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Managing Africa's Soils No. 21

Using local resources to improve soil fertility in Tanzania

Juma M. Wickama and
Jeremias G. Mowo

February 2001

This discussion paper series has been launched as part of the NUTNET project. NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa-Nutrient networks & stakeholder perceptions*. It brings together several research programmes working on soil fertility management in sub-Saharan Africa. Activities include research on farmer management of soil fertility and understanding of the perceptions of different stakeholders towards how best to improve soils management. This series will be continued under the INCO-concerted action programme *Enhancing soil fertility in Africa: from field to policy-maker* which builds on the work done by NUTNET and receives funding from the European Union.

The series encourages publication of recent research results on soil fertility management in Sub Saharan Africa in a discussion paper form. Emphasis will be on interdisciplinary research results which highlight a particular theme of wider relevance to development policy and practice. Themes include:

- Farmers' knowledge of soils and soil fertility management
- Socio-economic context of environmental change, including histories of soil management
- Nutrient budget analysis at farm and field level
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- Discussion of methodological aspects and dilemmas when analysing soil fertility management at farm level
- Approaches towards on-farm trials and technology development with farmers.

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About NUTNET

NUTNET is a network that aims to improve the management of soil fertility in Africa. It is a partnership of fifteen organisations from six African and two European countries: INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, Kenya; IER, Mali; Environment Alert & University of Makerere, Uganda; IES, Zimbabwe; IIED & IDS, United Kingdom; and AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, The Netherlands. NUTNET is funded by DGIS, the Ministry of Foreign Affairs in The Netherlands.

About *Enhancing soil fertility in Africa: from field to policy-maker*

This project builds on the work done by the NUTNET network, which has been extended to include the Swedish University of Agricultural Sciences (SLU), the Universidad Complutense de Madrid (UCM) and the National Agricultural Research Foundation (NAGREF) from Greece. It is funded by the International Co-operation for Development (INCO) programme of the European Union, which links ongoing research projects on soil fertility management in sub-Saharan Africa, focusing on the implications of diverse social, economic and environmental settings, and the differing perceptions held by stakeholders of research and policy design.

Acknowledgments

We would like to thank the African Highland Initiative (AHI) for funding this research, and the INCO programme for enabling us to publish our findings. Thanks are also due to the management of ARI–Mlingano for facilitating the research, and to the people of Kwalei village, particularly Mzee William Mauya, Zainabu Zuberi, Mohammed Shekibula, Fatuma Ramadhani, Paulo Mbilu and Mzee Paulo Hoza, who formed the village task force for investigating shrubs. We also wish to acknowledge the support given during fieldwork by Mr. Crispin Shangali from TAFORI Lushoto, Ms Beatrice Shemdoe from Community Development-TIP Lushoto and the agricultural extension officers Messrs Urassa, Matosho, and Komba at Soni (Kilimo). Finally, we would like to thank our colleagues Dr. A.S. Nyaki, Dr. G.J. Ley, Mama Ikerra, Dr. W. Veldkamp and Kenneth Masuki at ARI–Mlingano for their constructive criticism and support during the preparation of the report, and C.T. Shawa for supervising most of the laboratory work.

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Summary

Despite their concern about declining soil fertility, farmers from the Tanzanian village of Kwalei use very little mineral fertiliser to improve their crop yields. A PRA study in this benchmark site for the African Highland Initiative (AHI) revealed that although this type of input was available, it was considered too expensive for widespread use. As their livestock could not produce enough farmyard manure for their needs, farmers coped by using the leaves of certain local shrubs as green manure, which seemed to improve soil fertility when ploughed into the fields. However, although they based their soil fertility management strategies on these shrubs, researchers and extension workers did not know their scientific name or nutrient content, and it was agreed that an inventory should be made of this important local source of nutrients.

Farmers identified seven shrubs that seemed to improve the nutrient content and workability of the surrounding soil, singling out one called *tughutu* (*Vernonia subligera*) as the best for improving soil fertility. Their observations were confirmed by soil sampling and mineralisation studies, which also indicated that decomposition generally peaks within four to five weeks of application, and that a modest amount of mineral fertiliser will offset the subsequent reduction in nutrients released after this period.

A growing number of farmers have started using green manure on their maize, bean, and vegetable fields since researchers reported back on the results of the scientific analyses at a village meeting. While *tughutu* is particularly popular, farmers are also experimenting with various methods of application, including a combination of green manure and rock phosphate as suggested by researchers.

Participatory research methods revealed important findings about local knowledge of the diverse sources of nutrients available to farmers, and we have been able to increase our understanding of these practices by following up the initial results with more conventional scientific analysis. The inclusive, participatory approach used in this study also enabled farmers to become more involved with, and therefore more interested in, the outcome of the scientific analysis of these technologies and subsequent experimentation carried out on their farms.

French summary

En dépit de leur inquiétude concernant le déclin de la fertilité des sols, les agriculteurs du village tanzanien de Kwalei utilisent très peu d'engrais inorganiques pour améliorer les rendements de leurs cultures. Une étude, menée dans ce site-pilote de l'*Initiative African Highland* (AHI), a révélé que, si ce type d'apport était disponible, il était néanmoins considéré trop coûteux pour être communément utilisé. Comme leur bétail ne peut pas produire suffisamment de fumier organique pour satisfaire leurs besoins, les agriculteurs utilisent à la place les feuilles de certains arbustes en guise d'engrais vert qui semble améliorer la fertilité du sol une fois labouré dans la terre. Cependant, comme ils basaient leurs stratégies de gestion de la fertilité de leurs sols sur ces arbustes, et que les chercheurs et les vulgarisateurs ignoraient leurs noms scientifiques et leurs teneurs en éléments nutritifs, il a été décidé de faire un inventaire de cette source locale importante d'éléments nutritifs.

Les agriculteurs ont identifié sept arbustes qui semblaient améliorer la teneur en éléments nutritifs et rendre le sol environnant plus facile à travailler. Ils ont exprimé leur préférence pour *tughutu* (Vernonia subligera) qui améliore le mieux la fertilité des sols. Leurs observations ont été confirmées par des échantillons de terre et des études de minéralisation qui ont aussi indiqué que la décomposition généralement est au maximum quatre à cinq semaines après l'application et qu'une modeste quantité d'engrais inorganique compenserait la réduction ultérieure des éléments nutritifs libérés après cette période.

Un nombre croissant d'agriculteurs a commencé à utiliser de l'engrais vert dans leurs champs de maïs, de haricots et de légumes depuis que les chercheurs ont rendu leur rapport sur les résultats des analyses scientifiques lors d'une réunion au village. S'il est vrai que *tughutu* est particulièrement populaire, les agriculteurs expérimentent aussi diverses méthodes d'application, y compris un mélange d'engrais vert et de phosphate minéral suggéré par les chercheurs.

Les méthodes participatives de recherche ont révélé d'importantes connaissances locales concernant les diverses sources d'éléments nutritifs à la disposition des agriculteurs et nous avons été en mesure de parfaire notre compréhension de ces techniques en faisant suivre les premiers résultats d'analyses scientifiques plus conventionnelles. L'approche participative globale employée pendant cette étude a également permis aux agriculteurs de s'engager davantage et donc d'être plus intéressés par l'analyse scientifique de ces technologies et les expériences menées ultérieurement dans leurs exploitations agricoles.

1 Introduction

Scientists and farmers are becoming increasingly concerned about the declining fertility of soils in the highlands of Eastern Africa. A study of four villages in the Lushoto district in the Tanga region of northeast Tanzania (Ngailo et al., 1998) revealed that the only fields not showing a net nutrient loss were those used for horticulture. Farmers are prepared to apply more fertiliser to these plots because they generate quick financial returns. Since the withdrawal of subsidies in the early 1990s, they have been reluctant to follow extension recommendations to use mineral fertilisers (Mowo et al., 1993).

The National Soil Survey (NSS) of Tanzania used to focus primarily on developing recommendations for the use of mineral fertilisers, which were then passed on to farmers by the extension service. Realising that few smallholders actually follow their recommendations, and recognising the need for other approaches to soil fertility management, the NSS began researching soil fertility management practices in different farming systems in Tanzania, and has been developing participatory methods for an integrated approach to related problems (Wickama et al., 2000).

One of these research projects was undertaken as part of the African Highlands Ecoregional Programme, which covers a number of countries, and is better known as the Africa Highlands Initiative (AHI)[1]. Co-ordinated by the Consultative Group on International Agricultural Research (CGIAR), the AHI has a number of benchmark sites where a broad range of natural resource management issues is monitored and addressed through participatory experimentation with farmers. To help disseminate the technologies developed during the process, the site co-ordinator liases with agricultural extension services and NGOs in the district, researchers from the National Agricultural Research Institutes, and other stakeholders.

The village of Kwalei in Lushoto district was selected as the Tanzanian benchmark site. In 1998, scientists from NSS Mlingano and sister institutions in Tanzania, Kenya and Uganda carried out a Participatory Rural Appraisal (PRA) in Kwalei to determine the availability of resources and identify the opportunities and constraints to agricultural production, so that they could develop a programme of joint interventions with farmers.

1 The AHI focuses on the highlands of Kenya, Uganda, Tanzania, Ethiopia and Madagascar.

Smallholders reported that they believed declining soil fertility to be the primary cause of falling crop yields. When asked why they did not regularly use mineral fertilisers or farmyard manure, most replied that they could not afford the former and had too few livestock to supply enough of the latter. They also observed that a considerable amount of fertiliser was lost through run-off from their sloping fields (Lyamchai et al., 1998).

However, a few farmers reported that spreading leaves from various local shrubs over their fields and ploughing them into the soil seemed to improve fertility, and researchers from NSS Mlingano felt that soil fertility management in the village as a whole could be greatly improved by drawing up an inventory of these sources of nutrients.

This paper describes the methodology used in the research, the plants identified by farmers, and the results of tests on their chemical composition, their effect on soils and mineralisation. After a brief summary of the experiments subsequently carried out by farmers, it closes with the conclusions drawn by the team about the potential for using green manure in Kwalei.

Characteristics of the study area

Kwalei village is located in north eastern Tanzania, close to the border with Kenya, some 18 km east of the town of Lushoto. With an average population density of 127 people/km^2, and population growth of 2.8 %, the district is among the most densely populated areas in Tanzania (Bureau of statistics, 1988). An average household in the village has eight people, most of whom are children (Lyamchai et al., 1998).

The physiography and ecosystem of Lushoto district are typical of the East African Highlands. Separated by the Lwengera valley, the two large mountain massifs of the West and East Usambara Mountains make up almost 90% of Lushoto district. The West Usambaras rise to 2300 masl, with the plain situated at approximately 600 masl. The mountainous area is characterised by metamorphic rocks, schists, and gneisses, which are generally not very resistant to chemical weathering. Not surprisingly, these are also the dominant substrates of the soils in Kwalei (Ngailo et al., 1998; Meliyo and Masuki, personal communication).

The village lies in the "humid – warm" agro-ecological zone, receiving 800-1700 mm of rainfall each year, with long rains lasting from March to May and short rains falling in November and December. The average temperature oscillates between 18°C and 23°C, peaking in March and dropping to its lowest in July (Pfeifer, 1990).

The major soil types at Kwalei can be classified in descending order of importance as Humic and Chromic Acrisols, Luvisols and Lixisols. These deep, predominantly well-drained soils have dark red topsoils that are rich in humus, provided that they are not subject to erosion. Many soils on the valley bottoms are classified as Fluvisols, black and brown loams and clays that are imperfectly to moderately drained. Chemical and physical analysis indicates that soils in Kwalei are highly weathered and clayey in texture, varying from very strongly acid (pH 4.9) in hilly areas to strongly acid (pH 5.3) in the valley bottoms. The poor plant nutrient status of many soils is aggravated by the terrain, which encourages soil erosion and leaching. The organic carbon content of soils in most hillside areas varies from low (0.8%) to medium (1.8%), rising to >2% in the relatively small valley bottoms. At 0.2%, nitrogen levels are low for most crop requirements, but while there is little available phosphorous (< 7 mg/kg soil) or potassium (>0.2 cmol(+)/kg K), these levels are sufficient for most crops. Calcium and magnesium are also low (EuroConsult, 1990; Landon, 1991; Baize, 1993).

Cropping systems

Agriculture is the dominant economic activity in Kwalei. Most land is privately owned, while communal land consists of forest or areas that are left uncultivated in order to control soil erosion. Landholdings have become increasingly fragmented as they are passed down from father to son, and the average household now has less than 0.4 ha on which to cultivate crops. The entire agricultural output of village is produced by smallholders, who intercrop maize and beans as their main source of food, as well as growing bananas and sweet potatoes on a small scale. Most income is earned by selling farm produce such as vegetables, fruit, potatoes, coffee, tea, milk, and livestock. Farmers rely on their families to provide the labour for almost every agricultural activity and, as Kwalei is mostly hilly, the land has to be prepared by hand with hoes.

Farmers manage their soil fertility extensively. Mineral fertilisers are too expensive to be commonly used in hilly areas, where there is also a greater risk of losing them to erosion, while farmyard manure is both too scarce and too labour intensive to apply on all fields. These precious inputs are generally applied only to horticultural crops grown in the valleys, which produce high and immediate returns. However, a few farmers fertilise the soil with leaves from certain local shrubs, a practice which is discussed in some detail in section two below (Lyamchai et al., 1998).

Study methodology

The aim of the study was to improve soil fertility in Kwalei by using locally available sources of plant nutrients, with a specific focus on:

- Identifying local shrubs used to improve soil fertility;
- Establishing how they are used;
- Using laboratory tests to determine the principal nutrient content of these shrubs;
- Establishing patterns of nutrient release;
- Assessing whether their quality and use needs to be improved.

Research was conducted in two discrete phases. In the first phase, farmers were involved in drawing up an inventory of local sources of plant nutrients, which were then scientifically verified during the second phase.

Farmers took the lead in identifying the plants used to improve soil fertility. The main criterion for including plants in the inventory was that soils underneath them should give exceptionally good yields when they were used to grow crops. Information about the various uses for each of these shrubs was obtained through meetings with farmer groups and key resource people.

Scientists were shown the main growing sites for these shrubs by a small group of "expert" farmers, who knew where they were readily available. All the material taken for further study came from plants that had already flowered, and samples were analysed for their nutrient composition on whole plant basis. Plants identified as potential sources of nutrients for crops were identified and classified using standard botanical techniques and the facilities available at the Tanzania Forestry Research Institute (TAFORI) in Lushoto. The shrubs were classified in terms of their genus, species and family names.

Soil conditions across the village were assessed by taking composite soil samples from fields in the four main sub-villages of the Kwalei catchment area. Procedures outlined in the NSS Laboratory Manual (NSS, 1990) were used to analyse four composite samples, assessing parameters such as pH and exchangeable bases, soil texture and the total nitrogen, organic carbon and available phosphorous content. To assess their effect on soil conditions, samples of earth were taken from underneath and around the selected plants, and compared with composite soil samples from continuously cultivated fields.

In order to study decomposition, or mineralisation, 1 kg soil was mixed with 2.27 g of plant material, equivalent to applying 5 tons/hectare. The moistened mixture was kept at field conditions, with measurements taken over 6 weeks to analyse changes in available P, exchangeable K, and inorganic nitrogen levels (NO3-N and NH4-N)[2].

The main findings of these studies were presented to farmers at a feedback meeting. Fresh samples and easily readable tables were used to illustrate the nutrient content of each shrub and, after a brief explanation of their effect on crops, farmers were instructed how best to use them so that crops would receive the required amount of nutrients.

2 N was measured using the method described by Bremner (1965), while Bray II was used to measure P and K (NSS, 1990).

2 Inventory of useful shrubs

After discussions with various groups and "expert" farmers, seven shrubs were identified as being particularly effective in improving soil fertility. The local name in Kisambaa was recorded for each plant, and samples were collected so that their botanical name could be identified. Both are noted in the list below:

Local name	**Botanical name**	**Family**
Tughutu	*Vernonia subligera* (O.Hoffn.)	Compositae
Mhasha	*Vernonia amyridiantha* (Hook, J.)	Compositae
Mshai	*Albizia schiniperiana*	Mimosaceae
Mkuyu	*Ficus vallis-choudae* (Del.)	Moraceae
Sopolwa	*Kalanchoe crinata* (Andrew) Haw.	Crasulaceae
Tundashozi	*Justicia glabra* (Roxb.)	Acanthaceae
Boho	*Bothriocline tementosa* (S. Moore) M. Gilbert	Compositae

Farmers were particularly interested in and best informed about three shrubs: *tughutu*, *mhasha* and *mshai*. They showed a marked preference for *tughutu*, an indigenous plant with the longest record of use for regenerating soils, which German colonial extension officers used to recommend for stabilising anti-erosion ridges. This fast-growing plant is easy established from stem cuttings. Farmers claim that areas previously under *tughutu* are easier to cultivate when turned into farmland, that they generally produce healthier crops, and that *tughutu* helps to retain moisture in the soil. The shrub can also be used as fodder for goats during droughts, as firewood and for treating wounds. It takes about a year before a stem cutting of *tughutu* produces enough leaves to harvest as green manure.

Mhasha and *mshai* were ranked second after *tughutu* in terms of their capacity to improve soil fertility. *Mhasha* belongs to the same botanical family of Compositae as *thugutu*, although it has slightly smoother leaves, and is also used as aphrodisiac for men and for treating infertility in women. *Mshai* is used to support trailing crops such as passion fruit. *Mkuyu* was ranked third, with farmers reporting that soil collected from underneath this shrub is an excellent medium for establishing tree, fruit and tomato seedlings, producing more vigorous and faster growing plants. *Sopolwa*, *tundashozi* and *boho* were jointly ranked fourth. *Tundashozi* was noted as a valuable fodder plant for goats and sheep, while *sopolwa* and *boho* can be used for medicinal purposes.

It was interesting to note that *Tithonia diversifolia* was not included in the list of useful plants, despite the fact that it can be found in the village. However, we have included samples of it in our analysis for comparative purposes, as it is widely studied and used to enrich soils in Kenya.

Nutrient content

Table 1 presents the nutrient content of the shrubs identified by farmers. Five of them – *mkuyu, mshai, alizeti mwitu, mhasha,* and *tughutu* – had nitrogen levels of 3.0% or above. *Tughutu* had the highest levels of N (3.6%), *mshai* had the highest levels of P (0.32%), while *tughutu* had the highest K content (4.7%).

Table 1. Nutrient content of shrub samples taken from Kwalei

Local name	*Farmer Preference*	*Botanical name*	*Nitrogen %*	*Phosphorous %*	*Potassium %*
Tughutu	1	*Vernonia subligera*	3.6	0.25	4.7
Mhasha	2	*Vernonia amyridiantha*	3.4	0.23	4.5
Mshai	2	*Albizia schiniperiana*	3.1	0.32	1.3
Mkuyu	3	*Ficus vallis-choudae*	3.0	0.23	4.4
Boho	4	*Bothriocline tementosa*	2.1	0.27	1.5
Sopolwa	4	*Kalanchoe crinata*	2.1	0.23	3.8
Tundashozi	4	*Justicia glabra*	2.0	0.27	2.1
Alizeti mwitu	n.m.	*Tithonia diversifolia*	3.2	0.24	3.4

Key: n.m=not mentioned

Table 2 presents the results of the qualitative analysis of soil samples taken from under selected shrubs, in areas identified by farmers as having been left uncultivated for long periods. The samples collected from beneath shrubs are in better physical and chemical condition than those taken from areas under cultivation. This is probably partly due to the presence of decomposed plant material, and partly to the fact that areas covered by shrubs are less susceptible to erosion. The highest levels of nitrogen and organic carbon were observed in samples taken from around *mkuyu*, while phosphorous levels were found to be highest underneath *mshai*, followed by *mhasha* and *tundashozi*. The highest levels of potassium were found in soils around *tughutu* and *mhasha*, while samples taken beneath *mkuyu* trees had the highest levels of accumulated Ca and Mg.

Physical observation of soils underneath *tughutu* indicated that their texture and drainage is better than that of other soils, and that they therefore provide more favourable rooting conditions for crops. This confirmed farmers' claims that these areas are easier to cultivate. Received wisdom that the soil from under *mkuyu* produces healthier seedlings was reinforced by analytical evidence of high levels of organic carbon and nitrogen, as well as micro-nutrients such as calcium, magnesium and natrium.

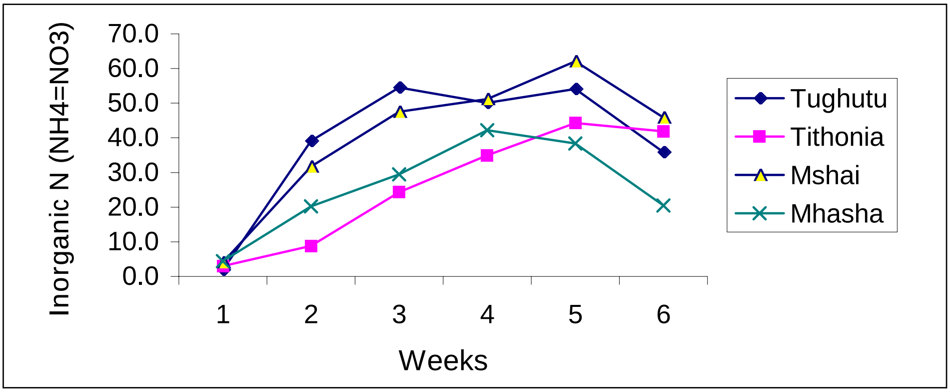
Table 2. Characteristics of soil samples collected beneath shrubs growing in Kwalei

Shrub	Botanical name	Organic Carbon	N	P	K
		%	%	mg/kg	cmols/kg (soil)
Tughutu	Vernonia subligera	2.2	0.5	7.8	0.9
Mhasha	Vernonia amyridiantha	2.1	0.5	10.3	1.1
Mshai	Albizia schiniperiana	1.6	0.4	13.5	0.8
Mkuyu	Ficus vallis-choudae	5.7	0.7	9.3	0.4
Boho	Bothriocline tementosa	2.0	0.4	6.8	0.2
Sopolwa	Kalanchoe crinata	2.7	0.5	9.1	0.5
Tundashozi	Justicia glabra	2.7	0.6	10.0	0.3
Alizeti mwitu	Tithonia diversifolia	2.1	0.3	8.3	0.8
Soil from cultivated field	–	0.8-1.8	0.2	6.7	0.2

Patterns of mineralisation

The amount of nutrients released by shrubs over a six-week period are presented in in Figures 1, 2 and 3 below and in Appendix 1.

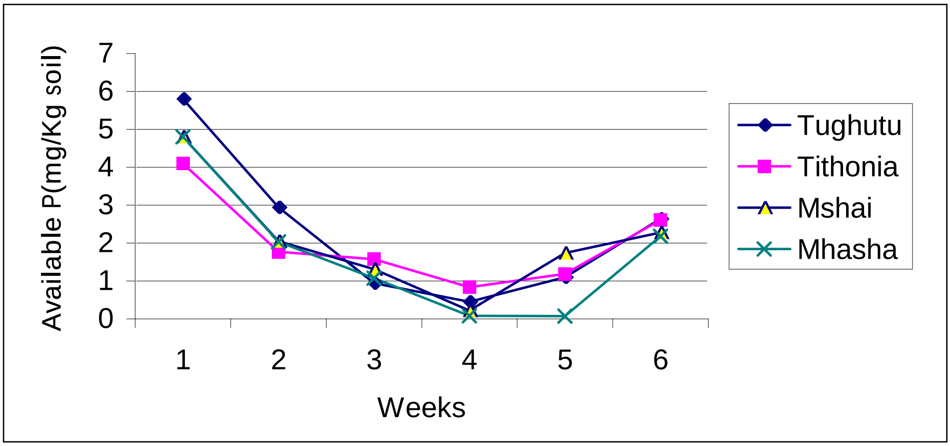
Figure 1. Pattern of mineralisation of inorganic N in four shrubs in Kwalei



The pattern for inorganic N (NH4 and NO3) indicates that for most shrubs, the rate of decomposition peaks after 4-5 weeks of incubation, decreasing thereafter (see Figure 1 and Appendix 1 for more detail). To derive maximum benefit from the mineralisation of N, crops should be planted immediately after green manure from these shrubs has been incorporated into the soil. However, as N levels start to decline after about five weeks, when many crops (e.g. maize) still require considerable amounts of this mineral, it is important that farmers do not rely solely on green manure for the entire growing cycle. To sustain the crops and produce good yields they therefore need to supplement N through other sources, and should consider using alternative inputs, such as mineral fertilisers, five weeks or so after the application of green manure.

The mineralisation pattern for phosphorous is presented Figure 2 (see also Appendix 1). The pattern for phosphorous was completely different to that of nitrogen. Levels of available P fell steadily, reaching their lowest point in week 4-5 and then rising again. This is probably partly due to the high P-fixing capacity of the soils, which had a strongly acid reaction, as well as the fact that very low levels of P relative to organic carbon can cause soil microbes to immobilise phosphorous.[3] Most of the soils from Kwalei had a P to C level of around 0.006. The increase in levels of available P after the fifth week is probably associated with the reduction of the C:P ratio caused by the decomposition of organic matter. Given that most soils in Kwalei are deficient in P, green manure alone is unlikely to provide newly established crops with an adequate supply of P for the first five weeks after application. Other sources of phosphorous, such as mineral fertilisers, will need to be applied, preferably at the moment of sowing.

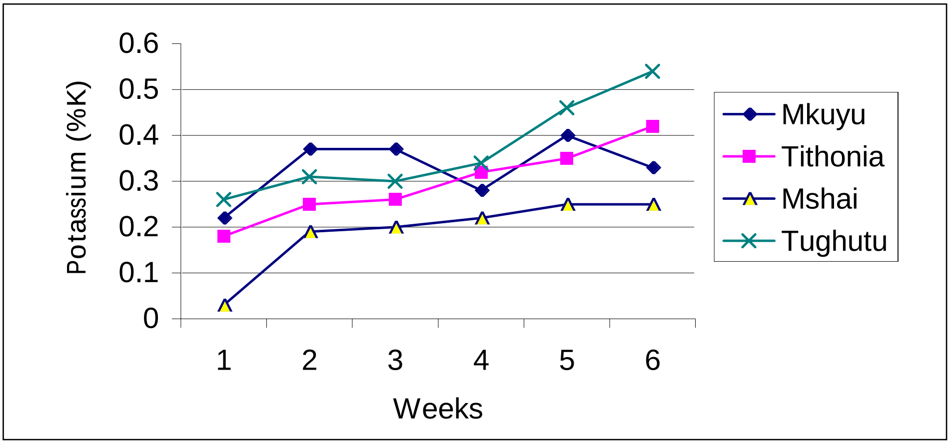
Figure 2. Mineralisation pattern of phosphorous for four shrubs in Kwalei



3 According to Donahue et al (1990), if the level of P is < 0.2% of organic carbon, there will be a net immobilisation of P, because the soil microbes will absorb it into their cells instead of releasing it for plant use.

Potassium was the only nutrient with a fairly consistent pattern of mineralisation throughout the incubation period. Figure 3 shows that levels of K in soils from around most shrubs gradually increased from the first to the sixth week. This is probably because levels of K are generally higher than those of nitrogen and phosphorous. Most soils have K levels corresponding to 0.2 cmols(+)/kg soil or more, which is above the level at which crops start showing symptoms of nutrient deficiency (Landon, 1991). Crops are therefore unlikely to suffer from K deficiency during the first few weeks of growth but, because of the potential K imbalance, farmers wishing to achieve high yields may find it necessary to apply mineral fertilisers as the biomass of the plants increases. Because of its metabolic importance in setting flowers and fruits, it is advisable to apply K fruiting crops before they flower.

Figure 3. Nutrient release pattern for Potassium for four shrubs in Kwalei



Feeding-back to farmers and developing a programme of experiments

The results of the various analyses were presented to farmers at a village meeting held before the onset of the long rainy season. The main recommendations were discussed, and a programme of experiments to be carried out by farmers was then developed. *Tughutu* was the most readily available shrub, and as there was no standard method of application, it was agreed that experimenting farmers would chop and spread it over their fields. As supplies of other shrubs were less plentiful, it was decided that each farmer would test them on an individual basis.

A group of 12 farmers volunteered to use a similar experimental design to test the *vernonia* shrub in their bean fields in the coming season, mixing the leaves with rock phosphate. A second group of 24 farmers, mostly vegetable growers, asked for training in the production and use of compost from these shrubs, and were subsequently given demonstrations by researchers. The AHI provided some inputs for farmers to use during experimentation, such as the local "Minjingu" rock phosphate, seeds of improved bean varieties and vegetables from northern Tanzania.

As a result of the feedback meeting, and other encounters, which included 51 farmers attending a training session on compost making, an increasing number of farmers are now using green manure on their maize, bean and vegetable plots. *Tughutu* has proved particularly popular, and in the long rains of the year 2000, it was used by a total of 80 farmers across the village. Many of them now try to ensure maximum benefit from the limited *tughutu* available by only using it in planting holes, instead of spreading it right across their fields as they did in the past.

3 Conclusions and recommendations

The lack of available farmyard manure and high cost of mineral fertilisers means that farmers in Kwalei concerned about declining soil fertility have had to turn to alternative sources of plant nutrients. Soil and plant analysis confirmed their observation that seven local shrubs can be used to improve soil fertility, as the soils beneath these shrubs were found to contain more nutrients and provide more favourable working conditions than those in cultivated fields.

The two shrubs with the most potential for use as green manure are '*tughutu*' (*Vernonia subligera*) and *mhasha* (*Vernonia amyridiantha*), which are readily available, have a high nutrient content and are easy to propagate. Going under the local name of *alizeti mwitu*, *Tithonia diversifolia* is a third significant source of nutrients, and although farmers did not include it on their list, it also grows abundantly in the village. While *mkuyu* and *mshai* trees contain comparable levels of nutrients in their leaves, they have less potential for green manure because they take a long time to establish and are not particularly plentiful. However, they provide excellent composting material when combined with leaves from *Sopolwa*, *Boho*, and *Tundashozi*, and are already being used in this way in Kwalei.

Despite the considerable possibilities offered by green manure made from these shrubs, farmers will also need to use small amounts of mineral fertilisers as compliments, to sustain soil fertility and maintain yields. N-fertilisers will be most effective if applied four to five weeks after green manure is incorporated into the soil, while fertilisers containing phosphates are best applied at planting time.

Regarding the methodological approach used in this study, we conclude that participatory techniques are an effective method of analysing problems at local level, identifying the resources available to farmers and making local knowledge available to researchers, who may then enhance new insights with more conventional scientific analysis. Engaging farmers from the start of the process gives them a greater interest in the results of formal analysis and how they might be integrated into current farming practices, as shown by the large number of farmers that have become interested in experimenting with green manure, producing compost and enriching it with rock phosphate.

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Appendix 1: Detailed results of mineralisation studies

Mineralisation pattern of inorganic N in shrubs from Kwalei

Sample/week	*Start*	*1st week*	*2nd week*	*3rd week*	*4th week*	*5th week*
Tughutu	0.8 (1.1)	16.8 (22.3)	29.9 (24.6)	23.2 (26.9)	20.5 (33.6)	17.2 (18.7)
Mshai	1.9 (2.2)	16.8 14.9)	29.9 (17.6)	38.1 (13.1)	49.4 (12.7)	34.7 (11.2)
Mhasha	2.2 (2.2)	16.1 (4.1)	19.4 (10.1)	29.1 (13.1)	26.1 (12.3)	7.1 (13.4)
Mkuyu	0.8 (1.1)	13.1 (7.1)	29.1 (25.1)	30.6 (24.9)	43.3 (17.2)	35.9 (7.8)
Boho	3.7 (2.2)	13.1 (6.7)	22.4 (11.6)	29.1 (15.7)	49.3 (14.2)	44.4 (6.7)
Sopolwa	3.0 (1.5)	13.8 (16.4)	30.6 (19.3)	25.4 (26.5)	12.0 (22.8)	8.2 (11.2)
Tundashozi	1.9 (3.4)	19.0 (4.2)	30.6 (6.4)	39.6 (12.0)	52.3 (9.7)	63.5 (3.7)
Tithonia	2.2 (0.8)	6.0 (2.8)	12.7 (11.6)	21.2 13.8)	33.6 (10.7)	34.4 (7.5)

Values without parentheses are ammonium N (NH4 – N); values in parentheses are nitrate- N (NO3)

Mineralisation pattern of Phosphorous (mg/kg soil) in Kwalei

Sample/week	*Start*	*1st week*	*2nd week*	*3rd week*	*4th week*	*5th week*
Mkuyu	6	2.15	1.53	0.9	0.49	2.57
Tithonia	4.1	1.77	1.57	0.84	1.19	2.61
Mshai	4.8	2.05	1.31	0.22	1.74	2.28
Mhasha	4.8	2.03	1.07	0.08	0.07	2.18
Boho	1.7	1.67	1.49	0.18	0.53	4.73
Sopolwa	4.8	2.37	2.15	0.43	0.53	2.6
Tundashozi	15.8	12.13	1.75	0.38	1.17	3.74
Tughutu	5.8	2.94	0.94	0.45	1.1	2.64

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