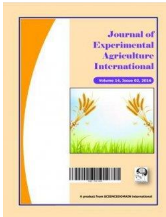

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# Initial Efficiency of Commonly Used Practices to Control Soil, Runoff and Nutrient Losses from Maize and Banana Based Systems in the Lake Kivu Basin

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***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

This study was carried out to determine the initial efficiency of commonly used practices to control soil erosion from Maize and Banana based cropping systems in Lwiro micro catchment in the Lake Kivu basin. Soil, runoff and nutrient losses were determined using runoff plot approach. Instrumentalised runoff plots of 2X15m were installed on maize intercropped with beans and banana gardens. Two soil erosion management practices, namely; *Tithonia* and contour bunds were tested on Maize intercrop with Beans and mulch for Banana. The experiment included a control practice for each crop. Each treatment and control was replicated four times. Runoff and soil loss were estimated for each rainfall event and aggregated on seasonal basis. Nutrient (N, P and K) losses were estimated per season. Results of the long and short rains of the first year of experimentation show that soil and runoff losses did not significantly change with practices and seasons (P>0.05) for both banana and maize based systems. Soil and runoff losses ranged from 15.73 to 32.93 Mg/ha,

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and from 168.14 to 322.17 $m^3$; respectively. Nutrient losses varied with practices and seasons ($P<0.05$) and ranged from 54.68 to 112.34 Kg/ha, 87.7 to 409.4 Kg/ha; 24.5 to 94.22 Kg/ha for K, N and P; respectively. Soil and runoff losses ranged from 8.99 to 20.6 t/ha, and from 85 to 152 $m^3$; respectively. Only K losses changed significantly with season ($P<0.05$) and ranged from 17.8 to 53.9 Kg/ha under Banana cropping system.

*Keywords: Land degradation; Lake Kivu Basin; pollution loading; Bukavu; D.R. Congo.*

## 1. INTRODUCTION

Soil loss and land degradation are considered as challenges of global dimension [1]. Soil erosion is widespread [2-5] and varies in magnitude from place to place depending on the land-use system, population pressure, community wealth, management, relief, and vulnerability of the soil to climate aggressivity [6-8]. [3] predicted about 15 Mg/ha/yr in Kondoa Eroded Area in Tanzania. [9] observed that soil loss was 30 times on road embankments in eastern Spain than on vegetated land. [10] observed that rills on roads in south eastern región of South Africa. Their dimension was significantly determined by gradient and percentage of vegetation cover of the roadcut while their widths and depths increased with the slope gradient and decrease with percentage of vegetation cover. The diversity of species in the vegetation covers also plays a role in the magnitude of soil loss [2] and increased soil erosion might lead to reduced plant diversity Due to increased grazing intensity soil erosion is becoming serious in the Tibetan grassland [11]. In several regions across the globe areas, steep sloepe with low vegetation cover including those with relatively bareland due to fire experience severe erosion [12], In Europe, soil erosion is most prone on vineyard [13,14] and on agrosilvopastooral mountainous ecosystems [5].

On the African continents, soil erosion is also alarming. In Ethiopia, many reservoirs constructed for hydropower generation, wáter supply have been siltated due to the alarming rate of soil erosion in some parts of Ethiopia [15]. In DRC, and particularly in Kivu mountain areas, soil erosion is believed to be one of the major processes of soil degradation [6]. The latter is reported to have reached catastrophic proportions on agricultural lands in the Kivu mountainous region [6,7,16].

Subsequently, the region is threatened by famine and food insecurity, it is reported that 70% of the population is affected by food insecurity [17]. Yet, the region has a great agricultural potential. Under rain-fed conditions, DRC can feed more than two billion people and 50% of its agricultural potential is located in the great Kivu region (Sud-Kivu, Maniema and Nord-Kivu). This situation is likely to exacerbate and reinforce the cycle of poverty-poor management- natural resources degradation [18-20]. On the other hand, soil erosion in the Kivu mountain region contribute to increased pollution loading into Lake Kivu, one of the deadly Lakes in the world. The Lake has reached critical concentration of $CH_4$ and $CO_2$ which can lead to an increased instability of the Lake which can trigger an explosion if any action is not taken to control the flow of carbon into the water bodies [21,22]. Lake Kivu is critical for the survival of millions of people around its basin and beyond [23]. It is a biodiversity hotspot area [24] and a source of protein and income for communities around it.

Although soil erosion is considered to be a major cause of land degradation in Kivu mountain region, very few studies have been conducted in the region to determine its magnitude and evaluate practices currently used for its control. Limited studies were conducted during the colonial time and in the 80s [25], and in Rwanda [26,27,28]. Acceptability, maintenance and replicability of some of these technologies has been challenging in the Kivu. Farmers' poverty and a long time span return of these technologies being the most determining factors. For many farmers adoption and continuous investment in these practices also depend on their short time performance on yield [29] which to some extent associated with their efficiency to control soil and nutrient losses, and enhance moisture conservation in the soil [30]. This study intended to determine the initial efficiency of commonly used practices to control soil erosion from Maize and Banana based cropping systems in Lwiro micro catchment in the eastern D.R. Congo side of the Lake Kivu basin.

## 2. METHODOLOGY

### 2.1 Description of the Study Site

This study was conducted in the River Lwiro micro-catchment within Lake Kivu Basin. The

River Lwiro is located on the eastern flank of Lake Kivu between latitudes 2°15' and 2°30' S and longitudes 28°45' and 28°85' E. Its headwaters are in the Kahuzi-Biega National Park mountain region; at an altitude of 2000 m. The 84 $km^2$ river basin is bordered on the east by Lake Kivu and on the west by the Kahuzi mountain forest (Fig. 1). This watershed of Lwiro river, the principal tributary of the Lake Kivu, covered 4 localities namely Irhambi/Katana, Bugorhe, Luhihi and Bushumba in the territory of Kabare, province of South-Kivu, Democratic Republic of Congo. Annual rainfall varies between 1134 mm and 1689 mm with an average of 1411 mm. The rainfall is bimodal with a dry season from June and July. The soil comprises of clay and rich volcanic soil, which is easily eroded. The geological composition is of Precambrian metamorphoses sediments (metamorphic rocks) and Preterozoic platform sediments [31]. [32]; describes metamorphic limestone and numerous travertines along Lake Kivu and Lake Edward. Carbonates for the production of cement are also found north and north-west of Lake Kivu [7].

The micro-catchment is dominated by small scale farming, forest and built-up area. Forest cover is more located in the mountainous area and is part of the Kahuzi Biega National Park. The geology of Lake Kivu has been described by [33] and [28]. It is a rolling landscape of convex and elongated hills, developed on the weathered lavas. In the Bukavu area, folded and faulted Precambrian strata are covered by thick Tertiary and Quaternary lava flows. The oldest series, not present at Bukavu itself, predates local rifting and is dated between 7 and 10 millions of years [34]. The middle and upper series are present at Bukavu. The middle series, of Mio-Pliocene age [35,34], is intimately related to the rift faults. The upper series started during the Pleistocene and continued to the last century. The chemical composition of these three series evolves from sub-alkaline over moderately alkaline to strongly alkaline [36]. Every lava series consists of many individual flows, separated in time [37]. The complex geometry of the present lava layers resulted from successive rifting and eruptive episodes. Weathering and erosion, as well as normal faulting, occurred between successive lava flow series, explaining the occurrence of palaeo-relief, contact metamorphism, smectite layers, probably Vertic palaeosoils, and clastic deposits having an alluvial and colluvial origin.

## 2.2 Design, Treatments and Replications

Soil, runoff and nutrient losses were determined using runoff plot approach. All the plots were established on a slope of 15%. A total of 12 Plots measuring 2X15 m were established on a farmer' garden at "Centre de Recherche en Science Naturelles" (CRSN-Lwiro) used for

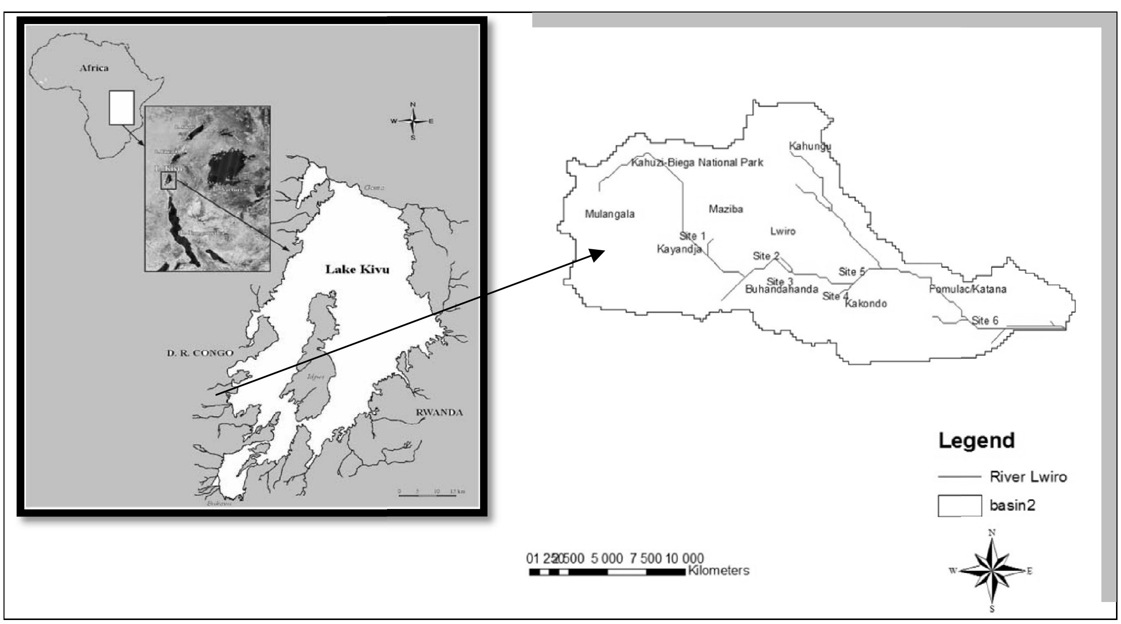


**Fig. 1. Lwiro micro-catchment and the main rivers, Lake Kivu basin**

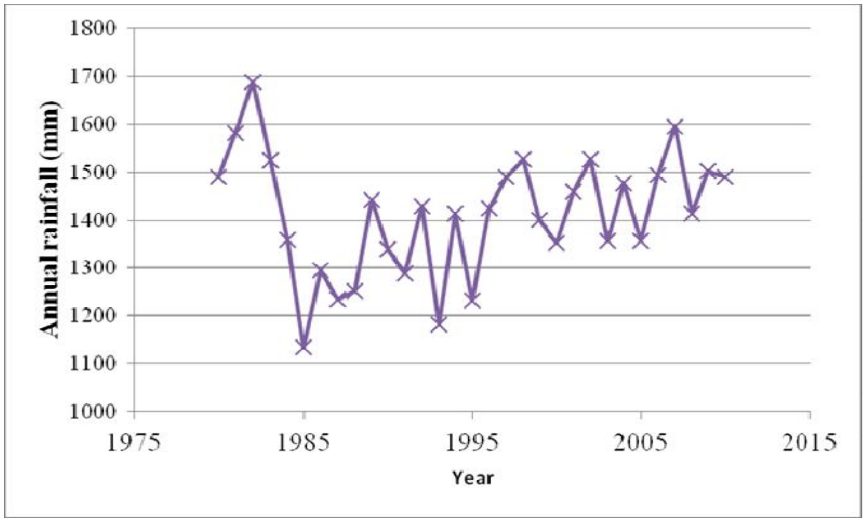


**Fig. 2. Annual rainfall in the Lwiro micro-catchment**
*(Source Merra Data)*

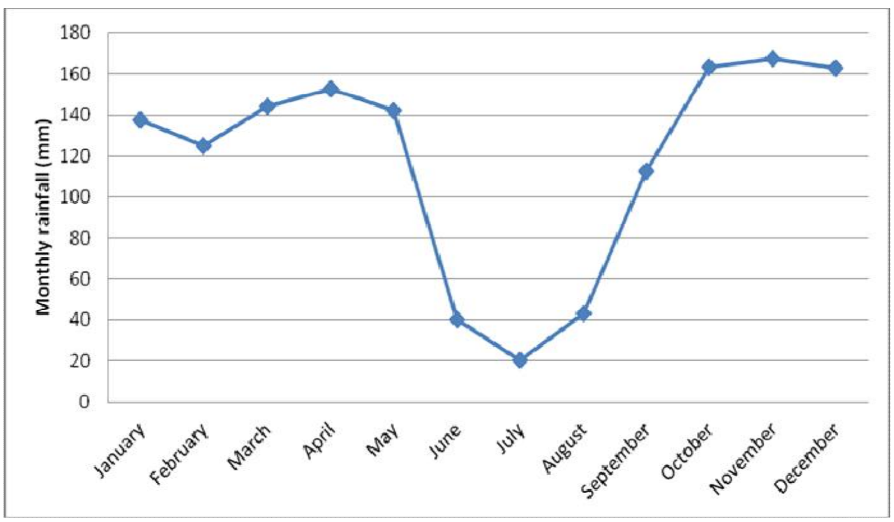


**Fig. 3. Monthly rainfall in Lwriro micro-catchment**
*(Source Merra data)*

growing maize and beans. Eight (8) other plots were established on a banana plantation. Each of the plots was equipped with dividers and collecting tanks. Two treatments and one control were imposed on the maize intercropped with beans garden; namely *tithonia* and contour bunds. On the banana garden one treatment (mulch) and a control were imposed. The runoff transfer coefficients were estimated in the field using water and an accurate balance. Local varieties of maize, beans and banana were used for the experiment; and banana was cultivated in monoculture. Each treatment and control was replicated four times.

## 2.3 Measured Parameters

The measured parameters included soil loss, runoff, nutrient losses and the crop yield. Runoff and soil loss were estimated for each rainfall event. Samples of collected runoffs were measured using a graduated cylinder and total runoff for the rainfall events were estimated by multiplying the collected runoff by the deviser's transfer coefficient. The collected runoff was thoroughly mixed and a 100 ml sample was collected for sediment concentration determination in the laboratory. In the laboratory, sediment concentration was determined by filtration. The total soil loss for the rainfall event was determined by multiplying the total runoff volume by the associated sediment concentration. Seasonal runoff was computed as the sum of the different event runoff [38]. The same was done for soil loss. Seasonal nutrient (N, P and K) losses were estimated for the short rainy season of year 2012 and the long rainy season of the year 2013. Plot composite soil samples were obtained by putting together sediment collected after each rainfall event for a given season. The composite samples were taken to the laboratory for N, P and K analysis. N, P and K were analysed using standard procedures [39]. Total N were analysed using Kjeldahl digestion method. Available P was extracted by Bray II method [40]. The exchangeable K+ cation was determined by a flame photometer. Total N and total available P was determined by multiplying their respective concentration with the total season soil loss.

## 2.4 Data Analysis

The survey questionnaires were coded and entered in PASW statistics version 18 for analysis. Frequencies, tables and graphs were obtained using descriptive statistics and cross tabulation. For the experiment, Analysis of Variance was used for mean separation at $p \leq 0.05$ in GenStat 13th edition.

# 3. RESULTS

## 3.1 Soil and Runoff Losses under Maize Based Cropping System

Soil and runoff losses for both season I (long rainy) and season II (short rainy) are presented in –Figs. 4 and 5 respectively. Soil loss and runoff losses did not significantly depend on soil erosion practices and rain seasons ($P>0.05$). However, soil loss under contour bunds was relatively the lowest followed by *Tithonia* and control for both seasons. A similar trend to that of soil loss was observed for runoff. The long rains season tended to have relatively higher value of soil loss and runoff for all practices. Soil loss under contour bunds varied between 15.73 t/ha and 20.49 t/ha, 19.29 t/ha and 23.33 t/ha under *Tithonia* and 30.91 and averaged 32.93 t/ha/season for the control for the two seasons. Runoff under contour bunds was also the lowest followed by *Tithonia* and control for both seasons. Runoff ranged between 168.14 and 203.22 under contour bunds, 206.60 and 240.13 under *Tithonia* and 264.29 and 322.17 t/ha/season under control.

Table 2 shows nutrient concentration under different practices and across seasons. Different nutrients were affected differently by practices and seasons. Practices effects was observed only on K while seasons affected N and P concentration in the sediment lost ($P \leq 0.05$). The interaction between seasons and practices was significant for K an P concentration in sediment lost ($P \leq 0.05$). Contour bunds tended to have a relativly high concentration of N and K and lower value of P compared to other technologies for the short rain season. All technologies had less variation in concentration of nutrients during the long rain season. Nitrogen concentration in sediments was relatively higher during the first season compared to the second season for all practices. Phosphorous concentration was relatively constant under *Tithonia* and control during the two seasons. It is important to observe that P concentration increased during the second season for contour bunds. K concentration increased under *Tithonia* and control during the second season. It is also important to note that K concentration decreased under contour bunds during the season.

Table 3 shows nutrient losses under different practices and across seasons. Nutrient losses from different land-use varied with practices and seasons ($p \leq 0.05$). Practices effects was observed on K, while N loss was only affected by season ($P \leq 0.05$). K loss and P loss was also affected by season ($P<0.05$). The interaction between seasons and practices was significant for K and P losses ($P<0.05$). Contour bunds tended to have a relativly high amount of K and N losses and lower value of P loss compared to other technologies for the short rainy season ($P<0.05$). Contour bunds had also relativlely low amount of K loss, N loss and P loss compared to other technologies in the long rain season ($p<0.05$). The amount of K and N losses decreased for plots with contour bunds during the long rain season while it increased for P loss. The amount of K loss and P loss increased for control and *Tithonia* during the long rain season while N loss decreased.

## 3.2 Soil and Runoff Losses under Maize Based Cropping System

Soil and runoff losses for both season I (long rainy) and season II (short rainy) are presented in Figures 6 and 7 respectively. Soil loss and runoff losses did not significantly depend on land-use practices and rainy seasons (P>0.05). However soil loss on mulched banana was relatively the lowest compared to the control (banana unmulched) for both seasons. A similar trend to that of soil loss was observed for runoff. The long rainy season tended to have relatively higher value of soil loss and runoff for both practices. Soil loss under mulched banana varied between 89.93 and 15.77 t/ha/season and between 13.88 and 20.61 t/ha/season under unmulched (banana). Runoff under mulched banana was also the lowest compared to the unmulched banana. Runoff varied also between 85 and 134 under mulched banana and between 118 and 152 t/ha/season under unmulched banana.

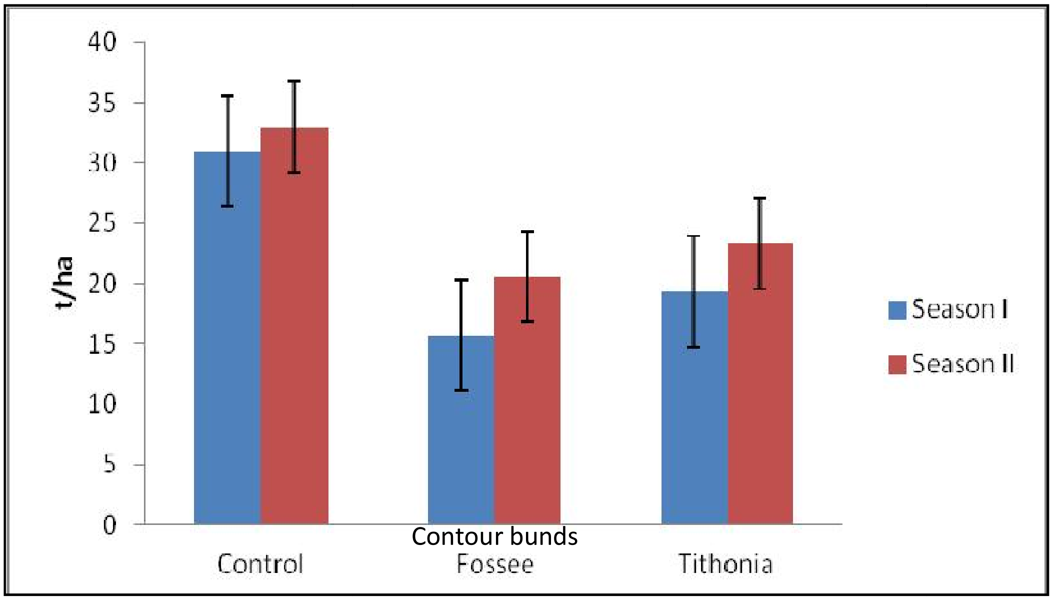


**Fig. 4. Soil losses under Maize cropping system**

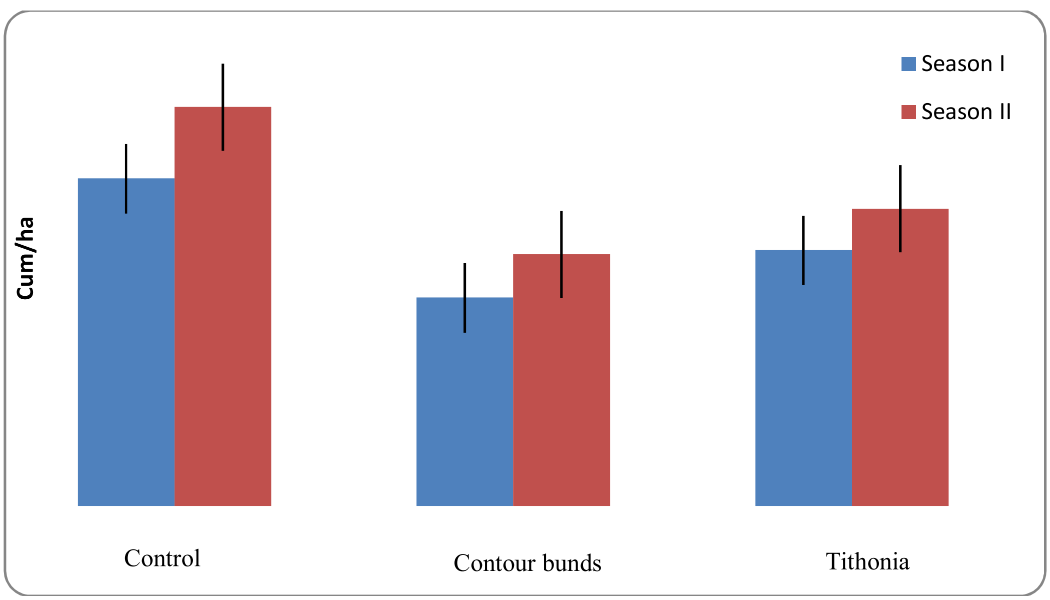


**Fig. 5. Runoff under maize cropping system**

**Table 1. Nutrient concentration under different practices and across seasons**

| Land use practices | Short rainy 2012 | | | Long rainy 2013 | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| | | | | % | | |
| Control | 0.87 | 0.23 | 0.19* | 0.36 | 0.28 | 0.34* |
| Contour bunds | 1.94 | 0.16* | 0.58 | 0.38 | 0.28* | 0.36 |
| *Tithonia* | 0.75 | 0.24 | 0.20* | 0.4 | 0.26 | 0.36* |
| LSD-*landuse* | NS | 0.06 | 0.34 | NS | NS | NS |
| LSD *Season* | 0.56 | | | | | |
| LSD Landuse*season | NS | 0.06 | 0.23 | | | |

**: Seasonal effects at P<0.05; NS = Not significant*

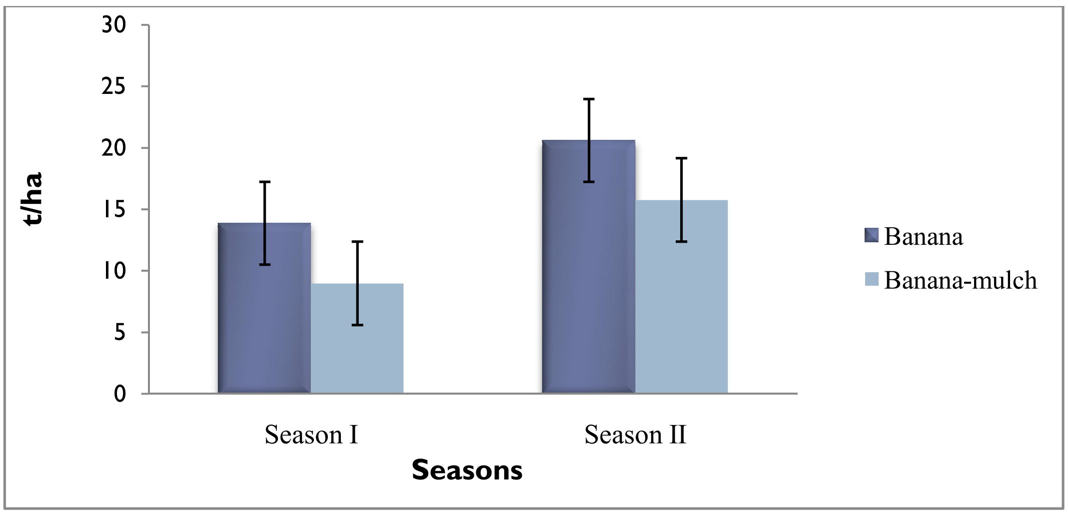


**Fig. 6. Soil losses under banana cropping system**

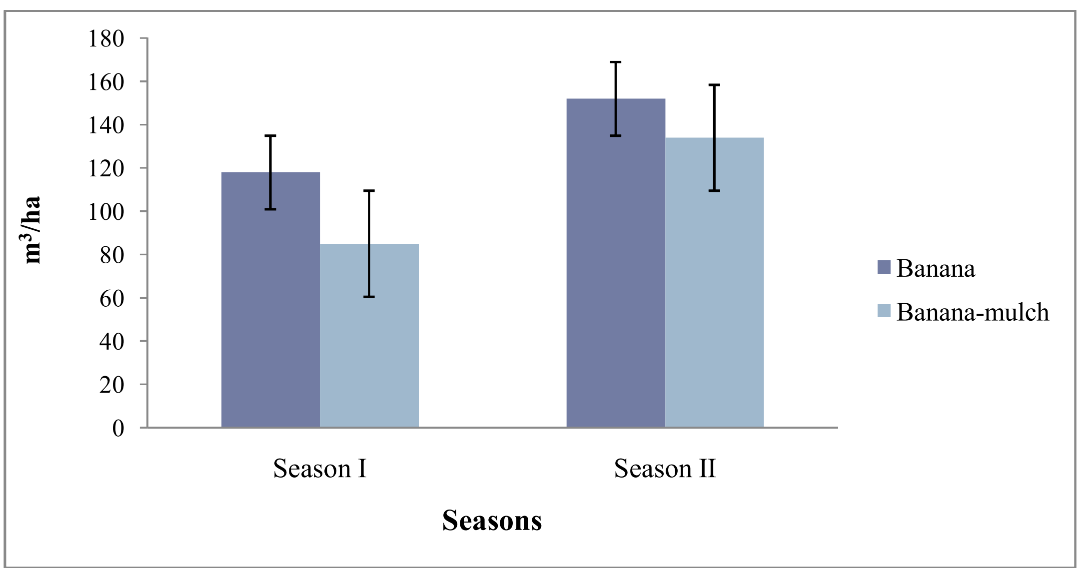


**Fig. 7. Runoff under banana cropping system**

**Table 2. Nutrient losses under different practices and across seasons**

| Land use practices | Short rainy 2012 | | | Long rainy 2013 | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| | Kg/ha/season | | | | | |
| Control | 291.8 | 68.01 | 54.68 | 125.9 | 94.22 | 112.34 |
| Contour bunds | 409.4* | 24.5 | 103.74 | 71.5* | 55.5 | 72.92 |
| *Tithonia* | 131.1 | 45.47 | 35.96 | 87.7 | 59.68 | 83.06 |
| LSD- *landuse* | NS | 25.26 | 28.81 | NS | NS | NS |
| LSD Season | 178.3 | 20.45 | 23.32 | | | |
| LSD landuse*season | 311.2 | NS | 40.72 | | | |

** Seasonal effects at P<0.05*

**Table 3. Nutrient concentration under different practices and across seasons for Banana**

| Land use practices | % | | | | | |
|---|---|---|---|---|---|---|
| | Short rainy 2012 | | | Long rainy 2013 | | |
| | N | P | K | N | P | K |
| Banana unmulched | 0.74 | 0.24 | 0.19 | 0.39 | 0.23 | 0.28 |
| Banana mulched | 0.55 | 0.26 | 0.21 | 0.42 | 0.24 | 0.32 |
| *LSD- landuse* | 0.08 | NS | NS | | | |
| *LSD-season* | 0.07 | NS | 0.04 | | | |
| *LSD landuse.season* | 0.11 | NS | NS | | | |

**Table 4. Nutrient losses under different practices and across season for Banana**

| Practices | Kg/ha/season | | | | | |
|---|---|---|---|---|---|---|
| | Short rainy 2012 | | | Long rainy 2013 | | |
| | N | P | K | N | P | K |
| Banana unmulched | 107 | 35.2 | 25.7 | 79 | 48.1 | 53.9 |
| Banana-mulched | 46 | 23.6 | 17.8 | 69 | 37.6 | 51.6 |
| LSD-landuse | NS | NS | NS | | | |
| LSD Season | NS | NS | 11.3 | | | |
| LSD Landuse.Season | NS | NS | NS | | | |

Table 4 shows nutrient concentration under different practices and across seasons. N and P were not signicantly affected by different practices and seasons (P>0.05). Only K was affected by the season (P<0.05). All the nutrients tended to have relatively the same concentration during the long rainy season for the different practices except the N concentration which decreased under control (banana unmulched) during the long rain season. Table 7 below shows nutrient losses under different practices and across seasons. Most of the nutrient losses were not affected signicantly by practices and seasons(P>0.05). Only K losses were significantly affected by the season(P<0.05). Mulched banana plots tended to have a relatively low nutrient losses in both seasons. K and P losses increased during the long rainy season for all practices while N losses decreased during the long rainy season for the unmulched banana.

Fig. 8. shows monthly rainfall amount in the catchment during the two seasons. Peak rainfall amount were observed in October 2012 and December 2012. Monthly rainfall amoun remained less than 150 mm from february to April 2013.

## 4. DISCUSSION OF RESULTS

The annual soil and runoff losses from both maize and banana cropping systems are severe and moderate; respectively [41], [42]. Nutrient losses are relatively lower under Banana compared to Maize. Soil and water management practices effects were not felt during the first year of experimentation for soil and runoff but was significant for nutrient losses under Maize and only for K under banana (P<0.05).

Soil loss under maize and banana in the study area are comparable with results obtained in the region [43-45]. [43] obtained soil losses of 45 t/ha on maize intercrop with beans under sub-humid conditions and on slopes of 22% in the Lake Victoria crescent. Measured average annual soil loss ranged from 86.8 t/ha/yr in Rakai; and 27.9 t/ha/yr under banana [44]. Similar results were observed by [46] where annuals lost 71 t/ha/season and 25.1 t/ ha/ season for banana. Runoff observed under this study was relatively very low compared to values obtained by [44] for the same land use. Runoff under maize and banana was a seventh and half of what was obtained by [44] for the same land use respectively. Nutrient losses were very high but less than values obtained by [44] in Rakai. Values of 0-2 and 0.1-13 kg $ha^{-1}$ $season^{-1}$for P and K, respectively, were reported on arable lands of sub-Saharan Africa [47]. A study by [48] showed that mulch could reduce up to 46% of runoff, and soil losses up to 88.7% and sediment concentration up to 84.4 % through increased infiltration. They observed that infiltration rate increased on average up to 167 % with mulch. In ants infested up to 167 % with mulch. In ants infested areas, up to 167 % with mulch. In ants infested areas,application of mulch materials can attract increased ants activities which will increase the macro pores and hence water infiltration [49].

Differences between the results of this study and aforementioned ones are attributed to slope, soil type and climatic conditions. However, very small values (1.4 t/ha/yr) of soil loss were measured by [50] in Kabale for similar slope of 10 % and quasi similar values of 30-t ha-1 yr-1 were recorded on slopes of 20%. Type of soil affects soil loss through infiltration and erodibility. The infiltration rate of the experimental soil was generally very rapid [51] compared to moderate and rapid rate under [44] and [52] soils. High infiltration rate contribute to reduced runoff, runoff sediment detachment [53] and nutrient loss [54], [55], [56]. Several studies demonstrate that runoff generation is driven by antecedent soil moisture [57-60], and soil management systems [61,62]. The latter generally affects soil surface structure [63,64], [53]. A strong relationship exists between soil structure, soil water retention and organic matter [65]. The experimental soils are deep and have high organic matter contents ranging from 3.68 to 5.7 %. This explains the higher values of infiltration for these soils.

Variation in runoff, soil loss and nutrient losses between the different studies is also due to aggressive climatic factors. The erosivity factor is relatively higher in the study area than in Uganda where Mulebeke and Majaliwa conducted their studies [44,52,25]. It was ranging from 170 and 196 J $m^{-2}$ in Uganda while in DR Congo it ranged between 220 and 300 J $m^{-2}$. This explain the need of soil and water conservation practices to control soil erosion which could be induced by such rainfall aggressivity [66,14,67].

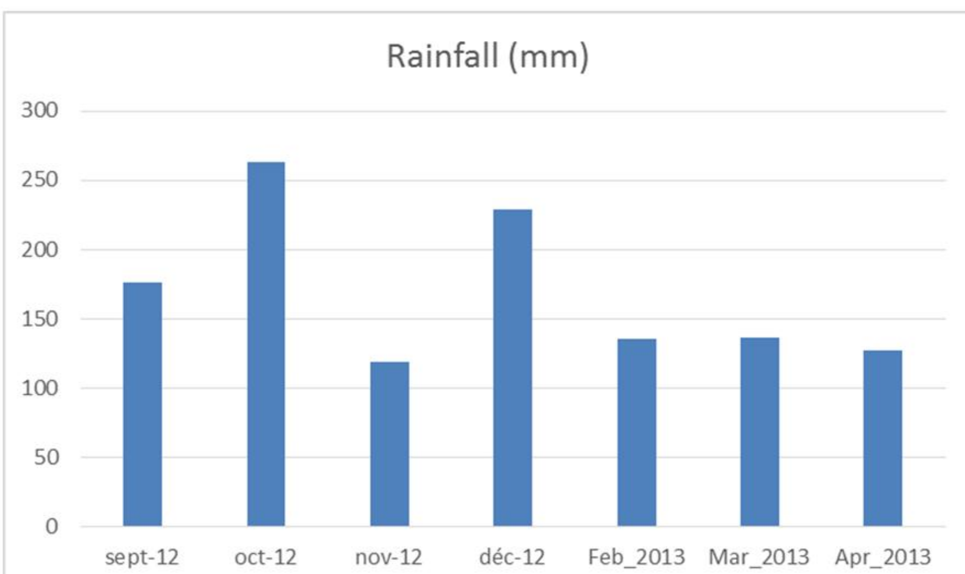


**Fig. 8. Rainfall data during the study period**

It is worthwhile to note that maize and beans yields were generally high despite declining in the second season. In Ethiopia, [15] observed yield reduction due to contour bunds. The soil chemical and physical properties were not significantly influenced by practices. This is due to the fact that effects of these practices is long term [38] High maize and beans yields are due to the good fertility status of the soil. Most of the soil parameters were above the critical values, therefore adequate for plant growth. For banana, mulched plots had better yield reflecting the relative better nutrient conditions of the soils under mulch in terms of organic carbon, available phosphorus, extractable potassium and nitrogen.

## 5. CONCLUSIONS AND RECOMMENDATIONS

In light of the above results and discussion, it was concluded that soil loss was generally severe on maize and moderate on banana; while runoff was relatively low ranging between 1 and 3% on banana and maize intercropped with beans; respectively. The reduction in soil and runoff losses due to soil and water conservation practices was not significant during the period of the study. Nutrient losses were generally high on both systems and varied from one practice to another under maize but only K under banana. Nitrogen, phosphorus and potassium losses under banana varied from 46-107 Kg/ha/season; 23.6-48.1 Kg/ha/season; and 17 -53.9 Kg/ha/season; respectively. They ranged from 71-409 Kg/ha/season; 24-94 Kg/ha/season; 35-112 Kg/ha/season for N, P, and under maize; respectively. Based on the results and observations made in the study area there is need to improve the extension services in the micro-catchment, and the country at large, in order to promote and increase the adoption of the tested soil erosion control practices; and to conduct long term experiments to assess the efficiency of existing soil erosion control practices in the Lwiro micro-catchment and the region.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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