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MANURE MANAGEMENT BY SMALLHOLDER FARMERS IN THE KANO CLOSE-SETTLED ZONE, NIGERIA

By F. HARRIS† *and* M. A. YUSUF‡

Centre for Overseas Research and Development, Department of Geography, University of Durham, South Road, Durham DH1 3LE, UK and ‡Department of Geography, Bayero University, Kano, PMB 3011, Kano, Nigeria

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SUMMARY

Manure is a key input to smallholder farming systems, especially in the semi-arid environment of West Africa where cost and availability limit the use of inorganic fertilizers. This paper considers manure management by farmers in an intensive integrated farming system in the Nigerian savanna. The paper reports farmers' indigenous knowledge concerning manure production, quality and application, chemical analysis of manure nutrient content and application rates of manure. The potential manure supply of the livestock population of the Kano close-settled zone is calculated and compared with application rates. Recommendations are made concerning methods for improving manure quality through changes in management practices.

INTRODUCTION

The Kano close-settled zone (CSZ) in northern Nigeria is the most intensive farming system in semi-arid West Africa (Snrech *et al*, 1995). Manure plays a key role in the sustainability of the integrated production of crops, trees and livestock. The importance of livestock manure to the maintenance of soil fertility in low-input farming systems has been emphasized in the literature (Powell *et al.*, 1995). Livestock manure provides a low-cost supply of nutrients and organic matter with which farmers can improve soil fertility and so is an important component of their soil fertility management strategy. The addition of manure improves soil water-holding capacity, cation exchange capacity, and soil structure. These, in turn, reduce erosivity of the soil. Manure is also a source of nitrogen, phosphorus, potassium and a range of micronutrients.

In the Kano CSZ, the integration of crop and livestock production systems provides a source of manure for the farmer, supplies fodder to feed livestock and brings the management of both resources (fodder and manure) under the farmers' control. Farmers can then manage the resources to ensure maximum recycling of the nutrients within the farming system and so enhance soil fertility. Effective and efficient management of manure is necessary to maximize the benefits of

†Present address: School of Earth Sciences and Geography, Kingston University, Kingston-upon-Thames, Surrey, KT1 2EE, UK. Email: f.harris@kingston.ac.uk

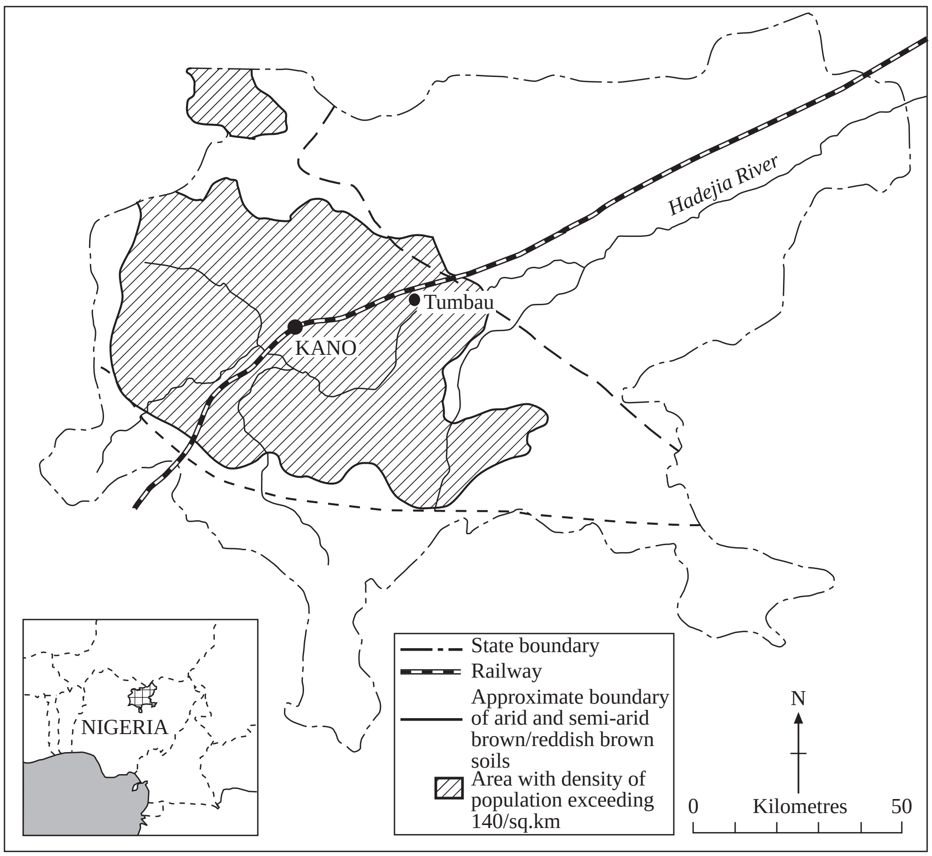

Fig. 1. The Kano close-settled zone (after Mortimore, 1970).

integrated farming systems and ensure the maintenance of soil fertility. This research, part of a larger study which aimed to determine the nutrient balances of farmland belonging to three smallholder farmers in the Kano CSZ (Harris, 1996; Harris, 1998), concentrated on farmers' management of manure in this farming system. This paper reports farmers' management and indigenous knowledge of manure; the nutrient content and distribution of manure; and the amount of manure available for farmers to improve soil fertility in the Kano CSZ. In conclusion, the paper makes recommendations for improving manure management in the region.

The Kano CSZ

The Kano close-settled zone (CSZ) is a large, densely populated rural area surrounding Kano city, defined as that area which had a population density of more than 141 km^{-2} at the time of the 1967 census in Nigeria (Mortimore, 1970) (Figure 1). Mean annual rainfall in the region is 822 mm (1906–1985 long-term average). The wet season extends from May to September.

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Historical records indicate the nature of agricultural expansion in the Kano CSZ (Hill, 1977), and studies of aerial photographs show that since the 1980s the CSZ has supported an intensive farming system on more than 87% of the land (Turner, 1997). Farmers engage in annual cultivation of millet (*Pennisetum typhoides*), sorghum (*Sorghum bicolor*), groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*), as well as minor crops such as cassava (*Manihot esculenta*), maize (*Zea mays*), sesame (*Sesamum indicum*), sweet potato (*Ipomoea batatas*) and chilli peppers (*Capsicum annuum*), and the production of tree and livestock products. The population density is such that there is no rangeland and fallowing is rare, only occurring when sickness or other calamity prevents farmers from cultivating their fields. As a result of this there are few herds of cattle compared with other areas of West Africa, although some Fulani migrate through the area during the dry season. Some farmers keep cattle for draught animal power and many keep donkeys, but the most common livestock are sheep and goats.

The farming system of the Kano CSZ lies on the brown to reddish brown soils of the arid and semi-arid tropics (Mortimore *et al*., 1990, Jones and Wild, 1975). The soils were formed by the deposition of an alluvial mantle over basement complex during the late Quaternary (McTainsh, 1984). They are light sandy soils with good drainage and aeration, low cation exchange capacity, low organic carbon and total nitrogen concentrations. By comparison, the concentration of available phosphorus is relatively high. Cation concentrations are maintained by the dust brought into the area every dry season on the Harmattan wind. The results of soil analysis (0–15 cm topsoil) of 12 dispersed fields within the study region showed that soil pH is approximately 6.1, 0.24% organic C, 0.05% total N, 27.83 ppm available P (Bray 1), 0.17% K, 0.55% Mg and 2.32% Ca. The soils are approximately 80% sand, with low levels (2–3%) of clay (Harris, 1995).

These soils, therefore, are not inherently fertile. Sustained cultivation has been the result of local land husbandry practices. Most observers and researchers of the Kano CSZ have noted the importance of manure in this farming system. According to Hill (1977), manuring has been practised on some fields since before 1900. Collier and Dundas(1937) described the farming system as follows:

'Once the demand for land becomes such that the recuperative period allowable is insufficient, the only hope of maintaining soil fertility lies in replacing the bush fallow by manure; a requirement that is realised in the fine, well-timbered permanent farmlands of Kano'.

In this integrated farming system, all livestock are tethered in the compound at night, and throughout the rainy season. Farmers use crop residues of cereal, groundnut and cowpea crops as fodder and they feed the livestock by leaving palatable crop residues, weeds and grasses on the ground where the animals are tethered. The lack of a feeding trough results in some spoilage of fodder. Refused fodder is trampled with faeces. Thus the manure applied to fields in this farming system is usually the urine and faeces of small ruminants and draught animals, mixed with compound waste, trampled vegetation, dirt, and possibly ash from cooking fires. In some cases, farmers add less-palatable residues or even unpalatable shrub material to the stabling area so that the material can be composted with the faeces. They hope that this practice will absorb livestock urine, and so enrich the compost.

Farmers transport the manure to the fields in panniers on donkeys. The pannier-sized load is referred to as a *mangala*. This local measure varies slightly according to the actual size of the pannier and how fully each is loaded. Each *mangala* is unloaded individually, and can be seen as a heap of manure in the field.

This recycling of nutrients is central to the maintenance of soil fertility within this farming system (Harris, 1996; Mortimore *et al*., 1990). Analysis of nutrient inputs to the farming system (calculations based on Harris, 1995) showed that manure is the source of approximately 35% of total N and 78% of total P inputs into the farming system. Inorganic fertilizer supplied 19% of N and 13% of P inputs. The remaining 45% of N inputs was from N fixation by legumes, and the remaining 8% of P from Harmattan dust. The management of the manure resource affects its composition and quality, and also its allocation to specific crops and fields. Through years of experience, farmers have gained their own knowledge concerning manure management with respect to sources, types, methods of production, storage, distribution and application rates.

EXPERIMENTAL PROCEDURE

Field studies

Location. The hamlet of Gamji Tara contains approximately 20 households. It is located in the village of Tumbau, a farming community in a rural setting approximately 30 km east of Kano and about 10 km from any tarred road. The main economic activity is farming. Low-lying, seasonally flooded grey hydromorphic soils (*fadama*), used for dry season irrigated agriculture and located about 5 km away, are of interest to only a few of the households. A small weekly market on Friday mornings in Tumbau trades locally-made products and foodstuffs.

Farmer selection. Many of the farmers in Gamji Tara were interviewed concerning farming practices, particularly soil fertility maintenance and manure management. Three farmers were selected to participate in a detailed nutrient balance study. The application of manure on each of their fields over a period of three years was measured. Each farmer's land was surveyed to measure field and landholding size. Previous planting and fertilization practices were discussed, as were past yields, animal ownership and family size.

Varieties of manure. Twelve farmers were interviewed about their local knowledge of the varieties of manure they could identify, the components of each and the way in which each was prepared. Farmers were also asked about specific attributes of each type of manure, and the most suitable crops for each type.

Application of manure. The variability in manure composition and *mangala* size meant that in order to assess the contribution of manure to the nutrient budget of the farming system, *mangala* size and manure nutrient content had to be quantified. This study was carried out over several farming seasons. At the beginning of the first season the *mangala*s of manure on each of the three farmers' fields were counted, weighed and described. They were classified into groups according to the farmer's description of the contents. Samples of different types of manure were collected for analysis for organic C, total N, total P and exchangeable cations. During the second farming season the number of *mangala*s on each field were counted. Some of the mangalas were weighed to confirm that the average weight of a *mangala* had not changed since the previous year. In view of the detailed work done the previous year, no further samples were taken for analysis. In the third year of the study, only the amount of manure applied to each field was recorded.

Laboratory methods

All the collected manure samples were air dried and ground to pass through a 2 mm mesh sieve prior to analysis. They were stored at room temperature. Standard analytical procedures for N and P were carried out in the laboratory of the Geography Department of Bayero University, Kano. Cation concentrations were determined at the Institute for Agricultural Research, Samaru. After wet digestion, the Mg and Ca concentrations were determined using atomic absorption spectrophotometry and K concentrations by flame photometry.

RESULTS

Sources of manure in the Kano CSZ

Farmers in the Kano CSZ recognised a wide range of sources of manure, each of which has its own characteristics (Table 1). Manure is a heterogeneous mixture of organic materials and ash from cooking fires. The composition of manure varied according to the number, type and age of animals owned by the farmer. Farmers had specific terms to describe the different types of manure. They also differentiated between manure which had been stored since its production during the previous rainy season (*takin shekarare*) and that produced during the dry season (*takin rani*). Ideally, farmers targeted specific types of manure to specific crops. Preferences depended mostly on the 'strength' of manure types, and also their consistency.

Manure quality

Table 2 shows the nutrient content of manure samples taken from farmers' fields. The number of samples of each manure type reflected its frequency of use on the case study farms during the research. Analysis of variance of the four largest groups was performed for the N and P contents, but showed no significant difference in N and P contents of the manure types distinguished by the farmers.

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Table 1. Local knowledge concerning manure in the Kano close-settled zone

Type of manure	Source of manure	Targeted crops
Small ruminant manure	Small ruminants kept in pen, droppings mixed with grasses and shrubs. Some plants collected to act as 'bedding straw', to absorb urine, and to increase the overall bulk of the material. Dampness due to rain, urine and faeces results in the decomposition of plants. Sometimes domestic waste is also added	groundnut, sorghum, millet
Stored small ruminant manure	Manure removed from pen and stored	peppers
Cattle manure	Cattle kept tethered in the compound. Cattle are better able to trample refused fodder and other vegetation than are small ruminants.	millet
Donkey manure	No vegetation is added as bedding straw. The area where the donkey is tethered is swept every 3–7 days as donkeys do not like to stand in their own waste. The result is manure which is poor in consistency and poorly mixed with plant material. It is often mixed with ash from cooking fires. Some farmers complain that donkey manure, if used alone, increases the incidence of *Striga hermonthica*. If mixed with cooking ash, this problem is reduced.	
Ash	This is the result of burning household waste and it is often mixed with grain husks (and sometimes donkey manure). Occasionally this mixture is taken to livestock pens to be trampled and decompose. It is considered very 'hot': destructive if too much is applied. It is claimed it can soften hard clay soils. Farmers say that if cooking ash and grain husks are mixed in equal proportions and left exposed to rain, within 7–14 days a well decomposed and good quality 'manure' will result.	Groundnut, (often mixed with other fertilizers)
Bird manure	From domestic birds, particularly doves, but also chickens, guinea fowl, and ducks. This is considered to be very valuable and is applied in small quantities as inorganic fertilizer.	Peppers (often mixed with other fertilizer)

Source: Yusuf, field data.

Table 2. Analysis of nutrient concentration of manure.

Category	No. of samples		Total N (%)	Total P (%)	Potassium (%)	Magnesium (%)	Calcium (%)
Small ruminant manure and straw	15	mean	0.34	0.14	0.82	0.25	0.83
		cv (%)	47	44	72	51	57
Manure from rainy season *(takin shekarare)*	8	mean	0.32	0.20	0.70	0.21	0.72
		cv (%)	33	37	68	59	51
Manure from dry season *(takin rani)*	5	mean	0.25	0.20	0.83	0.20	0.76
		cv (%)	29	35	74	89	62
Ash and grass	4	mean	0.17	0.18	0.97	0.25	0.91
		cv (%)	19	49	58	62	50
Small ruminant and cow manure	2	mean	0.37	0.36	0.69	0.32	0.88
		cv (%)	55	16	11	38	3
Cow and donkey manure	1	mean	0.38	0.14	0.44	0.18	0.45
Donkey manure	1	mean	0.34	0.28	0.40	0.22	0.48
Ash	1	mean	0.21	0.28	1.66	0.56	2.86
All manure samples	37	mean	0.30	0.19	0.80	0.24	0.84
		cv (%)	43	47	73	58	65

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The coefficient of variation was high throughout, although generally lower for N and P than for cations.

Application of manure

Manure accumulated at the place where livestock were tethered in the compound, so that by the end of the rainy season, there was a large accumulation of manure. As soon as harvest activities were completed, farmers began to clear the compound of manure and transfer it to their fields. They believed that the earlier this was done, the more beneficial was the effect. The reasons cited were (i) while in the field, the manure heaps 'trap' Harmattan dust, and so their quality improves, (ii) if allowed to sit on the soil surface for a long period of time, the goodness of the manure goes 'deep' into the soil, and (iii) if stored in the compound, the manure is attacked by a small white larva (called *gwazarma* in Hausa) that consumes the manure.

Throughout the dry season farmers continued to transport manure to their fields. At the onset of the rains, the farmers may spread the manure by hand and then have it ploughed in, or it may be left in heaps and applied to the crops once the crops emerge. By applying the manure to crops by hand, farmers were able to specify which crops received the manure. If the requirement was predominantly for food production, millet and sorghum were favoured whereas, if the requirement was for cash, then the manure was applied to groundnut. There was a visible residual effect of the manure heaps which corresponded to farmers' belief that the manure goes deep into the soil when it sits in heaps during the dry season

Table 3 indicates how much manure of each type was applied to each of three farmers' fields over a series of farming seasons. Application rates on individual fields could be as high as 17.5 t ha^{-1} (Farmer S, field 2); however, the average application (total amount of manure applied per landholding) was much lower, at around 4 t ha^{-1}. This average application rate would add approximately 12 kg ha^{-1} N, 8 kg ha^{-1} P, 32 kg ha^{-1} K, 10 kg ha^{-1} Mg and 34 kg ha^{-1} Ca (based on data in Table 2).

DISCUSSION

Manure quality

According to the farmers, each type of manure has specific characteristics which affect its suitability for crops. For example, donkey manure is said to promote the parasitic weed *Striga hermonthica*. Bird manure (pigeons, chickens or ducks) is considered to be the best quality manure in terms of nutritive value. Farmers are aware, however, that it is so strong that it must be 'diluted', by mixing with other soil amendments before being applied to crops. Small-ruminant manure is considered the most useful in terms of consistency. Rainy season manure is best for millet, whereas dry season manure is best for peppers. Cattle manure is applied to millet and sorghum, and ash and chaff are applied to groundnuts. Farmers did not feel that application of manure to cowpea was

Table 3. Application of manure to farmers' fields over three years.

	Year 1		Year 2		Year 3	
Farmer and field	Description	application	description	application	description	application
Farmer I 1		0	composted SR manure	9	small ruminant manure	9.3
			ash	1.5		
			donkey	1.5		
Farmer I 2	small ruminant manure	10.6				0
Farmer I 3	small ruminant manure	7.2				0
Total: Farmer I		4.1*		5.2*		5.1*
Farmer Y 1	small ruminant manure	1.9	small ruminant manure	4	small ruminant manure	0.6
			composted SR manure	2.3		
			ash and grass	1.2		
Farmer Y 2	SR and cow manure	0.7	small ruminant manure	2.5	small ruminant manure	2.1
	ash	0.3	composted SR manure	1.4		
			ash and grass	0.8		
Farmer Y 3: grain**	donkey manure	0.4	composted SR manure	1.9	small ruminant manure	5.3
	small ruminant manure	0.8	small ruminant manure	2.2		
	donkey and cow manure	0.3				
	composted SR manure	6.9				
Farmer Y 3:cassava	ash and grass	13.6			small ruminant manure	3.7
Farmer Y 4		0	small ruminant manure	1.7	small ruminant manure	10.9
			ash	0.9		
Total: Farmer Y		3.1*		5*		4.2*
Farmer S 1	SR manure and straw	8.9	composted SR manure	8.9		6.9
Farmer S 2	SR manure and straw	5.5	SR manure and straw	3.2		5.3
			composted SR manure	14.3		
Farmer S 3	SR manure and straw	1.7				0
Farmer S 4	SR manure and straw	2.4				8.4
Farmer S 5						0
Total: Farmer S		3.5*		4*		3.9*

*average application over whole landholding, including manured and non-manured plots
**This field was temporarily divided to create a cassava plot within the main field

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necessary. This list of 'best practice' guidelines was not always followed. In many instances farmers did not have the freedom to follow these recommendations. Often, farmers have to juggle the resources available to them to meet the current needs for fertilization. This results in less specific targeting of manure to crops.

Table 2 indicates the variability in manure quality. Farmers' classifications of manure were not distinguishable by statistical analysis. The co-efficient of variation of the analyses of each type of manure is high. There is considerable variability between different types of manure collected across Africa (see, for example, the analytical results quoted in Mortimore *et al.*, 1990, and in Lekasi *et al.*, 1998). The results from the Kano CSZ, and values cited in the literature, illustrate the point that 'manure' is very variable and, therefore, recommended application rates are almost meaningless. For example, a recommendation to apply 4 t ha^{-1} could provide anything from 1.2 to 10 kg N ha^{-1}.

When compared with other studies of manure, the results from Table 2 show that the quality of manure used in the Kano CSZ is low. The lower N concentration in Kano CSZ manure samples may be due to either their being mixed with dead grass or ash (which have lower N concentrations) or to losses by volatilization during storage within the compound or in the field. In this study, samples for nutrient analysis were collected at the end of the dry season, immediately prior to incorporation of the manure into the field soil, thus, the manure had been exposed to hot, dry, sunny weather for some time, and nitrogen losses are likely to have been considerable.

Application of manure

Based on the results of manure analyses in Table 2, the application of 1 t ha^{-1} is equivalent, roughly, to 3 kg N ha^{-1}, 2 kg P ha^{-1} and 8 kg K ha^{-1}. In the Kano CSZ, extremely large applications of manure are required to add significant amounts of N and P to the soil.

Manure is not distributed evenly over all fields, but concentrated in a few (Table 3). Farmers say that application of manure is rotated around fields year by year. It is believed that manure has a residual effect. Williams *et al.* (1995) estimate a manure decomposition rate of 50:40:10 (50% of the manure is broken down in the first year following application, a further 40% is broken down in the second year, and 10% remains until the third year after application). This would mean that manure has a visible effect for two years and corresponds with farmers' beliefs that fields should be manured every two years if possible. As the distances from home to some fields, however, are much further than others, and transporting manure to the more distant fields requires much more time and energy, some fields further from the compound receive less manure than nearer fields.

Obviously, moving manure from the compound to the fields is very labour demanding. This may be why the task is carried out throughout the dry season, particularly the earlier part while temperatures are still cool. Ownership of a donkey is of strategic importance. A farmer who does not have a donkey must borrow or hire an animal to carry manure or else carry the manure to the field by head load. When hiring donkey transport by the day, it is more efficient for a farmer to carry all his manure out to the nearer fields than to carry only a few *mangala*s of manure to the more distant fields. As yet, carts are not common in the Kano CSZ.

Once in the fields, farmers can either spread the manure prior to ploughing it in, or they can leave the heaps in the field, and spread the manure by hand to specific crops. This latter method allows them to target manure application to each plant within the intercropped field.

Factors affecting manure production

The high rates of application of manure seen in Table 3 may seem unsustainable. Typically in semi-arid West Africa, farmers complain of a shortage of organic material for composting, and a shortage of fodder for livestock (Williams *et al.*, 1995). In the integrated system of the CSZ, however, palatable crop residues (cereal stalks, groundnut haulms and cowpea hay) are harvested and fed to livestock. This might be supplemented with browse, and weeds and grasses collected in the rainy season. The use of crop residues for livestock fodder enables the farming system to support high numbers of livestock in spite of the lack of grazing land (RIM, 1992; de Leeuw *et al.*, 1995; Bourn and Wint, 1994). Hendy's (1977) study suggests that this high density of livestock has been maintained for

Table 4. Estimated manure production from livestock residing in the Kano close-settled zone.

	Livestock population figures (Source: Hendy, 1977)				
Local Government Area	cattle	donkey	sheep	goats	Total
Bichi	34048	19712	48384	77056	
Gabasawa	12597	7293	17901	28509	
Gwarzo	27797	16093	39501	62909	
Wudil	11172	9576	25536	65436	
Dawakin Tofa	23634	17069	48581	73528	
Dawakin Kudu	13482	9737	27713	41944	
Minjibir	7596	5486	15614	23632	
Kura	10455	19516	41123	64821	
Gezawa	5040	9408	19824	31248	
Ungogo	3645	6804	14337	22599	
Kumbotso	2985	5572	11741	18507	
Kano city and Waje	1276	2904	14916	14564	
Total (excluding Kano City and Waje)	152451	126266	310255	510189	
Average livestock density*	20.16	16.70	41.03	67.48	
Manure production ($t\ km^{-2}$)**	18.1	8.8	7.2	9.2	43.3

*assuming cultivated area of 7423 square kilometres
**based on annual production rates of 840 kg DM (cattle), 520 kg DM (donkeys), 175 kg DM (sheep) and 134 kg DM (goats) according to Fernandez-Rivera *et al*, 1995.

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many years. The large 'sedentary' herd of livestock produces the manure to keep the farming system going.

Table 4 presents calculations, based on census figures of 1968 (Hendy, 1977), that suggest that the livestock in the CSZ (as defined in the 1968 census) can produce 323 t a^{-1}. This would provide an average application rate of 43 t km^{-2} of cultivated land. At first glance, this is considerably less than the amount applied by farmers. It should be remembered, however, that this calculation concerns pure animal manure without any household waste, cooking ash, refused fodder, bedding straw, dust or dirt. Livestock numbers have increased since Hendy's research. Furthermore, the manure from Kano city (not included in the calculations but providing an extra 7200 t manure) may be exported to farmers close to the city, although irrigated peri-urban production may consume much of this now. Livestock manure does not provide all the nutrients required to sustain the farming system.

CONCLUSIONS

Farmers in the Kano CSZ obviously appreciate the role of manure in maintaining soil fertility and, therefore, the sustainability of their farming system. They also have clear ideas of the merits and failings of different sources of manure. Unfortunately, resources may not permit them to use manure optimally. The high levels of labour inputs that are involved in managing livestock, harvesting fodder, and transferring the manure to fields indicates the lengths to which they are prepared to go in order to maintain their farming system. The high cost of inorganic fertilizer, and its erratic availability, mean that significantly increasing inorganic fertilizer inputs into the farming system is not a viable alternative.

The results from Tables 2 and 3, however, show that compared with manures in other smallholder farming systems in semi-arid Africa, the quality of the manure which Kano CSZ farmers so laboriously manage is very low. Considering the labour efforts involved in moving such large volumes of material, improving the quality of the manure would be more useful than increasing the amount available. Furthermore, the number of livestock farmers may own is limited by fodder availability, thus limiting the ability to increase manure production.

The existing manure management regime results in either nutrient loss or dilution of manure nutrient concentration in a variety of ways:

- Stabling on the ground allows nutrients, particularly those in urine, to be leached into the soil, rather than stored in compost.
- The absence of shade increases evaporation of any urea.
- Poor storage facilities mean that the manure is exposed to hot, dry winds and sunshine resulting in volatilization of nitrogen and oxidation and break down of the organic matter.
- Livestock combine sand and dirt with the manure.

To improve nutrient cycling in the farming system, farmers should be encour-

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aged to adopt better manure management practices. The following list of recommendations is in order of incremental cost and effect.

- Improve shading of stabling area to reduce manure temperatures and evaporation of urine. This would also improve conditions for livestock.
- Provide a feeding trough for livestock to prevent spoiling of good quality fodder such as groundnut haulms and cowpea hay.
- Install an impermeable base below the manure collecting area to prevent leaching of nutrients and loss of urine before it is absorbed by bedding straw.

As manure is valued and appreciated it is expected that once shown to improve manure quality and effectiveness these suggestions will be readily taken up by farmers. Farmer-participatory trials or extension activities could provide the means to lead farmers towards improved manure management. Research by Lekasi *et al*. (1998) on manure management in Kenya confirms the value of these recommendations.

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