Natural Resource Problems, Priorities and Policies Programme
Working Paper Series

Improved land management in the Lake Victoria basin

Linking Land and Lake, Research and Extension, Catchment and Lake Basin

Final Technical Report
Startup Phase
July 1999 to June 2000

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Natural Resource Problems, Priorities and Policies Programme (Programme One)

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Improved land management in the Lake Victoria Basin: Linking Land and Lake, Research and Extension, Catchment and Lake Basin. Final Technical Report, Startup Phase, July 1999 to June 2000.

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EXECUTIVE SUMMARY

Lake Victoria is of immense economic and environmental importance in the eastern and central African region. The lake is the largest freshwater body in the tropics and its basin supports one of the densest and poorest rural populations in the world. About 21 million people rely primarily on subsistence agricultural and pastoral production for their livelihoods. But pervasive poverty has hindered sustainable use of the land resources and there has already been considerable land degradation. There is little doubt that sedimentation and nutrient run-off, urban and industrial point source pollution and biomass burning, have induced the rapid eutrophication of Lake Victoria over the last fifty years. Invasion of water hyacinth and loss of endemic biodiversity are interrelated and compound problems for the lake environment and the welfare of its people.

This project set out to assess the extent and causes of processes that contribute to pollution of the lake and to localize interventions for more sustainable land management. In a one year start-up phase, emphasis was placed on prioritizing river basins and assessing the land degradation problems in relation to nutrient and sediment inputs to the lake. This document summarizes progress on the proposed activities and the principal findings achieved under the start-up phase. The detailed results supporting these findings are given as an annex.

A regional assessment identified the Nyando River Basin as a major source of sediment and phosphorus flow into Lake Victoria, and so much of the initial work was concentrated on this river basin while methods were being refined. The study identified severe soil erosion and land degradation problems throughout the Nyando river basin. Accelerated run-off and sheet erosion over much of the

catchment area has led to severe rill, gully and stream bank erosion in lower parts of the river basin. The principal causes of erosion include deforestation of headwaters and overuse of extensive areas of fragile lands on both hillslopes and plains, coupled with loss of watershed filtering functions through encroachment on wetlands and loss of riverine vegetation. Associated with soil erosion, there has been substantial depletion of soil quality over much of the basin. Communities in the river basin are aware and concerned about water shortages and local land degradation but there is a low level awareness of the off-site effects. The lower parts of the river basin and the lake are particularly vulnerable to the return of a large rainfall event, such as experienced in the early 1960's, which would cause catastrophic damage.

The report outlines possible broad areas of intervention. The major requirements are to: (1) rapidly reduce pressure on vegetation cover over large areas of fragile land, including headwaters, shallow soils on hillslopes, and fragile soils on plains and the Nyando escarpment, (2) restore the filtering function of wetlands and riverine buffer strips, and (3) increase productivity of agricultural land that has high potential, particularly by removal of soil phosphorus and other soil nutrient constraints, which will help reduce pressure on fragile lands.

The current catchment extension approach of the Soil and Water Conservation Branch has received considerable penetration in terms of number of participating farmers, but the efforts are unlikely to have significant impact on sediment and nutrient transfers to the lake. The Branch has had most impact in high population density areas largely within cash cropping systems. In contrast, it is in the marginal areas with extensive agropastoral systems that erosion risk is high. These are mostly communally-used grazing lands and government trust land where population density is fairly low and there is little incentive for investment in soil conservation. Complimentary approaches based on integrated watershed management are needed that jointly consider agricultural areas, forest areas and trust land, with highly active community participation. The emphasis must be on large area management of fragile lands and buffer zones around riparian zones, wetlands, and headwater catchment areas. Given the high cost of rehabilitation of marginal areas, priority should be given to assessment of their natural regeneration potential, in conjunction with policy and institutional innovation for their improved management.

The project has been a focal point for the development of some exciting new methods for the quantitative assessment of land management problems that are of international significance. New remote sensing and ground survey tools were developed for rapid assessment of land and soil degradation and for precise spatial management of soils and vegetation. For example, critical target levels of dry season herbaceous vegetation cover depending on soil type and slope can be mapped. Progress towards achieving targets for buffer zone vegetation management can also be monitored. These tools are ready for deployment in the Nyando and other river basins.

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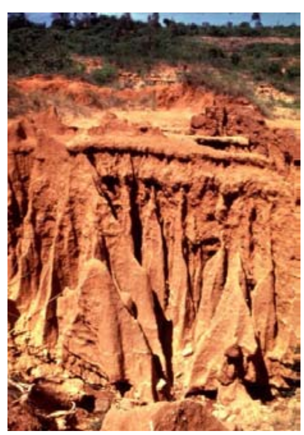

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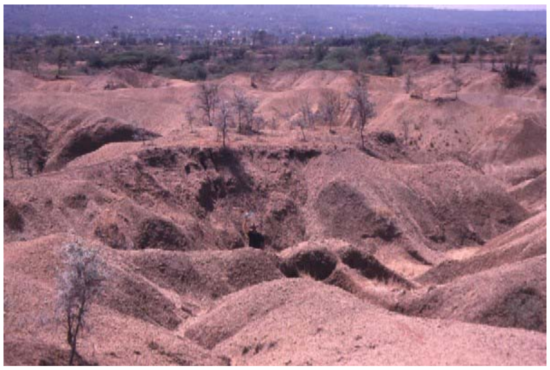

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1. INTRODUCTION

Lake Victoria, with a surface area of 68,000 km^2 and an adjoining catchment of circa 184,200 km^2 (see map in the Annex), is the world's second largest fresh water lake and the largest in the tropics. Lake Victoria is the source of the Victoria Nile, and as such the hydrological lifeline for much of Uganda, the Sudan and Egypt. Over the last 40-50 years the lake and its basin have undergone enormous ecological changes. In contrast, it takes about 73 years for a volume of water equivalent to the Lake's volume (~2,760 km^3) to flow out of it (Piper et al., 1986; Sene and Plinston, 1994).

Changes in the lake basin are linked to a number of interrelated problems such as: rapid population growth, poverty, land degradation, declining agricultural productivity and water quality, which in our opinion must be addressed concurrently to achieve sustainable development. The following sections provide overviews of these and highlight existing knowledge gaps.

1.1 High Population Growth

The Lake Victoria Basin (LVB) now supports one of the densest and poorest rural populations in the world, with densities up to 1200 persons per square kilometre in parts of Kenya (Hoekstra and Corbett, 1995). The first systematic population surveys for Kenya, Tanzania and Uganda, were conducted during the late 1940's. The 1948 estimate for Kenya, for example, is given at 5.7 million inhabitants (Lury, 1969). The current estimate is 28.4 million inhabitants giving an approximate population doubling time of 22.1 years. This means that the population of Kenya has doubled approximately 3.3 times in the time required for the water in Lake Victoria to turn over once. Moreover, population densities in the lake basin portions of Kenya, Tanzania, Uganda, Rwanda and Burundi are well above their respective national averages, indicating doubling times that are probably considerably shorter than the respective national averages.

National population growth rates, though declining due to the HIV/AIDS pandemic and other diseases, remain among the highest in the world and the populations in the five riparian countries are expected to double again over the next 25-35 years (UNPB, 2000). More specific projections and scenarios for Lake Victoria Basin are to our knowledge unavailable at this time. In the context of this project, these will be needed in order to provide realistic year 2050 land and water degradation scenarios based on which various management and policy options could be evaluated.

1.2 High Levels of Poverty

Lake Victoria directly or indirectly supports 28 million people who produce an annual gross economic product in the order of US$ 3-4 billion (or 107–143 $US GEP per capita). Over the 1965-95 period growth in per capita income levels in Kenya, for example, averaged 2.4% ± 2.6% (95% CI) per annum (World Bank Development Indicators, 1998). Even at the most optimistic end of this range (i.e., 5% growth per year), income doubling from 386 (in 1995) to 772 $US per capita (1984 eqv. U$) would be expected to take about 14 years. Under prevailing economic conditions, such a scenario seems highly unlikely, and even if it were to occur, Kenya would still rank in the lowest third of countries on a per capita income basis by current standards.

The Welfare Monitoring Survey implemented in Kenya in 1994 further shows that the incidence of "hard core" poverty was between 40% and 50% in three Lake Basin districts (Bungoma, Busia and Kericho) and between 30% and 40% in four Lake Basin districts (Bomet, Nyamira, Vihiga and Kakamega). Hard core poverty was defined as total expenditure of less than Ksh 703 per adult equivalent per month (Central Bureau of Statistics, 1998) and is thus a much stricter standard than the dollar-a-day rule used by the World Bank. It is currently unknown how these figures will project to the future in a lake basin-wide context, and there is thus a need to collate income as well as other relevant poverty indicators in other parts the basin. Unfortunately, most such statistics are compiled at the national-level, and are generally difficult to disaggregate toward sub-national entities.

1.3 Threats to Primary Production

The Lake produces about 170,000 metric tons of fish each year, with thousands of lakeshore residents employed in fishing and fish processing. Harvesting of Nile Perch (*Lates niloticus*), has generated about $US 100 million of foreign exchange in the past (Ayes et al., 1996) and there are about 10,000 people now employed at commercial fish processing facilities in the Kenyan towns of Kisumu, Homa Bay and Migori (Sunday Nation, April 11, 1999). The sustainability of the fishery is now threatened by: overfishing, pollution and uncertainty regarding ecological instability resulting from the introduction of the Nile Perch. Additional research regarding these threats will be needed to formulate long-term fisheries management strategies and policies.

Subsistence agriculture, pastoralism and agro-pastoralism currently support about 21 million people in the basin (est. from data by Deichmann, 1994) with average incomes in the range of US$ 90-270 per annum (World Bank, 1996). In view of the pervasive poverty among farming communities in the basin (see above), the use of inorganic fertilizer is limited, and primary productivity is closely linked to the inherent productive capacity of the soil. Moderate soil erosion in the order of 5-10 t ha^{-1} yr^{-1}, is associated with substantial losses in soil nutrients that contribute significantly to negative farm nitrogen, phosphorus and potassium balances (Van den Bosch et al. 1998, Shepherd and Soule, 1998). Depletion of soil fertility via biofixation and subsequent crop harvest, grazing, soil organic matter depletion and/or biomass burning exacerbate these problems and will not be resolved without the use of inorganic fertilizers. Perhaps the single greatest threat to primary production is the prevalence of land degradation as indicated by the decline in soil quality demonstrated in this report.

We therefore think it unlikely that fisheries, subsistence agriculture and extensive (agro)-pastoralism in their current forms will be able to support food and income requirements under the projected population doubling scenario over the next 25-35 years. Substantial investments in market infrastructure, roads, soil fertility recapitalization, education, fisheries management, conservation and human and veterinary healthcare will be necessary for sustainable intensification and economic growth in the region. It is currently unclear how such changes would be brought about, as it appears unlikely that these will be generated from within the agricultural and fisheries sectors in the foreseeable future.

1.4 Climatic Uncertainty

A number of paleoclimate studies have shown that long-term climate variability in the basin is periodic and tends to track events occurring over time periods that are characteristic of cyclical changes in orbital insolation and forcing (e.g., Kroll-Milankovitich cycles), and global ocean and atmospheric circulation (e.g. El Nino/La Nina cycles). Some of these studies (e.g. Stager et al., 1996) suggest that the post-1960 ecological shift in Lake Victoria may have had climate driven analogues over the last 10,000 years. This implies that although human impacts on the lake basin environment may now eclipse the events taking place, climate change could be reinforcing environmental degradation in the lake basin.

The more recent historical record shows the occurrence of an extraordinarily pluvial period from 1961-1964 in the eastern portion of the lake basin. During this time, the water level of Lake Victoria rose by approximately 2.5 meters, and discharges from rivers Nyando and Sondu Miriu, for example, were 10-20 times higher than their respective 35 year decadal averages. For the Nyando River Basin, interviews with local people suggest that many of the major soil erosion problems either started or were dramatically accelerated in their development during the early 1960's. We speculate that rapid land use changes, deforestation, infrastructure development and over-grazing structurally altered this landscape during the first half of the 20th century. Prevailing conditions during the early 1960's may then have been such that the basin was essentially primed for massive erosion/sedimentation during a period extraordinarily heavy rainfall in the region. Unfortunately, the current database does not allow us to estimate the return period of events of this magnitude, nor do we know how these affected sedimentation rates in the different river basins. This is of particular concern as we can only speculate what might happen now, should we witness the return of a rainfall period of the magnitude observed during the 1960's.

1.5 Eutrophication of the Lake

Though still somewhat controversial (see Johnson et al. 2000), it is very likely that sedimentation and nutrient run-off, urban and industrial point source pollution and biomass burning, have indeed induced the rapid eutrophication of Lake Victoria over the latter part of the 20th century. Ambient conditions in Lake Victoria now favor the dominance of nitrogen fixing cyanobacteria and the spread aquatic weeds such as water hyacinth (*Eichornia crassipes*). Phosphorus levels have increased 2-3 times over the last 40-50 years (Hecky, 1993, 2000). Algal concentrations are three to five times higher now than during the 1960's, and much of the lake bottom currently experiences periods of prolonged anoxia that were uncommon 40 years ago (Mugidde, 1993; Johnson et al., 2000).

Scheren (1995) suggests that the increase in phosphorus is primarily due to increases in atmospheric deposition from forest burning and wind erosion. On the other hand, Bullock et al., (1995) estimated that 50% of the nitrogen input and 56% of the phosphorous input is due to runoff from agricultural land, 30% of the nitrogen and 30% of the phosphorous is due to rural domestic waste, and 10-15% due to urban waste and atmospheric deposition. It should be noted that these figures are based on estimates and models rather than measurement of actual nutrient inputs from the various potential sources. Notably, both these estimates are based on models and ball-park estimates rather than measurements. There can be little progress in pinpointing the source of the problem until measurements of the various inputs are made.

1.6 The Spread of Water Hyacinth

Water hyacinth (*Eichhornia crasipes*) began to colonize Lake Victoria around 1989, from the River Kagera which originates in Rwanda and passes through Tanzania and Uganda. Water hyacinth has covered as much as 680 square kilometres of the Lake, with enough new hyacinth carried into the lake to cover about 3 hectares per day. Water hyacinth is concentrated along the shorelines where it has most impact on people's lives. Mats of water hyacinth cover about 80% of the Ugandan shoreline and 2000 hectares around the major Kenyan port at Kisumu (Ong'ang'a and Munyrwa, 1998; Pearce, 1998). New, vigorous hyacinth nurseries developing in the deltas of Rivers Siyu and Nzoia. (Robertson, pers. comm..). Potentially negative impacts on the Lake environment, include: (1) decomposition and sedimentation of rotting water hyacinth, (2) impeded light penetration leading to reduced growth of phytoplankton and herbivorous fish populations such as tilapia; (3) increased evapotranspiration and thus an increase in the rate of water loss; and (4) reduction in the diversity of aquatic plants and fish species (Ong'ang'a and Munyrwa, 1998).

Colonization by the water hyacinth has also had a number of direct economic impacts. While a full economic assessment of the economic impacts is not, to our knowledge, available at this time, a number of negative economic impacts have been noted. Commercial transportation has been slowed and made more costly and more risky. There has been a drastic decline in fish landings: a 50-75% reduction according to Ong'ang'a and Munyrwa (1998). Shoreline communities that were previously supported by fishing have been choked off. Many people in those communities have moved and those who remain have been forced to find alternative sources of livelihood. Bridges and dams have been damaged and the major power source for Uganda is under threat. At the Owen Falls hydroelectric plant on the Nile River in Uganda, four boats fitted with rakes and conveyer belts are needed to keep the turbines free of the weed. The cost of this operation alone is over $600,000 per year. Even with a clear surface, however, dead water hyacinth is dragged into the turbines by undercurrents. The turbines need to be shut down and cleaned each week, resulting in frequent power interruptions (Ong'ang'a and Munyrwa, 1998).

1.7 Losses of Biodiversity

Since Lake Victoria arose from a dry landscape 14,600 years ago, it has experienced rapid evolution of endemic species of cichlid fish, providing one of the most diverse flocks of fish species on Earth (Johnson et al. 2000). However, by the 1980s, some 400 endemic species were approaching extinction (Witte et al., 1992). The introduction of Nile Perch into Lake Victoria in early 1950 has been blamed for dramatic shifts in algal populations and the extinction of cichlids. However, the sedimentary record from well-dated short cores of the open lake, suggest that the lake system was poised for disaster since the early 1930s, parallel with the rise in human populations and agricultural activity (Johnson et al., 2000). Further evidence is required to confirm a cause-effect link between land degradation and loss of biodiversity in the lake.

2. OVERVIEW OF THE PROJECT

On July 1, 1999, a project entitled "Improved land management in the Lake Victoria Basin," was initiated by the International Centre for Research in Agroforestry (ICRAF) in collaboration with the National Soil and Water Conservation Programme (NSWCP) of the Kenyan Ministry of Agriculture and Rural Development. The Swedish International Development Agency (Sida) provided finance for a one-year "start-up" phase of this project through its bilateral assistance programme in Kenya. Additional funds for the research were provided by Danida (through its Associate Expert Programme), the Rockefeller Foundation and ICRAF core. The startup phase concentrated on Kenya, particularly on the basins of the Nyando and Sondu-Miriu rivers that enter Lake Victoria in the Winam Gulf. Together the Nyando and Sondu-Miriu River Basins cover about 7,000 km^2 of western Kenya. Activities undertaken during the startup year were to form the basis of a longer-term project extending beyond Kenya to include Uganda and Tanzania in the first instance, and later, possibly to Rwanda. Good progress has been made in developing the Kenya and Regional components of that longer-term project. The project objectives during the startup phase were:

1. to identify and prioritize drainage basins contributing sediment and nutrients to the Lake Victoria water system,
2. to quantify local sources and sinks of soil sediment and nutrients within priority drainage basins in the Lake Victoria water system,
3. to predict future land use and erosion hot spots for better targeting of preventive interventions,
4. to identify 'best-bet options' for simultaneously raising agricultural productivity and preventing or reducing non-point source erosion.

5. to strengthen the capacity of national organizations to identify erosion and non-point source pollution hot spots and assess approaches for dealing with those hotspots.

This document reports summarizes progress on the proposed activities and the principal results achieved under the start-up phase. The detailed results are given in a separate research report. Much of the material was presented during a field visit to Lake Victoria in April 2000 in conjunction with the semi-annual meeting of the National Soil and Water Conservation Programme (NSWCP). The principal findings of the project are summarized in Section 3. The project provided a platform for some major international scientific advances, which are summarized in Section 4. The main activities and report of progress on agreed outputs is given in Section 5 and training and capacity building achievements are summarized in Section 6. The final sections list project personnel and publications. The detailed research results are given in an annex.

3. PRINCIPAL FINDINGS TO DATE

This section presents the principal findings of the project start-up phase in relation to the goal of reduced non-point source nutrient loss and sediment movement from farming areas into the Lake Victoria and for improved land management in the Nyando River Basin.

3.1 Problem Identification

1. The Nyando River Basin is a major source of sediment and phosphorus flow into Lake Victoria. Of the eleven main rivers draining into Lake Victoria the Nyando river basin has the highest average slope and average sediment transport capacity. Satellite images, aerial video, and ground surveillance surveys indicate that there has been massive soil movement into the lake over the last 50 years, principally from gully erosion of the lake plain. Measurements of phosphorus (the main nutrient causing lake eutrophication) in the River Sondu also indicated that concentrations were lower than those in the lake, but concentrations in the River Nyando were five times higher than those measured in the Sondu. Consequently, much of the work in the start-up phase was concentrated on the Nyando river basin.
2. There are severe soil erosion and land degradation problems throughout the Nyando river basin (Table 1). These include accelerated run-off and sheet erosion over much of the catchment area leading to severe rill, gully and stream bank erosion in lower parts

of the river basin. Aerial video verified extensive gullying along the foot of the Nyando escarpment

3. The principal causes of erosion include deforestation of headwaters and overuse of extensive areas of fragile lands on both hillslopes and plains, coupled with loss of watershed filtering functions through encroachment on wetlands and loss of riverine vegetation (Table 1). Depletion of these vegetation resources is likely to have also considerably reduced the biodiversity of the area.

4. Notably, severe soil erosion problems have occurred over large areas where (1) shallow soils occur on hillslopes, and (2) where fragile soils have been inadequately protected, even on slightly sloping land. These fragile soils include soils prone to hard-setting and unconsolidated soils on the mid-catchment plains, scarp toe slopes and lake plain.

5. Surveillance surveys provided quantitative evidence for the links between vegetation cover, soil erodibility and observed soil erosion. Severe soil erosion is strongly associated with low dry season vegetation cover and erodible soil types. The maintenance of vegetation cover, notably herbaceous cover, is critical for the protection of the fragile lands in the basin.

6. There has been decrease in soil quality relative to undisturbed areas, as indicated by a number of indicators, in areas where sheet, rill and gully erosion have occurred. The loss in soil quality is related to the degree of erosion. For example, sheet erosion has decreased exchangeable bases by 39-47% and soil organic carbon stocks by 17-25% compared with intact sites. Where gully erosion has occurred the impacts are even more dramatic.

7. Soil phosphorus deficiency, a basic constraint to agricultural productivity, is prevalent in high potential agricultural areas. However, soil phosphorus levels are high enough to be of environmental concern in parts of the lake plain, where soil erosion risk is also high.

8. Conventional methods for assessing land degradation and soil erosion risk based on existing databases (climate, soils, topography) could not reliably map the observed land degradation and erosion problems at a river basin level. The new rapid surveillance protocols developed under this project need to be implemented in other river basins to reliably assess and monitor erosion and land degradation risks.

9. The Nyando basin is particularly vulnerable to the return of large rainfall events, such as occurred in the early 60's. The return of such an event could result in unprecedented mass soil movement from the lake plain into the lake. We expect that such an event would cause massive fish deaths and ecological damage due to prolonged anoxic conditions in the lake.

10. A recent survey of secondary growth of water hyacinth in LakeVictoria revealed that river mouths appear to be acting as nurseries for water hyacinth (e.g. Nzoia). Thus improved land management strategies in these river basins could have rapid impacts on the source of the water hyacinth problem.

11. Participatory appraisals (PRA) revealed that while community perceptions of natural resource management problems centred on water shortages, many of the above problems were also of important concern to communities, including floods on the plains, and soil erosion effects on soil fertility decline and land loss (by gully erosion). However, there was a low level of community awareness about upstream or downstream problems outside the community area of land degradation and lake water quality.

12. We conclude that unsustainable land management is the proximate cause of both the lake environmental problems and the major livelihood concerns of communities. Satellite imagery and monitoring of river water quality provided evidence for accelerated sediment and phosphorus inputs to the lake. Planned studies of lake sediment cores will help to confirm this trend. Surveillance surveys provided quantitative evidence for the effect of land use and vegetation cover on soil erosion and soil quality. It is possible that land degradation may have also contributed to the water shortages faced by communities. Although there are insufficient records to test this linkage in the Nyando basin as a whole, preliminary results from experimental watersheds suggest a link between degraded area, accelerated run-off and flash floods. Declining vegetation resources and soil productivity will directly threaten the future livelihoods of communities and further degrade water and nutrient cycling functions of landscapes. The return of a large rainfall event could be catastrophic and preventative intervention strategies need to be put in place now.

3.2 Possibilities for Interventions

1. A number areas for soil and water conservation intervention have been identified in broad terms during the start-up phase (Table 1). The major challenge is to identify strategies and mechanisms to: (1) rapidly reduce pressure on vegetation cover over large areas of fragile land, including headwaters, shallow soils on hillslopes, and fragile soils on plains and the Nyando escarpment, (2) restore the filtering function of wetlands and riverine buffer strips (3) increase productivity of agricultural land that has high potential, particularly by removal of soil phosphorus constraints, which will help reduce pressure on fragile lands.
2. Participatory appraisals revealed community awareness and concern over all the causes of land degradation problems listed in Table 1 and a number of solutions had been tried. For example, communities identified uncontrolled grazing of fragile lands by livestock as an important constraint to successful land management interventions.
3. The most striking feature of the required interventions is the need for strategies for large area management of fragile lands and buffer zones. This will require different approaches to compliment those currently used for farm-level soil conservation.
4. Community appraisals and a participatory workshop reinforced the need for long-term community involvement and institutional innovation for coping with these large area management problems. For example, the need for community-based land care approaches was recommended, as opposed to project-based interventions of limited duration that insufficiently involve communities.
5. Sensitive strategies for management of common and public lands are required because communities are dependent on these areas for various off-farm enterprises, such as basket-making near papyrus wetlands and potteries close to rivers. The involvement of government is also critical in public land management issues, such as riverine buffer zones.
6. Agroforestry could potentially play a role in most of the intervention areas recommended. However, given the large areas involved in fragile lands and buffer zones, and the high cost of rehabilitation, priority should be given to assessment of the natural regeneration potential of these areas together with policy and institutional innovation for their improved management.

7. The current catchment extension approach of the Soil and Water Conservation Branch is unlikely to have significant impact on sediment and nutrient transfers to the lake. Despite considerable penetration between 1988 and 1999, with 10,600 farmers in 177 focal areas having adopted at least one recommendation, the land area involved is only 8% of the total basin. It is primarily cultivated areas that have been targeted and, indeed, high rates of farmer implementation have been achieved in areas with high population density and cash crop production. These contrast with the extensive areas that have been identified as having high erosion risk. These are mostly communally-used grazing lands and government trust land where population density is low and there is little incentive for investment in soil conservation. New integrated watershed approaches are needed that jointly consider agricultural areas, forest areas and trust land.

8. New tools for rapid assessment of land degradation, erosion risk and soil quality were developed during the start-up phase. These permit rapid and reliable mapping of areas with different types of soil erosion, erodible soils and various soil fertility constraints. Even more importantly, sensitive areas can be delineated that are intact now but that are at risk of rapid degradation if not carefully managed. The survey protocol also provides tools for precise spatial management of soils and vegetation cover based on locally calibrated models. For example, critical target levels of dry season herbaceous vegetation cover can be established and mapped depending on soil type and slope. Progress towards achieving targets for buffer zone vegetation management can also be monitored. These tools are ready for deployment in the Nyando and other river basins. The next step is to develop awareness of these tools among potential clients and tailor them to the specific needs of users.

Table 1. Land degradation problems and types of interventions in Nyando River Basin

Problem cause	Effects	Interventions
Upper catchment hillslopes		
• Deforestation of indigenous forest • Unprotected farmland	• Increased run-off • Sheet and rill erosion • Aerosol emission	• Halt deforestation • Law enforcement • Land adjudication • Farm soil conservation
Mid-catchment hillslopes		
• Clearance of woody vegetation, overgrazing and cultivation on shallow soils & steep slopes	• Sheet erosion, land-slides, increased run-off	• Deferment, reforestation • Controlled burning on rangelands to promote woody cover regrowth • Land adjudication • Controlled access/use
Mid-catchment plains		
• Overgrazing and cultivation of fragile soils • Sugar cane burning	• Capping, sheet, rill and gully erosion, increased run-off • Aerosol emission	• Deferment; controlled grazing & burning • Gully revegetation; wetlands • Cutoff dams and diversion drainage

Scarps		
• Clearance of woody vegetation, overgrazing and cultivation on shallow soils & steep slopes • Poor road construction • Limited road access hence many unprotected footpaths and cattle tracks	• Very high run-off, sheet, rill, gully erosion, land-slides • Water shortages	• Deferment, reforestation • Controlled access/use • Cutoff dams diversion channels • Land adjudication • Infrastructure improvement
Kano plain		
• Overgrazing and cultivation of fragile soils; high run-off from scarp; erodible subsoils • Sugar cane burning • Urban runoff (Ahero) • Cane processing & agrochemical industry	• Capping, sheet, rill, gully, increased run-off • Raw sewage and agrochemical point source pollution • Aerosol emission	• Deferment, reforestation • Controlled access/use • Cutoff dams diversion channels • Gully revegetation • Sewage treatment • Law enforcement

River channel		
• High peak flows with large load • Devegetation of streambanks • Poor soil conservation practices in proximity to streambank • Straight channel; little filtering • Erodible subsoils • Watering points on river bank	• Streambank erosion • Fecal contamination • Massive floods	• Reduce run-off and load upstream • Wetland engineering • Riverbank revegetation & grazing control • Conservation tillage up to 1 km from streambank • Borehole and stock tank construction
Other		
• Unprotected farmland a local problem in all areas	• Sheet, rill erosion	• Farm soil conservation
• Roads and tracks: poor siting and drainage	• Increased run-off, rills, gullies	• Resiting of roads, tracks • Road drainage maintenance
• Phosphorus and potassium are already at low available levels over much of the undisturbed area.	• Low agricultural productivity	• Soil fertility replenishment
• Increased flood:through flow ratio	• Water shortages	• Reduce run-off through above

4. MAJOR SCIENTIFIC ADVANCES

The project has been a focal point for the development of some exciting new methods for the assessment of the quantitative assessment of land management problems that are of international significance.

1. A method for rapid assessment of soil and plant quality has been developed based on diffuse reflectance spectrometery using a portable spectrometer. Soil and plant properties and functional attributes can be calibrated to spectral signatures of the materials based on a limited number of samples (e.g. 10% of a population). Once calibrations have been developed, several hundred samples can be scanned per day and any number of attributes simultaneously predicted from the scans for these samples. The method enables a much higher sampling intensity to be achieved than was previously possible. New satellite sensors provide the same measurement of the land surface, and there are prospects for acquiring information about soil properties from space. This work is currently being submitted to *Science* magazine.
2. The spectrometry method was successfully applied in the surveillance surveys for distinguishing soils in different erosion classes and predicting soil fertility attributes. Good success (80% user accuracy) was obtained in delineating erodible soils and soils with low or high levels of available phosphorus from Landsat images.
3. Soil spectra were also used to reveal the sediment plume in lake Victoria originating from the River Nyando. This finding was reported in *Science* magazine (26 Nov 1999, Vol. 286 [5445], p. 1675).
4. A method is in the process of development to assess sedimentation rates and source areas of erosion based on sediment coring of river mouths and lake bottoms. Sediment cores provide a historic record of sedimentation rates when combined with isotopic dating methods. However such analyses are expensive and can only be conducted on a limited number of reference cores. Reflectance spectrometry can be used to distinguish and match strata among cores and thus greatly increase the number of cores that can be characterized. Spectral features of the sediments can be matched with those of source soils in the catchment. The method can also be used to locate sources of sediment taken from river water samples. These methods will allow us to rapidly build up a picture of sedimentation history and source areas for the eleven river basins around Lake Victoria.

5. SUMMARY OF ACTIVITIES AND OUTPUTS

The five tables presented in this section describe the activities that were proposed for the start-up year vis-a vis achieved outputs. The five tables relate to the five objectives. Each table begins with a statement of the objective and the overall output expected relative to that objective, followed by a description of the activities proposed for the start-up year, the specific outputs expected by June 2000, and the degree to which these outputs were achieved. While the project achieved a large amount in the start-up phase, successful completion of the overall outputs will require additional activities during the main project phase in later years.

<table>
<tr><td colspan="3">Objective 1: Identify and prioritize drainage basins contributing sediment and nutrients to the Lake Victoria water system</td></tr>
<tr><td colspan="3">Overall output expected for Objective 1: General agreement among partners in the region about the criteria that should be used to prioritize drainage basins for improved land management activities; priorities assigned for all river basins in the Lake Victoria water system</td></tr>
<tr><td>Activity</td><td>Expected outputs by June 2000</td><td>Achievements</td></tr>
<tr><td>1.1 Identify riverine networks and their constituent drainage basins that define the surface inflow area of Lake Victoria (i.e. the areas that contribute sediment and nutrients to Lake Victoria)</td><td>1: 1,000,000 scale maps and GIS databases delineating the major contributing drainage basins including the contributing areas and potential volumes, river networks, major basin inlets and outlets in Kenya, Tanzania, Uganda, Rwanda and Burundi.</td><td>Completed</td></tr>
<tr><td>1.2 Work with collaborators to prioritize Lake Victoria drainage basins for intervention on the basis of their current (1999) and predicted (2000 +) sediment and nutrient deposition potential.</td><td>GIS database for contributing drainage basins including information on: terrain, vegetation and land cover, soils, rainfall and rainfall erosivity, human population density and growth, administrative boundaries, and infrastructure including roads, urban areas, and travel times to market centers.

Method refinement for regional assessment, monitoring and prediction of sediment and nutrient deposition into L.V. water system completed.

Report including literature review, methods and modeling approaches, results and priorities for subsequent years.</td><td>Completed, except travel times are for Kenya only

Sediment tracking method developed. Building blocks to link river flow and NDVI records to sedimentation history.

Methods papers in progress. Prioritization deferred to main phase.</td></tr>
</table>

Objective 2: Identify and quantify local sources and sinks of soil sediment and nutrients within priority drainage basins in the Lake.Victoria water system.		
Overall output expected for objective 2: Agreement among partners in the region about the most important local sources and sinks of soil sediment and nutrients for all priority drainage systems in the Lake Victoria water system.		
Activity	**Expected outputs by June 2000**	**Achievements**
2.1 Refine remote sensing, ground-truthing and modeling methods for assessment and monitoring.	Ground sampling protocol established including: sampling locations for monitoring sediment and nutrient transport in streams and rivers, assessment of potential sediment and nutrient contributions from different land uses. Methods for remote sensing of soil properties, vegetation cover and land use refined and tested.	Completed Completed
2.2 Elicit farmers' knowledge about main erosion points, causes of erosion problems, local interventions / solutions, effectiveness of current control measures and rehabilitation strategies	Reports for PRAs implemented in several purposively selected locations around the Nyando and Miriu Sondu water systems by teams comprised of Ministry and ICRAF personnel.	18 PRAs conducted in Nyando District
2.3 Measure sediment loads in the rivers and hot spots in the landscape.	Preliminary measurements of the relative importance of sediment loss from different land use at various points along the length of the Miriu Sondu and Nyando rivers and from stratified samples of farms, footpaths and grazing lands with and without improved soil conservation measures.	Sediment trap monitoring system established in two catchments. Preliminary results available.
2.4 Quantify sediment and nutrient contributions from different land use types and watersheds within priority drainage basins.	1: 50,000 maps and GIS databases including information on land use / cover, soil properties, vegetation characteristics, soil erosion hotspots etc. for watersheds in the Nyando and Miriu Sondu drainage basins. Preliminary report on sediment and nutrient contributions in the Nyando and Miriu Sondu drainage basins including methods and monitoring protocols, results and priorities for subsequent years.	Completed for Nyando river basin Monitoring system established; also see coring method.

Objective 3: Prediction of location and causes of future hot-spots for targeting of preventative interventions		
Overall output expected for objective 3: A typology of different types of hot-spots, an understanding of major factors leading to their development, identification and mapping of most likely future hot-spots, and priorities for targeting of preventive interventions across the Lake Basin		
Activity	**Expected outputs by June 2000**	**Achievements**
3.1 Historical study of how and why hot-spots develop	Literature review of related work for Kenya Typology of hot-spots based upon biophysical and socio-cultural characteristics in the Miriu Sondu and Nyando drainage basins.	Draft completed. Types of land degradation problems and causes identified.
3.2 Analysis of factors contributing to hot-spot development	A preliminary spatial model for analyzing links between biophysical, socioeconomic factors and development of hot-spots.	Spatial database established for western Kenya; preliminary results for link between tree cover and socioeconomic factors.
3.3 Assessment and analysis of changes in land use and land cover changes in the Lake Victoria water system.	Protocol for using the stable carbon isotope method to assess changes in woody vegetation. Collaborative arrangement with advanced institution established.	Developed with Texas A&M University.
3.4 Simulations to predict future development of hot-spots	No output expected by June 2000	–

Objective 4: Identify 'best-bet options' for simultaneously raising agricultural productivity and preventing or reducing non-point source pollution of the L.V. water system		
Overall output expected for Objective 4: Recommendations on approaches to farmer organization, techniques that maximize complementarities between farm-level productivity and soil and water conservation for the watershed. Recommendations on technical and institutional approaches to conservation at the community and landscape levels.		
Activity	**Expected Outputs by June 2000**	**Achievements**
4.1 Develop an integrated framework for characterization of options and identification of 'best-bet' options	An integrated framework is developed that recognizes the potential tradeoffs between agricultural productivity, farm-level resource management, community benefits and sedimentation of Lake Victoria.	Development of environmental accounting protocol in progress with University of Florida
4.2 Identify promising new options for improving farm productivity, reducing sedimentation and nutrient flow.	Complete review of literature on riparian buffer strips and the use of trees as nutrient sponges in residential areas. Research protocol developed for testing the use of riparian buffer strips within the catchment approach.	Completed Foundations for protocol developed; participatory testing started.
4.3 Analyze the impacts of new and existing interventions on sedimentation and nutrient flow.	Develop protocol for a study of the impacts of the catchment intervention on sedimentation and nutrient flow. Preliminary assessment of the impacts of the catchment intervention on reducing sedimentation and nutrient flow.	Paired catchment study initiated and pipe sampling method for sediment monitoring developed.
4.4 Evaluate the likely adoption, diffusion and impacts of existing and new options at the farm and community levels.	Compile information from catchment records in the Nyando and Miriu Sondu drainage basins in order to assess the rate and level of adoption of different practices (water harvesting, agroforestry, grass strips, conservation structures). Community-level and household level surveys completed in a stratified sample of communities in Western Kenya to assess adoption, diffusion, and household-level impacts of existing pracrtices. Preliminary report prepared.	Preliminary assessment completed. Catchment survey of adoption completed. Two household-level studies completed.

4.5 Assess alternative approaches to working with local communities for watershed management and rehabilitation of degraded areas.	Review of the global literature and rapid appraisal to identify existing and promsing new approaches taken to working with local communities in Western Kenya. Report on a preliminary assessment of the advantages and disadvantages of the Catchment approach for dealing with the problems of productivity, local resource management, and non-point source erosion.	Literature review of community-based approaches completed. Discussions held at PRA workshop.
4.6 Use the framework developed under 4.1 to evaluate current and novel conservation practices, agroforestry techniques, and soil fertility replenishment measures for the Lake Victoria Basin.	Preliminary assessment of tradeoffs between farm productivity, community resource management and sedimentation for existing conservation and agroforestry techniques for the Sondu and Nyando water systems.	Deferred and expanded in next phase.

Objective 5: Strengthen the capacity of selected national and / or regional organizations to identify erosion hot spots and assess alternative approaches for dealing with those hotspots.

Overall output expected for Objective 6: Selected national and / or regional organizations have the interest, expertise, experience and equipment necessary to identify regional and local hotspots and evaluate options for dealing with those hotspots.

Activity	**Expected Outputs by June 2000**	**Achievements**
5.1 Graduate level training	Mwangi Hai develops PhD proposal and presents it at Stockholm University.	Registered in August 2000
5.2 Training of Conservation Branch personnel in GIS	2 Conservation Branch personnel are attached to ICRAF to work in the DSS lab for 2-3 months.	Deferred and transferred to Appropriation and Aid grant (A&A)
5.3 Training of Conservation Branch personnel in agroforestry	At least 8 district and division staff are trained in agroforesty.	Agroforestry training course held for 25 staff Proceedings available.

6. TRAINING AND CAPACITY BUILDING

Graduate Level Training

Mwangi Hai' research proposal was presented to the Department in a seminar held on 23/8/99 and attended by all three supervisors: Prof. Nils Kautsky, Prof. Chin Ong and Dr. Johan Rockstrom. The proposal was accepted and on this he was admitted to a four-year PhD research program running to June 2003.

Christian Tegtmeier had his dissertation research proposal accepted by the University of Bonn in Germany. He has conducted five PRAs, engaged in participatory action research in Rakwaro village, assisted in the development of Land Management Plans for Rakwaro, and completed a household questionnaire for about 150 households.

Sharing of Findings with Stakeholders

A one-day workshop was held at ICRAF House, Kisumu, on April 5th 2000, in order to update Ministry of Agriculture staff on progress with the project, particularly the findings of the PRAs. Over 40 people attended the workshop on April 5th, including Ministry of Agriculture staff from headquarters, from Nyanza Province, and from all five divisions in Nyando District. Eight ICRAF staff from Kisumu, Maseno and Nairobi also attended. Representatives from KEFRI, KARI, RELMA and the Forest Department also attended. That one-day workshop was followed by a planning meeting for the Ministry of Agriculture staff in Nyando District.

Agroforestry Training for Extension Staff

ICRAF and the Ministry of Agriculture and Rural Development organized a seminar on agroforestry for the Nyando District Agricultural Extension staff, 14th to 20th of May 2000. The seminar will be held at ICRAF house in Kisumu. Thirty-four extension staff were trained in (1) agroforestry technologies, (2) methods of participatory development, (3) adaptation of beneficial technologies and practices, and (4) monitoring and evaluation of development activities.

7. PROJECT PERSONNEL FOR START-UP PHASE

Long-term ICRAF Staff

Alex Awiti	GIS expert
Antonia Okono	Admin Assistant
Chin Ong	Co-leader, Hydrologist
Frank Place	Economist
Keith Shepherd	Systems agronomist
Paul Smithson	Lab manager, soil scientist
Brent Swallow	Project Leader, Economist
Markus Walsh	Landscape ecologist

Associate Scientists

Tina Svan-Hansen	Geographer

Long-term Consultants (* indicates funded by project)

Fridah Mugo*	NRM specialist
Oscar Ochieng*	GIS technician
Michael Maina*	Data entry

Short-term Consultants (* indicates funded by project)

Andrew Brenner*	Watershed management expert
Ahmed Khan*	Instrumentation
Keith Shepherd*	Land quality and erosion risk assessment

Students (* indicates funded by project)

Mwangi Hai*	PhD in systems ecology, U of Stockholm & Ministry of Agriculture
Christian Tegtmeier*	PhD in social geography, U of Bonn
Michelle Swallow	BSc in resource management, Caribou College, Canada

Ministry of Agriculture and Rural Development

PRA facilitators:

Shikuku Omushieni, Japheth Ondieki, Silas Deya, Titus Masila, Hellen Okombo, Tom Owour, Onyango Ong'or, Dedan Manyala, Isabella Adede, Gladys Mung'ala, Jacob Ongere, Ester Onyango, Phanuel Okoth Oringo, Henry Awiti, Erustus Owour, Fred Young, Charles Obenge, David Ombalo, Evaris Tinenga, Pamela Samo, James Samo, Nelson Agenyo, Martin Wauka, Luke Musewe, James Kharindo, Wilson , Otieno, Celetine Odhiambo

Analysts:

Shikuku Omushieni, Japheth Ondieki, James Ong'awa, David Ombalo

Workshop participants:

Shikuku Omushieni, Japheth Ondieki, Martin Grunder, J. Kiara, D. Nyantika

Steering Committee

Brent Swallow, Chin Ong, Martin Grunder, Francis Mbote, Kwesi Atta-Krah,

8. LIST OF PUBLICATIONS

Journal Articles

Shepherd KD and Walsh MG (2000) Light reflectance provides rapid assessment of soil quality. Ready for submission to *Science*.

Shepherd KD and Walsh MG (in progress) Diffuse reflectance spectrometry for rapid measurement of soil properties and performance To be submitted to *Soil Science Society of America Journal*.

Shepherd KD and Walsh MG (in progress) Measurement of management-induced changes in soil quality using diffuse reflectance spectrometry. To be submitted to *Soil Science Society of America Journal*.

Swallow B (2000) The effects of scales, flows and filters on property rights and collective action in catchment management. Paper presented at the Technical Workshop on Watershed management Institutions, System-wide Program on Collective Action and Property rights (CAPRi), Managua, Nicaragua, March 13-16, 2000.

Walsh MG and Shepherd KD (in progress). Screening for soil degradation in the Lake Victoria Basin. To be submitted to *Journal of Environmental. Quality*.

Walsh MG and Shepherd KD (in progress). Remote sensing of soil physical degradation in the Lake Victoria Basin. To be submitted to *Remote Sensing of Environment*.

Walsh M, Shepherd K, Verchot L, Albrect A, Noordvijk M van and Palm C (in progress). A rapid method for assessing soil carbon saturation deficit. To be submitted to *Soil Science Society of America Journal*.

Posters and Papers at International Meetings

Hansen, T Svan (2000) Evaluating the Environmental Impact of Participatory Soil and Water Conservation at the Watershed Level in Nyando Watershed, Western Kenya. Poster presented at the KL-2000 UNESCO/IUFRO Symposium: Forest – Water – People in the Humid Tropics: Past, Present and Future Hydrological Research for Integrated Land and Water Management. University of Kebangsaan, Malaysia, 30 July – 4 August 2000.

Mungai D, Ong C, Hai M (2000) The impact of land use and rainfall on sedimentation and runoff in the Lake Victoria Basin. Poster presented at the KL-2000 UNESCO/IUFRO Symposium: Forest – Water – People in the Humid Tropics: Past, Present and Future Hydrological Research for Integrated Land and Water Management. University of Kebangsaan, Malaysia, 30 July – 4 August 2000.

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1. Mugo, F.W. (1999). Natural Resource Use, Constraints and Possible interventions: The case for Kandaria West Focal Area. Start-up Phase Report No. 1. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

2. Mugo, F.W. (2000). Natural Resource Use, Constraints and Possible interventions: The case for Katuk-Odeyo Focal Area. Start-up Phase Report No. 2. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

3. Mugo, F.W. and Omushieni, S. (2000). Natural Resource Use, Constraints and Possible interventions: The case for Ombaka Focal Area. Start-up Phase Report No. 3. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

4. Mugo, F.W. (2000). Natural Resource Use, Constraints and Possible interventions: The case for Rongo (Kabienge) Focal Area. Start-up Phase Report No. 4. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

5. Mugo, F.W. (2000). Natural Resource Use, Constraints and Possible interventions: The case for Kobong'o River Bank Focal Area. Start-up Phase Report No. 5. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

6. Mugo, F.W. (2000). Natural Resource Use, Constraints and Possible interventions: The case for Lumbwa Catchment. Start-up Phase Report No. 6. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

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9. Ombalo D. and F.W. Mugo (2000). Natural Resource Use, Constraints and Possible interventions: The case for Olwa Catchment. Start-up Phase Report No. 9. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

10. Mugo, F.W. (1999). Natural Resource Use, Constraints and Possible interventions: The case for Nyalng'anya Catchment. Start-up Phase Report No. 10. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

11. Ombalo, D. and F.W. Mugo (2000). Natural Resource Use, Constraints and Possible interventions: The case for Ombeyi village. Start-up Phase Report No. 11. ICRAF, Ministry of Agriculture and Rural Development. Nairobi, Kenya.

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19. Mugo F. W., B Swallow and F. Place (2000). Natural resource use constraints and possible interventions: Synthesis report for 18 PRAs in Nyando District. ICRAF, Ministry of Agriculture and Rural Development, Nairobi, Kenya.

20. Mugo F W, D Ombalo, B Swallow and F Place (2000). Adoption of soil conservation measures in Dirubi catchment. ICRAF, Ministry of Agriculture and Rural Development, Nairobi, Kenya

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ANNEX:

RESEARCH RESULTS

Table of Contents

1. REGIONAL ASSESSMENT OF PRIORITY RIVER BASINS

Alex Awiti and Markus Walsh

1.1 Objective

Develop baseline information for characterization of major river basins to assist in the identification of priority areas for more detailed surveys of soil erosion risk and mapping activities in the Lake Victoria drainage basin.

1.2 Summary of Methods

Spatial databases consisting of digital elevation models (1 km resolution), stream networks (1: 1,000,000) obtained from USGS and DCW, were compiled for Kenya, Uganda, Tanzania, Rwanda and Burundi.

Basin Delineation
Stream networks were edited to isolate the main river systems that flow into Lake Victoria. Outlet and inlet points for all the river networks was used in combination with a depression free digital elevation delineate the upland drainage basins of the major river systems draining into Lake Victoria.

Spatial distribution of soil erosion/deposition
The geometry of the landscape can be used as a first level approximation for predicting movement of soil and water. In the USLE (Universal Soil Loss Equation), the influence of terrain on erosion is represented by the length-slope (LS) factor which indicates that soil erosion increases with increase in slope angle and slope length. Moore and Wilson (1992) have shown that the LS factor derived from this theory represents a dimensionless index of sediment transport capacity T, representing the influence of terrain on soil erosion.

$$T = \left(\frac{A_s}{22.13}\right)^m \quad \left(\frac{\sin\beta}{0.0896}\right)^n$$

Where, A_s is the specific catchment area (m^2m^{-1}) or flow accumulation, calculated from a digital elevation model. β represents slope angle (radians), and m = 0.6 and n = 1.3.

We use this function to characterize the spatial distribution of erosion and deposition processes for each of the delineated basins.

Fournier Index was used as an indicator of variations in erosion potential in the basins. The index is strongly correlated with sediment yields in streams.

Fournier Index $= p^2/\mathrm{P}$

Where p is the highest mean monthly precipitation and P is the mean annual precipitation. The Fournier Index is a good predictor of gully erosion (Kirkby and Morgan, 1980)

1.3 Results

1.3.1 Basin delineation

Eleven main rivers draining into Lake Victoria were identified. These are Nzoia, Yala, Nyando, Sondu Miriu, Gucha, Mara, Gurumeti, Mbalageti, Duma, Simiyu, Magoga, Isonga and Kagera. (See Figure 1.1)

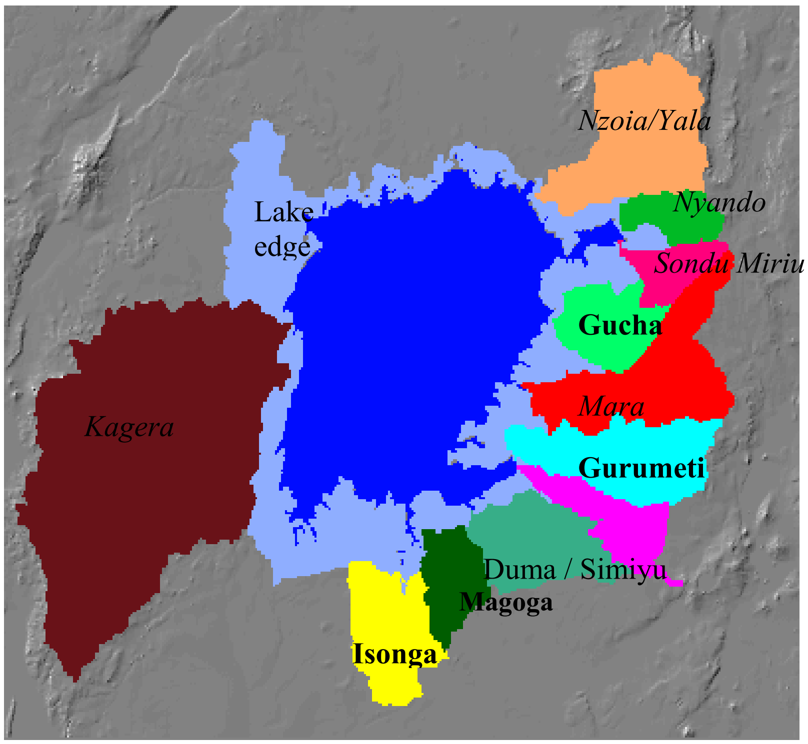

Figure 1.1 The Lake Victoria Basin

Table 1.1 presents summary descriptive information for each of the 11 river basins and the lake edge. Several results stand out. First, the overall lake basin covers 184,400 square kilometres and has an estimated human population in the year 2000 of 24,824,000, for an average population density of 135 persons per square kilometre. Adding Lake Victoria (68,000 square kilometres) and its catchment together gives an area of 252,400 square kilometres, slightly larger than the United Kingdom, sustaining a human population greater than the combined populations of Denmark, Finland, Sweden and Norway.

Second, only two of the eleven river basins are shared by more than one country. The Kagera is shared by Tanzania, Rwanda, Burundi and Uganda, while the Mara is shared by Kenya and Tanzania. Third, the largest river basin, in terms of both area and human population, is the Kagera. Next, in order of both size and human population, is the lake edge area. Runoff from this area drains directly into the lake, rather than into any of the 11 major rivers. Fourth, the four river basins that are contained within Kenya all receive considerably higher average annual rainfall than any of the other river basins. Indeed, average annual rainfall in the Miriu Sondu in Kenya is about twice as high as in the Mbalageti in Tanzania. Fifth, erosion risk, as measured by both percent slope and sediment transport capacity, is much higher in the Kenya rivers than in the Tanzania rivers. Average percentage slope is 5 percent in the Nyando and only 0.5 percent for the Mbalageti, the Simiyu, the Magoga and the Isonga.

River basin name	Countries sharing basin	Est. basin size (km^2)	Ave. est. 2000 pop. density (people/km^2)	Est. total pop. in 2000	Ave. annual rainfall (mm)	Ave. sediment transport capacity index	Ave. % slope
Nzoia / Yala	Kenya	15,143	221 (± 154)	3,346,000	1,306	0.14	2.3
Nyando	Kenya	3,517	174 (± 127)	611,000	1,360	0.30	5.0
Miriu Sondu	Kenya	3,583	220 (± 148)	788,000	1,415	0.14	2.3
Gucha	Kenya	6,612	224 (± 183)	1,481,000	1,300	0.16	2.0
Mara	Kenya Tanzania	13,915	46 (± 56)	640,000	1,040	0.15	2.0
Gurumeti	Tanzania	12,290	21 (± 26)	258,000	879	0.12	1.6
Mbalageti	Tanzania	5,702	37 (± 22)	211,000	766	0.05	0.6
Duma / Simiyu	Tanzania	9,702	50 (± 26)	485,000	804	0.06	0.5
Magoga / Muame	Tanzania	5,104	88 (± 47)	449,000	842	0.05	0.4
Isonga	Tanzania	8,972	48 (± 22)	430,000	897	0.04	0.3
Kagera	Tanzania Uganda Rwanda Burundi	59,178	181 (± 196)	10,711,000	1,051	0.24	3.0
Lake edge	Kenya Tanzania Uganda	40,682	133 (± 175)	5,411,000	1,077	0.21	1.4
Total basin		**184,400**	**135 (± 167)**	**24,824,000**			

Table 1.1 Demographic and biophysical charecterisation of the inlet drainage basins of Lake Victoria.

1.3.2 Spatial distribution of soil erosion/deposition

Figure 1.2 shows the spatial distribution of sediment transport capacity in the Lake Victoria drainage basin. Areas with high indices are those with higher potential for soil erosion.

Average values for sediment transport capacity index, slope, and Fournier index were computed for each of the basins. The results are summarized in Table1.1. Nyando and Kagera river basins stand out as distinctly different from the others. Nyando basin recorded the highest average sediment transport capacity (0.3) and average slope (5 %) in addition to a relatively high Fournier Index (31). Kagera had an average sediment transport capacity index of 0.24, average slope of 3 % and a Fournier Index of 31.

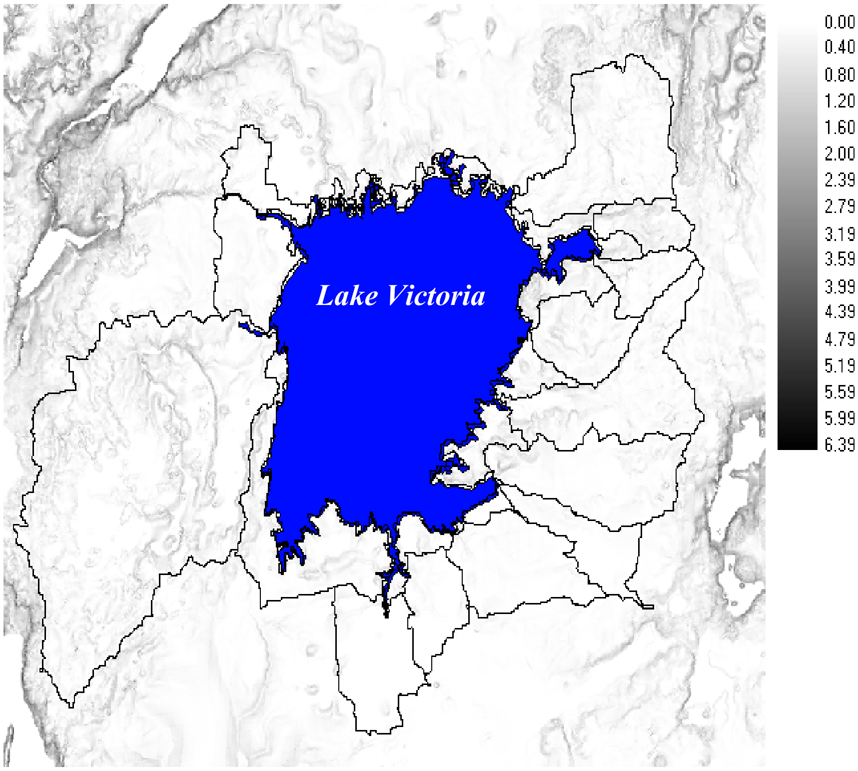

Figure 1.2 Sediment transport capacity for the Lake Victoria region

This coarse level basin characterization provides a quantitative basis for priority setting of river basins for more systematic assessment at finer scales, to specifically target the sub-basin erosion hotspots.

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Moore, I.D. and Wilson, J.P. 1992. Length of Slope Factors for the Revised Universal Soil Loss Equation: Simplified Method of Estimation. Journal of soil and Water Conservation 47: 423 – 428.

2. ASSESSMENT OF SOIL DEGRADATION IN THE KAVIRONDO GULF BASIN (WINAM GULF) OF LAKE VICTORIA

Markus Walsh and Keith Shepherd

2.1. Introduction

Soil degradation has negative impacts on agricultural productivity, ecosystem and atmospheric change, and water and habitat quality. The major soil degradation processes are accelerated soil erosion, depletion of soil organic matter and soil nutrients, and the deterioration of soil structure. It has been estimated that the degraded area of the world's arable land increased from 10% in the early 1970s to about 40% in the early 1990s. The greatest need for remediation is in developing regions of the world, where the rate of loss of agriculturally usable land has been estimated at 0.3% per year. Soil degradation through soil erosion, depletion of soil organic matter and soil nutrients, is a widespread problem in the Kavirondo Gulf Basin of Lake Victoria. As the use of inorganic fertilizer is limited in this area the productivity of both rangeland and farming systems are closely linked inherent productive capacities of soils. Additionally, many currently productive systems may be at risk for degradation as population pressure in many parts of the Kavirondo Gulf Basin is likely to double over the next 50 years.

Accelerated soil erosion and non-point nutrient runoff are also strongly linked to water quality degradation in Lake Victoria's waterways. Drastically enhanced eutrophication over the latter half of the 20th century has precipitated rapid ecological changes in the lake toward conditions that now favor the dominance nitrogen fixing cyanobacteria, the spread aquatic weeds such as water hyacinth (*Eichornia crassipes*). Nearly half of the lake bottom currently experiences periods of prolonged anoxia, compared to the 1960's when anoxia was localized and sporadic. It is believed that the combination of these factors in addition to the introduction of the Nile Perch (*Lates niloticus*) in the 1950's has negatively impacted the diversity of fish communities in the lake.

The principal objectives of this ongoing study are:

1. To assess the extents, magnitudes and etiologies of different soil erosion and non-point sediment source pollution processes in the Kavirondo Gulf Basin.
2. To evaluate risks of current land use practices with regard to selected soil fertility indicators.

2.2 Approach and methods

During the period of March 1999 - present a case-control protocol designed to assess the prevalence and impacts of soil degradation problems has been undergoing testing. To date 267 locations have been surveyed in the Nyando, Sondu Miriu and Nzoia / Yala river basins. Ground sampling locations were selected using a spatially stratified random sampling approach. All locations were georeferenced through survey-grade GPS and observations on land use, vegetation cover and composition, signs of accelerated soil erosion and occurrence of soil conservation structures were recorded. A total of 1604 soil surface (0-20 cm) and subsurface (20-50 cm) samples were collected. The vast majority of the topsoil samples have been analyzed in terms of basic soil properties such as texture, pH, organic carbon, extractable phosphorus and anaerobic mineralizeable nitrogen. All topsoil samples and approximately ¼ of the subsoil samples have been scanned with a diffuse reflectance spectrometer under laboratory conditions. Relationships between soil properties and soil reflectance measurements were assessed using partial least squares and graphical mixed models.

2.3 Initial results

1. A method that evaluates the extent and locations of active sediment sources using a combination of Landsat TM satellite imagery, ground survey and laboratory analysis has been developed and tested over the last nine months. An example is shown in Figure 2.1. Note that soil erosion hotspots have been highlighted in red in Figure 2.1b. This analysis complements and builds on earlier work that detected significant amounts suspended sediment in Nyakach Bay. The combination of the two approaches enables us to evaluate the relative magnitudes of suspended sediments emanating from the outlet of major rivers as well as to localize potential source areas. We are processing a broader dataset currently that covers both the Nyando and Sondu Miriu river basins in their entirety.

2. We have extensively tested diffuse reflectance spectrometry in the context of rapid assessment of soil degradation problems. Using soil reflectance measurements we are able to reliably predict many important soil properties (e.g., organic carbon, texture, "plant available" phosphorus contents etc). We have also been able to show that soils from different erosion surfaces have highly characteristic reflectance signatures, as do cultivated and non-cultivated soils (Figure 2.2). The differences in soil reflectances under different land use / soil erosion scenarios are due to differences in soil physical, chemical and biological properties that we believe occur as a direct result of soil degradation (also see result 3). In the future, these extremely promising results may enable us to differentiate these properties of soils from satellite images.

3. Evaluations of the properties of 802 topsoil samples showed that even moderately accelerated soil erosion appears to have highly negative impacts on soil physical, chemical and biological properties (Figure 2.3). For example, the effect of sheet erosion was to decrease soil organic carbon stocks by 17-25% and exchangeable bases by 39-47% over comparable intact soils in our sample and depending on whether samples were obtained from cultivated or uncultivated sites. The mechanism of this process appears to be related to stripping of fine material such as clay and silt from the topsoil. Severe problems such as gully erosion have potentially even more dramatic impacts. Note that the average soil reflectance profiles shown in Figure 2.2 correspond to the samples shown in this Figure.

Additionally, the Landsat image shown in Figure 2.1 was analyzed using the soil reflectance measurements of sheet eroded, uncultivated soils and hence provides an estimate of the distribution of these types of soils in the landscape.

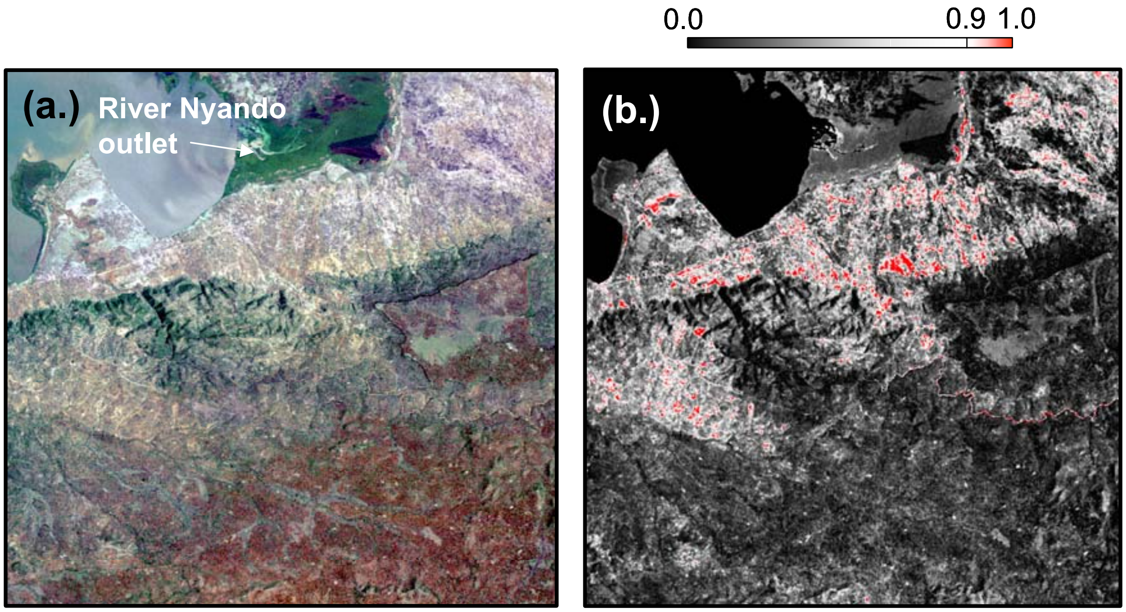


Figure 2.1 **Prevalence of severely accelerated soil erosion in the Nyakach Bay area of Lake Victoria:** (a) Landsat TM image. (b.) Processed image to highlight areas with high erosion probability.

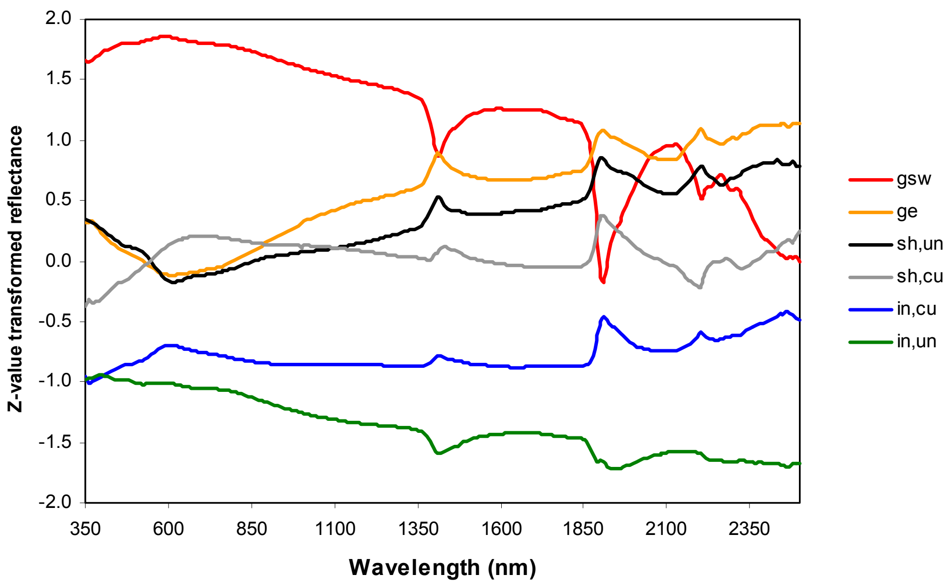


Figure 2.2 **Soil reflectance properties of different land use and soil erosion combinations.** (in,un = apparently intact, uncultivated soils, in,cu = apparently intact, cultivated soils, sh,un = sheet eroded, uncultivated soils, sh,cu = sheet eroded, cultivated soils, ge = soils at risk for gully erosion (60 – 100 m from currently active gullies), gsw = soils currently active gully side walls.

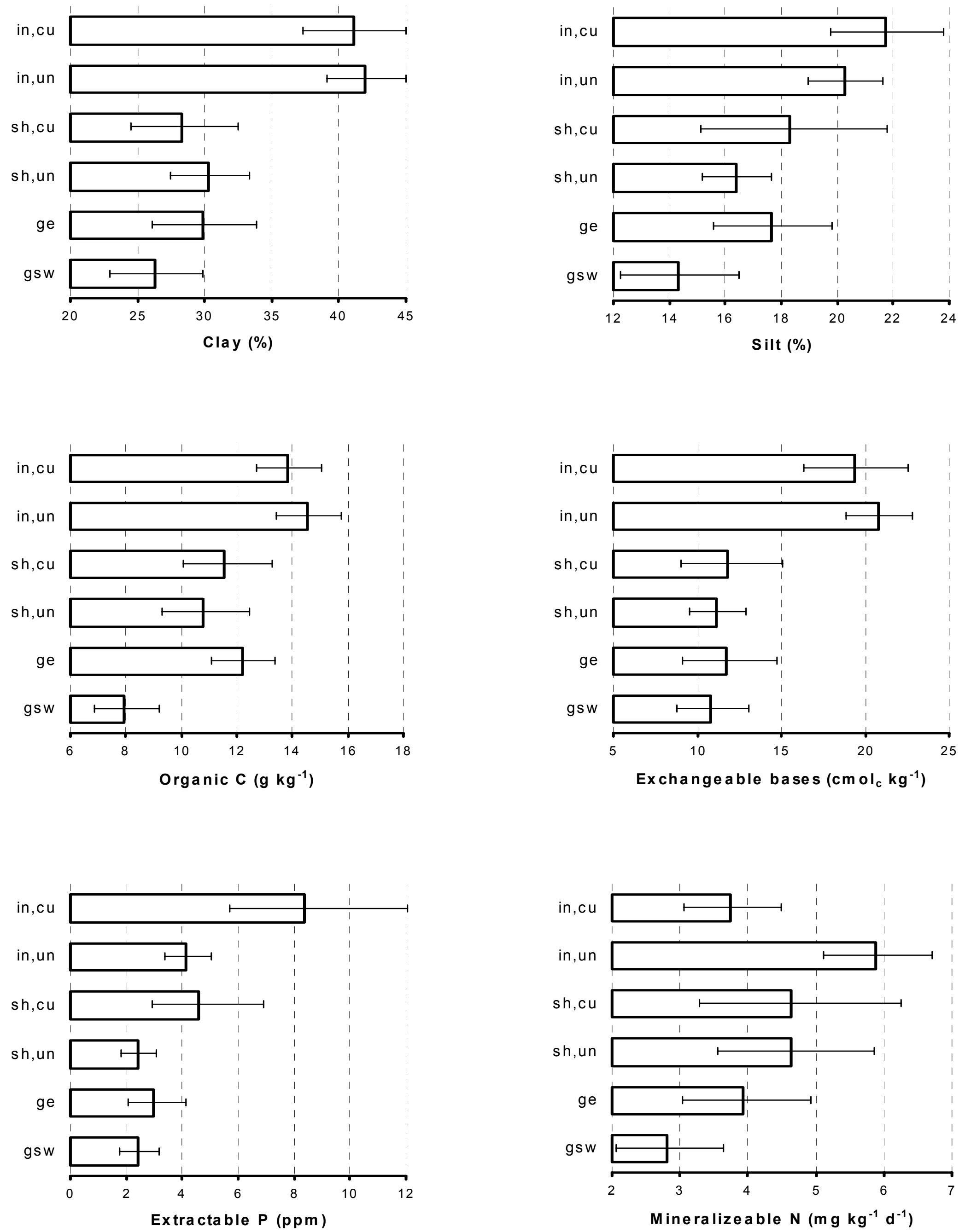


Figure 2.3 **Observed soil fertility indicator profiles under different land use and soil erosion combinations.** Bars represent least squares mean values, bracket bars are 95 % confidence limits. (in,un = apparently intact, uncultivated soils, in,cu = apparently intact, cultivated soils, sh,un = sheet eroded, uncultivated soils, sh,cu = sheet eroded, cultivated soils, ge = soils at risk for gully erosion (60 – 100 m from currently active gullies), gsw = soils currently active gully side walls.

4. Information on soil quality and soil erodibility can then be combined to answer more refined questions such as "where are areas with high erosion risk and elevated soil phosphorus levels?" (Figure 2.4).

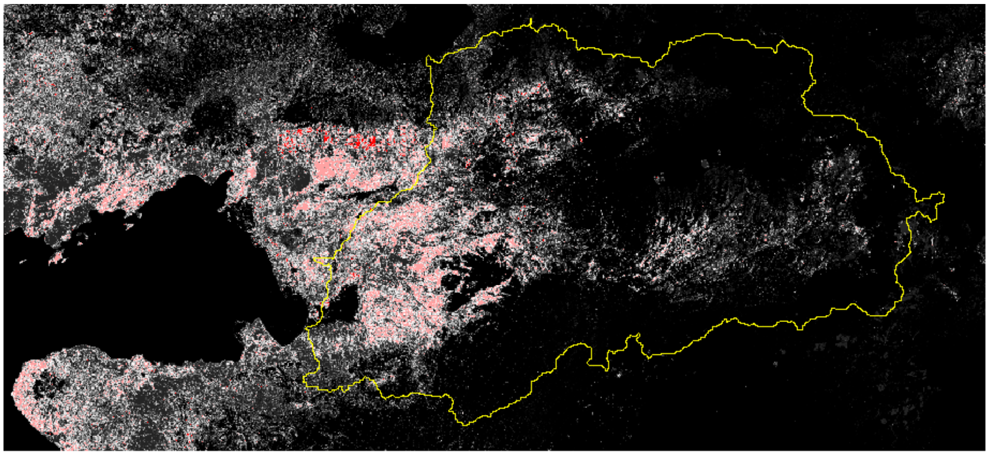


Figure 2.4 Image processed to reveal areas with elevated phosphorus erosion risk in the Nyando river basin (basin boundary highlighted in yellow).

5. Based on the results of the surveillance survey, models were developed that relate degree of erosion to vegetation cover, soil reflectance and slope (Figure 2.5).

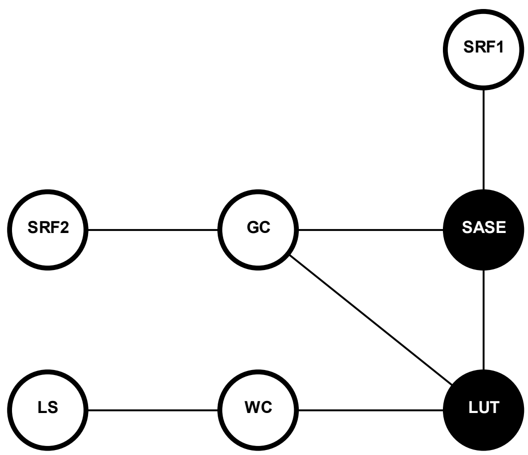


Figure 2.5 Graphical model showing modeled conditional dependencies between visible signs of accelerated soil erosion, ground observations and soil reflectance. Signs of accelerated soil erosion (SASE is a categorical variable in 2 classes 1 = no visible signs of accelerated soil erosion, 2 = sites w. rills, gullies or capped soils); land use type (LUT is a categorical variable in 3 classes, 1 = smallholder agriculture, 2 = commercial agriculture, 3 = other land uses incl. forest, rangeland & wetland categories); ground vegetation cover (GC in % cover to 1 m height), woody vegetation cover (WC in % basal cover) slope LS-factor (*24*) and soil reflectance (SRF1 & SRF2 = 1^{rst} two principle components of soil reflectance, SRF1 accounts for 94% and SRF2 for 5% of the variation in soil reflectance across all sampled 30×30 meter plots (n = 150)). All depicted conditional dependencies are significant at the $p < 0.01$ level.

These simple models allow critical levels of vegetation cover (both herbaceous and woody cover) to be established for the protection of different soil types and slope classes. These critical levels can serve as targets for sustainable land management.

6. We have developed a method for sampling and characterizing sediment cores from river mouths and lake bottoms. Two sediment cores were taken from the mouth of the Nyando. Spectral characterization of a reference core revealed a distinctive strata (Figure 2.6) below a depth of 1.25 m. Diatom analysis has suggested that sediment above this depth is derived from soil erosion. Dating of the cores is in progress so that a historic record of sedimentation can be built up. In this way, we can rapidly build up a picture of major contributing areas to sedimentation of the lake.

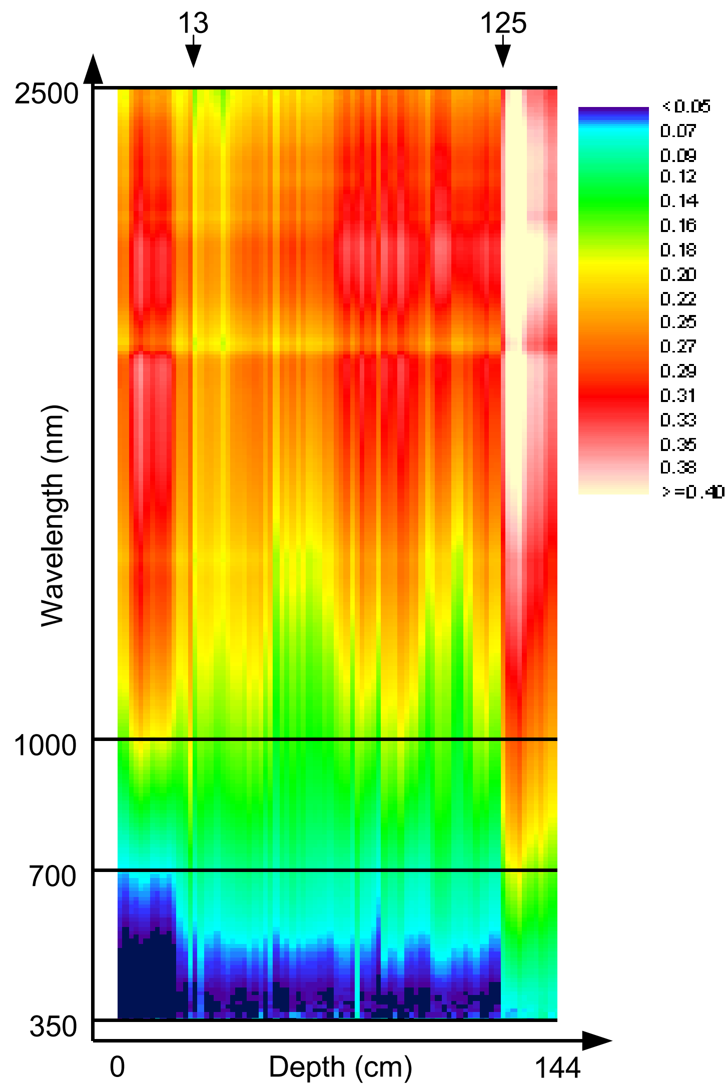


Figure 2.6 **Diffuse reflectance spectrometry is used to identify strata in sediment cores. Analysis of the cores will allow us to build up a historic record of sedimentation and identify source areas in the river basin.**

3. RELATIONSHIPS BETWEEN TREE COVER, LAND TENURE AND POPULATION DENSITY IN WESTERN KENYA

Markus Walsh

In 1986, Ecosystems Ltd conducted a low altitude aerial land use survey exercise of the Kenyan portion of the Victoria Lake Basin[1]. This database represents one of the most comprehensive land use inventories ever conducted in Western Kenya and includes over 1500 georeferenced observations distributed over an area of approximately 39,000 km^2. The database includes aerial estimates of tree cover (in forests and on agricultural lands), agricultural land use and cropping systems, population and housing unit densities and distribution of land tenure categories[2].

The data were analyzed using a graphical mixed model approach[3] to investigate the existence of associations between housing unit densities (as a proxy for population density), land tenure categories and tree cover estimates. Four potentially confounding variables (mean elevation, slope, agricultural field size and farm area under commercial crops) were included in the analysis to control for differences in physiography and agricultural production systems that are also related to human and tree population distributions in this landscape.

Relationships between tree cover and housing unit estimates were indeed strongly confounded with physiographic and production system variables. An example of this is shown for the freehold land tenure category in Figure 4.1. Nonetheless, highly significant ($p < 0.001$) positive partial correlations between tree cover values on farmland and housing unit density estimates were observed, after accounting for confounders (Table 4.1). This suggests that a relationship may exist between tree cover on farmland and population density beyond that explained by physiography and production system. This relationship is particularly pronounced under conditions of reasonably secure land tenure such as in the freehold land tenure category.

Relationships between forest tree cover, total tree cover and housing unit densities were less pronounced and depended strongly on land tenure category. An exception is freehold land, for which a moderately high positive partial correlation was observed between total tree cover and housing unit density.

Notes

[1] Ecosystems Ltd. 1986. Unpublished report.
Document and Access / Excel database available from authors.

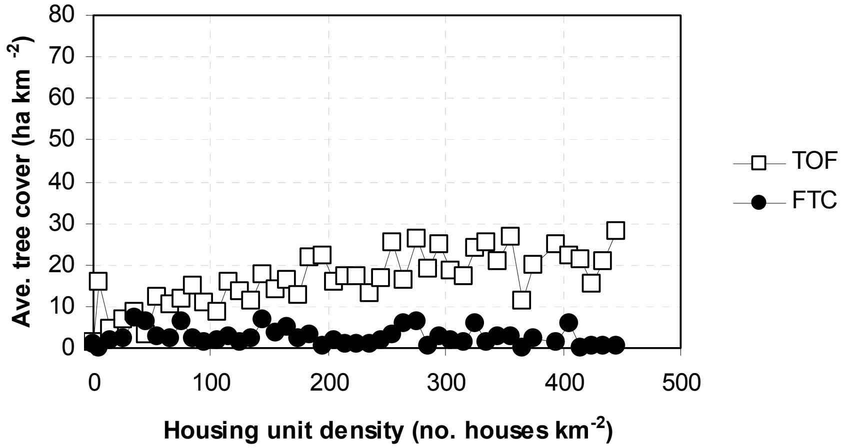
[2] Definitions: Government land. Trust land, Leasehold land, Freehold land

[3] D. Edwards.1995. Introduction to Graphical Modeling. Springer Verlag, New York. 275 pp.

Variables & parameters	Land tenure category			
	Government	***Trust***	***Leasehold***	***Freehold***
Dependent:				
Total tree cover (TTC in ha km^{-2})	44.4^{c}	13.0^{a}	15.9^{a}	22.0^{b}
Forest tree cover (FTC in ha km^{-2})	35.5^{b}	3.9^{a}	6.7^{a}	3.8^{a}
ρ TTC	*0.88*	*0.55*	*0.72*	*0.56*
Farm tree cover (TOF in ha km^{-2} farmland)	11.2^{a}	10.7^{a}	8.3^{a}	19.2^{b}
ρ TTC	*0.35*	*0.50*	*0.68*	*0.80*
ρ FTC	*-0.33*	*-0.28*	*-0.50*	*-0.47*
Independent:				
Housing unit density (no. houses km^{-2})	78.4^{a}	151.0^{b}	87.3^{a}	226.4^{c}
ρ TTC	*-0.11*	*0.24*	*-0.01*	*0.45*
ρ FTC	*-0.18*	*0.02*	*-0.16*	*-0.09*
ρ TOF				

Table 4.1 **Average tree cover and housing unit estimates by land tenure category (values with different superscripts are different at the $p < 0.001$ level). Also shown are the partial correlations (ρ) between variables after controlling for differences in mean elevation, slope, and size of agricultural fields and proportion of farmland under commercial crops.**

(a)



(b)

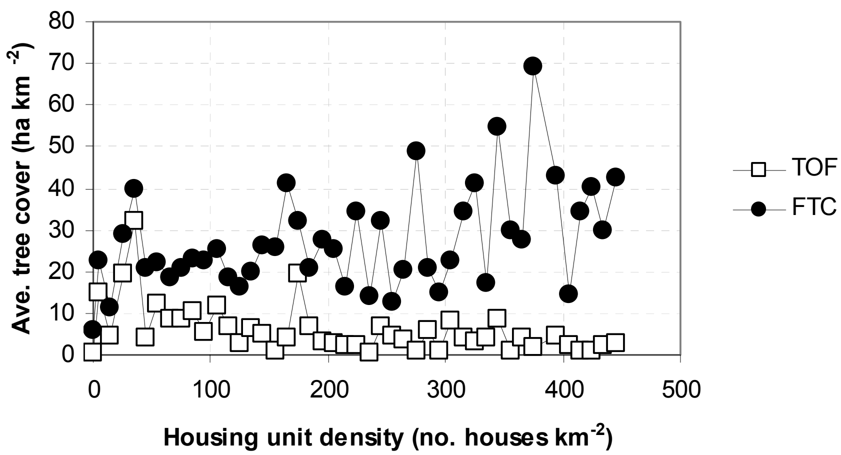


Figure 4.1 **Relationships between tree cover and housing unit density on freehold land in Western Kenya. TOF = Trees on farms; FTC = Forest tree cover. (a) is for elevations < 1,600 m a.s.l; (b) is for elevations > 1,600 m a.s.l. Tree cover values were averaged by housing unit density class (0-10, 10-20, …440-450) for clarity of display.**

4. ASSESSMENT OF SEDIMENT AND NUTRIENT LOADS IN RIVERS

Chin Ong, Paul Smithson, and Michele Swallow

An estimate of sediment load is important in determining pollution in the lake as well as in evaluating channel deposits along the lower reaches of the river and the dead storage of reservoirs. According to the Lake Basin Development Authority (LBDA), previous attempts to do this have been unreliable because of insufficient samplings of discharge and suspended load. Annual sediment loads from various rivers were attempted by several studies with insufficient data collected in the early 1940s and 1950s. For example, the sediment load of Sondu Miriu was estimated as 150t km^{-2} and Nyando as 423t km^{-2}. However, these estimates do not reflect the considerable changes in land use in both river basins since, which would increase the sediment load. An analysis of the published water quality data from 1985 to 1998 of the Nyando river confirms that average turbidity at Ahero has increased steadily from 80 to 150 NTU while the turbidity of the river at Kericho has remained unchanged over the same period.

We monitored the turbidity of both the Nyando and Sondu Miriu rivers from May to December 1999 and found that the average turbidity values for the last year was 750 NTU for the Nyando: ranging from a peak of 1870 NTU during the wet season to a low of 60 NTU in the dry season at Ahero. In contrast, average values for Sondu Miriu was 100 NTU at Koguta with a peak of 340 NTU and a low of 16 NTU. The high value of turbidity at Ahero is evidence of the continuing trend of growing sedimentation rate while the low turbidity of Sondu might reflect the impact of the construction of the Sondu Miriu Hydro-electric dam nearby.

The river samples along the entire length of both rivers were analyzed for total nitrogen and phosphorus. Results shows that P levels from Nyando are 5 times higher than the Sondu Miriu. Furthermore, P levels of the Sondu Miriu are consistently lower than in the lake near Kusa, suggesting that it is not a serious contributor to eutrophication to the lake. The major hotspots in the landscape are along the Kano plains, where the alluvial soils are most prone to riverbank erosion (See Figure 4.1). However, the sources for the energy for riverbank erosion are driven by peak flows in the river systems, which is not controlled by local environment but by the upstream watershed. The vast deforestation of the Nandi and Bondo escarpments has increased the velocity of the stream flow during the wet season. There is little data from the region of the amount of sediment moved by erosion of riverbanks, although studies on such relatively flat but erodible site have indicated that 75% of the sediment could have originated from the riverbanks.

Sampling of rivers was extended to other major rivers in Kenya, Tanzania and Uganda, to provide a preliminary comparison of the relative contribution from each country. The additional rivers sampled in October and November were Nzoia and Yala in Kenya, Mara, Simiyu, Gurumeti and Kagera in Tanzania, and Nile, Bukora, Kisoma and Katonga in Uganda. The Nile and Mara rivers were the cleanest, followed by an intermediate group consisting of Gurumeti, Simiyu, Kagera, Katonga and Bukora, and the dirtiest group includes Nyando, Yala and Nzoia. The last two groups of rivers, which contained P levels 2-3 times greater than the critical concentrations of 0.1 mg P L^{-1}, may accelerate the eutrophication of the lake.

Over all sites, total N and P levels in water tended to be correlated. Correlation of total P with turbidity (NTU or sediment load) was weak, though most P is usually associated with eroded sediment. Eutrophication potential of P inputs will depend on the proportion of "bioavailable" P. Spot checks of bioavailable P (estimated by resin extraction) showed from 7 to 29% of total P to be readily available, and was not strongly related to total P or sediment load.

River sediment and nutrient load will continue to be monitored regularly in Kenya and less frequently in Tanzania and Uganda.

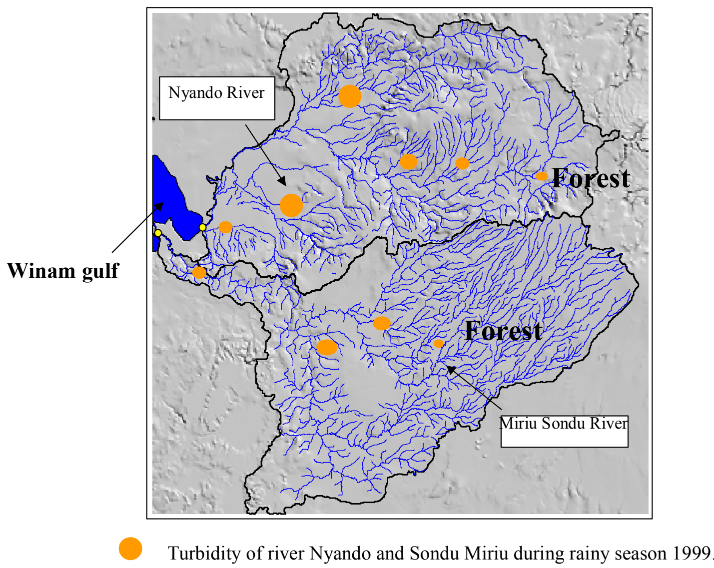


Figure 4.1 **Summary of data on the turbidity of rivers in the Nyando and Sondu-Miriu rivers during the 1999 rainy season**

5. LAND USE AND CATCHMENT HYDROLOGY

Chin Ong, Mwangi Hai and David Mungai

5.1 Introduction

The relationship between land use and hydrology is of interest worldwide especially in many developing countries, where extensive areas are converted from forests to agriculture. The largest changes in terms of hydrology and sedimentation often arise from deforestation and afforestation. There is considerable evidence from Kenya of the strong relationship between land use, runoff and sedimentation from drainage basins. For example, sediment yield from undisturbed forest catchments lose sediment at a rate of 20 to 30 t km^{-2} yr^{-1}, while agricultural basins range between 10 and several thousand t km^{-2} yr^{-1}, depending on runoff, topography, and the proportion of the basin that is cultivated. Average sediment yield from agricultural regions was only 90 t km^{-2} yr^{-1} with a range of 1,000 to 5,000 t km^{-2} yr^{-1} from the steepest and wettest slopes. Rangelands have similar variability but sediment yields are generally higher. In the Nyando district agriculture lands account for a relatively small proportion of the land therefore the adoption of soil conservation measures on cultivated land alone might not have a major impact on the sedimentation into the lake. On the other hand, the dense network of roads and footpaths, which comprises about 1% of the basin area, has a low infiltration capacity and might contribute between 25 to 50 % of the basin sediment yield.

5.2 The study area

The Ragen study area is named after one of the ephemeral rivers emanating from the steep Nyabondo escarpment and draining into the marshes of Nyakach Bay. The escarpment forms the boundary of Nyabondo Plateau. After field investigations, Rongo and Nyamarimba were selected as the most suitable study sites. Rongo was also selected for interventions. Nyamarimba shares its northern boundary with Rongo and also has a tributary of the main stream. The two areas are similar in land use, soils and weather patterns but may be different with respect to size and topography. Both streams and the larger Ragen are monitored with water measurement flumes.

A paired watershed approach is adopted to measure erosion from two similar watersheds using a combination of standard erosion plots with automatic tipping buckets for each land-use and H-flumes at the Rongo (with interventions) and Nyamarimba (control without interventions) watersheds (See Figure 5.2).

Results from the watersheds will be used examine the impacts on runoff and sedimentation of present land use and potential interventions using a terrain- based, TOPOG, developed by CSIRO, Australia. TOPOG is a process- based model for predicting water yield, storm flow runoff production, sediment production and soil moisture dynamics and to simulate the response to vegetation change (Vertessy RA et al., 1993). Water balance is computed for the area represented by each element. Non-topographic spatial attributes, such as soil and vegetation properties, are accounted for by overlays similar to those found in Geographic Information Systems.

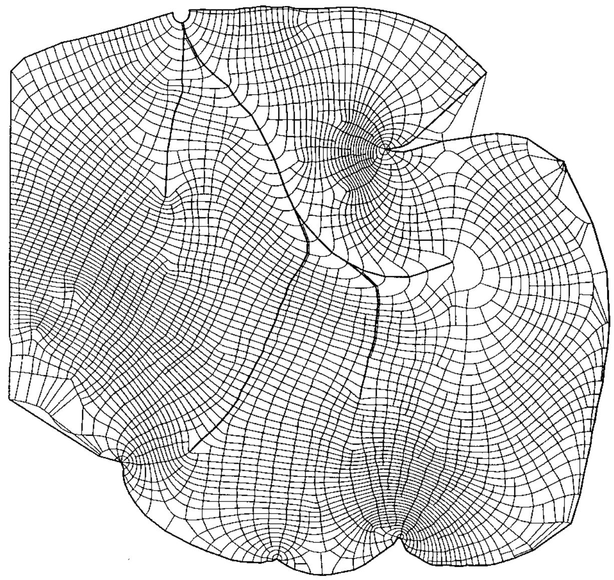


Figure 5.1 TOPOG-generated element network of the Rongo Catchment, Nyando District

5.3 The experiment

Goal and objectives

The goal of this research is to get information that can improve our understanding of the dynamics and possible impacts of land use change subsequent to deforestation of sloping areas. Better understanding of this environment will also help us develop and evolve more sustainable land use practices for the farming communities in similar areas. The specific objectives of this research are:

i) Assessment of land use changes over time

ii) Assessment of infiltration, runoff and soil erosion rates from different land uses

iii) Monitoring watershed runoff discharge rates and sediment yield

iv) Application of GIS techniques to map soil types, vegetation cover, slopes and erosion susceptibility

v) Modeling specific intervention measures to reduce runoff and erosion

The main activities carried out included:

a) assessment of runoff and soil loss from five dominant land uses – cultivated, grazing, bushland, footpaths and degraded areas

b) assessment of watershed behavior on rainfall impact

c) assessment of land use changes

d) assessment of long-term rainfall patterns and trends

e) preparing for the development of modeling capacity

Consequently, this experiment involves assessment of runoff and soil loss from five dominant land uses – cultivated, grazing, bushland, footpaths and degraded areas. In Rongo, a well-maintained pasture was also monitored for comparison of the effect of better pasture management on degradation. Plot-scale data of runoff volume is collected after every storm and runoff samples taken for further analysis. Moreover, stream runoff data is monitored during every storm and runoff samples taken.

5.3 Instrumentation

A number of instruments are used for data collection. These are described below.

Tipping buckets
This equipment was developed earlier and has been used extensively at ICRAF Machakos field station. It collects runoff from a defined area. A pair of tipping buckets meters the runoff volume, each bucket tipping at 3 litres. One side of the system collects 1% of the tipping volume. This volume is stored in a closed container. Each tip is recorded by use of a magnetic counter. When connected to a logger, this gives information on real-time runoff intensity. 22 tipping buckets (6 in Rongo and 16 in Nyamarimba) have been installed.

Pipe samplers
This is a simpler equipment used for monitoring runoff. It is especially useful in remote areas and where tipping buckets would be more difficult to install or maintain. Its biggest advantages include simplicity, low cost and ease of installation. In operation, runoff from a known area is directed to the sampler via a channel. As runoff flows through the sampler, 1% is collected through a vertical slot on the traverse side of the sampling pipe at the center of the channel, and is stored in a closed container. A total of 28 pipe samplers (24 in Rongo and 4 in Nyamarimba) have been installed.

Water-measurement flumes
Two types of flumes have been installed for this work. Two identical H-flumes of 3ft (91.5mm) top width were fabricated from 16G galvanized sheet at the Department of Agricultural Engineering, University of Nairobi. They were installed into 2m reinforced concrete approach channels. These flumes have a capacity of $857 ls^{-1}$. A larger Parshall flume (3048mm at the control section) was installed in the main river. Made of reinforced concrete, this flume has a capacity of 8.19 m^3s^{-1} (Bos, 1989).

Weather station
A weather station provided by ICRAF was installed at Buru Kamach primary school in Rongo sub-watershed. This station is recording data on rainfall, humidity and wind speed. The radiation sensor is not working.

5.4 Assessment of land use change

Aerial photographs of 1961 and digital images taken in March this year have been procured. This part of the study was done in July 2000 after the end of the start-up year. From these, a preliminary assessment has been done for Rongo, roughly 14% of Upper Ragen. The initial findings are presented in Table 5.1.

Land use type	Approximate area of coverage (ha)		% change
	1961	2000	
Bushland	28.56	26.56	-7.0
Cultivated	37.65	62.91	67.1
Degraded	6.51	7.15	9.8
Grazing	70.99	43.46	-38.8
Homesteads	5.65	9.28	64.2
Paths / roads*	0.70	2.16	198.8

* see Table 5.2

Table 5.1 Preliminary land use change assessment for Rongo sub-watershed

Evident from this table is that the area under bushland decreased by 7%. This was mostly converted to cropping or trees simply cut down for timber, building material or firewood. Cultivated area increased by 67%. This is perhaps a reflection on the population growth during the same period and therefore a natural response to produce more food. It is also consistent with the 64.2% increase in the land under homesteads. Homesteads house people and livestock at night. Due to trampling of the soil and a massive increase in the use of iron sheets, homesteads could also be a major source of runoff. It is proposed that short-term quantification of runoff from homesteads will be done.

The badly degraded area increased by 10%. Although appearing as a marginal increase, three important observations can be made about this change. One, the area just to the north west of the flume does not look degraded in the 2000 image. This is because some sparse grasses now cover the area, but otherwise the top-soil was washed away and what remains is basically a rocky, unproductive land. Secondly, some degraded areas towards the eastern boundary seem to have been rehabilitated. These now show terraces, and are therefore classified as cultivated areas, even if they are of a reduced production capacity and still possess a significant erosion capacity. Thirdly, there was an increase not only in the total degraded surface of area but also in intensity. The 1961 image shows degraded areas as merely devoid of vegetation and some few visible rills. Conversely, the 2000 image show an intense network of rills and deep gullies. This is collaborated on the ground. More soil may have been lost through the deepening of rills and gullies than by the increase in degraded surface area as such.

The grazing area shrunk by about 39%. Most of this was through conversion into cultivation fields in the lowland and colonization especially by bushes such as *Lantana camara*. In the same period, the network of roads and footpaths increased significantly. The length of footpaths and the corresponding area under this land use increased to 5925 m (145%) and 21645 m^2 (199%). The higher increase in area is attributed to widening of paths for use by vehicles. Whereas there were no roads in 1961, these increased to roughly 4km by 2000. Roads and paths vary in width and intensity of use by people and livestock, but represent a significant change to a potentially high runoff producing land use type.

No.	**Description of roads / footpaths**		**Estimated length (m)**		**Estimated area (m^2)**	
	1961	**2000**	**1961**	**2000**	**1961**	**2000**
1	All footpath	All motorable road	1292	1640	3876	9840
2	-	100m motorable	0	405	0	1515
3	All footpath	All motorable	250	250	750	1500
4	All footpath	All motorable	168	250	504	1440
5	All footpath	300m motorable	180	920	540	3660
6	-	300m motorable	0	500	0	2400
7	-	100m motorable	0	325	0	1275
8	-	All motorable	0	370	0	2220
9	All footpath	350m motorable	0	810	1020	3480
10	All footpath	150m motorable	340	465	555	1845
11	-	195m motorable	185	575	0	2310
	Total		2415	5925	7245	21645
	% change			+145.3		+198.8

Table 5.2 Computation of road and footpath lengths and areas in Rongo sub-watershed[1]

5.5 Assessment of plot and watershed runoff

Work so far has been mainly on runoff flow rates for two storms (11/4 and 11/5). An assessment of suspended sediment loading and nutrients has not been done yet.

Plot-scale assessment of runoff and soil loss

This report refers to a limited assessment of behavior of different land use systems at plot scale in Rongo sub-watershed. A typical presentation of runoff lost over a specified period is compared in Figure 5.2.

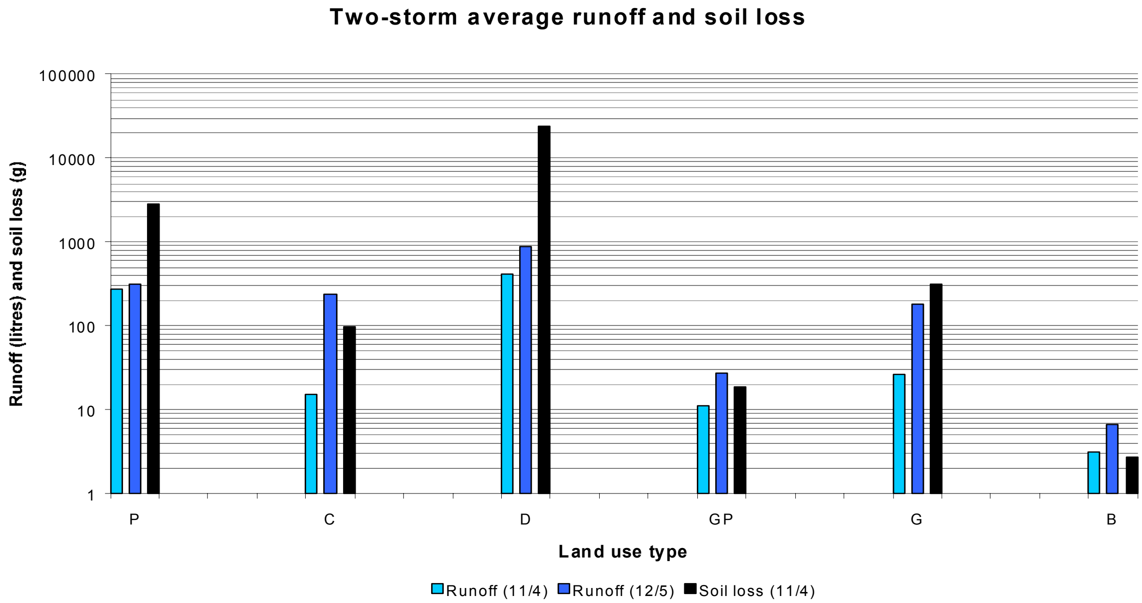


Figure 5.2 Relative runoff and soil loss values for different land uses

From these results, the initial assessment is that:

a) Bushland exhibited the lowest risk to land with regard to runoff loss and, perhaps, erosion susceptibility.
b) Well-maintained pasture was found to yield low runoff, and is therefore protective of the soil material.
c) Even terraced land loses a significant amount of runoff and soil, especially if the soil conservation structures are not maintained.
d) Paths are an important source of runoff. Although occupying a relatively small surface area, paths could possibly be playing a significant part in accelerating soil erosion.
e) Degraded surfaces are deceptively dormant; they look bad enough that one hopes they are no longer active. In reality, the limited data analyzed indicate that most degraded surfaces are still losing large amounts of runoff and soil.

Although only Rongo data has been presented here, it is expected that these findings are similar between Rongo and Nyamarimba.

Comparative watershed assessment of runoff
This report refers to initial impressions of the behavior of Rongo and Nyamarimba watersheds as measured using the two identical H-flumes. A typical hydrograph of the two watersheds is given in Figure 5.3.

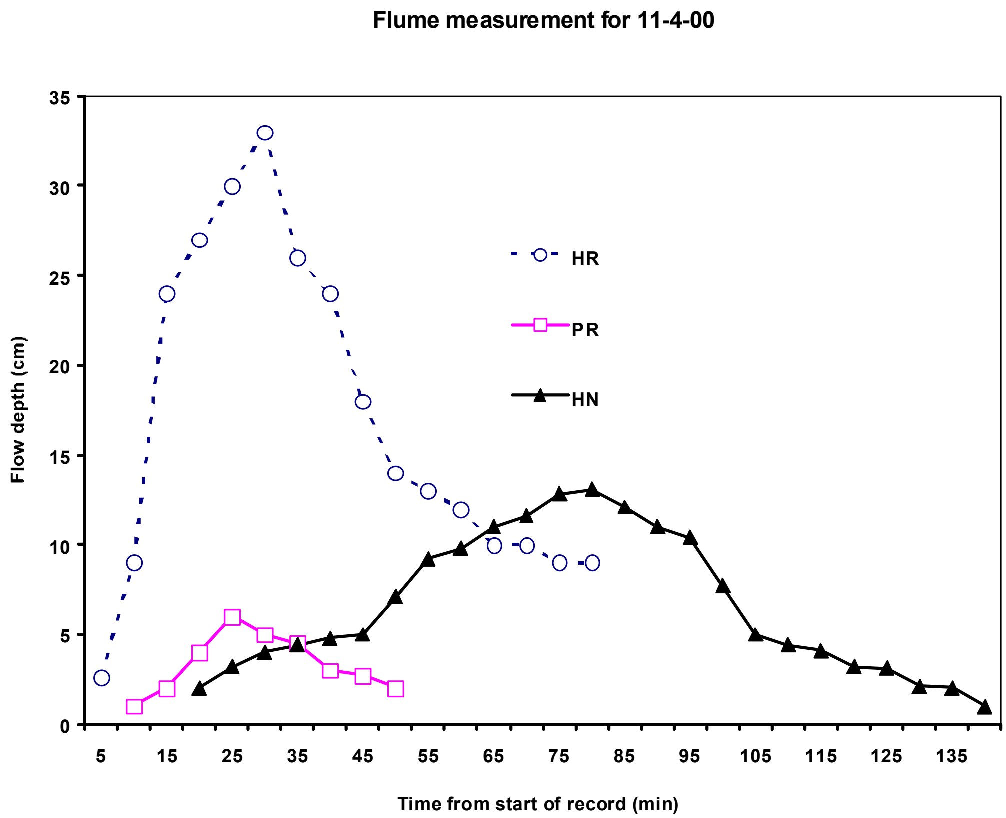


Figure 5.3 Comparative hydrographs of Rongo and Nyamarimba sub-watersheds HR=Rongo flume, HN=Nyamarimba flume, PR=Parshall flume on Ragen.

The results indicate that unlike Nyamarimba, Rongo sub-watershed is subject to flash runoff events. Within a very short time (usually about 30 minutes after the start of rains) the peak runoff occurs. This implies that the sub-watershed absorbs less rain. Initial suggestions are that this is caused by two factors: a) the generally steeper slopes in Rongo, b) the larger percentage of degraded areas. These and other possible causes making significant contribution to increased runoff will be analyzed further. However, our initial guess that the Rongo sub-watershed required interventions was shown to have been correct.

5.6 Assessment of long-term rainfall patterns and trends

This study was done with Prof. David Mungai of the Geography Department, University of Nairobi. It was based on 61 years (1939-1999) of monthly rainfall data from Kisumu Meteorological Station. The long term annual mean rainfall at Kisumu is 1324 mm with a standard deviation of 210 mm. Apart from below normal (1940, 1959, 1980-early 1990s) and above normal (1960-1979, early 1990s-) rainfall patterns, there were otherwise no specific annual trends discernible. However, long periods of below average rainfall had a tendency to be followed by exceptionally wet years, e.g. 1951, 1961, 1978 and 1997. This pattern of rainfall occurrence has implications on land use as well as land degradation in the study area.

5.7 Preparation for the development of modelling capacity

We have also been preparing for the development of modeling capacity. So far an Australian model, TOPOG, has been identified. This is a physically-based, distributed parameter model capable of simulating the behavior of small watersheds. A topographic survey has been done covering Rongo and a digital elevation model developed. The NT system at ICRAF could not handle modeling. A separate operating system, LINUX, was installed. Installation of the model is still on-going.

5.8 Preliminary conclusions

From the analysis given above, surface water management is critical in the management of soil erosion problems. Loss of rainfall through runoff adversely affects crop and vegetation growth by greatly reducing soil available moisture. Moreover, nutrients are lost from the landscape together with soil. Improved retention of surface water could greatly improve food production, pasture productivity and water availability.

These findings will be used to formulate the next phase of the research – interventions. The phased interventions are planned to start from September. The interventions will be concentrated in Rongo sub-watershed as it seems to have the bigger problem of runoff loss and a greater risk of erosion. Interventions will bring together a number of institutions – mainly Ministry of Agriculture and Rural Development, ICRAF, Relma and the local community.

[1] **Notes**

1) The data is obtained from aerial photographs of Jan 1961 and digital images of Jan 2000.
2) The lengths are scaled measures based on what can be discerned without a stereoscope.
3) The widths are approximated based on normal space allowed for minor roads and paths; footpaths were taken as 3m wide, roads as 6m wide.
4) Demarcation of roads and paths is an approximation based on general knowledge of the area.

Acknowledgements

I wish to gratefully acknowledge the immense contribution towards financing the equipment installed: Relma (*data loggers and pressure transducers*), ICRAF (*weather station, tipping buckets and pipe samplers*) and the Ministry of Agriculture and Rural Development (*water measurement flumes*). The last two have also provided all logistical support for the fieldwork. Special thanks also to Mr. Francis Mbote (Head, SWCB), Dr. Martin Grunder (former Senior Programme Advisor), Prof. Chin Ong and Dr. Johan Rockstrom (supervisors), and Dr. Brent Swallow and Prof. David Mungai for their special contributions to the work.

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6. PARTICIPARTORY APPRAISAL OF ENVIRONMENTAL PROBLEMS AND SOLUTIONS IN NYANDO DISTRICT

Six activities were conducted to generate information for different purposes. They include 18 PRAs, a soil and water conservation adoption study, a soil and water conservation baseline study, a livelihoods study, an agroforestry extension staff training and four agroforestry exposure field visits for staff and farmers to Kibwezi, Maseno, Kusa and Ombaka.

6.1. Introduction

Staff from ICRAF and the Ministry of Agriculture worked closely together in participatory assessment of problems and possible interventions. Eighteen Participatory Rural Appraisals (PRAs) were conducted in Nyando District to:

1. Identify constraints to the optimal utilization of natural resources in the lake basin;
2. Elicit farmers' knowledge on erosion hotspots, causes, effects, and effectiveness of current measures;
3. Identify livelihood options and their relative importance to the community; and
4. Identify the existing local institutions in the village, their activities, and constraints to their optimal operation.

It was also intended to identify possible interventions that will lead to land management practices that improve farm productivity while having maximum impact on reducing pollution into Lake Victoria.

Five of the PRAs were conducted in the steep hills, five in the gently sloping plains and four in the flood zone. The specific villages were: Ndori, Kwoyo, Rongo, Rakwaro and Kamgan in the steep hills; Kandaria, Olwalo, Katuk-Odeyo, Lumbwa and Ochieng-Odongo in the gently sloping plains; and Kowino, Ombaka, Kosida and Kakola in the flood zone. Two PRAs (Jaber and Ombeyi) were conducted in the sugarcane belt of Nyando basin and two (Nyalng'anya and Olwa) in the Sondu basin (See Figure 6.1).

Separate reports were written for each PRA and will be disseminated to all relevant institutions and individuals. In addition, an overall report is being prepared to summarize results across the 18 locations. Results of the PRAs were presented to stakeholders at a workshop held in Kisumu March 2000.

6.1.1 Research methods

Three methods were used to gather information. Each PRA started with a one hour transect walk followed by two hours' of a group interview in one home. It was concluded with a three hours' community meeting in a church or public ground. Information was gathered by three groups of four to eight purposively selected members of the community. Efforts were made to have an equal number of men and women in each group. Two extension officers from the Ministry of Agriculture and Rural Development facilitated information gathering in each group.

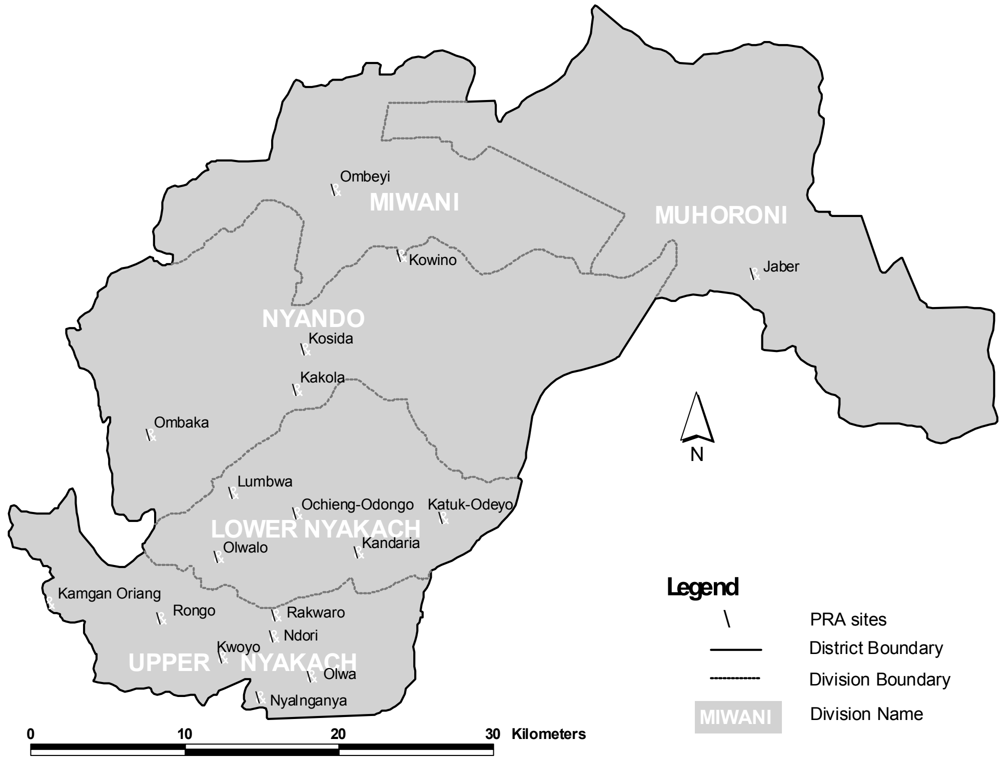

Figure 6.1 Map of Nyando district showing PRA sites.

6.1.2 Key findings from PRAs and implications

Importance of water - Almost every group in each PRA identified shortage of water for domestic use, and small-scale irrigation as the most important community problem. The problem was however more severe in the steep hills and gentle sloping areas where there is no permanent river and most of the water harvesting structures in place tend to dry during the dry season. Apparently, it is the same areas that have the highest water run-off. Communities in the plains also identified flooding as an important problem. The down stream communities indicated that if the upstream communities could harvest most of the water, then there will be no floods in the plains. Interventions that could avail more water to the communities were proposed as, deeper boreholes, many water pans in the landscape, roof catchment and piped water. Adoption of soil and water conservation structures were also seen as a way of increasing infiltration of more of the rain water which could in turn increase the occurrence of water springs. If water is availed within the homes, erosion from livestock tracks could also be reduced to a minimum. Efforts should therefore be made to link with the relevant institutions to support implementation of the proposed interventions.

Free grazing of livestock - Damage from freely grazed livestock is an important constraint to the successful adoption of land management interventions. Free grazing of livestock affects the establishment of trees, the integrity of the conservation structures, the vegetation on hillsides and destruction of riverbank areas. Restrictions on livestock grazing may only be possible if alternative sources of livestock feed are made available e.g. through planting napier grass, and fodder shrubs on grass strips. It was observed that during the long rains, livestock are restricted from free grazing because there are crops in the farms. It is therefore possible to follow the same practice for other times of the year if community members understand the need. In the near term, fencing of farms is necessary for trees to establish. Tree nurseries also need to be fenced to avoid destruction by livestock. Live fencing of farms with species that can yield livestock forage would be an added advantage.

Links between environment and poverty - Common resources provide a variety of inputs used by people to supplement their agricultural production and income. Mat, basket, and hat making were found to be important to areas near papyrus wetlands; rope making is important in the hillside communities where sisal is grown; pot making is important in areas near rivers and charcoal making and fuelwood production is important in riparian or hillside areas with some remaining forest cover. Sisal, reeds, and wood were reported to be in very short supply. There is therefore a need to deliberately plan for the production of the different products if the communities are expected to supplement their income from these products. Sisal growing is quite suitable for farm boundaries and contours for soil and water conservation but farmers have to be trained in management of the sisal plants. Reeds grow well along riverbanks and could specifically be recommended for planting along the rivers in the basin for river bank protection and also in suitable areas of the wetlands where they will filter sediments into the lake at the same time provide the reeds for basket weaving. Trees should be planted on all farms but farmers need guidance on what species should be planted in the different parts of the farm.

Erosion hotspots: Farmers identified erosion hotspots in their villages as steep slopes, roads, livestock tracks and footpaths, riverbanks and gullies. Sheet erosion occurred mainly in the gentle sloping land and the plains. The flood zone sites were all identified as sediment deposition zones.

Causes of erosion and flooding: Erosion in the landscape is caused by run-off from the hills, lack of vegetation cover, trees, shrubs and soil and water conservation structures. Others were identified as trampling on livestock tracks and footpaths, overgrazing, poor cultivation methods (e.g. across contours), burning vegetation, loose soils and boundary disputes. Flooding is caused by heavy run-off from the hills and upstream lands and sedimentation of the riverbeds.

Problems caused by erosion include: Formation of gullies that in turn reduce land size. Fertile topsoil is carried away leading to reduction of soil fertility, which in turn leads to poor crop yields. Erosion destroys roads. This leads to transportation and marketing problems. Overall, livelihood activities are slowed or hindered. Floods deposit rich soils where they occur but they also destroy crops, roads, and sometimes cause deaths. People are also forced to move to higher localities. This hinders optimal land productivity. Much soil is carried to the lake but the villagers didn't seem to have any perception of the negative effects caused to the lake. Most villagers appeared to be bothered only with what affects them directly.

Erosion control measures that have been tried include**:** Planting of trees, shrubs, sisal, and cactus. Some farmers have tried contour farming and construction of terraces while others have tried stone wall and gabions. Most gullies belong to individual farmers and they claim the problem of rehabilitating gullies is overwhelming. A few farmers have succeeded in rehabilitating gullies using a combination of bananas, bamboo, napier grass, sisal and *Thevetia peruvian*a shrub. Gullies along public rods have not been adequately attended to because no individual takes responsibility. Little has been done to reduce riverbank erosion probably because land along rivers belongs to the government. Where riverbanks appear to be conserved, it is mainly due to deposition of sediments and natural growth of vegetation, particularly *Sesbania sesban.*

There was very little soil and water conservation on the farms. All the above measures could be effective in different circumstances but most have not been effective because farmers have not received advice on the specific structures to put on their farms. In addition, the run-off water is much and comes at high speed hence unless there is joint efforts between up and down stream communities, conservation efforts by down stream farmers may be in vain. Ensuring that intensive conservation measures are applied upstream can enhance the effectiveness of erosion control measures on down stream farms.

Institutional arrangements: From the PRAs, it was found that the local institutions found in almost all sites were: Churches, women groups, youth groups, welfare associations, school development committees and catchment committees. Others were government institutions involved in different sectoral issues e.g. agriculture, livestock, water etc.

As observed from what was done by the Winam gulf project where farmers were paid to put conservation structures on their farms, any approach that will not constructively engage the community to take full responsibility for conserving their farms may not last since farmers may not maintain the structures put in place. The catchment committee was the only group that was working directly and exclusively on natural resource management issues. It was however reported that the committee is usually very active during the first year when the staff are developing the Land Management Plans. After the first year is over, they tend to fall apart. Even those that are very active and want to continue, usually have very few activities to bind them together. It was therefore proposed that an institution should be identified that can keep the committees together and active so that at the end of some years, all the catchment committees will still be networking and facilitating development of their communities. The other issue that was proposed was the need to identify ways of making the committees accountable to the institution that will be identified. Identifying and promoting one or several cash crops in given zones and making the institution responsible for coordinating the production through the catchment committees and marketing of the crop(s) is one possibility. Some of the crops proposed were ground nuts, cotton, and sisal in Lower Nyakach, Groundnuts, sweet potatoes and onions in Upper Nyakach and fruit trees particularly mangoes and pawpaws in the whole district.

6.1.3 Follow-up issues

The concluding session of the PRA workshop in Kisumu (April 5th) focused on the identification of key issues for future interventions. Three resource persons gave their opinions of key issues. Brent Swallow (ICRAF) commented on institutional issues, J.W. Kimani (Agroforester with the ministry of Agriculture and Rural Development) commented on agroforestry issues, and David Nyantika (Provincial Soil and Water Conservation Officer, Nyanza Province) commented on conservation and land management issues. The following points were raised by the participants and the plenary:

Institutional issues:

1. Importance of upstream-downstream cooperation. It was recommended that this is not the appropriate starting point for interventions. It is better to start with local solutions to local problems, then build towards catchment-scale issues.

2. Rights and management of river bank areas - these areas are hypothesized to be major hot spots in the Nyando river basin. One constraint to proposed solutions is that these areas are declared to be public land. It was recommended that co-management approaches should be tested. Community groups and the government could agree to common plans for the management of the areas or the areas could be used to generate income for the community groups while reducing erosion of the riverbanks. Community rights to those products would be guaranteed as long as they follow the management plan. Besides the direct interventions activities policy studies could be conducted to come up with longer-term management plans for the riverbanks.
3. On-farm substitutes for hillside resources - Hillsides are another hot spot; hillside erosion is caused by excessive removal of vegetation by farmers and livestock. More effective community management of those areas may require greater supply of those products on farm. Agroforestry and conservation interventions should focus on the production of fuelwood and fodder.
4. Harness the profit motive of individuals and groups - There may be many opportunities to increase the supply of seedlings and other inputs through local business. Farmers could contract local businesses to supply products that are needed, but not currently demanded.
5. There is need to empower local institutions while opening up new opportunities for new technologies and ways of doing things. Farmer exchange visits and a greater focus on experimentation among community groups was recommended.
6. There is need to extend the life span of the catchments well beyond the 12 months that they are in the spotlight. Experimentation with landcare approaches, involving partnership between research, extension providers and community groups was recommended.
7. Enforcement of rules on land use. It was recommended that new ways be found to implement and enforce rules at local levels.

Agroforestry issues:

8. Role of central nurseries. The ministry is moving away from central nurseries in general. However the most important thing is that farmers pay for what they get. If the Ministry sees a role for a central nursery, then it could contract its operation to a private person or firm. The main role remaining for a central nursery may be for training.
9. There is need to carry out surveys and mini-surveys of agroforestry so that the Ministry staff can help farmers make informed decisions about tree species.
10. Value added products - There is need to consider opportunities for adding value to agroforestry products, through, for example, assisting farmer groups in preservation and processing of fruit products.
11. Increasing value of conservation structures through agroforestry. This can be away to increase the utility that farmers get from conservation structures.

Conservation issues:

12. Use and conservation of water runoff - This is the main way that farmers and community groups can solve their number one problem - water supply - while alleviating environmental problems of sedimentation and nutrient movement. Run-off can be captured through roof water harvesting, sand dams, rehabilitation of drains, and diversion of water from roads to farms.

13. There is need for farmer-specific action plans - Action plans must be developed on a farm-by-farm basis so that the results will be appropriate and will put money in farmers' pockets.
14. The problems of run-off from roads - There is need for better dialogue between the Ministry of Agriculture and Rural Development and Ministry of Public Works.

6.2. Household-level adoption of soil conservation in Nyando district

In February and March of 2000, the project undertook a study of household-level adoption of soil conservation structures in Nyando District. The objectives of the study were to: (1) Relate the adoption of different soil conservation practices to key household characteristics, especially farm size, livestock holdings, labour, gender and education levels. (2) Assess the stepwise adoption of soil conservation and agroforestry practices. (3) Relate adoption of soil conservation and agroforestry to the activities of soil and water conservation branch and catchment committees.

6.2.1 Methods

Dirubi catchment was purposively chosen from the Sondu river basin. Dirubi catchment is a 1995/96 catchment. It was selected because it was reported as one with the highest adoption rates (over 80%) in Upper Nyakach Division.

In Dirubi, a census of the entire catchment of 105 households was conducted. However, only 95 of the questionnaires were analysed. In a few of the homes, the owners had died or were not available to be interviewed even after repeated visits. Information was collected through personal interviews using a semi-structured questionnaire with the head of household or spouse, document analysis of the catchment record book and map, physical measurements of the structure length using a tape measure, and measurement of woodlot areas and physical counting of trees on farms. The data was analysed using the SPSS computer software programme.

6.2.2 Technologies adopted and the magnitude of adoption

The results show that a total of 14 soil-conserving technologies (Figure 6.2) were adopted in Dirubi catchment. Grass strips, fanya-juu, and unploughed strips were the most preferred having been adopted by over 40% of the households. Over 35% of the households had adopted hedgestrips. Woodlots, banana strips, sisal strips and stone walls had been adopted by 20% of the farmers. Measures adopted by a small number of farmers include euphorbia hedges, fanya-chini contour trenches, cut-off drains, roof catchments, and retention ditches.

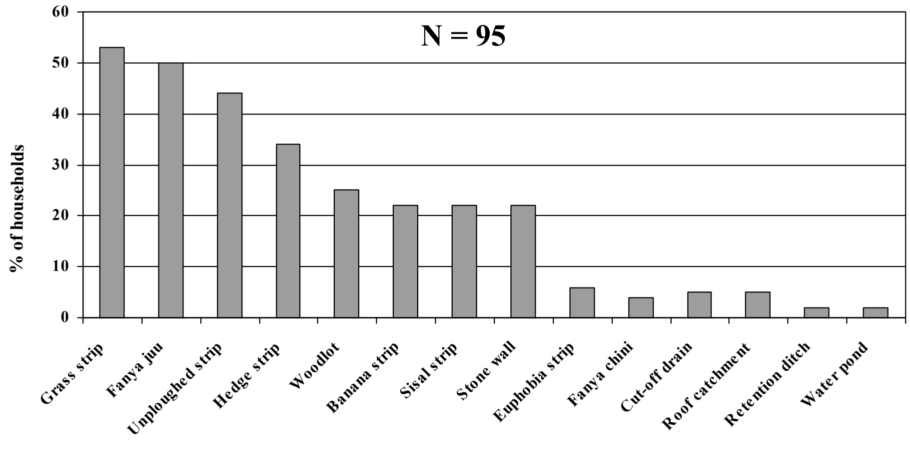

Figure 6.2 Adoption levels of soil conservation measures in Dirubi catchment

Most of these conservation practices appear as filter strips and are designed to intercept the lateral flows of soil and water across the landscape. The length of every filter strip was measured by the enumerator and farmers. A total of over 30 kilometers of filter strip was measured on the 95 farms (Figure 6.3), an average of almost 300 metres per farm. There was a total of 7.5 kilometres of grass strips, 6 kilometres of unploughed strips, 4.5 kilometres of hedges and 3.8 kilometres of fanya-juu structures.

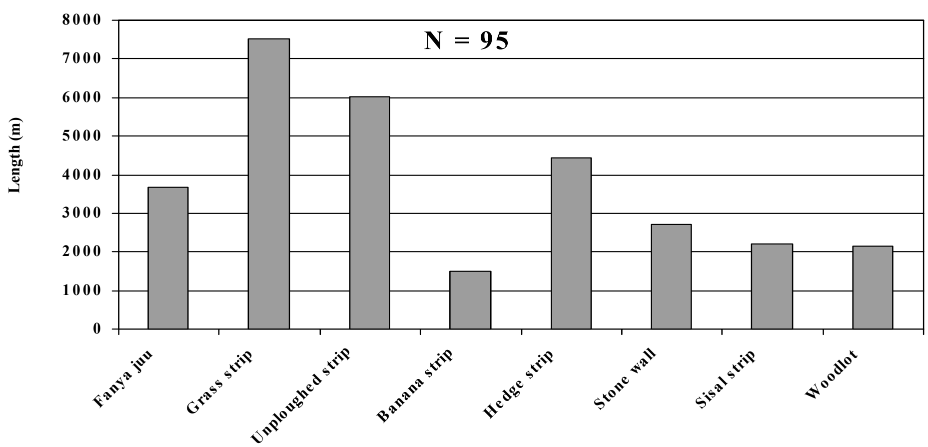

Figure 6.3 Total length of adopted soil conservation structures in Dirubi catchment

Further analysis from the catchment record book of what had been recommended to farmers by the extension officers revealed that it is mainly the three leading commonly adopted technologies with agroforestry tree species, which the extension officers had recommended to the farmers. However, according to the farmers and the extension officers interviewed, the trees were never planted as recommended due to lack of the desired seeds and seedlings.

The high adoption level (Figure 6.2) and total length (Figure 6.3) of grass strips could be due to two reasons. One, farmers who had adopted fanya-juu structures tended to plant grass strips along them and two, grass strips provide forage for livestock hence they are dual purpose. This suggests that technologies that have direct benefits are likely to be preferred by farmers.

6.2.3 Land size and adoption

The comparison of average land size between adopters and non-adopters of different conservation measures show that generally, the average land size for adopters is higher than for non-adopters (Figure 6.4).

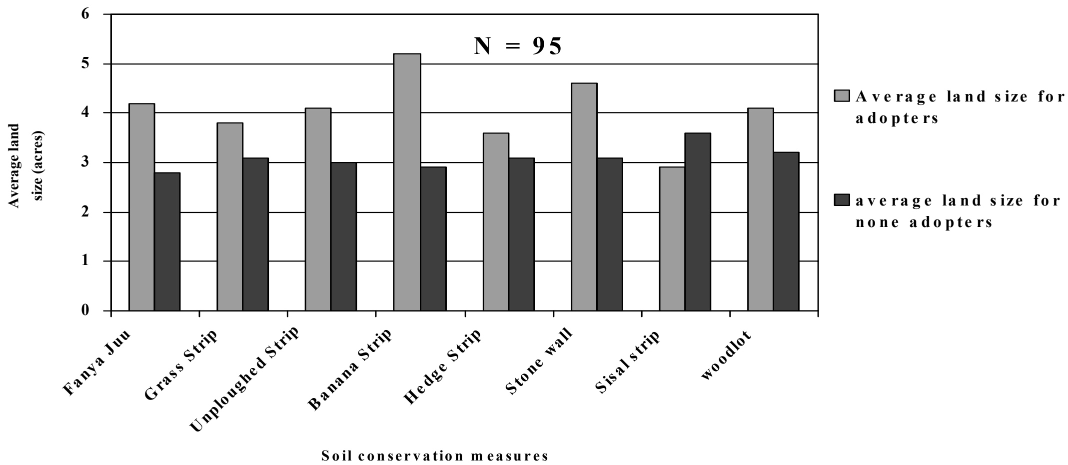

Figure 6.4 Average land size of adopters and non-adopters of different soil conservation measures

The difference was found to be significant for the farmers who have adopted *fanya-juu* (p=0.01), banana strips (p=0.00) and stone walls (p=0.02). Bananas, *fanya-juu*, and stone walls occupy a reasonably large size of land. Therefore, it is possible that it is only the farmers who have large sizes of land who adopted them. This leaves those with smaller land sizes (probably the poor) with very few soil and water conservation options. Given that most people have small pieces of land, there is need to recommended technologies that are appropriate for small land sizes. The design of *fanya-juu* could also be reviewed to suit the small farm sizes.

6.2.4 Livestock numbers and adoption

Except for unploughed strips (Figure 6.5), the adopters of soil and water conservation measures have more local cows than the non-adopters. However, significant difference was found between adopters of stone walls (p=0.00), grass strips (P=0.03) and banana strips (p=0.10). A strong correlation is expected between adoption of grass strips and number of cows because of the supply of forage. But for those who have banana strips and stone walls, it is possible that it is the large land sizes associated with the adoption of the structures that is being reflected and not the structures per se. Recommendation of conservation technologies with multiple benefits should therefore be encouraged.

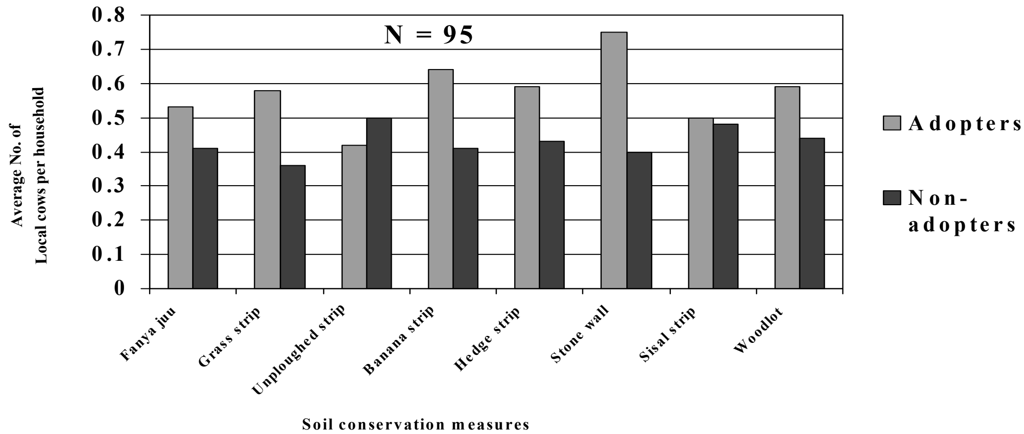

Figure 6.5 **Average number of local cows between adopters and non-adopters of different soil conservation measures**

6.2.5 Education and adoption

Considering the average education level of the head of household, farmers who have adopted banana and sisal strips had on average significantly more formal education than those who had not adopted (p=0.02 and p=0.10 respectively). The farmers who had adopted grass strips and hedge strips had higher education than the non-adopters (Figure 6.6) but the difference is not significant. Those who have adopted fanya juus, unploughed strips, woodlots and fanya chini have lower education than the non-adopters but the difference is also not significant.

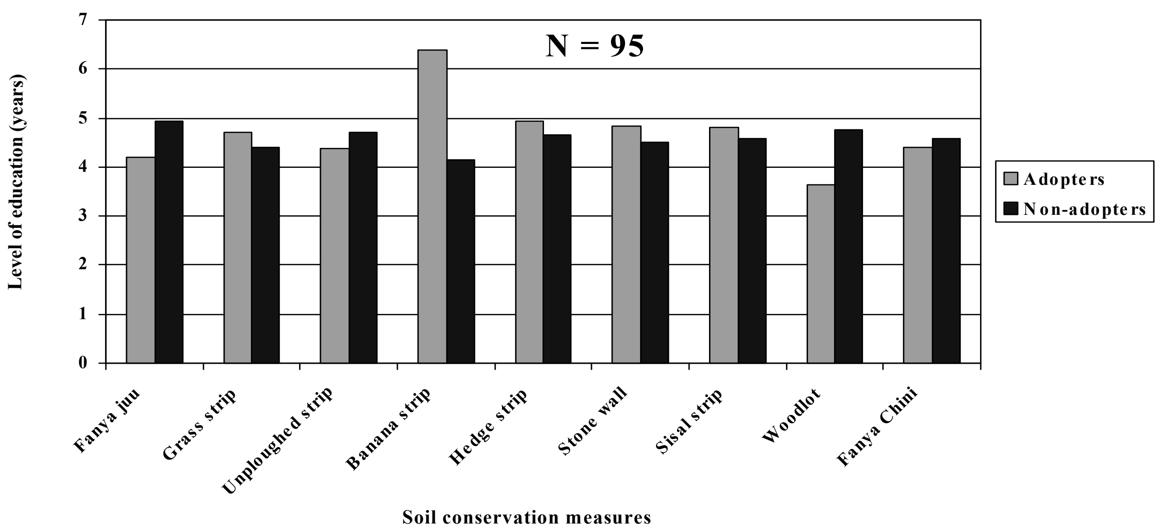

Figure 6.6 **Average level of education of household head adopters and non-adopters of soil conservation measures**

6.2.6 Household size and adoption

The average household size for adopters is higher than that for non-adopters of sisal strips, stone walls and banana strips (Figure 6.7). There is a significant difference between the average household size for those who had adopted sisal strips (p=0.00) and stone walls (p=0.10) the rest are more or less the same. Adoption of sisal strips was also found to be significantly higher among polygamous households than non-polygamous ones (p=0.04) suggesting that sisal strips may be adopted not necessarily for soil conservation but for marking farm boundaries. Adoption of soil conservation structures may therefore not necessarily be related to household size.

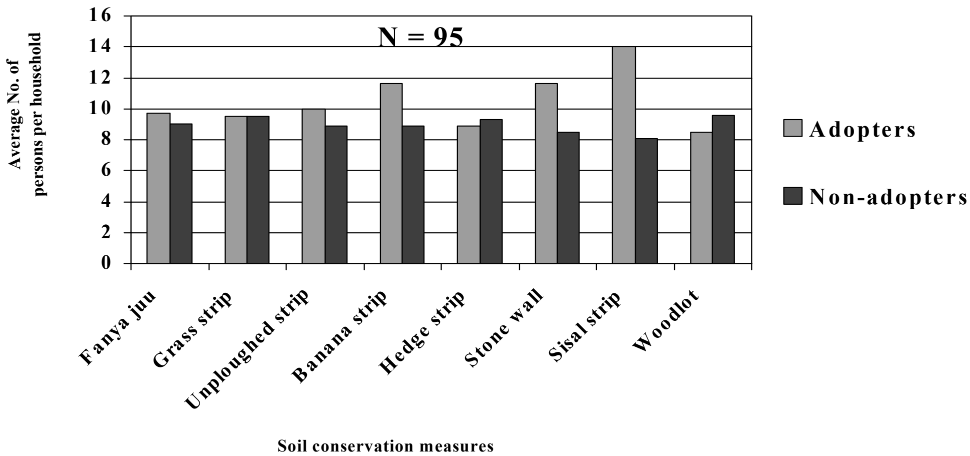

Figure 6.7 **Average household size of adopters and non-adopters of different soil and water conservation structures**

6.2.7 Gender of household head and adoption

Most households (67%) in Dirubi were headed by men. Twenty nine percent were headed by widows while 4% were headed by widowers. It is only the sisal structures which were adopted by 50% of the male headed and 50% women headed households (Figure 6.8).

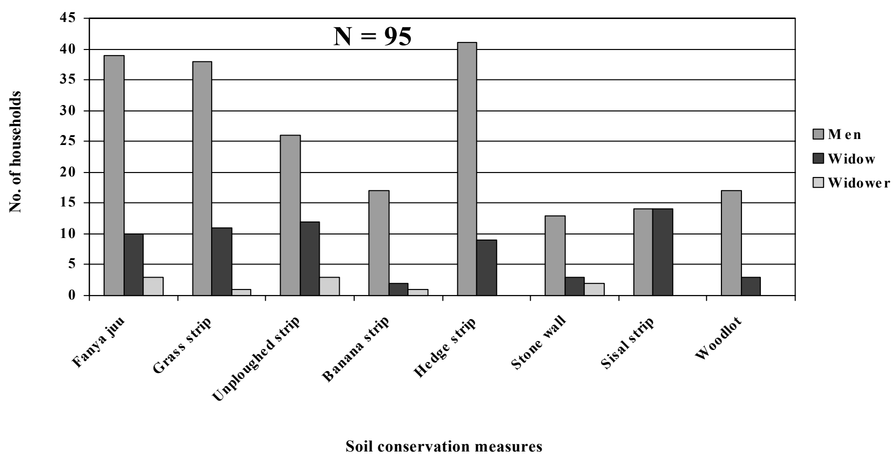

Figure 6.8 **Adoption of soil conservation measures by gender of household head**

For all the other seven soil conservation structures, most of the households that have adopted are headed by men. The least adopted by widows is banana strips. This may be due to the lower average land size owned by widows or the fact that women do not plant bananas in some communities.

6.2.8 Stepwise adoption of soil and water conservation measures and agroforestry

Farmers in Dirubi started adopting soil conservation structures as early as 1967. A comparison of the adoption of the different structures before and after the catchment approach was introduced reveal that a significant number of structures were already being adopted even before the catchment approach was introduced to the Dirubi farmers (Figure 6.9). The technology that was already highly adopted was hedge strips followed by sisal strips. After the introduction of the catchment approach in the catchment, fanya juu structures, grass strips and unploughed strips were adopted by a significantly higher number of farmers than before. This clearly shows the impact that the approach had on adoption of the particular soil and water conservation structures.

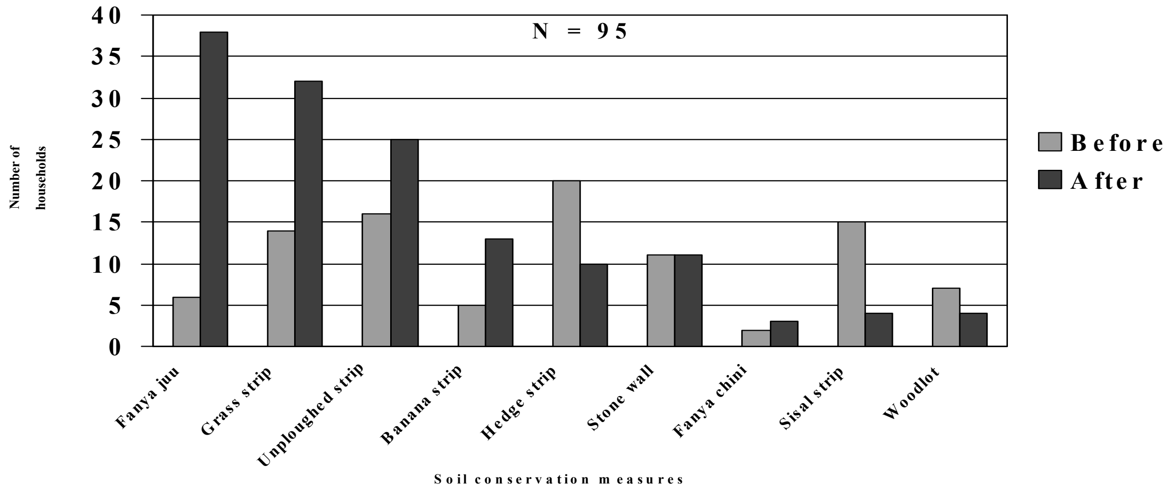

Figure 6.9 Adoption level of soil conservation measures before and after using catchment approach

6.2.9 The SWCB, Catchment committees and adoption

Farmers source of information on the soil conservation technologies adopted was examined and the survey revealed that information from each technology reached the farmers in different ways. For example, information on fanya juu, grass strips and unploughed strips was mainly obtained through the soil conservation extension officers (Figure 6.10). Information on hedge strips, sisal strips, woodlots and banana strips was mainly from other farmers. A reasonable proportion of grass strips, unploughed strips and banana strips information was also transmitted from farmer to farmer. The catchment committee and other agencies provided very little information to varying levels for the different technologies. These results clearly show the importance of extension officers and the need for them to target specific areas with specific beneficial technologies.

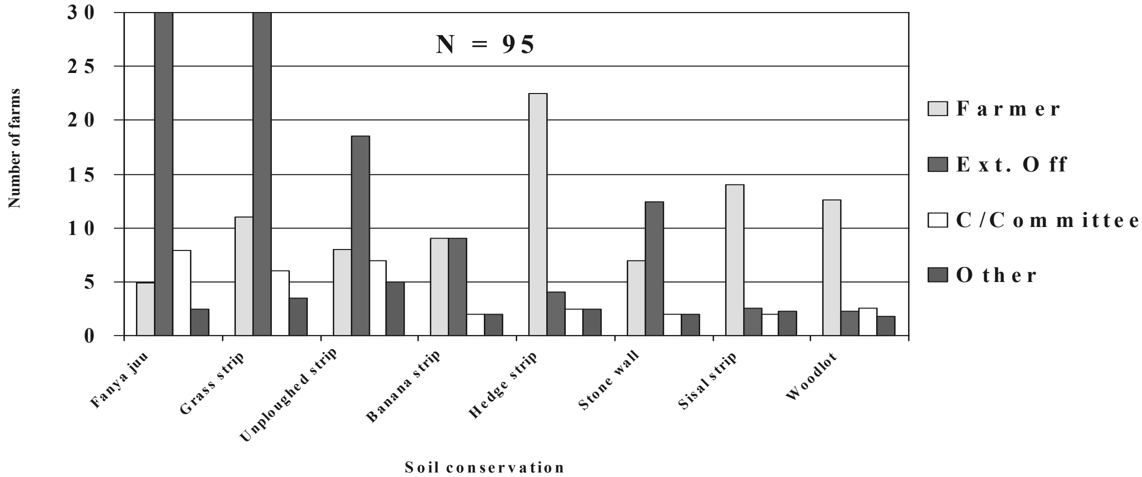

Figure 6.10 Farmers' source of information on soil and water conservation measures

6.2.10 Other factors

These included the cost of installing the structures and farmers perception of the effectiveness of the different structures to conserve soil. The least expensive structures were reported as grass strips by 50% of the farmers followed by unploughed strips (18%) while the most expensive was reported as Fanya juu by 50% of the households. Farmers reported that despite the high cost of fanya juus, they are the most effective. They particularly liked the grass strips because they also double as a source of forage for their livestock. The fact that a direct product is not obtained from unploughed strips gives it low rating as a soil and water conserving measure.

6.3 Agroforestry baseline study

For impact assessment to be meaningful, there is need to establish the baseline situation of the variables being measured before the interventions are put in place. Rongo catchment was selected for a baseline study for the intervention studies that are being undertaken in the area to assess their effects on run-off from different land use systems. Rongo has a stony landscape and is relatively dry receiving between 600-700 mm of rainfall in a year. A household survey was carried out in the catchment to identify the soil and water conservation technologies that have been adopted in the area, and relate different household and extension factors to the adoption of the indicated technologies.

6.3.1 Research methods

A census of the entire catchment of 95 households was conducted. However, only 94 of the questionnaires were analysed. One questionnaire was discarded for containing incomplete information. Information was collected through personal interviews using a semi-structured questionnaire with the head of household or spouse. The soil and water conservation structures and woodlots were measured using a tape measure. Trees on the farms were physically counted. The data was analysed using the SPSS computer software programme.

6.3.2 Technologies adopted

The preliminary results show that a total of 14 technologies (Table 6.1) had been adopted in Rongo catchment. Adoption of fanya juus in Rongo is relatively low compared to Dirubi (section 2) probably because of the stony landscape. This can also explain the high adoption rates (69%) of stone walls in the catchment. Further probing revealed that the stone walls are generally made to create land for farming and not to conserve soil, but in some cases, they are arranged to create land for farming and also conserve soil and water particularly where the slopes are high.

Type of technology adopted	Proportion of households (%)	Implementers of soil conservation measures by gender (%)			Proportion of farmers advised by extension (%)
		Male	Female	Other	
Stone wall	69	61	3	2	3
Sisal strip	45	40	3	2	3
Roof catchment	43	41	2	0	0
Woodlot	20	18	2	0	2
Fanya juu	17	15	1	0	3
Unploughed strip	16	14	1	1	2
Euphorbia strip	13	-	-	-	0
Hedge strip	3	3	0	0	0
Grass strip	3	2	1	0	0
Banana strip	1	0	1	0	0
Fanya chini	1	0	0	1	0
Cut off drain	1	3	0	0	0
Retention ditch	1	-	-	-	0
Water pond	1	-	-	-	0

Table 6.1 Technologies adopted, implementers and proportion of households advised (N=94)

6.4. Livelihoods study

A study of livelihood options was conducted in Lumbwa catchment to identify the major livelihood options in the catchment and perceptions of Lumbwa villagers as regards farming. Lumbwa was selected because it was reported as the catchment with the lowest adoption rates (<20%) for soil conservation measures. It was therefore hypothesised that Lumbwa villagers had other better livelihood options to farming that is why they had very little interest in conserving soils and water.

6.4.1 Research methods

A total of 45 households were interviewed. Seventeen households had at least one member (husband or wife) in formal employment. Of the 17, four were women (a nurse, a nursery school teacher, a cook and a public health worker) while 13 were men. In 28 of the households, none of the parents were in formal employment.

6.4.2 Preliminary results on main livelihood options

Results show that in households where there was an employed head or spouse, revenue from formal employment was ranked as the highest source of income for the household. This was followed by farming, mat making, and production of groundnuts. In the 28 households where the household head and spouse were not in any formal employment, farming was ranked as the main livelihood option followed by mat making and groundnuts production. The other sources of livelihoods mentioned were micro-enterprises like sisal and basket weaving, sand harvesting, hairdressing, trade in maize, mats, fish, and vegetables. It was surprising that groundnuts production was given a different category to the rest of the farming activities the reason being that it is generally treated as a cash crop. Contrary to expectation, farming is the priority livelihood option for the majority of Lumbwa villagers.

6.4.3 Constraints related to the main livelihood options

The constraints identified in farming were limited rainfall and marketing institutions for farm produce. Labour was also reported as limiting because most of the women are engaged in different micro-enterprises. For mat making, the main constraints were harvesting and transportation of the papyrus. Other constraints mentioned were lack of sisal for rope making, reeds for basket weaving, and low prices for sand harvesters.

6.4.4 Strategies for improving livelihoods in Lumbwa

The livelihood activities that most villagers were engaged in do not require much formal education hence they were quite suitable for the majority of women and the men who were not in formal employment. The livelihood options that depend on natural resources as raw materials can be strengthened by increasing the supply of the appropriate materials. Planting of sisal on farm boundaries and contours can contribute in conserving soils and water at the same time supply the required fibre for rope making. Planting of appropriate species of reeds along river banks can contribute to protecting the river banks while providing reeds for basket weaving. Since papyrus provides supplementary income to almost all the households and also acts as a sediments filter in the wetlands, there is need to study its management for optimal yields and even possibilities of planting it in some of the wetlands that have no vegetation should be explored. A system of easing transportation of papyrus from the lake to the catchment for the women should be devised. Proper markets for cash crops like groundnuts should be formed to encourage large-scale production.

6.5. Agroforestry training for extension officers

Mobilizing of communities to innovatively and optimally manage their natural resources requires enthusiastic, committed and informed development personnel. Intensive training in known beneficial technologies and participatory methods that focus on joint learning for action is therefore necessary for the extension staff. The project organized a six days' seminar for 34 district and divisional extension staff from Nyando District. The purpose of the seminar was to train the staff in agroforestry technologies, methods of participatory development, adaptation of beneficial technologies and practices and monitoring and evaluation of research and development activities.

The specific topics covered included agroforestry for fodder, woodfuel, timber, fruits, soil fertility improvement, soil erosion control and water management. Other topics covered were an overview of the project on improved land management in the Lake Victoria basin, tree-crop interactions, the link between land and lake, tree germplasm collection and handling and tree propagation methods. Topics in socio-economic issues included participatory extension techniques, PRA and field survey methods, participatory on-farm technology testing, linking farmers to markets for agroforestry products and participatory monitoring and evaluation.

The trainees found the training very informative as regards knowledge in agroforestry. It was recommended that the frontline staff who work directly with the farmers should also go through an intensive agroforestry course which will equip them with the knowledge with which to assist farmers in improving land use. Annual evaluations should also be conducted to monitor use of the knowledge gained and identify evolving new agroforestry training needs.

6.6. Farmer exchange visits

Tours and exchange visits have been proven to be an effective mechanism for exposing farmers and extension workers to new techniques and new ways of working. Four farmer tours were organized.

Tour 1: Kobong'o/Miwani to Ombaka:

Fifteen farmers and four extension staff participated in this tour to the farm of an innovative farmer in the neighbouring Ombaka catchment. The farmer demonstrated a simple technique for raising eucalyptus seedlings; diversification of farming to include fruit trees as a source of income; the use of fencing to improve the establishment of trees; and the integration of women in tree management.

Tour 2 : Kobong'o/Miwani to Maseno*:*

Twenty-six farmers and four staff participated in this tour to the KEFRI /KARI/ICRAF Regional Research Station in Maseno and Luwero catchment in Vihiga district. KEFRI, KARI and ICRAF have been working with farmers in Vihiga district for many years and have identified several promising agroforestry technologies. Farmers from Kobong'o/Miwani observed the: integration of improved fallows and biomass transfer into farming systems; importance of farmer committees and their roles in strengthening agroforestry initiatives.

Tour 3: Ragen farmers to Pap-Onditi and Kusa

Twelve farmers and two extension staff from the Ragen area visited Pap-Onditi and Kusa areas to view new soil and water conservation techniques, particularly those facilitated by RELMA.

Tour 4: Kobong'o/Miwani/Ragen to Kibwezi

Twenty farmers from the Kobong'o/Miwani/Ragen areas visited farmers in the semi-arid Kibwezi area. The farmers observed, among other things: Mango tree propagation techniques, including grafting; the control of termites on fruit trees by application of poultry manure; dry-planting techniques; different irrigation methods; and management techniques for *Melia volkensii.*

6.7. Participatory Action Research for Conservation of Hotspots

The research conducted to date, combined with evidence from the international literature, suggest that the most important land management hotspots in the Nyando rive basin include: deforested and degraded riverbanks, deforested and overgrazed hillside areas, gullies, roadways and footpaths. ICRAF, the Ministry of Agriculture and Rural Development and a few farm communities in Nyando District have begun participatory action research to deal with two of the hotspots.

In the Kobong'o/Miwani area, near Ahero in Nyando division, the focus of the action research is on riverbank protection. Riverbank protection committees have been formed in villages located on either side of the Nyando river to protect riverbanks along a one Kilometer stretch of the river. The Miwani riverbank protection committee includes 8 men and 4 women, while the Kobong'o riverbank protection committee includes 6 men and 7 women. Areas 10 meters wide by 1000 meters long were pegged on either side of the river and six species of trees were selected to be planted in those areas. The species selected were; *Grevillea robusta (25),* *Azadirachta indica (300*), *Kigelia africana (20), Tamarindus indica (100), Melia azaderach (100*) and *Casuarina equisetifolia (50).*

In the Rakwaro area of Ragen catchment, the PRA prompted a community group to develop a community land management plan. ICRAF and the Ministry of Agriculture and Rural Development staff have facilitated this development. This community suffers from serious hillside deforestation and gully erosion.

6.8. Conclusions and recommendations

1. To be effective in disseminating land improvement technologies, there is need to identify specific and appropriate technologies that should be promoted in specific areas. The adoption survey has shown that the catchment approach to extension, coupled with specific beneficial technologies can contribute to wider adoption of the technologies and it can also be very effective if implemented as designed.

3. Currently, there is a gap in knowledge as regards the actual conservation effects from the structures adopted. Quantifying the quantities of water and soil conserved by having the structures in place and converting into potential farm products can help in strengthening the case for farmers to adopt given structures hence improve land productivity. Previously, tree and shrub planting recommendations were made without a matching supply of the required seedlings. Sometimes tree nurseries are established but they produce very few seedlings. The actual demand for tree and shrub seedlings by farmers need to be assessed and mechanisms for their production from tree nurseries put in place so that all those who want to plant trees can plant them. Farmers' wood demand could also be computed in order to estimate the number of trees that could be established on the farms.

4. In the adoption study, farmers were requested to suggest three tree/shrub species that they desire most for planting and 73% requested for eucalyptus, 10% cypress and 17% fruit trees. Eucalyptus was also identified as the most preferred tree species in all the PRAs. The others were mainly fruit trees particularly mangoes, pawpaws, and avocado. There is need for a decision to be made about the planting of eucalyptus trees by farmers. The farmers who have large land parcels should be encouraged to grow while those with small land sizes should be advised on the most appropriate species for their small farms. In the sugarcane zone, for example, some farmers have large land parcels and can be deliberately encouraged to plant eucalyptus woodlots.

5. The frontline extension staff facilitating the development of Farm Specific Action Plans should be knowledgeable and confident for the farmers to take them seriously.

6. A locally based institution that can effectively coordinate natural resource management issues in the basin should be identified and facilitated to get established.

7. ASSESSMENT OF NSWCP ACTIVITIES IN THE NYANDO BASIN

Tina Svan-Hansen and Markus Walsh

7.1 Introduction

Lake Victoria, with a surface area of 68,000 km^2 and an adjoining catchment of about 155,000 km^2, is the world's second largest fresh water lake and the largest in the tropics. Lake Victoria is the source of the Nile, the lifeline for much of Uganda, Sudan and Egypt, and it directly or indirectly supports 30 million people. Today the Lake Basin supports one of the densest and poorest rural populations in the world, with population densities up to 1200 persons per square kilometre. During the past decades the high population pressure has caused severe land degradation and significant land-use changes such as, devegetation of shrub lands, and destruction of forests, wetlands and vegetation in the riparian zones. There has also been an expansion of cultivated areas into marginal and often highly erosion prone areas. Consequences of these changes are increased on-site erosion (overland flow) and reduced buffering capacity of the natural vegetation in wetlands and in the riparian zones. The flow of nutrients from land to lake is causing a decrease in soil fertility on farmers' fields and contributes to the eutrophication of Lake Victoria.

According to Hinchcliffe et al. (1995), soil and water conservation programmes have in general had surprisingly little success in preventing erosion, despite decades of effort. As Pretty and Shah (1994) outline, the past efforts have paradoxically frequently resulted in increased erosion. In response to these often discouraging results, there has been a paradigm shift in approaches to soil and water conservation over the past decades. More recently, numerous conservation programmes have emerged based on a more participatory approach to watershed management including soil and water conservation initiatives. Although these new approaches are in their initial phases, many of them show promising results (Hinchcliffe et al., 1995).

One of the new participatory soil and water conservation approaches that have tried to prevent erosion in the Lake Victoria Basin is the Kenyan National Soil and Water Conservation Programme (NSWCP) of the Kenyan Ministry of Agriculture and Rural Development. In 1988 the Soil and Water Conservation Branch (SWCB), introduced the "catchment approach". In the SWCB approach, the term catchment is not used in the hydrological sense, but refers to an area covering one or two villages. In this study the "catchment areas" are called focal areas. With this approach, resources and efforts are concentrated within a specific focal area (Munyikombo, 1999) for a limited time period with the aim at initiating conservation measures at all the farms in the specific area. The catchment approach is a participatory approach, where local communities are involved in the identification of problems and solutions. The community also acts in conjunction with the local soil conservation staff in planning interventions. Ultimately, each division is supposed to implement two focal areas each year. So far, the SWCB has reached 1.6 million farmers, mostly in areas with medium to high agricultural potential (Agrisystems, 1998).

Different impact assessment studies have shown considerable positive socio-economic impact in areas conserved under the SWCB catchment approach. Ekblom (1992) in Thomson & Pretty (1996) outlined a positive impact on crop yield, crop diversity and number of cows in an area conserved by the catchment approach. This was in sharp contrast to a neighbouring area conserved in the traditional extension approach. Another impact assessment study was carried out by Agrisystems (1998) in 15 focal areas spread across five different districts. It shows increased maize yield, improvements in soil management, decrease in time spent on collecting firewood due to increased number of trees and in some cases, increased milk production due to the use of Napier grass. According to Agrisystems (1998), they observed rehabilitated gullies but were not able to quantify the benefits.

This general success of the participatory approach has caused international efforts to implement it in two other countries bordering the lake - Uganda and Tanzania. However, despite the positive socio-economic impact of the approach, the improved soil management and increased yields which indicate improvements in soil fertility, i.e. less erosion at plot level, there are still a few uncertainties. Information is still lacking on the effectiveness of the approach in terms of lowering the amount of nutrients that are transported into Lake Victoria and contribute to the eutrophication of the lake.

This lack of information, combined with the fact that the approach might be extended to the neighbouring countries, motivated this study. The study is a part of a larger project "Improved Land Management in the Lake Victoria Basin: Linking Land and Lake, Research and Extension, Catchment and Basin". It was initiated in July 1999 by the International Centre for Research in Agroforestry (ICRAF) in collaboration with the Kenyan National Soil and Water Conservation Programme (NSWCP) of the Kenyan Ministry of Agriculture and Rural Development. The goal during the start-up phase was "to reduce non-point source nutrient loss and sediment movement from farming areas into Lake Victoria water system through interventions that are effective, well targeted and adapted to farmers' needs".

This present study aims at evaluating the effectiveness of the approach in terms of targeting areas of high erosion potential, and thereby lowering the amount of nutrients transported into the lake. Furthermore, it will generate recommendations on how the soil and water conservation branch could improve the approach (i.e. target their efforts) for greater impact at the watershed level.

An important methodological problem arose as the research was designed. At the watershed level, one of the most common ways of assessing the impact of soil and water conservation is to measure the long-term temporal changes in nutrient flows from different types of land use within the watershed as well as from the outlet of the river system. However, as it is the case in many developing countries, there was a lack of a comprehensive spatial and temporal dataset on nutrient flow at the watershed level. Again, other methods and sources of information had to be applied. Geographical Information Systems (GIS) and analysis of satellite images were found to be easy and cost-effective means of capturing information at the watershed level.

This present study applies Landsat TM satellite images, various GIS thematic layers, and a focal area census to evaluate the effectiveness of the SWCB's participatory soil and water conservation approach in terms of lowering the sediment/nutrients transport into the lake. It focuses on a selected watershed – Nyando - that drains into Lake Victoria. In addition, the results are used to assist decision-makers in the Lake Basin to better target their land management options for greater effect. The methodological framework facilitates the examination of the linkages between conservation, on-site erosion, and off-site effects.

7.2 Research design

7.2.1 Study area

Nyando watershed was selected as the study area for various reasons. Primarily it has been identified as one of the main contributors of sediment into Lake Victoria based on analysis of Landsat TM satellite images and turbidity measurements. A huge sediment plume is projecting from the outlet of the river more than 20 Km into the lake. Secondly, the watershed is very heterogeneous in terms of soils and climatic conditions, which has led to a mosaic of the different types of land use present on the Kenyan side of the Lake Basin. Thus, within the study area, some of the most common processes of erosion and conservation are represented. Finally, a wide range of social and biophysical scientists are currently working on different aspects of erosion and conservation in the watershed. This facilitates the comparison of results and provides integrated information on the various aspects of erosion and conservation in the area.

Nyando watershed covers an area of 3500 km^2. The total population was approximately 800,000 in 1989. Administratively, it is divided into 17 Divisions in 6 Districts, Nyando, Nandi, Kericho, Nakuru, Baringo and Uasin Gishu. Nyando District is in Nyanza Province, while the rest falls into Rift Valley Province.

The upland is very heterogeneous and there are huge spatial differences in the type and magnitude of erosion different areas face. The altitude varies from 1070 m at the lake shore in the South-western part of the watershed, up to 2700 m in the North-eastern end of the watershed. The annual rainfall ranges between 900 mm and 2200 mm. Following the altitude gradient, the watershed can roughly be divided into 5 different land use zones. Small-scale subsistence maize and sorghum farming characterize the lower part of the watershed, the lake plain, between 1100 – 1300 m. Large-scale sugar plantations and smaller sugar schemes are located between 1300 m and 1700 m. Gradually, the sugar plantations are being replaced by coffee in a zone ranging between 1600 m – 2000 m. Small-scale tea farmers and large tea estates are located between 1900m – 2100m. Relative large-scale maize and horticulture (potatoes, cabbage, etc.) farming mainly characterize the areas above 2100 meters.

The majority of the watershed is more or less continuously cropped. The few exceptions are two remaining forest areas – Tinderet and Mau forests – that are currently being heavily deforested, and the steep sloping escarpments – originally Government trust land – that are quickly being devegetated due to charcoal burning and illegal farming.

7.2.2 The approach

The approach focuses at watershed level, but data is collected both at watershed and focal area level.

In Nyando watershed, the effectiveness of the spatial distribution of the focal area is assessed according to erosion risk. The research activities included three components: 1) Identification of areas with a high risk of erosion; 2) Location and collection of baseline data on the soil and water conservation branch's focal areas; and 3) Assessment of the effectiveness of the spatial distribution of focal areas according to erosion risk.

Firstly, an initial erosion risk map – sediment transport capacity - was generated in GIS (IDRISI) for the watershed, based on slope and slope length (from a digital elevation model

(DEM)). Secondly, a census was carried out covering all the focal areas implemented in the watershed since 1988. A standard recording format was developed for collecting information on: size, number of farm families, implementation rates of conservation recommendations, ethnicities, presence of erosion, registration of title deeds, fragmentation of farm land, free or restricted grazing, type of livestock, and main cash and subsistence enterprises.
During the latter half of 1999, all divisions in the watershed were visited and the above mention information recorded for each focal area. Afterwards, the individual focal area was visited and the approximate centre point was recorded in UTM – coordinates using a Global Positioning Systems (GPS) unit (Trimble). The data were then entered into a database and imported into GIS software (ArcView and IDRISI). Thirdly, spatial data layers on various focal area information such as implementation were created. Afterwards, these data layers were overlaid with the erosion risk map, a land use map, population density map and various biophysical maps created in the ICRAF Decision Support Laboratory. Then the different combinations of data layers were visually interpreted. Finally, the relations between key parameters were statistically tested.

7.3 Preliminary Results

Between 1988 and 1999 the Kenyan Soil and Water Conservation Branch (SWCB) worked in 177 focal areas in the hydrological upland of river Nyando (Figure 7.1).

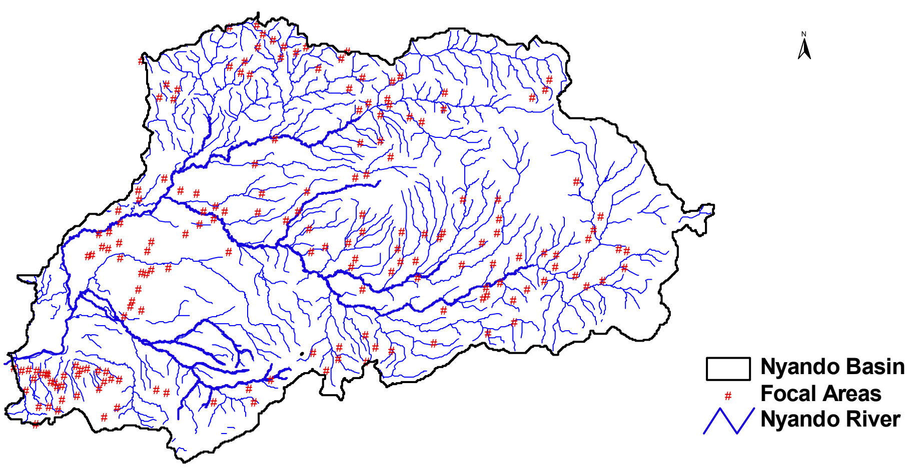

Figure 7.1 The location of SWCB focal areas in the Nyando Watershed

The implemented focal areas cover 17 % of the 3500 km^2 large basin. Approximately 10600 households adopted one or more of the recommendations, but their farms only occupy 7.7 % of the entire upland.

The focal areas are far from being equally spatially distributed. As seen in Figure 7.2, the focal areas are generally located in areas characterized by the highest population density.

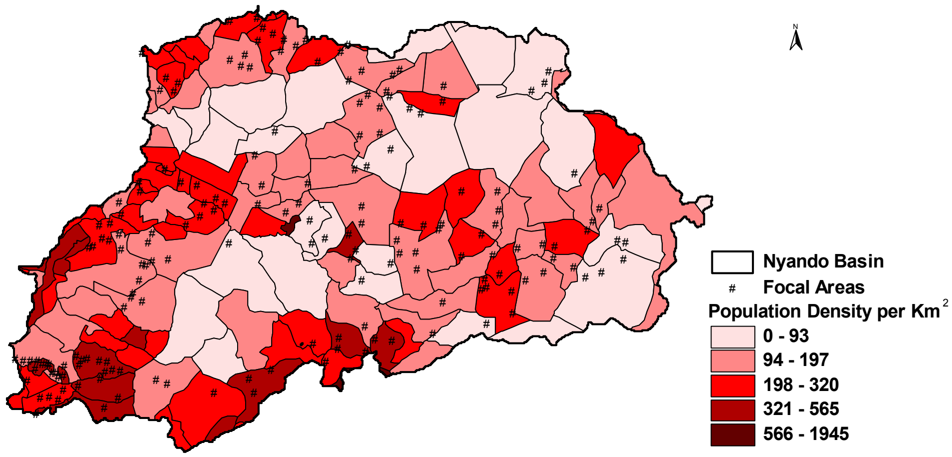

Figure 7.2 Population density in 1989 and location of SWCB focal areas in Nyando Watershed

The implementation rates vary between 7 and 95 %, as seen in Figure 7.3. The lowest percentages are found in the lake plain, characterized by subsistence farming, while the highest rates are found in the mid to steep sloping areas characterized by cash crop farming.

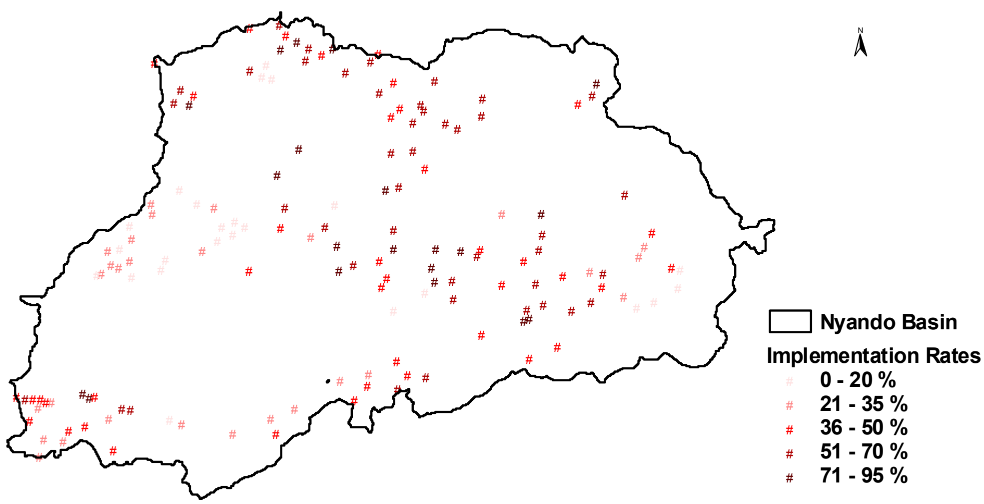

Figure 7.3 Implementation rates in the focal areas in Nyando Watershed

There are multiple factors influencing the success (i.e. implementation rate) of an SWC approach, such as the magnitude of the problem as perceived by the farmers, the farmers' knowledge / earlier exposure to SWC, land ownership, available human and natural resources, proximity to ethnic clashes, personality and the appropriateness/feasibility of the recommendations.

Among the influencing factors, the relation between slope and implementation rate was found to be the highest with $r = 0.5859$, (Spearman non-parametric test - $P<0.0001$). A critical point at about 4% slope was found by visual interpretation. This is the slope percentage that indicates the separation of the lake plain from the surrounding sloping areas. As seen in Figure 4, the average implementation rate for focal areas located in the sloping areas was more than 100% higher than the implementation rate in focal areas located on the plain. Interviews with farmers in the lake plain and results of 4 PRAs carried out in the area confirm this result. Farmers living in the area characterized by slopes less than 4% do not perceive erosion as one of their main problems. Hence, there is a low incentive for them to implement the soil and water conservation recommendations.

An additional factor influencing the incentive of farmers to implement recommendations is the issue of free grazing. Farmers in areas characterized by free grazing often face the problem of soil and water conservation structures being destroyed by livestock. As shown in Figure 7.4, areas with free grazing on average have a 22% lower implementation rate compared to areas with restricted grazing. Secure land ownership is another factor that has an impact on farmer-incentive for on-farm conservation. It was found that focal areas with title deed had a considerable higher implementation rate compared to focal areas without title deed.

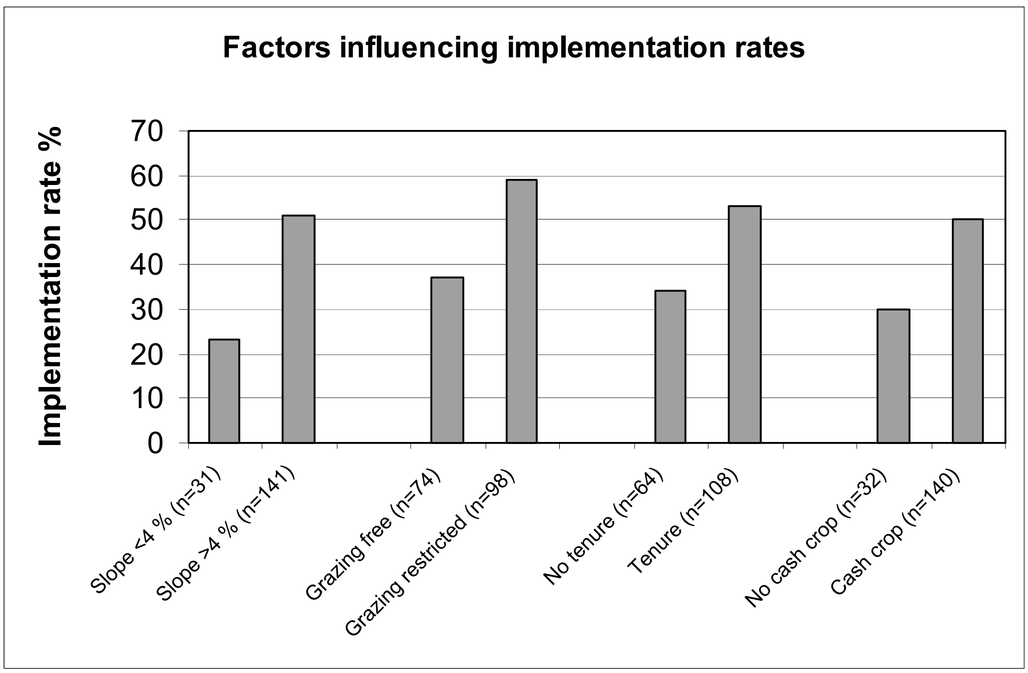

Figure 7.4 Factors influencing implementation of SWC recommendations

Another issue is that in most of the sugar, coffee and tea zones where the high implementation rates are found, the farms previously belonged to white settlers during the colonial time. In general, they paid a high attention to soil and water conservation. The cash crop farmers that bought the relatively well-conserved land from the white settlers seem to have maintained the structures, and are responding positively (high implementation rates) to the SWC approach. This is in contrast with many other areas, characterized by subsistence farming, where farmers viewed SWC negatively. In many cases SWC was forced upon the farmers by the colonial government and many farmers abandoned the structures after the end of the colonial period. As shown in Figure 7.4, the average implementation rate of cash crop farmers is 50%, compared to an implementation rate of 30% for subsistence farmers.

Figure 7.5 shows that Nyando River Basin has much higher erosion risk than the neighbouring Sondu-Miriu (South of Nyando). Only in a few cases, mainly in the South-western part, which are characterized by major gullies, are focal areas located in high erosion risk areas. There are still large areas of the Nyando River Basin, at high risk of erosion, that have not been covered by SWCB focal areas.

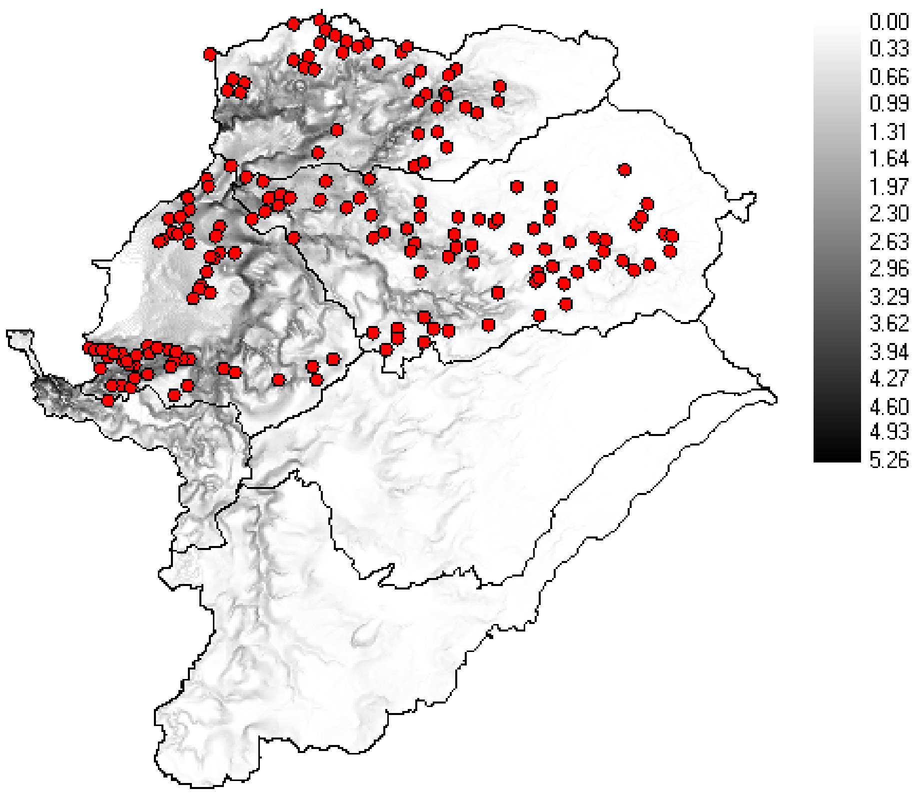

Figure 7.5 Overlay of SWCB catchments in Nyando Watershed with an index of sediment transport capacity for Nyando and Sondu-Miriu watersheds

When cross checking the DEM, the population density map and the land use map, it was found that many of the high erosion risk areas are either Government trust lands or sparsely populated areas. Since the Government trust lands are not supposed to be cultivated, these areas are not targeted by the SWCB.

7.4 Conclusions and implications

As an evaluation tool this type of combined EIA and decision-support system does not offer the same level of precision and should not be seen as replacing the more traditional hydrological monitoring. It is merely a tool to get an overall understanding of the situation under conditions where hydrological monitoring is not feasible.

With less than 8 percent of the area conserved by the approach and the fact that many of most erosion risk prone areas were not covered, there is only a slight probability of the approach having a great impact on the amount of nutrients transported into Lake Victoria. This is supported by preliminary results from analysis of sediment cores collected at various points in the sediment plume, caused by river Nyando. The initial results show no significant change in the sedimentation rate in the plume. Yet, it cannot be denied that the approach in certain areas well covered by the approach and with high implementation rates at sub-watershed level may have had an impact.

The primary target for the Soil and Water Conservation Branch is to limit on-site erosion, improve soil fertility and thereby raising farm production. Since the Branch is an integrated part of the Ministry it has to be present at divisional level. Yet, in terms of targeting areas of high erosion potential, a watershed approach would be more effective than the applied administrative approach. A substantial amount of work was carried out (31 focal areas) at the lake plain, where farmers don't perceive erosion as a problem and hence there the implementation rates are low. Consequently, these resources, which accounts for 17.5 %, could have been applied more effectively in other more erosion prone areas.

Another reason for the non-efficient location of focal areas is that many of the high erosion areas are not directly cultivated areas, and thus not covered by the SWCB approach. The majority of the high erosion risk areas are community-grazing land, shrub land and Government trust land. In order to conserve these areas and effectively reduce the flow of nutrients from the land into the lake, alternative approaches must be applied. One solution could be an integrated watershed approach that takes the agricultural areas, the trust land and the forest areas into account. This implies that decision markers from the involved ministries work together at watershed level to conserve the highly erosion prone areas, and thereby manage and lower the amount of nutrients that are transported into Lake Victoria.

Acknowledgements

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