nitrate-N and nitrite-N. A sample weighing 0.3 g was placed in a clean dry digestion tube and, after addition of the oxidising reagents, sulphuric acid + salicylic acid + catalyst, the tubes were placed in a digestion block at 360 °C for 3 h until the remaining digest was white. The tubes were removed and left to cool and diluted to 50 ml. 10 ml of the digest was taken for N determination by the distillation and titration method. The rest of the digest was used for P and K analysis. P was determined by the ascorbic acid/molybdate blue colour method while K was determined by flame photometry.

3.0 RESULTS

3.1 Household characteristics

All sample households in Murang'a District were headed by males with an average age of 50 years (range: 30-70) and with 30 years farming experience (range: 4-60). Farm sizes in the district ranged from 0.4 to 12.5 ha with an average size of 1.8 ha. Thirty-three percent of farms were less than 1 ha. Twenty-five percent of households in Kiambu District were female headed with an average age of 53 (range: 30-80) with 28 years of farming experience (range: 2-60). Farm size averaged 1.4 ha (range: 0.1-4.3 ha). Fifty-two percent of farms were less than 1 ha. These findings agree with those of Staal *et al* (1997) who found that 28% of households in Kiambu were female headed and mean land holding in the district was 1.1 ha.

Average household size for the sample was 7 individuals, which is close to the 6.2 persons per household found by Staal *et al* (1997) from a survey of households in Kiambu District. Household size was independent of farm size, as categorised in 3.2 below. Small farms had a mean of 7 persons per farm (range 3-15); medium farms 6.4 persons per farm (range 1-7); and large farms 7.7 persons per farm (range 2-17). This resulted in highly significant ($p<0.001$) differences in mean farm population density between farm sizes (small farms 18 persons/ha; medium farms 6 persons/ha; large farms 3 persons/ha). The very high farm population density on small farms does not represent a 'carrying capacity', since it is not known what proportion of income in any of the farm size categories is derived from off-farm activities, but does indicate the incentive for highly intensive management of natural resources on these farms in order to maximise both food production and income generation.

3.2 Categorisation of farms

In the tables below, farms are disaggregated according to size (Table 2). This has been done because the central hypothesis of this study is that as farm size decreases so the intensity of cropping will increase as farmers strive to maintain crop outputs to meet basic family food needs. The level of cropping intensity and hence nutrient extraction will be a major influence on farmer decision-making with respect to soil nutrient management, particularly use of manures. Cropping intensity is defined as total cropped area/year/total cultivated area (Byerlee, 1990).

3.3 Crop production

All farms grow a mixture of food crops. Higher altitude farms in the sample grow coffee as a cash crop. Vegetables such as potatoes (*Solanum* and *Ipomea*), kales, french beans, tomatoes, citrus fruit and bananas are grown partly for home consumption and partly for sale. Maize and beans (*Phaseolus*) are grown ostensibly for home consumption (sometimes as an intercrop) although, depending on market access, some of the maize crop is harvested at the dough stage and sold for roadside roasting.

Figure 1. Location of Central Province and Murang'a and Kiambu Districts within Kenya

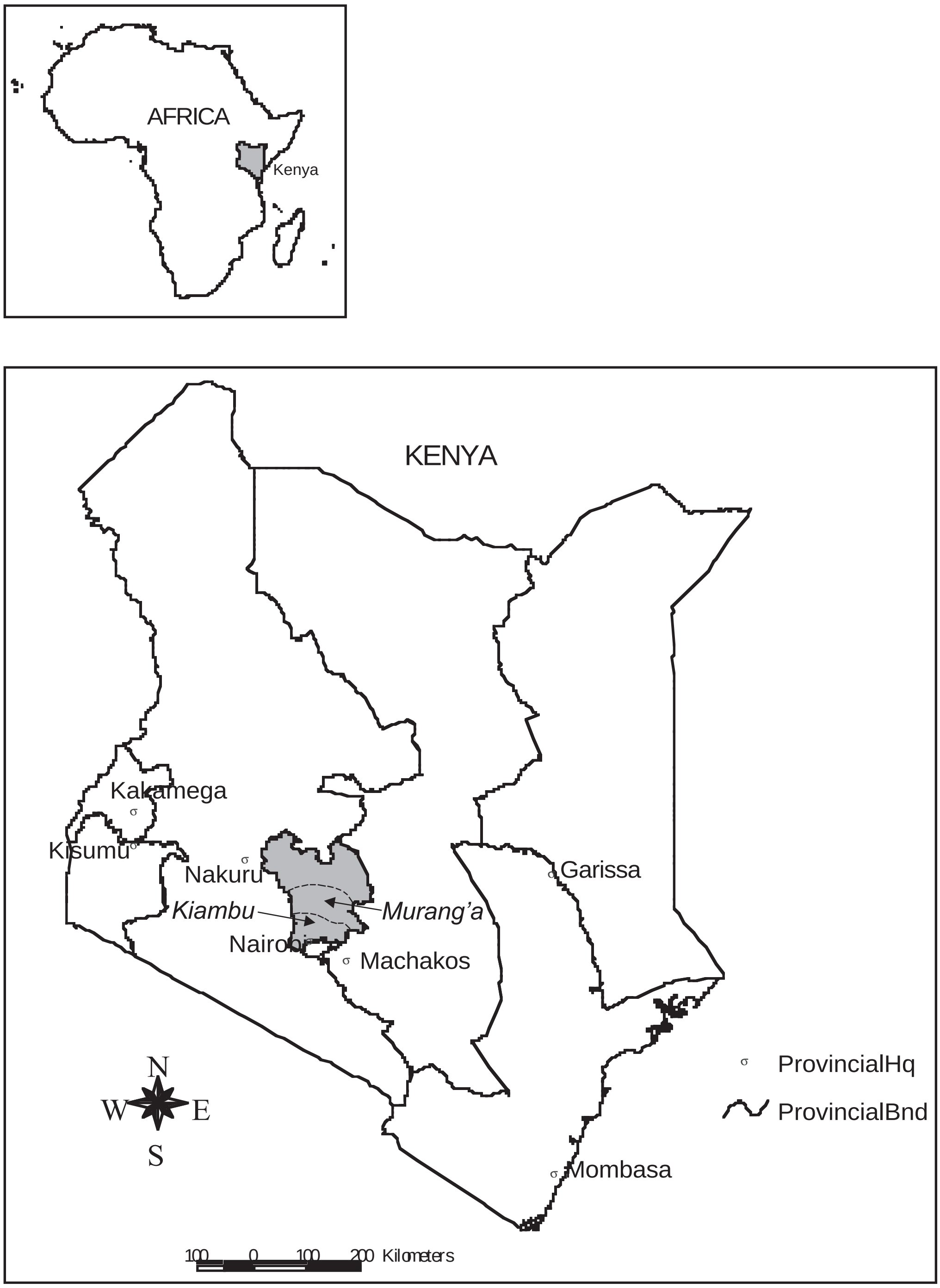


Figure 2. Location of sample farms within the agro-ecological zones of each district (some points represent two farms - see Appendix 1 for zone codes)

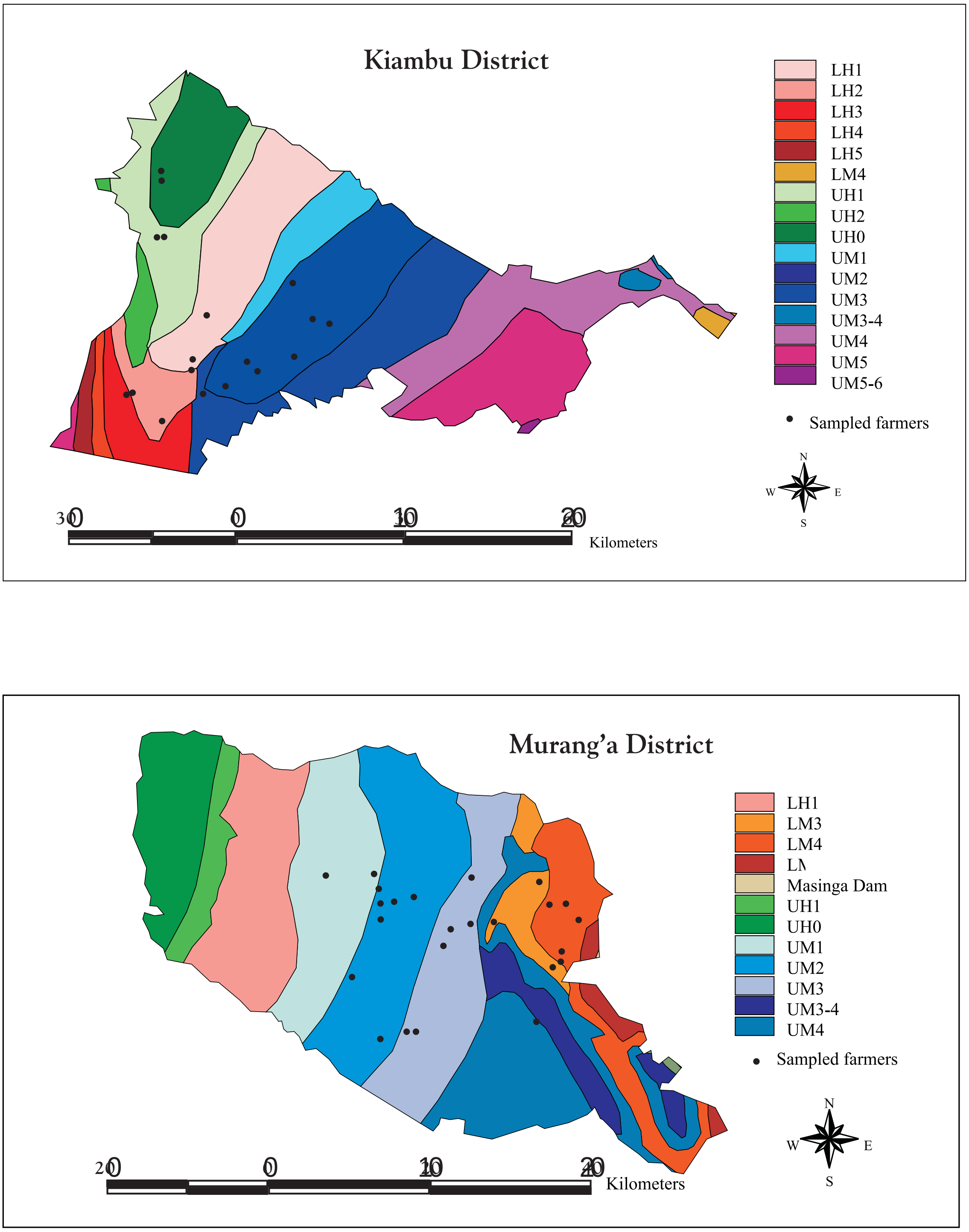


Table 2. Division of farms into land classes

Farm size	n*	Mean land area (ha)	s.d.	Range (ha)
Small	14	0.45	0.15	0.1-0.6
Medium	22	1.08	0.31	0.7-1.8
Large	21	2.82	0.99	2.0-5.2

**Three farms were removed from the dataset, one because of an abnormally large landholding (12.5 ha) and two because of unusually large numbers of small ruminant numbers per farm (> 50 head).*

3.3.1 Maize

Maize is a staple crop grown by almost all households (Table 3). Small farms sowed the largest proportion of land to maize in the long rains of 1996 and also obtained the highest yields. The yields obtained, based on farmer recall, were low but around the average of 1.7 t/ha reported by Karanja *et al* (1997) from a survey of 190 farms in the Central Kenya Highlands. Whether the maize was grown as a sole crop or intercrop was not recorded in the present survey. The proportion of land sown to maize in the current survey is similar to those found on other farms in Kiambu growing no perennial crops (tea or coffee) (Staal *et al, 1997)*.

3.3.2 Beans

Small farms sow the largest proportion of their farm to beans but fewer small farms than medium and large producers grow beans (Table 4). This may reflect the need during this drought year to replant sole maize crops on smaller farms to reduce purchases of this expensive grain (Dr J. Chui, KARI, Muguga. pers comm, 1998). Yields did not differ between farms of varying size.

3.3.3 Potatoes

Potatoes (*Solanum*) are cultivated by over 50% of the farms in each category of farm size (Table 5). Large farms allocate the lowest proportion of land to the cultivation of potatoes.

3.3.4 Napier grass

Napier grass (*Pennisetum purpureum*) is a planted forage used by farmers to feed dairy cows. It is also an effective means of controlling soil erosion when planted in rows along contours.

Table 4. Cultivation of beans in the short rains of 1996 (October - November)

Farm size	Percentage of farms growing beans	Percentage of farm sown to beans	Mean yield (t/ha (range))
Small	78	24	0.9 (0.1 - 1.8)
Medium	91	20	0.7 (0.1 - 1.8)
Large	86	15	0.9 (0.1 - 3.6)

Table 3. Cultivation of maize in long rains of 1996 (April - August)

Farm size	Percentage of farms growing maize	Percentage of farm sown to maize	Mean yield (t/ha (range))
Small	93	38	2.1 (0.4 - 5.8)
Medium	100	27	2.0 (0.6 - 4.5)
Large	90	20	1.6 (0.2 - 4.2)

Napier grass is present on 64, 73 and 43% of small, medium and large farms and occupies 27, 28 and 21% of the farm area respectively. This is higher than the average of 14% (range: 4-23%) for Kiambu farms reported by Staal *et al (1997)*. Yields of Napier grass were not reliably obtained from the present survey. Other survey work in the districts has shown, however, that yields are less than 10 t DM/ha/yr (D. M. Mwangi, KARI Muguga. pers comm, 1998).

3.3.5 Bananas

Approximately half of the farmers in each category grow bananas (Table 6). Small farmers allocate only 11% of their farm to growing bananas. This reflects the normal cultural practice of growing bananas along field boundaries and around the homestead/cattle shed. On small farms this amounts to a very limited area. Despite this, yields per hectare are twice those of the bigger farms at 5.2 t/ha (banana bunch weight about 25 kg - Muriithi, 1996).

3.3.6 Coffee

Coffee was present on 28, 41 and 33% of small, medium and large farms respectively, mainly those between an altitude of 1500 and 1700 m.a.s.l. Farms of increasing size in the coffee zone plant 42, 37 and 20% of the farm area to the crop, figures that lie near the 36% reported for coffee farms in Kiambu by Staal *et al* (1997). The present survey did not adequately capture the yield of coffee in 1996.

3.3.7 Vegetables

The main vegetable types: sweet potatoes, kales, carrots, cabbages and french beans are grown in various combinations on 43 - 45% of all farms (Table 7). Small areas are allocated

Table 5. Cultivation of potatoes (*Solanum*) in the long rains of 1996

Farm size	Percentage of farms growing potatoes	Percentage of farm sown to potatoes	Mean yield (t/ha (range))
Small	50	13	25 (8 - 48)
Medium	68	15	13 (2 - 40)
Large	67	9	25 (4 - 56)

Table 6. Cultivation of bananas in 1996

Farm size	Percentage of farms growing bananas	Percentage of farm sown to bananas	Mean yield (t/ha (range))
Small	50	11	5.2 (4.5-6.0)
Medium	50	19	2.2 (1.0-3.0)
Large	57	13	2.3 (0.7-6.0)

Table 7. Cultivation of vegetables in 1996

Farm size	Percentage of farms growing vegetables	Percentage of farms sown to vegetables
Small	43	11
Medium	45	17
Large	43	8

to the crops, usually next to the homestead. The crops are grown mainly for home consumption. Any surpluses are sold. Owing to the diversity of products in this category, yield weights were not captured in the survey.

3.4 Livestock production

Dairy cows were owned by all households in the survey since this was one of the criteria for inclusion in the sample (Figure 3). Local dairy genotypes were owned by 27 and 10% of farmers in Murang'a and Kiambu Districts, respectively. The most common exotic dairy breeds are Friesian, Ayrshire and Guernsey. All dairy cows on farms in the sample are kept in permanent confinement and fed by cut-and-carry. Replacement dairy stock; heifers and immatures, were owned by around only half of the households.

Local poultry are owned by 70 to 80% of all households in the survey in flocks numbering from 1 to 10 birds. Goats are more frequently owned than sheep and small ruminant ownership tends to be a feature of larger farms. Sheep, bulls, pigs, broilers and layers are the least frequently owned livestock categories. Broilers are kept in large numbers by only a few producers.

3.4.1 Herd/flock size by farm size

Table 8 shows that average cow herd size increases between small farms and large farms by a multiple of 1.7, although considerable variation within categories occurred. The biggest herd of cows in each of the farm categories was; small 4, medium 6 and large 25. The average cow herd size did not increase in proportion to the increase in farm size. There is clearly not a simple relationship between land holding and cattle herd size and this is explained below.

Bulls are a more significant feature of larger farms. Ownership of heifers, immatures (including calves) and goats did not differ significantly between categories of farm. Sheep, layers, broilers and pigs were owned by not more than one third of households in each category. However, these households tend to own large numbers of these stock.

The study by Staal *et al* (1997) of cattle-owning in Kiambu District reports that households had on average 0.2 bulls, 1.5 cows, 0.7 heifers and 3.0 calves. These figures only contrast with the present study for heifer and calf (immature) numbers.

3.4.2 Ranking the uses of livestock products on farms

Only cattle and goat products are considered in this section because these livestock species occurred on the majority of farms in both districts. Free-range local poultry, although also owned by a large proportion of farms and therefore, through sales, making an important contribution to livelihoods, were not considered because they would not contribute to manageable manure production. Broiler/layer units and pigs produce larger quantities of manure, of high quality, but ownership is limited to few farms. Owing to skewed ownership, these livestock categories are also excluded from the following analysis.

Farmers, including those not keeping that category of livestock, were asked to rank products from 1 (high value) to 5 (no value) and a mean taken of the total scores in each farm size class.

Table 8. Average livestock numbers and farm size

Farm size	Livestock type									
	Bull	Cow	Heifer	Immature cattle	Goat	Sheep	Layer	Broiler	Local hen	Pig
Small	0.0	1.9	1.2	1.5	1.3	0.2	48*	24*	5	1.4
Medium	0.2	2.2	1.1	2.3	1.2	1.1	55*	14*	14	5.0*
Large	0.6	3.2	1.6	1.2	1.7	2.9	76*	0	12	1.2

** Data influenced by a few larger producers of pigs and poultry.*

Figure 3. Percentage of farms of different size owning livestock categories

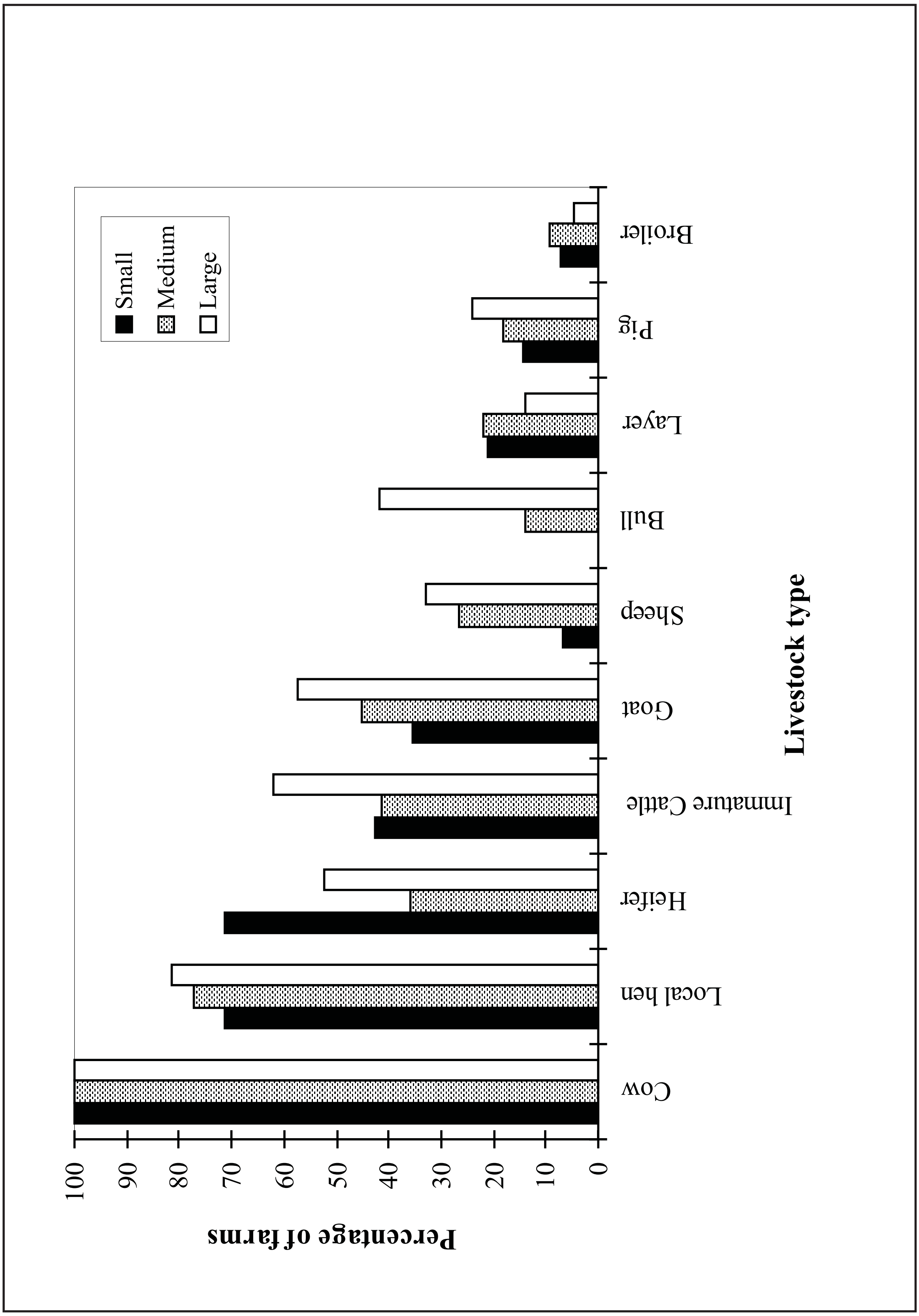


Table 9. Ranking of cattle products (1=high, 5=low)

Farm size	Cattle products		
	Milk	Manure	Offspring
Small	1.4	1.6	3.6
Medium	1.5	1.9	3.4
Large	1.6	2.0	3.4

Table 10. Ranking of goat products (1=high, 5=low)

Farm size	Goat products			
	Milk	Meat	Manure	Kids
Small	5.0	4.8	4.5	4.4
Medium	4.8	4.1	3.7	4.4
Large	4.9	3.9	3.7	4.4

Cattle products

Results indicate that milk and manure are almost equally ranked on small farms (Table 9). Calves are ranked lower than these products on all farms. Meat was not mentioned as an important output from the dairy enterprise.

Use of cattle products

Only 14% of small farmers produce milk solely for home consumption. Over 50% sell part or all of the milk. Thirty-six percent of households did not respond to this question.

Milk solely for home consumption is produced by only 10% of medium households. Almost 60% produce milk exclusively for sale. Fourteen percent of large farms produce milk solely for home consumption whilst 43% produce milk for sale only.

Sixty-seven percent of farms in each category were using their own cattle manure for crop production. Thirty-three percent did not respond to this question. No farms, small, medium or large, reported sale of manure.

The immediate fate of calves on over half of small farms was sale. Only 6% of medium scale farmers said that they would keep home produced calves as dairy replacements or fatten them for beef. Two thirds of large farms said the calves produced were sold soon after birth. Only 13% said they would rear the calves as dairy replacements or for beef.

It is worth noting that this reported strategy of rapid sale of calves is not corroborated by the ownership profiles in Figure 3 and Table 8. Other studies have found a lack of immature stock in cattle herds suggesting that rapid sale may reflect the cost and risk associated with calf rearing (Staal *et al*, 1997). The apparent inconsistency between farmers in this study is difficult to explain but the results in Table 8 may be skewed by a few farmers in Kiambu who keep a large number of calves. The area of smallholder dairy replacement rearing is currently undergoing study (MoA/KARI/ILRI Smallholder Dairy Project).

Ranking of goat products

Consumption of goat milk was not reported by any of the households and so received a low ranking by respondents (Table 10). Offspring received an equal and low ranking by all categories of farm. The products valued marginally higher were manure (by large and medium farms) and meat (by large farms).

Uses of goat products

Goat products generally received low ranking by all farmers but with manure being the most useful product for medium and large farmers. This may reflect that few goat products are actually consumed on farm, it being more likely that they are sold in times of need. Conceptually then, the goat itself is valued as a capital asset rather than for any one product *per se*. However, if this is the case it is unclear why kids are not ranked more highly in the ranking of goat products in Table 10.

As goat products received a low ranking it was decided not to detail any uses of goat products.

3.5 The relationship between ruminant livestock numbers and farm size

This relationship was investigated for two reasons: (1) it is hypothesised that the limit on stock numbers may be dictated by land available to grow forage (Napier grass and crop residues) and (2) the density of ruminant livestock will indicate the availability of manure per hectare. If the former hypothesis is true then livestock density should be similar across farm size or possibly decrease on smaller farms as limited available land is preferentially used for food production.

A significant positive linear relationship ($R^2 = 0.15$, $p = 0.003$) was found between land holding and the density of sheep and goats indicating that larger farms had a higher density of sheep and goats per hectare than small farms (Figure 4). However, there was a strong negative relationship ($R^2 = 0.176$, $p < 0.001$) between land holding and cattle density (Figure 5), which was better described by a logarithmic ($R^2 = 0.36$) than by a linear equation. Similarly, there was a significant negative relationship between land holding and total ruminant density ($R^2 = 0.16$, $p = 0.001$), again better described by a logarithmic equation ($R^2 = 0.28$) (Figure 6). Thus, the density of cattle and, as a result, also of total ruminants was higher on small farms. This suggests that livestock numbers, especially cattle holdings, are apparently not constrained by farm size and indicates greater manuring potential for the smaller farms.

Figure 4. The relationship between land holding and sheep/goat density

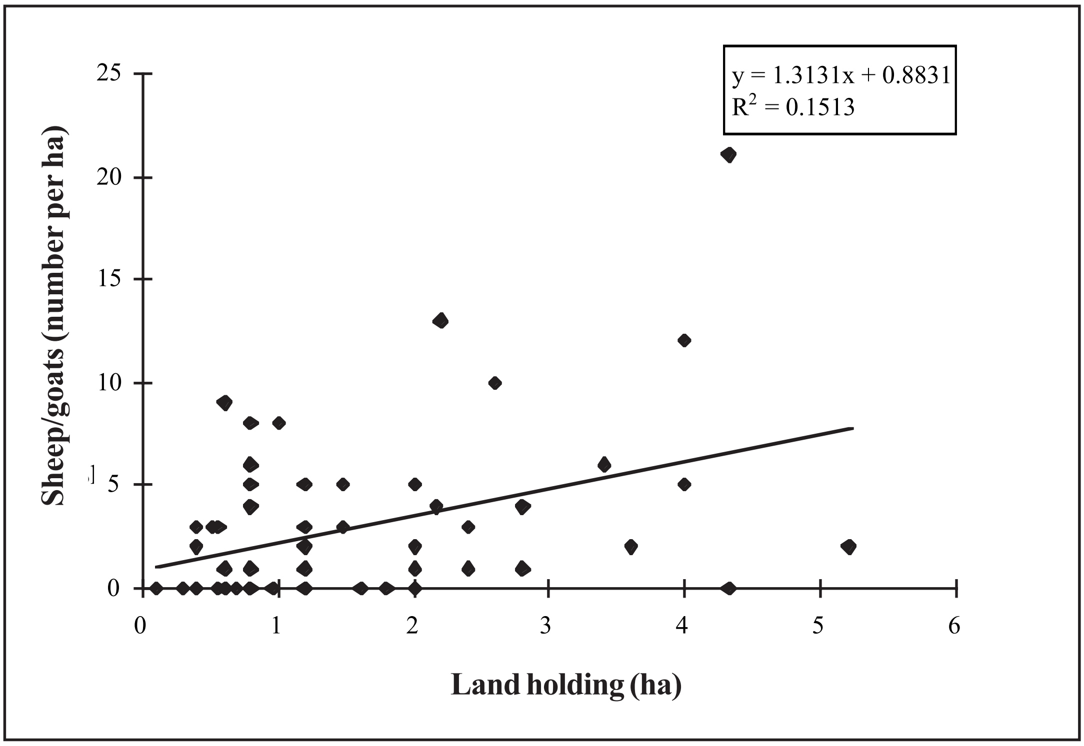


Figure 5. The relationship between land holding and cattle density

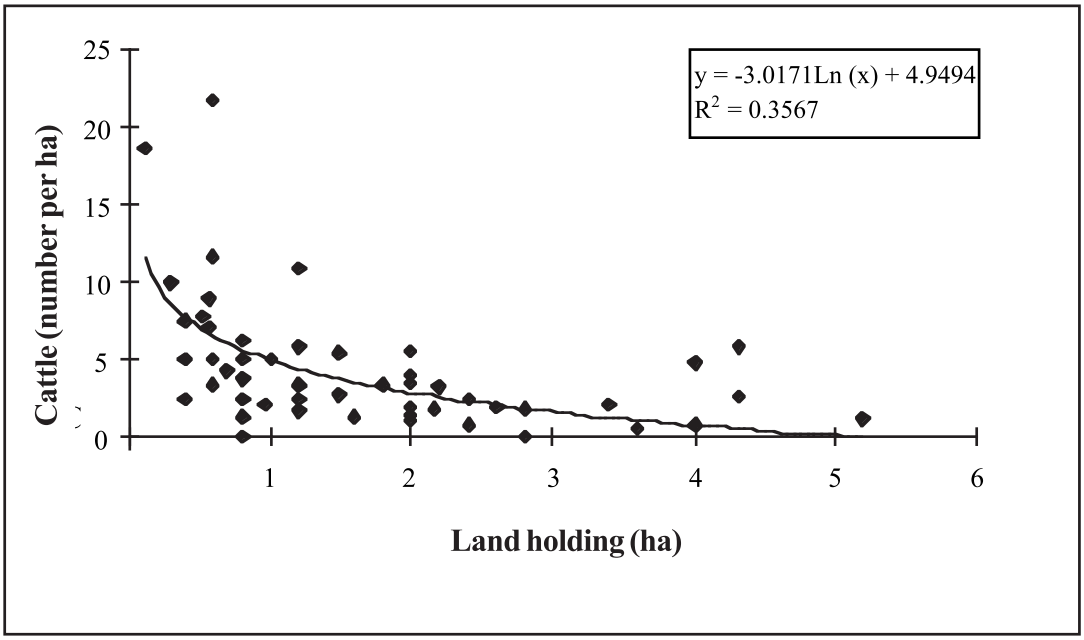
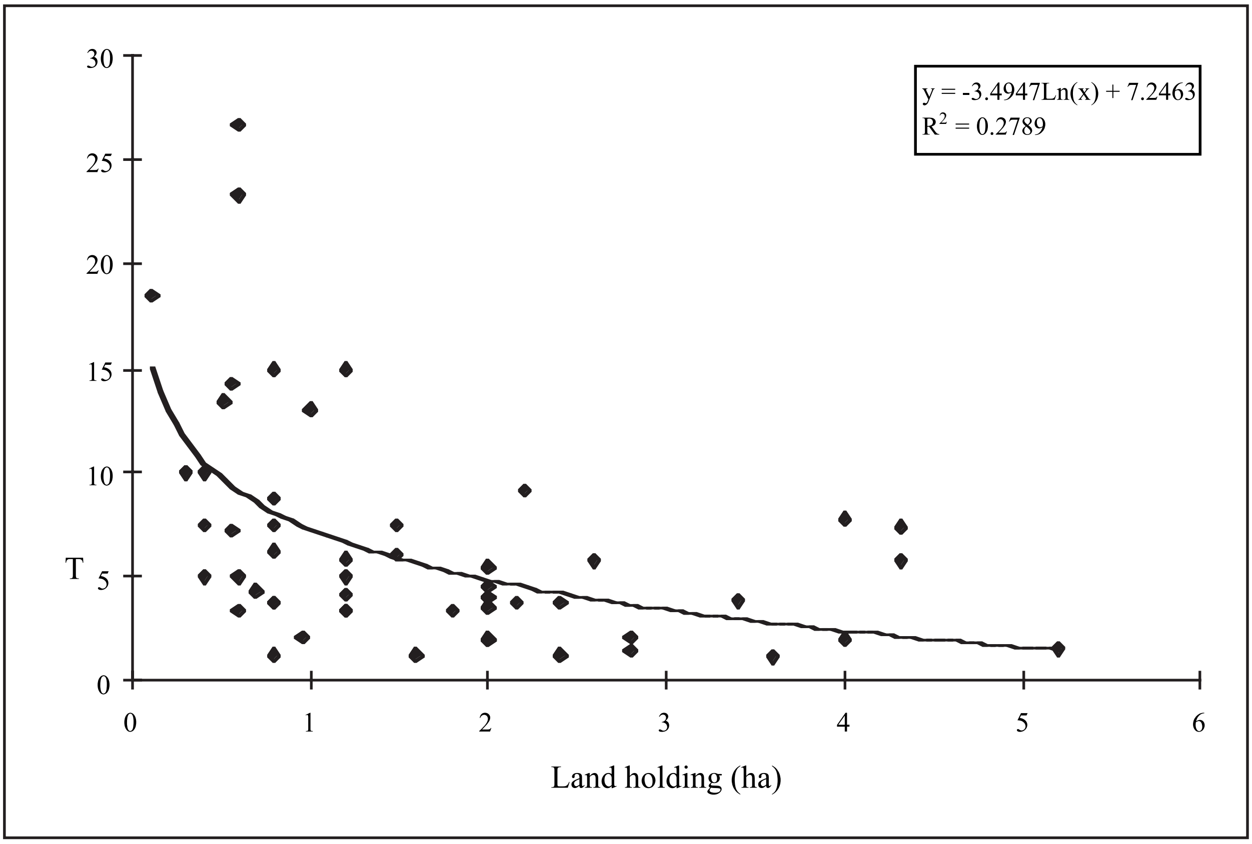


Figure 6. The relationship between land holding and total ruminant density



3.6 Factors affecting manure production

The greatest manure producing potential obviously emanates from owning the largest livestock species, cattle. All farms in the sample owned cattle. More importantly, all farms in the sample reported keeping cattle in permanent confinement throughout the year, allowing therefore, maximum opportunity for manure collection. The completeness of manure collection depends very much upon the way in which livestock are housed and the type of feeding they receive.

The following sections examine cattle housing, feeding, manure management practices and strategies to enhance the quantity and quality of manure produced on small, medium and large farms.

3.6.1 Cattle housing

Fifty seven, 68 and 71% of large, medium and small farms kept cattle in 'zero grazing' units (Plate 1). These are pens featuring distinct lying and standing areas for cattle with partial or complete roofing, feeding and water troughs. The rest of the farmers in each class kept cattle in traditional 'bomas' (Plate 2). These are pens with soil floors where litter (bedding and feed refusals) is allowed to accumulate across the whole floor area. They may be roofed, with feeding and watering facilities. All cattle in the two districts are kept in permanent confinement throughout the year.

Around 70% of all farms in each category with zero grazing units had concrete floors with good drainage. Those with soil floors in zero grazing units or traditional bomas reported poor drainage.

3.6.2 Feeding strategies for cattle

On small farms

Most farms indicated a fodder shortage in the long dry season (Table 11). No farms had access to grazing. So to compensate, 36% of farmers purchased fodder during the long dry season. Fifty percent of farmers did not report any forage compensation strategy.

Eighty percent of farms obtain some fodder from their own land all year (Napier grass and crop residues) and the same proportion used concentrates (dairy meal, maize germ, brans, wheat pollard) all year. Twenty-eight percent feed purchased poultry waste all year and all those that have larger poultry units (21%) feed the waste.

On medium farms

Seventy percent of farms experienced a long dry season feed shortage. No farms use grazing. Ninety percent of farms use home produced fodder all year but only 28% of all farms purchase fodder in an attempt to alleviate long dry season

Table 11. Cattle feeding strategies (% of households)

Farm size	Experience dry season fodder shortage	Use grazing	Use own land as source of fodder all year	Purchase fodder in dry season	Use concentrates all year	Use purchased poultry waste all year	Use own poultry waste all year
Small	80	0	80	36	80	28	21
Medium	70	0	90	28	86	20	20
Large	67	10	95	5	62	20	14

forage shortages. Eighty-six percent of farmers use concentrates all year. Twenty percent of farms purchase poultry waste to feed all year in combination with concentrates and the same proportion feed their home-produced poultry litter, again in combination with concentrates.

On large farms

Sixty-seven percent of farms experienced a shortage of feed during the dry season. All farms stall-feed year-round with only 10% of farms employing roadside grazing in addition to this. All farms, except one, used their own land as a source of cut fodder, this one farm routinely purchased fodder. Sixty-two percent fed concentrated feeds all year but 20% only used concentrates in the dry seasons. The rest (18%) did not use concentrates. Twenty percent of farms fed purchased poultry manure routinely throughout the year, 14% fed home produced poultry manure. All fed poultry waste in combination with concentrates.

3.7 Manure management

3.7.1 Manure collection

Few small farms (14%) actually report collecting cattle faeces in their manure heap/pits, compared with 40 and 45%, respectively, of medium and large farms (Table 12). Small farms are more likely to add feed refusals to the heap/pit and, together with medium farms, are more likely to purposefully collect foliage/litter from on or off the farm (eg *Grevillia* or *Eucalyptus* foliage) to add to the manure heap. Twenty percent of small farmers clean the cattle pen every day and store the manure. All other farmers clean less frequently.

It appears, therefore, that a greater proportion of small farmers are attempting to maximise manure production by adding biomass to the manure heaps/pits. To reduce physical loss of manure some are cleaning the pen on a daily basis. Fifty to 73% of farmers simply drained urine into the manure heap/pit as their means of urine collection. This may not be the most effective technique for urinary nutrient collection. However, only a few farmers employed the potentially better technique of collecting urine in a drainage sump (Plate 3) and then transferring it directly to crops.

3.7.2 Manure management techniques

Having collected manure, around one third of small and medium farmers afforded no further management to the pit or heap (Table 13). Only a quarter of larger farms did not manage the manure further. Four distinct management strategies were identified; covering, turning, adding ash or adding water. Only the small and medium farmers practised single strategies, the most notable being covering, by one third of small households. Seventy-five percent of large farms employed combined techniques.

The majority of farmers in each category saw that there was benefit to be gained from managing the manure heap. For smaller farms, covering was the single most important technique, presumably because this required low inputs of

Table 12. Cattle manure collection strategies (% of households)

Farm size	Collect faeces only	Add feed refusals to manure heap	Add collected foliage/ litter	Purpose -fully collect urine	Drain urine directly into manure heap	Clean animal pen every day	Clean animal pen less frequently	Take solid waste directly to field each day
Small	14	54	21	7	73	20	80	0
Medium	40	25	35	9	50	0	100	0
Large	45	33	14	5	50	0	94	6

Plate 1. A typical zero-grazing unit in Central Kenya. Note covered lying area with poor drainage (accumulated faeces and urine).

Plate 2. A traditional boma in Central Kenya. Note deep littering of soil floor using feed refusals (maize stover). No trough present, animals are fed from floor on Napier grass.

Plate 3. Improved zero-grazing unit in Central Kenya featuring urine/slurry collection channel and sump. Faeces are cleaned from concrete floor each day and piled separately.

limited labour resources. Seventy-five percent of large farms used two or more of the four techniques listed. Large farms tend to be better resource-endowed with greater access to labour for manure turning or can afford to divert water from essential domestic/livestock uses to improving manure.

3.7.3 Manure storage

Covering manure heaps/pits is a less labour intensive technique than turning to physically manage the manure, and a technique which could therefore be promoted if shown to improve manure quality. All farmers were asked why it was important to cover manure. Small farmers said that covering would speed decomposition and conserve nutrient status. Speeding decomposition was the only reason given by medium farms whereas a range of reasons and multiple reasons were given by large farmers the most important of which was to stop evaporation of water (Table 14).

Storage periods are short on small farms but longer on larger farms. This may indicate the intensity of manure use on small farms but could also be a factor of limited storage space and/or proximity to land requiring manure on small farms.

3.7.4 Manure quality

Table 15 shows the summary analysis of manure samples collected from farms during the survey. From the standard deviation and ranges given it can be seen that very considerable variation in the content of the major nutrients occurred among manure samples of the same type as well as between types. Large variations in nutrient contents among manure samples are not unexpected and have been reported previously for large scale surveys of manure quality in temperate farming systems (Dewes & Hünsche, 1998). To explore this further, farmers' perceptions of manure quality and their views on how to increase manure quantity and quality were recorded.

Table 13. Manure handling techniques (% of households)

Farm size	Non-managed heap/pit	Covered heap/pit	Turned heap	Added ash	Added water	Employed two or more techniques
Small	30	33	14	0	0	17
Medium	36	9	9	5	5	36
Large	25	*	*	*	*	75

** 75% of large farms practised at least two of the techniques.*

Table 14. Manure storage (% of households)

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

Are there differences in the quality of manures?

Around 80% of small and medium farmers said that there were differences between manures in their quality as soil amendments. Differences in manure quality were reported to occur between different livestock species and also as a result of different management techniques. Only 40% of larger farms said a difference could be detected.

Fifty percent of small farmers ranked cattle manure as best. Medium farmers ranked poultry manure as best whereas larger farmers were undecided which was best out of cattle, sheep/goat, poultry and pig manures. The criteria used for ranking were a combination of quality factors combined with the quantities that could be produced from each species.

What makes manure from one livestock species better than from others?

Few farmers could answer this question. Of the four small farmers who answered, three commented on the residual fertility effects of cattle manure on soils and one said it gave good effects on soil fertility. One medium and one large farmer said cattle manure gave the best residual effects and two large farmers said it was good because large quantities could be produced.

No small farmers had experience of using poultry manure as fertiliser but six medium and two large farmers commented that it should have an instant soil fertility effect. This confirms the view of farmers reported in Harris *et al* (1997). Nobody could comment on what the benefits were to using small ruminant manure.

How do you know what a good manure looks like?

Thirty percent, 20% and 50% of farmers in the large, medium and small categories respectively said a good manure is one that is fully decomposed. The remainder (ie the majority of farmers) said that the quality of the manure could only be known by applying it to a crop.

How could you increase the quantity of the manure that you produce?

Eighty percent of small farmers said that the way to increase the quantity of manure produced was to increase the use of crop residues, particularly maize stover, as fodder and bedding. Seventy percent and 60% of medium and large farmers agreed that this was the best strategy. However, of the remaining 40% of large farmers, half said they would offer larger quantities of a variety of feeds to their cattle and the other half said they would simply buy more cattle.

Almost all of the small farms (86%) and 55-60% of large and medium farms reported using bedding for their cattle. All used fodder refusals as bedding, especially rejected maize stover, except one quarter of small farms and 40% of large farms that used sawdust from local saw mills as the main bedding type.

3.7.5 How to increase the quality of the manure that is produced?

By feeding: Twenty-five percent of small farmers and 30% of large farmers thought that it was possible to improve manure quality by providing better feeds to livestock (note that most farmers fed concentrates).

By capturing urine: Sixty, 50 and 40% of small, medium and large farmers respectively said that the capture of urine was important to overall manure quality. Specifically, it assists in the decomposition of the waste heap said 43, 27 and 14% of the same farmers. Only 10% of medium farmers recognised urine as a source of plant nutrients. The rest were not aware of its influence on the nutrient content of manure.

By mixing manures: Eighty, 40 and 50% of small, medium and large farmers said that they thought mixing cattle manure with manure from other species, particularly poultry, would be beneficial to overall quality.

By composting: Thirty percent and 20% of small and medium farmers said that longer composting periods would improve quality.

Table 15. Mean, (s.d.) and range of N, P, K and C content and C:N ratio of collected manures

Manure type	n	N (%)	P (%)	K (%)	C (%)	C:N ratio
Cattle	55	1.4 (0.35) 0.5-2.0	0.60 (0.34) 0.19-1.61	1.34 (0.56) 0.54-2.72	35 (8.8) 17-52	26 (8.4) 17-56
Cattle + compost	10	1.3 (0.46) 0.8-2.1	0.44 (0.21) 0.21-0.90	0.78 (0.36) 0.30-1.39	25 (5.6) 18-35	21 (5.6) 11-30
Cattle + goat	1	1.3	0.29	1.11	27	20
Cattle: dung + urine	3	1.5 (0.22) 1.2-1.7	0.65 (0.36) 0.30-1.01	0.77 (0.23) 0.50-0.94	35 (6.5) 29-42	24 (0.8) 23-25
Cattle: fresh dung	2	1.5 (0.36) 1.2-1.8	0.54 (0.28) 0.35-0.74	0.80 (0.26) 0.62-0.98	39 (11) 32-47	26 (1.0) 25-27
Cattle: slurry	2	1.3 (0.40) 1.0-1.6	0.36 (0.04) 0.33-0.39	0.58 (0.06) 0.54-0.62	34 (14) 24-44	25 (2.8) 23-27
Goat	9	1.5 (0.51) 0.9-2.3	0.40 (0.19) 0.18-0.83	1.37 (0.60) 0.66-2.56	32 (9.3) 20-46	22 (3.4) 15-26
Goat + chicken	2	0.9 (0.10) 0.8-0.9	0.24 (0.06) 0.20-0.29	0.45 (0.17) 0.34-0.58	18 (0.4) 17-18	21 (2.0) 19-22
Goat + sheep	1	0.9	0.74	0.86	27	32
Pig	8	2.0 (0.23) 1.5-2.2	1.19 (0.44) 0.74-1.82	1.08 (0.22) 0.90-1.51	40 (8.0) 24-48	21 (3.5) 16-27
Poultry: broiler	2	2.4 (0.21) 2.3-2.6	1.60 (0.18) 1.50-1.75	0.88 (0.03) 0.86-0.90	41 (7.1) 36-46	17 (1.5) 16-18
Poultry: layers	8	1.8 (0.47) 0.9-2.4	1.27 (0.44) 0.29-1.73	0.67 (0.13) 0.54-0.90	41 (6.7) 28-48	23 (5.6) 16-33
Poultry: local	1	1.2	0.91	0.62	22	19
Rabbit	4	1.6 (0.33) 1.2-1.9	0.40 (0.11) 0.29-0.55	1.07 (0.49) 0.46-1.67	33 (11) 28-48	20 (5.1) 14-27
Sheep	1	1.5	0.33	1.35	33	22

By storing in a covered pit: Thirty-six percent and 20% of small and large farmers said that storing in a covered pit would enhance manure quality.

By adding ash and inorganic fertiliser: This would improve manure quality said 30% of medium farmers.

By adding green biomass: Said 14% of large farmers.

By collecting and storing faeces alone: Said 20% of large farmers.

By roofing the whole cattle pen: Thirty percent of farmers in each category said that this was good idea. These farmers were actually practising complete roofing.

All farmers in the small and medium categories could suggest one or several strategies to raise manure quality. However, just over 20% of large farmers declared that they had no idea how improvements in quality might be attained.

The findings reported here do not necessarily agree with those in Tables 12 and 13. Farmers demonstrated an understanding that management could affect manure quality but this does not mean that they necessarily employ these techniques.

3.7.6 Factors influencing manure quality

A statistical analysis of variance was carried out to examine ten factors which were considered by farmers/researchers to influence the quality of the cattle manure (N, P and organic C) which was sampled during the survey (Appendix 3). Whether the farmer:

- Fed concentrates
- Had a zero grazing unit or a traditional boma
- Had a concrete or a soil floor
- Had an animal unit with a sloping floor (ie collecting urine effectively)
- Had a completely covered animal unit
- Stored the manure in the open
- Shaded the manure heap
- Covered the manure heap
- Turned the manure heap regularly
- Composted the cow manure with other materials

Nitrogen: Factors which significantly increased N concentration were feeding of concentrates (1.4% versus 1.2%, p = 0.042, n = 12, 43); zero grazing unit rather than a traditional boma (1.4% versus 1.2%, p = 0.043, n = 36,11); concrete rather than soil floor (1.5% versus 1.3%, p = 0.024, n = 27, 20). Regular turning reduced the N content (1.2% versus 1.4%, p = 0.021, n = 35, 14).

Phosphorus: The phosphorus concentration of cattle manure was significantly increased by feeding of concentrates (0.64% versus 0.43%, p = 0.041, n= 43, 11); concrete rather than soil floor (0.71% versus 0.42%, p = 0.002, n = 27, 19). The phosphorus concentration was significantly reduced by covering the heap (0.42% versus 0.68%, p = 0.009, n = 15, 33).

Organic carbon: The organic carbon concentration of the manure was significantly increased by feeding concentrates (36% versus 31%, p = 0.041, n = 43, 12); concrete rather than soil floor (38% versus 30%, p = 0.0004, n = 27, 20); shading the heap (36% versus 29%, p = 0.022, n = 8, 41); and covering the heap (39% versus 33%, p = 0.016, n= 15, 34).

Interactions between these factors were not examined.

3.8 Estimated quantities of manure produced in 1996

Farmers were asked to estimate yearly production of manure from their ruminant stock using local units of measure (sacks, pick-up truckloads, 7t truckloads etc) which had been calibrated by Muriithi (1996). In parallel, an estimate was made of ruminant faecal production theoretically possible from the livestock present on farm (Table 8).

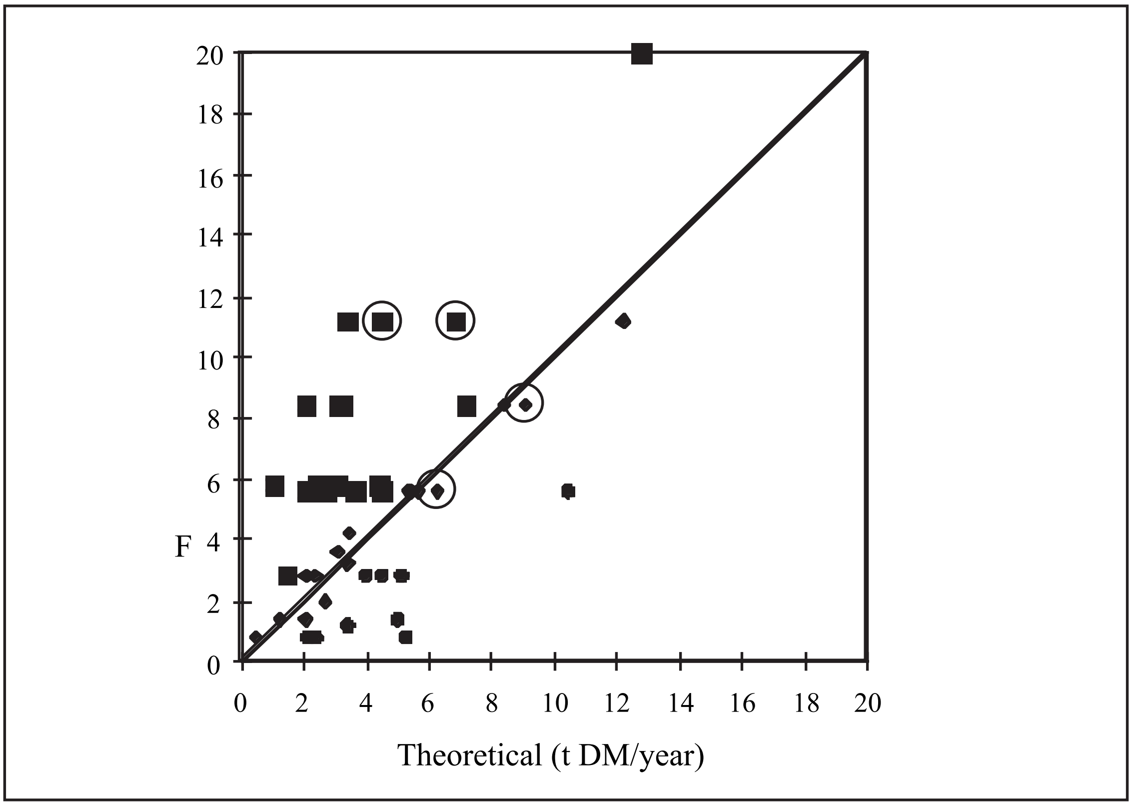
The generally accepted figure that a ruminant produces 0.8% of its liveweight as faecal dry matter (DM) in a day (Fernandez-Rivera *et al*, 1995, confirmed for the Kenya Highlands by Delve, unpublished data, 1998; Lekasi, unpublished data, 1998) was used to calculate faecal DM output. It was assumed that the DM of cattle faeces is 40% and that of small ruminants 50%, average figures derived from measurements taken from ruminant manure sampled during the survey.

Figure 7 shows how farmer estimations of manure production compared with theoretical values of faecal output based on the liveweight and number of animals present on the farm at the time of the interview.

Forty-five farmers estimated yearly manure production (1996) from cattle, sheep and goats. Seventeen farms lay above the line x=y (marked), where theoretical manure waste production is less than that estimated by the farmer (squares), nine farms below, where theoretical manure production is greater than the farmers' estimate (circles) and 19 close to the line, where theoretical manure production matched the farmers' estimates (diamonds).

The reason why some theoretical values are lower than the farmers' estimate may be because the calculation does not take into account the unknown quantities of additional organic amendments added to the manure heap. For example, the two farms circled (squares) reportedly added feed refusals and weeds to their heaps, whereas the two farms (diamonds) circled near the line x=y collected only faeces in the manure heap. Theoretical values higher than farmers' estimates could be due *inter alia* to changes in herd size over 1996, rapid dry matter loss from the manure heap during decomposition, loss of manure or inaccurate assessment of manure production by the interviewee.

Figure 7. Relationship between theoretical annual ruminant faecal production levels on farms compared with farmers' estimations of annual manure DM yields



On only 20% of the farms was manure production overestimated by the theoretical calculation. It is more likely therefore that manure production would be underestimated or predicted correctly. For this reason it was decided that the total ruminant livestock liveweight present on farm could be used as a valid predictor of total yearly manure output (faeces only).

3.8.1 Maximum theoretical production of manure (faeces only)

In Table 16, the average ruminant herd in each farm category has been divided into large cattle (bulls, cows and heifers) and small cattle (immatures and calves) (see Table 8). Liveweights for large cattle were arbitrarily taken as 350 kg, small cattle 100 kg and sheep/goats as 25 kg (B. Lukuyu, KARI Muguga pers comm). It is assumed that ruminants produce 0.8% of their liveweight as faecal DM daily (see above).

Table 16 shows that small farms have the greatest faeces availability per hectare with approximately twice and four times that available on medium and large farms respectively. This calculation of course assumes no DM losses during storage. The extent of DM loss is currently under investigation.

Evidence reported above suggests that the small cattle population on the farm is transient over the year because of frequent sales and purchases. Small ruminants are more likely to be fed through grazing. Thus, estimating the year-long contribution of manure from these animals as if they were stall-fed may be incorrect. It is worth noting however that the contribution made to total faecal DM production by the 'less mobile' large cattle population is between 81 and 89% across the three categories of farm.

Table 16. Ruminant holdings on farms of varying size and estimated annual production of faeces/ha

Farm size*	Mean (and range of) ruminant livestock numbers			Mean (and range of) estimated production of faeces (t DM/ha/yr)
	Large cattle	Small cattle	Small ruminants	
Small	3.1 (1-9)	1.5 (0-9)	1.5 (0-9)	8.2 (3.1-18.9)
Medium	3.5 (1-11)	2.3 (0-8)	2.3 (0-8)	3.6 (0.5-10.2)
Large	5.4 (0-20)	1.2 (0-5)	4.6 (0-21)	2.2 (0.1-5.1)

**Three farms were removed from sample, one with large land holding and two others with very high small ruminant numbers on limited land.*

Table 17. Theoretical N application rates to farmland from ruminant excreta produced on farms

Farm size	Mean (and range of) N application rates (kg/ha/yr)		
	Faeces	Urine	Total
Small	114 (43-265)	289 (97-696)	403 (140-939)
Medium	50 (8-142)	121 (17-355)	171 (25-498)
Large	30 (1-71)	78 (3-185)	108 (5-256)

Table 18. Theoretical P and K application rates to farmland from ruminant excreta produced on farms

Farm size	Mean (and range of) P and K application rates (kg/ha/yr)	
	Faecal P	Urinary K
Small	41 (16-95)	347 (116-835)
Medium	18 (3-51)	146 (21-427)
Large	11 (1-25)	93 (4-222)

3.9 Nutrients potentially available in faeces and urine produced on farms

The survey sampled stored manure on all farms and found the average N content of cattle manure to be 14 g/kg DM. Small ruminant manure was measured to contain 15 g/kg N (Table 15). For the following calculation, since cattle are the largest and predominant livestock on farms, it is assumed that manure N content was 14 g/kg N. Phosphorus content of stored manure was also analysed and was estimated to be 5 g/kg DM.

Lekasi (unpublished data, 1998) estimated that steers produce 25 g urine/kg liveweight/day, a figure which agrees with that given for ruminants by Sundstøl & Owen (1993). Urine is assumed to contain 10 g N and 12 g K/l (Sundstøl & Owen, 1993). If it is assumed that all faeces and urine are captured and that no N, P or K is lost in the course of a year, then if all excreta is conserved the application rates of N, P and K, shown in Table 17 and 18, could theoretically be achieved.

In the East African Highlands it is estimated that a 4 t DM/ha maize crop requires an input of between 16 and 24 kg P/ha and around 100 kg N/ha (Sanchez *et al*, 1997). The estimates above indicate that as long as nutrient losses from manure are minimised the smallest farms could easily achieve these nutrient application rates. The nutrient constraints for larger farms through the use of manure only are obvious and on these farms there appears a need to supplement with inorganic fertilisers.

It is important to note that the cost currently incurred by farmers who do not effectively conserve/use urine is high. Approximately 80-95% of the N and P consumed by livestock is excreted. Whereas most P is voided in faeces (Ternouth, 1989), N is voided in both urine and faeces (Powell *et al*, 1998). It has been estimated that urine contains more than twice as much N as faeces and values of 10 g N per litre of urine have been recorded in this study. Up to two-thirds of the urine-N is in the form of urea (Bristow *et al*, 1992) which is easily lost if poorly managed. The N loss from stored faeces is unknown and is currently being measured.

Again, present practices which inadequately conserve urine result in the loss of considerable quantities of K. Faecal P is less labile than faecal N compounds and so it is expected that less will be lost during manure storage.

3.10 Estimation of the monetary value of nutrients in faeces and urine

In this section an estimate is made of the value of total excreta (faeces and urine) production both on an inorganic fertiliser equivalent rate (N in urea and P in triple superphosphate (TSP), inorganic value) and on the current market rate for manure in the highlands of Kenya (organic value). Since P and N are the major limiting nutrients in highland soils the value of K was not considered here.

Nine farms in the two districts reported purchasing cattle manure in 1996. The average price of Kenya Shillings 5.3 / kg of dry manure is the figure used here to estimate the organic fertiliser value of home produced manure. Thus, using data in Tables 17 and 18, the following estimates of value can be made (Table 19).

Table 19. Estimated monetary value of animal waste potentially produced on farms

Farm size	Mean (and range of) monetary value of nutrients in faeces (KSh)*		Mean (and range of) monetary value of nutrients in urine (KSh)*
	Inorganic equivalent (N and P) as urea and TSP	Organic value based on manure DM	Inorganic equivalent (N) as urea
Small	3,800 (1,350-11,300)	18,400 (6,600-55,300)	4,400 (1,350-14,500)
Medium	4,200 (470-13,200)	25,200 (10,800-64,600)	4,600 (480-4,800)
Large	6,800 (300-23,750)	37,100 (1,550-116,100)	7,800 (300-27,800)

**1997: KSh 90 = £1. Daily minimum wage rate = KSh 70-90 per day.*

The organic fertiliser value of faeces is approximately five times that of its inorganic fertiliser (urea and TSP) equivalent. This presumably reflects perceptions on the effect of manure on the physical properties of soil as well as its role in plant nutrient supply as reported by Harris *et al* (1997).

4.0 CONCLUSIONS

Livestock, particularly dairy cattle, are an important enterprise in the Central Kenya Highlands. Staal *et al* (1997) and Harris *et al* (1997) estimate that 77 and 85% respectively of agricultural households in rural areas around Nairobi own dairy animals. Whilst dairy cattle numbers are greatest on larger farms, the keeping of exotic dairy animals is not the exclusive preserve of wealthier households. On the contrary, Staal *et al* (1997) found that 28% of crop/dairy producing households in Kiambu were headed by women. Female-headed households tend to be resource deficient indicating that dairy production supports the livelihoods of the poorest farm households. Baltenweck & Staal (1998) also point out that the smallholder dairy industry is a significant employer of non-family labour, often itinerant labourers or landless members of the community.

Milk production for sale ranked highest as the reason for keeping dairy cows on medium and large farms. However, on small farms milk and manure were ranked almost equal in importance. Use of milk for home consumption was a much stronger feature on small farms indicating the subsistence nature of farming on the smallest units.

The survey found that farms were allocating 20-38% and 21-28% of their land to growing maize and Napier grass respectively. With maize yielding around 4-5 t DM/ha of low quality fodder (J. Methu, KARI Muguga, pers comm, 1998) and Napier grass yielding no more than 10 t DM/ha/yr (D. Mwangi, KARI Muguga, pers comm, 1998), few farmers can depend upon farm feed resources to maintain herds throughout the year. Staal *et al* (1997) report that nearly half of farmers in Kiambu used purchased fodder as their main source of feed and that 70% fed concentrates on a regular basis. Regular purchase of feed thus represents a major route for the importation of nutrients onto the farm. Ineffective conservation of excreta quality could equally represent a pathway for considerable nutrient loss on farms.

4.1 Manure capture

All cattle in the survey were kept in permanent confinement. This is a management strategy common to the high potential areas of Kenya. Zero-grazing units were used by over half of all farms with small farms being the main adopters of this housing strategy (71%). Almost three-quarters of all farms with zero-grazing units had concrete floors with good drainage. Thus, by adoption of this system most farmers have already gone some way to maximising collection of faeces.

The estimates of faeces production in Table 16, particularly on small farms, are impressive and might be considered with some scepticism given that lack of manure is a commonly reported limitation on smallholder farms. However, of the 45 households which reported their assessments of yearly manure production, in only 25% of cases did the calculation of manure production from herd theoretical faecal DM yield actually overestimate the farmer's assessment of manure production. For 40% of farms the calculation actually underestimated total manure production because it was impossible to account for the contribution that feed refusals and bedding make to the total 'manure' yield. Thus the cattle confinement system already adopted by farmers yields large quantities of solid, organic fertiliser (faeces, feed refusals and bedding).

The survey shows that very few farmers were making an effort to trap urine separately, instead letting it drain to nearby soil or, more likely, directly into the manure heap/pit. Why this is so is discussed later. Suffice it to say that inadequate urine collection probably represents a major source of nitrogen and potassium loss along the nutrient transfer pathway. Current on-station research is estimating the scale of N and K loss through the urine route and also quantifying N and P loss in faeces during storage.

4.2 Manure use

Kagwanja (ILRI Addis Ababa, pers comm, 1996) studied manure use on 196 small farms in high potential Embu District, Kenya. She found that in 1993, 27% of farms had used no manure, 23% used 2.5-7.5 t fresh weight (FW)/ha, 32% used 10-15 tFW/ha and 18% used over 17.5 tFW/ha. Average application rate, 11 tFW/ha, was high compared with recommendations (5-8 tFW/ha). Otieno *et al* (1995) working in Busia District, western Kenya, also found application to be highly variable between farms in similar locations.

Kagwanja (pers comm, 1998) asked local extension workers to assess whether they thought that the application rates were adequate for soil conditions on each farm. Only 10% of farms were considered to be using inadequate levels of manure whereas 68% were using levels considered more than adequate in that year. Despite this, lack of manure was considered by farmers to be the major limiting constraint to manure use.

Otieno *et al* (1995) found that in Vihiga District, where population density is over 1,000 persons/km^2 and average farm size is 0.6 ha, two cattle in a zero grazing unit produce around one wheelbarrow of manure each day which is approximately 25 kg/day; just over 15 t/ha/yr. The authors note that farmers clean their zero grazing units twice each day so as to avoid manure loss. This again exemplifies the manure yield potential of the zero grazing unit and how, in highly intensive cropping areas such as Vihiga, manure collection is extremely thorough.

So, with evidence that small farms can produce large quantities of manure per unit area, why do farmers in the survey complain of insufficient manure? Kagwanja (pers comm, 1998) suspects that this is because farmers feel that soils can never receive too much manure and so demand appears insatiable. However, this phenomenon might be related to the fact that high manure applications are still not meeting the thresholds of certain limiting nutrients (perhaps P in the case of acidic highland soils, or micronutrients). There is an obvious need to pursue this aspect further, particularly looking at manuring rates and application strategies compared with nutrient extraction through crops, labour cost of manuring in relation to crop yield increases and farmers' perceptions of manuring requirements.

4.3 Increasing manure supply

All farmers in the survey wanted to increase manure supply. No households used organic materials, eg plant foliage, other than manure, directly as a fertiliser. Plant material is more likely to be fed to livestock or used as animal bedding than to be directly applied to soil. This is not surprising. Jama *et al* (1997) reported that *Calliandra calothyrsus* foliage was much more economically attractive as a protein supplement for dairy cows than as a fertiliser on smallholdings in high potential areas.

In the present study farmers felt that manure supply would be best increased by the greater supply of bedding or forage. A minority of farmers in each farm size category considered adding unpalatable biomass (such as *Grevillia* and *Eucalyptus* foliage) directly to the manure heap. Most farmers considered it important, however, that the biomass be channelled through the animal (as feed) or through the animal unit (as bedding). Thus livestock play the role of biomass processor; accelerating biomass decomposition by microbiological (digestion) and physical (treading + urine) processes.

Boosting manure supply by purchasing was not common in 1996. Only five large farms bought manure, from semi-arid areas such as the Rift Valley. However, Harris *et al* (1997) estimated that 60% of peri-Nairobi farmers buy manure, mainly from the Rift Valley. It is uncertain why so few of the sample farmers were buying manure. On-going manure marketing studies as part of this study suggest that there is indeed a thriving market for manures being imported into the highland areas from drier areas. Preliminary results show that these dryland manures are receiving around a 400% mark-up by agents who collect from the Rift Valley and deliver to highland farms.

4.4 Perceptions of manure quality

The basis for efficient use of manure hinges upon recognising differences in quality and adjusting application rates and timing of application accordingly. Mwarasomba *et al* (1995) report that in Kiamathare Catchment, Kiambu District, the preference ranking for manure was as shown in Table 20.

Similarly, the present study found that around 80% of medium and small farmers were well aware of quality differences between manures from each species. However, only between a quarter to one third of farmers in each category of farm size thought it possible to influence the quality from a particular livestock species by better feeding despite the analysis indicating the contrary. This could be related to farmers' limited experience of using quality feeds at a level where they would have an observable impact on manure quality.

If farmers think that there was little to be done to influence manure quality emanating from the animal itself, the survey showed that the majority thought raising manure quality was possible *post*-animal through better collection and storage techniques.

Capturing urine more effectively was reported to make the biggest difference to manure quality for farmers in all three categories. However, hardly any farmers made efforts to capture urine separately, feeling that incorporation into bedding in bomas or running it into the manure heap from zero-grazing units was sufficient. Concrete floors in the zero-grazing unit did have an impact upon N content of manure. This is presumably because fast drainage of urine into the manure heap/pit leaves less opportunity for evaporation of urine and concrete floors reduce leaching, even though leaching would still occur in the unlined pits.

One third of farmers in each category also thought that completely roofing the cattle pen would make a positive impact on quality, presumably by reducing the evaporation of urine and preventing infiltration by rain.

Farmers in all categories were affording some management to their manure heaps on the premise that this would improve quality. Covering the manure heap seemed to be the most widely accepted means to enhance or maintain quality.

Table 20. Preference ranking of manures in Kiamathare Catchment, Kiambu District

Type of manure	Crop response	Residual value	Moisture retention	Susceptibility to worms
Poultry	1*	4	4	0
Goat/sheep	2	2	2	0
Cattle	3	1	1	1
Compost	4	3	3	0

**1 = best , 4 = worst , 0 = not susceptible*

Evidence therefore exists that some farmers already practice strategies that they perceive will enhance manure quality. Small farmers, who have little opportunity to purchase fertilisers, may be marginally more innovative in this respect. Variable appreciation of manure quality might explain why wide variation in manure application rate occurs within similar locations (Otieno *et al*, 1995; Kagwanja, 1996). However, on the other hand, only half of the small farmers in the present survey had an idea of what a good manure looked like and the majority of medium and large farmers had no method of assessing manure quality. Whether smaller farmers vary their application rates according to perceptions of manure quality/soil deficiencies requires further investigation.

It is concluded that whilst farmers are aware of the ingredients and methods involved in making good manures they did not display competence in assessing the quality of purchased manures or appreciating when a home-produced manure is ready for application. Simple indices of manure quality are required that will enable farmers to combine manure more effectively with strategic quantities and placements of inorganic fertilisers and so more precisely meet the nutritional needs of crops.

4.5 Nutrient inputs through livestock

In addition to being an integral step in the nutrient cycle within farms, livestock, mainly dairy cattle, are the main reason for importation of exogenous nutrients onto highland farms (Shepherd & Soule, 1998). Farmers buy concentrates and forage on a regular basis to complement forage grown on farm.

The scale of this livestock-motivated nutrient transfer within Kiambu District alone is large. Staal *et al* (1997) estimated 150,000 t of fresh Napier (around 17% DM containing 1.4% N) to be traded amongst farms in Kiambu in 12 months spanning 1995-96. This amounts to a flow of 357 t N/yr, equivalent to 15,500 50 kg bags of urea. Since, in general, over 90% of the nitrogen ingested by ruminants appears in faeces and urine, much of this could be available for return to the soil. On-going monitoring of livestock feeding strategies in Kiambu District (DFID Livestock Production Programme Feeding Strategies Project) will reveal the scale of N, P and K importation onto farms in feed, compared with fertiliser purchases and nutrients re-cycled within the farm. These figures clearly show the importance of research into the role of livestock as a nutrient conduit in high potential areas. It is therefore particularly important to seek ways of improving manure collection, handling and storage systems.

4.6 Value

Table 19 presents the estimated value of faeces produced on-farm each year. Based on an average milk price in 1996 of KSh 13.4/l and cow ownership in Table 8, assuming all cows are lactating throughout the year, the value of manure produced in 1996 is equivalent to 28, 33 and 34% of the annual milk production on small, medium and large farms respectively.

4.7 Issues arising from the study

Dairy cattle are the most numerous and widespread livestock species owned by farmers in the sample. Since farmers rely upon purchased fodder/concentrates to supplement home-produced fodder, livestock numbers are not constrained by size of land holdings. Therefore, on the smallest farms, large herd size to land ratios result in the production of considerable quantities of manure per unit area each year. On larger farms, manure availability is much more constrained. However, these farms may have greater opportunity to purchase more manure and inorganic fertilisers.

All farmers felt that the quantity of manure they were producing was insufficient for their needs but could suggest strategies for increasing output. Since all animals were in permanent confinement, the strategies involved raising fodder or bedding supply.

There were widespread ideas on ways to improve/conserve the quality of manure during storage and also a reasonable number actually putting theory into practice. It was intriguing to note that despite the existence of knowledge on improved manure management practices very few farmers knew how to assess manure quality. Presumably they had adopted proven techniques which had then been verified by each farmer's own experiences. This is acceptable as long as the farmer knows the history of the manure but brings into question his/her ability to assess the value of an unknown, purchased, manure.

The survey raises a number of issues/questions:

- Potential manure application rates are greatest on the smallest farms because of higher livestock densities. This finding contrasts with those of Smaling *et al* (1992) who conclude that manure application is insufficient to sustain crop production in high potential Kisii District. The estimates in this report support observations of Kagwanja (pers comm, 1998) for Embu District that the smaller farms do actually apply considerable quantities of manure on a regular basis. There is a need to measure manure accumulation and application rates on the smallest (poorest) farms in high potential farming areas of Kenya.

- Further studies are needed to verify manure production levels, and recommended and actual application rates particularly on small farms. If small farms really do produce considerable quantities of manure, quite apart from addition of fodder refusals and bedding, why do these farmers perceive that supply is too low?

- If urine does make a difference to manure quality how can it best be captured? Taking into account the volatility of nutrients in urine, is urine then best captured separately, in collection sumps, typically constructed from concrete without lids, allowed to mix with bedding or simply directed into manure heaps as is current practice.

- What is the scale of nutrient passage through livestock? Very few organic amendments are made directly to the soil. All exogenous and endogenous nutrients on the farm pass through livestock, either through the digestive tract or the housing unit. How efficient is this routing? Losses of DM and other nutrients through this route must be measured and compared with direct application of organic materials to soils.

- How do farmers perceive manure quality? The survey indicated that some farmers do have their own perceptions/measures of quality and could suggest management techniques to improve the quality. However, further investigation into the basis of quality ranking is warranted, especially to test if these criteria influence application rate.

- What is the impact (cost/benefit) of the farmer-suggested improved manure storage methods on manure quality?

As farms intensify and become smaller through inter-generational sub-division, the need to enhance nutrient turnover will become more important. The overall impression from the survey was that the small farms in the sample already had a greater knowledge than the larger farms concerning improving the efficiency of manure management.

The study highlights that livestock are important as nutrient conduits, concentrators and converters on farms but points to the fact that there is need to: (1) validate the manure enhancement strategies reported by farmers, (2) quantify nutrient losses (eg urine losses) as a consequence of 'taking the livestock route' and (3) improve the efficiency of manure use. Outputs of research into area (3) should not only create tools to allow farmers to make better assessments of manure quality and match those with crop nutrient requirements but also provide simple criteria to enable farmers to meet manure nutrient deficiencies with strategic use of inorganic fertilisers.

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APPENDIX 1: AGRO-ECOLOGICAL ZONES OF CENTRAL KENYA

LH **Lower highland zones**. Annual mean temperature 15-18 °C, mean minimum 8-10 °C.

- **0** Perhumid. Forest zone
- **1** Humid. Tea-dairy zone
- **2** Subhumid. Wheat/maize-pyrethrum zone
- **3** Semi-humid. Wheat/maize-barley zone
- **4** Transitional. Cattle-sheep-barley zone
- **5** Semi-arid. Low highland ranching zone
- **6** Arid. Low highland nomadism zone

UM **Upper midland zones.** Annual mean temperature 18-21 °C, mean minimum 11-14 °C.

- **0** Perhumid. Forest zone
- **1** Humid. Coffee-tea zone
- **2** Subhumid. Main coffee zone
- **3** Semi-humid Marginal coffee zone
- **4** Transitional. Sunflower-maize zone
- **5** Semi-arid. Livestock-sorghum zone
- **6** Arid. Upper midland ranching zone
- **7** Perarid. Upper midland nomadism zone

LM **Lower midland zones.** Annual mean temperature 21-24 °C, Mean minimum > 14 °C.

- 0 Perhumid. Forest zone.
- **1** Humid. Lower midland sugar cane zone
- **2** Subhumid. Marginal sugarcane zone
- **3** Semi-humid. Lower midland cotton zone
- **4** Transitional. Marginal cotton zone
- **5** Semi-arid Lower midland livestock-millet zone
- **6** Arid. Lower midland ranching zone
- **7** Perarid. Lower midland nomadic zone

UH **Upper highland zones.** Annual mean temperature 10-15 °C. Seasonal night frosts.

- **0** Perhumid. Forest zone
- **1** Humid. Sheep-dairy zone
- **2** Subhumid. Pyrethrum-wheat zone
- **3** Semi-humid. Wheat-barley zone
- **4** Transitional. Upper highland ranching zone

APPENDIX 2: SURVEY QUESTIONS

UTILISATION OF ANIMAL EXCRETA (MANURES) AND INORGANIC FERTILISERS IN THE MANAGEMENT OF SOIL FERTILITY BY SMALL SCALE FARMERS IN KIAMBU AND MURANG'A DISTRICTS

Enumerator's Code ________________
Date of Interview ________________
Questionnaire/farmer number ________________
Name of respondent ________________
Respondents position in household ________________

1. Location Characteristics
1.1 Farm Location
1.2 Division
1.3 Sublocation
1.4 AEZ (Agro-ecological zone)
1.5 Longitude and Latitude

2. Household Characteristics
2.1 Household head: Sex ________ Age ________
2.2 Family size:
Male ________ Female _______Children (13-17 years) ________Children (</= 13 years)________

3. Farm Characteristics
3.1 Size of farm (acres)
3.2 Number of years cultivated
3.3 Does farmer cultivate other land parcels apart from this farm? Yes ________ No ________
If yes, ________ acres - distance from homestead ________ kms.

3.4 Crop enterprise on the farm (1996, short rains)

	Enterprise	Purpose	Acres	Output/acre		Total value (Ksh)	
				1990	1996	1990	1996
1.							
2.							

3.5 Livestock Inventory
3.5.1. Record the number of animals for the different species kept on the farm (except cattle)

	Goats		Camels	Sheep	Poultry			Donkeys horses etc.	Pigs	Rabbits
	Local	dairy			Local	Layers	Broilers			
Owned by HH										
Milked?										
Adult males										
Adult females										
Immatures										
Kept not owned										
Adult males										
Adult females										
Immatures										
Total										

3.5.2. Does the household have any dairy cattle?
If yes, record the precise population of cattle kept on the farm

	Local	Cross	High Grade
Owned by HH			
Bulls			
Castrated adult males			
Cows			
Immature males			
Heifers			
Suckling calves: male			
female			
Kept not owned			
Bulls			
Castrated adult males			
Cows			
Immature males			
Heifers			
Suckling calves: male			
female			
Total			

If you can remember, what were your livestock populations in 1990?

	Goats		Camels	Sheep	Poultry			Donkeys horses etc.	Pigs	Rabbits
	Local	dairy			Local	Layers	Broilers			
Owned by HH										
Milked?										
Adult males										
Adult females										
Immatures										
Kept not owned										
Adult males										
Adult females										
Immatures										
Total										

Record the precise population of cattle kept on the farm in 1990

	Local	Cross	High Grade
Owned by HH			
Bulls			
Castrated adult males			
Cows			
Immature males			
Heifers			
Suckling calves: male			
female			
Kept not owned			
Bulls			
Castrated adult males			
Cows			
Immature males			
Heifers			
Suckling calves: male			
female			
Total			

What has brought about the changes in your livestock composition numbers?
a) ________ b) ________ etc.

3.5.3. Livestock purpose

	Livestock type and breed	Products	Rank	Main purpose of product
1.				
2.				

3.5.4. Which are your main sources of feed and when are they used?

Place X in the boxes which correspond to the responses.

Type	Source	Long dry	Long wet	Short dry	Short wet	All year
Grazing	Own pasture					
	Public land					
	Crop residues					
Cut and carry Fodder and Crop residues	Own land					
	Rented land					
	Purchased land					
	Public land					
Commercial feeds						
Poultry waste						
Other (specify)						

3.5.5. Do you experience a shortage of feeds produced from your farm? If YES when?

	Long dry Jan-Mar	Long wet Mar-May	Short dry Jun-Aug	Short wet Sept-Dec	All year

3.5.6. What are you feeding or buying now that you were not feeding or buying in 1990?

Specific	Feeding now but not 7 years ago	Feeding 7 years ago but not now
Napier grass		
Maize stover (green)		
Maize stover (dry)		
Roadside grass		
Other crop residues		
Straw/hay		
Forage legumes		
Commercial concentrates		
Agricultural byproducts		
Maize bran		
Maize germ		
Wheat bran		
Pollard		
Oilseed byproducts		
Poultry waste		
Pyrethrum marc		
Brewer's waste		
Proprietary minerals/salt		

4. Manure management

4.1. How do you manage your excreta on a short term basis?
a) collect everyday together with urine
b) collect urine separately
c) collect and heap with feed refusals
d) heap with other organic materials
e) collect and apply in field without heaping
f) do not collect urine
g) skipping out
h) weekly clearing
i) other (specify)

4.2. Which organic materials are added to manure composting heap (if it is a feed refusal indicate with a tick)
a) ________ b) ________ etc.

4.3. Management of excreta on medium term.
a) heap alone
b) use in compost making
c) put in a pit
d) turning involved at intervals
e) add inorganic fertilisers
f) cover the heap
g) add water
h) add ash
i) others

4.4. How do you store the manures?
a) in the open
b) in a shed
c) under tree shade
d) under plastic
e) under fruit tree
f) cover with layer of soil
g) other (specify)

4.4.1. Do you think it is important to cover the manure? Why?
a) ________ b) ________ etc.

4.5. Which inorganic fertilisers do you add to which manures?

Source of manure	Inorganic fertiliser added	Reason for addition of inorganic fertilisers
1.		
2.		

4.6. Why do you store manure?
a) to decompose b) to accumulate: before use/ before sale c) others (specify)

4.7. What do you think happens to the manures during storage?
a) ________ b) ________ etc.

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

4.9. Is urine important as a livestock waste? Yes/ No.

4.10. Do you think manure from different sources are different? How much is produced?

	Source of manure (animal spp.)	How much is produced	Rank	Why?
1.				
2.				

4.11. Do you mix manure from different animals or do you handle them separately? Yes/No
If yes, which ones?
a) cattle manure + poultry b) cattle manure + goat c) cattle manure + pigs
d) all these manures together e) others (specify)

4.12. How do organic materials compare to manure-based composts?
a) ________ b) ________ etc.

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

4.14. How would you increase the quality of your manures?
a) ________ b) ________ etc.

4.15. What are the indicators of good quality manure before application?
a) ________ b) ________ etc.

4.16. Does feeding affect manure quality? Yes/No
If so what diets do you think would give better quality manure?
a) grazing only b) grazing and concentrates c) others (specify)

4.17. How are the livestock structures constructed?
a) Boma (kraal) type b) Roofed c) Type of floor (specify)

4.18. Is there usually bedding in the structures? Yes/No
If so which type and why?
a) ________ b) ________ etc.

4.19. Slope of floor
a) flat b) medium c) steep.

4.19.1. Is the drainage poor/good?

4.19.2. Is the standing area covered? Yes/No.

4.20. How are animals kept in the structures during the day?

Type and number of livestock	Boma type	Roofed with bedding	Free range	Tethered (where)	Other (specify)
1.					
2.					

4.20.1. Do you tether your animals on the crop field when empty (when there are no crops growing)? Yes/No

4.21. How are animals kept in the structures during the night?

Type and number of livestock	Boma type	Roofed with bedding	Free range *in situ manuring*	Tethered (where)	Other (specify)
1.					
2.					

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

4.23. Where did you learn about compost making?
a) ________ b) ________ etc.

4.24. Do you know of any additional techniques which other farmers use to manage their manures?
a) ________ b) ________ etc.

APPENDIX 3. DETAILS OF MANURE SAMPLES COLLECTED

Cattle manure management codes:
A - fed concentrates, a - not fed concentrates; B - zero grazing, b - traditional boma; C - concrete floor, c - soil floor; D - sloping floor, d - flat floor; E - standing area covered, e - not covered; F - manure stored in open, f - not in open; G - manure shaded, g - not shaded; H - manure covered, h - not covered; J - manure turned regularly, j - not turned

Farmer	Name	District	Division	Location	Manure Type	%N	%P	%K	%C	C:N ratio	Management codes
1	Teresia Njeri	Murang'a	Kiharu	Muchungua	Cattle	1.4	0.4	1.2	25.4	18.4	ABcdeFGhj
1					Cattle + goat	1.3	0.3	1.1	26.7	20.3	
2	Joseph Kariuki	Murang'a	Kiharu	Marangi	Cattle + compost	1.4	0.4	1.1	23.3	16.8	
3	PW Karanja	Murang'a	Kiharu	Mirira	Cattle	1.4	0.5	1.6	27.1	18.8	ABCDEfghJ
3					Goat + chicken	0.8	0.2	0.5	17.2	21.9	
4	Joseph Mwangi	Murang'a	Kiharu	Kambirwa	Cattle	1.2	0.3	0.9	27.5	22.5	ABcdefgHj
5	SM Gichane	Murang'a	Kiharu	Kambirwa	Cattle	1.0	0.4	1.4	22.3	21.9	ABcDefghJ
6	Julius Karanja	Murang'a	Kiharu	Gatundu	Cattle	1.1	0.4	0.9	28.3	24.9	ABcDEfGhJ
6					Rabbit	1.8	0.4	0.5	48.1	26.8	
7	Ndegwa Gathiora	Murang'a	Kahuro	Theri	Cattle	1.2	0.4	1.4	29.4	24.4	ABcDEfGhJ
7					Goat + sheep	0.9	0.7	0.9	27.4	31.7	
7					Pig	2.0	1.3	1.4	47.9	24.3	
7					Cattle: slurry	1.6	0.3	0.0	43.5	27.4	
8	Joseph Ruthuku	Murang'a	Kahuro	Gatuya	Cattle	0.5	0.3	0.7	16.5	30.9	abcDeFghJ
9	Joseph Mwangi	Murang'a	Kahuro	Gatuya	Cattle + compost	1.2	0.3	1.6	34.2	28.3	
10	Livingstone Mwangi	Murang'a	Kahuro	Mugoiri	Cattle	2.0	0.4	0.9	44.1	22.4	aBcDefGHj
10					Goat	1.1	0.4	0.7	24.4	21.7	
10					Rabbit	1.9	0.6	1.8	27.9	14.4	
11	Stephen Njoroge	Murang'a	Kigumo	Kigumo	Cattle: slurry	1.0	0.4	0.7	24.0	23.4	
12	Peter Njuguna	Murang'a	Kigumo	Kigumo	Cattle	1.0	0.3	0.7	21.5	22.3	abcDeFghj
12					Goat	2.3	0.5	0.9	34.9	15.0	
13	Samuel Njuguna	Murang'a	Kigumo	Kigumo	Cattle	1.9	0.3	1.4	32.9	17.4	AbcDeFghj
14	Peter Githinji	Murang'a	Kigumo	Kangare	Cattle + compost	2.1	0.7	0.9	34.9	16.5	
14					Cattle + compost	2.1	0.4	1.1	22.9	11.1	

Farmer	Name	District	Division	Location	Manure Type	%N	%P	%K	%C	C:N ratio	Management codes
14					Poultry: broiler	2.6	1.8	0.9	45.8	17.8	
15	Peter Wamuya	Murang'a	Kigumo	Kigumo	Cattle: dung + urine	1.7	0.7	0.5	42.2	25.0	
15					Cattle + compost	1.0	0.3	0.5	21.1	21.8	
15					Cattle + compost	0.8	0.4	0.5	22.5	30.0	
16	Samuel Muiruri	Murang'a	Maragwa	Maragwa	Cattle	1.5	0.7	1.4	29.1	19.3	ABCdEFghJ
16					Pig	1.5	0.9	0.9	24.2	15.9	
17	Hilary Kagethe	Murang'a	Maragwa	Ichagaki	Cattle	1.4	1.2	1.1	29.6	21.1	ABCDeFghJ
18	James Kienye	Murang'a	Maragwa	Ichagaki	Cattle	1.7	1.1	2.1	43.2	26.1	ABCDeFgHj
18					Cattle: fresh dung	1.3	0.7	1.6	31.5	25.1	
18					Cattle	1.8	0.4	2.5	32.3	18.2	ABCDeFgHj
18					Goat	0.9	0.3	0.7	19.8	23.3	
19	Eustace Wainaina	Murang'a	Maragwa	Ichagaki	Cattle	1.2	0.4	1.8	30.1	25.0	ABCDefgHj
19					Pig	1.9	0.7	1.1	32.2	16.8	
20	Thomas Mwangi	Murang'a	Maragwa	Ichagaki	Goat + chicken	0.9	0.3	0.7	17.8	19.1	
20					Rabbit	1.5	0.4	1.1	28.2	19.0	
21	Morris Wanyoike	Murang'a	Maragwa	Ichagaki	Cattle	1.9	0.3	0.0	42.6	22.0	abcDefGhj
22	Stephen Njagiri	Murang'a	Maragwa	Ichagaki	Cattle + compost	1.3	0.2	0.0	26.4	20.7	
22					Goat	2.3	0.4	1.8	46.1	19.8	
22					Poultry: local	1.2	0.9	0.7	21.8	18.6	
23	Pius Miringu	Murang'a	Makuyu	Gakungu	Cattle	1.1	0.4	0.9	21.6	20.5	abcDefGHj
24	Henry Mwaura	Murang'a	Makuyu	Makuyu	Cattle	1.3	0.3	1.4	40.6	32.1	ABcdefghj
24					Pig	2.2	0.8	1.6	42.5	19.6	
24					Cattle + compost	1.0	0.2	0.5	21.8	22.5	
25	Wilson Ngugi	Murang'a	Makuyu	Kamahuha	Cattle	1.6	0.6	2.8	27.7	17.5	ABCDEFghJ
26	Samuel Gachanja	Murang'a	Kandara	Muruka	Cattle	1.8	0.8	1.8	37.2	20.7	ABCDefgHJ
26					Pig	2.2	1.6	1.1	42.0	19.1	
27	David Ndebu	Murang'a	Kandara	Muruka	Cattle	1.5	1.6	1.6	27.3	17.9	ABCdEfghj
27		Murang'a	Kandara	Muruka	Poultry: layers	2.4	1.7	0.7	37.5	15.9	
28	Thomas Ngugi	Murang'a	Kandara	Muruka	Cattle	0.9	0.2	1.1	45.4	50.8	ABCfgHJ
28					Cattle	1.4	0.3	0.7	48.4	35.6	ABCfgHJ
28					Cattle	0.9	0.5	1.6	48.1	55.5	ABCfgHJ
28					Cattle	1.1	0.2	0.9	49.3	46.9	ABCfgHJ

Farmer	Name	District	Division	Location	Manure Type	%N	%P	%K	%C	C:N ratio	Management codes
29	Erastus Mwangi	Murang'a	Kandara	Ithiru	Cattle	1.8	1.3	2.8	36.7	20.1	ABCDefghj
29					Poultry: layers	2.3	1.5	0.9	42.8	18.4	
29					Pig	2.0	1.8	0.9	41.9	21.1	
30	Richard Maina	Murang'a	Kandara	Kaguthi	Cattle	1.0	0.8	0.7	37.1	36.4	ABCDEFghj
30					Poultry: broilers	2.3	1.5	0.9	35.7	15.7	
30					Pig	2.2	1.6	0.9	44.1	20.6	
31	Kirika Kabue	Kiambu	Limuru	Ndeiya	Cattle	1.2	0.5	0.7	44.6	36.5	AeFghj
31					Goat	1.6	0.3	1.6	42.7	26.1	
31					Poultry: layers	2.0	1.1	0.7	47.8	23.8	
32	Kibue Kigo	Kiambu	Limuru	Ndeiya	Goat	1.3	0.3	1.4	24.8	18.8	
33	Kaburu Mugo	Kiambu	Kikuyu	Kabete	Cattle	1.2	0.6	1.4	35.9	31.1	ABCdeFghj
33					Goat	1.6	0.8	1.4	39.8	25.4	
34	John Njoroge	Kiambu	Kikuyu	Muguga	Cattle	1.1	0.4	1.6	41.3	35.4	ABCDeFghj
35	Geofrey Njogu	Kiambu	Kikuyu	Muguga	Cattle	1.4	1.3	1.4	41.3	29.4	ABCDefghj
35					Poultry: layers	1.5	1.4	0.9	48.3	33.0	
36	Stanley Machai	Kiambu	Kikuyu	Muguga	Cattle	1.2	0.3	1.4	28.0	23.9	aBcdefgHj
37	Francis Kikanga	Kiambu	Kikuyu	Kikuyu	Cattle	1.2	0.8	0.9	40.0	32.4	AbcDefghj
37					Poultry: layers	1.9	1.4	0.7	45.6	24.5	
38	Eliud Makumi	Kiambu	Kikuyu	Muguga	Cattle	1.5	1.1	0.9	36.9	24.6	ABCdefghj
38					Poultry: layers	1.6	1.2	0.7	37.3	23.1	
39	James Ngugi	Kiambu	Kikuyu	Kabete	Cattle	1.8	1.0	2.1	41.5	23.3	ADefghj
39					Cattle + compost	1.0	0.9	1.4	17.9	17.3	
40	Samuel Gachunga	Kiambu	Kikuyu	Kabete	Cattle + compost	1.0	0.6	0.7	22.2	22.0	
40					Cattle	1.2	0.7	0.9	22.0	18.2	AbcDefGhj
40					Cattle	1.1	0.4	0.9	19.4	18.1	AbcDefGhj
41	Bernard Gakunga	Kiambu	Limuru	Ndeiya	Cattle	1.3	0.3	1.6	34.9	26.7	abcdeFghj
41					Cattle	1.4	1.0	0.7	40.4	28.5	abcdeFghj
41					Rabbit	1.2	0.3	1.1	25.7	21.4	
42	Samuel Wagakura	Kiambu	Limuru	Ndeiya	Poultry: layers	1.0	0.3	1.4	28.2	28.6	
42					Cattle	1.0	0.2	0.7	20.0	19.5	adeFghj
43	Eunice Kubai	Kiambu	Limuru	Ngecha	Cattle	1.6	0.3	1.6	37.5	23.4	ABcdEfgHj
44	Njeri Warui	Kiambu	Limuru	Ngecha	Cattle	1.7	1.0	0.9	41.4	25.1	A
44					Cattle	1.9	1.0	0.7	51.9	28.1	A

Farmer	Name	District	Division	Location	Manure Type	%N	%P	%K	%C	C:N ratio	Management codes
45	Joseph Ngunyi	Kiambu	Githunguri	Ikinu	Cattle	1.8	0.6	1.8	39.4	22.4	ABCDe
46	Peter Gateru	Kiambu	Githunguri	Ikinu	Cattle	1.6	0.4	1.8	39.4	24.1	ABCDefgHJ
47	Joseph Ngaruiya	Kiambu	Githunguri	Githunguri	Cattle	2.0	0.7	2.8	33.6	16.8	AFgHj
48	Mungai Gitema	Kiambu	Githunguri	Githunguri	Cattle	1.2	0.4	0.9	26.9	21.9	A
48					Goat	1.1	0.3	1.1	25.0	22.1	
49	Serah N Appolo	Kiambu	Limuru	Tigoni	Cattle	1.8	1.3	1.4	35.2	19.5	ABCDeFgHj
49					Poultry: layers	2.1	1.5	0.9	41.2	19.3	
50	Veronicah Muiruri	Kiambu	Limuru	Karambaini	Cattle	2.0	0.4	2.1	41.3	20.6	ABCDeFgHj
51	Paul Kimani	Kiambu	Lari	Kinale	Sheep	1.5	0.3	0.9	32.5	21.8	
52	Peter Waigongo	Kiambu	Lari	Lari	Cattle: dung + urine	1.5	0.3	1.1	34.9	23.8	
53	David Gitau	Kiambu	Lari	Kijabi	Cattle	1.0	0.5	0.0	20.4	20.4	abcDef
53					Goat	1.5	0.2	1.1	33.8	22.0	
55	Michael Njanga	Kiambu	Githunguri	Nduberi	Cattle	1.8	1.0	1.8	38.6	21.6	ABCDeFghj
56	Peter Mukaru	Kiambu	Kiambaa	Kiambaa	Cattle	1.7	0.5	2.5	45.6	26.7	aBCDeFghj
57	Joseph Karanja	Kiambu	Kiambaa	Kiambaa	Cattle: fresh dung	1.8	0.3	1.4	46.8	26.5	
58	Salome Mwaura	Kiambu	Kiambaa	Kiambaa	Cattle	1.2	0.4	1.6	47.3	38.4	ABCDEFgHj
59	Gideon Muriuki	Kiambu	Kiambaa	Kiambaa	Cattle: dung + urine	1.3	1.0	1.1	29.2	23.4	
59					Pig	1.8	0.8	0.9	47.0	26.5	
60	Paul Mugane	Kiambu	Kikuyu	Kikuyu	Cattle	1.9	0.8	0.9	34.3	18.2	ABCDefghj

NOTES

HDRA - the organic organisation

HDRA is a registered charity which carries out research into, collates and disseminates information about, and promotes an interest in organic growing and food in the UK and overseas. HDRA was founded in 1958 and has since become the largest organic organisation in Europe. The overall aim of HDRA's overseas work is to develop, improve and promote techniques for sustainable land use. The main focus is on poverty alleviation amongst small scale, resource-poor farmers through the improvement of existing farming systems, to increase food security and long term productivity. The Association's Information and Education Department provides information to the media, industry, statutory bodies, schools, colleges and universities. The Department also provides an advisory service for organic agriculture and agroforestry, and a tree seed distribution programme, aimed at development groups in the tropics and sub-tropics. The International Research Department carries out scientific research into field vegetable production, recycling of organic wastes and soil nutrient dynamics, agroforestry, and pest, disease and weed control both in the UK and overseas. The Heritage Seed Library works to conserve old and unusual vegetable varieties. At HDRA's two demonstration gardens, at Ryton and at Yalding in Maidstone in Kent, with associated trading activities, ways of gardening organically are demonstrated to the public. The Association also runs HDRA Consultants Ltd which was set up in 1995 to offer advice on recycling and large scale composting, and organic garden design and landscaping.