WORKING PAPER

INTEGRATED MANAGEMENT OF STRIGA SPECIES ON CEREAL CROPS IN TANZANIA: PRELIMINARY STUDY OF FARMER PERCEPTIONS OF SOIL RESOURCES IN CENTRAL, LAKE AND EASTERN ZONES

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Cover photos (Simon Pierce). Clockwise from top left: For women and men, hand hoes are the main tool for cultivation (Dodoma, in Central Zone); Cropping on ridges of lighter soil (Lake Zone). Red clay soil used for house construction (Dodoma, Central Zone); Chick pea planted after sorghum making use of residual moisture in heavier soils (Lake Zone);

1. INTRODUCTION

1.1 Background

The semi-arid areas of Eastern and Southern Africa cover approximately one-third of the land area and support one quarter of the population of the region. Because of inherent resource limitations and a risk prone climate for arable agriculture, these areas include some of the poorest sectors of the population. Many rural households in this environment are regularly under food-deficit and poverty limits their capacity for investment in crop production, or resource conservation.

1.2 The Striga problem

Striga species are noxious weeds that are widespread constraints to the production of staple cereal crops in semi-arid areas, principally attacking maize, sorghum, finger millet and upland rice. Semi-arid areas of Tanzania lie in a zone where the three most significant *Striga* species occur that infect cereals, i.e. *S. asiatica, S. forbesii* and *S. hermonthica*. Most of the districts in semi-arid areas of Tanzania have been surveyed and the distribution of *Striga,* found throughout these areas, is broadly known (Mbwaga 1994; Mbwaga 1996). Grain yield loss from parasitised cereal crops is difficult to estimate with any reliability due to variations in soil fertility, infestation levels and tolerance of local varieties. However, reports of 5-30% loss of potential yield are common in the literature for various parts of Africa. Other consequences of *Striga* infestation include farm abandonment, now difficult in the face of a shortage of productive arable land, or a change of cropping pattern to less favoured, albeit resistant crop species. Reichmann *et al.* (1995) reported that 75% of farmers interviewed in Shinyanga region of Tanzania considered *Striga* an increasing problem on sorghum, on which they were unable to obtain satisfactory advice from extension on effective control strategies.

1.3 The role of soil fertility

A previous DFID CPP funded project (R6921) confirmed the importance of nitrogen in maintaining sorghum and maize productivity under infested conditions and of cultivar traits and management practices which can delay parasite attachment. On-Station work in Kenya and Tanzania has demonstrated that the use of nitrogen fertilisers (ammonium nitrate and urea, respectively) are effective in lowering numbers of emerged *S. hermonthica* and improving host performance. In Tanzania urea applications of 25 and 50 kg N ha^{-1} were sufficient to lower the detrimental effects of *S. asiatica* in maize cultivars Katumani, Staha and TMV-1 with associated increases in host carbon assimilation and grain yield. Studies in Kenya show similar results with the use of ammonium nitrate at rates of 50 and 75 kg N ha^{-1} with increased grain yield and lower *S. hermonthica* emergence in improved varieties H511 and Pioneer. However, on-farm work in Kenya showed nitrogen applications of 50 and 75 kg N ha^{-1} increasing *Striga* emergence and grain yield was not increased above yield from plots where no fertiliser was added. The nitrogen status of infected cereals was significantly (statistically) lower on-farm compared with on-station, reflecting the soil nitrogen status. This suggests that nitrogen availability plays an important role in determining the impact of *Striga*.

The project has shown that the success of nitrogen fertilisers in both reducing the density of emerged *Striga* plants and in improving grain yield has been equivocal, varying greatly both geographically (e.g. within and between countries) and between cropping seasons, and also as a function of crop species (sorghum and maize) and genotype. Thus, there is not a universal relationship between the minimum amount of nitrogen, its form and time of application, that is required to elicit economic benefits to small holder farmers. For this reason, it is essential to understand how nitrogen perturbs the interaction between *Striga* and its cereal hosts, so that it can be used more efficiently with regard to interactions between genotype and environment.

1.4 A decision support tool for assessment of Striga tolerant sorghum cultivar x soil fertility interactions

The above findings indicate a need to identify the relationship between soil nitrogen status, and nitrogen additions with particular reference to local soil conditions and specific cultivars. This project (CPP project R7564) is, therefore, examining how tolerant/resistant lines perform on a range of soils in the Lake and

Central Zones. By a combination of laboratory and field work, supported by an investigation of farmers' perceptions of soil fertility issues, it is intended to provide guidance on the deployment of new cultivars in Tanzania. Resistance screening programmes in the past have largely been based upon monitoring the number of parasite stems emerging in the field but have not taken soil fertility into account. This work should lead to the development of a decision support tool for use elsewhere in Africa and could cut the time from field screening to variety release by matching cultivar traits to soil characteristics. The development of a decision support tool involves five main activities, which are explained below.

(i)Access to and management of soils by farmers investigated at benchmark Striga infested sites in Central, Eastern and Lake Zone.
Farmers access to and management of land, is an under-researched area in Tanzania. The Tanzania Soil Fertility Initiative (SFI) aims to prepare a soil fertility strategy and action plan in which a key principle will be the adoption of people centred learning approaches. This project will contribute to the aims of SFI through detailed case studies at the selected benchmark sites. A farmer typology will be developed based on relevant criteria such as wealth, gender and age. This will then be used to select people for a detailed study of their access to different land types and how different farmers manage the land/soil resources they have available to them.

(ii)Farmer perceptions of soil resources and management characterised.
Running concurrently with the above activity, farmers' perceptions of soil resources will be investigated at benchmark sites. The approach will involve the use of participatory tools and discussion with key informants and farmer focus group. This will facilitate researcher understanding of farmers' typology of soils; their characteristics and how they are managed/utilized. This information will be used to guide researchers in the development of interventions to improve soil fertility. It will also help to make the appropriate selection of locations for soil samples at benchmark sites.

(iii)Identification and chemical/physical characterisation of soils at benchmark sites.
Soil samples from benchmark sites will be subjected to routine chemical and physical analysis. Sampling and analysis will be undertaken in collaboration with SFI and soil scientists at ARI Mlingano. Both the reproducibility and accuracy of analyses will be determined through measurements of standard samples submitted to both laboratories.

(iv) Laboratory assessment of tolerant sorghum cultivar x soil nitrogen content (based on iii above) interactions.
A range of soil fertility levels will be set up for laboratory and glasshouse trials in Sheffield. These will be used for testing the response of a range of cultivars to *Striga* infection at levels of soil nitrogen representative of the range of conditions found at benchmark sites. A random factorial design will be employed using six replicates for each combination of treatments. Through the use of the rhizotrons developed at Sheffield, it will be possible to develop a prediction of the level of tolerance that each cultivar shows at particular soil nitrogen contents. We will examine the role of soil fertility on the interactions between *Striga* and sorghum/maize at three levels: (i) germination of parasite seed and stimulant production; (ii) attachment and penetration to host roots; and (iii) effects on the subsequent growth and especially yield of cereals following attachment. Data analyses from these measurements have been routinely completed under R6921, using the appropriate transformations for non-parametric and non-interval data. Special attention will be paid to the influence of nitrogen on the timing of these processes in different genotypes.

(v) Validation of laboratory findings in on-farm trials at benchmark sites
A set of cultivars which show differential response to soil nitrogen in the laboratory trials will be grown in replicated trials at benchmark sites that differ in soil nitrogen availability. If possible a randomised block design will be used. Final trial design will however depend upon the number of cultivars selected for testing. It is appreciated that homogeneous blocks may not be available for large blocks on-farm and that an incomplete block design may be more appropriate. Further discussion on the relative merits of the field plot design will be necessary prior to initiating the trials. Site identification will be based upon a

working classification of soils derived from farmer perception studies, complimented by characterisations derived from laboratory soil analysis. Vegetative growth will be monitored using non-destructive methods; e.g. plant height to the ligule of the youngest expanded leaf, which has been found to be a sensitive indicator of sorghum response to infestation. Yield data will also be collected and the results used to validate the findings from the laboratory trials. These will then be referenced to the farmers perceptions of the fertility of S*triga* infested soils to match cultivars to the categories of soil identified by farmers. The essential feature of this process will be to enable the recommendations on cultivars to be matched with the farmers understanding and classification of soils. This information will be of value locally to the government extension service and NGOs for planning the deployment of resistant and tolerant cultivars. It is hoped that the process followed through the activities leading to this output will find applicability for sustained production of tolerant cereal cultivars in parasite infested land elsewhere in Africa.

This paper is primarily concerned with activity ii above, ie farmers' perceptions of soils. The remainder of the report is organized according to the three zones where *Striga* research is taking place. The Central and Eastern Zone sections draw on fieldwork carried out in May and July 2000 together with some secondary sources. The information on the Lake Zone is based on existing literature.

2. CENTRAL ZONE

2.1 Background

The Central Zone comprises Dodoma and Singida regions, but Striga project activities have focused on Dodoma only, in particular Dodoma Rural district.

Soils

Soils and farmers' perceptions of soils in the Central Zone of Tanzania are relatively under-researched compared to the Lake Zone. Holtland (1994), referring to Mvumi division, comments on farmers' being able to differentiate many types of soil, 'ranging from pure sand soils to pure clay soils', but that the terminology is complicated, at least partly because kigogo is used alongside kiswahili. Holtland offers basic terms (Table 1), but points out that often there is a mixture of soil types and one may be overlying another as a result of erosion.

Table 1 Terminology of the most important soil types in Mvumi division

Kigogo	Kiswahili	Colour	Texture
Msawawa	Mchanga	Grey-yellow	Pure sand, deposited by rivers
Isangha	Kichanga	Grey-yellowish brown	Sandy, loam soils
Nghuluhi	Udongo mwekundu	Reddish-brown	Sandy clay loam (few sandy loam)
Ivuhi	Tifutifu	Grey	Loam soil, high percentage silt
Isanga-nyika	?	Dark grey to black	Clay loam, no cracks when drying
Nyika	Mbuga	Black	Heavy clay, cracks when drying
Magungu	Visiguu	Red-brown	Hard plan
Sakalawe	Changalawe		Stoney soils, mainly on slopes

Source: Holtland (1994)

According to Holtland, sandy soils are found on hill tops and in and around riverbeds. Clay soils are deposits resulting from erosion of surrounding hills, they can be very deep and usually form large flat areas. *Nghuluhi* soils are formed on the lower sections of hillsides. If they are found on steeper slopes they are more eroded, stony and sometimes a hard pan can be seen. If sites are flatter, they are quite fertile and have a good structure. Holtland mentions two other soils in the division, *ilolo (*soils which have a high water table, are occasionally flooded and are clayey/ fertile) and *ibebe* (reported as being common in Mvumi Makulu, these are (sandy) loam soils with a whitish colour).

During an RRA carried out in the division in 1991, 118 *shambas* were visited and the soil type and principle crops grown were recorded. The results were as shown in Table 2 below. Overall, Holtland suggests that i*sangha* soils occupy about two thirds of the arable area in Mvumi division.

Table 2 Soil types from a sample of 118 fields in Mvumi division (Source: Holtland (1994)

Soil type	No. of times reported
Msawawa	2
Nyika	2
Ivuhi	0
Isangha	49
Nghuluhi	40
Ilolo	15
Other/ mixtures	10

Holtland suggests three main factors determine the usefulness of a soil in Mvumi division: fertility, workability and water regime. 'Natural' fertility increases with clay content, but the actual fertility depends on the history of the *shamba.* Workability improves with increasing sand content. *Msawawa* and i*sangha* soils can be easily cultivated. All loam soils (i*vuhi)* and some sandy loam soils (mostly i*sangha)* become very hard when they dry up. In some places[1] the soil is difficult to work even after a two week dry spell. *Isangha-nyika* soils can be cultivated, although they are heavy. *Nyika* soils are too heavy to work with a hand hoe when dry and when it is very wet they are too muddy.

The water regime takes into account: water infiltration, water retention and drainage and the water table. Typically of semi-arid areas, most of the rain comes as heavy showers. Sandy soils have a high infiltration rate, making it possible for dry planted crops to germinate and survive after one shower. Holtland goes on to comment that 'the same high infiltration rate means that the natural N-flush (which occurs after the first rains) is quickly leached to deeper layers where it cannot be reached by the small roots of the germinating crops. This process makes dry planting on sandy soils very attractive or nearly a necessity.' The lower infiltration rate of clay soils makes dry planting less suitable. *Nghuluhi* appear to have the best combination of water retention and drainage. Soils which have a high water table in valley bottoms can be used to plant crops at the end of the rainy season. In the western part of Mvumi division there is an extensive area of sandy soils overlaying clay deposits with a high water table and this can be used for crops such as maize, sugar cane and tomatoes.

Land Use

The 1991 RRA provides information on crops associated with soil types (Table 3 below)

Table 3 Soil types and associated crops in Mvumi division

		Sandy	**Nghuluhi**	**Clayey**
	% of all fields	47	37	16
% of principle crop grown on soil types	Millet	59	38	3
	Maize	43	29	29
	Sorghum	37	42	21
	Groundnut	62	29	10
	Grapes	18	64	18

Source: Holtland (1994)

Land tenure and user rights

The land rights situation is a major, complex and dynamic issue in Tanzania (Shivji 1998). As in many sub-Saharan African countries, there are two systems of tenure in operation, the statutory *de jure* and the

[1] For example, Idifu village which has a reputation for being very productive producing crops such as groundnuts and sesame.

customary *de facto*. All land is officially owned by the state and according to state legislation, individuals cannot own land, but may have the right to occupy or use the land. Two main rights of occupancy exist. A deemed right of occupancy is derived from recognition by local authorities under customary law, where there is no land registration and no fixed time period. A granted right of occupancy is registered as a title deed, the period of occupancy is a limited period of time and the arrangement is subject to common law. In 1999, the Land Act and Village Land Acts were passed. There are widely differing views regarding the interpretation and implications of these new acts (see Appendix 1).

Almost all land in Mvumi division is 'owned' according to customary law. In case of disputes, the village government may resolve the issue, but if they cannot, it goes to court. In the eastern part of the division there is still some unoccupied land that could be allocated by the village government. In Mvumi Makulu (according to Holtland) there is no unoccupied land remaining. According to Wagogo tradition, land that is not used for two years would become common property again and livestock (rather than land) has formed the basis of inherited property. The actual situation is complex and varies considerably. In Mvumi, because of the pressure on land, unused land tends to be borrowed or hired. According to Holtland, selling of land occurs quite often, with areas suitable for sugar cane fetching the highest price (Tsh 60,000 / acre in 1993), compared to that appropriate for grapes (Tsh 20,000/ acre in 1991/92) and pearl millet (Tsh 3-5,000 / acre in 1991/92). Following the introduction of HADO (Hifadhi Ardhi Dodoma), opening up of new land on hillsides became illegal, but with land shortages, this is still taking place and 'is more or less silently accepted by the village government '(Holtland 1994).

Villagization (in the early 1970s) had a significant influence on people's access to and management of land resources. People were moved away from their land and at the same time allocated plots within the new village settlements. Prior to re-settlement people typically lived on the better soils where they would make their *vigundu* fields next to their homestead. Afterwards, people were often allocated plots without taking their agricultural potential into account and if soils were poor, it was no longer possible to develop *vigundu* fields close to homes and instead any plots which are suitable for bambara nut, groundnut or, for example, sweet potato are *vigundu* plots. Another important change was the collapse of the *milaga* system of privately protected areas near homesteads for livestock grazing in the dry season. De-stocking under the HADO project resulted in the official removal of all free-range cattle in the division and the introduction of zero-grazing primarily for dairy production.

2.2 Background to fieldwork

A multi-displinary team visited Dodoma between May 8th – 12th 2000. The team included:

Dr C. Riches	Weed scientist, Natural Resources Institute (NRI)
Dr A. Mbwaga	Crop Protectionist, ARI Ilonga
Mr J. Hella	Agricultural economist, Sokoine Univerity of Agriculture
Mr R. Lamboll	Socio-economist, NRI
Mr Omari	District Information Officer, Dodoma Rural District Extension Office
Dr G. Ley	Soil scientist, ARI Milingano
Prof. M. Press	Plant physiologist, University of Sheffield

The team visited the two main villages where on-farm *Striga* research is being carried out, Mvumi Makulu and Chipanga. In each village, the team was joined by the respective extension staff for that village, Mrs Ulomi (Mvumi Makulu) and Mr Kibaya (Chipanga). Two main sets of activities were carried out, one relating to the evaluation of the 1999/ 2000 trials and the other initiating studies of farmers perceptions and management of soil resources. Mvumi Makuku was visited over a two day period (May 9th-10th) and Chipanga for one day (May 11th) only.

2.3 Mvumi Makulu village

The village and the surrounding area

Mvumi Makulu is the only village in Mvumi Makulu ward and is located in Mvumi division, about 40 km south-east of Dodoma town. There are approximately 2017 households (11,000 people) of which about 105 have zero-fed cattle. The division has a population density of 76 people/ km^2 and the west of the division (where Mvumi Makulu is located) 117 people/km^2. According to Holtland (1994) there has been high population pressure in this area for over one hundred years. An associated feature, is the high level of out-migration (both temporary and permanent), particularly of economically active men. The people are mainly Wagogo and have been described as cultivating pastoralists. Traditionally livestock (rather than land) formed the basis of inherited property. In 1986, the HADO (Hifadhi Ardhi Dodoma) programme implemented a de-stocking programme in response to the high level of soil erosion which was associated with cattle numbers in the division. At this time, the proportion of households owning cattle had already declined to about 15% of households. All cattle within the division are now officially zero-grazed. Pearl millet and sorghum are the main staple crops of the area.

Approach to the fieldwork

Initial discussions were held with two women and two men from the village. They were asked what types of soil there were in the village and to provide the names in *Kigogo*. The names were written on post-it stickers and placed on a large manilla sheet.. The group were then asked how they differentiated between two particular soil types. They were then asked directly about the fertility (*rutuba)* of the soil, in particular to rank soil types from most to least fertile. Following this initial discussion, researchers made a transect walk with farmers to learn more about the soils which had been identified. On the second day, the findings from day one were discussed with a larger group consisting of 8 men and 4 women. This resulted in much discussion and explanation. The group was asked to further clarify the suitability of each soil type for particular crops and to rank the soils in terms of their area in the village.

Results

Table 4 shows farmers' classification of soils based on initial discussions with two men and two women. Seven soil types were identified, of which four were considered suitable for growing crops. The suitability of soils for particular crops and the stickiness of the soil were the two clearest criteria that emerged for differentiating soil types. The question of soil fertility resulted in some discussion amongst the farmers, but after attempting to rank the soils, it became clear that this group of farmers were not comfortable with a comparison of soil types on the basis of fertility. This appeared to be because different soils were considered more suitable for certain crops. Table 5 shows the results of further discussions with a wider group of farmers. A further criterion to emerge was how susceptible the soil was to water-logging.

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Table 4 Farmer classification and characteristics of soils in Mvumi Makulu.-smaller group

Kigogo soil type	Isawawa isanga	Isawawa chitope	Chitope	Nkhuluhi	Chiwumbo	Uwino	Nyhesi
Farmers Kiswahili description	Mchanga	Mchanga mzito	Mfinyanzi mweusi	Mchanga mzito mwekundu	Udongo wa kutengeneza vyungu	Udongo wa chumvi	Udongo mweupe
English translation	Sandy	Heavy, sandy	Black clay	Heavy, sandy red	Soil for making pottery	Salty soil	White soil
Crops grown	Pearl millet, groundnut, bambara, sesame.	Pearl millet, maize, sorghum, groundnut	Sweet potatoes, tomato, onions, beans, sugarcane, grape.	Pearl millet, maize, sorghum, bambara, cassava, grape	Not suitable for agriculture	Not suitable for agriculture	Not suitable for agriculture
Stickiness	+[1]	++	+++	++	+++	++	++
Fertility *		++		+++			

[1] + less; +++ more. * Criterion introduced by researchers

Table 5 Farmer categorisation of soils in Mvumi Makulu- larger group

Soil type	Area in Mvumi [1]	Water logging	Stickiness	Sorghum	Pearl millet	Maize	Cass-ava	Bamb-ara nut	G'nut	Sun – flower	Ses-ame
Isanga	3	+	+		3		3	3	3	3	
Isawawa											
Isanga Chitope	1	++	++	3	3	3	3				
Chitope		++++	+++++	3							
Nghuluhi	2	+++	+	3	3	3	3	3	3	3	3
Mwino											
Nhyesi											
Nghundula											

[1] Rank order; 1 = most common.
Sugarcane is grown on Chitope soils; Grape is planted on Nghuluhi soils.

Some interesting points emerged through discussions over the two days. The term *isawawa* appears to refer to sandy deposits that are particularly common along seasonal riverbeds. Pure *isawawa* would not be suitable for agriculture. However, as one women explained and illustrated through a drawing on a flip chart, these deposits may overlay *chitope* soil and this combination is suitable for cropping, particularly sweet potatoes. The planting material is planted in the easily worked *isawawa,* but as the plant grows it can draw on the moisture and nutrients of the heavy, clay *chitope* soil.

Farmers in the second group suggested that a more appropriate term for *isawawa chitope* would be *isanga chitope* and for *isawawa isanga*, simply *isanga (*or *isangha).* According to this group, the main soil types, therefore, are *isanga chitope* (most common), followed by *nghuluhi, isanga* and then *chitope*. Keeping with these terms, there appears to be consensus across both groups that: *isanga chitope* (a heavier sandy soil)is suitable for sorghum, pearl millet and maize; *nghuluhi* (a red soil) for sorghum, pearl millet, maize, cassava, bambara nut and grapes ; *isanga(*a sandy soil*)* for pearl millet, bambara nut and groundnut; and *chitope* (a black heavy/ sticky clay soil)for sugarcane and possibly sorghum

2.4 Chipanga 'A' village

The village and surrounding area

Chipanga 'A' lies about 60km west of Dodoma town. The people of Chipanga are Wagogo, although they consider themselves different from the Wagogo of Mvumi makulu. There is a lower population density than Mvumi division (Dodoma Rural (without Mvumi): 27 persons / km^2 in 1988). Cattle numbers are much higher and they are managed on open pasture, rather than zero grazed. The village borders a lake that provides options for fishing and IFAD have funded a rice irrigation project here.

Approach to the fieldwork

Information was collected in two ways in Chipanga. Firstly, a group of one woman and three men accompanied researchers on a transect walk through the village and along the way a chart showing soil types, criteria and characteristics was constructed. Secondly, 11 male and four female members of the *Striga* trials focus group were consulted during a field walk to examine trial plots. In the latter case only soils on which sorghum was growing were visited.

Results

Seven soil types were identified by one group of farmers in Chipanga and five criteria emerged for distinguishing between them (Table 6). Criteria included crops suitability, colour, extent of cracking, ease of digging, water-related characteristics. The most common soil type was reported as being n*gogomba*, followed by *nkuluhi* and *ilolo*. These three soils are all reported as being suitable for sorghum. An important feature of *ngogomba* is that it appears to be very difficult to cultivate. Further discussion about *ilolo* suggests that this may refer to sandy deposits overlaying heavier soils, which are found in low-lying areas, including seasonal riverbeds. This combination of soil types allows crops such as sorghum, maize and groundnut to be grown. *Isang(h)a* is reported as being the least common soil type and the only one suitable for pearl millet.

Table 6 Farmer perceptions of soil types: Chipanga village

Kigogo soil type	Ntope	Sugusa	Ilolo	Ngogomba	Isanga	Nkuluhi
Farmers Swahili description	Tope	Udongo chumvi	Udongo kichanga	Nchi kavu	Kichanga	Udongo mwekundu
English translation	Muddy	Salty soil	Sandy soil	Very dry and hard soil/ land	Sandy soil	Reddish soil
Crops grown	Rice	Rice	Sorghum Maize Groundnut	Sorghum Rice (with bank)	Pearl millet	Sorghum Maize Ground nut Bambaranut
Colour	Black	Ashy	Whitish/ Ash	Ash	Whitish/ reddish	Red
Cracking	Very severe	Severe	None	None	None	None
Ease of digging	Difficult	Difficult	Easy	Very difficult	Very easy	Easy
Water-related characteristics	Water flows above the ground	Some water flows above and some percolates in	Percolates through the soil	Flows as run off	Water table is high when rainfall is high	Run-off and some percolates in.
Area in village	4	5	3	1=most	6 =least	2

Source: Information provided during village transect by: Mwajuma Malyampa; Peter Boniface; Enzeleda Mavunde (Ms); Phillip Magonda

During the visit to the trial plots *Striga* was seen on n*gomba* (*ngogomba*) and *nkhuluhi* soils (Table 7). At one *ngomba kichanga* site although only a few *Striga* plants were seen on the droughted crop, the farmer reported that in wet years there would be many.

Table 7 Observations of soil types during visits to Striga trial plots

Soil	Characteristics and remarks
Isanga	Yellow/brown; with fine particles, mostly sand. Sorghum grows well (tillers well according to farmers) . Common in area.
Ngomba kichanga	Gery/brown; a mixed sandy soil. Less common.
Ngomba (Ngogomba?)	Grey; can be sticky due to clay content. Very common in the area according to farmers (= mfnyanzi).
Nkhuluhi	Red; Sticky when wet due to the clay content. According to farmers this soil is low in fertility and does not yield well without manure. In this case sorghum stems will be very thin. The communal seed farm is located on this soil type and is heavily infested by *Striga*.

There appears to be agreement between both groups of farmers that *ngogomba* is very (the most) common soil type, grey in colour and suitable for sorghum. *Nkuluhi* is a red soil and suitable for sorghum, but it is not clear if *nkhuluhi* is generally regarded as low in fertility or only at particular sites eg the CCT communal seed farm. *Isanga* is a sandy soil that according to one group is, and the other is not, suitable for sorghum. There was also a difference in opinion about how common this soil type was in the village.

3. LAKE ZONE

3.1 Background

The Lake Zone comprises Mwanza, Shinyanga, Kagera and Mara regions, but Striga project activities have focused on Mwanza only, in particular Misungwi district. Lake Zone may be divided into two broad physiographic regions, the Central Plateau and the Western Highlands (Enserink and Kaitaba (1996) based on de Pauw (1983 and 1984)). The farming systems of the Central Plateau (also referred to as Sukumaland) are characterised by cereal-cotton cropping and livestock production systems; maize is the preferred food followed by rice and sorghum; crop livestock interactions are intensive, but mainly focus on ox-traction, manure applications systems are not well developed. In the Western Highlands, farming systems are dominated by banana-bean-coffee cropping systems and the livestock component is not well developed. *Striga* is essentially a problem in the cereal systems of Sukumaland.

Soils

Soils and farmers' perceptions of soils in Sukamaland have a long history of research. Williams and Eades (1939) judged Kisukuma to be the language with the richest soil nomenclature of all East African languages (Ensrink and Kaitaba 1996). Oudwater et al (2000) note that 'according to most researchers the Sukuma people clearly describe and name their soils as they vary along the catena dominant in their areas. However, the nomenclature can vary among farmers depending on their place of origin, farming experience and gender.' The usefulness of the Sukuma terms has resulted in it being adopted by researchers from Ukiriguru ARI and elsewhere when implementing activities in this zone. Meertens et al (1995) emphasise the importance of looking at soils in relation to what they term physiography. The landscape is characterised by broad or narrow vallies between rocky hills (mainly granitic, sometimes gneissic, rocks) and in some areas huge plains of old alluvium or colluvium derived from granitic or gneissic rocks. Catenas (soil sequences from the top to the bottom of slopes) are common, with specific soil types along the slope being determined mainly by parent material, water movement and the occurrence of soil salts.

At a zonal level, spatial variation of soils has been typically described in terms of land units, rather than soils per se. Meertens et al (after de Pauw) recognise seven different land units, which are characterised using Sukuma soils terminology. Enserink and Kaitaba (1996) identify six land units and a summary of associated soil characteristics is shown in Table 8.

Land Use

A summary of land use in each of the above land units is shown in Appendix 2.

Land tenure and user rights

The traditional land tenure system in Sukamaland consists of 'individual land rights, limited to the period of effective occupation, restricted with regards to rights of transfer and controlled in relation to succession. Inheritance is through patrilineal descendance (Bunyecha et al 1994). Villagization resulted in people being shifted from scattered settlements to nucleated villages, often resulting in fields being a long way from the homestead. This trend is now being reversed. In Kwimba[2] and Misungwi districts the current land tenure system is based on deemed rights of occupancy, communal ownership, buying, renting or borrowing or allocated by the village government. The right of occupancy is established if an individual has cultivated a plot for significant period of time. Users rights are then inherited. Land may be purchased and in 1994 one acre was reported to be worth a cow in one village and Tsh 7,000 in another. Renting is common with the rent varying with soil type, eg *luseni*- Tsh 2,000; *itogolo*-Tsh 3-4000 and *mbuga* Tsh 4-8,000 (1994 prices). Land may be allocated by the village government, eg to immigrants, but rights to this land are lost if a person moves away from the village. Women generally have access to land through men. Married women through husbands; unmarried women through

[2] At the time of the survey (1994) the Kwimba district included the current Kwimba and Misungwi districts

brothers; widows through their former husband and divorcees land from her father. The recently passed Land Act (1999) may change this situation.

Table 8 Major land units of Sukumaland

Land Unit	Dominant soil	Parent material	Depth	Drainage	Colour	Texture	Fertility
Sukuma catena in narrow and wide valley systems	• Shallow hill soils with rock outcrops (Luguru);	Granite	Shallow	Well	Reddish brown	Sand	Very low
	• Luseni soils on footslopes;	Granite/ Gneiss	Moderately deep to deep	Well	Reddish brown	Loamy sand	Low
	• Itogolo soils on gently undulating plains;	Alluvial/ colluvial (Itogolo) & granite/ gneiss (Luseni)	Moderately deep to deep	Moderately well	Grey to brown	Sandy clay loam	Low to moderate
	• Pockets of mbuga soils on bottom lands.	Alluvial	Deep	Poor	Dark, greyish brown	Clay	Moderate
Itogolo plain	Itogolo with hardpan	Old alluvial and colluvial	Moderately deep	Moderately to imperfectly	Dark grey	Sandy clay loam to sandy clay	Low to moderate
Mbuga plain	Mbuga cracking heavy clays	Young alluvial	Deep	Imperfectly to poor	Dark or grey brown; subsoil mottled	Clay or sandy clay	Moderate
Ibushi plain	Ibushi	Lake sediments Lacustrine sediments	Shallow to moderately deep	Well to moderately well	Grey to brown	Clay loams to clay	Moderate
Kigungu dominated landscape	Kikungu	Granite and gneissic	Deep	Well	Red and reddish brown	Loamy sand to sandy clay loam	Low to moderate to high
Nduha dominated landscape	Nduha	Basic metamorph ic rocks	Deep	Well	Reddish or yellowish brown	Sandy clay to clay	Moderate

Source: Enserink and Kaitaba (1996)

3.2 Iteja village

The village and surrounding area

Iteja village is in Misungwi ward/ division/ district and is situated on Mwanza-Shinyanga main road, about 20 km south of Ukiriguru ARI. The village has a total of 609 households in nine sub-villages (*vitongoji*). Approximately 14% of the households are headed by women. A survey carried out in 1979 established the area of the village as 4902 hectares and the main soil types as *mbuga* (38.1% of land area), followed by *itogolo* (36.9%), *ibushi* (13%) and *luseni* (11.8%) (Kajiru et al 1996).

Farmers' soil classifications for Iteja village

Two recent studies have examined farmers knowledge of soils in Iteja village. Kajiru et al (1996) consider farmers' perceptions of soil types as part of an integrated soil fertility management programme based at Ukiriguru ARI. Oudwater et al (2000) carried out research on indigenous knowledge of soils aiming to develop methodologies and derive robust results for comparing and combining scientific and indigenous knowledge of soil and land resources.

The approach taken by Oudwater et al (2000) included an initial PRA that allowed a preliminary identification of soil types. This was followed by an in-depth study, that included: free listing interviews (farmers listing all soil types within their land holdings and village); sorting tasks (individual farmers arranging soil types into groups); household interviews (with emphasis on farmers' decision-making with regard to crop and soil management); transect walks (taking GPS readings); focus group discussions and participatory mapping (farmers locating different soil types on aerial photographs). The following section is taken from Oudwater et al unless stated otherwise.

Farmers used a range of criteria for classifying soils (Table 9). Soil fertility was the most important criterion for farmers to classify a particular soil type. Women especially, considered fertility properties as a major distinguishing characteristic among the different soil types. Men tended to use a wider range of criteria to classify soils. The criterion of fertility was mainly used for the extremes, for the very fertile soils such as m*buga*, s*hilugu* and s*higulu*, or the very unproductive ones such as i*kerege*.

Table 9: Frequency of farmers' criteria for sorting soil categories in Iteja village

Criteria	**Frequency**
Fertility	41
Location	22
Colour	18
Water holding capacity	17
Different names for one soil type	15
Workability	14
Suitability for particular crops	10
Texture	8

Source: Oudwater at al (2000)

Location, was used to differentiate between soils found in the uplands and in the lower areas, especially *itongo* that was often described as an upland area with differing soil types such as *shigulu, shilugu and luseni*. In a few cases, farmers also referred to the very localised nature of some soil types such as s*higulu* which was found on former anthills. Water-holding capacity was relevant to descriptions of waterlogged soils such as *ilago* and *inyalala*. Workability was associated with so-called hard-pan soils such as *ikerege* and *ibambasi* which are hard to cultivate due to a very hard surface and/or shallow soils underlain with a hardpan.

Farmers' soil classifications have mostly a flat structure, unlike the scientific classification that recognises major categories and numbers of sub-categories. A positive relationship exists between the consistency of farmers' criteria for categorisation and their level of consensus about particular soil characteristics. For example all respondents associated *mbuga* soils with "heavy soils" (high soil fertility) and subsequently the descriptions were more or less consistent. The description of *itogolo*, however, drew upon a wide range of different criteria and the soil descriptions in particular, were less clear. The level of consensus over some soil characteristics such as colour, fertility and infiltration was higher than for other soil properties such as soil depth, sub-soil, suitability for crops and vegetation. A wider range of descriptions for soil types such as *luseni*, and *itogolo* could be explained by the occurrence of mixtures and/or the continuum of properties that make farmers categorise a soil as *luseni*. L*useni* was described as a sandy soil, and it is likely that there are differences in the proportion of sand particles in the topsoil that has an impact on other properties. Farmers recognised some of the soils as being mixtures that had combined properties from two distinctive soil categories such as *luseni* and *ikerege.* This example would produce a soil that was very sandy, but with a hard sub-surface layer which would have an impact on agricultural practices in terms of land preparation, water holding and choice of crops for cultivation.

Declining soil fertility was perceived as a problem, but was only associated with the upland soils[3]. Farmers did not consider fertility to be a problem in the valley bottom soils. Soils in the uplands are also prone to erosion due to their location on slopes and the generally sandy texture of these soils that are easily washed away during heavy rains. A few farmers mentioned the increased pressure on land as a cause of the decline in soil fertility and increased soil erosion. This pressure forces farmers to crop their plots continuously without allowing the land to rest during regular fallows. Due to continuous cultivation, problems with weeds are increasing, resulting in low yields. This leaves the farmers no other option than to cultivate larger portions of land to meet food and cash requirements for their households. Farmers try to offset the reduced fertility by applying kraal manure to their fields. This was seen as a change in their agricultural practices. Other changes include the introduction of new short maturing, drought resistant and high yielding crop varieties.

The main constraints identified were weeds, pests and diseases and rainfall. The most common weed is S*triga* which was mentioned in all the interviews. Interestingly, of the four major soil types, *Striga* was reported as a constraint on relatively fertile soils such as *mbuga* and *ibushi*, as well as *itogolo*. However, it was not reported on *luseni*, because most farmers considered this soil not fertile enough for maize and sorghum.

A wide range of pests and diseases were perceived as having a negative impact on productivity, including green mites and mosaic virus for cassava, bollworm for cotton and the stalkborer for maize. Also small animals such as rats, posed problems for the farmers as they attack the crops at an early stage. Problems with rainfall depended on the location of the soils and the soil type. Excessive rainfall can cause flooding and waterlogging in the valley bottom soils such as *mbuga* and *ibushi*, whereas drought seriously affects the crops grown in the uplands.

The study was not able to extrapolate differences in farm management decisions related to wealth categories due to the limited number of respondents. However, it was suggested that farmers' decision making depends on access to land, the different soil types within their land holding, availability of labour and access to animal draught power. Soils like *mbuga* give the farmers with more flexibility in terms of crop choice; rice is cultivated in times of good rainfall whereas during times of drought or low rainfall, farmers clear the *mbuga* soils for sorghum and maize cultivation. Better-resourced farmers cultivate a wide range of different crops both for home consumption and sale, whereas the less endowed farmers tend to focus on a few crops only, such as cassava, rice and sweet potatoes, sorghum or maize. Female headed households had relatively larger share of cassava plots as a relatively low risk crop. Cotton was by far the most important cash crop for farmers from wealth category 3 whereas farmers from the first wealth category had rice, cotton, maize, cassava, groundnuts and chickpeas as cash crops.

Hiring animal draught power for clearing the land did not really seem to be an option for households from the lowest wealth ranking category, as none of the respondents reported doing so. They might have other ways of accessing animal draught power such as borrowing from relatives, but it was stated that land preparation was generally done by hand hoe. Methods of land preparation also depended on the availability of labour and the priorities set by the household. For example, ridges (and bunds) require more labour during land preparation as their construction is labour intensive and planting has to be done in holes instead of broadcasting, requiring more labour input. Apart from the advantages of water harvesting and improved moisture availability for the crops, ridges also save labour at weeding time, as the weeding is mainly concentrated on the ridges.

Farmers' descriptions and classification of soils

Kajiru et al (1996) list ten main soil types as indicated by farmers in Iteja, whereas Oudwater et al (2000) identified 19 different types (Table 10). However, the findings of the two studies are consistent in terms

[3] Kajiru et al reported that soil fertility problems mainly related to homestead gardens and was expressed by low yields and severe *Striga hermonthica* infections.

of farmers' perceptions of the main soil types in Iteja. These are *mbuga, ibushi, itogolo* and *luseni*, together with more localized soil types *shilugu, shigulu, ikerege, ibambasi* and *inyalala.*

There appear to be a number of reasons for the differences between the results of the two surveys. Firstly, the use of different words for the same soil type eg *inyala,ilago, sota, shinele* and *kizinze* are all terms referring to *luseni*-like soils which are permanently wet. Secondly, there is some question as to whether some terms refer to soil types or location of land types eg *itongo(*upland area or a soil type in an upland area?*)* and possibly *lugulu.* Thirdly, the level of detail or sub-categorization varies eg *luseni ludito* described as a more fertile (heavy) *luseni.* Fourthly, some terms may refer to a type of field or shamba eg *shikalanga (*a less fertile field where groundnuts are cultivated). Kajiru et al also mention the term *shilaba* which refers to fields allocated to women.

Farmers' descriptions of the four main soil types in Iteja village (from Oudwater et al) are given in detail below. The remaining descriptions are given in Appendix 3.

As part of Oudwater et al's study, a comparison is made between scientific[4] and indigenous soil classification through the use of GIS (Newcastle workshop may 1999). The study concludes that there are direct/ good correlations between some soils. For example, *mbuga* and Peli-calcic-Vertisols match closely partly because the occupy a distinct place in the landscape (valley floors) and partly because the scientific classification includes several top soil properties, eg dark coloured cracking clay which matches well with indigenous criteria. Another example is *luseni* and arenosols, where character of soil particles is used to distinguish the category in both the indigenous and scientific classifications. *Itoglo,* however, does not have principal defining criteria and is, therefore, more difficult to interpret scientifically. In some cases the indigenous classification captures very localized variations -eg *shigulu* and *shilugu* – which may not emerge in scientific soil surveys. However, the indigenous system may be less aware of sub-soil properties which may have implications for the extrapolation of results from on-farm trials. The study goes on to conclude that 'the correlations obtained between the indigenous and scientific classification systems are such that a combination of the two would be of benefit to extension workers and researchers interested in improving soil and water management, but for certain other applications in agricultural management the indigenous soil classification would suffice as long as thorough investigation was carried out to clearly define and locate the indigenous knowledge soil categories'.

[4] In this case the international soil classification system developed for the World Reference Base for Soil Resources (FAO-ISRIC-ISSS 1998

Table 10 Soil types identified by farmers during two PRAs in Iteja village

	PRA 1996	**PRA 2000**	**Comments**
Mbuga	3	3	A very heavy (= productive) soil
Ibushi	3	3	Located between *itogolo* and *mbuga*. Similar to *mbuga*, but less fertile
Shilugu	3	3	Former site of homestead/ kraal. Fertile soil made from ashes, manure, h'hold waste
Shigulu	3	3	'Raised land'-former anthill; fertility is good
Itogolo	3	3	Different explanations. Some relating to location (towards *ibushi*) and some texture (heavy and sticky)
Ikerege	3	3	White, unproductive , hard soil, difficult to cultivate and even grasses don't grow well
Ibambasi	3	3	Even harder than *ikerege* and no vegetation or crops can grow
Luseni	3	3	Sandy soil, easy to cultivate, but low fertility. Red *luseni* has larger particles and located in lowland; white *luseni* has smaller particles and located in uplands
Inyalala	3	3	Same properties as *luseni*, but it is always wet (located on a spring)
Nduha		3	Small patches, mainly between itogolo and ibushi and then mbuga
Itongo		3	Some refer to it as an upland area, others as a soil in upland areas
Luseni ludito		3	.A heavy (=fertile) *luseni*. Only acknowledged by some farmers.
Shikalanga		3	Refers to a groundnut field on less fertile soils
Ilago		3	Same as *inyalala, shinele* and *sota*
Sota		3	Same as *inyalala, shinele* and *ilago*
Shinele		3	Same as *inyalala, sota and ilago*
Kisinze		3	Same as *ilago, inyalala* and *shinele*
Luzela		3	Unproductive upland soil, not suitable for crop production
Lugulu	3		Rocky outcrop on hill

Table 11 Proportion of land area covered by different soil types in Iteja village according to different sources of information

	Farmers perceptions PRA 1996*	Farmers perceptions PRA 2000 **	RIDEP Planning & management Unit 1979 survey***
Mbuga	25	29	38
Ibushi	7	10	13
Itogolo	20	48	37
Shilugu	5		
Shigulu	4		
Ikerege	2		
Ibambasi	2		
Luseni	30		12
Inyalala	3		
Itongo		13	
Lugulu	2		

* Kajiru et al; ** Oudwater et al; *** RIDEP survey reported in Kajiru et al

Farmers' descriptions of main soil types in Iteja village

(Source: Oudwater et al 2000)

Mbuga

Classification criteria: (a)fertility/productivity (7 out of 9 respondents); (b)colour (2 out of 9)
Most farmers associated Mbuga with high fertility, commenting that it was very productive (= a heavy soil). Its black colour was of minor importance. *Mbuga* is located in valley bottoms, near the river. If it dries, the soil becomes very hard and cracks, the sub-soil underneath becomes very hard, and is therefore difficult to cultivate. If wet, the soil becomes very sticky. It is initially difficult to cultivate, but after some rainy days it becomes possible. At the onset of rains, the infiltration rate is good because of the cracks, but if the soil gets saturated, it is prone to waterlogging which can last from one week up to two months. Usually, *Mbuga* was ranked first in terms of fertility and farmers said fertilisers were not needed.

During the interviews, people had different views concerning erosion, a few said *Mbuga* is not prone to erosion, whereas others did not agree. During the focus group discussion, the participants reached a consensus on soil erosion. When the soil is dry, the soil contracts and can not be carried away easily, but if wet, the soil expands, becomes muddy and the topsoil can be carried away. The topsoil becomes light due to cultivation and rain. Only cultivated soil is prone to erosion, uncultivated *Mbuga* is mostly covered with vegetation.

Crops: maize, sorghum (if low rain fall), chickpeas, coriander. Not suitable for:

- cassava (dries up in dry season, produces too much vegetative growth due to high fertility)
- groundnuts, bambara nuts (too sticky, preference for sandy soils)
- cotton because of waterlogging.

Constraints: flooding, waterlogging (when there is high rainfall, rice is planted instead of maize), pests and rodents eating the seeds, maize stalk borer (ashes are put in the maize cobs), S*triga* (weeding before flowering) and other weeds like *mabalala* and *manunghi*.

Soil depth: There is little consistency in soil depth and the underlying sub-soil. Soil depths vary from 1 to 15 feet and deeper. Sub-soils are described as gravel, sandy, clayey and white or red in colour.

Vegetation: *Cyperus spp, Matenya, Migu, Malago, Majinji, Malambolambo, Madete, Malandolando, Kafula.*

In daily language, different names are used for areas of *Mbuga* soils located in different parts of the village. (A similar pattern exists for *Itongo).* A farmer might tell his neighbours that be is going to the *Halawa* and it will be understood that he is going to his *Mbuga* fields near the Magogo river. Three different named areas of Mbuga soils were identified - Ng'ong'oli: near the river Ng'ong'oli; Halawa; very fine, a bit drier, near Magogo river; Igaga: near the lake, only few people cultivate there, it is very wet.

Ibushi

Classification criteria:

(a) fertility/productivity (5 out of 9); (b) colour (3 out of 9); (c)location (2 out 9); (d) occasional criteria: texture, water holding capacity and workability

Ibushi is located near *Mbuga*, usually in between *Mbuga* and *Itogolo*. It is black in colour, but lighter than *Mbuga*. In general, *Ibushi* is similar to *Mbuga,* but less fertile. However, it has higher fertility than *Shilugu*. When the soil is dry, it is fine, friable and easy to cultivate, but if it has been left fallow for a while, it becomes hard and more difficult to cultivate. If it is wet, it is sticky and difficult to cultivate, but less so than *Mbuga*. Different opinions prevailed as to whether *Ibushi* was prone to waterlogging or not. During the final focus group discussion, it was agreed that the infiltration rate is moderate to good. *Ibushi*, located on flat land near *Mbuga* is prone to waterlogging, whereas *Ibushi* located on higher slopes does not get waterlogged; the water will just run off along the slope. In lower and flat parts of *Ibushi*, crops may remain stunted due to waterlogging. Moisture is retained longer than in other soils like *Shilugu* and *Shigulu*. It is not prone to erosion because the soil particles are heavy and sticky.

Crops: sweet potatoes, cotton, maize, sorghum (susceptible to *striga* infestation), rice (only if water stands on the surface and bunds are constructed for water harvesting), green grams, groundnuts and cassava (not common). Not suitable for;

- bullrush millet (*madohi* disease, at flowering stage, no grains are formed, and the plant becomes black and sticky)
- bambara nuts (because of high fertility and vegetative growth, pods can not be formed due to stickiness of soil)
- cowpeas (vegetative growth).

Soil-depth There was no consensus about soil-depth and underlying sub-soil. Soil depth varied from two to ten feet. Sub-soil was mostly described as white sandy soil followed by gravel, *Mbuga*, *Ikerege* and big red stones.

Constraints: depending on period of fallow, difficult to cultivate if dry, S*triga* infestation (especially for sorghum, less severe with maize), crops wilt easily during dry spells. During high rainfall there are problems of waterlogging which damages the harvest. Declining fertility if continuously cropped, especially during maize cultivation.

Vegetation: *Magahuluda, Mitundulu, Migu, Bunani, Malegi, Matenya, Manunhi and Lugobi.*

Itogolo

There was a wide range of classification criteria with no real consensus among the respondents.
(a) Texture (b)colour (c)crops cultivated (d)productivity (e)workability (f)water holding capacity (g)location

Different explanations were given about the meaning of *Itogolo*. The explanations often referred to its location along the slopes towards *Ibushi*. Other explanations focused on the texture. The colour is mostly described as between black and white (grey). If dry, the soil is very hard, some clods are formed which makes the soil very difficult to cultivate. If wet, the soil becomes slightly sticky and easier to cultivate. Compared to previous soil types (1-5), the infiltration rate is said to be moderate to poor, especially after it gets saturated. Water can be standing on the surface for one to seven days, depending on the amount of rainfall.

Different opinions prevailed about erosion. A few stated that the soil is prone to erosion if it is cultivated, during heavy rains and if it is located along the slope. During the final focus group discussion and some interviews, it was explained that it is not prone to erosion because the soil is heavy and sticky. In general, fertility was said to be moderate to poor. During the focus group discussion, it was agreed that fertility was poor for most crops apart from rice, which is cultivated within bunds for water harvesting.

Crops: rice, maize, sorghum, groundnuts, green grams, cowpeas, millet and sweet potatoes. Not suitable for:
- cassava (soil is too hard, sticky and dries to fast)
- chickpeas and bambara nuts
- Some farmers said that maize does not grow well because the soil dries too fast and has too low fertility.

Constraints: soil dries fast or gets waterlogged during heavy rains, S*triga* infestation due to continuous cropping of sorghum and maize, low fertility, weeds, rodents.

Soil depth: varies from one foot up to ten feet. Most informants mentioned that the sub soil is a mixture of white gravel/sand (*Bushanongu, Gymbia, Mabumba, Igereshi*), a hard pan was mentioned as well.

Vegetation: *Samang'ombe, Manunhi, Kahuluda, Madasa, Majinji, Matenya*

Luseni

Classification criteria:
A wide range with little overlap: (a)texture (sandy) (b) location (within *Itongo*) (c) water holding capacity (low) (d)same crops cultivated (e)colour

During interviews, two different colours were mentioned, white and red. During the focus group discussion, it became clear that there were two different types of *Luseni*, a white and a red coloured one depending on the size of the particles. The red *Luseni* has got larger particles and is located on the lowland. The white *Luseni* has got smaller particles and is located in the uplands. According to the respondents, there is no difference between them with regard to workability, fertility, water holding capacity etc.

Luseni is described as a sandy soil type, easy to cultivate with a poor soil fertility. If dry, it is friable, but can be either difficult or easy to cultivate (no consensus). During the focus group discussion, it was agreed that *Luseni* becomes very hard during the dry season, and is therefore difficult to cultivate. If wet, it is not sticky and easy to cultivate. Infiltration rate is good, but different opinions exist on whether it is prone to waterlogging or not (majority of respondents stated that water does not stand on the surface). During the focus group discussion, it was agreed that water does not stand on the surface and that *Luseni* remains moist for two to three days. It is prone to erosion if located on a slope and during heavy rains, because it is a light soil, thus easily carried away. It has low soil fertility.

Crops: groundnuts, green grams, cowpeas, bambara nuts, sweet potatoes. In a few cases maize, sorghum and cotton were mentioned. Not suitable for:
- chickpeas
- rice (soil dries too fast)
- maize, sorghum and cotton (all because of low fertility)

Constraints: low fertility, hot soil, crops wilt fast, waterlogging, weevils (sweet potatoes), weeds and need for fertilisers.

Soil depth varies from one to six feet with all different sub-soils.

Vegetation: *Majinji, Magogote, Bunani, Manungi, Lugobi, Samang'ombe*

3. 3Mwagala village

The village and the surrounding area

Mwagala is in Ukiriguru ward, Misungwi district and is more or less neighbouring Ukiriguru ARI. The village has a total of about 410 households. It is located in an area which may be broadly categorised as 'Sukuma catena', but dominated by *luseni* soils (Bunyecha et al 1994). The catena runs from the rocky granite hilltops through the upper footslopes, to the lower footslopes and then the valley floor (Bunyecha et al, Meertens et al (!995) -see Figure 1 below.

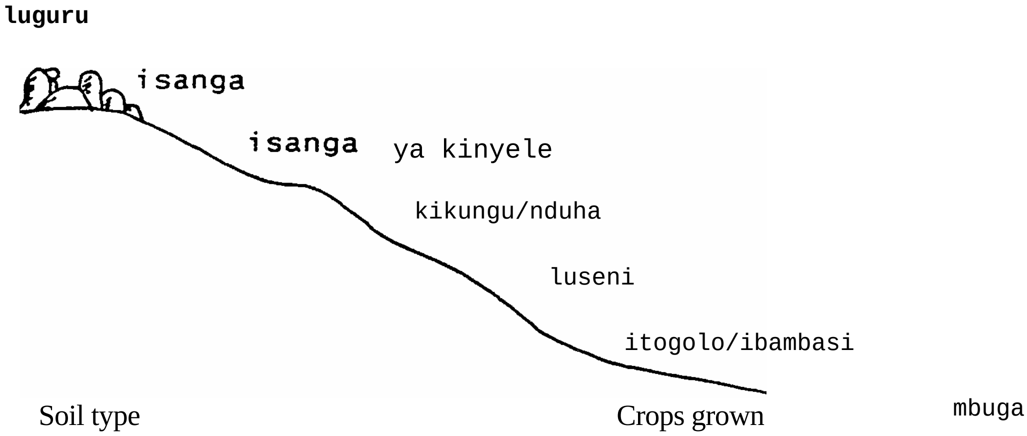
Farmers ' soil classification for Mwagala village

Bunyecha et al (1994) carried out an informal survey of what was then Kwimba district which included 12 villages, one of which was Mwagala. The survey team categorized Mwagala as lying in a Sukuma steep catena system. Buncyecha et al (1994) provide a generalized description of this catena in the then Kwimba district, with some specific reference to Mwagala. *Luguru* is described as the hill top, rather than a soil type. In most villages this area is a source of firewood and often is quite bare, but in Mwagala the local administration had enforced local by-laws to protect hill top areas. Moving down the slope various sandy soils can be found. *Ikurusi* is described as a course red, easy to work, relatively fertile soil. In Mwagala it was recorded as being used for cotton, sorghum and maize. *Isanga* is described as a course grained sandy loam, which may be used for cassava, sweet potato and bambara nut. Between isanga and luseni two other soil types may be found. Inyalala (also known as *isanga ya kinyele or sota)* refers to more moist types of *luseni.* Crops grown include cotton, sweet potato, rice, cassava and vegetables. *Kikungu* or *nduha* is a well-drained deep, relatively fertile soil where crops such as maize, cassava, sorghum and millet are grown. Maize intercropped with cassava is usually preferred. *Luseni* soils are fine textured soils of low fertility typically used for cotton, cassava, sorghum and millet. *Shiligu* is a man-made soil found on the site of a former homestead or kraal and preferred for maize or sorghum because crops grown here suffer less from *Striga.*

Moving down the slope, *itogolo and ibambasi* are described as hardpan soils. *Itoglolo* means open space in Sukuma language and the soil is found where footslopes merge into *mbuga*. These soils are typically shallow and not free draining and therefore are often used for rice cultivation. Sorghum, cotton, groundnuts and sweet potato are also cultivated, but are of secondary importance. *Ibambasi* soils are true hard pan soils, difficult to work and therefore usually left for grazing. *Mbuga* soils are a sink for water and nutrients higher up the slope. The main crops produced here are maize, chickpeas, cotton, rice and sorghum. Other important crops are horticultural crops, sugar cane and sweet potato (particularly maintaining planting material in dry season).

During the 1994 informal survey, farmers were asked to estimate the percentage of soil types in Mwagala. They reported: *luseni* (60%), *nduha* (10%), *itogolo* (20%), *mbuga* (10%).

Figure 1 A typical Sukumaland catena on granite (Source: Bunchyecha et al 1994)



Soil type	Description	Crops grown
luguru	granite outcrops with scarce source of firewood	source of fire wood
isanga	coarse grained sandy loam	cassava sweet potatoes bambara nuts
isanga ya kinyele	reddish sandy loam with water	sweet potatoes tomato, cabbage and onions
kikungu/ nduha	transported reddish sandy loam	cassava, cotton sweet potatoes sorghum
luseni	coarse to fine sands	cassava, maize sorghumJ cotton mi11et, sweet potatoes
itogolo/ ibambasi	hard pan sand clay	rice, cowpeas cotton, g'nuts grazing
mbuga	heavy clay	rice. maize chickpeas grazing
ilago/swamps	sand/loam clay	horticultural crops, grazing

4. EASTERN ZONE

4.1 Background

The Eastern Zone comprises Morogoro, Tanga, Coast and Dar-es-Salaam regions, but Striga project activities have focused on Tanga only, in particular Muheza district.

Soils

Land Use

A major feature of parts of the Eastern zone is the estate sector which occupies a significant proportion of the arable land.

Land tenure and user rights

A significant proportion of the land in this zone is occupied through granted right of occupancy, where the period of occupancy is a limited period of time and the arrangement is subject to common law.

4.2 Background to fieldwork

The purpose of the visit was to collect preliminary information on local classification and characterisation of soils at Mtakuja and Mbambakofi villages in Maramba, near Tanga. This work was an extension of that started at Mvumi and Chipanga in Dodoma in May, 2000. The team comprised of Dr GJ Ley, Dr AM Mbwaga and Mr J Hella. Fieldwork took place from July 24 to July 25, 2000

Discussions were held with farmers in both villages and these were followed by a quick drive through the farms to clarify what had been was discussed. In contrast to farmers in Mvumi and Chiganga in Dodoma -where they were predominately Wagogo- the farmers in Maramba are of from different tribes (particularly at Mbambakofi), having migrated to this area to work on the sisal plantations. Greater efforts were therefore needed to arrive at a more common understanding of soil types and their characteristics.

Results

4. 3 Mtakuja village

This information was provided in a participatory manner by two men and three women farmers at Mtakuja village and a field drive through the area. Fertilizers are not used because the farmers believe that JKT (*Jeshi la Kujenga Taifa*) -ie national army- farms are fertile. Soil fertility on their own farms has declined considerably. Most fields have been abandoned. The most common soil-type is *tifutifu* (red soil) which covers about 95% of the area. Striga infestations mostly occur in this soil.

Table 12 Farmer classification and characteristics of soils at Mtakuja village

	Properties as described by farmers			
Soil type	Colour	Consistency when wet	Fertility	Cop grown
Mfinyanzi (Uongo)	Black	+++	++	Coconut, rice, yarns, sugarcane, tomatoes, sweet potatoes (on ridge)
Tifutifu	Red	++	+++	Maize, beans, sweet potatoes, cassava, groundnut, green gram, cowpea
Kichanga (Msanga)	Pale red	+	+	Cassava, beans (with adequate rainfall) groundnut
Udongo wa chumvi chumvi (Uongo wa munyu)	Black	+	+	Generally not cropped but a few bananas plants can been seen
Ukoa	White	+	-	Not cropped. Used for white wash

+ less, +++ more. Soil types in Kisambaa shown in brackets.

4.4 Mbambakofi village

The information was provided in a participatory manner by two men and three female farmers of Mbambakofi village and a field driver through the area. Farmers classify their soils according to colour and consistency. The area is dominated by red soil (about 95% +). *Striga* infestations mostly occur in this soil. Because of declining soil fertility and *Striga* infestations, farmers have planted perennial crops to their fields and grow annual crops on borrowed Mwele seed farm.

Table 13 Farmer classification and characteristics of soils at Mbambakofi village

	Properties as described by farmers			
Soil type	Colour	Consistency when wet	Fertility	Cop grown
Mfinyanzi (low lying areas)	Black	+++	++	Bananas, sugarcane, tomatoes, vegetables, sweet potatoes
Udongo mwekundu	Red	++	+++	Maize, cassava, sweet potatoes, groundnut, cowpea, sorghum
Udongo mweusi (sandier than mfinyanzi)	Black	+++	+++	Maize
Udongo uliochanganyi-kana kototo (shallow <50 cm deep)	?	+	+	Maize, cassava
Kichanga	Pale red	+	-	Sweet potatoes, groundnuts

+ less, +++ more

5. SUMMARY OF MAIN POINTS

1. The ultimate aim of these research activities is to develop improved options for management of *Striga* and increase productivity of sorghum. These provisional studies of farmers perceptions' of soil resources were carried out as a component of the development of a decision-making tool to match sorghum cultivars -and their management- to categories of soils identified by farmers.

2. The three sites selected for study provide interesting comparisons. In Central Zone, farmers provided a soil classification in kigogo. The people of the two villages involved are culturally relatively homogenous[5], but there are differences and there appear to be both similarities and differences in the terms used to describe soil types. Farmers' soil classification appears to be less well understood and little used by researchers (and probably extensionists) in this zone compared to the Sukuma classification of Lake Zone. The Sukuma system has been recognised by researchers for over 50 years as a rich system for describing soils and recent studies support it's usefulness in developing soil and water management interventions. The study villages in Muheza district of Eastern Zone are adjacent to areas of public/ alienated land – JKT/ army land; sisal estate and the Mwele (parastatal) seed farm- with at least two major related characteristics. Firstly, many people have migrated to work in this area, making the population culturally more diverse and so less likely to reach consensus regarding soil classification. Secondly, there appears to be a severe land shortage. The soil classification was provided in kiswahili, with some kisambaa terms also provided. Both villages appear to be dominated by one major soil type.

3. Across the three study sites, results so far suggest there are differences in the diversity of soils, farmers' perceptions/ knowledge of these soils and the extent to which other agencies are aware of farmers' perceptions/knowledge. As well as differences, there are some similarities eg some criteria for differentiating soil types appear to occur at all sites eg suitability for particular crops and colour.

4. For a decision tool to be useful, it must be possible to interpret it in a localized context. The variations occurring in the different study sites provide the opportunity for testing the development of a decision tool which can have applicability across a wide range of local environments.

5. Further work- at the Central Zone and Eastern Zone sites the research team now has a basic understanding of farmers' soil classification. This needs to be built upon (perhaps drawing on work carried out by others in Lake Zone) in terms of differing perceptions of soil resources and their management according to eg gender, wealth age. In Lake Zone this is, perhaps, already well documented, but it may be useful to learn how people are perceiving the changing land tenure situation. In all zones we need a better understanding of access to and management of soil resources by different people (the DFID Sustainable livelihoods framework may be a useful tool for guiding us).

6. At this stage, it is not clear to the project team how agricultural support services interpret soil resources in their local situation. This information is likely to be important in the development of the decision tool.

[5] In both village kigogo is spoken, but there according to some reports, the people of Mvumi makulu consider themselves 'true Wagogo' and those from Chipanga 'A', Wanyembwa.

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Appendix 1 Land Tenure in Tanzania

Tenure determines the links between responsibility and authority over land and other natural resources, and it is a major determinant of the incentive structures for sustainable use. In Tanzania, all land is held in trust by the state, however, as in many countries there are two systems of tenure in operation, the statutory *de jure* and the customary *de facto*.

According to Sundet (writing in 1997), 'Tanzania's land tenure regime has consistently been designed to allow the executive control over the use and ownership of land with the main aims being to ensure that land is effectively developed and utilised and that the rural population has access to "sufficient land"'. A summary of changes in Tanzania's land tenure regime is shown in the table below. He goes on to say 'The resulting policy framework produced the worst of both worlds. The legislation is weak on customary rights for smallholders and pastoralists and overly reliant on administrative procedures for its implementation. Customary holders of land are consequently facing acute insecurity of tenure and in many cases suffer land losses which undermine their welfare and livelihood which is in direct contravention of the colonial and contemporary tenet that the people's present and future needs for land be 'protected'.

Insecurity of tenure can undermine welfare and livelihoods and there is a prevailing view that the uncertain status of customary rights works as a disincentive to commit resources to both improve productivity and ensure the environmental sustainability of the land. This is the context in which land and natural resource management policies and legislation in the mid-late 1990s were drawn up.

The Land Commission

In 1991 the Tanzanian government formed a Commission of Inquiry into Land Matters and published a report in 1992. The chair of the Commission was Professor Issa Shivji. The LC report argues that for the foreseeable future Tanzania is likely to remain a small peasant/ pastoralist economy. Differentiation in the smallholder economy will result in 'accumulation from below'. Shivji emphasises the link between land and democracy –'deep structural link between the use and control of resources and the organization and exercise of power.'. The LC recommended that all land should be either village land (VL) or national land (NL). National land being defined as all land that was not village land. The NL would be under a National Land Commission whose governing body would be the Board of Land Commissioners. The VL would be under Village Assemblies and the aim would be that 'village lands are primarily for the use and benefit of villagers and shall be inalienable to outsiders.' It is envisaged that a land market will develop within the village and as the smallholder economy becomes more differentiated there will be 'accumulation from below'.

The National Land Policy (1995) and draft Land Bill (1996)

The Government of Tanzania did not accept the findings and recommendations of the LC and these were not incorporated into the National Land Policy and draft land Bill. Significant points include:
All lands are rested in the president to be held in trust for the people of Tanzania;
Commissioner for lands is the sole authority;
Three land types: General land –allocated under rights of occupancy by the C for L
Village land – registered or non-registered villages
Reserved land – eg Forest reserves, national parks, Ngorongoro CA.

GL would be under the authority of the C for L. VL would be under the authority of Village Councils who would be directly responsible to the C for L. VLs can be transferred to the category of GL by the C for L. Non-village organizations can be granted customary right of occupancy for up to 99 years. Land already occupied by non-village organiztions remains the direct responsibility of the C for L. Individual outsiders may obtain village land if they show their intention to base their residence or business there. VCs may grant a derivative right and villagers holding a certificate of customary right may give derivative rights to outsiders.

Land Act and Village land Act (1999)
Under the recently introduced land acts there are three categories of land: Village; General (in effect the State) and Reserved (Use and occupation is regulated by law). According to the new legislation village councils are managers of village land (estimated to occupy more than half of the country). Within each Village Area the Village Council (in agreement with the community) is to set aside land to be held in common. The remaining land is to be registered in a Village Land Registry and –if the community agrees- private deeds or titles are to be issued. Reserved land (currently approaching 40% of land area) may be managed by virtually any entity or legally established body (eg village council or a private company), but they will be obliged to abide by the relevant laws governing reserved land.

This new legislation appears to provide for significant devolution of land rights, however, there has been a mixed response in interpreting what is likely to happen in practice (see Shivji and Wily in Palmer 1999). Wily argues that there has been a radical change and that 'once vested at the periphery, powers will not be readily surrendered, and will consolidate and mature over time' and 'the law visibly protects existing rights in land….it does this through removing inequalities between statutory and customary rights' (Wily in Palmer 1999). However, Shivji is less optimistic and suggests 'the most striking feature of the two bills is the enormous power over the ownership, control and management of village land placed in the Ministry, and through the Ministry, the Commissioner. The Commissioner has even greater powers over reserved and general land. The role of more elective bodies, like the local authorities, and more representative and open bodies, like the village assembly, have been virtually done away. Village council manages village land more as an agent of the Commissioner rather than as an organ of the village accountable to the village assembly' (Shivji in Palmer 1999).

Clearly much depends on the performance of the village councils and 'the enactment of the new land laws marks the start (not the end) of a long process of land tenure which will take place for several decades to come' (Ministry of Lands in Palmer 1999).

Summary of significant events in land tenure situation in Tanzania

Period	Land tenure situation
Pre-colonial	Various forms of customary land tenure
Colonial German: 1885-1916 British: 1918-1961 1958	Assumption by authorities that indigenous occupants had no ownership rights over land. Under the Land Ordinance Act (1923 No.3): Customary tenure was recognised, but there was no legal security; Governor was authorised to make land grants 'right of occupancy' Ultimate control held by the state Proposal to move towards ITR (Individualisation, Titling and Registration) -as in Kenya –'to give access to land to those who are best able to use it'. Opposed by Nyerere.
Early Independence (1961)	Transformation Approach (recommended by World Bank) – settling selected farmers in villages as examples of good farming to others. By 1966 acknowledged to have failed due to over-capitalization and top-down management.
Post-Arusha declaration (1967)	Para-statals acquired land held under granted rights of occupancy and deemed rights of occupancy. Typically without consultation eg NAFCO/ Barabaig in Arusha region (P. 10)
Villagization (1970s)	Villagization occurred with 'total disregard of existing customary land tenure systems' with greater potential for alienation than colonial times (P12). Legal framework remained unclear (P15) –'villagization destroyed what was left of the security of deemed rights'. Resulted in some re-distribution of land. Village titling initiated (based on recommendation in National Agricultural Policy 1982) and granted rights of occupancy to the Village Council. Potential for VC to grant land to outsiders and village boundary disputes. (P20)..
Liberalizarion policies (1980s)	Ujamaa polices abandoned and moves towards the creation of a land market. Attempts by customary title holders to reclaim land through the courts resulting in 'peasants in affected areas witnessing massive dislocation and expropriation of their lands twice within a decade' (P 18)
Land debate 1990s	Land Commission (1992) National Land Policy (1995) Draft Land Bill (1996) Land Act and Village Land Act (1999)

Source: Compiled from Shivji (1998)

Appendix 2 A Short Description of Major Smallholder Farming Systems in Sukumaland

(extract from Ensrink and Kaitaba 1996)

Given the present state of knowledge. it is already possible to present adequate descriptions for some of the identified farming systems. However, as activities of the zonal FSR-team have until recently been focused on Kwimba (recently split into Misungwi and Kwimba), Maswa, Meatu and Bukoba districts, other districts are less well covered. Consequently, little information exists on some of the identified farming systems. However, this will change within a period of two years. Many detailed district physiography, soil and landuse studies will then have been completed. In addition, the FSR-team expanded its diagnostic survey work to Karagwe and Biharamulo districts (FSR project, 1995a and 1995b) and will expand to other districts soon. Other organizations add to this body of knowledge by implementing similar surveys (ICRA, 1989; Meertens and lupeja, 1994; Bakema, 1994; Ebong, 1995; FAO-IFAD, 1995). Although agricultural zonations, proposed in many diagnostic survey reports, are still predominantly based on secondary material, it is anticipated that this will soon change. In depili surveys and village-based studies combined with new information on soils, physiography and landuse will provide suitable primary material to verify the present farming systems zonation and to change it when and where required. Again it is emphasized that we are at the start of a process; results require continuously updating.

1. Sukuma system on the Luseni/ltogolo catena

The Sukuma catena on granite dominates large areas of the lake Zone. The catenary soil sequence from hill tops to valley bottoms and the specific characteristics of luguru, luseni, Itogolo and Mbuga soils have been described in detail in Chapter 4.1.2. In the narrow valley system with steep granite hills luseni soils dominate. In the wide valley system of gently undulating granite landscapes Itogolo soils dominate.

The narrow valley system (where luseni soils dominate) was the first area to be inhabited by the Sukuma. It is roughly located in a concentric circle around Mwanza town within a radius of 30-50 krn where rainfall is more favourable. Although deep, these sandy soils have limited water storage capacity .High hand-hoed ridges are constructed to prevent runoff and stabilize production. Due to the long settlement period and high population pressure, soil fertility has dropped to very low levels (Budelman, 1996). Push factors for migration are strong.

Crop yields are low due to low soil fertility .Due to the small farm size labour constraints on weeding are less important. Maize, the major cereal crop, is interplanted with cassava in October. Once maize is harvested (February-March) cassava will continue growing till the rainy season ends (June). Although cotton is produced competition with food crops is heavy.

Valley bottom areas only cover a relatively small proportion of the available land. However, in the past decades these areas (with Itogolo and Mbuga soils) originally used for grazing or sorghum cropping, were completely transferred into bunded rice fields where diverted runoff water is trapped. Rice has become an important cash crop but it is increasingly also used as a food crop. Due to land pressure some intensified rice production practices (e.g. establishment of seedling nurseries) have already been adopted. Over the past two decades return to labour and capital were higher in rice than in cotton production.

Manure availability is limited; only 20-40% of the households possess livestock. Population pressure is too high to allow cattle to roam freely. Conflicts between livestock and non-livestock owners are common

The degree of oxenization is low as many households do not possess oxen and the local ridge construction method requires hand-hoeing. Labour constraints are therefore mainly concentrated during the land preparation phase. Manure is preferably applied to horticultural crops which are mostly planted off-season. However, if manure is applied to ridge-planted crops (e.g. maize) it is best applied to last season's furrows once the weeds have been scrapped from the ridges. Subsequently, the old ridges are split to construct the new ridges on top of the scrapped weeds and manure. So, weed seeds are buried deeply and resulting weed infestations are low and not troublesome.

Tomatoes and cabbages have become important cash crops and are irrigated with buckets from hand-dug shallow wells during the dry season when sufficient labour is available. The nearby market in Mwanza town guarantees a sufficient demand. In these areas manure has become scarce; in some villages it is even paid for. Along the shore of Lake Victoria many households are involved in fishing.

Although in the 1960s cotton provided indirect food security for farmers (reliable payment and favourable prices) this function has now been taken over by rice, tomatoes and cabbages. The only way cotton may regain part of its former function is through a reliable institutional setting (e.g. competitive pricing) combined with an intensification programme to increase yields. Soil fertility issues are among the first to be tackled.

The wide valley system (where Itogolo soils dominate) is located further away from Mwanza town and covers large parts of e.g. Magu, Misungwi and Kwimba districts. Due to formation of a hardpan layer, Itogolo soils are well suited for rice cultivation. Rainfall, although rather favourable in these areas, is not sufficient for rice production. Runoff water has to be collected and diverted into bunded fields. The upper part of a slope (about 1 kill in length) supplies runoff water for rice crops to be grown on the lower part (also about 1 kill in length). When Itogolo slopes are long (3-6 kill), two or more segments of bunded rice fields are developed, separated by segments serving as water catchment areas. This prevents erosion which may occur when the runoff catchment area becomes too big.

If fields have not received enough water in November-December, chances are slim that rice crops will survive January-February dry spells. Transplanting (February-March) may then be an option. However, if insufficient seedlings are available, or when rains are delayed (e.g. end of March), farmers often regard the season as lost for rice production. In severe dry years many bunded fields are not supplemented by runoff water and 50-80% of the rice fields remain fallow. In some areas rice cultivation has reached maximum expansion. There is a balance between water catchment area (providing runoff water) and the potential area suitable for rice production. The upper Itogolo fields often monopolize runoff water, although they are less suitable for rice cropping. Their lower soil fertility and higher water percolation levels (due to their sandier soil texture) are constraints to optimum yield production and runoff use.

Other food crops (maize, sorghum, cassava, sweet potatoes, beans) as well as cotton are grown on the upper half of the catena with Luseni soils. However, cotton can also grow on the lower half, on fields which are less prone to waterlogging. Consequently, cotton and rice compete for land, especially for the more sandy fields on the upper Itogolo zone. As explained before, these fields are less suitable for rice production. Past socio-economic circumstances favoured rice on such fields.

The wide valley system is characterized by medium population pressure. The degree of oxenization is moderate; between 30-60% of the households possess oxen. Rice and cotton fields are often established by the broadcasting and ox-ploughing method; the other food crops are often planted on ridges constructed by hand-hoeing. However, in some areas (e.g. Mwakilyambiti; FSR Project; 1994) farmers use ox-ploughs to construct low ridges for cotton cultivation. As crop areas are larger than those on the narrow valley system, there is a labour constraint, particularly for weeding. This is aggravated as rice weeding requires much labour . There seems to be a natural balance within this system. When good rains occur most bunded rice fields will receive sufficient water. With good weed control high rice yields will be realized. In such seasons management of cotton will indeed be at its lowest and the acreage sown will be small. However, the opposite occurs during a dry year; many rice fields do not fill up and remain fallow. However, more cotton is planted using high standard weeding practices. In this way, both crops are stabilizing the system, but under different conditions.

Soil fertility problems are less pronounced than in the narrow valley system. Farmers consistently refer to weeds as their major problem. However, urea application (30 kg/ha N) to rice crops show high marginal rates of return to capital, indicating that fertility problems (although more hidden) already exist (Enserink, 1994; Kajiru, 1995). Manure availability is moderate. Farmers complain that manure applications increase their weeding constraints. Local manure carries many weed seeds which will germinate easily when the manure is broadcast and only shallowly worked into the topsoil. This is often the case when crops are directly sown (broadcast and ploughed) and flat cultivation is practised (e.g. rice, cotton). However, some farmers apply manure on fields where transplanted rice crops will be established. They claim that if manure is applied early in the season, all weed seeds have germinated by the time fields are prepared for rice transplanting.

Many farmers, however, complain that their fields are too far away from their kraals which are located in their homesteads' compounds. As transport facilities (ox-carts) are limited, this may also restrict the use of manure in soil fertility management. Rice yields of 2,000-3,000 kg/ha are quite common. Due to these high yields and favourable selling prices, cotton production encounters fierce competition in this system. Competition with horticultural crops is less fierce due to the distance to the Mwanza market.

As explained before, cotton lost part of its cash crop function to rice. However, it still plays a major role during unfavourable rainfall seasons. It may be expected that when cotton prices and payments become more attractive to farmers, the less suitable rice fields located higher up on the catena will again be turned into cotton fields. This will stabilize the system. Further increase in cotton production may be expected but only if intensification efforts are rewarded. Important topics for intensification efforts are related to the introduction of labour saving equipment fo.r weed control and maintenance of soil fertility .

2. Sukuma system on Itogolo plains

In these almost flat plains Itogolo hardpan soils dominate. As these plains are characterized by considerable seasonable waterlogging, they were in the past mainly used for grazing. However, after the introduction of ox-ploughs and the increase in farmers' knowledge on rice cultivation techniques, households increasingly migrated to these areas.

If these plains are situated in the **wetter parts** of Sukumaland (e.g. Malampakka and Kakama) extensive areas may be allocated to rice cultivation. In these areas sufficient water can be trapped in bunded fields to let rice survive the January-February dry spells in most of the cropping seasons. The cropping systems in these areas are resembling those in the wide valley system of the Sukuma catena. Deviations are mainly the result of too much waterlogging; the cropping of cotton and maize is more difficult. Consequently, rice has become the most important food as well as cash crop. The livestock component is more important to stabilize the system and for provision of ox-traction. Use of manure is less common.

However, if these plains are located in **drier parts** of Sukumaland (e.g. Meatu district) rice cultivation is not possible as the period of waterlogging is too short to let rice survive the long dry spells in January and February even if water has been trapped in bunded fields. Farmers in these areas have to depend on sorghum, sweet potatoes and cotton cropping which are risky enterprises as the hardpan soils are shallow and the rainfall is unreliable resulting in either (seasonally alternating) drought or waterlogging conditions. Cassava cannot be grown as the dry seasons are too long. Consequently, the livestock component is very important to stabilize the system. Animals can be sold in case of food shortage and oxen are used to plough the rather extensive fields. Use of manure is rare.

The present data on the location of Itogo1o plains appear to be unreliable. Pauw (1983) indicated already that he had very limited information about these plains. Our maps (which are based on a generalization of his soil and physiography map) are therefore also not very reliable. A recent soil survey in Maswa district (NSS, unpublished) indicated Itogolo plains to cover much smaller areas than Pauw assumed; the opposite was true for lbushi plains. For Kahama district a similar confusion seems to exists. Many reports (e.g. Bakema, 1994; Ebong, 1995) indicate large rice production areas to be located on Mbuga plains. We have considerable doubts about the accuracy of these observations. Based on our experience, we suggest to investigate if rice cultivation in Kahama is in reality not taken place on ltogolo plains. We assume that hardpan soils are involved.

3. Sukuma system on Mbuga plains
This heavy black, cracking clay soil is mainly situated on the extensive floodplains of local rivers (e.g. south of Mabuki in Mwanza Region and around Old-Shinyanga). Most Mbuga soils are deep and have a moderate fertility .Limited areas of Mbuga soils are located on the lowest parts of the Sukuma catena. Here they receive a lot of excess water from the higher Luseni and Itogolo parts and are often temporarily flooded after heavy rains.

In the extensive alluvial floodplains, waterlogging in itself may pose a problem, but flooding is not frequent. It only occurs when the river overflows its banks after prolonged heavy rainfall has occurred in a large part of the catchment area. Waterlogging and its heavy texture are serious constraints on hoe cultivation and cropping. Consequently, before the 1960s, Mbuga soils were mainly used for dry season grazing. Mbuga cropping in the Sukuma catena was restricted to sorghum being tolerant to both waterlogging and drought. When rice was introduced many farmers tried it. However, Mbuga soils appeared to be less suitable for rice cropping than Itogolo soils. Mbuga has no hardpan and in case of drought, percolation of water beyond the rooting zone may seriously affect rice production. Rice cropping on the extensive Mbuga plains is even more risky as runoff water is less common and deep cracks may be formed during the January-February dry spells.

Further discussion is focused on the extensive floodplains. These areas were thinly populated in the past. After bush clearing campaigns to reduce tse-tse fly infestations and widespread adoption of ox-ploughs in the early sixties, farmers could migrate to and settle in these areas. Current farms are characterized by large crop acreages. The degree of oxenization is high; without ox-ploughs it is impossible to cultivate these heavy soils. Some large-scale farming enterprises using tractors developed around Old-Shinyanga. Most farmers cultivate their fields with oxen. Although ox-cart availability is better than in any other system, farmers still regard transportation of field crop produce as a constraint. Distances to fields are long, fields are large and much crop produce needs transportation (e.g. maize cobs, chickpea plants to be threshed at the homestead, seed cotton, sorghum and rice). As households are wealthy. introduction of low-cost, animal-drawn transportation equipment appears promising.

Due to the relatively high soil fertility and the temporary waterlogging risk, weeds pose a serious problem. Although manure is available in large quantities, soil fertility is not a serious constraint on this system yet. Consequently, hardly anybody uses manure as a fertilizer , although kraal rotation is practised. Farmers consistently refer to weed control as their major husbandry constraint. As they are cultivating large areas, labour shortages have forced them to develop special management techniques.

In the **wetter parts** of Sukumaland maize is the major crop, mostly planted in October on the flat, often dibbled behind the plough. It may be mixed with green grams and cowpea Attempts are made to keep maize crops free of weeds (sometimes even ox-ploughs are used). In April the maize is cut and stooked on large heaps. This clears the field for ploughing and chickpea planting. Chickpea will receive another month of rainfall and then survives on residual soil moisture until its harvest in August. When cleanweeded, there is no need to plough fields again prior to planting subsequent maize crops. Maize is then established by hand-hoe dibbling. If farmers manage to weed their maize crops successfully, fields do not have to be ploughed before chickpea crops are sown; they can also be established by hand-hoe dibbling. Therefore, this intensive cropping system involves some internal management arrangements to ease labour constraints during planting and weeding.

A built-in balance for crop production and food security is also found in this system. When flooding occurs and maize gets waterlogged for a longer period its yields are drastically reduced. However, the deep soils then get fully charged and residual soil moisture is sufficient for chickpea to produce substantial yields. If flooding does not occur maize yields will be substantial, but residual soil moisture is limited and chickpea yields may be reduced.

Not all fields are suitable for this relay-cropping system of maize and chickpea. Lighter or shallower Mbuga soils do not store sufficient moisture for successful chickpea cultivation. Farmers classify their fields accordingly. On less suitable fields where only maize can be grown, cotton is also a potential crop. Cotton cannot be relay-cropped with chickpea as it needs the drier May-July period for boll-opening and picking.

Maize and chickpea are cash crops. Moreover, maize is the preferred food crop of the Sukuma. Maize and chickpea are sold readily during the dry season, when traders can reach the villages. Under present conditions, only 10% of the fields in typical Mbuga villages (e.g. Chasalawe) are planted under cotton. However, over 75% are planted under maize/chickpea. The remainder is planted under sorghum and rice. Food security is high.
Cotton faces fierce competition from maize/chickpea crops. Only on the lighter soils cotton has the potential to stabilize the system (especially in dry years). If cotton becomes more attractive to farmers, some lighter textured fields may again be used for cotton cultivation. Further increase in cotton production may be expected but only if intensification efforts are rewarded. Some investments, however, such as introduction of suitable ox-weeding equipment and ridgers (to reduce the risk of waterlogging) will benefit all cropping systems.

On Mbuga soils in the **drier parts** of Sukumaland it is not possible to practise relay crops of maize and chickpea. Due to less rainfall only single crop systems are possible. However, on most of the drier Mbuga plains limited attention is paid to crop production as livestock production dominates the farming system. Floodplain of local rivers are mainly used for dry season grazing (e.g. the floodplain of the Sibeti river in Southern Meatu). Only limited areas are used for cultivation of sorghum, sweet potato, cotton and maize. In contrast to the livestock population, the human population is low. Although farmers produce insufficient food, food security is stabilized by livestock and cotton sales.

4. Sukuma system on lbushi plains
lbushi soils cover large areas in the more semi-arid parts of the districts of Meatu, Maswa and Shinyanga Rural. Ibushi is a shallow friable calcareous clay loam which generally overlies a layer of calcium deposits. These areas were thinly populated in the past. After bush clearing campaigns to eradicate the tse-tse fly and ox-plough introduction, farmers could migrate to and settle in these areas. Current farms are characterized by relatively large crop areas.

lbushi soils have a moderate natural fertility and are well drained. They are easy to cultivate by plough and weed control by hand-hoe is easy. Due to their shallowness, rooting possibilities and water storage capacity are limited. Hence, drought-resistant crops (sorghum, cotton, sweet potato, cowpea, tepary bean) are recommended. However, many farmers try to grow maize as it is their preferred food crop. The degree of oxenization is high; over 50% of the households are ox-plough owners. Although manure is available, it is not applied as the current soil fertility level are considered to be sufficient. Transportation and labour problems may also playa role. Due to increasing conflicts between farmers practising a mixed farming system and pasturalists the latter have started to migrate elsewhere.

lbushi soils can easily be overworked. Although agriculturally speaking, they are fertile, their physical properties require care to preserve crumb-structure and avoid wet-weather poaching and dry-weather pulverization. Careful conservation is required as both wind and water erosion threaten its sustainability .

Although farmers are growing maize, it is a risky enterprise; yields are low and frequent crop failures occur. Rice cannot be grown in this area and the cash value of ot11er locally produced food crops (sorghum, sweet potatoes) is limited. Farmers have no other option but to grow cotton if they want to earn cash to stabilize their system. Therefore, cotton remains and will remain an important local crop. However, the cotton area planted on each farm, is highly dependent on the offer of reliable and favourable prices. Cash obtained from cotton sales is used to buy maize (their preferred food) or is invested in livestock.
At present, possibilities for cotton expansion may be found in an expansion of acreage grown within each farm. There are few other economic and crop enterprises. As such expansion increases the weeding

constraint, research and development efforts should be aimed at addressing this issue. However, efforts should take into account dry-Iand farming practices and soil conservation methods. Introduction of ox-weeders should be accompanied by development of suitable minimum soil tillage packages. As new ginneries are constructed in this area, there is an urgent need to address farmers' problems, especially with a view to minimizing environmental degradation. Applied research is urgently required.

5. Sukuma system on Kikungu and Nduha dominated landscapes

Little information is available on the current farming systems in these two different physiographic units. The key criterion to differentiate the two units is their parent material; Kikungu soils have developed from gneissic or granitic rocks; Nduha soils have developed from basic metamorphic rocks and associations with banded ironstone are common.

Kikungu and Nduha soils are mainly found on gently undulating slopes and plains. However, Kikungu soils may also be found in a landscape with hill-footslope catena's. Similarly, Nduha soils are frequently found on the gently foots lopes of hill-footslope catena' s; the gentle footslopes have then developed from basic metamorphic rocks and the hills (consisting of banded ironstone) are high, steep and rocky (e.g. in the area around Geita). However, the hill tops do not carry a boulder tors which is so typical for local granitic hills. As stated before the local names Kikungu and Nduha are often intermixed by farmers; therefore confusion is common. Both soils are reddish in colour; the name locally used strongly depends on the area where the Sukuma settlers originated from. A more detailed and better characterization is urgently required.

Judging from a technically point of view the texture of the two soils differs; Nduha has a higher clay fraction, which may explain its higher natural soil fertility .However, soil fertility of both soils can be easily reduced to low levels due to frequent cropping. Based on the experience of the FSR team its appears that soil depth, rainfall amount and distribution, and enrichment with volcanic ash are important additional factors to understand local farming practices. The future will learn if these factors are more important than the present criterion (parent material) to distinguish different farming systems. Two examples will illustrate these considerations .

Between Maswa, Bariadi and northern Meatu there exists an extensive area with a more fertile Kikungu soil; probably due to some enrichment with volcanic ash these Kikungu soils have a higher clay content. These Kikungu soils are deep. Local rainfall is relatively adequate and reliable. As a result people are growing a lot of maize, which is used as a food and cash crop (FSR project, 1989) .The second food crop is sorghum. Cotton and rice are of minor importance. People still migrate to this area. Since the 1960s fields are ploughed by oxen and maize has become the dominant crop. Continuous cropping on rather extensive fields has increased the weeding constraint. The trend here is towards the investment of more labour to maintain yields. Farmers try to maintain soil fertility levels and decrease the weed problem through mixed cropping practices. In Ipililo and Kisesa ward the maize/pigeon pea mixture has become common. Maize and pigeon pea are both planted early (October-November). After reaching maturity maize is stooked in the field (April-May). Stooking provides space for the pigeon pea plants which continue growing using residual moisture. In addition to shading out weeds (thus keeping fields clean) and nitrogen fixation, pigeon pea provides much fuelwood (Kileo, 1992; Bunyecha, 1994).

In the hilly southwest area of the former Kwimba district (currently within Misungwi district) there are limited areas with Nduha soils. These Nduha soils are however shallow. Although rainfall is rather favourable farmers prefer to plant pearl millet. Probably the soils are too shallow to support maize with sufficient residual soil moisture during the January-February dry spells. However, difficulties with the establishment of maize in a bushy environment may also playa role; germinating maize seeds are tasty and are often dug out by wild animals.

Our understanding will only increase through diagnostic surveys, farmers' interviews, on-farm research and more detailed soil and landuse surveys. It is anticipated that soon it will be possible to propose anew and better differentiation among the Nduha/Kikungu farming systems. It is again emphasized that we are at the start of a process requiring regular updating.

Appendix 3 Farmers' descriptions and classification of soils in Iteja village
(extract from Oudwater et al 2000)

1 Mbuga
Classification criteria:
(a) fertility/productivity (7 out of 9)
(b) colour (2 out of 9)

Most farmers associated Mbuga with high fertility, commenting that it was very productive (= a heavy soil). Its black colour was of minor importance. *Mbuga* is located in valley bottoms, near the river. If it dries, the soil becomes very hard and cracks, the sub-soil underneath becomes very hard, and is therefore difficult to cultivate. If wet, the soil becomes very sticky. It is initially difficult to cultivate, but after some rainy days it becomes possible. At the onset of rains, the infiltration rate is good because of the cracks, but if the soil gets saturated, it is prone to waterlogging which can last from one week up to two months. Usually, *Mbuga* was ranked first in terms of fertility and farmers said fertilisers were not needed.

During the interviews, people had different views concerning erosion, a few said *Mbuga* is not prone to erosion, whereas others did not agree. During the focus group discussion, the participants reached a consensus on soil erosion. When the soil is dry, the soil contracts and can not be carried away easily, but if wet, the soil expands, becomes muddy and the topsoil can be carried away. The topsoil becomes light due to cultivation and rain. Only cultivated soil is prone to erosion, uncultivated *Mbuga* is mostly covered with vegetation.

Crops: maize, sorghum (if low rain fall), chickpeas, coriander. Not suitable for:
- cassava (dries up in dry season, produces too much vegetative growth due to high fertility)
- groundnuts, bambara nuts (too sticky, preference for sandy soils)
- cotton because of waterlogging.

Constraints: flooding, waterlogging (when there is high rainfall, rice is planted instead of maize), pests and rodents eating the seeds, maize stalk borer (ashes are put in the maize cobs), S*triga* (weeding before flowering) and other weeds like *mabalala* and *manunghi*.

Soil depth: There is little consistency in soil depth and the underlying sub-soil. Soil depths vary from 1 to 15 feet and deeper. Sub-soils are described as gravel, sandy, clayey and white or red in colour.

Vegetation: *Cyperus spp, Matenya, Migu, Malago, Majinji, Malambolambo, Madete, Malandolando, Kafula.*

In daily language, different names are used for areas of *Mbuga* soils located in different parts of the village. (A similar pattern exists for *Itongo).* A farmer might tell his neighbours that be is going to the *Halawa* and it will be understood that he is going to his *Mbuga* fields near the Magogo river. Three different named areas of Mbuga soils were identified - Ng'ong'oli:near the river Ng'ong'oli; Halawa; very fine, a bit drier, near Magogo river; Igaga: near the lake, only few people cultivate there, it is very wet.

2 Ibushi
Classification criteria:
(b) fertility/productivity (5 out of 9)
(c) colour (3 out of 9)
(d) location (2 out 9)
(e) occasional criteria: texture, water holding capacity and workability

Ibushi is located near *Mbuga*, usually in between *Mbuga* and *Itogolo*. It is black in colour, but lighter than *Mbuga*. In general, *Ibushi* is similar to *Mbuga,* but less fertile. However, it has higher fertility than *Shilugu*. When the soil is dry, it is fine, friable and easy to cultivate, but if it has been left fallow for a while, it becomes hard and more difficult to cultivate. If it is wet, it is sticky and difficult to cultivate, but less so than *Mbuga*. Different opinions prevailed as to whether *Ibushi* was prone to waterlogging or not. During the final focus group discussion, it was agreed that the infiltration rate is moderate to good. *Ibushi*, located on flat land near *Mbuga* is prone to waterlogging, whereas *Ibushi* located on higher slopes does not get waterlogged; the water will just run off along the slope. In lower and flat parts of *Ibushi*, crops may remain stunted due to waterlogging. Moisture is retained longer than in other soils like *Shilugu* and *Shigulu*. It is not prone to erosion because the soil particles are heavy and sticky.

Crops: sweet potatoes, cotton, maize, sorghum (susceptible to *striga* infestation), rice (only if water stands on the surface and bunds are constructed for water harvesting), green grams, groundnuts and cassava (not common). Not suitable for;
- bullrush millet (*madohi* disease, at flowering stage, no grains are formed, and the plant becomes black and sticky)
- bambara nuts (because of high fertility and vegetative growth, pods can not be formed due to stickiness of soil)
- cowpeas (vegetative growth).

Soil-depth There was no consensus about soil-depth and underlying sub-soil. Soil depth varied from two to ten feet. Sub-soil was mostly described as white sandy soil followed by gravel, *Mbuga*, *Ikerege* and big red stones.

Constraints: depending on period of fallow, difficult to cultivate if dry, *striga* infestation (especially for sorghum, less severe with maize), crops wilt easily during dry spells. During high rainfall there are problems of waterlogging which damages the harvest. Declining fertility if continuously cropped, especially during maize cultivation.

Vegetation: *Magahuluda, Mitundulu, Migu, Bunani, Malegi, Matenya, Manunhi and Lugobi.*

3.Nduha

Classification criteria:
(a) colour (red) (3 out of 7)
(b) good fertility (3 out of 7)

Nduha occurs in small patches, and is mostly located in between *Itogolo* and *Ibushi* and then *Mbuga*. The colour is very red compared to other red soil types. During interviews and the final focus group discussion, it was stated that if *Nduha* soil is dry, it is fine, friable and easy to cultivate, similar to *Shilugu*. However, a few farmers said that *Nduha* is hard when dry and therefore difficult to cultivate. The soil is cultivated immediately after the first rains before it gets too sticky and difficult to cultivate. The infiltration rate is good, water does not stand on the surface and it remains moist for two to three days. Farmers had different opinions whether *Nduha* is prone to erosion or not. During the final focus group discussion, they agreed that erosion depends on the location and the amount of rainfall. It is more prone to erosion on slopes than in flat areas. At the onset of rains, the light, fine and dry soil becomes very muddy and is easily carried away, but after heavy rains the soil becomes heavy, very sticky and less prone to erosion. Fertility was said to be moderate to high; fertilisers are not required.

Crops: maize, cassava, sweet potatoes, groundnuts, green grams, in general almost all crops. Not suitable for:
- rice (water does not stand on the surface)
- cotton (vegetative growth)
- sorghum (*striga* infestation).

Constraints: crops wilt during a dry spell, *striga* (sorghum and maize)

Soil depth: Farmers are not sure about soil depth and sub-soil. Soil depth varies from 6 to 10 feet; occasionally, it was said that white gravel was found at a depth of 6 feet.

Vegetation: *Magahuluda, Malamata, Lugobi, Manunghi, Makumbokombo, Malegi, Migu, Mitundulu, Bululambuli*

4 Shilugu

Classification criteria:
(a) fertility/productivity (7 out of 12)
(b) location (former homestead/upland) (3 out of 12)
(c) colour (black) (2 out of 12)

The name *Shilugu* means a place where people have been living and homesteads and kraals have been located in the past. The soil is a mixture of ashes, cow dung and household waste. A few farmers described it as an artificial soil on top of an original soil type. There was a high level of consensus about the soil characteristics of *Shilugu* and the descriptions given were consistent and straightforward.

The colour is grey; a mixture of ashes and cow dung. The soil is fine, loose and easy to cultivate whether dry or wet. If wet it is a little bit sticky but less so than *Shigulu*. The infiltration rate is good; water does not stand on the surface. The soil is able to absorb a lot of water because of the mixture of ashes and cow dung. The soil remains moist for five to seven days, but dries fast as well. Most farmers said that *Shilugu* is hotter than *Shigulu*. Almost all respondents agreed that *Shilugu* is not prone to erosion because if it gets wet, the soil becomes very heavy and therefore is not easily carried away (the mixture of ashes and cow dung enables high water absorption). The fertility is good and there is no need for fertilisers.

Crops: maize, cotton, sorghum, green grams and cow peas. Not suitable for:
- rice (water does not stand on the surface)
- groundnuts (due to high fertility, mainly vegetative growth)
- bambara nuts (vegetative growth)
- sweet potatoes[6] (grow, but do not become as sweet as in other soil types)
- cassava does not do very well, and tastes different from cassava grown in other soil types.

[6] After harvest the sweet potatoes are dried, sliced and stored (*Michembe*).

Constraints: soil is hot, crops wilt easily during a dry spell because the soil is very fertile[7]

Soil depth: There was significant variation in the soil depths and underlying sub-soils mentioned by farmers, because *Shilugu* is an "artificial" soil on top of an original soil type, which consequently can vary from location to location.

Vegetation: *Lugobi, Malamata, Shimama, Manunhi, Bunani, Kafula*

5 Shigulu

Classification criteria:
(a) fertility (6 out of 11)
(b) location (uplands, anthill) (3 out of 11)
(c) colour (2 out of 11)

The name *Shigulu* means "raised land" a sign that there used to be an anthill at that spot. It occurs in small patches. There was a high level of consensus about the soil characteristics of *Shigulu* and the descriptions given were consistent and straightforward.

The colour depends on the location; within the lowlands (*Mbuga* and *Ibushi*) it is black, and in the uplands the colour is grey. If dry, the soil forms clods (*ibombile*), which are very hard and difficult to cultivate. If wet, it is sticky but a bit easier to cultivate (after rains it takes one day before it is possible to cultivate). The infiltration rate is good, the water does not stand on the surface and it remains moist for about a week. The soil is not prone to erosion because it is mostly located on flat land so there is no run-off. Also the soil is heavy and sticks and does not contain any sand. The fertility is good and there is no need for fertilisers.

Crops: cotton, sorghum, green grams, groundnuts, maize, cow peas and sweet potatoes (if there is enough rainfall). Not suitable for:

- rice (water does not stand on surface)
- cassava (mainly vegetative growth and small tubers)
- bambara nuts (vegetative growth)
- chickpeas (favour a place with enough moisture after rains).

Constraints: *striga* due to continuous cropping of sorghum. It is a hot soil that dries fast therefore only a few crops can be cultivated in times of low or no rainfall; hard to cultivate if dry, termites (attack cow peas, maize especially when harvested late), weeds (*Shimama*).

Soil depth varies from seven feet up to ten and underlying sub-soil is described as white stones/gravel which are named differently (e.g. *bushanongu*, *gymbia* or *mabumba*).

Vegetation: *Lugobi, Manunhi, Shimama, Malamata, Kafula* and *Bunani*.

6 Itogolo

There was a wide range of classification criteria with no real consensus among the respondents.
(b) texture
(c) colour
(d) crops cultivated
(e) productivity
(f) workability
(g) water holding capacity
(h) location

Different explanations were given about the meaning of *Itogolo*. The explanations often referred to its location along the slopes towards *Ibushi*. Other explanations focused on the texture. The colour is mostly described as between black and white (grey). If dry, the soil is very hard, some clods are formed which makes the soil very difficult to cultivate. If wet, the soil becomes slightly sticky and easier to cultivate. Compared to previous soil types (1-5), the infiltration rate is said to be moderate to poor, especially after it gets saturated. Water can be standing on the surface for one to seven days, depending on the amount of rainfall.

Different opinions prevailed about erosion. A few stated that the soil is prone to erosion if it is cultivated, during heavy rains and if it is located along the slope. During the final focus group discussion and some interviews, it was explained that it is

[7] Explanation by one of the local researchers: In dry times there is no water to dissolve the nutrients therefore the soil becomes very hot.

not prone to erosion because the soil is heavy and sticky. In general, fertility was said to be moderate to poor. During the focus group discussion, it was agreed that fertility was poor for most crops apart from rice, which is cultivated within bunds for water harvesting.

Crops: rice, maize, sorghum, groundnuts, green grams, cowpeas, millet and sweet potatoes. Not suitable for:
- cassava (soil is too hard, sticky and dries to fast)
- chickpeas and bambara nuts
- Some farmers said that maize does not grow well because the soil dries too fast and has too low fertility.

Constraints: soil dries fast or gets waterlogged during heavy rains, *striga* infestation due to continuous cropping of sorghum and maize, low fertility, weeds, rodents.

Soil depth: varies from one foot up to ten feet. Most informants mentioned that the sub soil is a mixture of white gravel/sand (*Bushanongu, Gymbia, Mabumba, Igereshi*), a hard pan was mentioned as well.

Vegetation: *Samang'ombe, Manunhi, Kahuluda, Madasa, Majinji, Matenya*

7 Itongo

The term *Itongo* seems to be used in two senses; as a land use description and as a soil type. During household interviews, most respondents mentioned *Itongo* as a soil type within their land holding (11 out of 15). However, during the sorting task (5 out of 8) and especially during the focus group discussion, participants were straightforward in pointing out that *Itongo* was definitely not a soil type and even denied that they had ever said that *Itongo* was a soil type. During the household interviews, respondents were inclined to mention a more general name, whereas during the sorting task the respondents were presented more detailed soil types for categorisation. Therefore, farmers were somehow encouraged to go into further detail that might have resulted in a more refined categorisation of all soil types.

Criteria for sorting:
a) location (*Itongo* = upland) (5 out of 8)
b) sandy (texture) (1 out of 8)
c) same crops (1 out of 8)
d) water holding capacity (low) (1 out of 8)

Itongo as a land use description
Itongo refers to an area/shamba (=field) in the uplands (=*Magulya*). The difference between the use of *Itongo* and *Magulya* is not very clear. An elderly farmer explained that *Itongo* is an area where their grandparents and parents used to live and die. Their children have moved to lower lands, but they still call these areas *Itongo*. *Itongo* is an area where different soil types like *Luseni, Shigulu, Shilugu, Ilago, Inyalala, Ikerege, Ibambasi* and *Nduha* can be found. An *Itongo* field is suitable for any crop cultivation e.g. cassava or groundnuts.

Itongo as a soil type
A few respondents said that *Itongo* is red in colour whereas others described the colour as white. Two respondents said that there are two different types of *Itongo*, a red and a white one, but having the same name. In general, the name *Itongo* was explained as a location in the uplands and/or a mixture of different sandy particles. Sometimes *Luseni* was mentioned as well, *Itongo* being a mixture of *Luseni* and fine particles.

In both ways, dry or wet, it is fine, friable and easy to cultivate. The infiltration rate is good, there is no water standing on the surface apart for a few hours immediately after heavy rainfall. The soil remains moist for about a week. The majority of the respondents said that the soil is prone to erosion especially after heavy rainfall, because of its location along the slope (run-off) and its light particles. A few mentioned the construction of bunds for protecting their plots from erosion. The fertility is poor and there is a need for fertiliser application.

Crops: cotton, maize, green grams, cowpeas, sorghum, bambara nuts, beans and sweet potatoes. Not suitable for:
- rice
- chickpeas
- one respondent mentioned sorghum (*striga*) and maize (poor fertility)

Constraints: crops wilt easily after a dry spell (bunds construction for water harvesting), *striga* infestation, weeds, rodents and low fertility.

Soil depth: varies from 30 cm up to 6 feet, the sub-soil is described in different ways: red stones, white gravel, red gravel and sand.

8 Ikerege

Classification criteria:
(a) workability (difficult to cultivate because of hard pan) (6 out of 17)

(b) fertility/productivity (low) (4 out of 17)
(c) Location (2 out of 17)
(d) Colour (2 out of 17)
(e) infiltration rate (1 out of 17)

A few respondents mentioned that *Ikerege* and *Ibambasi* are different names for the same soil type. However the majority of respondents said that they were different. This was confirmed during the final focus group discussion. Farmers' descriptions were quite consistent.

Ikerege is white in colour and means an unproductive, hard soil that is very hard to cultivate and even grasses do not grow well on it. If dry, it is hard, clods are formed and the hoe might break trying to clear the land. Some farmers explained that *Ikerege* has a very shallow top layer of loose sand that is easy to cultivate, but is underlain by a hard pan. If wet, the soil is still hard but a bit easier to cultivate. Some said that it is still hard and dry but according to others, it gets a bit sticky. The infiltration rate is poor, and sometimes water stands on the surface (normal rainfall up to two days and after heavy rainfall, up to a week). If bunds are constructed for water harvesting, the water can be standing for one to two months (also confirmed during the focus group discussion). According to other respondents, water mainly runs off along the slope and there is not a problem of waterlogging. During the focus group discussion and most interviews, it was pointed out that *Ikerege* is not prone to erosion because the soil is hard and sticky. Some said that the topsoil is prone to erosion because it is light, especially during heavy rainfall. It has poor soil fertility.

Crops: Half of the respondents said that *Ikerege* is not suitable for any crop production because of low fertility and hard pan. However, others mentioned crops such as ground nuts, maize, sorghum, green grams, cotton, rice (bunds for water harvesting) and sweet potatoes. According to the latter ones, *Ikerege* soils were not suitable for crops such as cassava (hard and dry), cow peas and bambara nuts. There are probably different mixtures of *Ikerege,* possibly depending on the soil depth of an underlying hard pan. Another possibility is that it depends whether people are forced to cultivate poor soils or have the choice of better, more productive soils.

Constraints: not suitable for any crop production at all, poor fertility, hard to cultivate, *striga* infestation and prone to waterlogging.

Soil depth: varies from 1-6 feet, the sub-soils mentioned are *Bushanongu/Mabumba*; a mixture of white clay and gravel and a hard pan. Most respondents did not know the sub-soil because it is too difficult to dig up an *Ikerege* soil.

9 Ibambasi

As already explained in section 4.2.8 *Ikerege*, some farmers said that *Ibambasi* is a different name for *Ikerege*. However, during the focus group discussion and most interviews, *Ibambasi* was described differently from *Ikerege*. The main differences are that *Ibambasi* is harder than *Ikerege* and no vegetation and any crop production is possible on *Ibambasi*.

Classification criteria
(a) workability (hard to cultivate)
(b) waterlogging/ poor infiltration rate
(c) location
(d) an unproductive soil

Ibambasi is white in colour, and located in small patches in the upland. *Ibambasi* is a very hard and unproductive soil on which no vegetation or crops grow (white hard pan = *Sindamu*; "you can't use a hoe"). If dry, it looks like it is plastered; it is too hard to break and therefore difficult to cultivate. If wet, it is slightly sticky but it dries very fast (there is no moisture underneath) and becomes very hard again and remains difficult to cultivate. Different opinions exist about the infiltration rate. All agree that the infiltration rate is poor, but some said that the water does not stand because of run-off, whereas others said that water could stand for a number of days. It is likely that run-off and or standing water probably depends on the location (slope, flat land). *Ibambasi* is not prone to erosion because the soil dries very fast and is very hard, so soil is not being carried away by water run-off. Soil fertility is very low.

Crops: respondents who stated that *Ibambasi* is the same to *Ikerege* mentioned crops like groundnuts, sorghum, green grams, cow peas. Others, who said that *Ibambasi* clearly differs from *Ikerege,* said it was not suitable at all for crop production. Very few mentioned that rice can be cultivated if bunds are constructed for water harvesting. Not suitable: for almost all crops, apart from the crops listed above.

Constraints: not suitable for crop production, low soil fertility, *striga* infestation, low fertility, very difficult to cultivate.

Vegetation: In general, it was said that no vegetation at all grows on *Ibambasi*. Others who said that *Ikerege* and *Ibambasi* are the same, mentioned *Lugobi, Manungi* and *Bunani*.

10 Luseni

Classification criteria:

A wide range with little overlap:
(a) texture (sandy)
(b) location (within *Itongo*)
(c) water holding capacity (low)
(d) same crops cultivated
(e) colour

During interviews, two different colours were mentioned, white and red. During the focus group discussion, it became clear that there were two different types of *Luseni*, a white and a red coloured one depending on the size of the particles. The red *Luseni* has got larger particles and is located on the lowland. The white *Luseni* has got smaller particles and is located in the uplands. According to the respondents, there is no difference between them with regard to workability, fertility, water holding capacity etc.

Luseni is described as a sandy soil type, easy to cultivate with a poor soil fertility. If dry, it is friable, but can be either difficult or easy to cultivate (no consensus). During the focus group discussion, it was agreed that *Luseni* becomes very hard during the dry season, and is therefore difficult to cultivate. If wet, it is not sticky and easy to cultivate. Infiltration rate is good, but different opinions exist on whether it is prone to waterlogging or not (majority of respondents stated that water does not stand on the surface). During the focus group discussion, it was agreed that water does not stand on the surface and that *Luseni* remains moist for two to three days. It is prone to erosion if located on a slope and during heavy rains, because it is a light soil, thus easily carried away. It has low soil fertility.

Crops: groundnuts, green grams, cowpeas, bambara nuts, sweet potatoes. In a few cases maize, sorghum and cotton were mentioned. Not suitable for:
- chickpeas
- rice (soil dries too fast)
- maize, sorghum and cotton (all because of low fertility)

Constraints: low fertility, hot soil, crops wilt fast, waterlogging, weevils (sweet potatoes), weeds and need for fertilisers.

Soil depth varies from one to six feet with all different sub-soils.

Vegetation: *Majinji, Magogote, Bunani, Manungi, Lugobi, Samang'ombe*

11Luseni ludito

Luseni ludito (ludito = heavy = fertile) was mentioned once during the free listing. During the sorting task, half of the respondents did not know *Luseni ludito* whereas the other respondents mostly put it together with *Luseni* in one group.

Classification criteria:
(a) location (2 out of 5)
(b) same crops (2 out of 5)
(c) texture/sandy (1 out of 5))

Most participants of the focus group discussion argued that *Luseni ludito* was not a distinct soil category at all. According to them, *Luseni* is always red in colour. It might be dark red when it has not yet been cultivated, but it becomes lighter in colour after continuous cultivation. As an old female farmer said: "No *Luseni ludito*; you can't say I have harvested a good crop on *Luseni*, no you always get poor yields!" However, a few participants confirmed that they made a distinction between different types of *Luseni*, and would call the more fertile one *Luseni ludito*.

In general, *Luseni ludito* has a higher soil fertility than *Luseni*, but confusion exists about the size of soil particles (fine and large). The colour is in between red and black. If dry, the soil is friable and varies from soft to hard, depending on the size of soil particles. Most respondents said that it is easy to cultivate. If wet, the soil is slightly sticky and easy to cultivate. The infiltration rate is good, the water does not stand on the surface, but assessments of its water holding capacity varied significantly, from being moist for two days up to one month. Most respondents agreed that the soil is not prone to erosion, although if it is located on a slope it might be washed away by water run-off. The soil fertility is low, so there is a need for fertilisers. The soil depth varies from two to six feet. The sub-soils mentioned were *Luseni lope* (white *Luseni*) and *Mashololo* (red stones.

Crops cultivated are: cassava, cow peas, green grams, maize, beans, ground nuts and bambara nuts. One respondent said that *Luseni ludito* is not suitable for any crop cultivation due to low fertility and another respondent said that only sweet potatoes could be grown because of waterlogging.

Constraints are waterlogging, *striga* infestation and in times of low rainfall and a dry spells, crops wilt very fast (hot soil).

12 Shikalanga

Classification criteria:
Many different criteria were used to group *Shikalanga* with hardly any overlap at all.
(a) colour
(b) same crops
(c) productivity
(d) workability
(e) poor infiltration rate
(f) location
(g) the same as *Luseni*

During the focus group discussion and interviews, *Shikalanga* was explained as a name for a field where groundnuts are cultivated (groundnuts = *kalanga*), usually located within *Luseni* or *Itogolo*. During the focus group discussion it was added that if somebody grew groundnuts in *Ibushi*, (s)he would not call it *Shikalanga* because of *Ibushi's* high fertility. *Shikalanga* refers to a groundnut field on less fertile soils. During individual interviews, however, *Shikalanga* was described as being a distinctive soil type, although these descriptions are not consistent at all, which can probably be explained by the fact that *Shikalanga* is a groundnuts field that can be located within different soil types (see above).

Little consistency exists on the colour; white, grey, black and red like *Luseni*. If dry, it is friable, but can be either soft or rough and if rough, it is hard to cultivate. If wet, it is not sticky and is easy to cultivate. Different opinions exist about the infiltration rate, ranging from good to moderate or poor. Water can stand on the surface for one to two days, and it remains moist for three to seven days. Half of the respondents said that *Shikalanga* is not prone to erosion because it is a heavy and fine soil whereas others stated that it is prone to erosion because the soil is light and loose. It has low soil fertility.

Crops: mainly groundnuts, but also other crops such as sorghum, cowpeas, sweet potatoes and bambara nuts. Not suitable for maize (low fertility).

Constraints: *striga* infestations, low fertility, weeds and limited numbers of crops that can be grown.

Soil depth: varies from two up to six feet with different sub soils as well: *Mashololo* (large red stones), *Bushanongu* (white gravel and clay) and *Ikerege*.

13 Ilago
Almost all respondents said that *Ilago* refers to the same soil as *Inyalala, Shinele,* and *Sota.* This was also confirmed during the final focus group discussion. Only two farmers said that *Ilago* was similar to *Inyalala* and *Shinele* but that *Sota* was different. The day before the focus group discussion, we conducted a transect walk assisted by farmers. Two of them had said that *Ilago, Inyalala, Shinele* and *Sota* were the same, whereas the other two had agreed that *Sota* was different from the other three. After the latter had shown and explained the differences between *Sota* and *Ilago* etc., the other two farmers agreed. However, these farmers changed their mind the following day at the focus group discussion saying that these were just different names for the same soil type.

Classification criteria:
(a) different names for one soil type (*Inyalala, Sota, Ilago* and *Shinele*) (3 out of 7)
(b) ability to hold water (3 out of 7)
(c) of minor importance was the location (1 out of 7)

Two colours, red and white, were mentioned. At the focus group discussion farmers said that *Ilago* has the same properties as *Luseni*, the only difference is the wetness. *Ilago* is always wet and its sandy soil particles are a bit finer than in *Luseni*. This could explain the two different colours because *Luseni* also occurs in two different colours, red and white. *Ilago* is described as being wet throughout the year ("*land which is always wet"* or *"and located on a spring"*). In both ways, dry and wet, the soil is friable and easy to cultivate. The infiltration rate is poor and water can be standing on the surface for a long time, some months up to a year. Water is underneath the surface throughout the year; if you dig a hole, water comes out. *Ilago* is not prone to erosion because the soil is heavy and covered by grass that holds the soil together. The soil fertility is low, there is a need for application of fertilisers. *Ilago* is located in the lower parts of the uplands.

Crops: sugarcane, sweet potatoes (during the dry season it is used for food production and planting materials (vines) to plant at the onset of the raining season), cabbage, tomatoes, onions, rice and maize (during the dry season). Not suitable for all other crops due to waterlogging such as sorghum, millet, chickpeas, cowpeas and bambara nuts.

Constraints: limited number of crops can be grown, low fertility and weeds like *Lugobi* and *Magogote*.

Soil depth and subsoil: soil depth varies from two to seven feet. There was no consistency on the type of sub soil.

14 Inyalala
The same as *Ilago, Shinele* and *Sota* (see description of *Ilago above*)

Classification criteria:
(a) different names for one soil type (3 out of 7)
(b) water holding capacity (3 out of 7)

15 Sota
The same as *Ilago*, *Shinele* and *Sota* (see description of *Ilago above*)

Classification criteria:
a) different names for one soil type (3 out of 7)

As already explained in 4.2.13, almost all respondents and participants at the focus group discussion said that *Sota* was the same soil as *Ilago*, *Shinele* and *Inyalala*. However, two farmers said that *Sota* was different. According to their description, *Sota* is a stream, where water comes out all the time. On *Ilago*, you would never find water floating along the surface. *Ilago* remains wet underneath throughout the year but the surface can get dry unlike *Sota*. The texture of *Sota* is very fine, if wet it is very muddy and sticky (clay). The colour is dark grey, darker than *Ilago*. Infiltration rate is poor, water moves along the surface. Often farmers direct the water to nearby fields (e.g. *Ikerege*) where rice bunds are constructed for water harvesting. *Mashololo* stones (large red rocks) are found on the surface where the water comes from. These stones can reach to two-three feet deep and there is no water underneath.

16 Shinele
The same as *Ilago*, *Shinele* and *Sota* (see previous paragraph (4.2.13) *Ilago*)

Classification criteria:
a) different names for one soil type (2 out of 4)
b) water holding capacity (2 out of 4)
A significant number of respondents (5) did not know the name *Shinele*.

17 Luzenze
Most people did not know *Luzenze* at all (the name was derived from the PRA report). At the focus group discussion, it became clear that farmers did not recognise it because of the wrong spelling. It should have been *Kisinzi*, which is the same as *Ilago, Inyalala* and *Shinele*.

18 Luzela
Less consistency exists about *Luzela* with regard to its properties such as texture, suitability for crop production, water holding capacity, erosion, soil-depth and sub soils. A few respondents said that *Luzela* was a different name for *Ilago*, because it was wet throughout the year. However, other people said that it was a hard, dry and unproductive soil that belonged to the same group as *Ikerege*. One respondent categorised *Luzela* as a single group because of the red colour and its non-productivity. Although there was a wide range of different descriptions and criteria, they had two characteristics in common; unproductive and poor soil fertility.

Classification criteria (varied a lot with hardly any overlap):
(a) same crops
(b) unproductive (3 out of 7)
(c) colour
(d) workability
(e) water holding capacity
(f) different names for one soil type.

Luzela occurs in small patches in the *Magulya* (=uplands). It is red in colour. If dry, it is friable and easy to cultivate, however a few said that the soil is hard and therefore difficult to cultivate. During the focus group discussion, it was agreed that the soil is very loose, the sand just falls in when digging a pit in a *Luzela* soil. If wet, the soil is not sticky and is easy to cultivate. The infiltration rate is poor, water stands on the surface for three days up to a week and remains moist for two days up to two weeks. Different opinions exist about erosion. Participants of the focus group discussion and a few respondents from the individual interviews said that *Luzela* is not prone to erosion, whereas others stated that *Luzela* is prone to erosion because the soil is very light. The soil fertility is poor.

According to some respondents, *Luzela* is not suitable for any crops because of waterlogging, low water holding capacity and low fertility. In few cases, the following crops were listed: sweet potatoes, tomatoes, sugarcane, cassava, maize, cotton and rice (if high rainfall and construction of bunds for water harvesting). In general, all respondents agreed that only a limited number of crops could be grown due to low fertility and waterlogging which was perceived as a main constraint. During the focus group discussion, it was agreed that Luzela is not suitable for any crop production. Seeds may germinate but the crops remain short and stunted. Vegetation: *Malago* and *Maluha*.

Appendix 4 Iteja study (Oudwater et al 2000) Conclusions and recommendations
Indigenous knowledge is context specific. The use of a number of different tools, applied in different contexts, allowed for cross-checking and refinement. The methodologies for investigation and the social and gender differences among participants, give rise to different emphases and meaning in describing and depicting local knowledge of soils

The study proceeded from broad descriptions of landscape and agricultural livelihoods in the PRA, to a more detailed investigation and analysis. This phasing allowed us to explore the consistency of classification and the differences in the bases for soil categorisation, through an interactive approach. Certain terms used by farmers to describe soils had clear descriptions and definitions while others were ambiguous. The terms used could signify a range of different reference points, for example;

- soil types (clearest for the categories which exhibited high levels of consistency in grouping and consensus in description, e.g. *Mbuga, Shilugu, Shigulu, Ikerege and Ibambasi*)
- soil combinations or mixtures (different types of luseni)
- broader land areas (*Itogolo* might fall into this category)
- specific place names for certain village areas, such as the different locations where *Mbuga* was found
- types of fields, e.g. *itongo*, (a field in the uplands), fields for food crops, fields for groundnuts etc.

The methodology allowed some reflection on the relative roles of direct observation, participatory mapping, household interviews on soil and crop management and the investigation and comparison of soil categories.

Direct observations
Examples were the field observations during the in-depth study and the transect walks. These allowed discussion to be linked with physical identification of the soil in question and generated lively discussions among all the participants. The transect walks contributed to a better understanding of indigenous soil categories by encouraging discussions among farmers and between farmers and the research team, based on concrete examples of farmers' classification that could directly be cross-checked. An important observation made during both the transect walks and field observations, that did not come out of the sorting tasks, household interviews or group discussions, was that farmers recognise "combined" soil types, which have properties of two different soil types. The more detailed scale meant that transect walks were more likely to discuss soil types rather than land systems or place names. Micro level transitions were identified in contrast to the large land areas located on aerial photos. Where the transition points were geo-referenced, these could be linked to the IK soil maps.

Participatory mapping
Generally mapping seems to encourage delineation of land use, or broader land classifications or topographical sequences at village level, rather than the smaller-scale variations in soil types which farmers identify on transect walks or take account of in cropping decisions. Only four categories were identified on the maps although discussions covered many more. Farmers recognise that the less frequent soil types, *shigulu*, *shilugu* are included in the larger areas of *Itogolo* and *Itongo* but they were not mapped. There was marked similarity between the different maps drawn irrespective of levels of farmers' participation. However, the mapping exercise allowed the comparison of farmers and scientist maps using GIS.

Household interviews
Household interviews were useful to explore actual crop management in relation to different soils and soil moisture conditions. It was valuable to understand from the household perspective the implications of access to different soil types. Access to a range of soil types gives flexibility in dealing with drought or heavy rainfall and allows a broader range of crops to be grown.
Discussion of soil categories
The detailed information on the different soils generated in the in depth-study is highly relevant to actual management decisions and to development of potential management improvements. Fertility was the

main criteria of classification, followed by location, colour, waterholding capacity, workability, suitability for crops and texture.

The free listing exercise was helpful in identifying the maximum range of terms which could then be examined. The sorting exercise helped to increase understanding of farmers' perceptions by exploring the relationships of soil types to each other and their similarities and differences. The focus group discussions were very useful to further refine this long list and to contextualize the information gathered during different stages of the study. During individual interviews, farmers tended to describe the soil in their particular field, whereas during the group discussions, descriptions were at a more abstract level. In addition to greater abstraction, the group discussion also helped to clarify and refine previous inconsistencies in descriptions because different soil properties, such as erodibility, were put into the context of the location of soil type (slope/flat) and timing of rainfall. The in-depth study allowed researchers to understand where ambiguity comes from, a necessary requirement in order to address particular soil management needs. After these clarifications, indigenous soil classification was a good indicator of crop management practices.

The GIS was useful for storing and managing different information sets and linking their analysis. However, in this study it was mainly used as a tool for analysis by the research team. It is suggested that GIS could be useful for generating maps for feeding back to the farmers' focus groups for clarification and eventually for more practical discussion of possible actions or interventions. This would create a more integrated and participatory use of GIS which could support the exploration of IK.

The research highlights the importance for researchers and extensionists of a systematic exploration of farmers' knowledge and an appreciation of the context in which discussions take place. Interaction between farmers and researchers is itself a learning process, through which shared understandings are reached.