REPORT ON EROSION CONTROL PRACTICES

AND THE DETERMINANTS OF THEIR ADOPTION

Report carried out by the School of Agricultural Sciences and the Environment

The Evangelical University in Africa

On behalf of the USAID South Kivu Food Security Project (FSP)

In consortium with Mercy Corps, World Vision, APC and Harvest Plus

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Acronyms and Abbreviations

- **CATALIST:** Catalyze Accelerated Agricultural Intensification for Social and Environmental Stability, a program implemented by the IFDC
- **CEC:** Cation Exchange Capacity (the total **capacity** of a soil to hold exchangeable cations, which influences the soil's ability to retain nutrients).
- **FFS:** Farmer Field School
- **FAO:** Food and Agriculture Organization
- **FSP:** Food Security Project
- **SLM:** Sustainable Land Management
- **ISFM:** Integrated Soil Fertility Management
- **GPS:** Global Positioning System
- **IFDC:** International Fertilizer Development Centre
- **INRA:** French National Institute for Agricultural Research
- **ITAV**: Technical, Agricultural and Veterinary Institute
- **MAE:** Anti-Erosion Mission in Kivu
- **PATECORE:** Land Management and Resource Conservation Project on the Central Plateau, an FAO project
- **pH:** Potential of Hydrogen
- **DRC:** Democratic Republic of Congo
- **RUSLE:** Revised Universal Soil Loss Equation
- **GIS:** Geographic Information System
- **SOTERCAF:** Soil and Terrain Database for Central Africa
- **RDT**: Rural Development Technicians
- **UEA:** The Evangelical University in Africa
- **USAID:** United States Agency for International Development

Table of Contents

Preface

This study is rooted in an action research scheme run by the FSP program, funded by the United States Agency for International Development (USAID), Office of Food for Peace (FFP) and led by the consortium Mercy Corps, APC (Action for Peace and Concord), HarvestPlus, UEA and World Vision. It is based in the health zones of Miti Murhesa, Katana and Kalehe and aims to answer various questions regarding water and soil management in order to increase the project's chance of success.

Solely improving soils is not enough to develop agriculture in the mountainous Bushi region, of which the territories of Kabare and Kalehe are part, and where soils have already degraded to an advanced state. Soils must also be conserved by limiting the phenomenon of erosion. Therefore, it is important that the water and soil management techniques value the land most and that the extra work required by erosion control is justified; as such, it is important to hear the views of the farmers. Investigations must be carried out before taking any action in regard to agricultural development in order to support a water and soil management strategy, taking into account the interests and constraints of farmers and the actual situation on the ground. This is the benefit of having led this research during the first year of the implementation of the FSP project.

We would like to thank the entire team that has contributed to the accomplishment of this work. Our colleagues and partners at Mercy Corps have been very helpful in the methodological conception - we express our gratitude to them. We thank the investigators and assistants of the UEA who carried out the bibliographic referencing and the coordination of the investigations – particularly GéantChuma, Marcellin Chokola, Serge Ndjadi, Safina Bora, Espoir Bagula, Nadège Cirezi and Laurent Bigirimwami.

This work was supervised by professors Gustave Mushagalusa Nachigera and Katcho Karume of the School of Agricultural Sciences and the Environment of the UEA. This current report is structured around two sections: a section for the bibliography and one for the investigation.

Prof. Gustave Mushagalusa Nachigera

Introduction

According to the International Fertiliser Development Centre (IFDC), Africa is losing 8 million metric tonnes of soil nutrients each year. In total, more than 95 million hectares of land have been degraded to the point of significantly reduced agricultural productivity (Henao and Baanante, 2006). According to estimates, at least 85% of African countries suffer from a nutrient uptake of more than 30 kg per hectare per year and 40% of the countries suffer from a loss of more than 60 kg of nutrients per hectare per year (Henao and Baanante, 2006). A study conducted in the Great Lakes region by the project CATALIST of the IFDC revealed that the nutrient balance of the soil in this region is the most negative in the world. According to this study, almost 100 kg of nutrients are lost annually per hectare of agricultural land.

The main causes of this are: 1) the high population growth rate, which increases pressure on overexploited land, 2) a dependency on agriculture that is vulnerable to environmental changes, natural resources and fragile ecosystems, 3) high rates of erosion and soil degradation, and 4) frequently low yields and post-harvest losses. Moreover, a sensitivity to variations in climate and to climate change in the long term are also contributing factors (Smaling *et al*, 1997).

In light of the problems above, Sanchez et *al*. (1997) have concluded that the exhaustion of soil fertility in farms is the main cause of the decline in food production per capita in Africa.

Losses of such magnitude require certain response measures, particularly the restoration of soil fertility and more efficient recycling of biomass materials in the agricultural system in order to improve the productivity of crops.

The degradation of soil caused by non-sustainable land management practices represents a threat to the environment and to the means of existence in the mountainous Bushi region in eastern DRC, where the majority of people depend directly on agricultural production (Bagula *et al*, 2014). A devastating spiral of overexploitation and degradation, aggravated by the negative impacts of climate change, is currently leading to a decrease in the availability of natural resources and to a decline in productivity - this endangers food security and increases poverty. Sustainable land management (SLM) is an antidote, it helps to boost average productivity, reduce seasonal yield fluctuations, diversify production and increase income (Pypers *et al,* 2011).

In the case of South Kivu, the joint efforts to manage soil degradation must target splash erosion of soils on steep slopes, conservation and restoration of soil fertility and management of organic matter and biodiversity. Sustainable land management in this part of the country must make an effort to increase agricultural production using systems that are both traditional and innovative and must improve their resilience to various environmental threats.

Thus, the main objective of the Food Security Project in South-Kivu (FSP) working is to increase incomes in vulnerable households despite exposure to shocks and *environmental constraints*.

Three key strategies are essential to achieving this, including the improvement of land productivity, the means of support and the ecosystems.

To contribute to the improvement of agricultural production, and therefore household income, the Farmer Field School approach (FFS) will be used. This approach invariably passes through the following steps: selection of participants, training of facilitators, plot choice, preparation of the field, participatory community diagnosis of constraints and opportunities, establishment and conduct of the FFS (investigated plots/guided visits), counting and analysis of the results by the community and the facilitators.

Justification of the study

Different farming practices allow the current imbalance between extraction and input of nutrients into the soil to be tackled. These include: the improvement of ground cover, crop combinations, spreading of animal manure and compost thanks to integrated crop-livestock systems, appropriate input of mineral fertilizer as well as the retention of sediments and nutrients from the soil by levees, plants or structural traps. These techniques are all part of an Integrated Soil Fertility Management (ISFM) system which allows the level of organic matter and the structure of the soils to improve, as well as land productivity (Sanginga and Woomer, 2009).

A strategic choice of crop combinations adapted to several conditions alongside effective management is also essential in the framework of this project. Protecting the soil against erosion will be of top priority.

Despite the constraints and difficulties that they encounter, farmers willingly adopt the practices of SLM if they allow them to get better yields, reduce the risks to which they are exposed to, or a combination of the two. The main problem with adopting the practices of SLM lies in the cost-efficacy relationship, particularly for short and long-term benefits (Roose, 1995). Farmers adopt practices that provide easy, quick and sustainable returns in terms of food or income. The implementation of certain measures sometimes necessitates assistance for small-scale farmers when costs exceed their means and quick returns are not guaranteed. The maintenance costs must be insured by the farmers themselves in order to encourage their capacity for initiative. It is therefore important to properly assess the cost/benefit ratio in monetary and non-monetary terms (Liniger *et al,* 2011).

The adoption of SLM practices by farmers sometimes requires additional input, in relation to materials (tools, seeds, fertilizer, equipment, etc.), work, markets and knowledge. Work and input pose a particular problem in the regions affected by rural exodus.

Changes towards SLM must be made while taking into account local values and standards; they must allow flexibility, adaptability and innovation in order to improve the means of support. Good SLM practices are those that require minimum learning and development of competences whilst being easy to learn.

Objectives of the research

During the Refine & Implement process, along with Mercy Corps' STRESS process, UEA conducted this study on ecosystems aiming:

1. To identify the socio-economic practices of erosion control and sustainable management of soils used within FSP area and the obstacles to adopting improved practices
2. To map the factors related to the process of erosion, with a localisation of susceptible areas
3. To propose a plan for training in erosion control techniques

Chapter 1: Literature review on erosion control practices and conservation of soil water

1.1 Definition

Erosion is defined as the wearing away and transport of soil particles from an original location by different agents (gravity, water, wind) to a place where they are deposited. In all cases, whether the cause of erosion is water, wind or tillage, the soil detaches, it is transported and then deposited (Le Bissonnais *et al,* 2002).

The topsoil layer, which is fertile, alive and rich in organic matter, is swept away to a new location where it accumulates over time, or out of the field in drainage systems. The erosion of the soil lowers the productivity of the land and contributes to the pollution of waterways, wetlands and adjacent lakes. This phenomenon can be slow and go relatively unnoticed. It may also occur at an alarming rate and then cause heavy losses of topsoil. Other causes of deterioration are soil compaction, depletion of organic material in the soil, degradation of soil structure, bad internal drainage and acidification issues (FAO, 1983).

1.2 The gravity of the erosion issue

Many reports (PNSA, 2010; PRSP, 2005; DFID, 2002, World Bank, 2015) have been written on fields suffering from erosion in different continents. According to some estimates, erosion carries away 10 hectares of agricultural land every minute across the entire surface of the globe - these are average figures (The World Bank, 2013).

The gravity of the erosion issue can be measured by the amount of land lost per hectare; however, it is not always as simple as this. Particularly in hilly areas, such as Kalehe and Kabare territories, the thickness of the fertile layer varies significantly from one place to another over very small distances. The issue of erosion varies both globally and locally, for example, for two farmers living on the same mountainous slope, the situation can be very different. Generally, the poorest and least resilient social group is affected most severely by the effects of this phenomenon (Liniger *et al.,* 2011).

1.3 The gravity of erosion

The erosion of soil is a very important economic problem, particularly when the productivity of the soils has to be restored. The means used to reduce surface run-off and loss of land are very expensive.

Demographic pressure leads farmers to search for food producing crops to grow, even on marginal land unsuitable for agriculture. These could be steep slopes, shallow soils, etc. The cutting down of forests to obtain agricultural cropland, firewood and timber leaves the land bare and exposed and erosion occurs until the underlying rock is exposed, allowing the ground to become more and more infertile (Barros, 1995).

1.4 Types of erosion control

Many authors have referenced the strategies of erosion control that have evolved from traditional methods toward the concept of Conservation Management of Water, Biomass, and Soil Fertility (Mati, 2005).

In South Kivu, farmers have made adjustments (such as planting according to contour lines of the hills, or anti-erosive hedges) for the conservation of soil and water, in order to combat erosion in their fields. These adjustments comprise of a few mechanical, biological, agroforestry and cropping techniques. The objective of these adjustment techniques is to slow down and store water run-off as well as to reduce wind force in the case of windbreaks.

Principles

According to Kuypers *et al.* (2004), to minimize erosion, one can only intervene with factors affecting surface conditions (soil and vegetation) and to a lesser degree, with topographic factors. One cannot intervene (for the moment) with climatic factors.

Like in the context of South Kivu, erosion is generated by the impact of rainfall and the flow of water run-off. If we want to minimise this, we must intervene with these two causes. For an effective response, the analysis of factors influencing erosion shows that the means of intervention must encourage one of the following objectives:

1. Increasing stability and resistance of aggregates;
2. Absorbing rain energy;
3. Limiting or slowing down surface run-off;
4. Reducing surface run-off by boosting infiltration.

The first two have an effect on the impact of rainfall and the last two on surface runoff. These principles have to be understood for development intervention, knowing that erosion can be minimized in the field by intervening with the crops and soil management, cultivation methods and conservation.

The soil in this region is very sensitive to crusting and the rain is aggressive. The risk of erosion due to surface run-off is significant. The traditional techniques of erosion control encountered in this zone can be grouped into two broad categories: mechanical methods and biological methods.

1.5 Water and soil management practices

1.5.1 Contour bunding

These are rows or barriers of stone blocks (approx. 25 cm in diameter) perpendicular to the direction of water flow. The width of land that is levelled follows the area of the water passage. It is often a few meters long. Most often, there are two to three levelled areas per field. At times of heavy rainfall, with a lot of water run-off, the blocks move often, which forces farmers to perpetually repair the barriers (Saidou *and* Ichaou*,* 2015; Rabdo, 2006).

Photo of the contour bund technique

(Source: Carsten Riedelcerca de Djimé (Benin) available on https://es.wikiloc.com/rutas-outdoor/technique-cordons-pierreux-1-3-ha-13667513/photo-8453525/20/12/2017).

These stone barriers are found mainly in outfields, where there is the problem of transporting the blocks. Failure to comply with the contour lines whilst they are being built frequently results in loss of land. Channels are created by the water during its passage to the ends of the barriers. These channels can produce gullies in the fields (Roose *et al.,* 1998).

Contour bunds are labour intensive and costly. For example, between 1987 and 2006, the PATECORE project in Burkina Faso helped to revive more than 100,000 ha of degraded lands in Burkina Faso with 30,000 km of contour bunds. However, this required the extraction and transport of 2.5 million cubic meters of stone, for a net cost of $200/ha and 100 to 150 unpaid working-days per hectare on the part of the farmers. Nevertheless, they proved to be both very effective and sustainable, and often act as a catalyst for additional innovations like the planting of trees or herbs on the bunds, as well as increases in nutrient input for the field crops (Zougmore *et al.,* 1993; Rabdo, 2006)**.**

1.5.2 Peripheral Bunding

This system is composed of an earth bank that surrounds the protected farms - in most cases these are comprised of rice fields and other crops located in the low lands. Its implementation involves an elevation of land of 15 to 20 cm in height around the plot. The contour is done at the beginning of the rainy season to avoid any risk of being swept away by water runoff. It includes gaps that are used for expelling excess water during heavy showers and are located on the waterways. The dimensions of the bund depend on those of the field (Rabdo, 2006; VLAAR, 1992).

The peripheral or contour bunds will help to prevent the drainage of the mineral particles and humus in the soil via water run-off. The location of these plots of land in the lowlands explains the presence of such systems to keep water and mineral elements on site. Weeds pulled out in the fields are deposited on the bunds during maintenance work. The bund is repaired in each cropping season and the farmer strengthens the system during the rainy season. The infields, including plots intended for the cultivation of corn, are also often protected using this technique (PATECORE, 1996). In Mali, the bund is built during the preliminary tillage, but is often replaced by contour bunds, which, according to farmers, are more resistant and require less maintenance.

1.5.3 Terraces

Different types of terraces used for erosion control have been known to exist for a long time and are used in mountainous landscapes. Their types and objectives often differ on the same slope: progressive terraces are used to slow down the surface run-off and retain the land on top of the slopes, and step terraces are used to store soil and water in semi-arid environments and facilitate irrigation in the vicinity of springs and rivers (Roose, 1995).

Photo of terrace works at Mabingu in the Kabare territory taken during household investigations conducted by the UEA team on behalf of the FSP Project.

Their efficacy of terraces in retaining water and soil, which is still widely unknown, has been demonstrated by only a few experiments on plots of several hundred square meters and on some micro catchments. However, in some cases where slopes are too high (>60%), the area is prone to earthquakes, rocks are subject to landslides (gypsum marl, schist, gneiss) and expansive soils prone to cracking or holes from burrowing animals, the terraces have proved inadequate. These techniques that are either traditional or forcibly imported, have often been abandoned because they require too much work (better valued in the city) and fertilization to be economically profitable (Ganaba and Kiema*,* 2000). They can be improved by selecting intensive cultivation systems specific to mountains by reducing work time, using easier techniques to stabilize slopes (agroforestry/hedges and legumes), protecting the surface of the soil and adapting the fertilization and irrigation rationale.

In Bolivia, in the nineties, the installation of terraces was abandoned because their efficacy was questioned by farmers, hydrologists and researchers. It has in fact been shown that terraces do not reduce the degradation of soils between slopes, but also that the weak maintenance of terraces concentrates water flow in the gullies and accelerates the undermining of water run-off.

1.5.4 Zaï

Zaï is a traditional technique, with a specific form of cultivation that allows one to concentrate the water in pockets and the manure in micro-basins where seeds will be planted (Droux, 2008). During the dry season, the holes (30-40cm in diameter, 10-15cm in depth), are dug in quincunx alignment every 80cm. The excavated soil is deposited in the shape of a crescent downstream from the holes, which improves the roughness of the surface and, therefore, limits the run-off, the wind speed and overall erosion (Roose *et al.* 1995; FAO, 2001, Bagula *et al.* 2013 and Bagula *et al.* 2016). This preparation of the land allows sand, silt, and organic matter to be transported by the wind and trapped in the pockets. The surface of the soil that is not used around the holes serves as an *impluvium*, and therefore allows an increase in the quantity of water retained in the pockets (Baboule *et al.* 1993).

Photos of the Zaï technique taken in 2011 in during tests on water management technologies in Kamanyola (Bagula et al. 2013)

The advantages of Zaï mainly concern the capture of run-off water, the preservation of seeds and organic manure, the concentration of fertility and water available at the beginning of the rainy season (early planting) and at the end of the season a good filling of grains (Baboulé *et al*, 1993). Zaï increases the biological activities of the soil: rapid growth of seedlings that benefit from the mineralization of manure brought at the end of the dry season (Roose and Rodriguez, 1990). This technique increases cultivated areas and cereal yields, except in exceptionally dry years, or years when rainfall is well distributed. It allows crops, especially cereals, to adapt well during periods of their cycles when they are sensitive to water stress (tillage, heading, flowering, grain filling). It can therefore reduce the negative impact of climatic hazards on the crop and secure production (Roose, 1995).

However, the practice of Zaï also knows limits. It can reduce the impact of a drought by 2 to 3 weeks if the soil can store enough water (which is not the case for soils that are too shallow or too stony), but Zaï cannot function satisfactorily if it does not rain enough (minimum 400 mm with a soil storage capacity of 50 mm) (Bagula *et al*,2016). Similarly, if it rains too much, the crop will become clogged at the bottom of the basins and nutrients will leach (observed in Cameroon) (Baboulé *et al*., 1993). The optimal application zone for Zaï seems to be limited to the Sudano-Sahelian zone (between 400 and 800 mm) but this should still be specified according to plants and soils. Even in the Sudano-Sahelian zone, the extension of Zaï is limited by the availability of labor and manure. The Zaï requires 300 hours of very hard work with the traditional pickaxe (short handle and angle too closed between the iron and the handle), that is to say approximately 3 months to arrange one hectare (at a rate of 4 hours during 25 days per month) (Roose, 1990; Anschütz *et al*, 2004). Carried out manually, this technique is thus to recommend on small surfaces such as the peasant culture in the plain where the peasants exploit on average 0,8ha per agricultural household.

1.5.5 Fallow

Fallow is a traditional soil restoration technique. It consists in suspending any form of exploitation of the plot for a certain period, generally several years, to allow the reconstitution of soil fertility. In traditional systems, fallowing remains the only technique for regulating and stabilizing environments that are constantly disturbed by humans (Fournier et al., 2000). The resting time required to restore the physical, chemical and biological potential of ecosystems is empirically determined by the farmer; this time generally varies from 5 to 10 years and more, depending on the climatic region, the nature of the soil and the crops grown (Roose, 1995).

In traditional and subsistence agriculture, given the growing need for agricultural land to feed an ever growing population, there is also the problem of the availability of agricultural land leading to a reduction in fallow time. In the Andes in Peru, fallow time has disappeared to represent only the dry season period (7 to 9 months), which poses a real problem of conserving the production potential of the environments and, in the long term, the very problem of survival of the populations in the area (Sebillotte *et al*., 1993; Laudelout, 1990). The same issue is visible in Kalehe and Kabare territories, where fallows have been abandoned with the pressure of necessary food availability.

1.5.6 Ridges

The ridges are small earth dikes built along the contour lines of the slope. Water that accumulates above the ridges can thus seep into the ground. This method of soil moisture retention is used on slopes with an inclination of up to 7%. The soil structure must be relatively stable, otherwise the ridges may be undermined and destroyed by run-off. Ridging requires more work and financial investment than strip cropping (Anschützet al, 2004).

Partitioned ridges

These are earth piles behind which a furrow is dug to collect runoff from an uncultivated strip located between the ridges with a construction of partitions in the furrow at regular intervals to prevent runoff along the furrows (Van den Ban, 1994).

It is one of the ancient techniques of water and soil management in African agricultural environments subject to various climatic hazards and severe droughts. It increases the infiltration surface of the soil, reduces runoff almost completely for soils and allows a notable increase in water availability of 45% at most (Drechseletal, 2006; Dijksterhuis, 1995).

Photo of ridges (2011) taken as part of water management technology trials in Kamanyola (Bagula et al. 2013)

Ridging presents advantages for seepage management and for the establishment of lands suitable for cultivation due to the weak compacting of soil in the ridges (Bagula *et al*, 2013). The studies performed by Bagula *et al*. (2013) showed that the ridging columns improved seepage, and also increased the yield in crops (500 to 1000 kg/ha/year for the cereal).

Others have tried simulating rain. In the region of Lake Bam, Colliunet *et al*. (1979) observed that the ridging columns on hills of less than 1% gradient allowed infiltration of 60 mm of rainfall per hour and stored more than 100 mm in the soil, i.e. three times as much as if the soil had been worked.

Dijksterhuis (1995) in 1995 observed that the use of ridging columns must be combined with the use of fertilizer. The main disadvantage of this technique is that the weak soil density caused by ridging can lead to rapid drying up of the soil around the seeded area, increasing the risk of crop failure in dry conditions. (Makindu, 2012). Ridging, like mounding, is a dangerous practice because, in theory, it extends the surface area for soil seepage (therefore, in reality, it reduces the flow of water), and it also increases the average hill gradient, reduces the cohesion of the soil and concentrates the flow of the water to one line. Finally, it is believed to further erosion at an exponential rate with gradient of the land (Roose, 1973, 1977).

It is therefore important to reduce the soil loss and crop water on the ridges and columns, by using mulch (Drechsel *et al*, 2006) and putting it in the contour lines.

1.5.7 Mulching

Mulching is a commonly used, traditional conservation technique, consisting of covering the soil with a layer of grass or dry straw that is 2 cm thick. This layer protects soil from erosion due to the impact of rainfall and delays crusting over. Mulching reduces evaporation and preserves soil humidity. Furthermore, it keeps the temperature of the soil within a consistent range, which provides a better environment for microorganisms during the dry season. Finally, it slows the growth of weeds. Shallow-rooted crops draw particular benefits from mulching because their roots are found in the partially decomposed layer situated between the soil and the straw (Elis, 1998).

Photo of mulching technique taken in 2011 shows attempts by the water management technologies at Kamanyola, in South Kivu (Bagula et al. 2013)

The farmers proceed to harvest the grass **(***Imperatasp, Hypparheniasp, etc.***)** that they collect in the savannahs (Kuypers *et al,* 2004). Their possible uses, such as feed, diminish after blossoming due to the needles that develop and discourage cattle from consuming them. Where the grass is not sufficient, certain producers use dry leaves from different trees, *Acacia Senegal or Acacia Nilotica* in particular.

In the FSP areas acacias are available along with other trees/bushes such as *Caliandra, Leucena* or *Thitonia* that can provide mulching materials in addition to being organic fertilizers.

Another advantage of mulching is that it attracts termites. The termites dig tunnels in the soil and at the surface, destroying the soil crust. Thanks to termites, the porosity and the permeability of soil increases considerably in hot tropical regions. The success of this technique for soil conservation is important, especially as it limits the risks of crusting over and encourages seepage, but its effectiveness decreases as the ratio of clay increases (Collinet *et al,* 2008). However, it must be noted that the uses of harvest residue, such as feed, thatching or miscellaneous artisan items, frequently makes straw from the fields scarce. The farmers are thus obligated to travel long distances to acquire the straw, which limits the large-scale use of this technology.

In term of recommendation, FSP should promote the use of Thitonia that would provide leaves for the mulching in farmers' fields.

1.5.8 Wooden Obstacles

These are objects made from tree trunks or large branches that build up on the soil. They are seen in square fields. The tree trunks are deposited perpendicularly to the direction of flowing water. They are found on the outskirts of rivulets and ravines crossing the plot. They are designed to break the speed of water and limit gully erosion linked to the turbulent flow phenomenon. Large branches, contrary to tree trunks, are arranged in rows and fill shallow ditches. They are sometimes associated with plates of armor. The branches are placed perpendicular to the slope, sometimes following the contour lines. They play the same role as contour bunds. This form of defense is, however, unappreciated by farmers who emphasize the instability of the materials (decomposition of wood due to water and, above all, termites). The instability adds to the eventual displacement of the wood due to a strong stream of water.

1.5.9 Half-moon Terraces

The half-moon terrace is a basin created in the form of an open semi-circle with the aid of a pick, axe and shovel. The excavated dirt is deposited around the semi-circle to create a raised semi-circle with a flattened top. It is constructed with the help of a 2 m radius compass. The commonly used dimensions are: 4 m in diameter with a 0.15 to 0.25 m depth. The number of half-moons terraces per hectare varies, averaging 312 to 417 in accordance with specific spacing requirements (Digué, 2011). Their size and staggered row arrangement allows for accumulation of necessary quantities of water. The water that flows between two half-moons is collected downstream by a third.

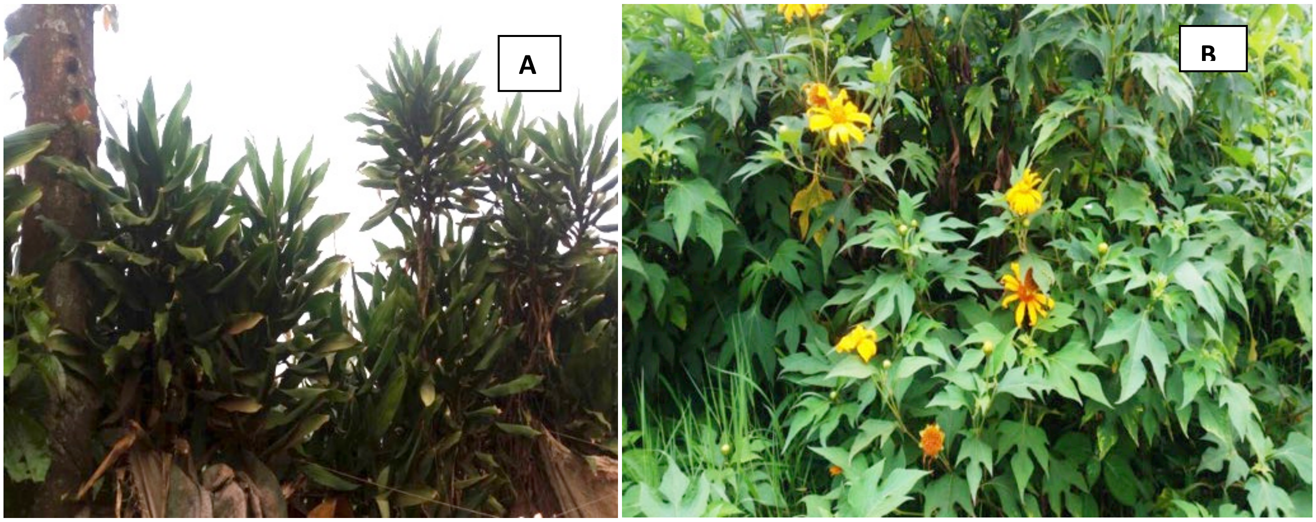
The half-moon terraces allow moisture reserves in the soil to improve, thus causing the moisture depth to reach20 to 40 cm. This increases agricultural production, an affect that increases when used in combination with a mineral or organic supplement. In Yatenga (Burkina Faso), the half-moon terrace/manure combination gives a production variant within 1.2 and 1.6 t/ha of local sorghum seeds. The half-moon terrace/compost combination leads to a growth in yield using the half-moon terraces without the supply of fertilizer (Rabdo, 2006).

Photos of half-moons terraces taken at the announcement of Roose (1995) in Burkina-Faso

The impact of half-moon terrace production has been analyzed by Sangare (2002). He states in his study that these terraces encourage a variety of wood and herb growth due to the half-moons consecutively trapping and transporting seeds either by wind or by streaming water. The half-moons are also suitable for agricultural production of fodder and wood. Arranging the half-moon terraces is very demanding for the workers yet equally important to ensure the soil does not crust over. The terraces require annual maintenance, especially if the bulges are not reinforced by stones. The depth is a very sensitive factor because if the half-moons are too deep, the collected water stays in the ditch for a very long time and plants are at risk of asphyxiation. Therefore, this technique cannot be adapted to humid environments, as shown in the work of Bagula *et al,* (2016) and as was seen in South Kivu. However, for fields on hills side the half-moon terrace can be an efficient way to contribute to restoring land fertility if combined with mulching.

1.5.10 Defensive Hedgerows

A defensive hedgerow is a row of bushes with intertwined branches that prevent animals from passing through. The aim of this technique is to protect agricultural fields (nurseries, perimeter plots, orchards, plantations, etc.) against wandering animals and to fight against erosion by stabilizing the dirt bunds. Additionally, it ensures very effective protection against the wind and helps with marking out the production fields (Kong, 1992 ; Roose *et al.,* 1994). This technique can be observed in South Kivu where hedgerows have been made from certain plants, like the *Tithonia diversifolia* and the *Dracaena fragrans* (*Asparagaceae* called *Kaharhi* in the vernacular), and where the objective is to mark out the fields and to protect them against wandering domestic animals.



Picture of different plant varieties: Dracaena fragrans (A) and Tithoniadiversifolia (B).

Due to the differing heights of the plants, the hedges allow a variety of by-products (feed, etc.), green fertilizer, firewood, and stakes for growing beans to be obtained. In Senegal, farmers find that the initial installation of defensive hedgerows is relatively expensive, yet necessary for large plots. However, the integrated defense of the hedgerows during the first three years increases the initial cost of installation. It is necessary that regular maintenance is seen to at the beginning and end of the rainy seasons, particularly regarding the height of the hedges (Diane, 1992 ; Hiev, 2004 ; Kupers *et al.,* 2004).

1.5.11 Different Ploughing Techniques

The different types of ploughing used in the Bushi mountains are disc ploughing and moldboard ploughing or mounted ploughing.

Photo of sweet potato ridges in Bushumba (Kabare territory) taken during household surveys by the UEA

Moldboard ploughing or mounted ploughing ensures excess water to be expelled on the surface. The ridges are laid out one next to the other in a series of 2 to 10 bands. The ridges are separated by small strips of land. Mounted ploughing is used on moist soil or while the arable land allows it (VLAAR, 1992).

1.5.12 Soil Fertilization

The farmers are more and more convinced that water is not the only limiting factor for agricultural production. With the development of anti-erosion tillage, farmers have increasingly noticed that water and the reduction of erosion is not enough to maintain a steady yield. The general sensitivity towards issues related to fertilization have notably increased, in particular with regards to easily accessible organic manure (ProGeCo, 2008). But the promotion of integrated soil fertility management stays the most credible option in the soil fertility restoration framework, especially in the context of tropical soils. Researchers in the Bushi mountains indicate that the use of organic fertilizer blends allows crop yields to increase, such as with corn and manioc (Pypers et *al*, 2011, Bagula, 2014).

The supply of organic compost is a wide-spread practice in the region of South Kivu, but the majority of farmers do not adequately use the potential organic matter available. This is due to a lack of sufficient number of carts in villages and a weak development of composters. Decomposed organic compost is buried by ploughing or scarification. The recommended amount is five tons of fertilizer per hectare every two years. But often, the farmers in this region do not have enough (ProGeCo, 2008). Bagula *et al*. (2014) have proven that the use of low-quality organic matter does not allow increases in the agronomic effectiveness of fertilizers in damaged tropical soils. It is necessary to play with the quality in order to find the optimal agronomic effectiveness and yield of crops. The way muckspreading is done is a factor that also allows effectiveness of the organic matter to improve.

Chapter 2: Methodology

2.1 Field research

The collection of data provided was collected in five villages belonging to five affected health areas in FSP zones. The data was collected by direct observation in different fields and paired with interviews and focus groups discussions as well as a cartography of the zone made according to the susceptibility to erosion.

For the field observations in each village, a diagonal mark has been made, and the fields that fell on the diagonal were considered. The transect has been marked in the topography of the fields in order to identify practices fighting against erosion and water management practices in use in shallows, on slopes and on plateau's. In each transect, a total of 30 farmers have been interviewed. The survey has been paired with the direct observations on the practices implemented for erosion management.

Thus, a total of 180 fields have been observed and the different erosion control practices have been identified. The snowball method has been used to collect the maximum amount of information possible, in order to identify other farmers who are part of the anti-erosion combat. The people practicing certain anti-erosion methods have again helped to identify farmers who use other methods or similar control methods.

The cartography has served to determine the susceptibility to erosion in each area, and to create a list of the used methods according to the susceptibility to soil erosion (low, medium, and high gradients). It has also allowed identification of influencing factors in these practices that have been used in the universal equation of soil loss for evaluating the susceptibility and level of erosion exposure. Pictures from the ground as well as those taken by drones have been used for better viewing of practices in the region.
The observations and the collected information deals with the topography of the terrain, state of erosion, types of techniques (traditional or modern) practiced, use of soils, type of soil, characteristics of the gradient and depth of the soil. This information has allowed us to determine the rate of water use and soil management practices in the region.

Table 1 presents the different villages involved in the study.

Table 1. Repartitions of surveyed villages in health areas and zones

Health Zone	Health area	Village
Kalehe	Bushushu	Rambira
Katana	Mushweshwe	Buhehe
Miti Murhesa	Kalwa	Cinjoma
Miti Murhesa	Bushumba	Bushumba
Kalehe	Lemera	Nyamutwe
Katana	Mabingu	Kangoko

The completion of this study has resulted in solutions from six students/pollsters (two women and four men) under the supervision of three assistants from the agronomic sciences department of UEA.

2.2 Focus Group Discussions

A total of three focus groups were organized in health zones covering 2 villages per focus group. Each focus group was made of 12 people. In each village, 6 people were randomly selected to participate in focus group discussions and provide information on the adaptation or use of water management technologies and the anti-erosion fight.

The members of the focus groups were made mostly of:

- TRD (technicians of rural development) of health zones
- Representatives of farmers' associations
- Key farmers using water management technologies in the anti-erosion fight.

The key farmers were identified during the transect and the household survey by respecting the style of management and consisting of at least 20% youths.

The discussions in focus group also allowed the identification of technologies that were tested in rural schools, and the selection of farmers who took action in the evaluation of these technologies. These exchanges also clarified the perception of the community on the different practices that can allow effective soil management, and allowed alternative solutions to be presented. The questionnaire or interview guide for the focus groups has been elaborated on after the preliminary analysis of the given household surveys.

Key terms such as soil management, erosion, management techniques, food security, style, and agricultural productivity have been discussed to this effect.

Some observations on the fields have been made after each focus group to identify the methods that exist.

2.3 Mapping of Erosion and Water Management Techniques

The objective was to map the factors linked to the erosion process with a localization of susceptible zones, as well as to proceed to an analysis of historic changes linked to the vegetation cover and the use of soil. The soil gradient quantities per hectare have been evaluated by GIS and the integration of the revised universal model of soil gradients. The evaluations and the topographical map of major historical tendencies linked to deforestation, erosion, pastureland and agricultural expansion in the FSP program zones have also been produced.

Data Collection

The data includes the vectors and the satellite images. The satellite images can be downloaded from the website: earthexplorer.usgs.gov/ by clicking on this link. But, due to snow coverage in this region, certain high-resolution images had to be purchased. The priority has been given to RapidEye images of 5m spatial resolution. For determining the local practices, some tasks have been undertaken using drones in order to have the images in high resolution.

The set of data was collected using the best possible measure:

- DEM of type ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) or SRTM (Shuttle Radar for Topographic Mission) of 30 m spatial resolution was used for generating the basin slope and to determine the topographic LS factor,
- Landsat 8 OLI with 30 m of spatial resolution or RapidEye with 5m resolution covers column 173, and line 061 and 62 were captured and allowed for classification of soil covering in order to determine the C factor of the RUSLE model. The period in which the images were taken was between 2014 and 2016 dependent upon snow covering. For agricultural practices, the classification was made using drones in the region. This has allowed for a better understanding of how the adopted practices changed the course of erosion in each area.
- The database on soil SOTERCAF (Soil and Terrain Database for Central Africa). Data was downloaded from the website *www.isric.org* and was used to create different soil grades. Thus, the soil samples collected in each soil grad helped determining the parameters that influence erosion like texture, structure, and organic carbon rate. This data has allowed the determination of K soil erodibility. Eighteen soil samples were collected and analyzed (granulometry, pH, CEC, organic carbon, N, P, K) for updating the soil data.
- The pluviometry data coming from NASA stations was obtained online at globalweather.tamu.edu and corrected with the help of data obtained locally. This was conducted for determining the erosivity factor R.
- GPS was used to document the geographical coordinates in order to validate the results.

Data Analysis

Our approach is based on using the Revised Universal Equation of Soil Loss (RUESL) model selected for evaluating soil loss by using remote sensing data for a spatial understanding of erosion susceptibility in the study site, and, on the use of geographical information system (GIS) for the erosion process analysis operation. In order to do this, different satellite images and different databases were used.

Evaluation of Soil Loss

The Revised Universal Equation of Soil Loss (RUSLE) has been chosen to evaluate soil loss prompted by the rivulet erosion of the ravine on the site. This allowed the establishment of the risk of the erosion study in anticipation of proposing some effective erosion management techniques in the region. This forms a well-used model across the globe for the evaluation and quantification of soil erosion (El Garouani *et al,* 2007). This equation predicts the annual median rate of long term erosion on the slope of a hill for rainfall function, soil type, topography, crop rotation and crop management practices. This reviewed version is integrated in the geographical information system.
According to this model, erosion is a multiplying function of rain erosivity (factor R) and for the resistance of the area, understood as K (soil erodibility), LS (topographic factor), C (vegetation cover and cultural practices) and P (anti erosive practices).

The RUSLE/USLE formula that has been used is as follows:

A = R x K x LS x C x P

With:

- A = potential erosion rate (T/ha/an)
- R = Erosivity factor (MJ * mm / ha * h * an)
- K = Erodibility factor (T * ha * h / ha * MJ * mm)
- L = Length of slope factor
- S = Inclination of slope factor
- C = Vegetation cover and soil management factor
- P = Soil conservation practices factor.

In using these remote sensing tools and the GIS, through elaborating the documents which allow us to estimate the parameters in each point of the catchment basin, then one continues with the cartography of the erosion using the RUSLE model to finally evaluate the soil loss in the region in t/ha/year.

Chapter 3: Results and Interpretation of Data

3.1 Characteristics of Farmers

Tables 2 to 5 present the producer characteristics in the zone of study

a. Head of Households' Main Tasks Surveys.

Table 2: Head of households' Main Tasks (%).

Profession	Kalehe	Katana	Miti-Murhesa	Proportion
Civil Servant	3.24	2.37	0.49	2.64
Farmer	85.98	94.77	82.4	88.51
Trader	3.72	1.55	3.39	2.96
Teacher	1.55		3.11	1.21
Herdsman			0.27	0.03
Others	3.77	1.31	8.2	4.65

The results of this table indicate that the producers of the zone of study promptly make agricultural duties their main tasks (88.51%). Certain heads of household have as their main task: commerce, teaching, or they are public officials and work in public service. They also highlight the importance of a herdsman who also practices agriculture. Despite the low proportion of these last activities, they can form a good driving force for popularization and boost the adoption of technologies in view of the social return that they provide in society. These results also indicate that all action taken to improve the conservation of water and of soil are predicted to have a positive impact on more than 88.51% of the population.

b. Head of Households' Secondary Tasks

Table 3. Head of households' Secondary Tasks (%).

Activities	Kalehe%	Katana%	Miti-Murhesa%	Proportion%
Civil Servant	3.33		1.67	1.67
Agriculture	13.33	6.67	16.67	12.22
Commerce	23.33	20	21.67	21.67
Hairdressing	1.67			0.56
Livestock farming	8.33	13.33	3.33	8.33
Teaching		3.33	5	2.78
Masonry			1.67	0.56
Others	13.33	10	15	12.78
Nothing	20	28.33	23.33	23.89

The results of table 3 indicate that around 23.89% of heads of household do not have secondary tasks. This category is dominated by the farmers who give all their time to agriculture. In fact, those who do not have agriculture as their main task consider it as their secondary task. However, it also distinguishes the farmers who have small businesses, or who do hairdressing, livestock farming and masonry as related activities.

c. Age and Professional Experience in Agriculture

Table 4 shows that the average age of producers is 40.52 years old, with more than 20.7 years of experience in agriculture. This professional experience was an advantage in the speed practices that were learned in the region, but also constitutes an advantage in the appreciation of the impact of management practices for water and soil conservation. However, in view of cultural consideration and with its connection to ancestral soil management practices of the population, farmers can be resistant to change and to the adoption of new technologies and this must be taken into account for future improvement.

Table 4: Age and professional experience in surveys

Characteristics	Kalehe	Katana	Miti-murhesa	Average
Median age of farmers (years old)	39.06	38.41	44.1	40.52
Professional experience in agriculture (years)	19.16	19.56	23.4	20.71

d. Education Level of Farmers

Table 5 presents the education level of farmers in the zone of study.

Table 5: Distribution of farmers according to their education level

Mode	Kalehe%	Katana%	Miti-murhesa%	Average%
Illiterate	33.34	56.67	50	46.66
Primary School	25	23.3	30	26.11
High School	41.67	16.67	16.67	25
University Level	0	3.33	3.33	2.22

As shown in table 5, around 47% of interviewees in agriculture are illiterate. However, it can be noted that around 27% have at least a high school level of education. The number of illiterate students in the zone constitutes an obstacle to development, above all in the transfer of technologies seeing as they do not know how to read or write. Therefore, appropriate popularized methods must be developed to build on the demonstrated approaches in field school participants. The low percentage of educated farmers can serve as a catalyst for the diffusion of technologies, but also as 'pilot test' farmers.

3.2 Characteristics of Farms

e. Modes of Land Acquisition

The allocation of different modes of acquiring land are presented below:

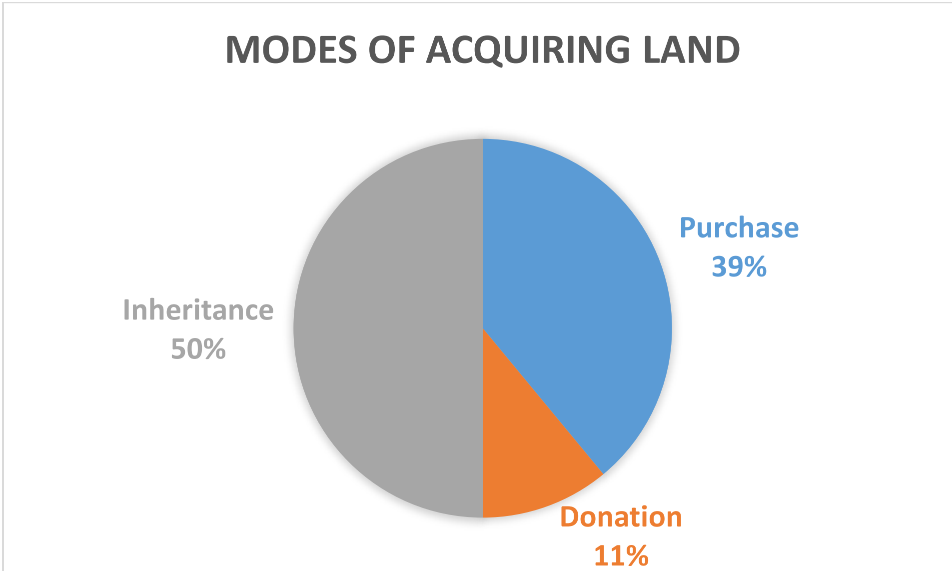


Figure 1: *Allocation of different modes of acquiring land ownership*

Many modes of acquiring land exist in South Kivu as indicated by figure 1. In fact, inheritance constitutes the most frequent mode of acquiring land (50%). This mode is often observed through the death of a parent; their ownership of land is distributed between the surviving children. Through marriage of one of these children, a part of the land is also offered as real estate capital for the couple to start from when creating their new household. Purchased land constitutes another medium of access to land for more than 39% of farmers, while there is 11% who acquire theirs through donation. Donation can sometimes be subject to sharecropping payment. These modes of acquiring land often influence water and soil management and conservation practices.

f. Land area exploited according to households

Table 7 shows the land area exploited by the farmers according to different locations.

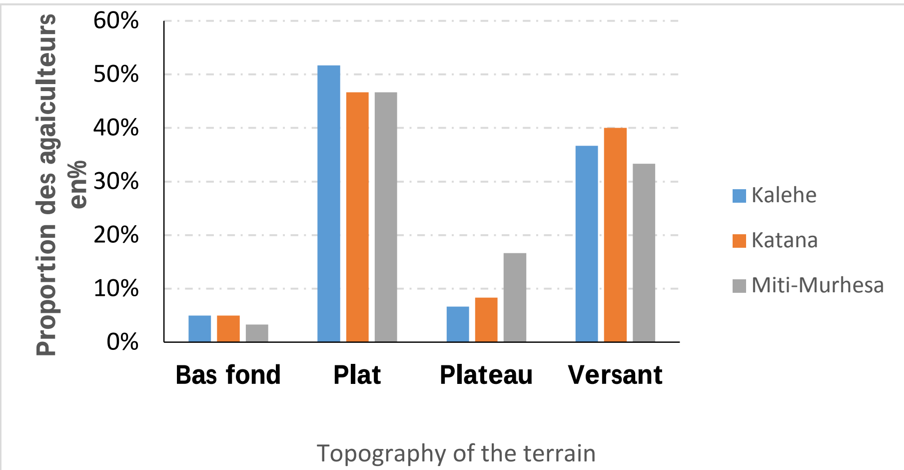
Tableau 7. Land exploited by farmers in the studied areas (%).

Land area occupied in ha	Kalehe%	Katana%	Miti-Murhesa%	Average%
<0.25	21.67	38.33	30.00	30.00
0.25-0.5	51.67	40.00	36.67	42.78
0.5-1	21.67	11.67	30.00	21.11
>1	5.00	10.00	3.33	6.11

The area covered by this study belongs to the Bushi zone, which is one of the most densely populated zones in the country. Indeed, in these parts, there is a reduction in cultivatable land from generation to generation following the mode of access to land but also due to the rate of population growth. It should be noted that more than 72% of farmers have less than 0.5ha of total exploitable land per household for food crops. And only 6% of farmers use more than 1ha. In this area, the large land sectors are dominated by private plantations used for the production of manufacturing culture, to the harm of food crops.

g. Topographic area of farmers' fields

Figure 2 shows the topography of the fields used in agriculture in the different investigated sites.



Bas fond – shallows

Plat – Flat ground

Plateau – Plateau

Versant – Catchment basin

Figure 2. *Proportion of producers and topographic variations in the areas of study.*

The majority of exploited fields (48.33%) are on flat terrain typical of the area. However, a large proportion of the farmers also have fields located on mountain slopes (36.67%) with a strong exposure to erosion. The fields located at the bottom [of the slopes], as well as those on plateaus are poorly represented. If the fields situated on the slopes are subject to erosion and soil loss, those located at the bottom and on flat ground are at risk of flooding. Consequently, the different management techniques of water and soil must take into account this topographic classification to make erosion and water management effective in these sites.

3.3 Overview of anti-erosion techniques

3.3.1 Known anti-erosive techniques in the study area

There are many anti-erosion techniques in the fields according to the topography and the characteristics of the area. They vary from simple to more complex and have varying levels of effectiveness. Seven techniques have been identified for water and soil management within the study area, which include ridging, terracing, mulching, the planting of hedgerows, stone barriers, channelization, and infiltration pits.

In terms of knowledge, certain techniques (channelization, mulching, anti-erosive hedgerows and ridges) were more well-known. Stone walls and terracing were less known (Table 8). Terracing was the most known by the coffee growers and the small farmers near centers such as INERA and ITAV/Mushweshwe.

Table 8: Knowledge of main anti-erosion techniques

Techniques	Bushumba	Bushushu	Kalwa	Lemera	Mabingu	Mushweshwe	Total
Ridging	66.7	73.3	60.0	53.3	60.0	60.0	62.2
Terracing	16.7	36.7	6.7	16.7	16.7	23.3	19.4
Mulching	66.7	86.7	63.3	73.3	80.0	73.3	73.9
Pits	66.7	56.7	66.7	56.7	66.7	46.7	60.0
Hedgerows	63.3	73.3	60.0	46.7	80.0	70.0	65.6
Stone walls	16.7	6.7	3.3	0.0	10.0	13.3	8.3
Channelization	86.7	96.7	90.0	86.7	93.3	76.7	88.3

3.3.2 Anti-erosion techniques used in the study area

The result of this study shows that the knowledge of one practice does not necessarily mean that the practice is put into use. Indeed, 66.1% of the population practice some form of channelization and 88.3% had knowledge of it; though as commonly practiced channelization is not implemented properly and often accelerates erosion rather than combatting it. Techniques such as terracing are used by less than 7% of the community and especially by those who grow coffee. The stone walls are practically not used at all. The following table illustrates these results:

Table 9: Use of anti-erosive techniques in the study area in %

Techniques	Bushumba	Bushushu	Kalwa	Lemera	Mabingu	Mushweshwe	Total
Ridging	46.7	56.7	10.0	40.0	30.0	50.0	38.9
Terracing	3.3	23.3	3.3	6.7	0.0	6.7	7.2
Mulching	50.0	60.0	56.7	53.3	56.7	46.7	53.9
Pits	23.3	26.7	16.7	30.0	30.0	20.0	24.4
Hedgerows	30.0	40.0	13.3	40.0	50.0	26.7	33.3
Stone Walls	0.0	0.0	0.0	0.0	0.0	3.3	0.6
Channelisation	50.0	63.3	80.0	73.3	80.0	50.0	66.1

The use of these different techniques are often influenced by multiple factors in these areas among others:

- *Size of the farm:* smaller sized plots do not allow farmers to carry out protection of the soil against erosion because they fear that they would reduce their area for cultivation, which would risk the reduction of expected plot yield.
- *Ownership of the fields:* The average farmer does not see the benefit of protecting a field that does not belong to him or is not rented, because his concern is maximizing the yield. Moreover, the duration of the lease of the area is limited. Often, when the field is exploited well and well treated, the landowner breaks the lease of the land for his benefit, to the detriment of the tenant.
- *Infertility of the soils:* Most of the terrain is located on steep slopes and are very exposed to erosion. Being unprotected, they can suffer from run-off processes, which can lead to the transportation of nutrients from arable soil layers, resulting in the loss of fertility of the soil. Note that we are in a region of the world where the fertility of the soil is very poor. Thus, the farmers

have difficulty protecting a soil that is already infertile because the investing in the protection would not be recuperated by production. This infertility results in the abandonment of the field and the technique.

- *Rural exodus linked to insecurity:* this leads to the abandonment of the fields and is accentuated when insecurity is associated with the theft of agricultural production. As a mitigating solution, in order to avoid the stealing of crops, the farmers plant trees (eucalyptus, for example) in their longer fields.
- *Lack of agricultural tools* for executing the implementation of the techniques defined by the peculiarity of each technique.

3.3.3 Evaluation of the anti-erosion techniques employed by the farmers

Ridging

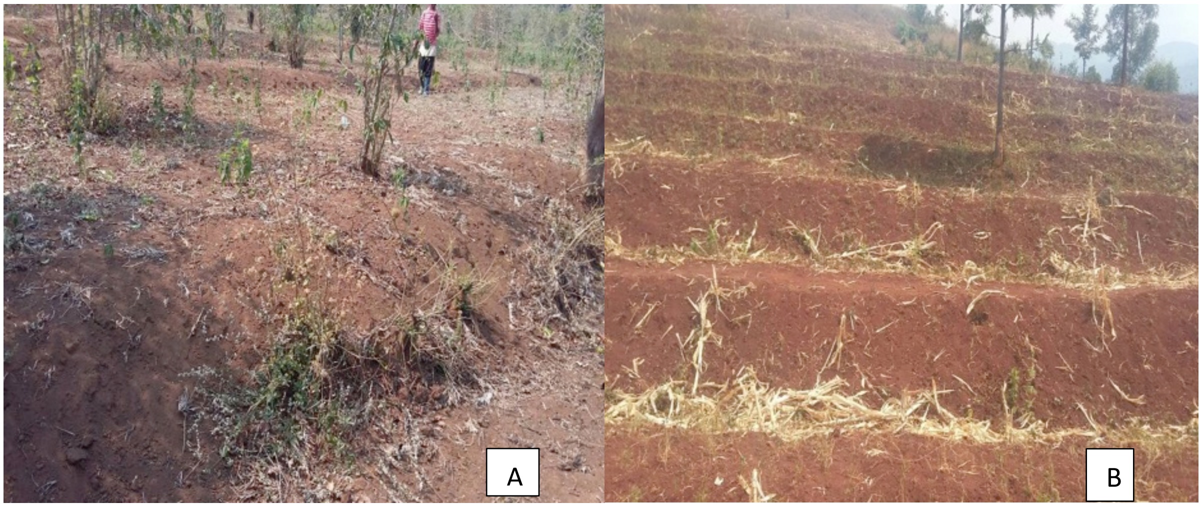
A technique deemed as being effective in its execution and management, ridging has the capacity to stop or to capture run off water and the farmers have experience in the execution of this practice. It is often used for crops with tuberous roots and tubers. Those who do not use it are typically uninformed about the process, while others think it is hard work.

Photos of the ridging taken in Mabingu and Kalwa

This photo shows that the farmers who have knowledge about ridging the bottom correctly follow the contour lines.

Terracing

Terracing is the least common technique due to the lack of information and the absence of tools for its execution, which are also very costly. On top of this, the terraces do not guarantee short term results especially when the soil fertility is poor, which means that the farmers are not really interested in the technique. The cost linked to the restoration of soil fertility is high. This technique is practiced by a few coffee growers in the region.

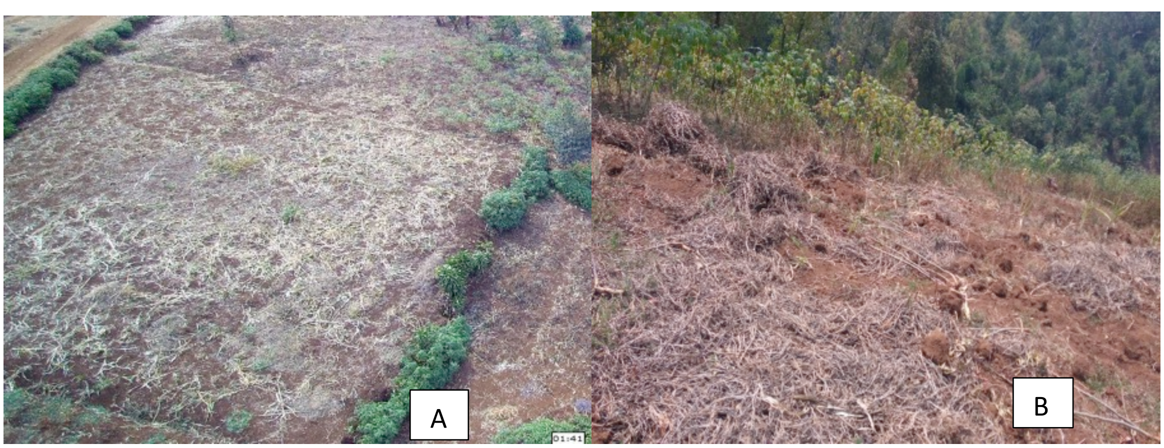


Photos of terraces taken in Rambira (A) and Mabingu (B) in the Kalehe territory.

This photo shows the terracing in the coffee plantations of Rambira and a radical terrace carried out in Mabingu. This sufficiently demonstrates that there are people in the area that know about and have the capability to carry out terracing. This old technique dates back more than 50 years in the region, thanks to the *Mission Antiérosive du Kivu (MAE).*

Mulching

A common technique in the area and valued highly due to its ease of execution, its ability to restore soil fertility after the decomposition of used residues, and its ability to maintain soil moisture. However, it is also contested because it acts as a shelter for pests. Moreover, its capacity to regenerate constitutes a probability of competition with other crops in place. The obtaining of mulch and the cost of its acquisition in certain areas poses a problem for its use. Mulching is mostly used when the farmers are market gardeners.



Photos of mulching in a field in Nyamutwe (A) combined with hedgerows and in Mushweshwe (B)

Quickset hedgerows or anti-erosion hedgerows

Using hedgerows is a technique known and used thanks to its effectiveness and capacity to retain soil. The plants used like hedges also serve as feed for cattle and provide wood for construction. The plants that are most often used include the *Trypsacum sp* and the *Pennisetum purpureum*. Others include plants that restore soil fertility such as the *Tithonia*. The farmers use certain plants to demarcate their fields, which can create anti-erosion hedgerows. However, farmers often complain about the technique as being the cause of a reduction in growing space, causing growing competition with crops already in place and serving as shelter for pests.

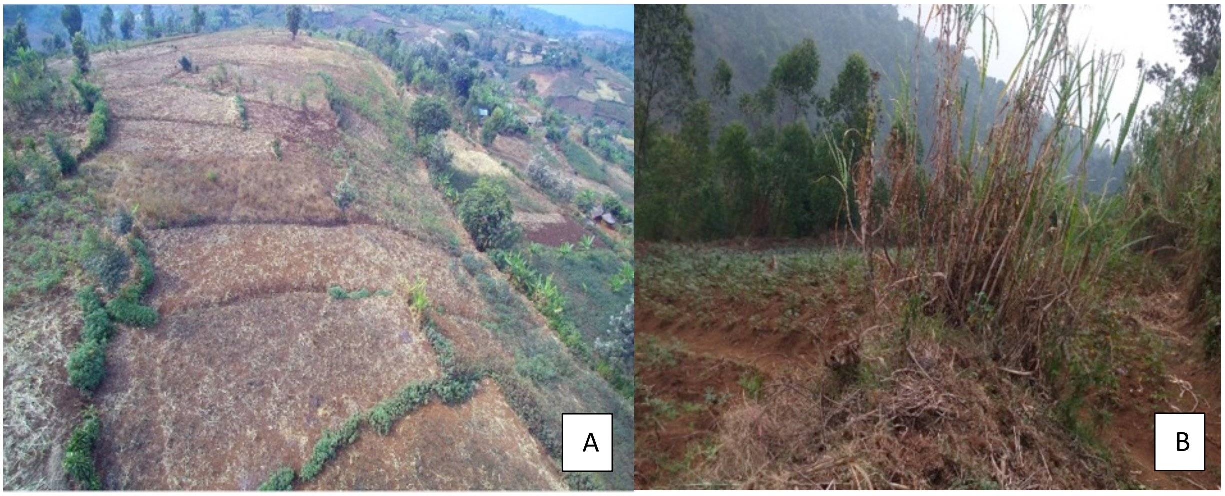


Photo of hedgerows taken by drone in Nyamutwe, Lemera (A) and Bushusha (B)

These hedgerows pictured in the photos firstly serve as a demarcation boundary and then as a device against erosion.

Stone walls

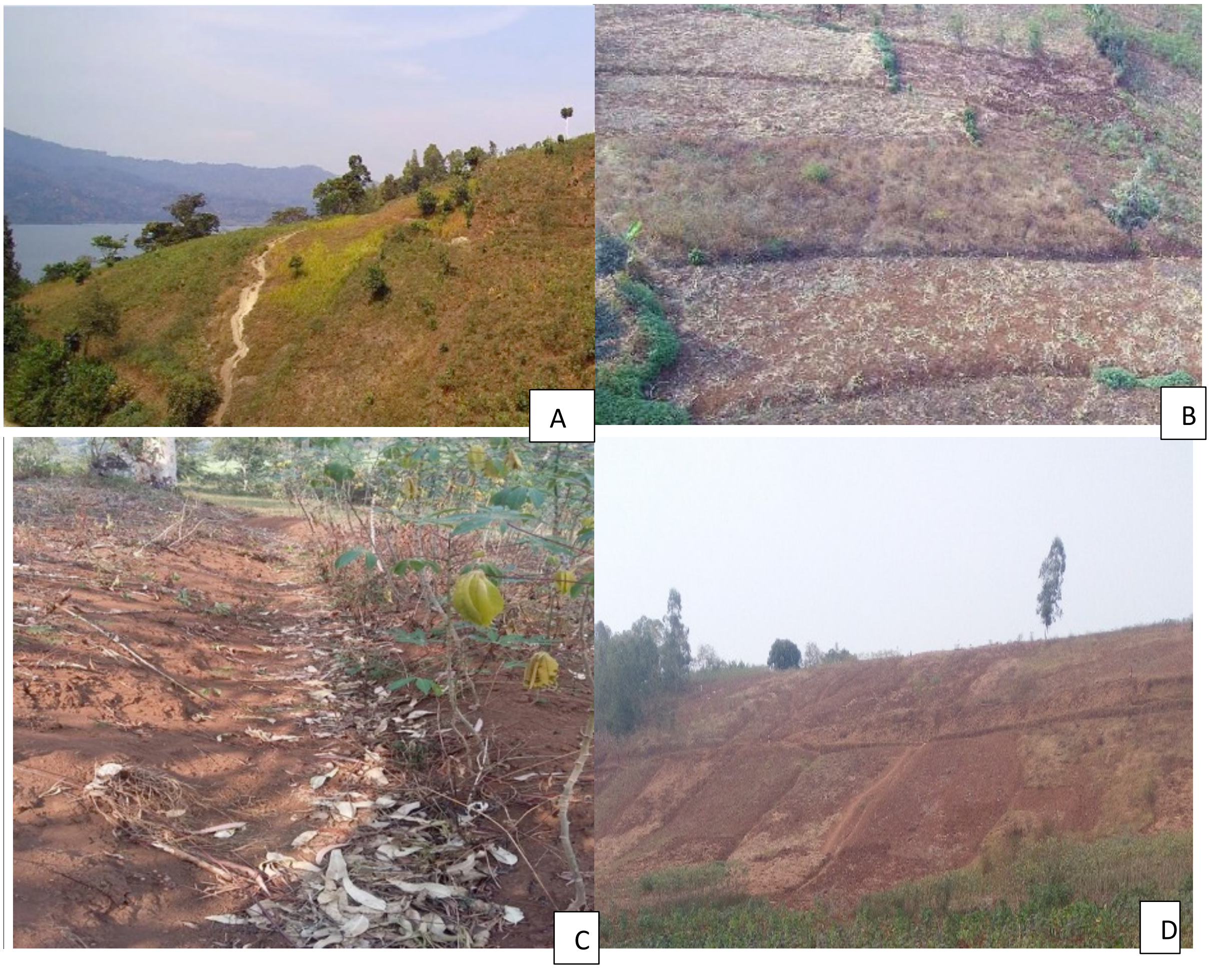
This technique is less known in the region; it is therefore not frequently used. It is very costly and demands a vast amount of labour to set it up. The materials required for the technique are not locally available. The technique can cause damage to agricultural tools during field work (weeding, plowing). Nevertheless, the only farmer who used it acknowledged that it was effective and durable against erosion.

Infiltration pits

Infiltration pits are deemed to be effective because they reduce the speed of run-off water from rain. However, some farmers experience difficulties in creating them, such as the arduousness of their design, the time required for their regular maintenance (cleaning) as well as the encroachment on growing space. In most cases, the pits are made by the communities upstream of hills to avoid damages on the flanks and lower land. This activity requires an effective participation of the community. In the village of Mushweshwe, the pits are made by communal mobilisation.

Channelization

This is the most common technique in the study area and the most used by the farmers because it guarantees the collection and direction of run-off water and is easy to execute. Some farmers nonetheless lack information about the technique and can orient the channel parallel to the slope, something which accentuates erosion in their fields. When they are perpendicularly placed to the slope, they are deemed to be more effective, but the farmers think that they reduce growing space and are too costly.



Photos of the channels inclined perpendicularly and parallel to the slope in the villages of Mushweshwe (A), Cinjoma (B), Rambira (C) and in Nyamutwe (D).

These photos show clearly that there are efforts to provide protection against the erosion phenomena. These ditches, created perpendicularly to the slope, are basically gullying in the field. The reddish colour of the field gives a clear indication of the soil quality, which seems poor.

3.3.4 Evaluation of the use and sustainability of technologies in the areas.

Table 10 shows the different factors that determine the use and techniques against erosion in the considered sites.

Table 10: Factors influencing the sustainability of anti-erosion technologies

	Techniques			
	Ridging	Terracing	Hedgerows/Pits	Mulch
Gender			✓	
Civil status	✓			
Type of house		✓		
Total area of land/fields	✓			
Method of acquisition	✓	✓		✓
Association member				
Distance covered	✓			
Educational background		✓	✓	
Types of materials used		✓	✓	
Difficulty in protection		✓		
Villages			✓	
Seniority in agriculture			✓	
Number of fields owned			✓	
Practised crops	✓		✓	✓
Affiliation to an association	✓		✓	

As shown above, many of the management techniques for water and soil are used in the fight against erosion, the most encountered being the use of partitioned ridges, terracing, hedgerows, channelization, infiltration pits which are continuous or discontinuous, and mulching. However, their durability is under the influence of the 15 factors indicated in Table 10. These factors vary from one technique to another and from one environment to another. The use of the partitioned ridging technique is influenced by civil law, the type of crop grown, the area of exploited field, the distance covered between the field and the house, the method in which the field was acquired and the affiliation or not to a farmers' association ($p<0.05$). This technique is most often carried out by married individuals (91.43%) on fields where the area is comprised of 0.25 to 0.5 ha (44.25%) or 0.5 and 1 ha (30%).

The technique of terracing is carried out by farmers who had been to school (90%) and those who had inherited land from their parents (41.67%) or who bought it (34.56%). It is rarely practised in rented fields.

The techniques of pits and hedges are often combined. Their use is linked with the gender of the farmers (practiced by men), their level of education and their seniority in agriculture, to the number of fields that are exploited by these farmers, to the type of crop grown, to the method of acquisition of the fields, to the type of materials required by the technique and the affiliation or not to a farmers' association ($p<0.05$). These techniques are carried out mostly (51.11%) by educated farmers (53.33%). Their adoption has increased over 30 years, by farmers with an average of 3 endowed-as-owner fields (86.11%). They have been adopted by farmers who are part of a farmers' association (52.86%).

Regarding mulching, its durability is explained only by the types of crops grown and the coverage over the fields ($p<0.05$). The farmers carry out this technique in their own fields (88.57%). It is much more observed in tubing crops and in monoculture as well as being associated with leguminous plants or other crops. Mulching is observed in the growth of cassava related to the bean, in the combination of maize bean and in mixed cultures based on cocoyam. It is also practiced in market gardening such as tomato and eggplant.

Channelization is also a frequently used technique because of the effects of run-off water on the fields. The majority of farmers follow the lines of flow of the run-off water in the field. It is easily adopted due to the fact of its ease and low demands.

3.4 Evaluation of the determinants of the durability of anti-erosive systems

Concerning the determinants of use and the sustainability of anti-erosive systems, the results show that certain areas have received training from the government-led "*Mission Antiérosive*" and from the Kabare Project of SIM Bushi sponsored by the GIZ. Most of the anti-erosive systems were destroyed during times of war, with current difficulties concerning their re-establishment. Only a small percentage of the population managed to maintain their systems. The use of these techniques combating erosion in the region is determined by:

- The continued training received by the farmers and their active participation in farmers' associations.
- The level of education.
- The way the land is owned.
- The fertility and productivity of the land.
- The operating costs.

The quantitative analysis also gives evidence of other factors such as the possibility of use of paid labour for a rich household, or even the wealth of the household and the level of perception about the gravity of erosion for the use of techniques such as terracing. It has been observed, however, that where anti-erosive systems are in place, the frequency of their renovation remains low. The proximity to the INERA/Mulungu centre, to ITAV and ISEAV/Mushweshwe allows farmers to improve their knowledge of anti-erosion techniques. The villages far away from these institutions use less anti-erosion techniques.

This result is an indication that erosion control systems and soil fertility regeneration are still being carried out under the auspices of development and research programs. From this collected data we note that it is the development programs that have played a role in the establishment of anti-erosion systems. State efforts of agricultural policy in terms of outreach and implementation, which incite the protection of soil, are non-existent. Moreover, the results show that the number of farmers that do not use anti-erosive systems is very high in a region where the topography is uneven. The support for a sustainable anti-erosion system should be envisaged in the long term, but the initiatives are abandoned right after the end of the projects. We can therefore conclude that the farmers remain relatively unconvinced by the intrinsic benefits of anti-erosive systems which Mathieu (1984) had already noted, without measuring their scale.

It can be observed that heads of households who have an extra-agricultural charge behave differently to those who do not partake in secondary activities. The probability of using and keeping an anti-erosive system decreases when the head of the household does not have an extra-agricultural job. Ultimately, those who have kept the anti-erosive system, are the very ones who claim that the last project that popularized anti-erosion techniques, has given tools like hoes, shovels, picks, etc. Many recommendations made by the farmers insist on the importance of farming tools in order to maintain anti-erosive works.

Some significant efforts should be carried out to popularize techniques. This should be done with extensive demonstration work and carried-out by listening to people and their problems instead of simple mobilization, which has not produced a convincing result for many years (Mathieu, 1984).

From this, it can be seen that continuing training/education would play a vital role in the adoption and maintenance of anti-erosion systems. With this in mind, questions in the focus groups also revealed that a lot of work needs to be done regarding participative research with the farmers, and making explicitly clear that the techniques are beneficial to their personal success.

Finally, responses to open questions in the focus groups showed that the anti-erosive pits/ditches, hedgerows, and nitrogen-fixing plants are the practices which were the most popularized by the Kabare project and MAE. Terracing, undeniably because of their high costs, was not.

Even though the adoption levels of different techniques remain low and identical across the different farmers' groups (probably due to the fact that projects use material incentives that farmers are drawn to, but ultimately without the commitment or conviction to absorb or apply the learned material, eventually leading to abandoning the projects), **it was found during the focus groups that farmers who participated in the trainings and who own cattle or supplementary resources are the farmers who consistently conserve the best and who continue to use anti-erosive techniques.** These farmers should receive FSP's attention in order to promote its soil fertilization agenda.

In the focus group discussion and in household surveys, farmers using little land are less keen on adopting anti-erosive systems, considering that the space taken up can be used for crops; which seems realistic when an anti-erosive hedge occupies an average of 1 square meter, space which can take away up to 10% of exploitation. In the promotion of anti-erosive hedges, it is important to identify varieties of local material that occupy little space, and to participate in the in the production of fodder, wood or organic fertilizers in order to compensate for the loss of cultivable surface.

In the case of nitrogen-fixing plants, we recall here that the results of the surveys showed that the farmers have less than $40m^2$ of cultivated land. Despite the resources that can be obtained by fixing grass, the priority of poorer households is to feed their families. These poorer farmers also complain about the fact that nitrogen-fixing plants become competition for other crops, and can attract domestic animals that damage their fields. The choice of species occupying less space is therefore crucial to improve the adoption level of anti-erosion systems.

The other arguments provided included a lack of time, tools, or strength needed to dig anti-erosive ditches; a reason that would have pushed many development programs to make significant investments in food for work or cash for work with very mixed results (Maldague, 1980; Mathieu, 1984; Unger, 1984; Hudson, 1987; Guizol, 1995; Roose, 2004). For many of these projects, the maintenance of anti-erosive systems lasted no longer than the design.

Favouring heavy investments such as anti-erosion ditches or terraces would therefore greatly increase farmers' mistrust of anti-erosion systems. Research in this field must focus on the development of simple and inexpensive technologies.

It is important to place the fight against erosion in the broader context of conservative water management, to increase the biomass and fertility through the participation of farmers, to associate the goal of improving production with protecting the environment.

From the point of view of youth, the lack of land and productivity in agriculture seems to be the push factor for learning agricultural techniques. Young people who practice agriculture use the same techniques used by their parents in the community. However, young women seem to be more active in the use of new techniques, which also depends on their level of training. In general, the attractiveness of the urban environment affects young people who are more interested in income-generating activities than in agriculture. The recent improvement in the transport sector such as motorcycling has greatly affected the number of young people going into agriculture.

In terms of interventions, some community members report that some agricultural support projects, primarily aimed at improving gender conditions, do not contribute to soil protection and restoration. In fact, men have a preference for profitable crops (banana, market garden, etc.) that are not the subject of support initiatives, whereas these crops play an important role in the fight against erosion and the stability of the hills. They state that their priority is in most cases not taken into account in development projects aimed at women's crops, while their investment in erosion control work remains paramount.

Chapter 4: Cartographic results of flood risk zones

a. Soil data

The results of the soil analysis chart (below) show us that most of our region’s soil suffers from the problem of inadequate cation exchange capacity, which means that the retention of minerals in the region remains low. Nitrogen levels are low in all soils. However, organic carbon is still at moderate levels in the soil. It is necessary to improve its level in order to increase its retention and to improve its physicochemical properties. Soil texture varies according to the environment, which means that the quantity of carbon must be different in order to increase the efficiency of nutrient retention.

N°	Location	pH_{H2O}	P (ppm)	Al^{3+} *(méq/100g)*	C (%)	N (%)	C/N	CEC (cmol/kg)	% Clay	% silt	% Sand
1	Bushumba Mid-slopes	6.22	16.13	0.85	3.476	0.268	12.97	12.13	22	10	68
2	Bushumba Fundiko	6.2	23.16	0.49	3.734	0.289	12.92	16.28	18	6	76
3	Bushumba Runesha	6.32	19.34	0.87	3.082	0.263	11.719	12.58	20	8	72
4	Cinjoma Lowland	6.26	20.03	0.72	3.565	0.274	13.011	18.34	56	24	20
5	Cinjoma Mid-slopes	6.62	19.39	0.52	3.319	0.261	12.716	16.06	15	9	76
6	Cinjoma Summit	6.54	18.03	0.46	3.061	0.276	11.09	13.12	28	8	64
7	Kangoko Bas fond	6.11	17.95	0.52	3.473	0.281	12.359	14.53	26	18	56
8	Kangoko Mid slopes	6.71	18.13	0.41	3.284	0.257	12.778	15.14	48	32	20
9	Kangoko Summit	6.3	23.13	0.36	3.245	0.251	12.928	14.31	19.2	9	72
10	Mushweshwe Mid-slopes	5.8	29.27	0.58	3.28	0.278	11.799	20.17	20	4	76
11	Mushweshwe Summit	6.58	19.83	0.79	3.289	0.273	12.048	19.23	25	25	50
12	Mushwheshwe Lowland	6.41	20.25	0.78	3.468	0.288	12.042	18.31	22	8	70
13	Nyamutwe Esther	6.13	22.36	0.92	3.388	0.283	11.972	16.17	17	6	77
14	Nyamutwe Summit	6.12	18.51	0.62	3.238	0.259	12.502	11.02	16	7	77
15	Nyamutwe Summit	5.1	21.78	0.47	2.957	0.264	11.201	13.23	16	7	77
16	Rambira Lowland	5.83	20.1	0.86	3.647	0.278	13.119	12.1	44	40	16
17	Rambira Fina	5.7	21.32	0.59	3.657	0.285	12.832	19.32	16	12	72
18	Rambira Naomie	6.21	25.36	0.64	3.602	0.279	12.91	15.06	48	6	46
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b. Erosion hazard map

The figure below shows the map of erosion in the health zones of Miti-Murhesa, Katana and Kalehe. The results reveal that around 40% of land in the region is exposed to erosion. Agricultural regions are the most vulnerable, since here even preventive anti-erosion techniques are less numerous and ineffective. Most regions that are not exposed to erosion are within the vicinity of the park. These are forested regions, but also plantation areas for trees and for perennial crops such as the tea bush, cinchona, and coffee bush.

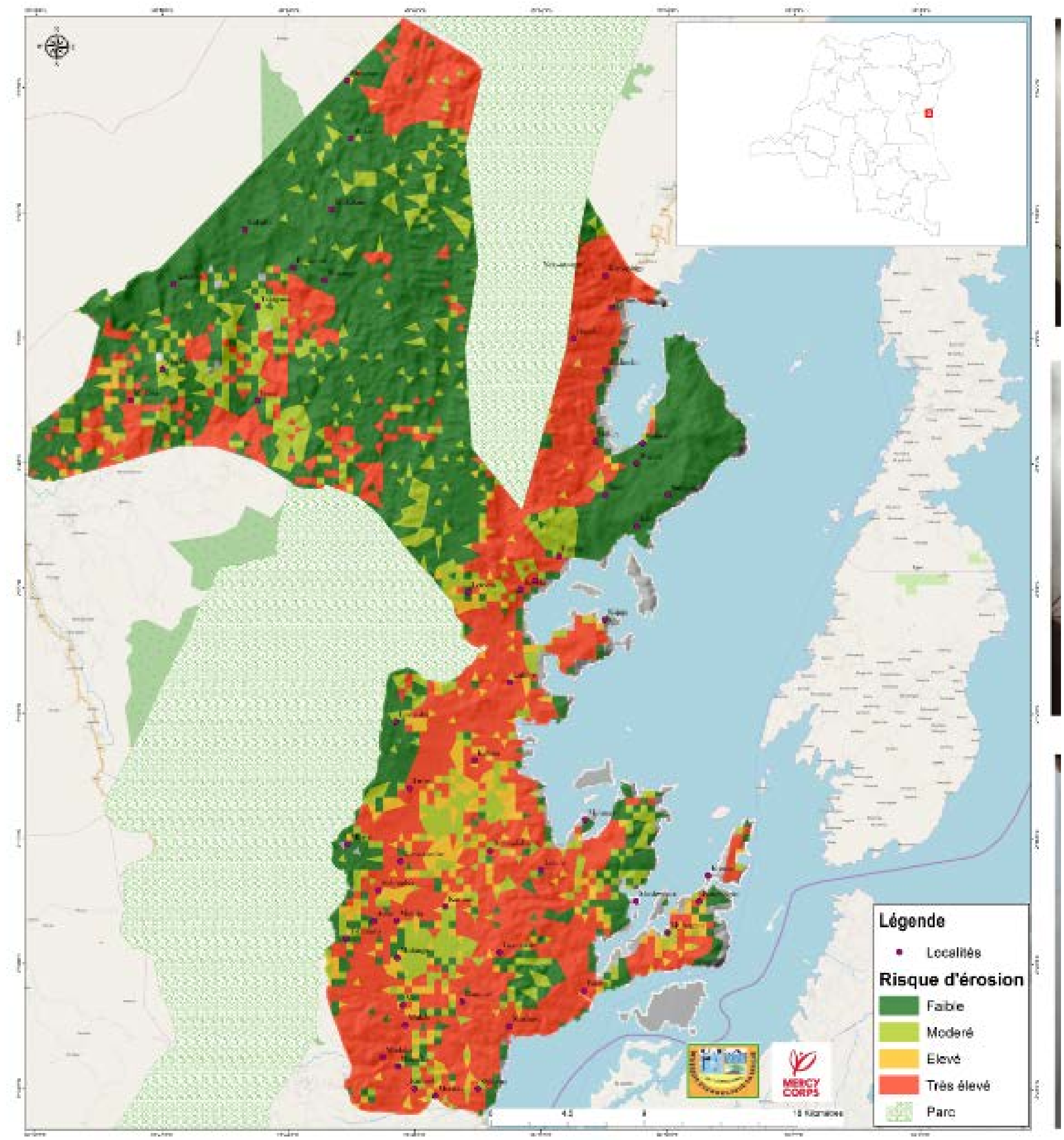

Figure 3: *Map of susceptibility to erosion in the health zones of Miti-Murhesa, Katana, and Kalehe*

c. Geomorphological profile and landscape reconstruction

The following images present the reconstruction of the landscape in the area of study.

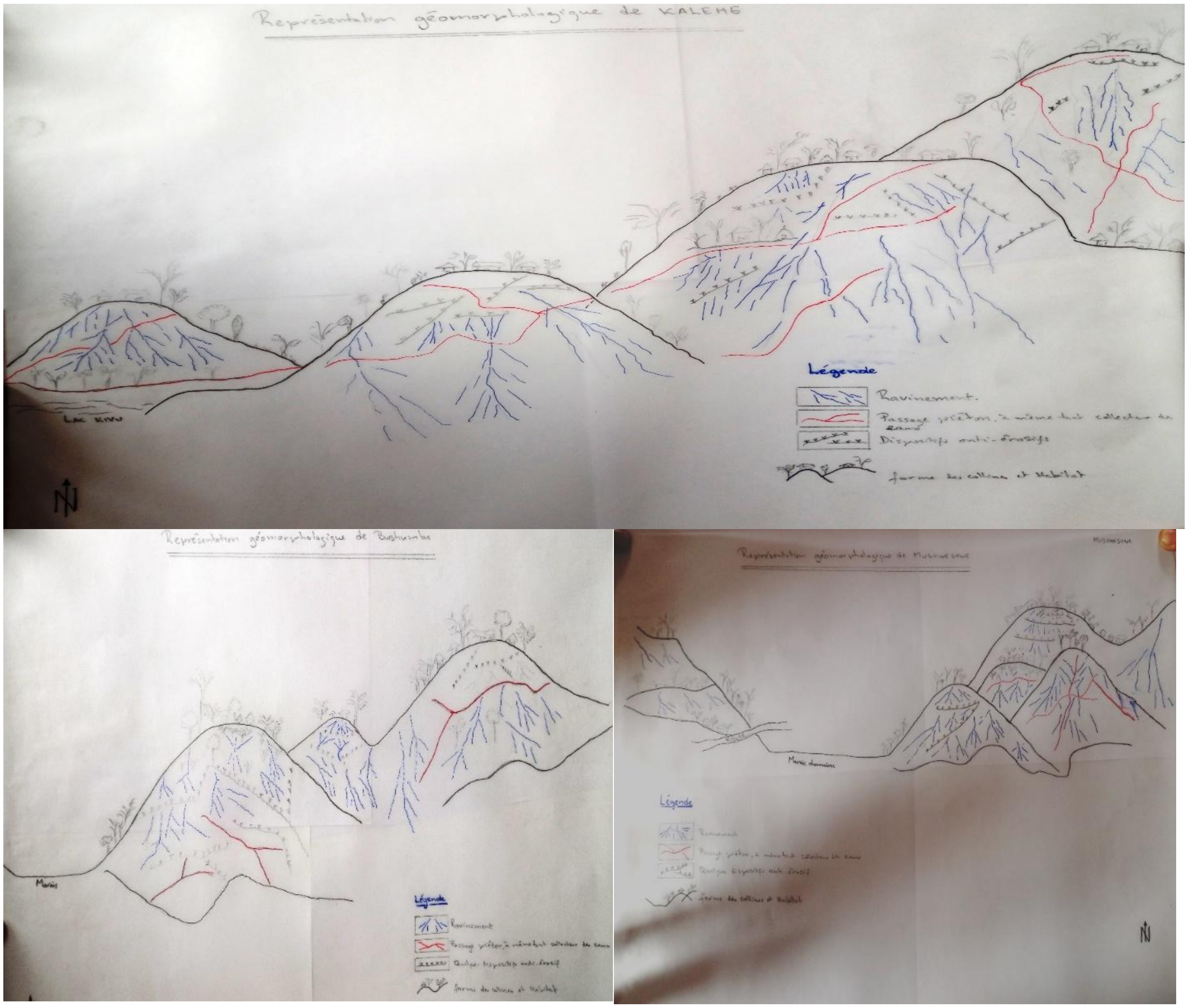

Figure 4: *Geomorphological profile and layout of the landscape in the area of study*

The reconstruction of the environment's geomorphological profile shows that landscapes in the studied regionare heterogeneous. The most represented items in the landscape are those of agriculture, fallow fields, and small living huts, in addition to trails and some roads. The figures show that most of the hills are subject to gully erosion, the environmental impacts of which are visible. Most paths and passages in the village make for unexpected areas of water drainage, which intensifies erosion since water collection canals and some anti-erosion hedgerows are not arranged perpendicular to gradients.

In the hills, farmers resorting to hedgerows and soil-fixing grass generally do not respect plantation standards; contoured structures are barely noticeable and sometimes run parallel to the topographic gradient, which accelerates the process of erosion even further. Another observation is the limited scope of soil protection activities in the hills. In fact, with farmers not acting in tandem, their protection initiatives, taken individually on their field, sees their results annihilated by the absence of similar intervention coordinated in respect of the hill's other fields.

In light of this observation, the hill approach, an approach entailing the implementation of protective measures at hill level, could propose an appropriate method of improving soil and water management techniques. There is therefore a need to create a general management plan of the hills and landscapes, with strong community involvement to manage the issue of erosion in the hills.

Some authors, such as Baboulé et al. (1993), also favour protection against erosion at a landscape and basin level instead of on an individual basis.

Conclusions and recommendations

Soil erosion remains one of the key agricultural challenges in the high-altitude region of South Kivu. Beyond agriculture itself, soil degradation is a considerable – and long-term – issue with regard to the conservation of natural resources and to the resilience of the rural communities of the Kabare and Kalehe territories.

The increase in extreme weather events brought by climate change will intensify the existing problems attributed to wind and water erosion, and will give rise to new problems. Agricultural stakeholders and public authorities must prioritise the protection of agricultural land by paying particular attention to the most high-risk situations that expose soil to erosion.

If in South Kivu some agricultural producers seek to improve their strategies to fight against soil erosion on their land, most producers are unaware of the issue, and awareness ordinarily comes once the land has suffered damage and shows losses in arable soil. With regard to the fight against erosion, farmers are faced with the challenges of access to information, to technical advice, to training as well as to financial resources in order to realise the necessary adjustments, which are often costly given rural poverty.

Thanks to the research into and enhancement of knowledge and skills, farmers have an array of techniques at their disposal, be they biological or mechanical, in order to restore their degraded soil. If the different mechanical techniques observed offer advantages (increase in agricultural yields, conservation of water, regeneration of wood and grass cover), the fact remains that limits of application persist, such as the high demand for labour and the absence of means of transport, the limited availability of organic matter and the increase in working hours. The demand for labour in itself makes development over large areas difficult. Where biological techniques are concerned, the advantages mainly concern the regeneration of plant cover and the reduction of runoff and of erosion. However, reservations are not an appropriate option for bare and encrusted surfaces.

Apart from biological and mechanical techniques, agroforestry techniques also have advantages for the protection of soil against erosion, the restoration of plant cover, the stabilization of physical water and soil conservation structures and the production of goods and services. Among their drawbacks, we may find the competition with other agricultural activities, the limited availability of grass roots, the poor quality of plants, the wandering of animals and the slow development cycles of the plants used.

Owing to the constraints that they face, farmers and smallholders resort to techniques which are simpler yet do not follow convention. Owing to the absence of resources and of leadership from local authorities, protection is carried out on the level of the individual's plot, and not on a landscape level.

Recommendations

A **hill approach** to land management: in terms of its areas of intervention, the FSP project should favor a hill approach for the watershed's general layout (pilot hill) and should take into account the specificity of methods of buying land and of dividing plots. In fact, anti-erosion measures on an individual plot are doomed to fail for farmers who, having invested in them, have seen their upstream neighbour's lack of commitment nullify their efforts.

The first implication of this project resides in the selection of farmers for the FFS's activities: besides traditional selection criteria, favouring households with young children, the FSP should ensure that the farmers assembled through the FFS farm on the same hill and receive the same teaching, since it is when implemented at hill level that the impact of anti-erosion and soil fertility activities will be remarkable and sustainable.

The FFS training course will also have to provide other elements of training integrated within land management, such as the use of new varieties, the use of organic matter, the fight against pests, the possible adjustments according to different situations, etc.

Strategic investments: preventive anti-erosion and soil restoration measures are costly, demanding the strong motivation of communities and with a positive impact measured only over years. The FSP project must target a minimum number of hills for renovation, but also invest as much as necessary in these sites in order to guarantee and demonstrate success. By capitalizing on the applied technological itinerary, by collecting ratios and costs of implementation, and by operating an annual progress monitor from now until 2021, FSP will be in a position to communicate and offer the itinerary to other stockholders in development as well as to state authorities.

Mobilizing to support the initiative: In order to support the fight against erosion and the restoration of soil fertility, the FSP must lead a massive number of community mobilisation measures to promote the adoption of good practice and behaviour. Days such as World Environment Day represent excellent vehicles for communication in order to support this agenda. In addition, FSP shall conduct costs/benefits analyses to convince farmers on the positive economic returns of erosion control.

An agenda too important for a food security project: the fight against erosion and the restoration of soil fertility fall within the framework of responsibilities far greater than the FSP project. The FSP should be positioned as a catalyst and be surrounded by the other active stakeholders in the field (WCS, GIZ, FAO...) in order to provide support to the chiefdoms of Kabare and Buhavu, upon which it is incumbent to preserve the environment and production capacities for future generations. The concerned chiefdoms have demonstrated their interest and their motivation to support this agenda. Besides their legal rights, they also have the power to engage large landowners who lease their lands to small-scale producers.

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