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The Role of Boma Manure for Improving Soil Fertility

M.E. Probert,* J.R. Okalebo,† J.R. Simpson§ and R.K. Jones**

Ruthenberg (1980) stated that 'hardly anything is as destructive in terms of maintaining a balanced environment as the expansion of impoverished smallholder farming producing unfertilised arable crops on depleted soils in a tropical setting'. Continuous cultivation without replenishment of nutrients must in time result in productivity declining to a low level. The only means of reversing this insidious process is through inputs of nutrients. For resource-poor subsistence farmers in the semi-arid areas of eastern Kenya, the principal source of nutrients that is available for their crops is farmyard manure (FYM) produced on their holdings. Its use provides a means of recycling nutrients and, where animals have access to forages outside the croplands, a means of collecting nutrients from surrounding areas.

Nutrient deficiencies are a major constraint to crop production in the semi-arid areas targeted by our project. Consideration must therefore be given to the effectiveness with which farmers use the manure they have.

In this paper we outline how farmers in the Machakos District of Kenya keep their animals and manage the manure on their farms, estimate how much manure is likely to be available on the farms, review previous studies in the region on the effectiveness of manures as sources of nutrients for crops, and present results for the amount and quality of the manure being applied by farmers and the accumulation of nutrients beneath the boma.

The Boma System

Farmers' animals are kept in small enclosures (bomas) overnight and at various times during the day. The animals are taken for watering and grazing in both the morning and afternoon, but spend the balance of their time (i.e. at least 16 hours per day) in the boma. Goats and sheep may be kept in separate bomas from cattle. For convenience and security, bomas are located close to the homestead. They are usually built cheaply of bush poles and/or thorn branches and once constructed may remain in use for many years. Excreta from the animals accumulate in the boma. Crop residues may be fed to animals in the bomas soon after the grain is harvested. Unconsumed stems and coarse residues are trampled into the soil and dung and to some extent are composted in the bomas.

Each year, usually at the end of the long dry season (August–October), the manure is dug out of the boma, perhaps stored temporarily in a heap to dry and (reputedly) cool, and then transported to the croplands using ox-carts, and less often wheelbarrows, where it is deposited in heaps. These are subsequently spread and ploughed in.

The trampling of the excreta and crop residues with the soil in the boma and the digging out of the manure each year, result over time in the boma area becoming a shallow pit. On some soil types at least, water collects in the boma for extended periods and animals may stand to their hocks in a slurry of mud and manure. These conditions could be expected to produce anaerobic soil zones conducive to denitrification. Furthermore, because there is no uptake of water from the boma (other than by evaporation), leaching of nutrients can be expected to occur. Both mechanisms will lower the nutrient content of the manure recovered from the boma and constitute possible inefficiencies in the recycling of nutrients.

The Effectiveness of Manure

Application of manure can have beneficial effects on both the physical properties (e.g. structure, infiltration rates) and chemical fertility of soils. A large part of the responses obtained is undoubtedly due to the nutrients that the manure contains. Some studies of the effectiveness of manure have been carried out previously in the area (Ikombo 1984; Kilewe 1987; Okalebo, unpublished data).

* KARI/ACIAR/CSIRO Dryland Project, PO Box 41567, Nairobi, Kenya. (Present address: CSIRO Division of Tropical Crops and Pastures, 306 Carmody Road, St Lucia, Queensland 4067, Australia.)

† Kenya Agricultural Research Institute, National Agricultural Research Centre (Muguga), PO Box 30148, Nairobi, Kenya.

§ KARI/ACIAR/CSIRO Dryland Project, PO Box 41567, Nairobi, Kenya. (Present address: 40 Holmes Crescent, Campbell, ACT 2601, Australia.)

** CSIRO Division of Tropical Crops and Pastures, 306 Carmody Road, St Lucia, Queensland 4067, Australia.

The responses Ikombo (1984) obtained in the yields of maize at two sites are illustrated in Figure 1; at a third site (Katumani Research Station) there was no response to either manure or the fertiliser treatments and high yields were obtained on the control treatment.

The manure used in this study was collected from the dairy yards at Katumani Research Station and stockpiled prior to use (B.M. Ikombo, pers. comm.). It may not be typical of the manure available to farmers as it had been subjected neither to trampling and mixing with crop residues and soil, nor possible denitrification or leaching losses.

A feature of the results is the good residual effect obtained in subsequent seasons. Ikombo concluded that 'the application of FYM at the rate of 8 t/ha appeared to give high and consistent yields, close to that obtained by applying the standard rate of mineral fertilisers (this was 40 kg/ha of N and 17 kg/ha of P), indicating that this could supply maize plants with enough nutrients'. An application of 8 t/ha of the manure used by Ikombo (1984) would have supplied 130 kg of N and 40 kg of P. Bearing in mind that not all of these amounts would become available for uptake by the crop in the first season, they are reasonable rates of application in terms of the requirements of a maize crop. No conclusion was reached on how often the manure should be reapplied. Because of the residual effects, it would not be expected that applications of this magnitude would be required every year. The findings of this study are the basis of current recommendations for farmers of the region concerning the use of manures (B.M. Ikombo, pers. comm.).

Kilewe's (1987) results are illustrated in Figure 2. They

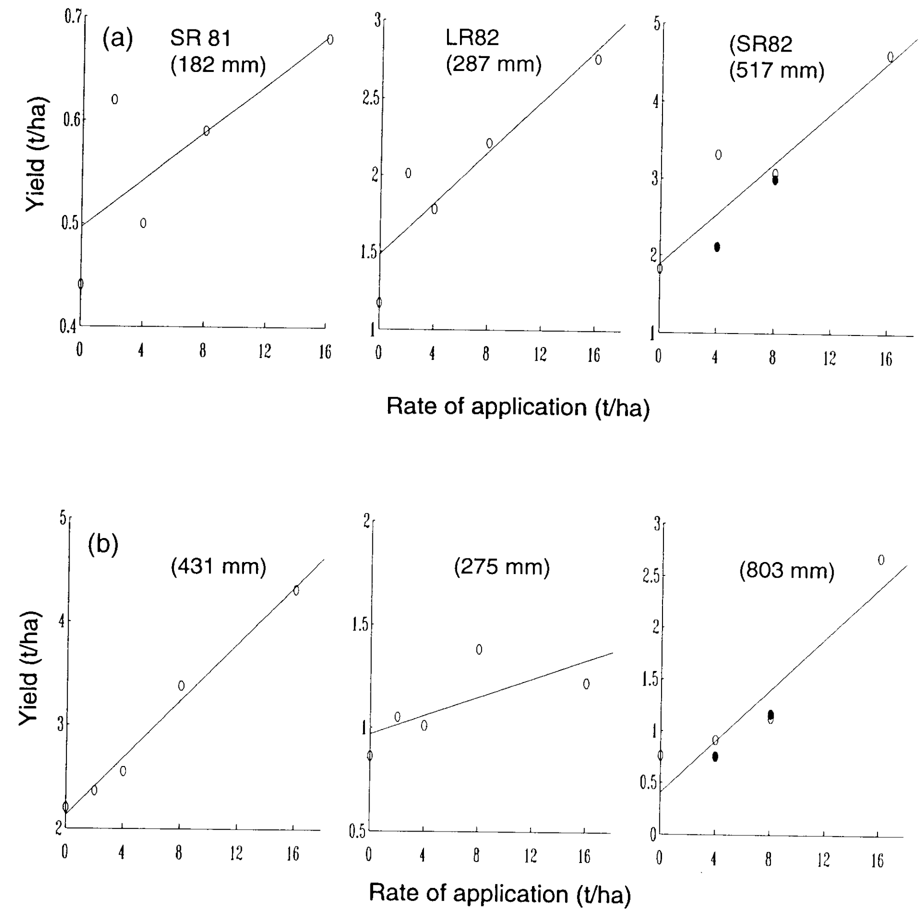

Fig. 1. Effects of application of farmyard manure on grain yields of maize at (a) Kampi ya Mawe and (b) Ithookwe. Initial applications of manure were made to the crop in short rains (SR) 1981, residual effects were determined in long rains (LR) 1982, and some fresh applications (denoted by solid symbols) were made for the SR 82 crop. Seasonal rainfall (mm) is shown in parentheses. Adapted from Ikombo (1984).

show that 40 t/ha of air-dry manure yielded a crop at least as good as that from the highest input of fertiliser, which supplied 120 kg N and 40 kg P per hectare. The two lower rates of application of manure did not give a full crop yield. No information on the source or nutrient content of the manure was given.

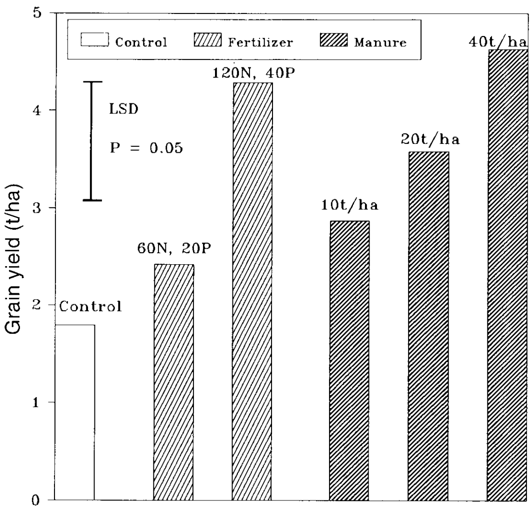

Fig. 2. Effects of fertiliser and manure on the yield of maize. Data from Kilewe (1987) are the means of the treatments that had zero or 3 cm of surface soil removed. The rates of application of manure are on an 'air dry' basis.

In these studies no effort was made to identify the nutrient(s) responsible for the response. Manure provides both N and P (and other nutrients), but they present in less soluble forms than in commercial fertilisers. The response obtained will thus depend upon the deficiencies that occur in the soil and the rate at which the nutrients in the manure are made available. The nutrient responsible for residual effects will not necessarily be the same as that causing responses when freshly applied.

In studies carried out by Okalebo (unpublished data), an attempt was made to separate the effects of N and P by including treatments that compared their effects (alone and combined) with those obtained with poultry manure and FYM; however there were only single rates of application of each fertiliser material. The results from the three sites were similar and the means are presented in Table 1.

In no instance was the response to separately applied N or P significant, making it impossible to determine which of the nutrients in the manure caused the responses. When N and P were applied together, yields were similar to those obtained with the FYM and poultry manure. Residual effects following a single application of the fertiliser materials tended to be greater for the manures than the inorganic sources, but yields were below what could be achieved with fresh application of the manures.

Table 1. The effects of fertilisers and manures on the yield of maize grain (kg/ha) averaged over three sites. Data of Okalebo (unpublished).

Treatment	First season	Second season	
		with fresh application of fertilisers	initial application only
Control	2340	1507	1336
CAN (60 kg N/ha)[a]	2378	1332	1046
TSP (40 kg P/ha)[a]	2228	1769	1432
CAN + TSP	3212	1876	1392
FYM[b]	3084	2212	1767
Poultry manure	3998	1972	1788
s.e.	109	91	95

[a] Sources of N and P were calcium ammonium nitrate (CAN) and triple superphosphate (TSP)
[b] The farmyard manure used was not the same at all sites. Rates of N and P applied (kg/ha) in the FYM treatment were: at Kathonzweni and Kampi ya Mawe 103N and 44P, at Kimutwa 215N and 49P. The poultry manure supplied 106N and 58P.

How Much Manure Could Be Available on Farms?

The amount of dry manure that can be expected to be deposited in bomas has been estimated by workers at ILCA (P.N. de Leeuw, pers. comm.) at 1 t/year/tropical livestock unit. This would be of good quality and, based on the nutrient contents assumed by S. Sandford (unpublished data), would contain 19 kg N and 3.5 kg P.

Data presented by Ockwell et al. (1991) show average figures for seven farms in Mwala, Wamunyu and Makueni locations as follows: crop area 3.4 ha, grazing area 5.1 ha with 2.4 oxen, 7.7 cattle, 8.1 goats and 1.3 sheep, which converts to 8.7 livestock units. Applying the figure above for the yield of manure, an annual rate of application of 2.5 t/ha of cropland would be possible, containing 50 kg of N and 9 kg of P.

Thus, if there were no inefficiencies in the system, the potential annual inputs of nitrogen and phosphorus on an 'average' farm are enough to support a yield of about 2 tonnes of maize grain per annum. This must be viewed as the upper limit of productivity determined by the return of nutrients in manure. It assumes that all the nutrients in crop residues are fully recycled via manure, that there are no losses of nutrients from deposited manure, and that the nutrients in manure can be fully utilised by the maize crop. These are obviously unrealistic assumptions but there is no information available that permits one to ascertain just how unrealistic they might be.

Where the numbers of animals kept by a farmer are fewer, as they are in more closely settled areas nearer to Machakos, the potential for maintaining soil nutrient status with manure will be even lower.

The On-farm Situation

Studies carried out in the Mwala location before the short rains 1990–91 addressed the following two issues.

- The rate and quality of the manure being applied by farmers. This was achieved by counting the number of heaps of manure placed on a given area and measuring the mass of selected heaps. The heaps were subsampled and analysed to determine the quality of manure.
- Accumulation of nutrients beneath bomas. Soil samples were collected from beneath bomas after the farmer had removed the manure and from nearby areas (within 20 m) where soils were judged to be similar but unaffected by the bomas. Unless prevented by stoniness or other impenetrable layers, samples were collected to 2.1 m. Samples were air-dried, sieved and analysed.

Some observations made while carrying out the sampling in the field are pertinent. There is a considerable discrepancy between when farmers expect to clean out their bomas and move the manure to the croplands and when they actually do so. Ten farmers were contacted in July who agreed to permit us to sample manure on their farms. They all asserted they would move manure in August or early September. Yet when we concluded sampling on 4 October several of these had not yet removed their manure from the boma. The presence of pigeon peas awaiting harvest is a major constraint to the operation as it inhibits the use of ox-carts to carry the manure to the terraces. The delay in moving the manure creates a bottle-neck in that it has to be moved, spread and the land ploughed, and as a consequence the farmer may miss the opportunity to plant early, which is recognised as being of benefit in this environment. We encountered one farmer in our study who recognised the importance of the timeliness of the job; even though he had pigeon peas on the area where he wanted to apply his manure he had decided to get the job done by using a wheelbarrow! On one other farm that was sampled, a wheelbarrow had been used to move manure to the portion of the terrace closest to the boma and an ox-cart to the more distant part.

Ockwell et al. (1992a,b) in discussing the labour requirements of various farm activities indicate that harvesting of pigeon peas occurs in July–August and manure is moved in August–September. This closely corresponds to when our farmers expected to move their manure, yet the reality was rather different. We have no reason to suspect that the season when we conducted our sampling was unusual in that pigeon peas were harvested later than normal.

Rates of Application of Manure

Because of the small number of heaps that were measured — in most instances only two per sampled area — the sampling strategy was less thorough than it might have been. The estimates of the rate of application of dry manure are considered correct to within 20% as ascertained from agreement between the masses of duplicate heaps.

The data in Table 2 show that estimated rates of application varied widely, from 38 to 168 t/ha. It is very noticeable that the larger the heaps in the field, the higher the rate of application. Rates of application were higher than those found in two areas of Zimbabwe (Magwira and Shumba 1986) where the estimated application rates ranged between 14 and 72 t/ha, the average being very close to the recommended rate of 37 t/ha every four years. None of the farms studied had sufficient manure to apply to the whole crop area. One farm had applied manure to one of ten terraces, another to half of a terrace out of three. On this limited evidence the frequency with which croplands might receive manure is less in the Mwala district than in the Zimbabwe study. All of the farmers visited asserted that they practice a policy of applying manure to different terraces each year. However, in our study of the fertility of farmers' terraces (Okalebo et al., these proceedings), higher soil P levels were found on terraces closer to the homesite. It is likely that this effect is associated with these terraces receiving more frequent applications of manure.

Table 2. Measured rates of application of manure.

Farmer	Area sampled (m^2)	Number of heaps	Average mass of heaps (kg DM)	Rate of application (t DM/ha)
John Nzioka	472	18	110	42
Matenge Mbaki	290	65	17	38
Gregory Ngao	840	35	322	134
Mrs Kasiva Ngului				
(i) small heaps	127	18	55	78
(ii) large heaps	185	14	222	168
Dominic Makuti	384	22	156	89

The Quality of the Manure

The manures sampled from the heaps on the farmers' croplands were air-dried, ground and analysed. The results are given in Table 3 together with some other published data on the analysis of manures.

The most obvious feature of our results is the extremely high ash content of the samples. This corroborates the impression gained in the field that the manures contained substantial amounts of soil. A consequence of the mixing of the manure with soil is that the nutrient content of the manures that farmers carry to their croplands is poor. The N content of the manures we sampled is only about one-third of that used in the field experiments of Ikombo(1984). Even the materials used by Okalebo, collected from farms where he carried out his studies, contained higher concentrations of nitrogen than we found on farms in the Mwala location.

Because the materials sampled contained so much soil, we have also performed some analyses using routine soil analytical methods (Walkley-Black organic carbon, mineral-N and Bray No. 2 extractable P). No strong relationship between the ash content and organic carbon was found. Mineral N and extractable P levels in the FYM samples were high compared with the levels usually found in soils, indicating that they would be expected to be useful sources of these nutrients.

Averaged across the five farms where data on rates of application of manure and its nutrient content were obtained, inputs amounted to 280 kg N, 91 kg P and 448 kg K per hectare. Despite the low nutrient content of the manures, farmers are applying it at rates that provide high inputs of nutrients, considerably above those that have been used in the experiments of Ikombo (1984) and Okalebo (unpublished).

Accumulation of Nutrients in Soil Beneath the Bomas

Soils were sampled from the floor of bomas and from adjacent areas on seven farms. Results of nutrient analyses are summarised in Table 4. There was very clear evidence that the soils beneath the bomas had become enriched with nutrients. This showed up especially in the data for mineral-N and extractable P, K and Ca.

The soils beneath the bomas also had a much higher pH. The only exception was on Farm 1 where the soil on which the boma was located was a vertisol and the adjacent soil already had a high pH. Typically, the soil

Table 3. The nutrient content of boma manures from the Mwala location and other African data.

Reference	Ash	C	N	P	K	Ca	Bray 2 P	Mineral N
	(%)						(ppm)	(ppm)
This study[a] (Farmer's name)								
Nzioko	94	4.4	0.63	0.14	0.84	1.24	648	81
Mbaki	92	5.1	0.55	0.16	1.10	1.94	727	47
Ngao	94	1.6	0.17	0.08	0.26	0.58	185	81
Ngului	88	3.4	0.33	0.13	0.66	0.96	473	87
Makuti	89	4.4	0.50	0.14	0.68	0.84	214	87
Kioko	91	3.0	0.35	0.20	0.78	1.47	894	135
Kioko — ex goat boma	79	5.3	0.62	0.25	1.56	3.09	946	124
Ikombo (1984)			1.62	0.50	1.34	0.26		
Okalebo (unpublished)								
Kimutwa			1.33	0.30	2.11			
Kathonzweni			0.81	0.34	2.44			
P.N. de Leeuw (ILCA) (pers. comm.)								
fresh cattle manure	53		1.28	0.45	2.65	1.26		
old cattle manure	81		0.49	0.31	1.65	0.85		
small stock manure	74		0.59	0.57	0.57	1.76		
Magwira and Shumba (1986)								
Chiota communal area			0.98	0.13	0.99	0.48		
Svosve communal area			1.05	0.19	1.47	0.58		
Mokwunye (1980)								
Range for various samples from west Africa			0.48 to 1.95	0.06 to 0.57	0.39 to 2.62			

[a] For the present study the analyses were performed on air-dry samples but results are reported on an oven-dry basis.

in the floor of the boma had a pH in water of 8.5–9.5 and these high pHs extended to depths of more than 0.5 m. These high readings indicate the presence of carbonate in the soils, and some of the potassium and calcium measured will be present in the soil solution rather than as exchangeable cations. The high pHs beneath the bomas are likely to have arisen from the oxidation of organic anions added to the bomas (K.R. Helyar, pers. comm.). Once such high pHs are created, conditions will be conducive to loss of N by ammonia volatilisation.

The differences between the soils beneath the bomas and the adjacent areas were not as marked in the organic carbon or total N data. This is probably because a variable amount of soil had been removed with manure during the time that the bomas had been in use, so that comparisons are being made between what was once subsoil and the surrounding surface soils.

The mean values of mineral N, Olsen P and extractable K are shown in Figure 3. For both mineral N and extractable K the enrichment extended to the full sampling depth (2.1 m), but for extractable P the effect was restricted to the layers closer to the surface. The data for mineral N and extractable K suggest there is a downwards flux of these nutrients, so that unknown quantities of these nutrients may have leached beyond the depth of sampling.

The boma areas are reasonably small: the range for the farms sampled was approximately 50–300 m^2 depending on the numbers of animals being kept. Nonetheless, there is an accumulation of nutrients beneath the bomas and these areas are acting as sinks for nutrients that have been removed from farmers' soils and are no longer being put to any use.

Needs for Further Research

The studies reported here indicate that the nutrients in manure that are available for use on farms in the semi-arid region of Kenya are not being used as effectively as they might be. There can be no doubt that the continuous cropping system has resulted in a decline in the fertility of the soils, and that this process is continuing. Recycling of the nutrients within the farming system has the potential to retard the decline in soil nutrient status thereby making the system less demanding on the input of nutrients from other sources. Any inefficiencies, due to loss of nutrients from the system, must contribute to the impoverishment of the soils.

The studies that have been made identify a number of causes for concern. Firstly, the quality of the material that is being recovered from the bomas and applied to the croplands is poor. In particular the N content of the manure is very low. This arises partly from the fact that the manure is mixed with much soil, but there is also evidence that processes are occurring within the boma system that will lead to a loss of N from the system. Direct evidence is provided of leaching losses as shown by accumulation of nutrients beneath the bomas. The high pH of the soils under the boma was unexpected and will be conducive to ammonia volatilisation. The very wet conditions that sometimes occur in the bomas can be expected to cause losses through denitrification.

The second issue relates to the rates of manure being applied by farmers. This is a scarce resource and there will never be enough of it to satisfy the nutrient requirements of all the croplands. We found that some farmers were applying what seemed to be extraordinarily high rates, especially when one considers that they had only enough manure to treat a small fraction of their crops. One would suspect that better returns would be obtained by a lower rate of application to a larger area. Unfortunately, there is a lack of information on the responses that farmers can expect to see to the nutrients in boma manure and which could form the basis for recommendations on its rate and frequency of application. There would seem to be a role for incubation studies to measure the rate at which the N and P in manure become available, and also for field studies to measure the

Table 4. Comparison of soil analyses for samples collected beneath bomas and from adjacent areas; + indicates that the values are higher under the bomas.

Farmer	Soil property							
	pH in H_2O	C (%)	N (%)	Mineral N	Olsen P	Bray 2 P	Extr. K[b]	Extr. Ca[b]
1. Matenge (5)[a]				+	+			+
2. Nzioka (18)	+	+	+	+	+	+	+	+
3. Muinde (~30)	+			+	+	+		+
4. Ngao (~10)	+	+	+	+	+	+	+	+
5. Ngului (~20)	+			+	+	+	+	+
6. Makuti (~10)	+		+	+	+	+	+	+
7. Kioko (>10)	+			+			+	+

[a] Numbers in parentheses indicates the time (in years) that the boma had been in use.
[b] Extractable K and Ca using the ammonium lactate–acetic acid solution of Egner at al. (1960).

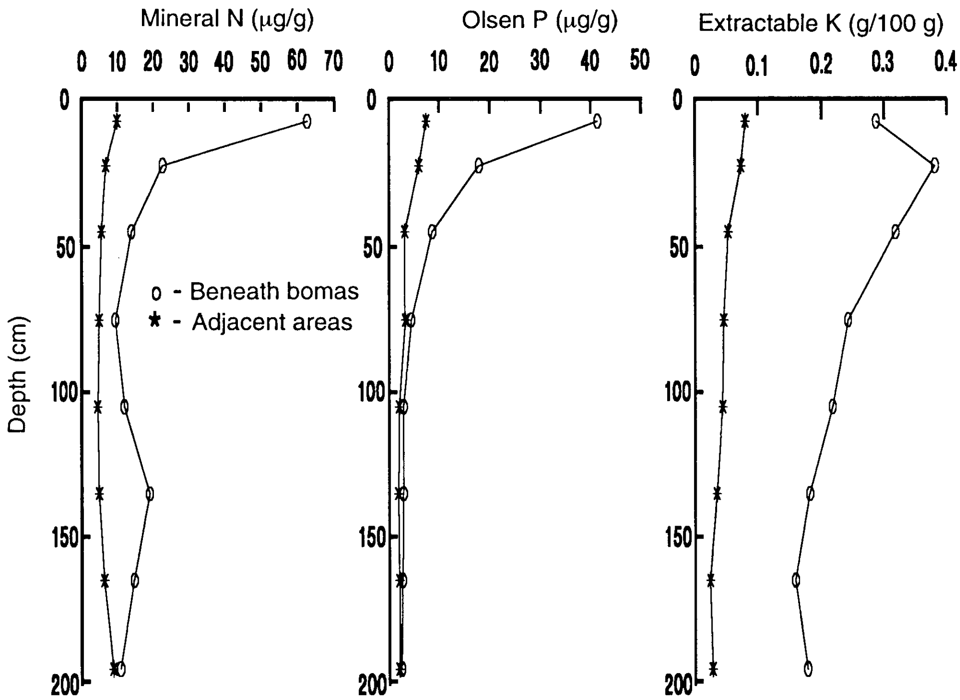

Fig. 3. The accumulation of nitrogen, phosphorus and potassium beneath bomas. Data plotted are means for the seven bomas that were sampled.

immediate and longer-term effects of application of manure. Any such studies should involve 'typical' manure as used by the farmers. In field experimentation it is imperative that the nutrient(s) responsible for the effects are identified and their effects separated. Other issues that could be addressed relate to the manner in which manure is applied. Would it be more effective if it were localised below or along the rows as it is sometimes applied around tree crops such as citrus or coffee?

Our studies have shown that enrichment of the soils beneath the bomas does occur, but gaseous losses of nitrogen, as ammonia volatilisation or via denitrification, may be of even greater importance than leaching losses. While it would be of interest to have better information on the conservation of nutrients in the boma system (a direct comparison of what goes in as crop residues and excreta and what comes out as manure), such information could not be directly applied to the benefit of the farmers. Of more fundamental importance is to question the suitability of the current boma system as a means of recycling nutrients. It might be preferable to locate the boma in an elevated position so that it sheds rather than gathers water thereby reducing the likelihood of losses of N by denitrification and leaching, though losses in runoff from the boma might then become an important process leading to loss of nutrients. Perhaps the dung could be removed from the boma more frequently during the year so that it is less exposed to the anticipated loss mechanisms. How would this affect the yield of manure and its quality? Are there alternatives whereby the animals could be enclosed temporarily on different, rotated areas of cropland thus enriching these directly for the benefit of subsequent crops? Answers to such questions might lead to better conservation and recycling of nutrients in the mixed farming systems of the semi- arid regions.

Acknowledgment

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