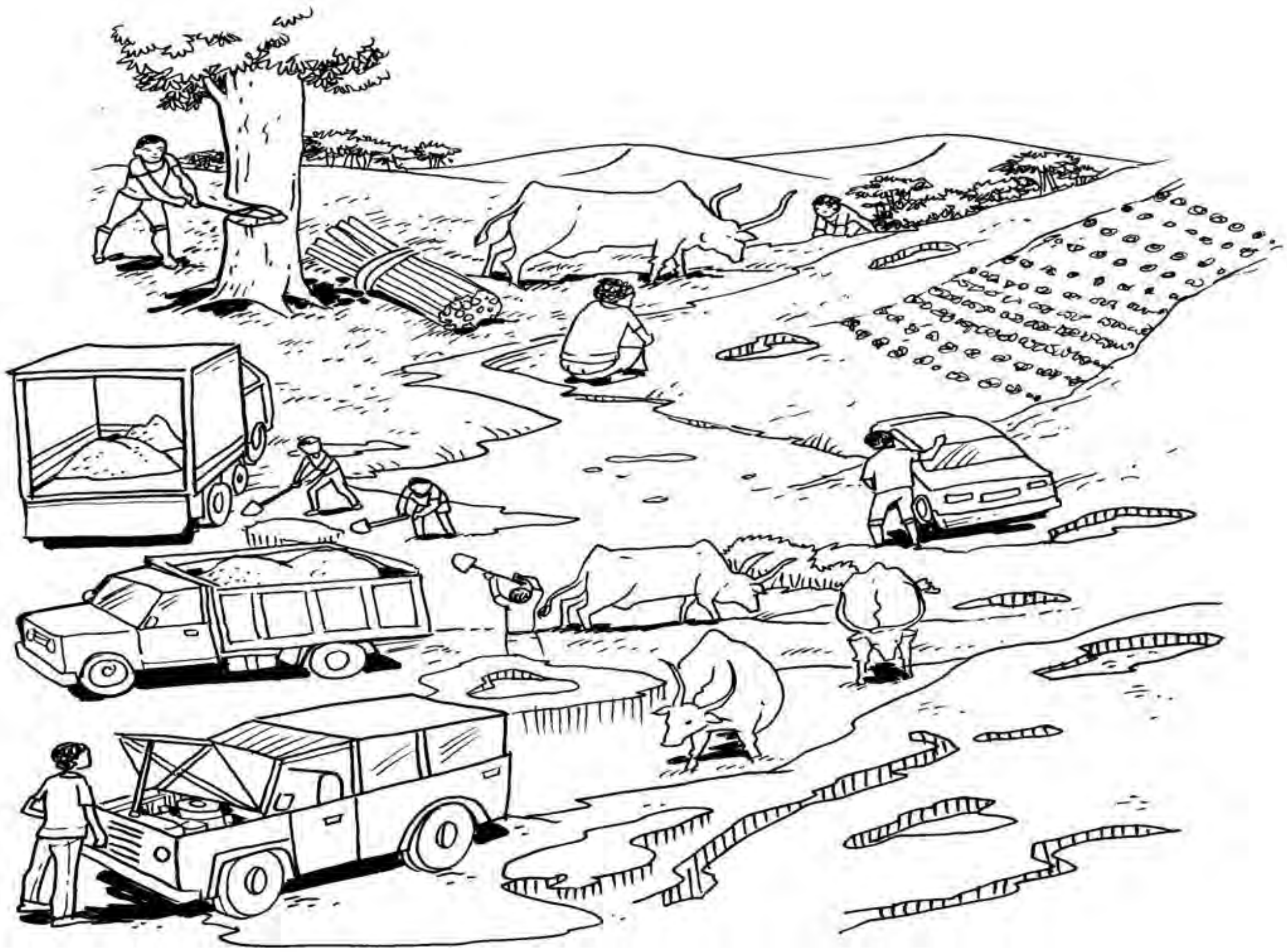
Soil and Water Conservation Technologies in the Upper Rwizi Micro-catchment of Southwestern Uganda



The continuing decline of agricultural productivity in many areas in Uganda, particularly in the Lake Victoria Basin (LVB), has been attributed to land degradation and, as a consequence, farmers encroach on forests, wetlands, and marginal steep slopes (NEMA, 2009; Mugonola, 2013c). Cultivation of these areas using unsustainable agricultural production methods contributes to increased soil erosion, loss of buffering capacity, sediment deposition, and pollution of water bodies. Degradation of farm and rangeland has on-farm and off-farm effects. On-farm, it leads to reduced current and future land productivity and land values, while off-farm, soil erosion results in environmental degradation, desertification, siltation of waterways, and flooding, among others.

The rapid land-use changes taking place in the LVB, including the upper Rwizi micro-catchment, continue to contribute to land degradation. For instance, banana production in the Rwizi-micro catchment of southwestern Uganda is expanding rapidly in response to increasing demand for cooking banana in urban places in Uganda and neighboring countries. This rapid expansion leads to changing land use and conversion of marginal areas (wetlands, steep slopes, valley bottoms) for agricultural production. However, these new areas may not sustainably support crop production because they are prone to land degradation through soil erosion. Soil losses through erosion leads to loss of the topsoil, organic matter, and inadequate water penetration and retention. The resulting effect is crop failure and reduced productivity due to nutrient and moisture stresses.

To abate soil erosion and the associated land degradation, smallholder farmers need to adopt water-smart technologies that include mulching, grass strips, runoff diversion, agro-forestry, and water harvesting, among others. These approaches, grouped into soil and water conservation (SWC) technologies, include biological, physical, and management-related techniques (WOCAT, 1992). Soil and water conservation is the rational use of land resources, application of erosion control and water conservation technologies, adoption of appropriate cropping patterns, and prevention of land degradation (Hudson, 1987). Adoption of SWC technologies will enable smallholder farmers to utilize resources such as land and water in ways that promote water-smart agriculture (WaSA).

SWC in the Upper Rwizi micro-catchment

Many technology dissemination and technology uptake pathways exist in Uganda—these include the research-extension farmer linkage, demonstration plots, progressive farmers' approach, Zonal Agricultural Research Development Institute (ZARDI), and exposure visits, among others (Mugisha *et al.,* 2012). In addition, various environmental management committees at different levels of local government are expected to oversee the wise use of natural resources.

New technologies, including SWC technologies, are taken up using these dissemination and uptake pathways. Once smallholder farmers get the right information, they act on it for as long as it is perceived to improve their economic and/or social conditions. These individual actions to conserve soil and moisture in the farm land that collectively lead to conservation of the Rwizi River through reduced deposition of sediments and nutrients, thus contributing to WaSA.

The upper Rwizi micro-catchment is drained by the River Rwizi, which originates from the Buhweju hills in present-day Buhweju District. The river flows eastward, dissecting a number of papyrus swamps and finally discharges into Lake Victoria through River Bukora, the Sanga plains, and Lake Mburo National Park. River Rwizi is drained by the Itojo wetland systems in Ntungamo District, the Bujaga/Nyaikaikara wetlands in Mbarara District, the Nyakambu wetlands in Buhweju, Buhweju District, and the Kooga wetland systems in Sheema, Bushenyi and Mbarara districts (NEMA, 2009; Wanyama, 2012). These wetland systems are naturally replenished by the water sources in the ridges of Buhwa and Bucuro (in Buhweju and Kashari), Ryengoma in Ibanda District and Rubindi. The Rwizi River is the main source of water for domestic, livestock, and industrial consumption in five districts (Bushenyi, Ntungamo, Mbarara, Kiruhura and Isingiro) of southwestern Uganda (NEMA, 2009).

The River Rwizi has a catchment area of 2,282 km^2 (228, 200 ha^2); altitude ranges from 1,262 to 2,168 m asl, with a bimodal rainfall of 1,000–1,500 mm per annum in most of the catchment area. However, the upper Rwizi micro-catchment is an area of high population density (ranging between 96.7 and 323.6 persons per km^2 of land area (NEMA, 1997), and high agriculture potential, supplying mostly banana and livestock to the urban areas of Uganda and neighboring countries (Wanyama, 2012). The predominant farming system in the upper Rwizi micro-catchment is the western banana-cattle system (Wortmann and Eledu, 1999; Wanyama, 2012) from which majority of the population derive their livelihood (NEMA, 1997). The major sources of income is the sale of crops and livestock. Major crops include banana, coffee, pulses (beans and peas), cereals (millet, maize, and sorghum), root crops (potato) and vegetables (Mugonola, 2013c). The annual crops require clean tillage practices, which expose the fields to water erosion and nutrient loss through leaching and nutrient mining at harvest (Wortmann and Kaizzi, 1998; Isabirye et al., 2007). Banana production is a major economic activity in this area and therefore takes up a considerable portion of farm-level resources (Bagamba, 2007). Bananas are planted along the hill slopes mainly as monoculture, but sometimes intercropped with coffee and beans.

Many of the valleys have been either fenced off as grazing paddocks or are used to cultivate crops, especially vegetables and potato. The wetland vegetation, especially papyrus, is cut and used for various purposes such as mulching banana plantations, thatching houses, and making arts and crafts, among others (NEMA, 2007). Since the hilltops and slopes have become unproductive due to overgrazing, loss of fertility, and degradation, agricultural activities have shifted to the valley bottoms and wetlands (Mugonola, 2013c). This change in land-use impacts on the catchments as bare hilltops and slopes are prone to massive soil erosion and the buffering capacity of the wetlands is eventually overwhelmed. For these reasons, the upper Rwizi micro-catchment is often described as land degradation 'hot spots' (Isabirye, 2005; NEMA, 2010). The river system receives all the eroded sediments and sediment-fixed nutrients from hillsides and agricultural land unabated, which eventually end into Lake Victoria (Isabirye, 2005; De Meyer et al., 2011).

Sample selection

The study used multi-stage sampling strategies involving purposive selection of districts and subcounties, where the extent of degradation was highest, "degradation hot spots," random selection of villages (bearing in mind the distance from the river), and clustering of respondents by economic activity (intensity of banana production and livestock density). A household survey was conducted among 271 households drawn from Mbarara, Bushenyi, and Ntungamo districts in selected subcounties of Bukiro, Bubaare, Rwanyamahembe, Rwengwe, Bugamba, Kyangyenyi, Rugando, Ndeija and Itojo (Mugonola et al., 2013a). In addition, sediment measurements were taken in selected subcatchment areas along the river, targeting areas with intact, medium, and completely degraded wetland vegetation.

The adopters of SWC technologies were 45% while the nonadopters were 55%. The adopters were small-holder farmers that had any or a combination of mulching, retention ditches, grass strips, and runoff harvesting channels, among others. This implies that majority of the respondents had not taken up any measures to conserve their soils and water, thereby increasing the risk of soil erosion and sediment deposition into the Rwizi river system. The demographic characteristics of the adopters and nonadopters of SWC technologies in the Rwizi microcatchment are presented in Table 1.

Conceptually, this analysis assumes that smallholder farmers optimize the benefits that accrue from the adoption or nonadoption of SWC technologies. However, as smallholder farmers seek to optimize the benefits of SWC, they may be affected by a number of factors, which may hinder them from taking favorable decisions toward adopting SWC technologies (Fig. 1). The observed differences in the decisions of the smallholder farmers toward

***Table 1**. Demographic characteristics of adopters and nonadopters of SWC technologies in the Rwizi microcatchment.*

Dichotomous variable	Adopters (N = 122)	Nonadopters (N = 149)	Pooled (N = 271)
Male-headed households	47.9	52.1	78.6
Female-headed households	34.5	65.5	21.4
Presence of SWC technology	45.0	0.0	45.0
Absence of SWC technology	0.0	55.0	55.0
Severe signs of erosion	44.8	55.2	92.3
Absence of signs of erosion	47.6	52.4	7.7
Agriculture main income	47.2	52.8	84.5
Non-agriculture income	33.3	66.7	15.0
Belongs to farmers' group	47.5	52.5	29.5
Not members of farmers' group	44.0	56.0	70.5
Access to agric extension	58.1	41.9	38.7
No access to agric extension	36.8	63.3	61.3
Access to agric credit	50.4	49.6	42.0
No access to agric credit	41.0	59.0	58.0
Off-farm agricultural income	43.6	53.0	57.6
No off-farm income (%)	47.0	56.4	42.4

Source: Mugonola *et al.,* (2013a).

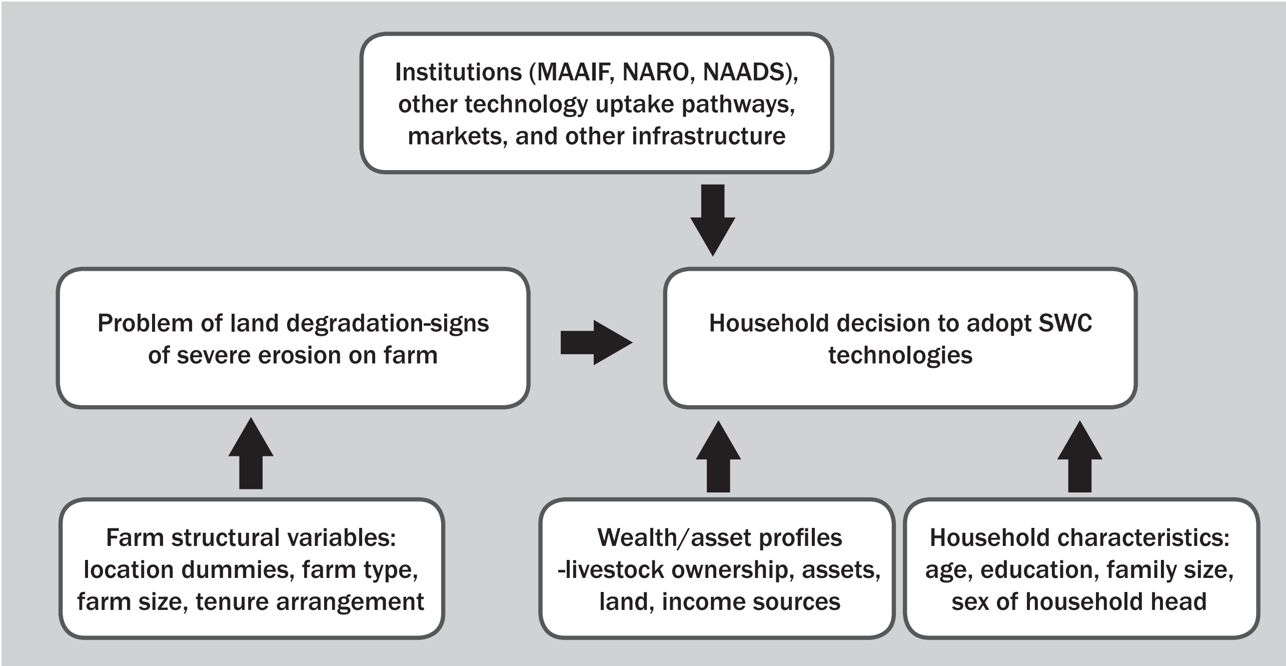


Fig. 1. Conceptual framework of land degradation and smallholder decisions in the Rwizi micro- catchment (Mugonola et al.*, 2013a).*

adoption may be explained by the differences in socioeconomic characteristics, asset endowments, farm structural characteristics, perception of land degradation problem, and access to institutional support (Mugonola *et al.,* 2013a).

Results

As indicated in Table 1 and Figure 2, most of the adopting smallholder households were male-headed, had access to extension message, belonged to a farmers' group, had agriculture as main source of income and had access to credit facilities. As a result of the adoption of SWC technologies, a number of observations have been made as a result of this initiative: increased banana yields, reduced soil erosion and deposition of sediments into the Rwizi river system, finding a market for grass as mulching materials, integration of livestock and banana production in the form of using the manure to replenish soil fertility and using banana residues to feed livestock, among others. The results further indicate that only 45% of the farmers have adopted SWC technologies in the upper Rwizi microcatchment. In addition, these adopters were shown to be more technically efficient than their nonadopting counterparts. Average technical efficiency values of about 70% were reported for the adopting farmers (Mugonola *et al.,* 2013b). This implies that adopters obtained higher output (banana) per unit of inputs used. However, the fact that technical efficiency was only 70% implies more room for improvement only in the upper Rwizi microcatchment.

Sedimentation of River Rwizi

Soil erosion of bare land leads to generation and transportation of sediments. In the upper Rwizi catchment, average suspended sediment yield (SSY) in a year is 465 tons/km^2 the range is from 40 to 1,152 tons/km^2 per year in the sub-catchments (Wanyama, 2012). The amount of SSY is influenced by the type and extent of land-use/vegetation cover change. (Land-use/cover change in the upper Rwizi catchment refers to conversion of grassland to cropland with no SWC measures on the hill slopes and the elimination of the natural sediment filter system of papyrus swamps, which impacts on the land degradation and catchment sediment dynamics). Cropland (bananas) on the steep slopes is very sensitive to gully incision when there is runoff producing land-uses upslope of it (e.g., degraded grasslands) (Wanyama, 2012). Gully channels in the catchment increase sediment transportation and are responsible for the delivery of runoff and new coarse sand and rock fragments to rivers. As an adaptation

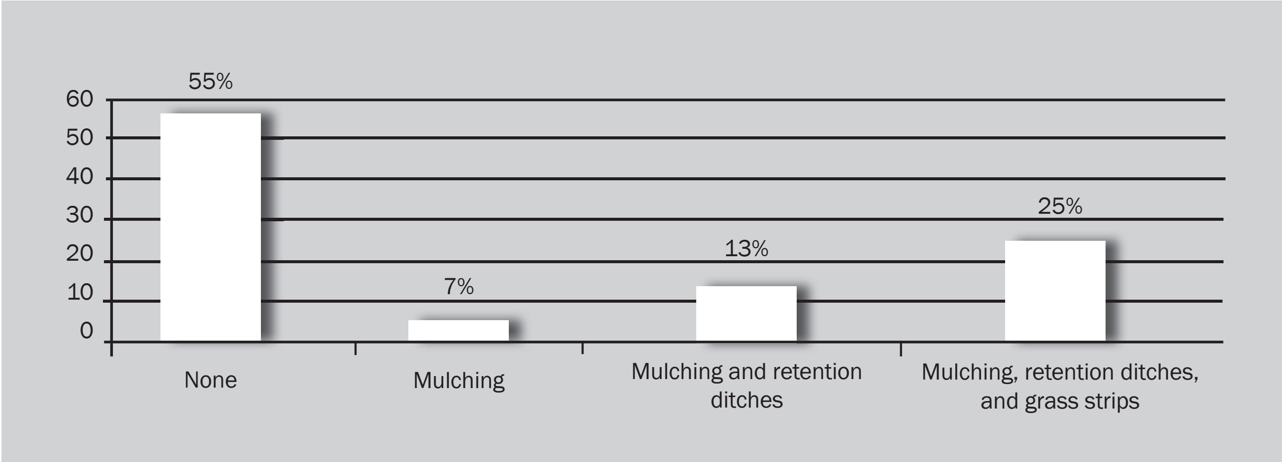


Fig. 2. *Adopters and nonadopters of SWC technology in the upper Rwizi micro-catchment (N = 271) (Mugonola* et al.*, 2013c).*

to the new conditions created by the flash floods and sediment deposits, the river channels are eroded and widen in cross-section.

Key challenges

The challenges with project-supported work include the following:

- Interventions normally end with the end of the project and therefore no resources are left to scientists for follow-up activities.
- The farmers have also learned to position themselves to seem to be doing something right to entice the project teams and hence tap some resources but not to build their capacity to carry on with the interventions.
- The local populations in these communities were hostile to the research team due to the fact that, at the time of the study, there had been clashes with the National Environmental Management Authority (NEMA) officials over encroachment on the wetlands.
- Measurement of sediment transportation and deposition in the river, especially following the rainfall episodes, was challenging as the volume of the water was high.

Conclusions

This research concluded that for sustained adoption of SWC technologies to take place, there is need for institutional support. For instance, the extension system needs to be supportive of the technology dissemination and awareness creation programs. The extension system in Uganda involves both the public system and nongovernment organizations. Institutional support in terms of markets, farmer groups, infrastructure, and financial institutions, among others is very important in fostering technology adoption. In addition, land ownership came out as a strong factor suggesting a land-area threshold for farmers to adopt these SWC technologies. This represents the importance of asset ownership in technology adoption. Equally important was gender consideration. Male-headed households were more likely to adopt SWC technologies probably due to the drudgery of some practices, security of tenure, and access to financial assets.

This study revealed that the extent of adoption of SWC technologies is limited to only 45% of the farmers, yet, the River Rwizi micro-catchment is the lifeline of a significant proportion of the population in the five districts of southwestern Uganda. Urgent attention is therefore needed to reverse the level of degradation by enforcing adoption of SWC technologies and other WaSA principles. It is further recommended that catchment management initiatives be geared toward "wise use" of land resources to promote WaSA. This will reconcile the need to meet the increasing demand for food resulting from rapid population growth and the general concern over widespread degradation of the resource base and sedimentation of water resources.

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