Chapter 10
Recycling Nutrients from Organic Wastes in Kenya's Capital City

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Introduction

Background to the Study

The question how much of the potential soil nutrients contained in urban wastes are being used and what processes are involved led to this study in the early 2000s. The issue is of central importance to understanding the potential benefits of a properly managed urban agriculture sector, since soil fertility is a major problem in Sub-Saharan Africa and urban wastes represent a large potential source of nutrients (Savala et al. 2003). Mougeot (1993, p.114) highlighted the importance of solid waste management and offered insights into the use of organic wastes by farmers as compost for their crops. When the Consultative Group on International Agricultural Research (CGIAR) was starting up its new system-wide program – Urban Harvest – in Africa in late 2000, stakeholders called for better documentation of these processes. In response, we came together from a number of institutions in Kenya to identify and map out the basic market and material flows for composts and manure in Nairobi and identify opportunities for improving the functioning of the system.

Several of us were also involved in a UN meeting at the end of 2001 on the links between waste management and urban agriculture (Kahindi et al. 2001), and the two CGIAR centres based in Nairobi both had a stake in the issue. The International Livestock Research Institute (ILRI) had done some preliminary work in 15 countries on crop–livestock system intensification in peri-urban areas (Staal 2002), and the World Agroforestry Centre (ICRAF) was interested in market chains involving urban nurseries using compost and manure. Coming as well from a local NGO and a national research organization, we formed an interdisciplinary team. Participatory methods were employed because a basic value underlying our collective approach was that research has a greater impact if the potential users of its results are engaged in the process and have a stake in the outcome.

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Rapid urbanization in Sub-Saharan Africa without parallel economic and employment growth has led to urban agriculture (UA) being widely practiced as a means of supplementing household income while also contributing to food security and the alleviation of hunger (Lee-Smith et al. 1987). UA is defined as the production, processing and distribution of food and non-food items through the cultivation of plants, tree crops, aquaculture and animal husbandry within urban and peri-urban areas (Mougeot 2000). Crop–livestock integration allows small farmers to intensify production and increase ecological integrity with potential improvements in livelihoods and natural resource management. It has been found that crop–livestock interactions increase with human population densities, interactions starting at 150–160/km^2 and being optimal around 375/km^2 after which they again reduce (McIntire et al. 1992; Staal 2002). In Nairobi the population density in 1999 was 10 times higher, averaging 3079/km^2, 1284 in high- and 17 283/km^2 in low-income divisions (Republic of Kenya 2001).

Most urban areas of Sub-Saharan Africa have increasing problems of pollution and waste disposal due to rapid growth accompanied by widespread poverty, socio-cultural change and weak, resource-poor local governments. While most such governments grapple unsuccessfully with solid and liquid waste management, the urban poor are known to be involved in waste recycling and compost production on a limited scale in many towns, and a study of urban food production in Kenya identified widespread use of organic inputs by urban crop farmers (Lee-Smith & Lamba 1991). We therefore set out to investigate the operations of compost-making groups, while holding parallel stakeholders' meetings with local government and other interested organizations to lay the groundwork for producing research results that could impact the practical side of urban planning and management (Urban Harvest 2002).

The problem of solid waste recycling can no longer be treated lightly, especially in view of its many inherent advantages, which are being tapped increasingly as recycling becomes the norm in many cities of the industrialized world. However, approaches developed in rich countries are not always applicable to poor countries as conditions vary. This study is a contribution to research and development based on prevailing conditions in one African capital. Since it relates to the agricultural use of the product in nutrient cycling, both livestock manure and compost – mainly from vegetable matter in domestic refuse – are looked at. The use of human waste in nutrient cycling is not treated directly except in brief reference to the practice by some urban farmers in Nairobi. The health aspects of urban crop–livestock interactions and of urban agriculture in general, including health risks from wastes, have been examined in parallel studies supported by Urban Harvest, as described in Chapters 9 and 12.

Nairobi Situation and How it Guided the Enquiry

Nairobi covers an area of 700 km^2 in southern Kenya, 500 km from the coast at 1670 m above sea level (Hide et al. 2001). The mean annual temperature is 17°C, with a mean daily maximum of 23°C and minimum of 12°C (Situma 1992). Nairobi receives an average of 900 mm of rainfall which comes in two distinct seasons, from mid-March to the end of May ('Long Rains') and from mid-October to mid-December ('Short Rains') (Kenya Meteorological Department, 2009). The city's population was estimated at three million in 2003, with an annual growth rate of 4.5 percent (Ministry of Planning and National Development 2003). Sixty percent of this population lives in low-income informal settlements, with poverty levels varying from 60 to 78 percent and the numbers of urban poor projected to increase 65 percent by 2015. Unemployment stands at 18, 14 percent for men and 24 percent for women (Ministry of Planning and National Development 2003).

UA in Kenya's capital is practiced in backyard farms, on open spaces under power lines, along roadsides, railway lines and river banks as well as on institutional land. In the mid-1980s, when it had a population of around one million, 20 percent of Nairobi households were growing crops and 17 percent kept livestock within the city limits (Lee-Smith et al. 1987). In the 1990s it was estimated 30 percent (150 000 households) were involved in urban farming (Foeken & Mwangi 2000). In 1998, there were about 24 000 dairy cattle in Nairobi, which produced about 42 million litres of milk, while an estimated 50 000 bags of maize and 15 000 bags of beans were also produced in Nairobi annually (Mukisira 2005).

The city generates approximately 2000 metric tonnes of solid waste daily, only 40 percent of it collected and disposed of at dumpsites (ITDG-EA 2003). Given that 60 percent of people live without services in informal settlements, heaps of garbage are a common sight. About 70 percent of the city's solid waste is biodegradable material which, if recovered, could be used either as livestock feed or for compost making. If this were recovered, it is estimated that about 2223 tonnes of nitrogen (N), 2223 tonnes of phosphorus (P) and 3700 tonnes of potassium (K), worth about US$2 million, would be generated annually from the estimated 635 000 tonnes of waste produced in Nairobi (JICA 1997). These nutrients could potentially be available to both urban and peri-urban agriculture or even sold to rural farmers currently constrained by lack of soil amendments (Njenga et al. 2004). In the wider Sub-Saharan Africa urban context, millions of tonnes of waste are produced annually, for example 646 780 tonnes in Dar es Salaam (Kiongo & Amend 1999), 313 900 tonnes (domestic) in Kumasi (Cofie 2003), and 765 040 tonnes in Accra (Etuah-Jackson et al. 2001), suggesting high-nutrient cycling potential.

Not all waste collection in Nairobi is done by the City Council. Three large companies and 30–40 community-based organizations (CBOs), the majority comprising unemployed youth, also collect waste, most such CBOs coming from medium- and low-income areas of the city (ITDG-EA 2002). In 2002, an umbrella body for waste-handling groups, Collectors and Recyclers (CORE), was formed with four sections, for plastics, paper, metal, glass and bones and the last one for organic materials (ITDG-EA 2002). The groups engage collectively in advocacy, marketing of recycled products and fund-raising.

Large-scale composting projects have not been well adapted to developing countries. Such composting plants in Ibadan, Nigeria and Accra, Ghana were expensive to maintain, subject to government instability, unable to meet demand for compost, and even caused environmental problems due to large heaps of accumulated waste resulting from numerous breakdowns including power shortages (Agbola 2001; Etuah-Jackson et al. 2001). Despite such failures, nutrients could hypothetically be better exploited if strategies were based on needs identified through local research and development. In particular, involving community groups and small-scale businesses in handling and processing of wastes seems more appropriate, given their current activities and the need for employment, rather than focusing exclusively on capital-intensive public or private enterprise investments. The study therefore focuses on current functioning of markets for manure and compost as well as the opportunities and constraints for integrating community-level waste management. Our study benefited from the Kenya Greentowns Partnership Association (KGTPA) networks that link to such groups in the Nairobi slums.

Compost quality is an issue for community groups; scientists from Kenya Agricultural Research Institute (KARI) assessed composting methods and the quality of the product. To produce suitable compost for agriculture, the process needs to be mostly aerobic so that the organic matter is partially mineralized and humidified. Control is needed particularly of the choices of substrate, moisture content and aeration (Lekasi et al. 2003). Waste composition affects the amount and quality of compost that can be produced and the higher the organic fraction the better (Drechsel & Kunze 2001). In terms of health risks, the four main concerns that need to be considered in compost production when reusing urban organic solid waste materials are pathogens, attraction of disease vectors by heaped compost, injuries from non-biodegradable fragments and heavy metal contamination (Lock & De Zeeuw 2001).

The quality of compost as a soil amendment is measured as the ability of the compost to supply plant nutrients N, P and K. Definitions of quality have usually focused on N, the limiting nutrient in most soils in Kenya, with N content sometimes being used as the measure of compost quality (Lekasi et al. 2003). However, nutrient content may not be the most valuable benefit since compost and manure not only recycle nutrients but also improve soil structure by helping water to infiltrate, which in turn reduces soil erosion (Hollings 1995). Maintenance of soil structure provides an aerated yet moisture-retentive environment for optimum root growth while composts and their leachates also inhibit soil-borne pathogens (Hoitink et al. 1997), either by enabling the plant to overcome sub-clinical root damage or more probably by allowing increased microbial activity to take place in the rhizosphere and soil zone around the plants, thereby encouraging microfloral antagonism to the growth of pathogens. Similarly, nematode populations may also be decreased (Gallardo-Lara & Nogales 1987).

In theory there is an unlimited market for good-quality compost if the organic materials were simply recycled back to the rural areas where the bulk of urban food originates. However, the cost of production, transportation and application of composts could exceed the benefits and hence may not be competitive with manures and chemical fertilizers. Farmers' awareness of the benefits of compost and good marketing are needed for a commercial compost initiative to work well (Hoornweg et al. 1999). Marketing strategies require assessment of all existing and potential markets, information about the product, its potential uses and limitations on these, as well as a price estimate. Marketability of the finished compost is affected by local soil fertility, government policies restricting imports of chemical fertilizers or subsidizing them, availability and cost of other soil conditioners including manure as well as crop residues, transport costs, local agricultural practices, and finally the reliability, quality and quantity of compost production itself (Hoornweg et al. 1999).

The need to understand and document all these led us to structure the study in three parts:

- The dynamics of CBOs working on urban organic waste recovery and UA;
- A characterization of the quality of compost produced by these groups;
- A characterization of compost and manure marketing chains in Nairobi.

Tracking the flows of compost and manure also led us outside the city in order to understand some of the constraints to either market (compost or manure) functioning properly. A major constraint of these activities of low-income groups is undoubtedly their informality, meaning illegality, which produces many of the other effects such as poor pricing information and low-quality production.

Land access is in turn a major issue affecting performance of informal sector enterprises. With farming in urban areas generally considered illegal, there are no rules regulating farmers' access to public land, so as land values increase farmers are displaced to the urban periphery. To protect the interest of the low-income urban farmers who rely on informal access to land for subsistence farming, local governments would need to undertake localized land-use planning and guarantee adequate compensation for the loss of access to land (Poulimenos et al. 1996). Similarly, activities that interact with urban farming systems, including nutrient cycling involving compost making and manure handling, are equally affected by the absence of an enabling policy framework. Thanks to the stakeholder-based process, members of the study team were able to bring these matters to the attention of a land-policy review process in Kenya.

Methods Used

The study was designed and managed by an interdisciplinary team from the following institutions:

- Urban Harvest, a system-wide initiative of the Consultative Group on International Agricultural Research (CGIAR);
- International Livestock Research Institute (ILRI);
- World Agroforestry Centre (ICRAF);
- Kenya Agricultural Research Institute (KARI);
- Kenya Green Towns Partnership Association (KGTPA), a non-governmental organization (NGO).

The project was technically backstopped and managed by ILRI and Urban Harvest, while KGTPA led the study of group dynamics in urban organic waste recovery and urban agriculture, KARI led the study of compost quality characterization and ICRAF led the study to characterize compost and manure marketing chains.

CBOs involved in organic waste recovery and urban agriculture were identified through KGTPA contacts and secondary sources (Ishani et al. 2002; ITDG-EA 2003) as well as an iterative search based on high population density or known presence of crop and livestock farming and composting activities. Most high population density areas are informal settlements without city council services, meaning CBOs doing waste management were more likely to be found there. A further study site outside the city was included, based on the resource flow mapping that indicated manure was mostly sourced from a dry-land area in Kajiado, where Maasai cattle herders actively market manure. Fieldwork from March to December 2003 was carried out at the resulting study sites shown on the map in Fig. 10.1.

Primary data were collected using qualitative and participatory approaches. Focus group discussions (FGDs) were held with an initial set of CBOs to investigate group dynamics, compost production and marketing. This led to the identification

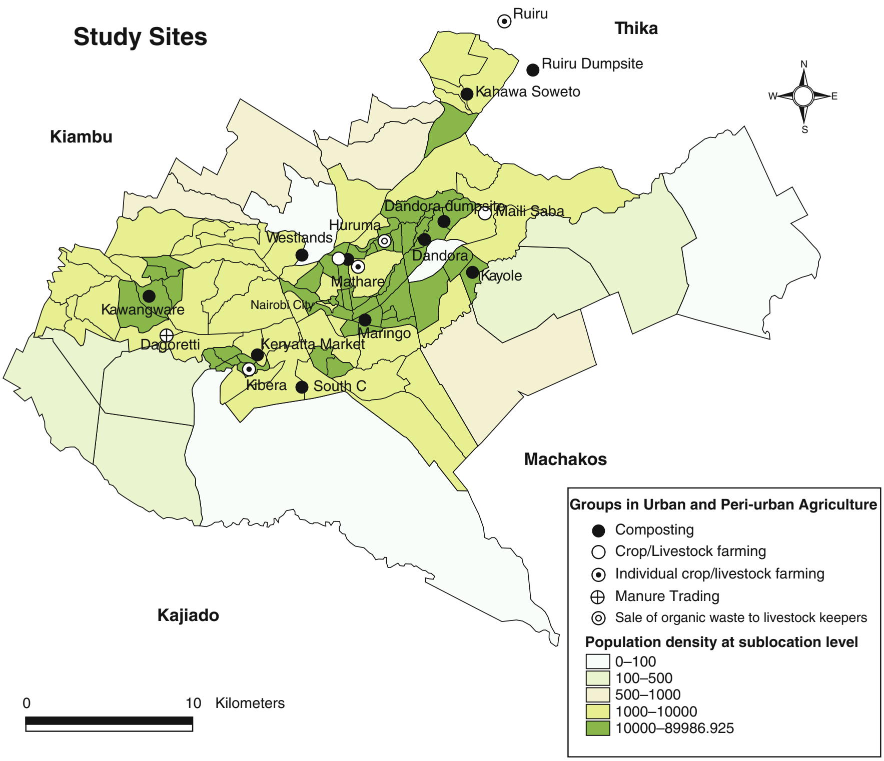

Fig. 10.1 Map of Nairobi showing study sites and population densities at sub-location level

of further CBOs and a total of 14 were included in the study. Rural, peri-urban and intra-urban resource flow patterns for organic waste and livestock manure were mapped through site visits and interviews with six manure traders and two landscapers. Two informal settlements, *Kahawa Soweto* and *Maili Saba*, were selected for in-depth study on the basis of their involvement in household waste management, crop production and livestock keeping. This began with FGDs with farmers and non-farmers as well as the CBOs identified. Participatory socio-economic and resource management mapping was done in both places, followed by questionnaire design to collect household information from 22 livestock manure producers found operating close to compost-making sites.

Although the aim was to find all CBOs involved in compost production in Nairobi, only 11 were found. While we cannot be sure this covered all such groups, we consider the findings give a good characterization and estimate of the total activity in the sector that is managed by CBOs. However, compost production by individual farmers, schools and other institutions has not been captured. A random sample survey of urban farmers in Nairobi in the 1980s found 35 percent of crop growers used compost and 29 percent used manure while 91 and 44 percent respectively were producing these inputs on their own farms. There was virtually no market in these products, only 4 and 2 percent respectively obtaining compost and manure from shops or markets, although 10 percent of farmers obtained manure from friends (Lee-Smith et al. 1987).

If the same proportions held for 2003, it can be roughly estimated that 54 500 households in the city were using compost and that 41 400 of these produced it themselves. Similarly, 37 700 households would have been using livestock manure to fertilize crops in the city, and 16 600 of these were producing it on their own mixed crop–livestock farms. Of these, about 2000 households would have been purchasing compost, and about 750 purchasing manure. Likewise, it is known that schools and other institutions in the city (prisons, orphanages and so on) engage in farming, including compost production. Since the quantities of compost and manure handled by these urban farming entities are not known, it is not possible to make a reasonable estimate of the total quantities involved. Nonetheless it is clear that the scale of this activity is much larger than that undertaken by CBOs, although the amount marketed is very little.

Thirteen compost samples and nine zero-grazing unit cattle manure samples were collected from CBOs for quality characterization through estimation of nutrients and heavy metal content. The compost and manure samples were analysed using Kjeldahl digestion procedure followed by Tecator steam distillation (Walkley & Black 1934) while organic carbon, total P, exchangeable calcium (Ca), magnesium (Mg) and K were analysed according to prescribed procedures (Anderson & Ingram 1993). Analysis for heavy metals such as lead (Pb) and zinc (Zn) was also done according to the same procedures (Anderson & Ingram 1993), all laboratory analysis being carried out at KARI.

Finally, a stakeholder workshop was held at the end of the project to share results and decide how to act on them. The workshop brought together government departments, Nairobi City Council, the National Environmental Management Authority

(NEMA), national and international research institutions, NGOs and representatives of the CBOs interviewed. Their recommendations provide the conclusions at the end of this chapter.

Discussion of the Results

Groups Involved in Organic Waste Recovery and Urban Agriculture

The 14 groups studied had diverse objectives. Eleven produced compost using organic waste, one practiced mixed farming, one kept livestock and another collected household waste (which was sorted and the organics sold to livestock farmers). All groups aimed at generating income and 11 also tried to clean up their neighbourhoods (Table 10.1). Others were involved in raising public health awareness and rehabilitating street children (Table 10.1). Seven groups were located in

Table 10.1 Objectives and gender composition of organic waste recovery and recycling groups in Nairobi

Name of group	Income generation	Environmental management	Public health	Street children rehabilitation	Gender ratio M:F	Group type
Tuff Gong Garbage Recycling Group	✓	✓	✓	✓	8:3	2[a]
Kuku Women Group	✓				2:8	4[a]
Kayole Environmental Management Association	✓	✓			5:5	4[a]
Mukuru Recycling Centre	✓			✓	0:12	3[a]
Mathare Borea Composting Group	✓	✓			4:4	4[a]
Garbage Recycling Programme (Save The Children)	✓	✓		✓	4:0	1[a]
City Garbage Recyclers S.H.G	✓	✓			9:6	2[a]
Youth United Against Environmental Pollution	✓	✓	✓		20:8	2[a]
Soweto Youth In Action	✓	✓	✓		16:5	2[a]
City Park Environmental Group	✓	✓			4:8	4[a]
Kawangware Afya Bora S.H.G	✓	✓	✓		5:15	4[a]
Ngei 1 Youth Development Group	✓	✓		✓	55:9	2[b]
Youth Foundation	✓	✓	✓	✓	12:0	1[b]
Siranga Ya Ngombe S.H.G.	✓				11:4	4[b]

1 Male youth group *2* Youth group (mixed) *3* Women's group *4* Mixed group (age and gender)
[a]composting groups
[b]non-composting groups

informal settlements, two in low-income residential estates, three in crop produce markets and two at dumpsites (Fig. 10.1). The informal settlement groups in particular engaged in organic waste recovery and recycling of other items as well as composting, thus providing services to households and the community in general as well as generating income from products other than compost.

Ten CBOs provided financial or material assistance to their rural families but four, consisting of former street people, had no rural ties. The CBOs with rural–urban linkages follow in the tradition of urban adaptation of rural self-help organization and of maintenance of ethnic and family ties through flows of goods and resources including money and food, as documented in various parts of Africa (Bryceson 2000; Maxwell et al. 2000). However, whereas women predominate in most rural associations, young men predominated in our study, as shown in Table 10.1.

Formed between 1978 and 2001 as legally registered self-help groups and providing employment to 151 poor urban people, most of whom have families with small children, most of the composting groups had declining membership, overall numbers being 55 percent less than on formation. Although one of the composting groups was growing, instability in most came as a result of frustration at the low-income generated, poor leadership, poor participation in composting activities and lack of space for doing it. Internal conflicts noted in six groups were attributed to disputes over role allocation and financial management.

These disputes were rooted in gender differences. While most of the CBOs had a mix of men and women, the general pattern was of high numbers of male youths and older women, with a gender role differentiation in waste collection, sorting and turning and financial management. Women engaged in manual work while men dominated decision making and financial management, making the women quite unhappy and in some cases resulting in conflicts between gender and age categories. These gender inequalities resulted from attitudes and cultural beliefs, as well as low levels of education, especially among the women, leading some more educated male youth to treat them dismissively. Role sharing was however observed to be less of a problem in youth-only groups.

Group Compost Operations

The groups sourced and used different organic materials and applied different composting methods. The four techniques found were pit, windrow, co-composting and dumpsite mining. In pit composting, typical of rural practices (Lee-Smith 1993), heaps of materials were contained below the soil surface. In the windrow method, materials were piled up in elongated layers on the ground, turned weekly and watered when dry (Karanja et al. 2005). Co-composting was like windrow but with the addition of livestock manure. Both windrow and co-composting heaps were covered with banana leaves, maize stalks or perforated plastic sheets, either

Plate 10.1 Women members of the City Park Environmental Group preparing compost

in the open air or under shade, except for one group using the windrow method (Plate 10.1).

These methods took 7–9 weeks to produce mature compost whereas dumpsite mining simply involved digging out already decomposed materials. Windrow and co-composting were most frequent (five and four groups respectively) while pit composting and dumpsite mining were only applied by one group each.

The CBOs sourced organic materials from household, market and food waste from canteens and hotels as well as agro-industrial waste (coffee husks) and animal manure. They generally used haphazard mixtures of these to produce their compost, with two groups using only one type of raw material, one from a market and the other from a dumpsite (which however also contained a mix). Although CBOs responded willingly to questions about composting, they did not keep good records of their compost activities such as watering and turning, or of the temperatures and time taken to mature.

Six groups transported waste 0.2–9.0 km to their composting sites using wheelbarrows, handcarts and vehicles. Only two groups used vehicles, one hiring at about US$14 per round trip while the other had a pickup acquired as a capital asset from a United Nations (UN) project aimed at promoting recycling waste from the headquarters of the two agencies located in Nairobi. The three groups located in markets moved the materials up to 1 km using wheelbarrows or handcarts. Only two groups did not transport waste as one mined decayed materials at a dumpsite while the other worked at a dumpsite where sorting and composting took place. Transport was said to be the limiting factor on the amount of materials groups were able to handle.

Only 2500 tonnes, equivalent to 0.6 percent of the total organic waste produced in the city annually, was used for compost making by the CBOs in our sample. Although very little of the city's waste is processed this way and even less is well utilized, compost making does contribute to neighbourhood cleanliness in the informal settlements where local authority services are lacking.

For example, 21 km East of Nairobi, Soweto Youth in Action collected household waste at a weekly fee of US$0.3 per bag and had about 100 customers in 2003. They used wheelbarrows to take waste to their site for sorting and after composting the organics the rest was either burned or collected for dumping through an arrangement negotiated with Nairobi City Council. The village was cleaner than other sites visited. The compost was sold on site to various buyers (Fig. 10.2), who transported it using hired vehicles for distances greater than 20 km and bicycles, wheelbarrows or carts for shorter distances. The group was planning to start collecting manure from livestock keepers and use it for co-composting for crop production at a plot they planned to hire outside the village.

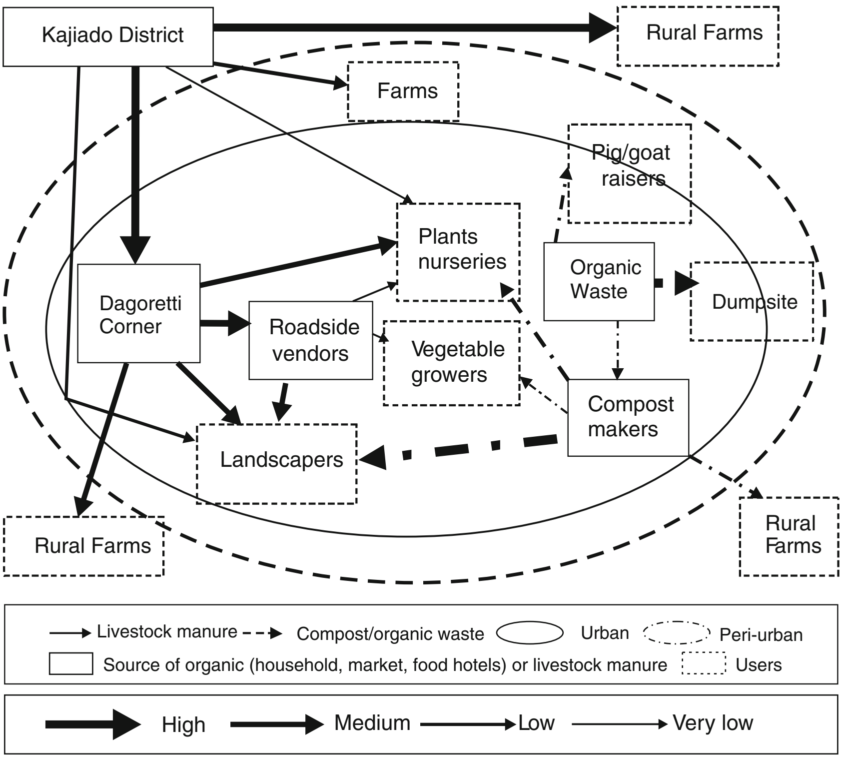

Fig. 10.2 Rural-urban manure and compost flows in and around Nairobi. Source: adapted from Njenga et al. (2004)

With less-dramatic results for the neighbourhood appearance, but no doubt of great benefit to nearby high-rise dwellers, Ngei 1 Youth Development Group collected household refuse at Huruma for Ksh 30 per household per month, then sorted and sold the organics to livestock keepers, who came to collect it on bicycles from Mathare North, 5 km away. Other items were recycled for sale.

Compost Quality

We measured the differences between urban waste compost and zero-grazed cattle manure (See Table 10.2). The nutrient content in terms of N, P and K were lower for compost than for cattle manure although there was no significant difference except in the case of carbon ($t = 1.93$; $p \leqq 0.05$). The Carbon:Nitrogen (C:N) ratios for compost and manure were both well below the optimum. The N, P and K levels for compost were lower than optimum as were some for manure, while both had zinc concentrations above recommended levels (Lekasi et al. 2003; World Bank 1997).

Table 10.2 Chemical levels in compost and cattle manure samples in urban and peri-urban Nairobi

Nutrient content	Organic waste compost Mean (+sd)	Zero-grazing cattle manure Mean (+sd)	t-test	Acceptable levels
Nitrogen N (%)	1.19 + 0.31	1.70 + 0.96	–1.53	1.7[a]
Carbon C (%)	9.90 + 2.49	16.43 + 9.91	1.93[b]	
C:N ratio (%)	8.91 + 3.71	9.82 + 1.76	0.72	25[c]
Phosphorous P (%)	0.45 + 0.16	0.60 + 0.25	–1.71	1.55[a]
Potassium K (%)	1.85 + 1.08	2.05 + 0.95	–0.43	2.07[a]
Calcium Ca (%)	1.22 + 0.90	0.72 + 0.59	1.44	
Magnesium Mg (%)	0.56 + 0.18	0.68 + 0.23	–1.26	
Zinc Zn (%)	0.23 + 0.57	0.04 + 0.02	1.06	0.03[a]
Lead Pb	Trace	Trace		0.015[a]

[a]World Bank (1997)
[b]Significantly different at 0.05 probability level
[c]Lekasi et al. (2003)

The C:N ratio in compost is influenced by the proportion of green (high N) and dry (high C) materials and how they are arranged during layering (Karanja et al. 2005) and turning (Lekasi et al. 2003). Inclusion of other types of organic materials can also affect compost quality, as when household wastes are recycled to produce organic compost, for example. Further detailed studies, as well as capacity building, are needed both to document and to improve how materials are used and how practices such as watering, turning, temperature control, covering and time taken to mature are executed by CBOs.

These factors influence quality because they affect the biological decomposition process through presence of microorganisms and invertebrates, oxygen supply and aeration, pH, nitrogen conservation and moisture content. Low P values in compost could probably be addressed through fortification with suitable sources of P, such as phosphate rocks or other waste materials high in phosphorus. Co-composting organic waste with livestock manure would enhance quality by reducing N losses, a win-win opportunity that should be exploited as it would also reduce the problem of manure disposal especially in informal settlements where space is limited. Use of earthworms in making vermi-compost has been identified as a promising method for improving K value in organic waste compost production (Savala 2003). These and other options could usefully be investigated through consultation with the groups.

Zinc (Zn) contamination from items such as wires, screws, nuts, bolts and some paints in unsorted garbage needs attention as it may be inhaled or consumed through crops and poisoning can result in anaemia, reproduction and foetal growth problems and gastrointestinal upsets if daily intake exceeds 100–250 mg, which is 10–15 times higher than recommended (Opresko 1992). We found a case of compost contaminated with zinc (0.11 mg/kg) during a related study in Nakuru (see Chapter 11), while the compost samples from this study had higher than recommended Zn levels (Table 10.2). Such heavy metal contamination of compost could be mitigated through source sorting of waste involving communities, and this would reduce not only risks but also workload and enhance recovery of other types of waste such as plastic, metal, glass and bones.

Compost and Livestock Manure Marketing Chains and Flows

Most compost production took place close to a raw materials source where there was also a demand for cleaner neighbourhoods, but with transport problems limiting movement of organic waste. And while raw materials were free, labour costs pushed up compost price.

The main urban customers for the CBOs' compost were plant nursery operators, ornamental gardens, landscapers or real estate developers and urban farmers. Rural customers were small-scale farmers and large horticulture farms, mainly in the Rift Valley Province (Fig. 10.2). Amounts sold varied greatly, with groups such as the City Park Environmental Group that sells along main roads having higher demand than supply and selling up to 4 tonnes per month. Others, like the City Garbage Recycling Programme in Maringo, 6 km from the city centre (Fig. 10.1) had established strong networks with organic farmers and were able to sell 2.5–5.0 tonnes per month. Similarly, Kayole Environmental Management Association, located about 10 km from the city centre, was also able to sell 4 tonnes per month for landscaping to its regular customer, Jomo Kenyatta University of Agriculture and Technology. By contrast, groups located far from the city centre, such as Soweto Youth in Action, 21 km away, and those inside inaccessible informal settlement sites where security is an issue, such as Mathare II, only managed to sell meagre amounts.

Compost was packed in recycled bags and sold at the production sites in varied amounts based on customers' need. Only 40 percent of the total compost produced (253 tonnes per year) was traded by the groups at US$67–133 per tonne. Groups said sales were low due to customers' limited information about where to buy, low compost quality diminishing its value, customers' fears about possible health risks, inaccessibility of composting sites in the informal settlements, and insecurity of land tenure.

To this might be added the high price compared to manure, which sells at different outlets in the city at US$14–24 per tonne, two to ten times lower than that of compost. Increased market information would negatively affect compost sales since its price compared to that of manure and chemical fertilizers determines whether farmers buy the compost or other products (Nugent 1997). Another factor affecting demand for both compost and manure was wastewater farming. For example, very little compost or manure produced in *Maili Saba* was used by farmers there, as over 80 percent of them used wastewater from a nearby sewage treatment facility as a fertilizer. They, like farmers elsewhere in Nairobi, have discovered wastewater is a rich source of plant nutrients (Hide et al. 2001).

Large clients like landscapers, plant nurseries and rural horticulture enterprises, used their bargaining position to buy compost in bulk at a reduced price. High demand for compost from the large-scale horticulture farms is attributed to their need to meet international organic-farming requirements such as those in European markets as well as their awareness of compost's role in soil health.

Most animal manure used and traded in Nairobi came from the pastoral areas of Kajiado district, 60–100 km from the city. Manure bought at US$ 5–6 per tonne truck load was transported to Dagoretti Corner's manure trading centre 15 km from the city centre where it was sold at US$ 14–24 per tonne. Although customers included plant nursery operators in the city, ornamental gardens, landscapers or estate developers and farmers from urban and peri-urban areas of Nairobi, the bulk of this manure was purchased by rural farmers in the high potential areas up to 150 km away from Nairobi, mainly horticulture, coffee and tea enterprises producing largely for export. Thus Nairobi is a point of exchange in the movement of nutrients from the drier ecosystem to the moister one.

Vehicles carried the manure to rural areas while in the city transport was mainly by bicycle, wheelbarrow or handcart. Middlemen located in various parts of the city along the manure market chain either sourced directly from Kajiado or bought at Dagoretti Corner and sold to customers they had identified. Some manure users, mainly owners of plant nurseries, circumvented them and bought directly from Kajiado (Fig. 10.2).

Kajiado manure comes from cattle kept in traditional Maasai *bomas* (compounds) at night and herded in the surroundings during the day. Being completely decomposed and dry, it is considered to be of good quality. Urban manure, coming mainly from cattle kept in zero-grazing systems, was found to be not linked to the main marketing chain. At Kahawa Soweto, about 60 percent of the manure is dumped in rivers and open spaces or burned. One group, Siranga Ya Ng'ombe at Maili Saba, Dandora, produced *boma* manure from their freely grazed cattle but were unable to dispose of it through established markets like Dagoretti. Retailers there said they were unaware of the existence of this source. When so informed by the research team they said they were afraid to collect the manure due to insecurity at Dandora.

Thus, while rural manure production supported some urban livelihoods, including farming, urban manure production was de-linked from the market chain. This gap is partly due to lack of information, but product quality and urban insecurity also play a part. Livestock in urban centres are mostly kept in confinement meaning the manure produced is usually wet and bulky. The failure to collect urban livestock waste needs to be addressed in order to protect public health and maintain urban cleanliness.

Conclusions

What we found in this study is that nutrient flows in and around the city are sporadically managed by a few large and small-scale actors in an uncoordinated way, with small-scale actors operating mostly outside the market. CBOs are not currently the main actors involved in managing nutrient materials flow in Nairobi due to their small numbers compared to the volume of urban households engaged in mixed crop–livestock farming systems that recycle nutrients on farm or through non-market exchanges. Further, the materials and market flows of compost and manure are entirely disconnected from each other and both are characterized by lack of market information and ad hoc arrangements between producers and consumers. This applied to both large consumers wanting to fertilize commercial farms and landscapes and small farmers needing items like livestock fodder or trying to get rid of livestock wastes. Also a factor is the lack of security and safety in informal settlements, as highlighted by farmers at the final stakeholder workshop where the research results were discussed.

While urban farming is extensive, the poor are proportionally under-represented mainly due to their lack of space (Foeken 2006; see also Chapter 11). Since the bulk of nutrient cycling currently seems to take place on backyard urban crop–livestock farms which belong to the less-poor segment of the population, some improvements could be addressed through promotion and support of on-farm urban waste management, as is done in Kampala, Uganda, as described in Chapter 6, above.

However, over 60 percent of Nairobi's population live in informal settlements which cover only about 5 percent of the total land area (Ministry of Planning and National Development 2003). This means that wastes produced on a large scale have little chance to be recycled through local crop–livestock farms and the problem of waste management remains enormous in such places. Under these circumstances CBOs represent an important opportunity to address waste management and generate employment in the informal sector, through processing and sale of composts to customers outside the settlements. Of course, the human rights injustice of poor households living in very restricted space with little or no chance for producing food remains a major concern in Nairobi.

For community groups involved in waste management and producing commercial composts, lack of recognition of their activities and lack of space are major issues. Unless local authorities are prepared to work with these groups, their informal status, low level of knowledge and small resources will limit their contribution to city waste management, nutrient recycling, or improvement in their own incomes and well-being. Their main contribution at present is cleaning up their neighbourhoods where they sort garbage. Recognition and support from Nairobi City Council (NCC) might encourage existing groups to continue and other groups to emerge. The challenge of inaccessibility could be resolved if NCC allocated spaces to the groups next to markets and main roads.

For composts, the issue of product quality also has to be addressed. This study shows that Nairobi's urban and peri-urban composts are of lower quality than cattle manure and way below optimum levels, especially for N and P (which are important for Kenyan soils). The compost samples also had a low C:N ratio. Quality must be higher to generate demand for urban compost in competition with chemical fertilizers and manure. Further studies are needed to understand the effects on compost quality of using different types of waste such as vegetables, fruit, banana leaves, eggshells and ash. These and other possible measures to address compost nutrient content and heavy metal contamination have been proposed here. However, the main issue is whether there is political will to support informal sector enterprises. The fact that small and large rural farms are among the main customers for urban compost suggests good market potential provided other issues are resolved.

The CBOs themselves need capacity building in organic resource recovery and on how to establish sustainable governance structures, including gendered project management committees and constitutions. In this direction, several of the partners in this project have already jointly developed and run training courses on sustainable and healthy compost production for community groups and produced a manual on low-cost composting addressing compost quality and marketing challenges they face (Karanja et al. 2005).

In the case of manure, the organized market links rural herders with urban and rural crop production enterprises via a market in Nairobi. However, local production of manure by urban livestock keepers is disconnected from the organized marketing system and the product is mostly dumped or burnt. This seems to be due to lack of market information, the difficulties in accessing the manure market because of informal settlement conditions and traders' ideas about the quality of local manure. There seems to be a good potential for using urban livestock manure for co-composting with organic vegetable waste because livestock-keeping enterprises were identified less than 2 km from all the composting sites. This method would enhance compost quality without necessarily increasing production costs since manure currently dumped could be acquired with very little transport cost. Again, the main missing elements are information and institutional support. Political will from the authorities entailing allocation of space and technical advice would make composting worthwhile for groups, enhancing their livelihoods as well as contributing to environmental clean-up.

Urban farmers themselves attributed the low use of compost and livestock manure in crop farming not only to lack of secure land tenure but also to the availability of nutrients in wastewater, another form of nutrient re-use studied elsewhere (Hide et al. 2001; Karanja et al. 2008) and observed in all informal settlements visited. While addressing the health issues surrounding this practice is beyond the scope of this article, it is touched on in Chapter 9, above, and in Cole et al. (2008). Briefly, safe practices for re-use of wastewater in urban food production do need to be developed and promoted (IWMI 2002).

Associations, networks and forums such as CORE and the Nairobi and Environs Food Security, Agriculture and Livestock Forum (NEFSALF), which include public sector participation, are already doing advocacy, support and training for CBOs involved in nutrient cycling in Nairobi. Political will from NCC and government to work with the informal sector and low-income groups in general is essential however. Absence of an enabling legal framework was found to limit compost demand in Nairobi, composting groups having no formally acquired space to operate and farmers showing reluctance to invest in fertilizing soils on land that did not belong to them, meaning they focus on short-term profitability since the risk of investment loss is high.

A task force to develop an urban agriculture policy in Kenya was formed in 2007, led by the Ministry of Agriculture's Provincial Agriculture Board and KARI. The Ministry of Agriculture convened the group to begin drafting in early 2009. Nutrient recycling is expected to be part of the policy initiative. Public awareness campaigns, media articles and official statements could then be developed, promoting compost production as a strategy for cleaning up the city, which would improve the demand for compost and its business potential. An urban agriculture policy also needs to be localized through bylaws for enhanced regulation and control at town level, as is already underway in Nakuru as described in Chapter 11. Some of the considerations for legalizing urban agriculture and organic waste management have also been incorporated in a draft Land Bill for Kenya (Ministry of Lands & Settlement 2006).

In addition to these policy steps, further research is required, especially through pilot community projects, to explore, evaluate and demonstrate strategies such as source sorting of organic materials and co-composting as options for quality enhancement. These could be combined with communities learning about heath risk management. An economic study on cost–benefit analysis, willingness to pay, perceptions and attitudes, market threats and opportunities of community-produced compost would help groups develop business plans and arrive at unit prices to compete effectively in the market. Finally, there is need for more detailed quantification of the amounts and quality of organic resources involved in rural–urban flows and their role in natural resource management in both urban and rural ecosystems, based on this preliminary mapping.

These measures would enhance urban organic waste recovery hence reducing nutrient mining in food production areas while also reducing environmental pollution in consumption areas, helping to close the nutrient cycle.

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