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An integrated approach to sustainable utilisation of land resources for a better environment

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Abstract

The drive to increase food production for the growing population in Uganda is undermined by high levels of environmental degradation which has arisen through increased population pressure, nutrient mining, deforestation, poorly managed hillsides, and inappropriate use of wetlands. The environmental degradation has led to soil erosion, siltation, and pollution of water resources. Agricultural productivity is further exacerbated by the very low efficiency in the capture and utilisation of rainfall in smallholder agricultural systems. This paper highlights some of the research and pilot activities that have been undertaken to develop and promote technologies to mitigate further natural resource degradation. These include a catchment approach to evaluate the effects of landuse on agricultural productivity and the environment. Participatory approaches were used to identify problems and manage land resources for increased crop production and to reverse the land degradation trends. These approaches have led to a better appreciation of land degradation and development of appropriate land management packages/ tools that can be adapted to other agro-ecological zones.

Key words: Environmental degradation, farmer experimentation, integrated soil management, participatory learning,

Introduction

Although a backbone to Uganda's economy, agricultural production has registered a progressively declining trend (FAO, 1999). A widening gap exists between actual and potential yields in smallholder agriculture, coupled with accelerated degradation of land and water resources. The need to increase food production for the growing population is undermined by high levels of environmental degradation. This is reflected in declining soil fertility partly due to nutrient mining through crop harvests with limited nutrient replenishment (Wortmann and Kaizzi, 1998; Sanchez *et al.*, 1997), low soil fertility mainly N, P deficiencies (Bekunda *et al.*, 1997). Extensive environmental degradation also arises from poorly managed hillsides, resulting in erosion and runoff (Bagoora, 1990), destruction of important habitats (forests, water sources, wetlands) through reclamation, cutting and burning practices coupled with poor land management practices. Degradation is worsened by high population densities, resulting into encroachment on marginal lands and reduced or elimination of fallow periods (Bojo, 1996). This is exacerbated by the very low efficiency in the capture and utilization of water in smallholder rainfed agriculture. It is estimated that up to 80% of the rainwater falling on crop fields or rangelands can be lost as evaporation or runoff causing erosion, flooding and sedimentation of rivers. Inadequate water often contributes to poor crop yields and lack of response to applied fertiliser (FAO, 1996). In addition, poor infrastructure and inadequate access to markets and support services limit farm productivity. Furthermore, farmers' use of strategies like crop diversification, sustainable intensification, and use of an enterprise approach to farming is limited (Scherr, 1999). A consequence of all these is food insecurity and widespread poverty. In the East African highlands for example, 51% of the households are 'resource poor' and live below the poverty line (Krishna, *et al.*, 2004).

Research and development activities in the region have developed many agricultural and natural resource management (NRM) interventions to mitigate constraints and improve agricultural productivity. These encompass both soil and water conservation (SWC) activities (Wangati, 2000; Zake and Magunda, 1998; Thomas *et al.*, 1986) and soil fertility management (SFM) based on use of mineral and organic fertilisers (Bekunda *et al.*, 1997) and biological nitrogen fixation (BNF) systems. In many instances, however, uptake of research products has been limited and restricted to pilot project areas. Consequently, smallholder farmers are hitherto unable to reverse losses in soil nutrient supply using mineral fertilizers due to socio-economic factors, or organic sources because of high labour requirements, limited quantities of such materials available, etc. Among the commonly cited reasons for the poor adoption of soil management technologies are that many of the recommended techniques mismatch the local conditions and unable to address the priorities which are relevant to local people (Hudson, 1992; Bunch, 1999). Limited impact of research-generated knowledge in soil management on farmers' practices, system profitability and sustainability has also been attributed to lack of farmer involvement in problem diagnosis and research planning (Gundel *et al*., 2001). The adoption of technologies for improving NRM has also been severally limited by lack of suitable innovative and participatory approaches to generate and disseminate technologies, poor links between research and development, and diverging policy and community needs. Some NGOs have had success in helping farmers with soil management but these effects tend to be very local and rarely significant at a district or national level. Examples of success on a larger scale are few and can usually be linked to a level of market access that is unrealistic for the most of Africa (Tiffen *et al*., 1994; Wiggins, 1981).

Partly as a result of the perceived 'failure' of the conventional institutions to deal with the soil problem there is today a much broader multidisciplinary interest in land management. It is now recognised that new approaches to soil management need to be participatory, interdisciplinary, locally based, sensitive to people's problems/priorities and combining resource conservation and livelihood improvement (Ghai, 1992; Ellis-Jones, 1999). By incorporating rainwater harvesting/soil erosion control with judicious use of mineral and organic fertilisers, Integrated Soil Management Approach improves soil productivity, increasing crop yields and achieving increased, sustainable agricultural production, food security, farmers' income and environmental protection. This integrated approach has been applied in a number of studies discussed in this paper, to address the deteriorating soil productivity leading to environmental degradation.

Interventions

The Soils and Soil Fertility Management Programme of NARO together with other collaborating institutions, have undertaken on-station and on-farm research activities aimed at reversing the above land degradation trends and thereby improve people's livelihoods. These encompass participatory identification of environmental problems, understanding the underlying causes, sensitising stakeholders about these problems, identification and experimentation with different potential solutions, leading to development and dissemination/promotion of 'best-bet' technology options for better land management. With researchers, NGO and extension officers serving as facilitators, farmers choose from a range of options, the technologies they wish to try. This process has led to development of appropriate soil fertility management (SFM), rainwater harvesting/soil water conservation (SWC) and integrated land management packages incorporating SFM and SWC for different agro-ecological zones. Below are examples.

Integrated soil and water conservation activities in Rakai district

Soil degradation by water erosion is recognised to be a major agricultural and environmental problem in the Lake Victoria crescent. Unfortunately, there is lack of quantitative data on the magnitude, rates and severity of runoff, soil and nutrient losses. Such data is required for the identification, selection and recommendation of appropriate land-use management practices and policies. The objective of the study was to quantify runoff, soil and nutrient losses from the four major land use types of the area: banana, coffee, annual crops, and degraded rangelands, and assess the effect of contour bunds in reducing these losses. The study also assessed the impact of contour bunds on rangeland recovery and the resulting effect on water quality of major streams in the sub catchment.

Methods

This study was conducted in Kifamba sub-county, Rakai district, which predominantly lies in the Bukora sub-catchment of the Lake Victoria basin (Figure 1). Bukora sub-catchment covers 2,100 km^2 and is drained by river Kibale, a major tributary of Lake Victoria. The geology/ geomorphology of the area consists of highly dissected plateau underlain with phillites. The soils are *petroplinthic plinthosols* and *hyperskeletic leptosols* at the summit, shoulder and upper backslopes of the flat topped ridges and round topped hills, and *haplic luvisols* on footslopes (Ssali and Isabirye, 1998). The vegetation cover follows the physiographic pattern of the landscape. The tops of plateau are covered by *Themeda-Loudentia* grass savanna, and the ill-defined pediments and vales are covered by a dry *Acacia* savanna with *Themeda* spp and *Bracharia* spp. dominating as ground cover. The agricultural system is mainly subsistence with small-scale cash agriculture.

To quantify runoff, soil and nutrient losses 13 runoff plots of 15 by 10 m constructed on each of the major land use types of the area namely, banana, coffee, annual crops, and degraded rangelands. Each land-use practice was replicated three times, except banana. To assess the effect of contour bunds in reducing these losses, contour bunds were hand constructed on representative farmers' fields two years after establishment of runoff plots, at 20-m spacing interval. The effect of contour bunds on rangeland recovery (as reflected in vegetation biomass, ground cover and species diversity) was also assessed during this study. Mulching and tree planting were introduced onto other demonstrating farmers' fields, representing the four major land use types. These soil management practices were selected during an initial PRA survey for the project. Information on weather data was collected through a dense rain gauge network distributed in the study area, backed up by a fully automated weather station at Rakai district headquarters.

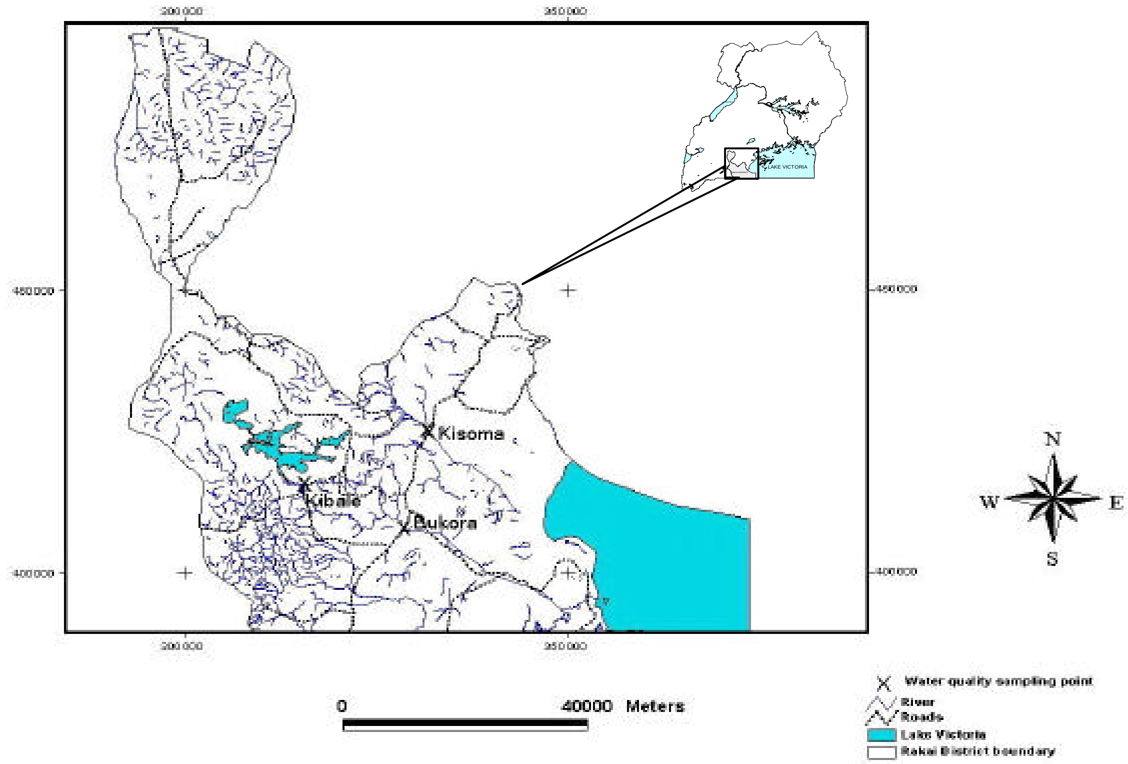

Figure 1. Location of experimental sites in Rakai district of south Uganda

To monitor water quality, identify major sources of water pollution and assess the impact of the soil management practices introduced in the sub-catchment on water quality, three hydrological stations were constructed on two major rivers in the sub-catchment, namely Kibale and Kisoma rivers. Kibale river originates from south-western Uganda and flows through predominantly pastoral districts of Mbarara and Ntungamo (locally known as river Ruizi in these districts). Two of the hydro stations (Kibale and Bukora) were located on the same river (river Kibale), with Bukora located on the downstream side of the river. The river traverses a series of wetland systems as it traverses from Kibale to Bukora before draining into Lake Victoria. A deliberate effort was made to involve farmers in the project areas through setting up of on-farm demonstrations on different soil management practices, plus daily recording of all data for runoff, rainfall and river flow patterns, among others. Figure 1 shows the location of the study sites.

Results and discussion

Results from this study showed that prior to establishment of contour bunds, average annual runoff ranged between 315 and 2439 m^3ha^{-1}/yr, with degraded rangelands contributing relatively higher amount of surface runoff water compared to banana and coffee ($p<0.05$). The average annual soil loss ranged from 27.7 to 86.7 t/ha/yr. It was highest on annuals (85 t/ha) compared to banana (28 t/ha), coffee (27 t/ha) and degraded rangelands (45 t/ha) ($p<0.05$). Seasonal soil losses contributed to more than 75% of the annual losses for all agricultural land-use. Eroded sediments had relatively higher nutrient concentrations than the remaining soils, and varied with land-use and/or seasons ($p<0.05$). Establishment of contour bunds significantly decreased soil loss and runoff on all land use types, resulting in increased crop yields (Table 1) (Majaliwa, 2004). Contour bunds also improved the soil moisture content and nutrient availability on degraded rangelands, resulting in higher mean vegetation biomass production (19.6 vs 7.1 t/ha), ground cover (86.1 vs 50.9 %) and species diversity ($p<0.05$) (Abesiga, 2003).

Results also showed that Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) are major sources of pollution in the streams of Bukora sub-catchment, possibly associated with extensive soil erosion in the area. Within the 3-yr period, mean annual concentration for TN ranged from 3.2 to 10.4 mgL^{-1} with loads of 40 to 70 $tonyr^{-1}$. The TP concentration ranged from 0.2 to 0.4 mgL^{-1} with loads amounting to 3.6 to 51 $tonyr^{-1}$ while TSS concentrations ranged from 12 to 94 mgL^{-1} with loads of 1.8 to 40 $tonyr^{-1}$ (Semalulu *et al.*, 2003). These values were higher than those reported for Kakira estate into the Fielding Bay (Idrakua, 2002) but are much lower than those reported for some rivers in the Winam Gulf of lake Victoria, Kenya (Calamari *et al.*, 1995). However, the monitoring period was rather short for the beneficial effects of improved

Table 1. Effect of contour bunds on the yield of different crops (Majaliwa, 2004)

	Annuals (beans, t/ha/season)	Bananas (mean bunch wt, kg)	Coffee beans (t/ha/yr.)	Pasture (t/ha/yr.)
No Contour bunds (CB)	0.38	11.7	0.90	6.3
1 yr. after CB	1.30	20.7	2.15	25.7
2 yrs. after CB	0.60	29.0	3.00	22.0
$LSD_{0.05}$	0.10	11.0	0.70	19.4

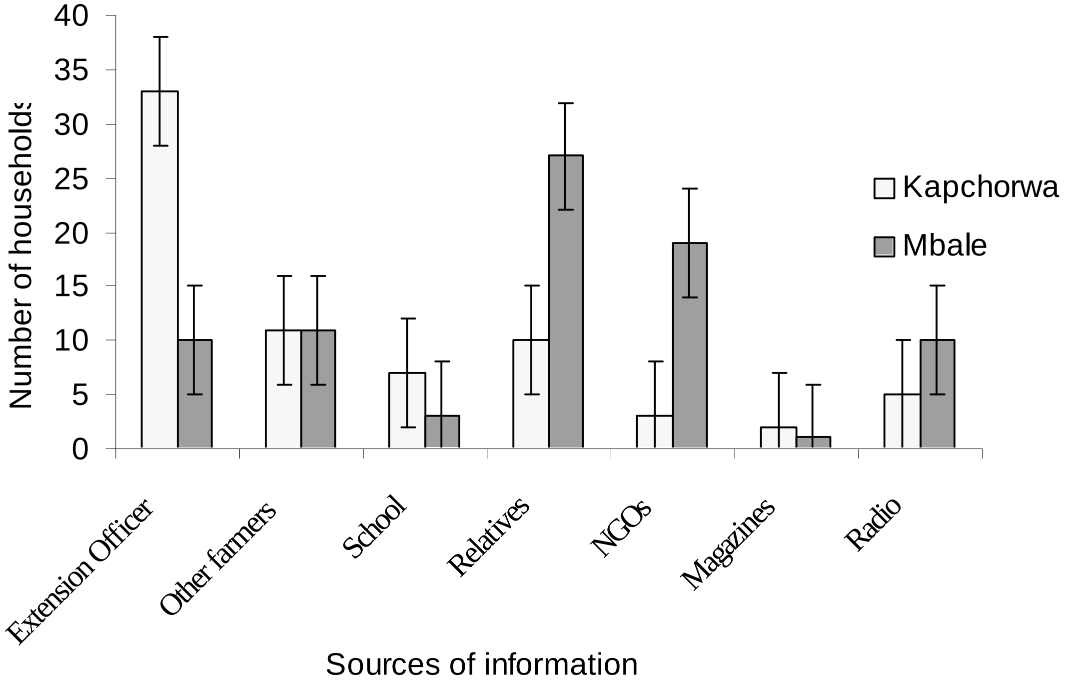

Figure 2. Farmers' accessibility to the sources of available information

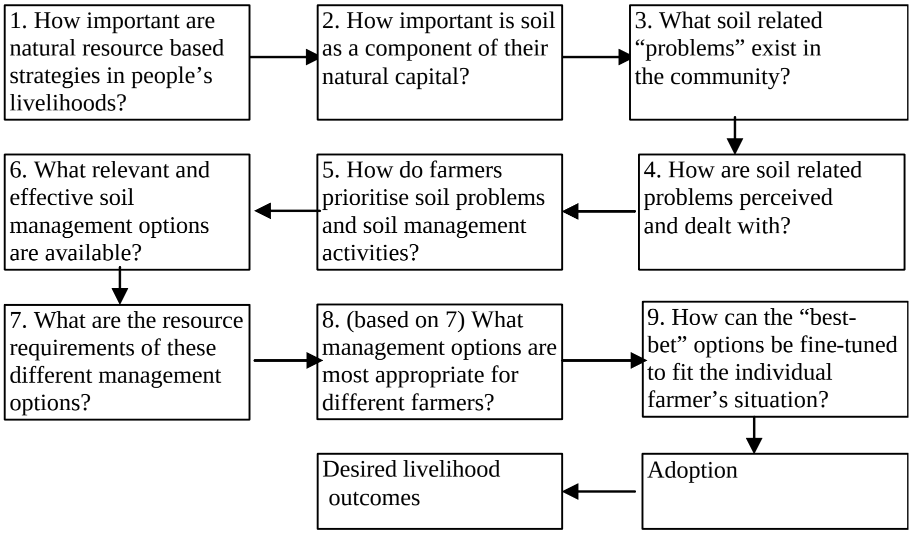

Figure 3. The framework to link soil management with local livelihoods

catchment management (construction of contour bunds, afforestation and mulching) to be reflected in the quality of water in the monitored surrounding streams.

From this study, degraded rangelands/barehills were identified as major erosion hot spots contributing to extensive runoff. These should be targeted to control non-point pollution in water bodies to achieve improved catchment management for better environmental quality. Annual crops are a major source of sediments (soil) that lead to siltation of rivers and lakes, and consequent loading with nutrients. They should be targeted for control of non-point pollution. Contour bunds are effective in controlling runoff and soil erosion from degraded rangelands and annual crops systems, particularly where stabilised with vegetation/tree species and/or afforestation. A combination of contour bunds and afforestation is recommended as a viable low cost technology options for faster and better recovery of rangelands/barehills. Practices such as mulching should be encouraged in annual crop fields and coffee to reduce of soil loss. Improved land management practices should also aim at promoting better livestock management such as reduction in stock numbers and controlled grazing both to reduce risks of rangeland deterioration due to large numbers and ensure that animals are confined to specific grazing areas. Massive sensitisation of communities and mobilisation into community level micro catchment commitees should be emphasised to achieve wider adoption/ up scaling of better land management technologies.

From this study, annual crops and rangelands were identified as major land-use types contributing to non-point pollution in water bodies and should be targeted for improved catchment management for better environmental quality. Contour bunds, mulching and afforestation, were found to be viable low cost technology options for control of soil erosion and runoff on the different land use types in this micro-catchment.

Participatory development of practical tools and methodologies for soil management

This study was preceded by a participatory needs survey of Mbale and Kapchorwa districts to identify and prioritise constraints to farming, opportunities for research, technology transfer and development. Results of the survey formed a basis for developing a comprehensive client-oriented research agenda for the region. Following the identified constraints, the Soils and Soil Fertility Management Programme of NARO in collaboration with the University of East Anglia, UK set to address some of the identified constraints relating to soil management related issues. From the first survey, it was evident that land scarcity has lead to continuous cultivation plus encroachment on marginal and/or protected areas, often without proper soil management and conservation measures. Extensive environmental degradation through soil erosion, declining soil fertility and landslides have resulted, and coupled with unreliable rainfall distribution, field pests and diseases, post harvest crop losses and poor infrastructure, all threatening the food security of the region (Semalulu *et al.*, 1999). In addition, constraints relating to insufficient knowledge in soil management were identified. Recognising that a wealth of information exists in the region and elsewhere on good soil management practices for the hillsides and beyond, weak linkages between research and extension was identified as a probable cause.

The Mt. Elgon farming systems survey was conducted in Wanale and Bungokho sub counties, Mbale district and Kaproron, Binyny and Ngenge sub counties in Kapchorwa district in 1998. The PRA tools used in the survey indicated semi-structure interviews, wealth ranking, resource flow mapping and transect walks with key informants of representative parishes. Using similar PRA tools, a further household survey was conducted in 2000, specifically in the villages selected for project activities, (Sipi and Chesower sub counties in Kapchorwa district; Bududa and Butiru sub counties in Mbale district, two villages per sub county). The village survey enabled us to capture more detailed information regarding farmers' livelihoods, wealth categories and existing soil management practices for households of different resource endowments, among others. With poor access to information on soil management identified as one of the constraints, this 3-yr project was designed to develop simple practical tools and methodologies that a local professional (LP) could use in disseminating soil management information to farmers. The local professional in this case could be a field extension worker, NGO officer or even contact farmer. The project was a joint undertaking between researchers, sub county extension workers and farmers in the project areas. Activities brought researchers, extension workers and farmers together in a simple informal dialogue to identify the types of tools and methodologies that the LP could use, the forms they should take and the possible communication formats the different materials should be packaged. Farmers' interest in this exercise was further stimulated through on-farm demonstrations and experimentation on a range of viable, low cost soil management technologies that could fit into their socio-economic setting, as well as on-farm testing of the draft tools and methodologies at different stages of development.

Household survey

Results from the household survey indicated that the role of the extension worker in providing agriculture-related information is still recognised in both districts (Figure 2), differences in the two districts probably reflecting differences in the extension officers deployed. However, there was a general complaint that extension officers are often not present, or unavailable to farmers, and if present they at times lack the information most relevant to farmers. All in all however, extension is still listed as one of the most important sources of information (Nkalubo *et al.*, 2003). Improving this service is therefore particularly relevant.

By developing simple practical tools and methodologies for LPs involved in soil management related activities, this project directly contributed to reversal of land degradation, especially in hillside environments. In particular, tools and methodologies were developed to enable the choice of soil management options to be better targeted to specific biophysical environments, cropping systems and client farmer groups. Primarily visual, the tools comprise simple materials for teaching farmers on soil-plant processes, field diagnosis of soil-related problems, identifying their potential causes, solutions, and farmer experimentation and fine-tuning of different options to select viable technologies that can fit into his/her social economic status. These tools have been fully described and presented in Semalulu et al. (2002).

This study also developed a framework for conceptualising a soil-related problem versus a range of potential management options available, any fine-tuning necessary in the technology, and how that particular technology fits into the livelihood and resource endowment of the farmer versus the potential benefits/impact to be realised out of such practice (Lu et al., 2002) (Figure 3). For example, where the perceived benefits from a new management option are relatively modest and uncertain, farmers are understandably reluctant to devote resources to it. However, in some aspects of farming only minor change or resource re-allocation is required, e.g. for the adoption of a new variety of an already established crop, uptake rates for improvements in these areas are traditionally high. In other cases and unfortunately, almost always with soil management, significant change and/or resource investment is required to adopt a new practice and this, combined with modest returns (real or perceived), leads to the generally poor uptake rates for improved soil management practises. It then becomes more important to shape the practice to fit the system, which leads to the conclusion that, for soil management at least, it *is* necessary to fine-tune and tailor soil management options to fit the farmer. A simple framework is presented in Figure 3 that illustrates why and when fine-tuning of management options is most likely to be required for successful adoption.

Realising that the farmer is the only person who can say for sure what his/her best-bet option might be and that she will generally be able to say this after trying it out, farmer *participation* and *experimentation* come through as principles in any successful approach. The farmer must be involved and he/she must be able to try and adapt management options him/herself before committing to adopt. The LP acts as a facilitator in this entire process and primer of farmer-led experimentation. The need to achieve good coverage means that one-to-one modes of working cannot be the norm. Farmer experimentation relieves the LP of the burden of spending resources on descriptive activities in the field such as wealth rankings, institutional or livelihood analyses.

During the process of developing tools and methodologies, a range of farmer experimentation activities were carried out on a number of low cost soil management options affordable to poor resource farmers, with farmers themselves choosing the technologies to try out and fine tune according to their needs. Technologies experimented on included some common ones such as mulching, compost, farmyard manure, soil bunds, tree planting, use of grass strips, diversion ditches for roadside runoff and use of mineral fertilisers, and the less common ones such as use and management of cover crops. Because of the participatory manner in which these activities were carried out, high rates of adoption were recorded in the project areas and beyond (Figure 4), with certain technology options more readily adopted than others. Field observations from this study showed that the more readily adopted soil management technologies were those with a low investment cost, low labour requirement, having multiple uses (e.g. napier grass for soil erosion control and for fodder), involving use of readily available materials (e.g. use of banana residue for mulching), and especially where the impact is visible in a relatively short period, such as one season (e.g. use of retention/diversion ditches for control of roadside runoff in the hillsides).

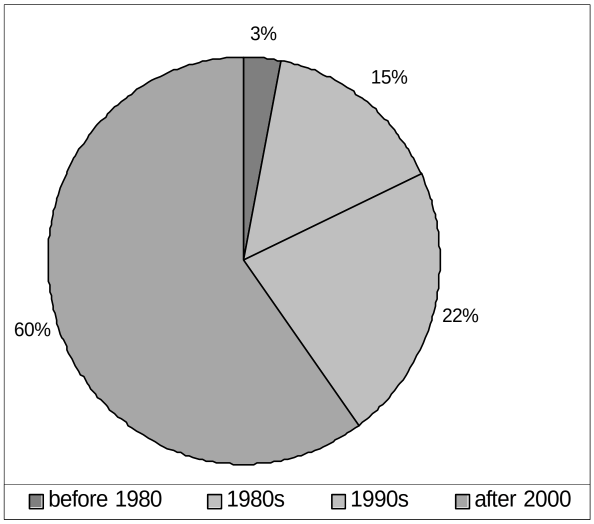

Figure 4. Soil management activities practiced by farmers in the project areas over time.

Combining scientific and indigenous knowledge for land improvement

Recognising the value of indigenous knowledge (IK) in land improvement (SFM & SWC), this study developed a methodology for participatory integration of IK with scientific knowledge (SK) to ensure effective use of both sets of knowledge, thereby promoting sustainable agriculture in resource poor farmers.

The study was carried out in Wera and Torona sub counties, Katakwi district. Participatory and scientific approaches were used in parallel to examine IK and SK, respectively, then combined at different stages of implementing different tasks of technology development (Tenywa et al., 1999). The tasks aimed at characterising land resource productivity and constraints, identifying technology interventions, and farmer experimentation on different technologies. The PRA tools used in IK survey included mapping, rankings, transect walks, semi-structured interviews, seasonal calendars and historical profiles. Scientific tools included GIS, GPS, field and laboratory tests, supplemented by household interviews and focused group discussions to identify different soil types, their characteristics and field boundaries. Based on the identified problems, technology interventions were identified through study tours for exposure of available technologies. Impact was studied through participatory monitoring and evaluation.

Results and discussion

Farmers classified their soils basing on their features, capability and limitations. The IK-identified soil units were compared with those identified scientifically. There was good agreement between the farmer-identified soil units and those obtained scientifically (Tenywa et al., 1999). Working from the farmers' existing practices and coping strategies for moisture stress and SFM, entry points were identified for farmers to test a range of potential options, assessing the benefits and weaknesses associated with different options. Farmers were then able to select soil management options of their choice.

Identifying critical entry points

Within a new community, farmers have their own most pressing priority concerns at any given time. To win acceptability within the community and therefore succeed with project activities the researcher may wish to first tactfully address/pay attention to these key issues before tackling ones that the project/research might be interested in. Such farmers' pressing concerns may not necessarily be the very ones that the researcher is interested in, and in some instances, the research project may not even have the expertise to address the community's 'burning' issues. One community in Kooki county, Rakai district for example, identified lack of clean drinking water as their most pressing problem, although the new project intended to address soil management issues. The new project therefore identified provision of clean drinking water as an entry point. The researchers provided clean drinking water to the community and mutually agreed with community that following these efforts, the community would take on soil management issues. In a cost-sharing arrangement, the project facilitated the community (through another NGO already operating in the district) to construct ferro-cemented water tanks at household and institutional (schools) level. The community contributed 10% of the total cost and agreed on strategic locations to locate the tanks. Some members of the community were also trained in construction of these tanks, so that more tanks could be constructed in future within the community and beyond. Following successful construction of 53 water tanks, the community willingly took up soil management technologies that the new project introduced, with remarkable adoption rates.

Another case was in Chesower sub county, Kapchorwa district, where farmers' fields had been devastated by diversions for roadside runoff. Although the focus of the new project was to develop communication materials for extension workers dealing with soil management, the project team identified control of roadside runoff as an entry point, following which the project activities would later be introduced. Construction of simple structures like retention/ diversion ditches was demonstrated to farmers, with remarkably successful results, as reflected in better maize crop and higher yields only one season after construction of the runoff control structures. The technology was adopted throughout the community and beyond and indeed, farmers participated in project activities of development, testing and fine-tuning of communication materials, which the new project was addressing.

Conclusions

Most farmers appreciate the benefits associated with the technologies developed. On a broader scale, however, adoption of these practices is still low especially among smallholder farmers. This is attributed to inability of smallholder farmers to invest resources in land management, yet they constitute the majority of the farming population. Future technology development approach/strategies should therefore focus on simple, low cost technologies that target resource-constrained smallholder farmers, yet integrating SFM and SWC. Participatory approaches should utilise scientific knowledge to identify and address gaps in indigenous knowledge in SWC, especially targeting the identified hot spots for runoff and soil erosion such as degraded rangelands and annual cropping systems, to contribute to improved environmental quality. The SFM efforts should especially target reversal of nutrient mining using an integrated soil fertility management approach, to sustain agricultural productivity. Production technologies should also target linking farmers with market opportunities so that farmers produce according to the market demands. This will contribute to their realisation of the need to invest in better land management. Diversification of farmers' income base and identification of off-farm activities will reduce pressure on the land and facilitate farmers' ability to invest in farming. New strategies should promote farming as a business, to contribute towards poverty reduction, sustainable land utilisation and a better environment.

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