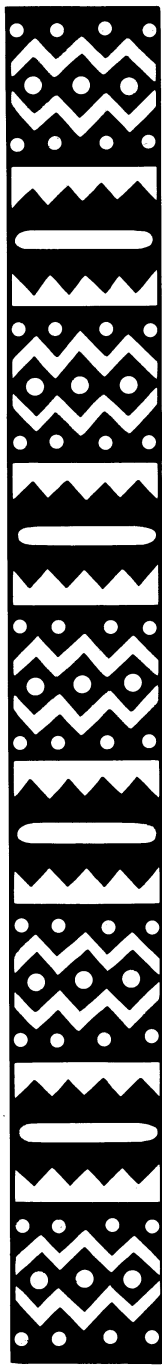
Managing Africa's Soils No. 4



Farmers' responses to soil fertility decline in banana-based cropping systems of Uganda

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About the author

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About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa-Nutrient networks & stakeholder perceptions*. It was drawn up with the primary aim of bringing together the following three research programmes:

- *The dynamics of soil fertility management in savannah Africa* co-ordinated by IIED and IDS/UK;
- *Spatial and temporal variation of soil nutrient stocks and management in sub-Saharan Africa systems* (VARINUTS) co-ordinated by SC/DLO the Netherlands;
- *Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda* (LEINUTS) co-ordinated by LEI/DLO, the Netherlands.

NUTNET is a partnership of 15 organisations coming from 6 African and 2 European countries. They are INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, Kenya; IER, Mali; Environment Alert & Makerere University, Uganda; IES, Zimbabwe; IIED & IDS, United Kingdom; AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, The Netherlands. NUTNET has been made possible through generous funding from the Netherlands Development Agency (NEDA), Ministry of Foreign Affairs, the Netherlands.

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Summary

Bananas are farmers' principle staple crop and a major source of income in the *Lake Victoria Crescent* region of Uganda. Most bananas are cultivated near homesteads. Other crops are intercropped with young banana plants. However, land pressure has increased and intercropping is nowadays widely practised in older plantations, resulting in an acceleration of nutrient depletion and reducing the life span of the plantation. Mulching of bananas is an indigenous practice. Farmers do this to suppress weed growth, maintain soil fertility and conserve soil moisture for the shallow rooting banana crop.

Organic manures are the most important fertility amendments that farmers apply. They give priority to bananas. Cattle manure used to be the most important source of nutrients, but has become less available due to decreases in farm size. As an immediate strategy, farmers resort to the utilisation of small ruminants livestock manure and processing of composts from household waste.

In recent decades, banana productivity has been declining, which has been attributed to soil nutrient depletion, pests and diseases. It affects both farm incomes and food security. Scientists have chosen soil fertility management as the entry point for re-establishing productive banana stands. Research is oriented towards the formulation of alternative soil fertility management strategies, and to create more awareness of this issue.

In one study, researchers determined partial nutrient balances for selected farms. The results show an alarming rate of net nutrient removal from banana plantations, despite the often high volume of organic materials applied. This is probably due to low nutrient concentrations in these organic materials.

Integrated nutrient management methods, combining mineral and organic nutrient sources, offer better results than reliance on one source alone. Banana productivity can be increased through a one-time application of fertiliser in planting holes, the periodic addition of organic manures and by removing pest-infested residues after harvest. Trials have also demonstrated that the application of these pest-infested banana residues to a nearby cabbage field, increased the yields considerably. Fertiliser application tests based on one banana mat, are being conducted on farmers' fields. Farmers can use the resulting recommendations to correct soil fertility deficiencies in selected sites of their banana plantation.

French summary

Réactions des agriculteurs face au déclin de la fertilité des sols dans les bananeraies d'Ouganda

L'Ouganda est le premier producteur de bananes du monde. La banane constitue l'alimentation de base et une importante source de revenus pour les agriculteurs de la région du lac Victoria *(Lake Victoria Crescent)*. Autour du lac, l'altitude varie entre 1100 et 1400 mètres. Les sols sont ferralitiques, dégradés par les intempéries et d'une faible fertilité inhérente. L'agriculture dépend des pluies bimodales qui sont en moyenne de 1218 mm par an. Les principales cultures sont la banane, le café, le haricot et une variété de légumes et de tubercules.

La plupart des bananiers sont plantés près des habitations. Les céréales et les autres cultures se trouvent dans des champs plus éloignés. Le bétail est parqué dans des *kraals*, près des maisons. On cultive parfois la banane sur la même parcelle de terre pendant près de 50 ans. D'autres cultures sont intercalées avec de jeunes bananiers. Lorsqu'il y avait encore beaucoup de terres disponibles, ces cultures intercalaires ne duraient qu'une année et l'on pratiquait ensuite un paillage. Toutefois, la pression sur les terres agricoles s'est accrue et les cultures intercalaires sont maintenant chose courante dans les bananeraies déjà anciennes, ce qui accélère les pertes d'éléments nutritifs et réduit la durée de vie de la plantation.

Le paillage des bananeraies est une pratique indigène. Les agriculteurs le font pour contenir les mauvaises herbes, maintenir la fertilité du sol et conserver l'humidité à proximité des racines peu profondes du bananier. Les engrais organiques sont le meilleur moyen d'amender les terres pour les agriculteurs qui les réservent en priorité à la banane. Le fumier de bétail était la source la plus importante d'éléments nutritifs mais il est devenu moins disponible avec la réduction de la taille des exploitations. Cette diminution rend aussi moins abondants les résidus des cultures des champs extérieurs qui sont normalement déposés dans les plantations de bananiers. Dans l'immédiat, la stratégie des agriculteurs consiste à avoir recours au fumier des petits élevages et au compost fait à partir de déchets domestiques.

Depuis plusieurs décennies, la productivité de la culture bananière connaît un déclin, attribué aux pertes d'éléments nutritifs, aux parasites et aux maladies. Ce recul affecte à la fois les revenus agricoles et la sécurité alimentaire car les autres cultures vivrières

telles que le maïs et le manioc poussent mal dans les anciennes bananeraies aux sols appauvris.

Les scientifiques ont choisi la gestion de la fertilité des sols comme point de départ pour rétablir des peuplements de bananiers productifs dans la région du lac Victoria. Depuis les années 1990, la recherche s'oriente vers la formulation de stratégies nouvelles de gestion de la fertilité des sols et insiste sur l'importance de la gestion de la fertilité.

Dans une étude, des chercheurs ont déterminé les équilibres partiels d'éléments nutritifs dans des fermes sélectionnées. Les résultats montrent des taux alarmants de perte nette d'éléments nutritifs dans les bananeraies, en dépit du fort volume de matériaux organiques souvent appliqué. Cela est probablement dû aux faibles concentrations d'éléments nutritifs présents dans ces matériaux organiques. Avec le cours actuel de la banane, l'investissement en engrais acquis à l'extérieur n'est pas rentable dans les plantations de bananiers.

Les méthodes intégrées de gestion des éléments nutritifs qui associent des apports d'origine minérale et organique, constituent de meilleures solutions techniques que les apports d'une seule origine. Les scientifiques ont démontré que la productivité de la banane peut être augmentée par une seule application d'engrais dans les trous faits au moment de la plantation, un apport périodique d'engrais organiques et l'élimination des résidus infestés de parasites après la récolte. Il a aussi été prouvé que l'application de ces résidus de bananes infestés de parasites dans un champ de choux voisin, accroissait considérablement le rendement.

Des tests de l'application d'engrais effectuée sur un seul bananier sont menés dans les bananeraies d'agriculteurs qui peuvent alors suivre les recommandations qui en résultent, pour corriger les carences en fertilité des sites choisis dans leurs plantations.

1 Introduction

The importance of bananas

Uganda is the world's largest producer of bananas, nearly all of which are used locally. Consumption is estimated at 228 kg per year and per habitant (FAO data cited in Spore, 1998), making Ugandans the largest consumers of bananas in the world. More than 75% of the farmers in the country grow bananas, accounting for 54% of the total tonnage of fresh food produced (Ministry of Planning and Economic Development, 1998). Accounts of early explorers already revealed the importance of bananas as a staple: "there was no want of food here for I never saw such a profusion of plantations anywhere else; the people were brewing *pombe* (banana wine) all day and cooking them for dinner every evening" (Speke, 1863, cited by Langlands, 1966).

Four groups of varieties are recognised in Uganda, differentiated according to their use. These are:

(i) Cooking bananas (*matoke*): mature but still green fruits are harvested, peeled, steamed and mashed before eating,
(ii) Beer bananas: mature fruit are ripened and squeezed to extract juice that is fermented with sorghum to produce banana wine,
(iii) Dessert bananas: eaten when ripe,
(iv) Roasting bananas: fruit are ripened and roasted before eating.

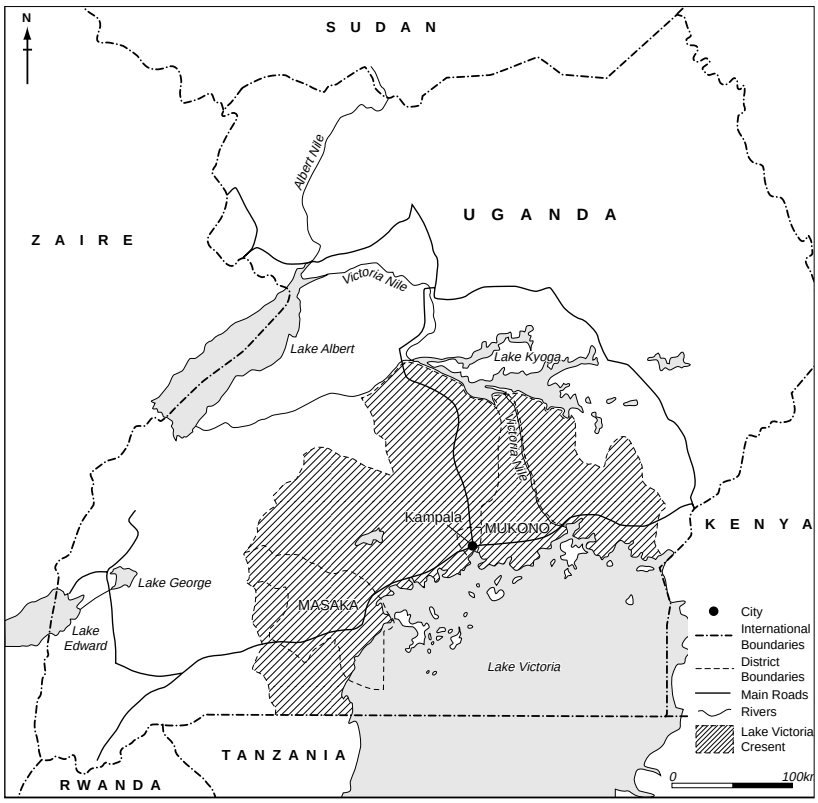
In recent decades banana productivity has been declining, from more than 18 kg per bunch in 1971 to, in some cases, less than 1 kg per bunch (Woomer et al., 1998). On fields with a low soil fertility it is common to see bunches with less than ten fingers. This yield decline has been attributed to soil nutrient depletion, pests (banana weevil and burrowing nematode) and diseases (especially black sigatoka). It affects farm incomes and may endanger food security. Alternative staple crops, such as maize and cassava, do not perform well in the degraded former banana fields, unless soil fertility is improved. Stakeholders, such as farmers, consumers, scientists, extension workers and, politicians, are therefore striving to understand the causes and reverse the decline in banana productivity. A multi-disciplinary approach to solve the decline in banana productivity has been proposed.

2 Study area and methods

Study Area

South-Central Uganda is commonly referred to as the Lake Victoria Crescent (see figure 1). The Lake Victoria Crescent consists of hills and ridges dissected by streams and swamps. Altitude ranges from 1100 to 1400 metres above sea-level.

Figure 1. Map of Uganda



Typically, the soils of the area (ferralsols) are old, highly weathered and of low inherent fertility (table 1). Moderately deep, residual soils are located on hillcrests. Very deep, residual soils are found on side slopes (commonly with a gradient of 3-12%), while alluvial soils are located along drainage ways. When virgin, however, these soils have a high organic carbon content, which results in a good nutrient holding capacity. Consequently, sustainable use of the soils for agriculture depends on maintaining high levels of organic matter.

Table 1. Selected soil characteristics*

Characteristic	Analytical value	Rating
Soil pH (0.01M $CaCl_2$)	5.33	moderately acidic
Total organic C (%)	1.06	low
Total N (%)	0.14	moderate
Available P (Olsen, ppm)	9.0	low
Total potassium (%)	0.29	low
Soil texture		sandy-clay, loam

Source: Lekasi, 1998.
*These characteristics are typical of the soils on which bananas are growing in the Lake Victoria Crescent.

Agriculture in the Lake Victoria Crescent is rainfed, with bimodal rainfall (March to May and August to November) averaging 1218 mm annually (Yost and Eswaran, 1990). The average annual minimum and maximum temperatures are 15.0 and 27.5^{0}C respectively.

The main crops grown are bananas, coffee, beans and a variety of vegetables and root crops. Bananas and coffee are farmers' main source of income. Livestock is not an important enterprise in this area. The cash income in the central region of Uganda is less than 50 US $ per head for 42% of the population, between 50 and 100 US $ for 30% of the population, and 28% has an income over 100 US $.

Traditionally, South-Central Uganda has been the main banana growing area in the country, providing the preferred food for the native Baganda. It is in this same region that banana production is now declining at the most rapid rate. Two of the most affected areas are Mukono and Masaka districts, with yields of only 6 and 4.2 ha^{-1} $year^{-1}$ of banana fruit respectively in 1998. Mukono has a higher population density (180 pp/km2) than Masaka (152 pp/km2). Average farm size is 1.9 ha in Mukono and 1.4 in Masaka (see table 2).

One result of this failing productivity is a loss of income for farmers who are close to the biggest urban markets and who gained considerable cash returns from banana sales. Banana growing has extended to other areas in response to a high level of market

demand. The south-western region has now become the main source of banana fruits for the Kampala market.

Table 2. Mukono and Masaka district profiles

Parameter	Mukono	Masaka
Land area, km^2	4594	5531
Population density km^{-2}, total	180	152
Household size	4-5	n.a
Average farm size, ha	1.9	1.4

Sources: Bekunda and Woomer, 1996; Ministry of Finance and Economic Planning, 1992

Study methods

Survey

Scientists from the Agricultural Research Institute, Makerere University, have chosen improved soil fertility management as the entry point for re-establishing productive banana stands in the Lake Victoria basin. First, a household survey was conducted to characterise current resource management practices. This involved a total of 510 farm families from six districts within the Lake Victoria Crescent (see figure 1). The families interviewed were taken from the sub-county lists of taxpayers. Data collected included farm area, demographic changes, off-farm income, banana and other crop residue use, livestock type and number, manure use, external nutrient inputs, banana spacing, farmer estimates of average bunch weights and number of bunches harvested, market sales price, and intercropping species and frequency. Data were then analysed, and correlations between various farm practices determined for the sample as a whole. Considering the number and type of resources farmers used, several categories of organic residue management were identified. These were later subjected to GIS analysis to assess distribution patterns. Farmers' resource management strategies were then characterised according to their potential to improve nutrient supply and the possibilities for enhancing their efficiency.

Nutrient balance study and trials

In other associated studies, the "easy to measure" resource flows into and out of the soil were determined on selected farms (Bazira, 1998).

Several promising approaches to improve banana productivity were selected for evaluation through on-station trials. This paper reports on a trial with integrated nutrient management methods, combining mineral and organic nutrient sources. On-

station experiments were also conducted on the agronomic effects of using banana trash as an organic input to high value vegetable (cabbage) production (Lekasi, 1998). Farmers and extension agents regularly visited these trials and exchanged views with scientists.

Case study

A case study is made of nutrient flows and soil fertility management at the Madu Farm, located 12 km east of Kampala where coffee and bananas are grown. The farm has also two livestock enterprises: a poultry unit and dairy cattle kept under zero-grazing.

3 Results and discussion

Banana cultivation

Most bananas are grown on smallholdings near homesteads. Banana fields show a gradient from high yields near the household to lower yields towards the outer field boundaries. This reflects the typical, unequal distribution of organic fertilisers in a smallholder farming system, since the labour effort to carry wastes will be greater as the distance from the house increases.

Bananas have perennial characteristics and may be grown on the same piece of land for up to 50 years. Cultivation is through clonal propagation. Establishment is best when using suckers about 1.5 m high, with a 45 cm girth at the base, free from pests and diseases. The usual spacing is 3 m by 3 m. When being established, crops like beans, coffee, maize, and sweet potatoes are intercropped with the young banana plants. When land was still plentiful, the intercrop would be phased out after a year (two cropping seasons) and farmers would start mulching the bananas. Only a few tree crops like ficus (*Ficus nataliensis*), jack fruit (*Artocarpus heterophyllus*), pawpaw (*Carica papaya*), remained in the plantation, primarily to serve as windbreaks. Recently, however, land pressure has increased and intercropping is nowadays widely practised in old plantations (figure 2a). This results in acceleration of nutrient depletion and reduces the life span of the plantation to 7-10 years. Before independence, byelaws were

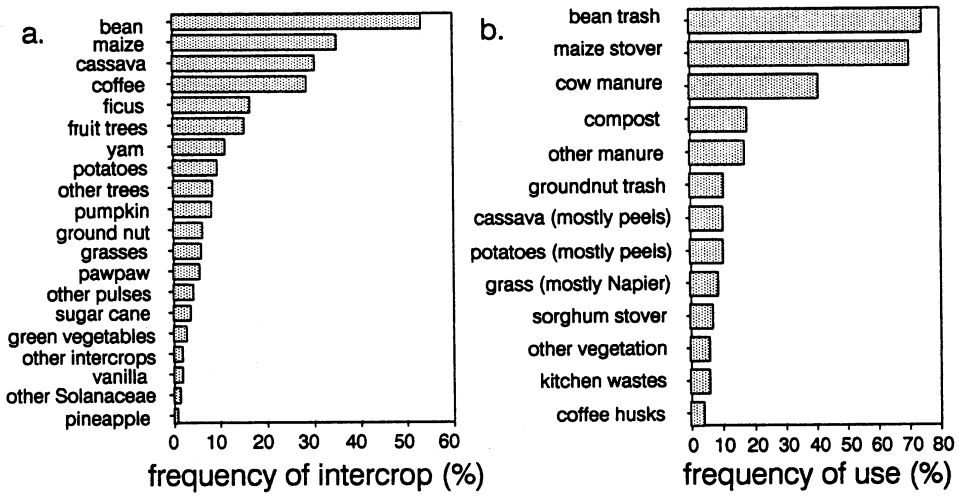
Box 1. Pre-independence byelaws on resource conservation measures.

Implementation of soil conservation during the colonial period was primarily through local agricultural rules (byelaws) instituted by agricultural department staff and implemented through the system of chiefs who had authority to impose a fine on the person failing to follow the rules. In addition to these coercive measures, attempts were made to encourage people to practice soil conservation through education, propaganda and conservation competitions at sub-county or county level. The technical success of these measures was never evaluated before or after the colonial period. The coercive implementation techniques led, perhaps in part, to a reduced desire to maintain such conservation measures after independence.

enforced that promoted mulching (see box 1) and other physical soil conservation methods, and discouraged intercropping in older plantations. Plantations could then be maintained for more than 50 years.

Mulching of bananas is an indigenous agronomic practice and was already in use before the colonial period (Jameson, 1970). Farmers favour mulching because they know that it suppresses weed growth, maintains soil fertility and conserves soil moisture for the shallow rooting banana crop. Traditionally, pruned banana leaves, and the plant parts remaining after harvest (harvest stools) are spread on the plantation floor. These are supplemented with other organic materials brought in from outfields, fallow fields, and swamps. Banana peelings and other homestead wastes are also usually returned to the plantation. Farmers are aware of the importance of using mulches but have difficulty in distinguishing between the effects of different types of mulch or application rates. Scientists are now undertaking studies to try and assess such effects as will be noted later.

Figure 2. The frequency of banana intercrop (a) and farmers' organic resource application to banana mats, other than banana stalks and leaves (b).



Organic residue recycling and transfers

Banana is the principle staple crop and also a major source of income in the Lake Victoria Crescent. Farmers therefore give priority to banana when applying organic manures, especially those generated within the farm, as was clearly seen in the household survey. The fact that banana plots are located close to the homestead is also of influence since this reduces the time and effort needed to transport organic wastes to the crop. Cereals and other crops are grown on outer fields. At harvest, grain and crop residues are transported from outer fields for threshing at the homestead and the chaff and other crop residues are deposited in the banana plantation.

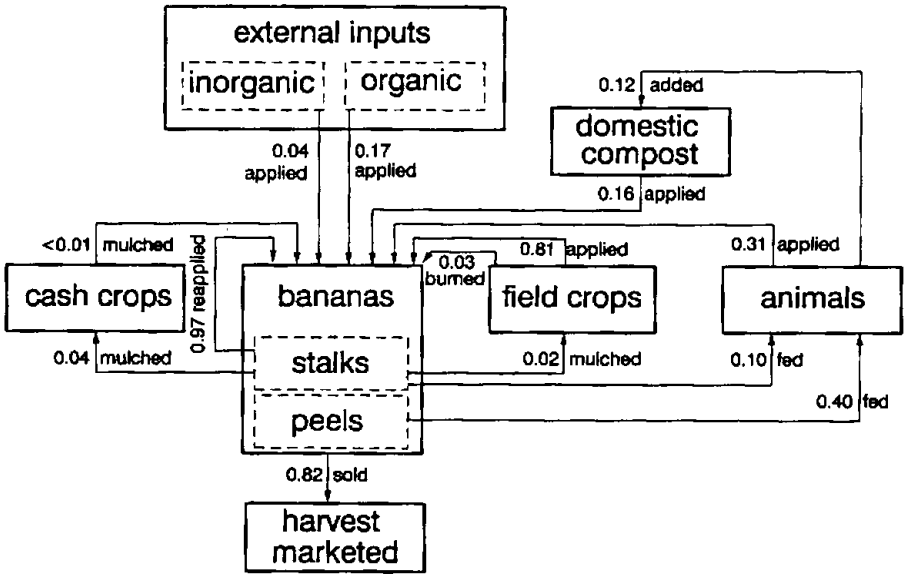
Livestock is herded on pastures or fed with forage from the outfields. For much of the time they are kept in kraals close to the home, which also favours the easy allocation of manure to the banana plantation. Cattle manure used to be the most important source of nutrients for the banana crop, but has become less available with population increase and the decrease in farm size, a trend which has also been observed for some other parts of the country (Tukahirwa, 1992). The use of off-farm agricultural inputs is limited.

Banana residues are universally recycled within the farm. The most important other sources of organic fertilisers applied to bananas are presented in figure 2b. Bean and maize residues were the most frequently used. These crops are also most frequently reported as intercrops in banana fields (figure 2a). The higher application frequency suggests, however, that residues from maize and beans grown on the outer fields are also applied to bananas. The third most reported organic input was cattle manure, followed by compost, manure from other animals and a variety of crop residues. More than 50% of the farmers supplemented banana residues with three or more other resources. Other resources are either under-utilised, e.g. coffee husks which farmers purchase from far away coffee processing centres, or contribute to soil fertility without direct action by farmers, e.g. leaves fallen from tree crops.

Figure 3 presents the number of farms reporting different levels of external inputs and organic resource transfers. It demonstrates the considerable integration of the various farm enterprises as most households demonstrate internal resource transfers. Banana residues, other than peelings, are used as mulches to field and cash crops (6% of households), or animal feed (10% of households). The figure also indicates that 81% of the field crop residues are applied as mulches to bananas and 31% of the manure available. This confirms that bananas are a priority recipient of organic inputs. By contrast, field crops of maize and beans must manage with much lower input levels.

Only 21% of the households reported the use of resources from outside the farm, of which 4% concerned inorganic inputs and the rest organic. Yet, since 82% of the farmers sell banana fruits, at least 61% of the farms in the survey must have net resource outflows.

Figure 3. Frequency of resource transfers within 510 banana-based cropping systems in the Lake Victoria basin of Uganda



Partial nutrient balance

A nutrient balance study focusing on the 'visible' flows was conducted on seven farms in the Lake Victoria basin over a period of one year. Partial nutrient balances were calculated on the basis of a quantitative and qualitative analysis of the biomass that went into or out of the banana field. The values present the differences between organic inputs obtained from outside the plantation (IN2) and fruit harvests (OUT1). There were no additions of inorganic fertilisers, and only limited intercropping with windbreak trees (see table 3). Export of banana trash from the plantation was not significant. This study did not consider other sources of nutrient inputs or loss which are more difficult to measure, such as nutrient loss through erosion, leaching, atmospheric emission, and gain through sedimentation, and atmospheric deposition. However, bananas are quasi-perennial and fruit yields may have been influenced also by previous organic matter applications. The assumption made is that the inputs and outputs recorded reflect farmers' normal routines.

The results from these seven surveyed farms show that when considering the resource transfers, there is an alarming rate of net nutrient removal from banana plantations, despite the often high volume of organic materials applied. This is probably due to the fact that nutrient concentrations in these organic materials tend to be very low. The negative partial nutrient balance seems to be caused primarily by farmers' inability to

purchase 'fertility' inputs. Investment in external inputs for banana plantations is not possible, when considering that the average fruit yield of 6.26 t ha^{-1} (survey estimates) at the current banana prices ($0.15 per kg) provides an annual per capita income of approximately $140, assuming that all the bananas are sold. Farmers will have to use income from other enterprises to finance the use of external inputs for banana plantations.

Table 3. Net biomass and partial nutrient balance in kg ha^{-1} over a one year period on seven banana growing farms in the Lake Victoria Crescent.

Farm	Biomass	N	P	K
Kiboga	-101	-33.8	-5.8	-42.0
Butambala	-550	-93.6	-15.2	-113.0
Luwero	+580	-45.3	-8.1	-5.1
Bulemere	+1030	+18.0	+0.8	+8.0
Kabale	+60	-52.6	-9.0	-63.0
Mityana	+280	-25.7	-4.8	-31.0
Makenke	+45	-132.0	-22.7	-159.0
Mean value	*+192*	*-52.6*	*-9.3*	*-58.0*

Source: Bazira et al., 1997.

Farmers' management strategies

A variety of organic inputs were used as fertiliser and mulch in different combinations as shown in Table 4. It has been observed that in the past, when population densities were lower and farm sizes larger, reductions in yield were countered by shifting to new areas or fallowing. Banana plantations were planted continuously and managed separately from other enterprises (Du Montcel, 1987). As population grew and farm sizes diminished, more intensive systems, such as intercropping, were adopted. This demonstrates that farmers' practices are a logical response to changing conditions and opportunities as well as a means of preserving their resources. For example, the data on mat density (Table 4) suggests that farmers who practise intercropping, which is indicated by their use of field crop (FC) residues, reduce the banana mat density. They judge that intercropping with annual crops is only possible with less canopy interception by the larger banana. In turn, healthy intercrops provide greater amounts of crop residue for mulching bananas. Outfields also generate crop residues which are used in banana plantations.

Where farm sizes are still large, cattle are raised and their manure (CM) is used as a source of organic nutrient inputs. Ninety per cent of this category of farmers are cattle owners and obtain better banana bunch sizes as can be seen from table 4. Reduced farm size results in fewer opportunities to produce and apply cattle manure and crop

residues. As an immediate strategy, farmers resort to utilising the more limited small livestock manure and processing composts from the small amount of household waste. Better integration and more efficient use of the limited organic resources on such farms provide a challenge for researchers working on sustainable soil fertility management.

Table 4. Comparison of system parameters between different organic resource management strategies of banana cultivation.

System parameter parameter	Resource use system[1]					
	B	B+FC	B+FC+CM	B+FC+SLM	B+FC+DC	P[2]
Frequency (%)	13.9	39.2	23.1	7.4	16.4	NA
Average bunch weight (kg)*	13.1	16.4	20.3	14.3	12.9	<0.01
Banana yield (kg $ha^{-1}yr^{-1}$)*	7497	6614	6899	3950	4510	0.02
Farm size (ha)	1.1	1.6	3.1	1.9	1.4	0.13
Mat density (ha^{-1})[3]	902	600	453	490	643	<0.01
Mat age (years)	7.2	7.5	7.5	9.2	15.2	<0.01
Livestock number	1.5	2.1	5.4	4.0	4.3	<0.01
Population density (persons ha^{-1})	8.8	6.8	6.1	5.4	6.3	0.02

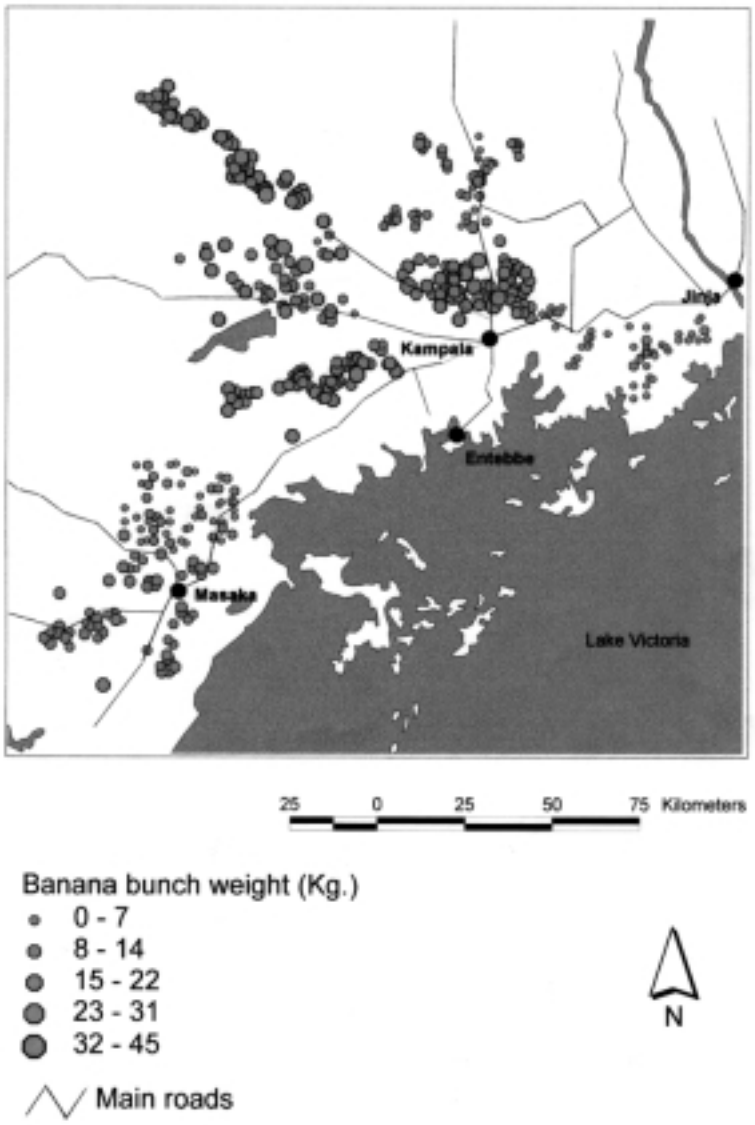
Source: Bekunda and Woomer, 1996.

[1] B, banana stalks and leaves; FC, field crop residues; CM, cattle manure; SLM, small livestock manure; DC, domestic compost.
[2] Probability the highest significant difference
[3] Banana mat density calculated as: banana mats per farm/banana production area per farm
* Farmer's estimates
NA, not applicable

The distribution of different management practices

Mukono (near Jinja) and Masaka have the lowest banana productivity in the Lake Victoria Crescent, when using 'average bunch weights' as the main indicator (figure 4). These are therefore likely to be the regions with the most degraded soils. The resource management practices used differ between the two areas. In Masaka, composting is widely practised as a means of producing fertiliser from domestic waste (67% of the interviewees). In Mukono, however, many farmers raise goats and sheep and apply their manure to the banana fields, demonstrating a higher level of crop-livestock integration than in Masaka. These results show that technologies used to address the fall in banana yield via soil fertility management, may not be the same for different locations within a given farming system.

Figure 4. Distribution of banana bunch weight in Lake Victoria Basin



The data also showed that the strategies used to cope with reduced banana yields differ between the two areas. Marketing opportunities are available in Mukono, due to its proximity to Kampala. The proportion of the farm dedicated to banana production has fallen to less than 40%, in favour of cash crops such as coffee, vanilla and fruit trees. Masaka, however, has poor access to markets, so farmers maintain a large proportion

of their land (80-100%) under banana plants largely for domestic consumption. The low yields obtained were balanced by intercropping banana with other food crops such as cassava, maize and beans.

The research agenda

Land rehabilitation and maintenance of productivity on smallholder farms through improved use of inputs and management of resources have become a research priority. In the banana-based mixed farming systems of Uganda, organic manures are the most important fertility amendments that farmers apply to cropland. The efforts of researchers during the 1990s have been directed towards the formulation of operational strategies, targeted at their optimal use, and to create more awareness of the importance of fertility management by farmers.

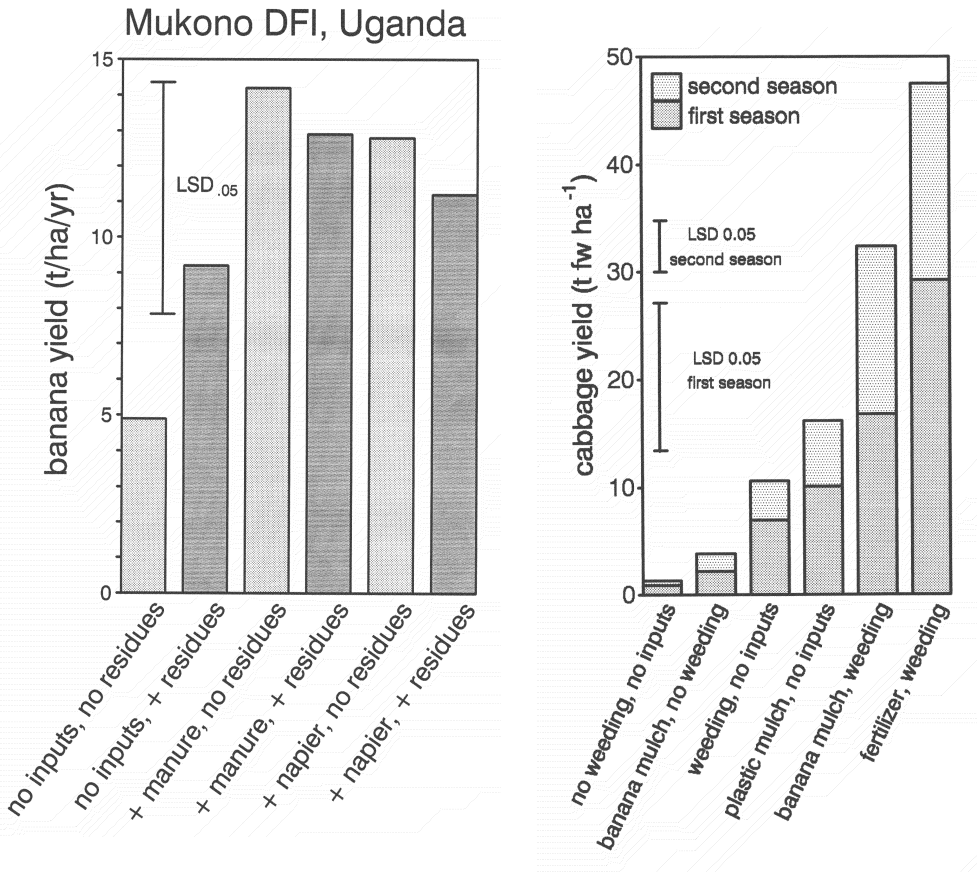
As pointed out earlier, farmers are conscious of the functions of mulches. However, they are unable to quantify the effects of the different mulch materials or the various application methods. Knowledge of the effect of mulches is, however, an important management tool. The key questions being addressed therefore, include considerations of where materials are from, and which fields/parts of fields or which crops they are returned to and in what way. The first need is therefore to generate basic information on these processes. This is the reason why most studies on nutrient management in bananas were either on-station or on-farm researcher-managed trials. However, scientists are conscious of the need to take the results to farmers and assist them in adapting these to their own conditions. Thus, farmers are invited for field days at the research station and discuss the experiments with researchers. Farmers and extension agents are also involved to various degrees in on-farm studies.

The following examples serve to indicate the potential contributions of research. Integrated nutrient management methods, combining mineral and organic nutrient sources, offer better technical solutions than reliance on one or other major source alone. In the severely affected Mukono District, scientists have demonstrated that banana productivity can be increased from 5 to 13 kg bunches in the first year of harvest. This requires a one-time application of fertiliser (34 kg N and P $^{ha-1}$) in planting holes at establishment, the periodic addition of organic manures or crop residues (50 kg N $^{ha-1}$ equivalent annually which is about 10 tons of napier grass) and by removing pest-infested residues after harvest (figure 5). Ten tonnes of napier grass is a substantial amount, but already 10 times less than recommendations cited elsewhere (Zake et al.,

Fertiliser application tests, based on one banana mat, are being conducted on farmers' fields. They will result in fertiliser recommendations that farmers can use when they want to correct soil fertility limitations in selected sites of their plantation.1994).

Figure 5 (left). Banana yields for various combination of inorganic fertilisers and organic inputs

Figure 6 (right). Cabbage yields for various treatments with banana mulch in combination with weeding



It has also been demonstrated that the application of pest-infested banana residues to a nearby cabbage field will increase the latter's yields by 22 t ha^{-1} over the next two cropping cycles. Banana residues can thus also serve as an important source of manure for other crops (figure 6). The net profit of this treatment was Ush 340.546 (about US$ 340) as opposed to Ush 116.656 (about US$ 116) for cabbages grown without mulch. The 4% of the interviewed farmers (figure 3) who transfer banana residues to cash crops thus benefit from increased yields of other crops while also reducing damage by pests to bananas.

Policy support

The overall development policy in Uganda is to modernise agriculture. With respect to soil fertility management, this "..implies improving agricultural techniques, whether aided by chemicals, machines such as tractors, or relying on organic means of fertilisation.." (Museveni, 1997). The operational policy plan envisages sustainable utilisation of soils and other renewable resources. Despite these favourable policies, farmers have received minimal assistance from government programmes due to severe limitations in policy implementation.

In fact, the many fertility management strategies used by farmers, as depicted in Table 4, show their innovativeness and resilience in resource use efficiency, without assistance from the government. There are only a few farmers in the category of Mr Makanga (see box 2), willing and able to invest substantially in agriculture and take risks. His Madu Farm presents an example of how investment of available resources, in anticipation of fair market returns, can result in a higher level of integrated resource management in the long run. They will eventually overcome soil fertility constraints.

However, the priority of most small-scale farmers is the immediate production of food. Longer-term issues of sustainability have to be addressed not only at household but also at national levels. Government can offer security and support to farmers, when they understand their objectives and limitations. Successful policy implementation can only be achieved through the active participation of the farmers, and closer linkages between farmer, researcher, extension agent and planners.

Box 2. A case study of an enterprising farmer

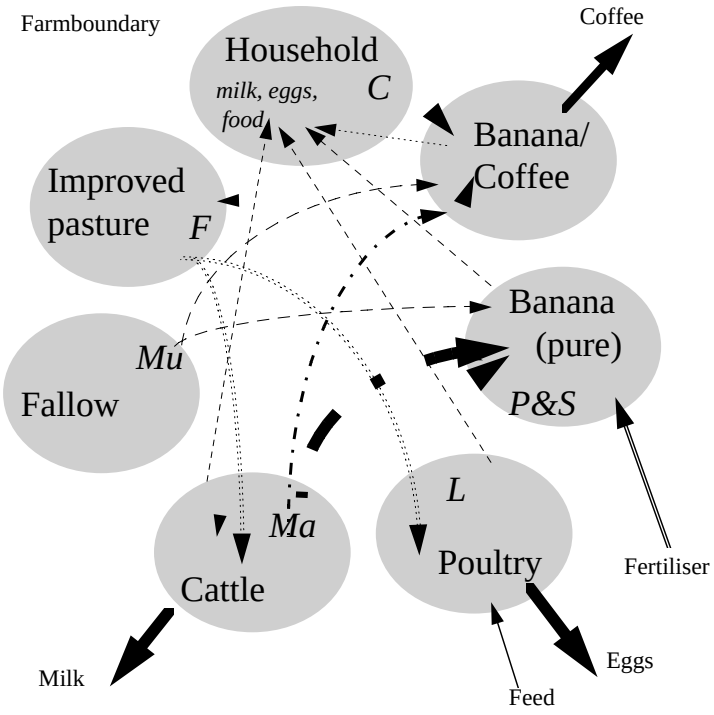
Mr. Makanga Dunstan is the owner of Madu Farm, located 12 km east of Kampala. He started in 1991 with 2 acres and now has 17 acres of land. He is growing 4 acres of clonal coffee, mostly intercropped with bananas and agroforestry trees, and 2.5 acres of bananas. Cereal and vegetable crops are grown on a small scale for home consumption, rotated with land that is kept under fallow. There are two livestock enterprises: a poultry unit with more than 1500 layers and 5 dairy cattle kept under zero-grazing. He grows fodder, which is a mixture of napier and legumes. The farm is run by a 16 person labour force headed by a certificated farm manager. He started by consulting extension officers to gain advice but now he is employing one of his own. Mr Makanga welcomes visits from other farmers to share experiences. The success of his farm presents a learning example on all aspects of farm management for the many farmers that visit him.

Mr. Makanga has always considered farming as a business. His first investment was the purchase of a 2-acre piece of land to start with sericulture (silkworm production). The profits were partly invested in the purchase of more land, which was cheap at the time.

About three acres of land were acquired in exchange for a black and white television set! He also started a poultry unit in 1993, beginning with 500 laying birds. Sericulture, however, was no longer generating profits and therefore phased out. From the profits of the poultry unit, a series of other enterprises were established as follows:

1994	construction of a new poultry unit housing 1000 birds; establishing a coffee garden using cloned material
1995	the poultry unit was further expanded
1996	start of zero grazing unit; 3 Friesian cows were purchased 3 acres of cloned coffee were planted, intercropped with bananas and trees
1997	two cows (a Jersey and a Guernsey) were purchased a banana plantation (102 cooking, 303 dessert mats) was established

Figure 7. Major resource flows between different enterprises at the Madu farm



Legend: *C*= Compost, *Mu*= Mulch, *F* = Fodder, *P&S* = peels and stem, *Ma* = Manure, *L* = Litter
The thickness of the arrow reflects the flow's importance.

Mr. Makanga recognises that livestock plays a crucial role in his farming system, providing daily cash income, and a source of fertiliser for the crops (figure 7). Income from crops is seasonal. Livestock also is supported by crop output to a certain extent, which provide forage (including banana peel and stalks) and bedding materials. Both enterprises have a finite potential to support one another and methods of cycling nutrients amongst soil, crop and animals are already practised. Household wastes are composted before use, cattle manure is stored in the shade when not used immediately, and cattle urine is stored in containers for at least seven days before spot application.

The problem is that a substantial amount of farm produce is sold, resulting in an "export" of nutrients from the farm which is not sufficiently balanced by nutrients added from outside the farm. Mr. Makanga is not very aware of this process of nutrient depletion and associated risks. As depicted in his resource flow chart, nutrient flows are predominantly uni-directional from fallow and improved pasture units, towards livestock and crops. There is a risk that the fallow and fodder plots will become degraded, in favour of other parts of the farm. Some nutrients are 'imported' since cash income from the sale of farm produce is used to purchase inorganic fertilisers, animal feeds and other inputs to improve productivity. Clearly, Mr. Makanga's soil fertility management strategy will be 'market-driven' as his farm is geared towards profit maximisation.

Mr Makanga's farm is a model farm. His willingness to exhibit and explain his farm management to others makes him a potential *Extension Link Farmer*. This is a terminology used by the Uganda National Farmers' Association (UNFA) for a farmer who voluntarily offers to train other farmers. UNFA also organises study tours for groups of farmers. Through UNFA, farmers also express their need for better information on research, technologies and extension services.

UNFA is a national association of Uganda farmers and farm families. It was established to respond to the need for change in farming practices. It is built on the conviction that agriculture will be strengthened through co-operation and that farmers have great potential to solve many of their problems when united. UNFA has developed its own "extension" structure comprising an Extension Link Farmer (ELF) who leads a Special Interest Group (SIG) usually organised around a commodity crop (e.g. banana). Each group also has a Contact Farmer (CF). The ELF's selection criteria are based on being a good farmer and willing to volunteer part of his/her time to (i) train, demonstrate and provide basic technical support to the SIG; (ii) encourage other farmer members to form SIGs; (iii) assist marketing centres. ELFs are given extra training on the job by professional extension advisers. Soil fertility management forms an important component of resource management training at this level (UNFA, 1998).

4 Conclusion

Banana yields in the Lake Victoria Crescent of Uganda are declining, partly due to soil fertility depletion. Interviews with more than 500 farmers in the region, made clear that they do their best to manage their soils. They use practices to prevent soil fertility depletion, given the types and amounts of resources available to them. In general, however, the application of organic inputs was inadequate for replacing the significant amounts of nutrients lost from banana fields. Manure used to be important, but its availability has declined following population increase and decrease in farm size.

Such conditions have promoted farmers to shift to other resource-use strategies, such as the use of composted household wastes. Farmers may also benefit from nutrient-saving management approaches, which research can help develop. The generated knowledge should be turned into implementable, national policies. Otherwise, short-term subsistence based considerations at the household level will continue to result in the use of management constrained by farmers' objectives and access to resources, but with adverse implications for a sustainable nutrient management.

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