Evaluation of management practices to mitigate drought effects / Performance of selected on-farm practices on runoff in selected climatological rainfall zones of Uganda

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Abstract

A study was conducted in two selected sub-catchments, namely Lwemikunya and Awoja, respectively in central and eastern Uganda, to determine the efficiency of selected management practices to reduce runoff. Drought mitigation practices were evaluated on banana (perennial), annuals (maize and cassava) and grazing lands in Lwemikunya; and annuals (sorghum and cassava) and grazing land in Awoja using the runoff approach. Runoff plots of 20 x 2m were established on demarcated experimental sites. Each of the experimental plots was sampled for selected chemical and physical soil properties at the beginning and the end of each season. Experimental data were analyzed using Genstat and variation in soil properties and biomass due to the introduction of contour bunds was evaluated using geo-statistical methods. The application of cover crop reduced significantly runoff on cassava garden ($P<0.05$), regular spacing of sorghum reduced significantly runoff compared to the broadcasting ($P<0.05$). On grazing land, the efficiency of contour bunds increased linearly with season ($R^2=0.87$). Generally, rangelands on steep slope had the highest runoff compared to other land-uses ($P<0.05$). Perennials (Banana) had the lowest seasonal runoff volume. Contour bunds on annual crops reduced runoff linearly overtime ($R^2=0.63$), though runoff increased by about 80% during the first season just after the introduction of the contour bunds. Under banana, the effect of mulch on runoff was positive even during the first season, with a relative reduction of 36.2%. Existing soil and water conservation practices present high runoff reduction efficiency and the latter increased with time. It can therefore be used to control runoff losses, and significantly increased crop yield in the two sub-catchments. There is need to sensitize the communities on the efficiency of the existing soil and water conservation practices and promotes them.

Key words: Drought effect, Management practice, runoff, Uganda

Introduction

Modern and indigenous practices have been employed to achieve improved yields for areas devastated by floods and drought. Success scenarios for rain-fed agriculture in East Africa that are going a long way in positively altering lives of many poor farmers have been reported in topical studies (Reij and Waters-Bayer, 2001; Bittar, 2001; Abbay *et al.*, 2000; Hatibu and Mahoo, 2000; Critchley *et al.*, 1999). These interventions range from soil and water conservation, rainwater and runoff harvesting systems, integrated soil fertility management (Ndakidemi *et al.*, 1999), integrated pest management, tillage and soil management systems, improved seeds, and innovative agronomic practices.

A critical component of agricultural production is water and soil nutrient management. In flood prone areas, water and nutrient conservation technologies are dictated by the need for soil conservation on usually very steep slopes while draining excess runoff safely, while in drought prone areas there is need for water harvesting and conservation. However, the available technology is usually manual or draught animal, and labor. Several studies (McCall, 1994; Reij *et al.*, 1996; Wolde-Aregay, 1996; Thomas, 1997; Mutunga *et al.*, 2001; SIWI, 2001) from Ethiopia, Kenya and Tanzania have reported a rich heritage of indigenous and innovative water and nutrient conservation technologies, including irrigation and water harvesting systems that date back centuries.

Soil and water conservation practices can be expressed as activities that reduce water losses by runoff and evaporation, while maximizing in-soil moisture storage for crop production, but also are rain water harvesting practices. However, these management practices for floods and drought that complement each other are differentiated by the fact that under soil and water conservation, rainwater is conserved *in-situ* wherever it falls, whereas under water harvesting, a deliberate effort is made to transfer runoff water from a "catchment" to the desired area or storage structure (Critchley and Siegert, 1991).

Farmers throughout East Africa are implementing diverse modern and indigenous technologies under many development projects on agriculture, soil and land management (Reij and Waters-Bayer, 2001; Mulengera, 1998; Hamilton, 1997; WOCAT, 1997; Reij *et al.*, 1996; Lundgren 1993; Hurni and Tato, 1992) aimed at coping with effects of floods and drought. The most popular practices are those that have proved easier to replicate, with applicability over wider biophysical conditions involving low labor (Mati, 2005).

The frequency of natural disasters (e.g. droughts, floods) is on the rise worldwide, with multi-dimensional negative impacts on communities, infrastructure, environmental assets, livelihoods and agricultural production (Garbero and Muttak, 2013). This is particularly true for Uganda where the majority (80%) of the farmers depends heavily on rain-fed agriculture (Mwerera *et al*., 2010). The objective of this study was to determine the efficiency of selected management practices to reduce runoff.

Methodology

This study was conducted in two selected sub-catchments, namely Lwemikunya in central Uganda and Awoja in eastern Uganda (Figure 1).

Lwemikunya falls under the former district of Rakai at the border with Tanzania, while Awoja cuts across Mbale, Kumi, Sironko, Soroti, Moroto, and Nakapiripirit. Given the extended area of the Awoja sub-catchment, Soroti district was given more attention for issues requiring to be considered from administrative perspective. Viewed under the climatological or agro-ecological angles as per the delineation of Uganda into climatologically homogenous rainfall zones using the Principal Component Approach/PCA (Basalirwa, 1995; Taylor *et al.*, 2006), Soroti pertains to the zone labeled "D", Awoja cut across E, F, H and D while Rakai falls under CE/A1.

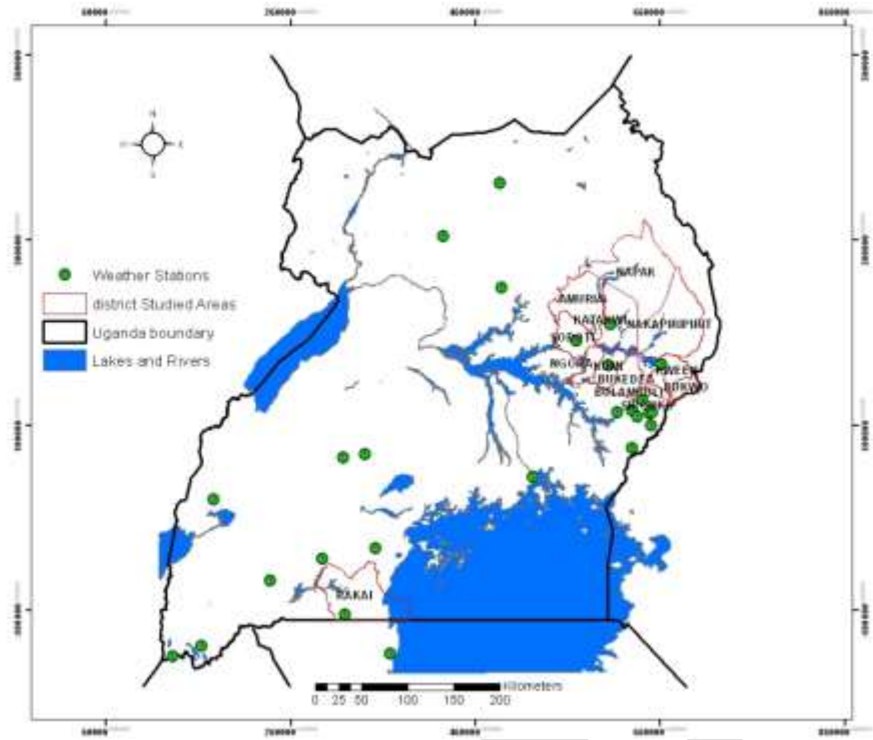


Figure 1: Study areas showing the districts in which the studied sub-catchments are located

Each of the two sub-catchments is intersected by the cattle corridor. The cattle corridor (Figure 2) extends from the north-east, through central to south-west of Uganda.

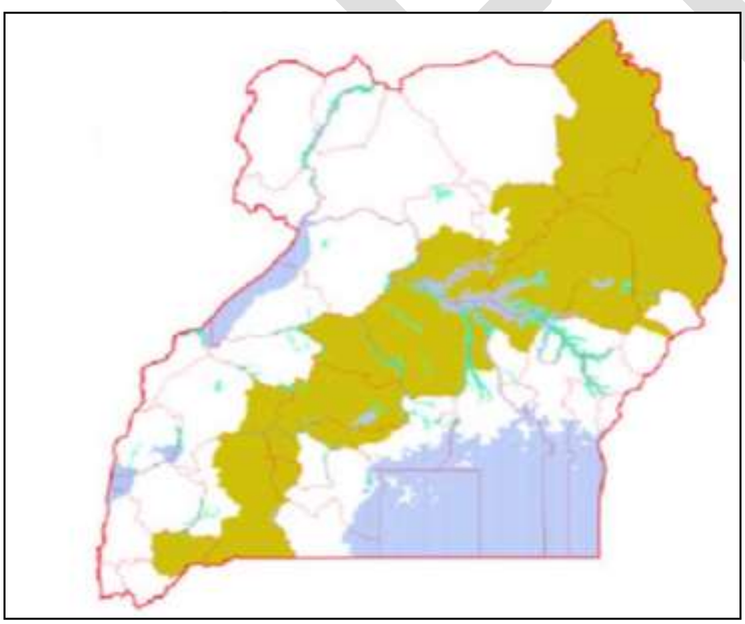


Figure 2: Cattle corridor of Uganda

Drought mitigation practices were evaluated on banana (perennial), annuals (maize and cassava) and grazing lands in Lwemikunya; and annuals (sorghum and cassava) and grazing land in Awoja using the runoff approach. These were identified as major agricultural land uses in the selected drought and flood prone areas during the survey. Commonly used water management practices were identified during the Focus Group Discussions (FGDs) and the structured questionnaire analysis. A few of them were tested in each of the two sub-catchments. These included mulch (banana plantations) and contour bunds (grazing land and annuals crops) in Lwemikunya; and cover crop (cassava), contour bunds (grazing lands) and myccorhiza applications (sorghum) in Awoja. Each individual experiment had a control and treatments replicated three times. In Lwemikunya two slope steepness categories were considered for the grazing land namely slope (0-8% and >25%). Efforts were made to have all the banana and annuals experiments located on the same soil unit, in each of the two sub-catchments.

Four dominant soil types exist in Lwemikunya (Rakai), namely Acric Ferralsols, arenosols, gleysols and leptosols (Figure 3).

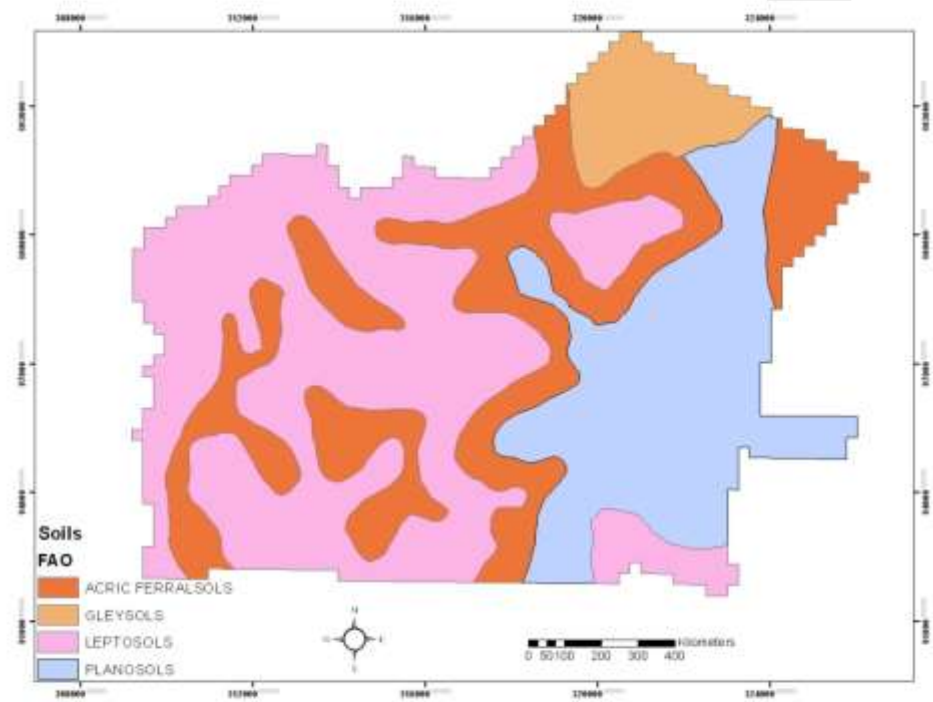


Figure 3: Soils map of Lwemikunya sub-catchment

In Awoja the major soils are lixic ferralsols, petric plinthosols, vertisols (Figure 4). Other soil types include: arenosols, gleysols, eutric regosols, histosols, nitisols, luvisols and acri-ferralsols.

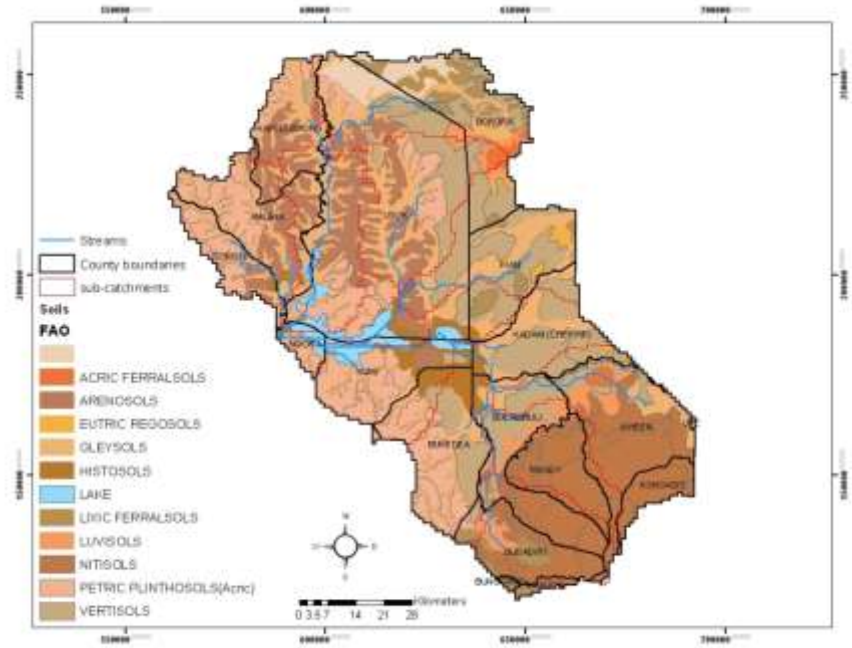


Figure 4: Soils map of Awoja sub-catchment

In Lwemikunya, banana plantation was dominated by Bwazirume variety planted at a 3m spacing, maize (longe 5) was planted at 75 cm x 30 cm. Mulch was applied at a rate of 5t/ha on the banana plantation. In Awoja sub-catchment cassava (nigera variety) was planted at 1 x 0.75 m spacing. Sorghum (Seredo variety) was planted at 15 cm by 75 cm spacing. The cover crop (mucuna) was intercropped with cassava.

Three treatments were considered for sorghum: sorghum-inoculated and broadcasted, sorghum-broadcasted-with no-inoculation and sorghum-spaced-inoculated. Sorghum-broadcasted-with-no-inoculation was the local practice.

On grazing land, the effect of contour bund was tested. Efforts were made to exclude animals from the grazing lands. In Soroti/Awoja, plants with thorns were placed around the demarcated experimental sites. In Rakai/Lwemikunya, pastoralists were sensitized about the experiment.

Runoff plots of 20 x 2m were established on demarcated experimental sites (Plate 1). Due to limited availability of land, plots were arranged in split plots design. The cultivated gardens were managed by farmers. Runoff was measured for each rain event. The amount of water measured into the collecting jerry cans (Plate 2) was extrapolated to 1 ha. At the end of the season, seasonal runoff was determined by summing all individual runoffs from the different events.

Yield data (bunch weight for banana, grain yield or tuber weight for annuals, and biomass on grazing land) were determined regularly and annual values estimated. This information was collected for a period of five (5) seasons for all the treatments except for grazing land in Awoja sub-catchment for which only three seasons were monitored. In addition, one rain gauge was installed in each of the experimental areas for rainfall measurements (Plate 2).


Plate 1: Runoff plot on annual cropping systems in Rakai


Plate 1: collecting jerry cans and rain gauge installed in each of the experimental areas

In addition, each of the experimental plots was sampled for selected chemical and physical soil properties at the beginning and the end of each season, from two soil depths (0-15 cm, and 15-30 cm); except for grazing land where only 0-15 cm depth soil was collected. Soil chemical parameters considered included soil pH, organic matter, total nitrogen, available phosphorus, extractable potassium, sodium, and calcium. The physical parameters considered in this study were bulk density, hydraulic conductivity and texture. The soil pH was measured in a 1:2.5 soil to water ratio using a pH electrode (Okalebo *et al.*, 1993). Nitrogen analyses were precluded for limitations in preservation. These soil chemical characteristics were determined by standard methods of soil analysis i.e. exchangeable bases were extracted with excess of neutral 1 M NH_4OAC (Ammonium acetate solution) (Tekalign *et al.*, 1991) and the exchangeable K^+, and Na^+ cations were determined by a flame photometer while Ca^{2+} was determined by Atomic Absorption spectrophotometer. Available phosphorus was extracted by Bray II method (Bray and Kurtz, 1945). Soil organic matter was determined by oxidation method (Okalebo *et al.*, 1993, 2002). Soil bulk density was determined using the core method, and hydraulic conductivity was determined using the constant head method. Soil texture was classified according to the FAO classification (FAO-UNESCO-ISRIC, 1990). At the end of the third year, soil samples on the grazing land was collected using a 10 m-grid.

Grass was collected from 1 x 1m quadrat and biomass measured in the laboratory using 0.1 g balance. Biomass was assessed using the harvesting method. Grass in the quadrat was harvested and oven-dried at 40 ^{o}C in the laboratory and weighed.

Qualitative data obtained from interview were entered in excel and analyzed using SPSS 17.

Experimental data were analyzed using Genstat. ANOVA and multiple regressions were used to separate means and to establish functional relationship between dependent and independent parameters. Spatial information was analyzed in the GIS environment. Variation in soil properties and biomass due to the introduction of contour bunds was evaluated using geo-statistical methods. VARIOWIN was adopted for geo-statistics calculation. Lag tolerance was set to 0.5 (5 m). Spherical and Gaussian models were used to fit the semi-variogram curves. Only the points with more than 30 data pairs were used in diagrams and calculations.

Results and Discussions

Performance of selected on-farm practices on runoff

Soroti area

a) Overall performance

The overall performance of the different practices is given in figures 5, 6 and 7 below. The application of cover crop reduced significantly runoff on cassava garden ($P<0.05$). Runoff on plot under farmers' management yielded slightly more than 3 times runoff generated in gardens with seasonal incorporation of cover crops.

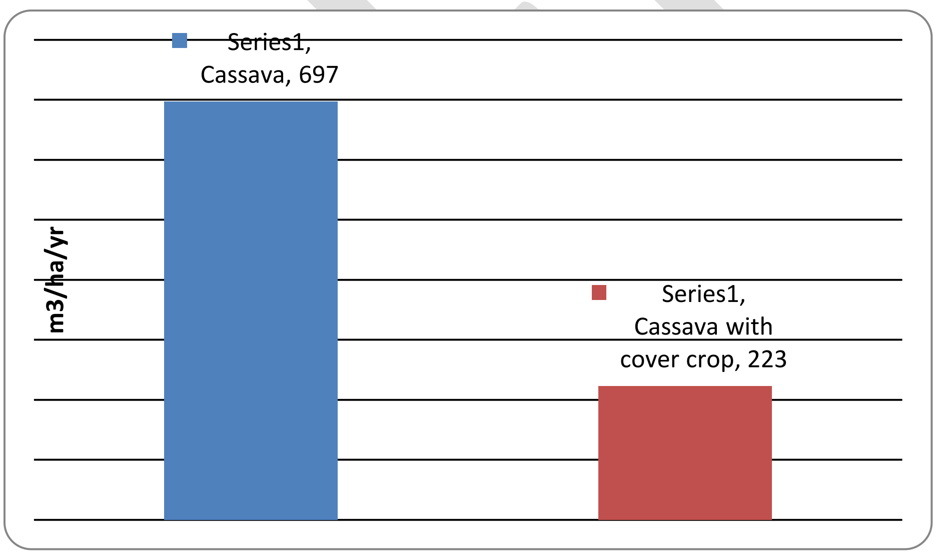


Figure 12: Effect of cover crop incorporation in soil under cassava in Soroti district

Regular spacing of sorghum also reduced significantly runoff compared to the broadcasting practiced by farmers (Figure 9). Although the application of MakMYCO seemed to have relatively reduced runoff compared to regular spacing alone, the difference was not statistically significant (P>0.05).

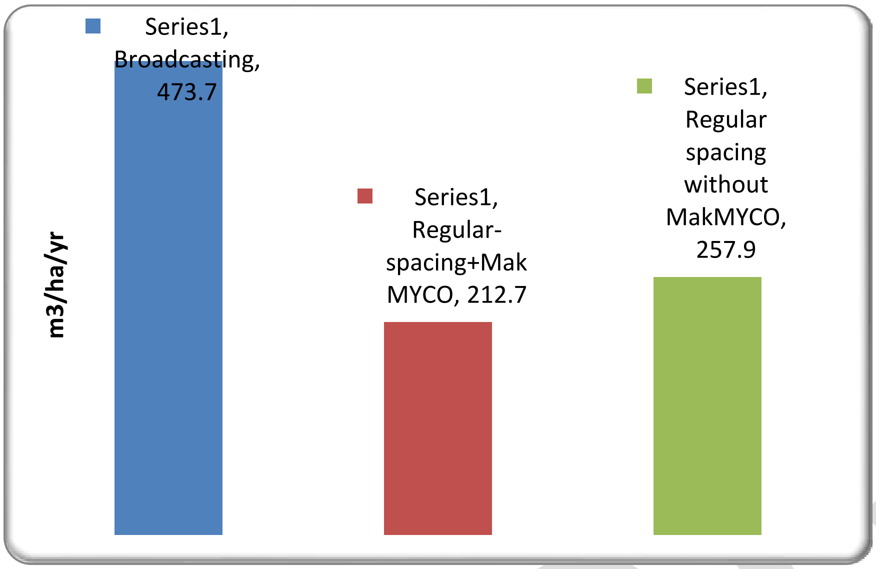


Figure 13: Effect of sorghum regular spacing on runoff generation in Soroti

Construction of contour bunds with a 5 m strip band reduced significantly runoff generated on rangeland in Soroti (P<0.05). After two years a 27.8% reduction was observed on rangelands with contour bunds and vegetation strip compared to those without any treatment.

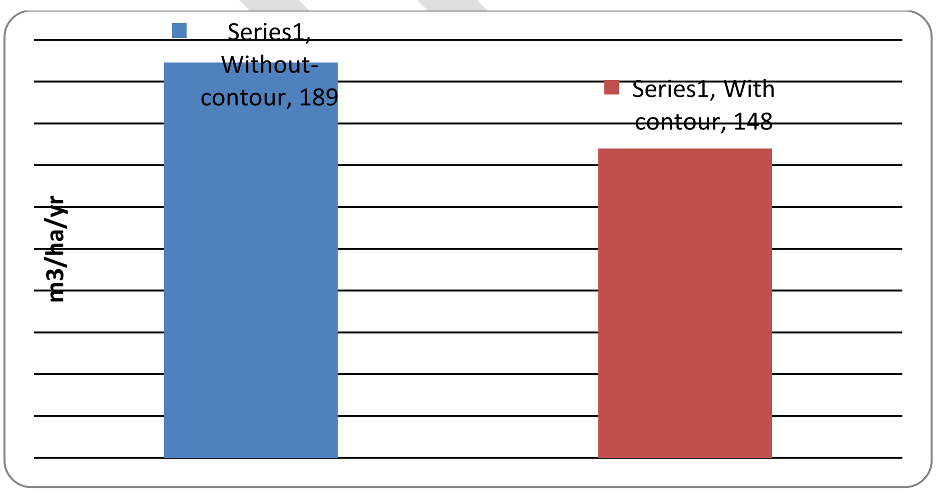


Figure 14: Effect of contour bunds on rangeland runoff generation in Soroti

b. Trends over time

b.1 Cassava plots

Runoff change overtime on the cassava plots is given by figure 38 below. Generally, up to the four first seasons, runoff remained quasi constant.With the fifth season the trend became exponential on cassava with cover-crop (R^2= 0.63) and sole with bigger increment on cassava sole plots (R^2=0.57).

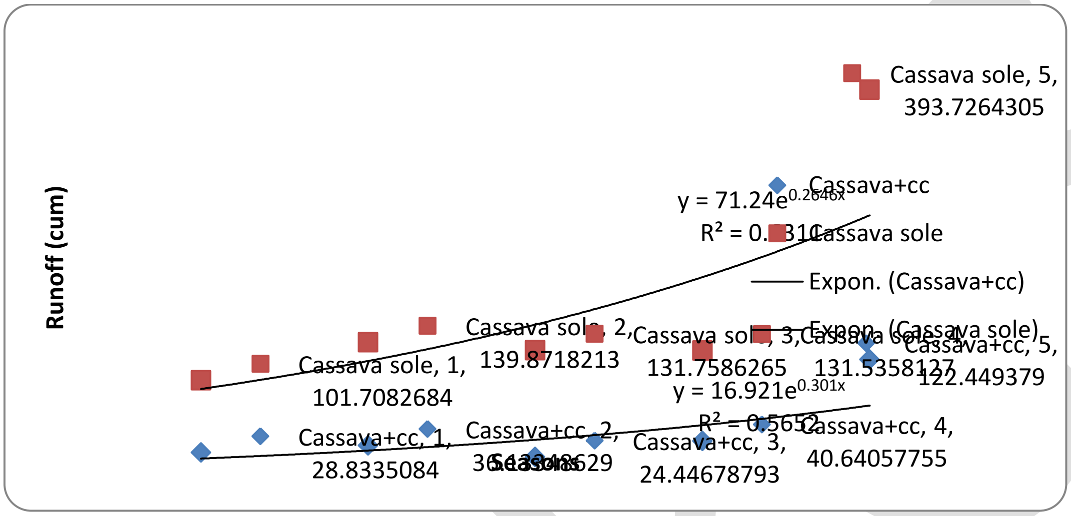


Figure 15: Runoff change overtime on the cassava plots

b.2 Sorghum

Similar pattern to that observed on cassava plots were observed on sorghum plots. Runoff remained quasi uniform across seasons until the fifth season when runoff increased on all plots. Mycchorized plots with sorghum spaced had the lowest slope gradient (183.68 m^3/season). As for cassava the control (Sorghum broadcast) was the most affected compared to other practices ($P<0.05$).

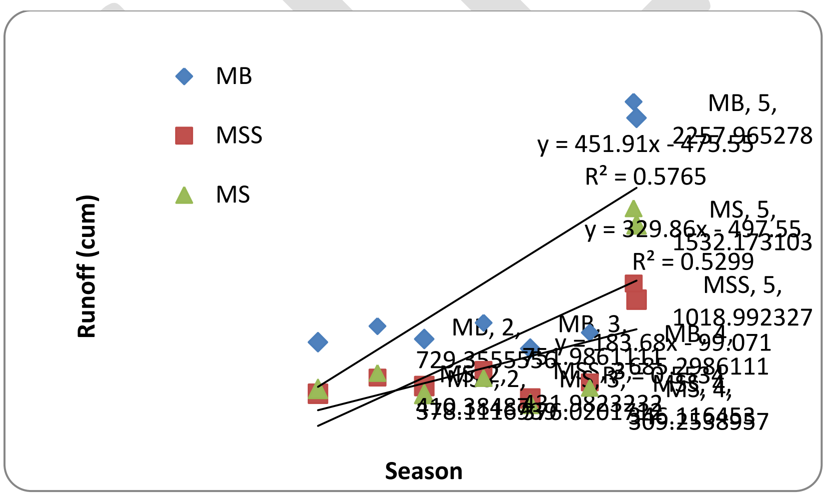


Figure 16: Seasonal trend in runoff under sorghum plots in Soroti

b.3 Grazing land

As for the previous two agricultural land-uses, runoff increased linearly with time, with the higher gradient for grazing land without contour bunds (30.63 m^3/season) (Figure 10).

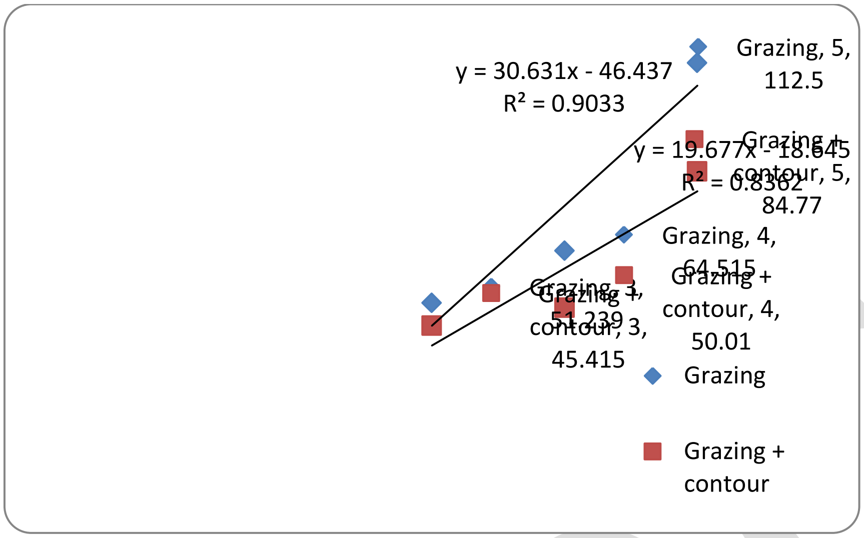
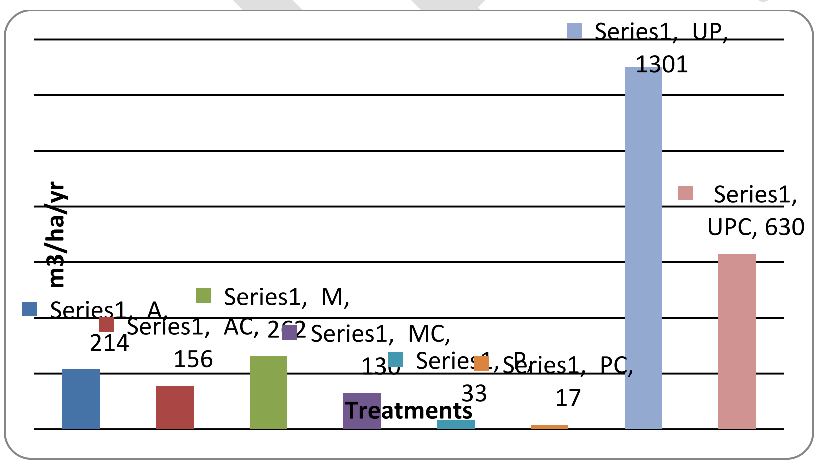


Figure 17: Linear increase of land uses runoff

Lwemikunya area

a. Overall performance

Runoff from the different treatments tested in Lwemikunya sub-catchment is shown in figure 11 below. Runoff considerably varied from one agricultural land-use to another. Generally rangelands on steep slope had the highest runoff compared to other land-uses ($P<0.05$). Perennials (Banana) had the lowest seasonal runoff volume.



A: Annuals, AC: Annuals +contours, M: Grazing land in middle slope, Grazing land in middle slope with contour, P: perennials; PC: Perennials with contour; UP: Grazing upper slope; UPC: Grazing upper slope with contour

Figure 18: Average seasonal runoff from the different land-uses in Lwemikunya

b. Efficiency of the different practices on seasonal runoff

The efficiency of the different practices is shown on figures 12 and 18 below. Contour bunds on annual crops in Lwemikunya reduced runoff linearly overtime (R^2=0.63), with a reduction rate of 24.94% every season. It is worthwhile to note that runoff increased by about 80% during the first season just after the introduction of the contour bunds.

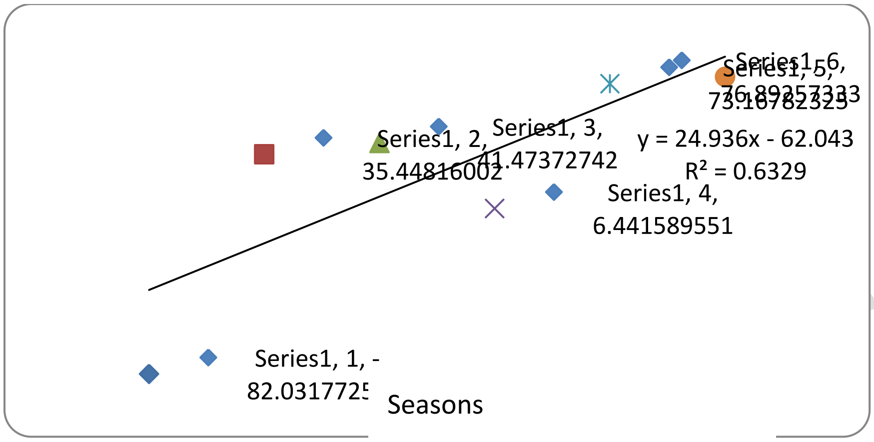


Figure 19: Effect of contour bunds on runoff under annual crops in Lwemikunya (Rakai district)

The effect of contour bunds on runoff from rangeland located on steep slope (>25%) also showed a significant linear trend overtime (R^2=0.55). The gradient in efficiency increase was of 11.18% per season. The introduction of contour bunds on these slopes reduced runoff by 49% before going down for the next season and then steadily increasing with time.

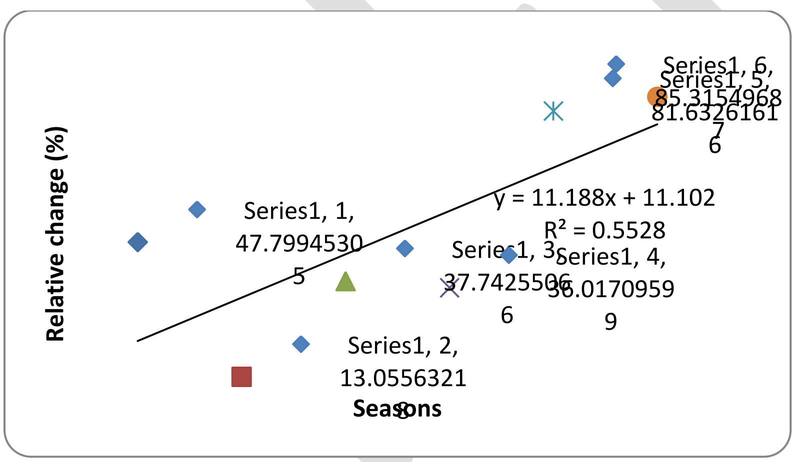


Figure 20: Effect of contour bunds on grazing land's runoff in Lwemikunya sub-catchment (Rakai district)

Under banana, mulch produced a similar trend on runoff (R^2=0.64) as for contour bunds under annuals. The effect of mulch on runoff was positive even during the first season, with a relative reduction of 36.2% (Figure 14). The gradient in efficiency of mulch however only increased by 6.51% every season.

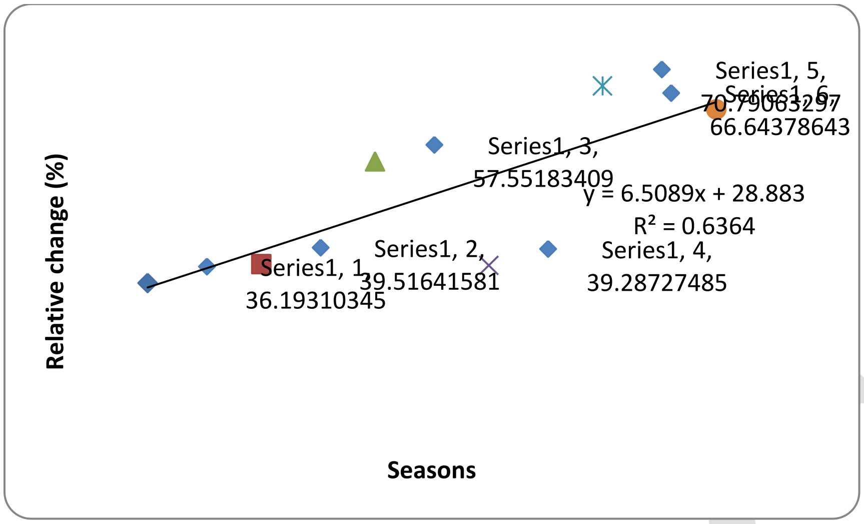


Figure 21: Effect of mulch on runoff under banana Lwemikunya sub-catchment -Rakai district

The trend of the introduction of contour bunds on middle slope rangelands showed a quadratic form (R^2=0.54). During the first season the efficiency reached 61.3%. This efficiency decreased gradually up to forth season before jumping again to 63.4% (Figure 15).

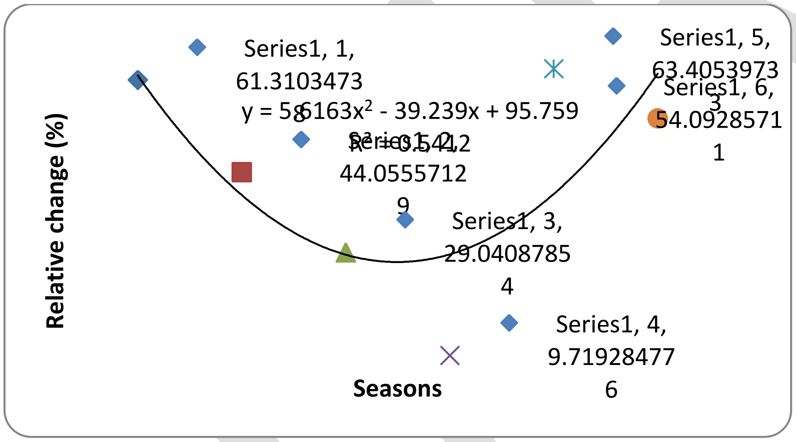


Figure 22: Efficiency of contour bunds on runoff reduction on grazing land in the middle slope (Lwemikunya)

The efficiency of cover crop in reducing runoff remained above 70% for five seasons. For the five seasons it followed a quadratic trend (R^2=0.53). It first increased for three seasons reaching 80% before declining to 70% (Figure 16)

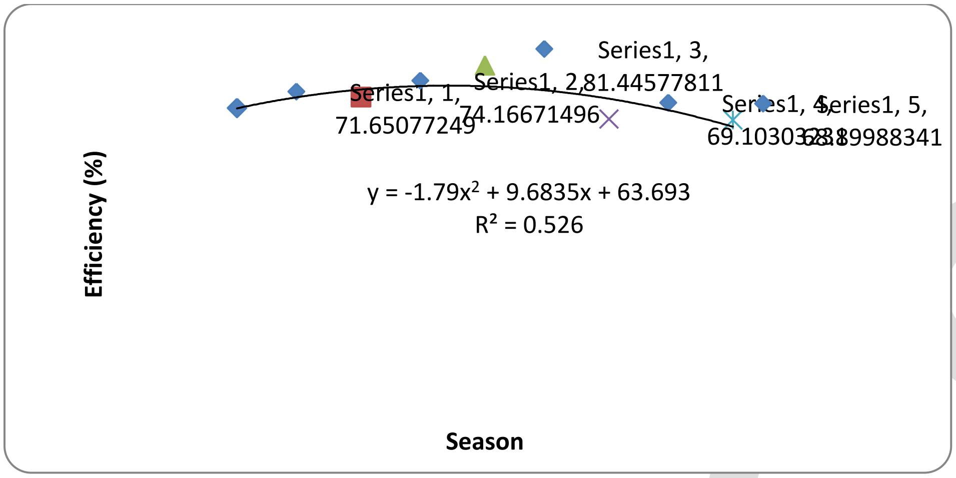


Figure 23: Quadratic trend during the five seasons

On Sorghum in Soroti (Figure 17 below), mycorrhized sorghum with regular spacing had its runoff reduction efficiency increasing exponentially (R^2=0.45) from 45% to 55% while mycchorized sorghum broadcasted's efficiency showed a quadratic trend. For the latter it increased for the first three seasons gradually up to 55% from 43% before dropping to 31 for the last season.

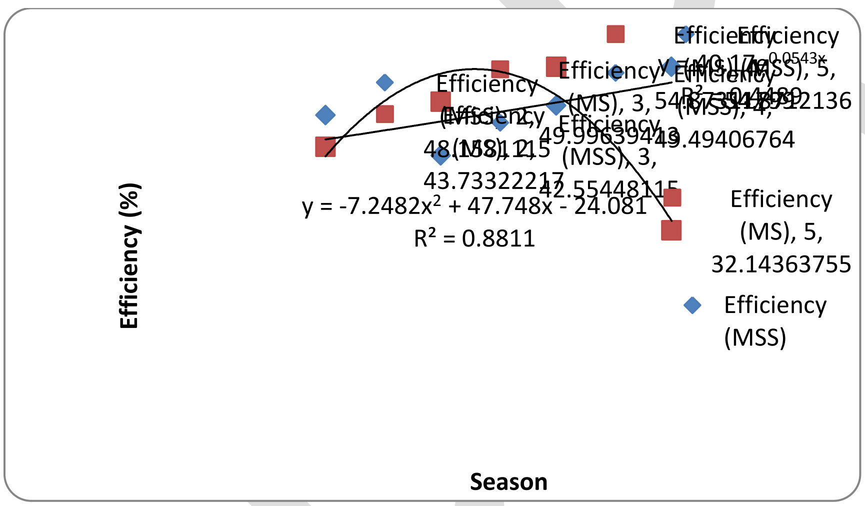


Figure 24: The case of Sorghum in Soroti

On grazing land in Soroti, the efficiency of contour bunds increased linearly with season (R^2=0.87). It increased from 10% to 27% in three seasons, with a increment of 6.6% every season (Figure 18)

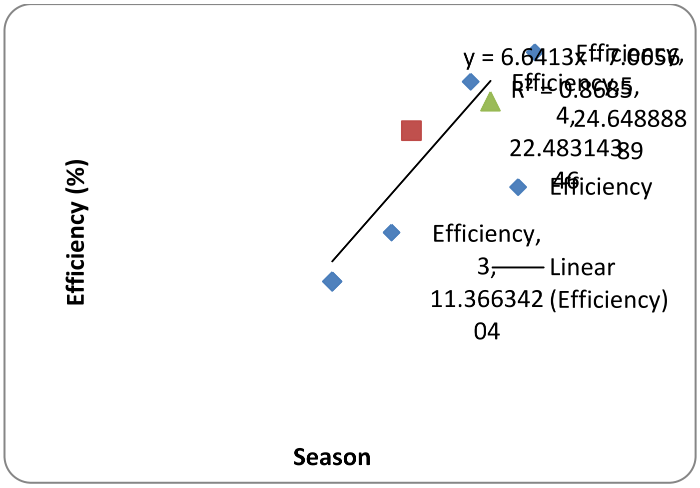


Figure 25: Linear increase of the efficiency of contour bunds in Soroti

C. Effect of the practice on yield

C.1 Grassland biomass

Only results for the middle slope of Lwemikunya are presented here. This is because the grassland (upper steeper slopes of Lwemikunya and in Awoja) were burnt before the harvest. As figure 19 depicts it, biomass tremendeously increased on contour bund-treated area compared to non-treated land. Non-treated land had its biomass ranging from 0 to 378.32 g/m^2 while the plot with contour bund had its biomass ranging from 0 to 1273.22.69 g/m^2. The figure also shows that the portion of the land with contour bunds had gradual increase in dry biomass.

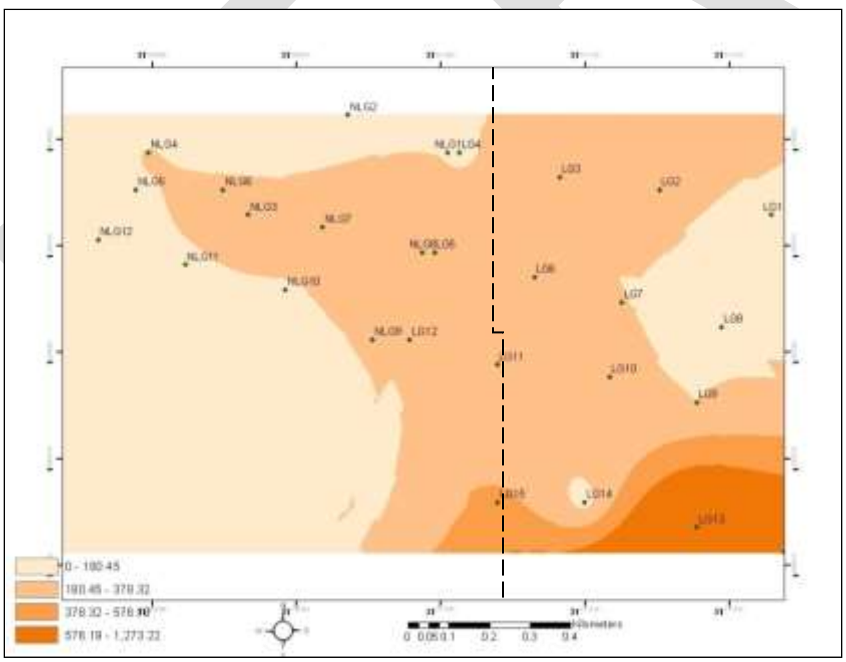


Figure 26: Comparison of the biomass between treated and non-treated land in Lwemikunya

Only data from Lwemikunya will be presented for rangeland since in Awoja farmers burnt the biomass before the period data was supposed to be collected.

Selected soil properties of the rangeland in Lwemikunya (low slope) including OM, pH, P, N and bulk density are depicted in the Figures 20 to 24. Generally, plots with contour bunds had relatively high organic matter than those without contour bunds. Soil organic matter tended to gradually increase downward.

Soils were generally strongly acidic, however, plots with contour bunds presented patches of acidic conditions (4.5< pH<5.5). Although both plots with and without contour bunds were dominantly with low P content in soils, there was a tendency of P content increment downward on plots with contour bunds as compared to plots without contour bunds. Nitrogen content showed a gradual decrease on plot without contour bunds while most of the plot with contour bunds tended to have low nitrogen content. Bulk density was relatively high under plots without contour bunds compared with plots with contour bunds. Opposite trends exist between the two treatments, a declining trend downward and an increased trend for plots with contour bunds and plot without was observed.

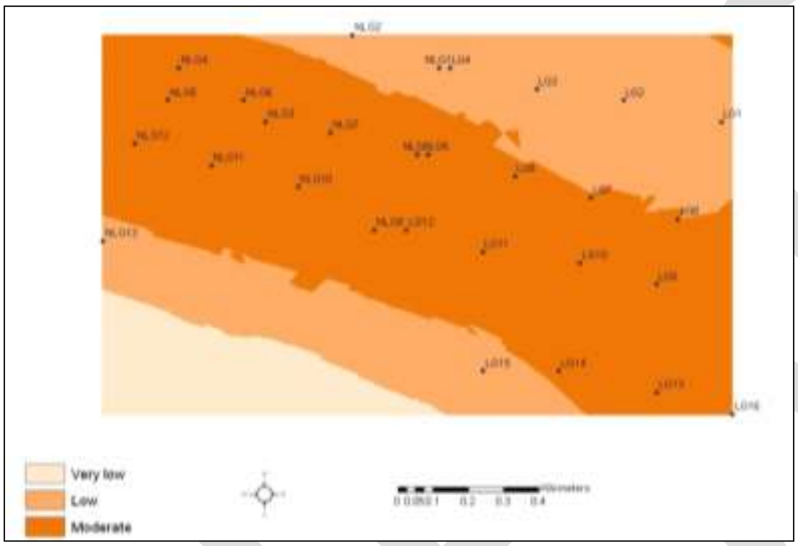


Figure 27: Soil organic matter of treated and non-treated land

Figure 28: soil pH of treated and non-treated land in Lwemikunya

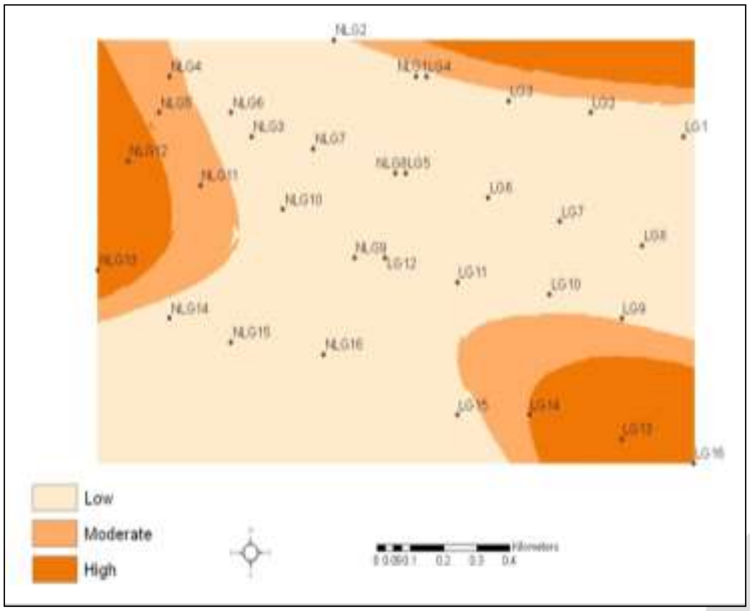


Figure 29 : Soil P of treated and non-treated land in Lwemikunya

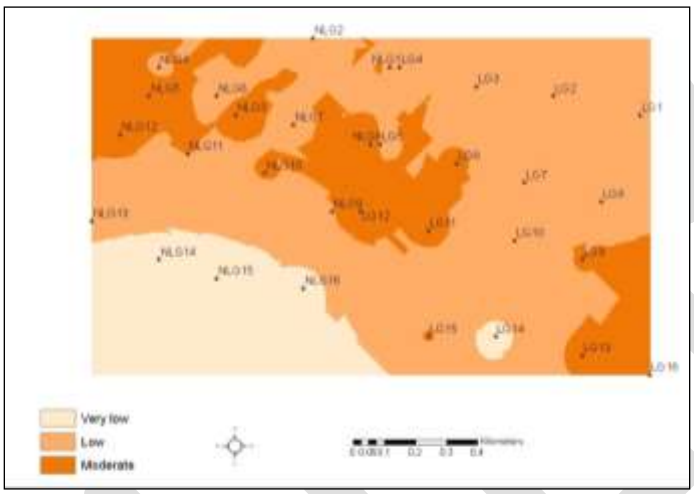


Figure 30: Soil Nitrogen of treated and non-treated land in Lwemikunya

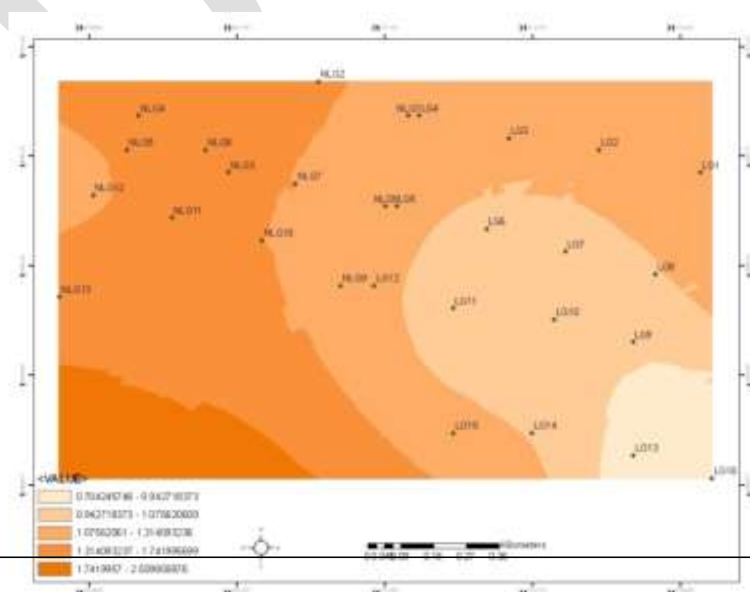


Figure 31: Soil bulk density of treated and non-treated land in Lwemikunya

c.2. Yield of other crops

C.2.1 Sorghum in Awoja

Sorghum yield in Gweri/Soroti district is given in Figure 25. Sorghum yield varied from 450 Kg and 1250 Kg/ha. Sorghum spaced with mychorriza application yielded highly during the sorghum planting season for the two years of sorghum experiment compared with Soghum spaced without mycorrhiza and sorghum broadcasted with myccorrhiza.

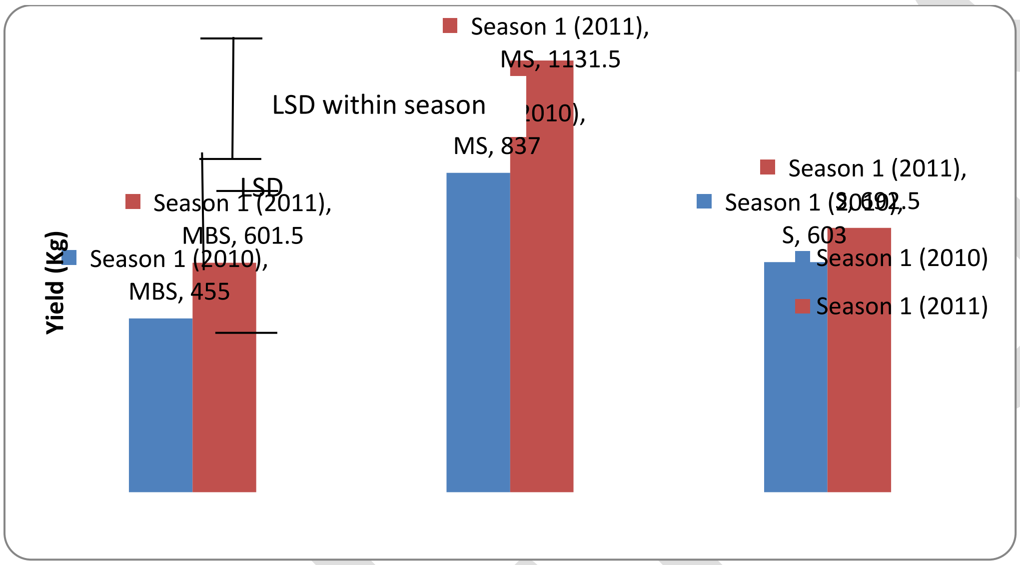


Figure 32: Yield of sorghum (2010-2011)

C.2.2 Cassava and groundnut in Gweri

Cassava yield is presented in Figure 26. The yield of cassava with cover crop (16.75 t/ha) was higher than that of cassava without cover crop (8.45 t/ha) (P=0.06). This represents 98.3% yield increment. Yield of groundnut planted during the 2010 season 2 is also given in Figure 27. It was also observed that plots with cover crop yielded more groundnut than those without cover crop (p=0.031). Plots where cover crop were incorporated yielded 649.5 Kg/ha while those where cover crop was not incorporated yielded 408.2 Kg/ha.

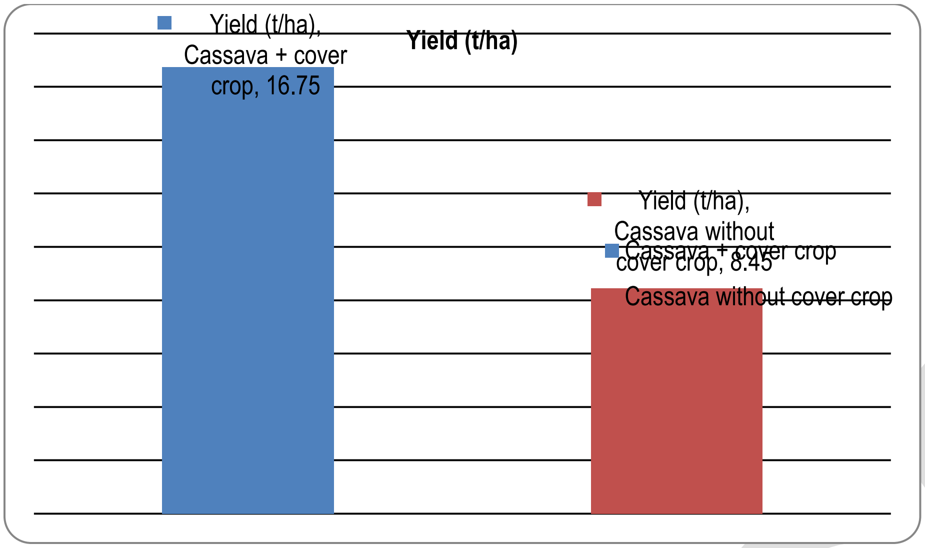


Figure 33: Yield of cassava in Gweri (2008-2011) (Annual Average)

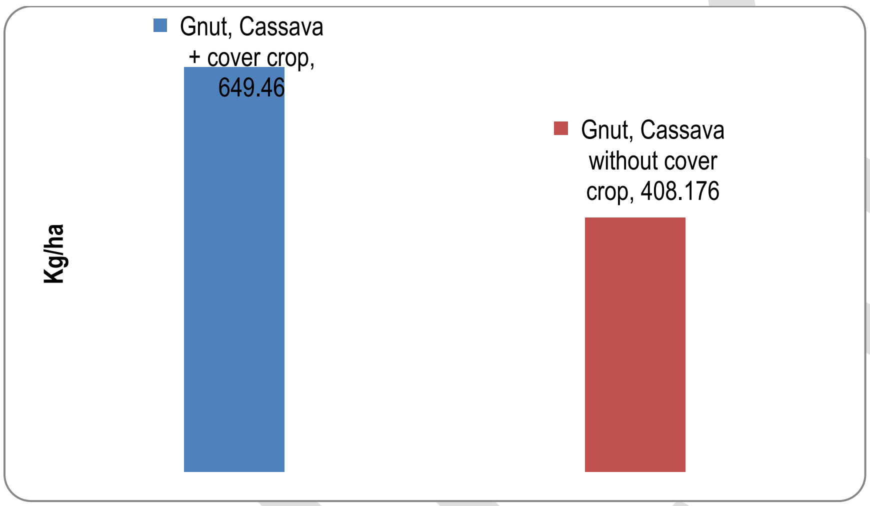


Figure 34: Yield of cassava in Gweri (Season 2, 2010)

C.2.3 Maize in Rakai

Maize yield under annuals and annuals + contour bunds are summarized in Table 1below. The two treatments showed significant differences from year two and three (p=0.002). In 2011 maize yield under annuals without contour bunds increased significantly (p=0.009) compared to that of the previous years. Maize yield under the two treatments increased linearly with time, with those under contour bunds presenting a relatively higher gradient (121 Kg/yr compared to 94.5 Kg/ha for plot without contour bunds) and coefficient of determination (98% compared to 71% for plot without contour bunds).

Table 1: Maize yield under annuals

Treatment	**Year**		
	2008	**2009**	**2011**

Annuals	575	564	764
Annuals + contour bunds	625	813	967
LSDtrt < 0.05	**107.8**		
LSDyr < 0.05	132.0		

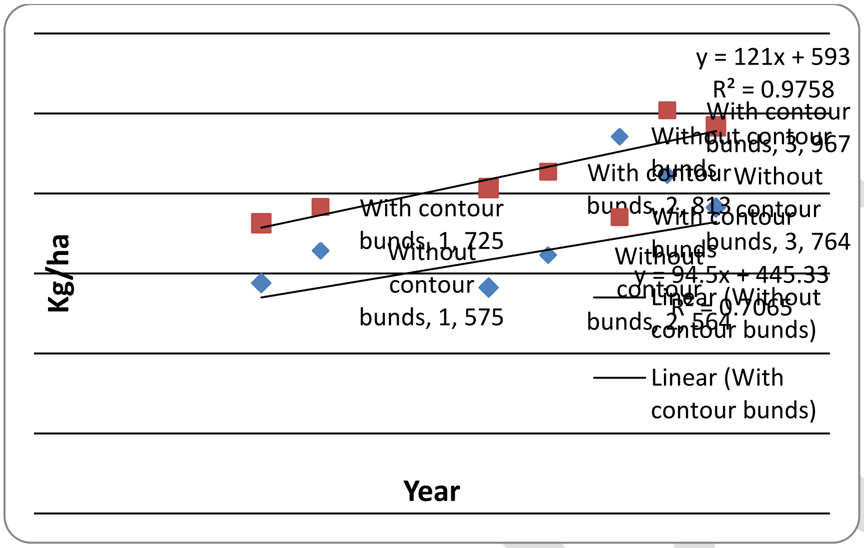


Figure 35: Trends in maize yield on plot with contour bunds and without contour bunds (Lwemikunya)

Groundnut yield did not significantly change with the treatment (P<0.05) but changed with time in both treatments (Figure 29). On average groundnut yield was of 828 Kg/ha. Ground nut yield increased significantly linearly with time on both treatments (R^2=0.96; Y=134X+560.33).

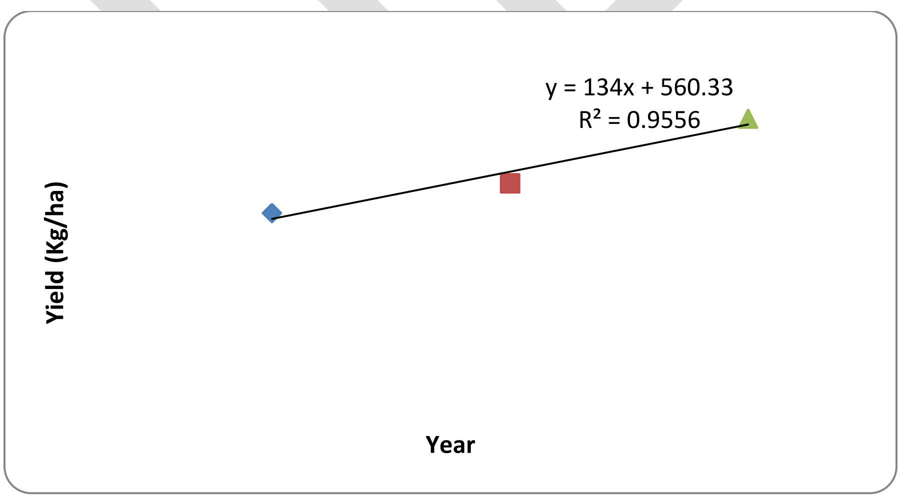


Figure 36: Trend in groundnut yield on annuals plots in Lwemikunya

C.2.4. Banana in Rakai

At the end of 2011, the average yield of banana bunch is presented in Figure 30 below. The weight of bunches under plots with contour bunds and mulch was significantly higher than that of the plots without contour bunds and mulch (P<0.001). This yield was three time higher.

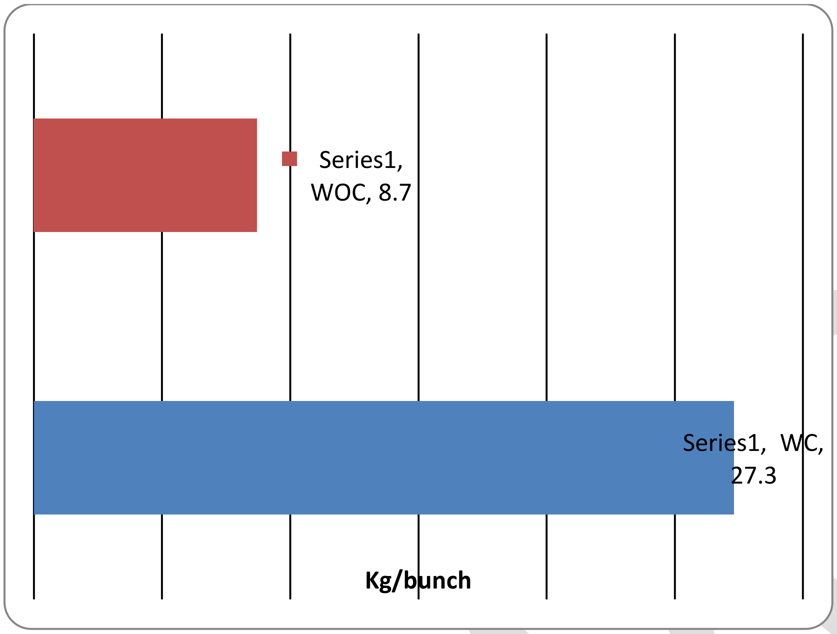


Figure 37: Average weight of banana bunch on plot with contour bund and mulch and on plot without contour bund and mulch.

Discussion

Contour bunds significantly reduced runoff on grazing land, annuals (maize intercropped with ground nut, cassava and sorghum) and increased biomass on grazing land, maize and groundnut, sorghum yield overtime (p<0.05). The efficiency of contour bunds was highest in Lwemikunya-Rakai than in Awoja-Soroti. The introduction of contour bunds on annuals in Lwemikunya induced a relative increment in runoff compared to the control in the first season before reducing thereafter to reach 80% of efficiency after three years. Cover crop had relatively low runoff efficiency under annuals for the first and second seasons before increasing afterward. Mulched banana had consistently improved its efficiency over time.

The efficiency of contour bunds in this study confirms early findings by several other scholars (Herweg 1993; Gebremedhin *et al.*, 2000; Pender and Gebremedhin 2004; Benin 2004) who had shown that terraces and several other land management practices can increase productivity fairly quickly by increasing soil moisture retention, thus being profitable for farmers in lower rainfall areas of the northern Ethiopian highlands. It is also in line with previous findings in the Rakai region by Majaliwa (2005). In Machakos district in Kenya, Tiffen *et al.* (1994) observed that the adoption of "fanya juu" terraces played an important role in reducing land degradation over the period from 1930s -1990s when population increased more than fivefold. Results from studies have shown substantial increases in yield on land with "fanya juu" terraces compared to non-terraced land (Ngigi, 2003). Studies in Kangundo, Machakos District, Kenya (Lindgren 1988) showed that incremental yield could be realized on terraced land versus the yield from the non-terraced land. In fact Lingren (1988) obtained 47 percent increment in 1984/1985, and 62 percent in 1987/1988. Tied ridges have been found to be very efficient in storing the rain water, which has resulted in substantial grain yield increase in some of the major dryland crops such as sorghum, maize, wheat, and mung beans in Ethiopia (Georgis and Takele, 2000). The average grain yield increase (under tied ridges) ranged from 50 to over 100 percent when compared with the traditional practice. This increase, however, will vary according to the soil type, slope, rainfall and the crop grown in dryland areas. The same techniques were, however, much less profitable in higher rainfall areas of the highlands since they can actually reduce farmers' yields by reducing the effective area of the plot, causing waterlogging, or harboring pests (Herweg 1993; Benin 2004).

The importance of mulches in reducing surface runoff losses is re-confirmed by this study. Similar observations were made in an experiment in the Laikipia District of Kenya, where in the absence of mulch, 40-60 percent of the rain that fell was lost to evaporation, and that if 40-50 percent of the ground was covered with mulch, surface runoff losses were reduced to almost zero and evaporation losses halved (Liniger, 1991). Crop yields were found to double or triple and biomass to feed the livestock increased. A participatory experiment with farmer innovators in Mbozi District, showed that by planting velvet bean under coffee the weeds were reduced (smothered by the cover of the bean), while the coffee yield increased due to water conservation and soil fertility improvement, as a result of nitrogen fixation by the beans; (Hilhorst and Toulmin 2000; Kibwana 2001; Mruma and Temu 1999; Thomas and Mati, 2000).

Performance of selected on-farm practices on runoff: In the relatively dry area of Soroti/Awoja sub-catchment, the influence on runoff of the on-farm practices tested proved positive overall. The application of cover crop reduced significantly runoff on cassava garden ($P<0.05$), by more than three times over the research period. Regular spacing of sorghum also reduced significantly runoff compared to the broadcasting practiced by farmers. Although the application of MakMYCO seemed to have relatively reduced runoff compared to regular spacing alone, the difference was not statistically significant ($P>0.05$). Contour bunds reduced significantly runoff generated on rangeland in Soroti ($P<0.05$). The trend over time of these positive effects on runoff varied with treatments and with land use types. Myccorrhized sorghum with regular spacing had its runoff reduction efficiency increasing exponentially ($R^2=0.45$) while mycchorized sorghum broadcasted's efficiency showed a quadratic trend. On grazing land, the efficiency of contour bunds increased linearly with season ($R^2=0.87$).

In the sub-humid region (Rakai/Lwemikunya sub-ctachment), Runoff considerably varied from one agricultural land-use to another. Generally rangelands on steep slope had the highest runoff compared to other land-uses ($P<0.05$). Perennials (Banana) had the lowest seasonal runoff volume. Contour bunds on annual crops reduced runoff linearly overtime ($R^2=0.63$), though runoff increased by about 80% during the first season just after the introduction of the contour bunds. The effect of contour bunds on runoff from rangeland located on steep slope also showed a significant linear trend overtime ($R^2=0.55$). Under banana, the effect of mulch on runoff was positive even during the first season, with a relative reduction of 36.2%.The trend of the introduction of contour bunds on middle slope rangelands showed a quadratic form ($R^2=0.54$). The efficiency of cover crop in reducing runoff remained above 70% for five seasons, following a quadratic trend ($R^2=0.53$).

Effect of the on-farm practices on biomass and yields: In Lwemikunya/Rakai on middle slope grazing land, biomass tremendously increased (gradually) on contour bund-treated area, ranging from 0 to 1273.22 g/m^2 compared to the control where biomass ranged from 0 to 378.32 g/m^2. With regard to soil properties, generally plots with contour bunds had relatively high organic matter compared to those without contour bunds. Soil organic matter tended to gradually increase downward the slope. While soils were generally strongly acidic, plots with contour bunds presented patches of reduced acidic conditions ($4.5 < pH < 5.5$). There was a tendency of P content increment (downward on plots with contour bunds as compared to plots without contour bunds. Nitrogen content showed a gradual decrease on plot without contour bunds while most of the plot with contour bunds tended to have low nitrogen content. Bulk density presented a declining trend for plots with contour bunds while an increasing trend was observed for plot without contour bunds.

Like the biomass, the yields of the other crops proved to have been positively impacted by the evaluated on-farm practices in both relatively dry area of Soroti and sub-humid zone of Rakai: In the dry area of Soroti , sorghum yield varied from 450 Kg to 1250 Kg/ha. Sorghum spaced with mychorriza application yielded highly compared with Sorghum spaced without mycorrhiza and sorghum broadcasted with myccorrhiza. The yield of cassava with cover crop (16.75 t/ha) was higher than that of cassava without cover crop (8.45 t/ha) (P=0.06), representing a 98.3% yield increment. Similarly, plots with cover crop yielded more groundnut (649.5 Kg/ha) than the control (408.2 Kg/ha) (p=0.031). In sub-humid zone, comparison of maize yield under annuals, and annuals treated with contour bunds showed significant differences from year two and three (p=0.002): In 2011 , maize yield for plot under contour bunds presented a relatively higher gradient (121 Kg/ha/yr, R^2=0.98) compared to 94.5 Kg/ha/yr, R^2=0.71) for control plots. Groundnut yield did not significantly change with the treatment (P<0.05) but the average groundnut yield was of 828 Kg/ha and it increased significantly linearly with time on both treatments (R^2=0.96). At the end of 2011, the weight of banana bunches on plots with contour bunds and mulch was significantly three times higher than that of the plots with none (P<0.001).

Conclusions

There is need to sensitize the communities on the efficiency of the existing soil and water conservation practices and promotes them.

Existing soil and water conservation practices present high runoff reduction efficiency and the latter increased with time. It can therefore be used to control runoff losses, and significantly increased crop yield in the two sub-catchments. These practices included contour bunds for maize and grazing land, mulch and contour bunds for banana (sub-humid region), mycchoriza for sorghum and cover crop for cassava in Soroti.

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