# Assessment of Crop Yields And Soil Fertility Based On The Location Of Bench Terraces In The Landscape

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**Abstract**

Soil erosion is a pressing challenge causing deterioration of soil quality and bench terraces are measures to minimize it nonetheless crop yield is not t of quality the same and quantity along the terraces. The objective of this research was examining the crops growth and yield parameters and soil properties along the slope of terraces. Testing of soil samples and evaluating crop growth parameters collected on upper, middle and lower slopes of Mugera bench terrace. There was a decrease in acidity from upper to lower slopes while there was an increase in maize yield Therefore, compering the yield trends by location in the landscape, the effect of the slope was very clear. The maximum grain yield of 6.21 tons per hectare was observed in down slope, followed by Middle slope which produced 5.78 t/ha. The upper slope produced a minimum of 5.031 t/ha. These differences in the grain yield according land steepness are due to the soil properties, soil fertility as shown by the results.



**Key words:** Crop Yields, Soil Fertility and Bench Terraces

## 1. INTRODUCTION

Land degradation implies reduction of resource potential by one or a combination of processes acting on land. These processes include soil exhaustion, water erosion, wind erosion, and sedimentation by those agents, resulting in long term reduction in amount or diversity of natural vegetation (Suresh, 2002). The decrease in soil productivity and yields as a consequence of continued land degradation in Rwanda is a serious threat to sustainable livelihoods for the rural population and it is a major factor of the high level of poverty in the countryside. (MINICOFIN,2009). Soil degradation has become a major concern in sub-Saharan Africa (Oldeman *et al.*,1994). Erosion, salinization, acidification and the loss of organic matter are the main forms of soil degradation. The loss of soil organic matter is a slow process that is related to improper management practices and natural degradation processes and due to the water erosion flows downward

The main cause of soil erosion in Rwanda is rainfall since other forms of erosion are not significant. The high slope gradient of (75% of the cultivated land), the fragility of soils, the high rainfall and the way the land is utilized, make Rwanda very susceptible to soil erosion; this erosion occurs on all national territory at different degree according to agro-climatic regions and depending on slopes (MINAGRI, 2002). In North and Oust of country the landslides cause the disasters and caused the death of people.

Bench terraces are a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers (Inbar, *et al*., 2000). Crops and other forms of vegetation vary considerably in their ability to protect the soil from the erosive effects of rainfall and runoff. Furthermore, differences in the rates of maturity, extent of leaf cover, root systems, and crop-specific farming practices, are some of the more important factors that determine the relative effectiveness of various forms of agricultural land use in controlling soil loss. These factors can also affect the overall performance of land engineering strategies. The horizontal steps make it possible to absorb all water and to capitalize the manure that one accumulates there. But, it must be clear that the radical terrace requires large investments in work 500 to 1.200 days per hectare and in inputs of 20 t/ha of manure, 1 to 5 lime t/ha and other manure specific to each culture. (König 1994). The aims of bench terraces are: to control the velocity of overland flow and to check excessive soil erosion on hill slopes, to achieve optimum rain water utilization by increasing infiltration opportunity time for it and to ensure equitable soil moisture distribution and for providing required drainage (Tengnass, 2000). The main objective of this study is to assess the crop yields and soil fertility based on the location of bench terraces in the landscape in Gatsibo District.

## 2. Materials and Methods

The components of the research were in two objectives which were achieved through the appropriated materials, methods and techniques. The first objective of this research concerned assessing the maize growth and yields parameters by evaluation the germination, height and yield of maize based on to the location of bench terraces in the landscape of Mugera site of Gatsibo District. The last was concerned to the assessment of the soil fertility based on the land slope.

## 2.1. MATERIALS

### 2.1.1. Description of Study Area

Gatsibo District is one of the seven Districts in the Eastern Province. It is divided into 14 Sectors spreading an area of 1585.3 $km^2$. The District borders Akagera National Park in the East, Nyagatare District in the North; Gicumbi District in the West, and in the South it borders Rwamagana and Kayonza Districts.

The District is located in the granite low valley whose average altitude is 1550m spread on the plateau and the savannah of the Eastern part of the country. (www.gatsibo.gov.rw). The volume of annual precipitations on the whole of the district lies between 900 and 1400 mm of rains, the The hydrography of Gatsibo District is largely constituted of streams and rivers such as; Walfu, Karungeri, Cyamuganga,Kanyonyomba, Rwangingo, Kabahanga, Kagina, Kagende, Rwagitima and Ntende. (www.gatsibo.gov.rw).

The soil is characterized by a ferralisols one originating from laterite. Agriculture in terms of crop production and livestock is the principle economic activity in the district. According to Integrated Household Living Conditions Survey 3 ( EICV3), 84.9 % of Gatsibo population depends on agriculture. Of these at least 80% use traditional agriculture practices. The major food crops produced in the district are beans, rice maize, potatoes, sweet potatoes, bananas, sorghum, cassava, passion fruits, peas, maize and soya. (www.gatsibo.gov.rw).

## 2.2. **Methodology**

### 2.2.1. Sites selection

The study site was selected because of its size and proximity. It is the largest among other sites in the District with more than 50 hectares of terraces and it is located 450 M away from main road.

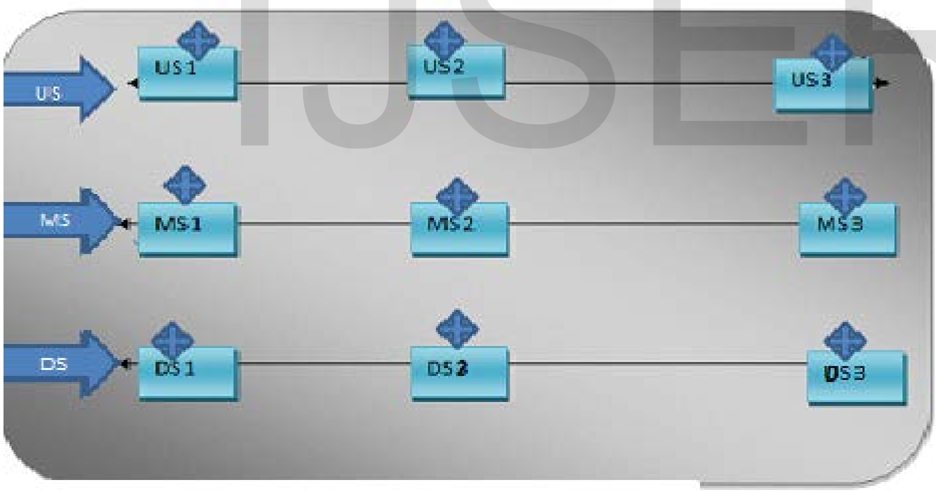
### 2.2.2. oil sampling and experimental design

Before planting, soil samples of 1,5 kg were collected for laboratory tests. Nine samples of soil in Mugera site were taken using an auger at a depth of 30 cm: 3 samples from upper slope (US), 3 from middle slope (MS) and 3 from down slope of site (DS), as illustrated in Fig 1. One composite sample was made from the 3 collected sub samples meaning that each level of slope was considered. The samples were sent to Rwanda Agriculture Board (RAB) Rubona Research center in soil and plant analytical laboratory for processing and analysis. The analyzed properties include; soil pH, soil texture and available nutrients including N, P, K, OM, Ca, and Mg.

**The experimental design:**

We divided the site into three groups/parts according to the steepness/slope and each group has 3 plots of 2.5 mx5m as shown with below figure.






2.5mx5m=12.5m$^2$

*US: Upper Slope*
*MS: Middle Slope*
*DS: Down Slope*

**Figure 1 : Sample point and plots**

### 2.2.3. Crop management

**Planting:** Before planting, the land was ploughed using hoes to a depth of 20-30cm. White Hybrid Maize Seed PAN 67 was used for the study experiment. This variety has a medium duration maturing variety that takes 100-115 days to mature with 8-11t $ha^{-}1$ in controlled condition or station. Planting was done at a depth of 4-5cm on the 15$^{th}$ and 17$^{th}$ of September 2015 (season A2016). The plant spacing was 75cm x 40cm. In the season before the experiment, Mugera site was cultivated with beans. At planting the time, 20t/ha of organic manure and 100kg/ha of DAP were applied in furrows as basal dressing to the plots.

**Weeding:** Weeds were controlled by hoes, two weeding sessions were conducted to make sure that the crop is kept weed free throughout the whole season. This was done on the 14th, of October and 13th of December 2015 for the 1$^{st}$ and 2nd weeding sessions respectively, 50kg/ha of urea was used.

### 2.2.4. Data collection

**Plant Sample Selection**: After recording germination and then thinning to two plants per pit, seven plants for the further measurement were selected using 'Z' type distribution from top to bottom along the plot, avoiding the border plants in case of edge effects. Non-destructive measurements were carried out at intervals during the growing season after fertilizer application, including height, leaf number and leaf area the same seven plants were used per plot, with non-representative and border plants excluded.

**Seeds Germination**: seven to nine days after planting, crop establishment assessment was conducted. Physical plant count was done for each experimental unit,. Five rows were randomly selected per each experimental unit; plants were counted and recorded against the expected 100 plants for the five rows. The total germination plants recorded per each experimental unit were used to calculate the germination percentage for that specific sub plot.

**Plant Height:** Plant height was measured 50 days and 80 days after thinning the seedlings. The height was measured from the soil surface to the top of the longest leaf. After maize flowering, the height was measured with decameter from the ground surface to the top of the flower.

**Harvesting and final yield assessment**: Harvesting was carried out when the crop was physiologically mature at 100-120 days after sowing in January 2016. Yield was measured based on; 1000 gain weight and grain yield. The yield of different treatments was calculated, based on these data. The maize yield of whole plots records was weighted after harvesting.

### 2.2.5. Data analysis

Data were presented using MS Excel tables and chart. To make sure that a chosen sample is really representing the whole site, the formula given was used after data collection, data were arranged and analyzed using MS Excel spreadsheet and discussion were performed.

## 3. RESULTS AND DISCUSSION

### 3.1. Introduction

This chapter provides a detailed presentation, interpretation of results as well as their discussion according to the research objectives. The results are based on experimental work of field-based research and associated laboratory experiments.

### 3.2. Soil characteristics and fertility

The table below illustrates the results of soil fertility of Mugera bench terraces site for across different slope level, lower, middle and upper slopes.

**Table 1**: soil fertility parameters across different slope level

| Location | pH-$H_2O$ | pH-Kcl | N % | OM % | Bray-P mg kg-1 | K $cmol_c$ $kg^{-1}$ | ca mgk g-1 | Mg mgk g-1 | Na mgk g-1 | Sand % | Clay % | Silt % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | 4.4 | 4.1 | 0.2 | 5.6 | 18.77 | 1.0 | 2.4 | 1.9 | 0.04 | 60 | 29 | 11 |
| MS | 5.1 | 4.9 | 0.4 | 6.8 | 17.08 | 1.1 | 2.3 | 2.3 | 0.07 | 57 | 30 | 13 |
| LS | 5.8 | 5.6 | 0.6 | 7.00 | 20.51 | 0.6 | 2.2 | 3.3 | 0.14 | 56 | 31 | 13 |

The above table showing the results of characteristic of soil obtained from Mugera bench terraces site. There were differences in clay, Silt and sand content among the slope positions, whereas silt content was at lower slope (13%) than upper slope (11 %) positions. Considering the three slope categories, the highest clay fraction (31%) was found at the lower slope, while the highest sand fraction (60%) was found at the upper slope. This may be due to recent crop cultivation encroachment to the top of the land topography and which brings less weathered sandy soil resulted by erosion; According to Roose, (1977), if the quality of eroded soil and the runoff water collected downstream of the eroded plots is compared with the soil left in place to a depth of 10 cm, in terms of plant cover and extent of losses through erosion.

Conversely, the suspended finer particles were transported down the slope where they accumulate at the bottom thus increasing the clay and silt contents. The reason could be, during the erosion processes, the suspended clay particles also leach down the results above are evidences.



The results on pH-$H_20$ proved that: on up slope the average is 4.4, Middle slope is 5.1 and 5.8 on down slope and in general the distribution of soil pH across the upper, middle and down slope positions was moderately acidic 5.1.

Soil pH is a fundamental property controlling soil biological and chemical processes, such as biological nitrogen fixation, root growth and the mineralization of organic matter. It is also an indicator of soil acidification due to acid deposition resulting from industrial processes, or from agricultural activities. There are several standard ways of measuring soil pH, each with advantages under particular circumstances (for example in 1M KCl, 0.01 M CaCl2, saturated paste extract). The proposal is for a single, easily-applied index (Snyder, 1989).

Therefore the lowest value of pH at the up slope could be due to the water erosion and perhaps suggesting the washing out of solutes (Na+) from these parts to the lowest part. The increase in soil pH down the soil depth could be attributed to the downward movement of Ca and Mg and accumulation therein the subsurface soil layer. Hao and Chang(2016) reported similar results and revealed that in irrigated soils Ca2+ decreased in surface soil but increased according to the land steepness due to the downward movement of lime with erosion water to subsurface soil that cause an increase in soil pH.

Soil analysis results showed that the available P contents were increasing with increasing slope percentage, up slope, middle slope and down slope by 20.51, 17.08 and 18.77 respectively. The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of organic matter and commercial fertilizers. Pruess,. Bushiazzo,. Schlichting and Stahr (1992) argued that the amount of organic matter in the semi-arid region is the main factor of controlling P and other soil fertility parameters. Thus, increased in SOM content at higher slope with less erosion hazards might have increased the available P in soil at higher slope position. The Ca content was 0.6 cmolckg$^{-1}$ at the lower slope compared with 1.0 cmolckg$^{-1}$ at upper slope.
The results in Mg and K content showed the same trends compared with those of Ca table 1. The Mg and K content were 3.3 cmolckg$^{-1}$ and 0.6 cmol cmolckg$^{-1}$ at lower slope as compared with 1.9 cmol ckg$^{-1}$ and 1. Cmolc kg$^{-1}$ at higher slope respectively.

Therefore nutrient losses grow in parallel with the volume of runoff and eroded matter; but the nutrient content of soil falls more slowly than the rise in the volume of displaced soil and water; much higher proportions of nutrients are found in the water and eroded soil than in the soil in place (horizon: 10 cm); this is clear for carbon, nitrogen, phosphorus, clay and loam but still more striking for exchangeable bases (Fungo, *et al*., 2011). Therefore this confirms the results obtained during our study done at Mugera site.

Organic matter decreased with increased slope gradients. Higher values of organic matter (7.00) were recorded in the lower slope and 5.6 in the upper slope. The relocation of topsoil materials from the upper to lower slope positions is probably due to the effect of cultivation and geomorphological processes that involves the mechanical movement of soil materials. This observation corroborate earlier studies by Brunner *et.al* (2004), Mulumba (2004), Essoka and Jaieyeoba (2008) where they reported that that lower slope carrying and deposition of organic residues is common in Mountainous areas.

The study showed that erosion dominates the hill slope tops, particles are detached and then carried downwards. Consequently, a gradual clay enrichment of the surface horizon is observed along the slope, at the hill slope scale (Fungo, *et al*., 2011). However, top sequence variation in other soil properties was remarkable. There were distinct patterns in soil properties across the different slope positions. The reason for this could be due to land use types, soil erosion and other more factors (Agriculture) where samples were collected. This is quite common in African soils (Fungo, et.al, 2011). The result above helps us to test our hypothesis and accepted it because the soil fertility, P,K,N organic matter and other nutrients, soil properties such as clay, silt and sand vary according to the slope site.

### 3.3. Assessment of maize growth and yields parameters

Germination rate, Plant height and yield were measured from the ground level to the growing point and the observation were recorded at the end of the growing period for each treatment and were expressed in percentage (germination rate) and centimeters. The observations on yield were recorded at the time of harvesting. After harvesting, the grains were weighed from each treatment plots were summed up and expressed in tone/ha, table 2.

**Table 2** Maize growth parameters on land steepness.



| **Treatment** | **Germination Rate % (7-9days)** | **Plant height (Cm)** | | **Average Number of cobs /plant** |
|---|---|---|---|---|
| | | **After 50 days** | **After 80 days** | |
| **US** | 98 | 170.00 | 216.00 | 1.8 |
| **MS** | 97 | 173 | 219.33 | 2.0 |
| **LS** | 98 | 176 | 222.33 | 2.2 |
| **Average** | **97.6** | **173.00** | **219.22** | **2.03** |

Germination rate assessment started on the 7th till the 14th day after planting. Data showed that the effect of land slope on plant height with a slight difference of 3 to 6 cm at $50^{th}$ day after sowing. Plant population in *Table 2* showed that maximum plants height at $80^{th}$ day (222.33 cm) was observed in lower slope, in the middle slope the plants growth 219.33 cm and 216 cm for upper slope. These results are in line with the findings of Whitehea (2011) who reported that: It will be seen that the average leaf area and plant length at the lowest wind speed was many times greater than that at the highest speed.

The number of cobs per plant is an important yield parameter of maize. Data regarding to the number of cobs per plant as affected by plant land slope revealed that the number of cobs per plant was changed notably with land slope where in the down slope the average of cobs number per plant is 2.2 but in the middle slope was 2.0 in upper slope the average is 1.8 cobs/plant. The results showed that the maximum number of cobs per plant was produced in the lower slope with 2.2 cobs /plants.

**3.4. Maize yields parameters as affected by land steepness**

**3.4.1. Grain weight**

Maize cropped on the lower slope had high yield than maize grown on upper slope( fig.2). the yile

The data along with analysis of 1000 grain weight and yield maize are presented in below figure. The comparison of different slope showed that maize cropped on down slope produced more than maize grown upper slope.

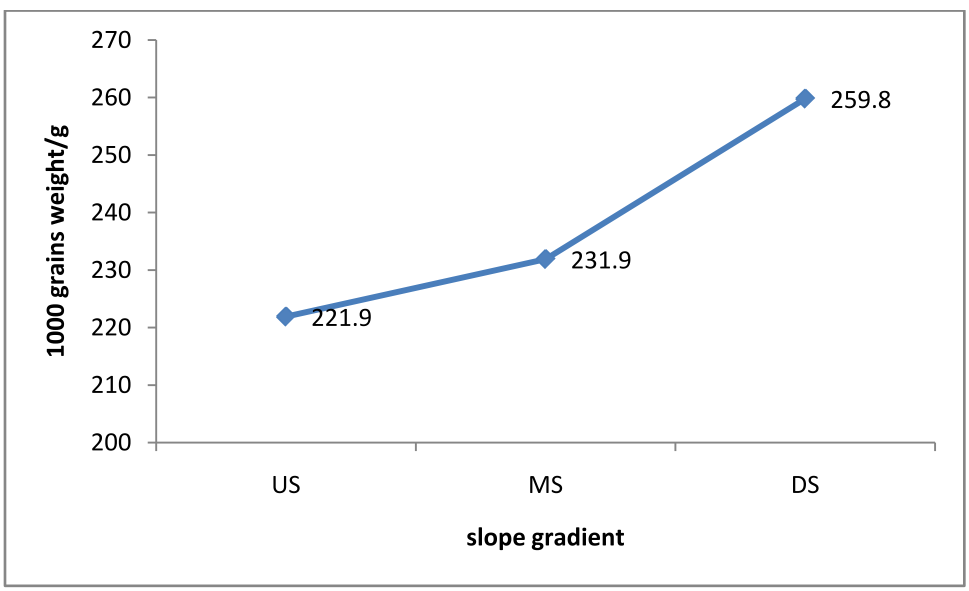



**Figure 1: 1000 Grains weight/g**

The 1000 Grains weight is an important yield contributing factor, which plays an important role in showing the potential of a variety andquality of grain. Data in *figure2* indicates that big different effect of land slope on 1000 grain weight.

The maize grown on lower slope produced significantly maximum (253.83 gr) weight of 1000 grains, followed by maize grown on middle slope which produced (231.90) grams 1000- grain weight and few grams obtained on Upper slope with 221.9 g and comparing the yield trends of three experiments on Mugera site, the effects of different slopes were very clear. Grain yield is on the yield components of a crop.

Although a function of genetic makeup of cultivars, morphological, physiological processes and growing conditions, topographical conditions may also influence maize grains

### 3.4.2. Grain yield

Maize cropped on the lower slope had high yield than maize grown on the upper slope ( fig.3). the yield of lower slope was ……..% higher than on the upper slope while there was no significant different between the yield on the middle slope and upper

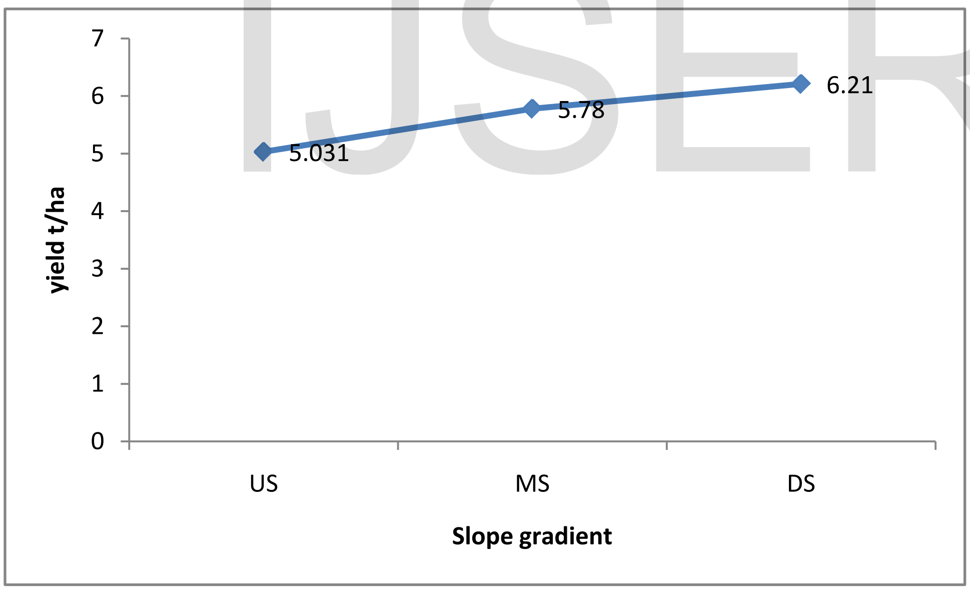



**Figure 2 : Grain yield t/ha**

It is clear from the data that the maize on the same site but difference slopes differed highly considerably in grain yield from each other. The maximum grain yield 6.21 tons per hectare was observed in down slope, followed by Middle slope which produced 5.78 t/ha. The upper slope produced a grain yield of followed by a minimum of 5.031 t/ha. Grain yield is the product of crop dry matter accumulation and the proportion of the dry matter allocated to the grain.

These differences in the grain yield according to the soil steepness are due to the soil properties, soil fertility table 1. The same results were found by Konuskan (2000);Gozubenli *et al*. (2001) and Farnham (2001).

According to the Roose (1977), if the quality of eroded soil and the runoff water collected downstream of the eroded plots is compared with the soil left in place to a depth of 10 cm; in terms of plant cover and extent of losses through erosion.

Therefore nutrient losses grow in parallel with the volume of runoff and eroded matter; but the nutrient content of soil falls more slowly than the rise in the volume of displaced soil and water downward movement; much higher proportions of nutrients are found in the water and eroded soil than in the soil in place. Therefore the crops grow better in down of the hills than up because of these nutrients. Sheet erosion is thus selective in terms of the nutrients and colloids that are the essence of soil fertility; the lower the eroded volume the greater the selectivity of sheet erosion,

Losses of cereal production and tuber production due to the loss of soil nutrients caused by water erosion can be roughly quantified as $20 per ha and with 1,160,000 ha in cultivation this translates into $23,200,000 a year. With agricultural GDP at $650 m, the drop in value is 3.5% of agricultural GDP. While these are generalizations from specific data in poverty stricken country hopes of economic growth in the agricultural sector will depend on reversing the productivity decline including dealing with the land degradation problem (König 1994). Accordingly the second hypothesis has been rejected.

## **4.** Conclusion

The results of our work confirmed that detrimental effects of soil erosion are higher at upper slope as compared to middle and lower slope thereby changing the soluble salts and mineral nutrient concentration in the root zone thus affecting soil productivity. Comparing the yield trends of three slope levels experiments in Mugera site, the effects of different slopes were very clear. The maximum grain yield 6.21 tons per hectare was observed in lower slope, followed by

Middle slope which produced 5.78 t/ha then lower slope with 5.031 t/ha. These differences in the grain yield according to slope level are due to the soil properties, soil fertility as shown by the results. And were presumed to be due to past soil erosion affect that removed the finer soil particles including soil organic matter and other plant nutrients. Special attention may be given to top slope and middle position to control such damaging effects for its soil fertility restoration which would require soil restoration strategies such as using the many organic manure and green manure.

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