ECONOMIC IMPACT ANALYSIS OF RADICAL TERRACING PROJECT

Case study CYABI NGO Sector in GAKENKE District

Presented by:

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For the fulfillment for the requirements of bachelors’ degree (A0) in Soil and water management

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Academic year, 2011
DECLARATION

I, Jean BIZIMANA declare that the work presented in this memoir is my own research and has not been submitted for any degree in any other University /Institution of higher Learning and that all the sources of information here in contained have been duly acknowledged.

Signature .......................... Date ................................

Supervisor Signature ............ Date:..................................
DEDICATION

Almighty God
My beloved parents
My brothers and Sisters
All my Relatives
All my friends, classmates and colleagues
ACKNOWLEDGEMENT

The success of this research is the shared effort; whether materially or morally attributed to many persons and sincerely acknowledge them for having considerably supported me during my study at ISAE.

I first and foremost thank the Almighty God for his abundant blessings and protection during my studies and field work. I feel highly indebted to the Government of Rwanda through MINEDUC and I.S.A.E staff for the support given to us throughout this research and all academic programs in general. I am much thankful to my Supervisor Mr. NARAYANAN KANNAN lecturer of Soil and water management for his valuable guidance, collaboration and constructive suggestions, encouragement and his dedication which helped me to come to the successful completion of this research.

My special thanks are due to Suresh Kumar PANDE, and other lecturers of Soil and Water Management department for their kind assistance in theoretical and practical courses. I express my heartfelt gratitude to my parents, brothers, sisters, relatives and colleagues whose affection and encouragement have been a driving force for achieving my study. Last, I thank all my friends and classmates for their help and everybody who directly or indirectly has contributed to the achievement of this field research.

Jean BIZIMANA
ABSTRACT

Land degradation is a global constraint to economic development in countries such as Rwanda that has a complex topography where soil erosion is an important problem. Governmental and private institutions are promoting adoption of soil conservation Practices such as construction of slow formation terraces, and radical terraces yet they lack accurate estimates of the private and social benefits and costs of these investments. My intention in this study was to assess the changes in yield of selected crops (maize and bean) which are due to the radical terracing. The objective of this study is to provide a better understanding of the economics of terrace investments by developing a method to conduct a sensitivity analysis of an integrated assessment model designed for the agricultural production systems in Rwanda, and conducting an economic analysis of the effects of terraces on productivity and their economic implications. The key parameters in this study are:

- Investment cost
- Operating cost
- Percentage increase in yield and income and
- Benefit cost ratio

The analysis of data from surveyed farmers has been assessed, and output per ha in term income generated by obtained yield were calculated both before radical terracing project and after radical terracing project and it has been observed that there is significance between those two alternatives. To implement the project terracing actors are interested on suitable crop which generates much income than others, in our case is Maize. The results show that the changes are more occurred for maize crop than for bean crop where 39.86 % and 23.42% were the increase in income respectively for maize and bean.
RESUME

La dégradation du sol est une contrainte majeure dans les pays en voie de développement comme le Rwanda qui possède une topographie complexe où l’érosion du sol constitue un problème de grande importance. Les institutions privée et gouvernementales sont entrain de promouvoir l’adoption des pratiques de conservation des sols telle que les terrasses progressives et les terrasses radicales, qui manquent encore l’estimation occurrentes, l’intérêt social ainsi que les couts de ces investissements. Mon intention dans cette étude était d’évaluer changements des rendements de ces cultures sélectionnées (le maïs et le haricot) qui sont dus au terracement radical. L’objectif de cette étude est de fournir la bonne compréhension de l’économies des investissements des terraces par le développement d’une méthode sensitive d’analyse d’une modèle d’évaluation planifiée pour le système de production agricole au Rwanda, et de conduire l’analyse économique des effets des terrasses sur la productivité ainsi que leur implications. Les paramètres clés d’analyse sont :

- Le cout d’investissement
- Cout d’opération
- Prix d’achat
- Le pourcentage d’augmentation du rendement et du revenue ainsi que
- Le raport du profit au cout

Une analyse des données provenant des agriculteurs enquêtes a été évalué. Ainsi la revenue per ha produit par la récolte obtenue en cultivant les cultures sélectionnées dans la region. Ce revenue a été calculé avant le terracement radical et après ce terracement. Il a été observé qu’il y a une différence de rendement entre ces alternatives. Pour mettre en action du Project de terracement radical les acteurs sont appelés à sélectionner la culture qui donne beaucoup de rendements dans notre cas c’est le maïs. Les résultats ont montré que ces changements sont remarquable plus pour le maïs que pour le haricot, où 39.86 % et 23.42% sont le pourcentage d’augmentation respectivement pour le maïs et le haricot.
LIST OF CONTENTS

DECLARATION ........................................................................................................... i
DEDICATION ............................................................................................................. ii
ACKNOWLEDGEMENT ............................................................................................. iii
ABSTRACT .................................................................................................................. iv
RESUME .................................................................................................................... v
ACRONYMES AND ABBREVIATION ...................................................................... viii
LIST OF TABLES ....................................................................................................... ix
LIST OF FIGURE ...................................................................................................... x
LIST OF APPENDIXES .............................................................................................. xi

CHAPTER 1 : INTRODUCTION ................................................................................. 1
  1.1 Problem statement ............................................................................................ 2
  1.2 Significance of the study .................................................................................. 3
  1.3 Benefit of the study ........................................................................................... 3
  1.4 Scope and delimitation ....................................................................................... 3
  1.5 Overall objective ............................................................................................... 3
  1.6 Specific objectives: ........................................................................................... 3

CHAPTER 2 : LITERATURE REVIEW ........................................................................ 5
  2.1 Background on bench terraces ......................................................................... 5
  2.1.1 Definition and description ........................................................................... 5
  2.1.3 Objectives of bench terraces ....................................................................... 5
  2.2 Locations and conditions for use ...................................................................... 6
  2.3 Design specifications ........................................................................................... 6
  2.4 Diagrams, nomographs and tables .................................................................... 11
  2.5 Layout and surveying procedures ....................................................................... 11
  2.6 Surveying ........................................................................................................... 13
  2.6.1 Preparatory work ........................................................................................... 13
  2.6.2 Equipment ..................................................................................................... 13
  2.6.3 Basic techniques ............................................................................................ 13
  2.6.4 Special techniques ........................................................................................ 13
  2.6.5 Marking stakes ............................................................................................. 15
ACRONYMS AND ABREVIATION

BCR: benefit cost ratio
CDF : Common Development Fund
DAP: Diammonium Phosphate
DH : dyke height
DS: Direct support
FAO: Food and Agriculture Organization
FS :Financial Services
Hr : height of riser,
ISAE : Institut Superieur d’Agriculture et d’Elevage
LWH:Land water harvesting
MINAGRI: Ministère de l’Agriculture et des ressources animales
MINECOFIN: Ministère de Commerce et de la Finance
MINEDUC: Ministry of Education
NPK: Nitrogen Phosphorus Potassium
PADL: Program d’appui au Development local
PADL:Programme d’appui au Development local
PSNP: Productive Safety Net Programme
PW: Public Works
RLDSF : the Rwanda Local Development Support Fund
Rwf :Rwandan francs
SPSS: Social Package of Statisics for Social sciences
VI : vertical interval
VUP:Vision Umurenge Program
LIST OF TABLES

TABLE 1 : The average production per hour for different widths of terraces on moderate slope 19
TABLE 2: Repartition of household chiefs by sex ................................................................. 30
TABLE 3: Land exploitation and categories of farmer .......................................................... 33
TABLE 4: capital cost of terracing project .............................................................................. 35
TABLE 5: operating cost for maize ......................................................................................... 36
TABLE 6: operating cost for bean ......................................................................................... 37
TABLE 7 : Yield and income of maize before terracing both sasons ........................................ 43
TABLE 8: Yield and income of maize after terracing both seasons ........................................ 43
TABLE 9: Yield and income of bean before terracing both seasons ......................................... 44
TABLE 10: Yield and income of bean after terracing both seasons .......................................... 44
TABLE 11: Increase in yield and income ..................................................................................... 45
Table 12: benefit cost ratio before and after terracing ............................................................... 45
LIST OF FIGURE

FIGURE 1: Cross-sectional view and computations for reverse-sloped bench terraces.

FIGURE 2: Volumes of soil to be cut and filled per hectare for reverse-sloped bench terraces (FAO, 2009).

FIGURE 3: Size of house hold.

FIGURE 4: Education level of surveyed.

FIGURE 5: Percentage of adopted mechanical measures for farmers of the study area.

FIGURE 6: Yield of maize before radical terracing.

FIGURE 7: Yield of maize after radical terracing.

FIGURE 8: Yield of bean before radical terracing project.

FIGURE 9: Yield of bean after radical terracing project.

FIGURE 10: Unit of selling price for maize both seasons.

FIGURE 11: Unit of selling price for bean both seasons.
LIST OF APPENDICES

Appendix 1: SURVEY QUESTIONNAIRE ................................................................. 49
Appendix 2: Investment cost of terracing project .............................................. 55
Appendix 3: Operating cost .............................................................................. 56
CHAPTER 1 : INTRODUCTION

Rwanda economy is still dependent on agriculture and about 90% population is primarily relies, on agriculture as a source of livelihood. Agriculture contributes 45% gross domestic product, while other sectors such as industry and services sector contribute 20 and 34% respectively (MINICOFIN, 2004). Land degradation contributes significantly to poor performance of the agricultural sector, which is a key pillar of the Rwandan economy. 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.

Environment deterioration, and in particular land degradation caused by soil erosion has serious adverse implications for the entire region, especially for the Northern Province; in which Gakenke District lies (PADL, 2007). Consequently, sustainable land use management and specifically soil conservation has been clearly emphasized on, as critical for the country’s long-term development (LWH, 2008).

The conservation of soil should aim at multi-faceted approach involving biological and mechanical.

The greater the slope the greater the need for radical terracing inputs. Even though they are much more labour intensive, radical terraces require considerable technical advisory input (site, width and height of terraces) and they create major positive changes in soil structure and fertility when properly done. In many agricutural project, farmers use to choose a project either soil conservation project or any other project without analysing out put and input of the project to ensure the feasibility of the project.

It is in that context that radical terracing project has been implemented in GAKENKE District in order to improve soil fertility. But according to Prager et al. (2010), the issue of agricultural soil degradation and possible ways to achieve improved soil management concerns not only policy makers and farmers, but also a range of implementing agencies, interest groups, agricultural advisors, researchers and many others. Reasons why our research is focused on “economical impact analysis of radical terracing project in cyabingo sector of gakenke district”.


1.1 Problem statement

In the areas where biological measures are not sufficient to resolve the problem of soil and water conservation, radical terracing is used as one of the best mechanical measures in Rwanda.

Of course, radical terracing is said to be one of the best mechanical measures to improve the soil fertility. But assessment of economic impact analysis must be taken into consideration. Therefore, there should be a need to amend the soil in order to reconstitute its structure and fertility as well, the money spent to the whole project must be calculated to verify whether farmer gains or loses from the project. Beside these constraints, the following figure shows the problems meet by farmer in his agricultural project.
1.2 Significance of the study

The results derived from the field will serve as guide for the decision making in implementing agricultural project by analysing the benefit of the project. The study will be also useful for the provision of the information on the use of soil after its conservation. It will also reveal the information on suitable crop to grow which generates the highest income in the terraced area.

1.3 Benefit of the study

- Results from this research will provide an useful understanding of the economics of terraces investments and the important factors that affect returns to this investment;
- Results can be used by researchers to implement soil conservation projects;
- On the other hand the benefit of the study will return to Gakenke District especially, the farmers of CYABINGO sector, who will be aware of how to perform suitable projects that reduce soil erosion and contributes to the agricultural income generation.

1.4 Scope and delimitation

The study deals with economical analysis of terracing project, where it is limited in Nothern province precisely in CYABINGO sector of Gkenkeke district and it focuses on the following objectives:

1.5 Overall objective

The overall objective of this analysis is to evaluate the economic impact of radical terracing project.

1.6 Specific objectives:

- To evaluate the investment and operating cost of terracing project,
- To identify the income generated by terracing project with different crops grown,
- To compare the expected yield after terracing project and the yield before terracing
➢ To evaluate the percentage increase in yield and in gross income and to calculate benefit cost ratio (BCR)
  To achieve these objectives, following hypotheses were established for verification: those are as follow:

✔ Obtained yield of maize and bean before terracing is more than the yield obtained after terracing for both season,

✔ Percentage increase in gross income of maize is higher than that of bean,

✔ The benefit cost ratio is more than one
  The research is scheduled as follow:

☆ The literature review that includes background on soil conservation by means of terracing and on economical analysis of agricultural project;

☆ Experimental details that includes materials and methods used; as well as

☆ the presentation and discussion of results.

☆ This work ends with a conclusion and recommendations.
CHAPTER 2: LITERATURE REVIEW

2.1 Background on bench terraces

2.1.1 Definition and description
Bench terraces are a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers. Bench terraces are also level or nearly level steps constructed on the contour and separated by embankment known as risers.

2.1.2 Types of bench terraces and criteria for selection

The following are two main types of bench terraces:
- Irrigation or level bench terraces: These are used where crops, such as rice, need flood irrigation and impounding water.
- Upland bench terraces: These are used mostly for rain-fed crops or crops which only require irrigation during the dry season. They are generally sloped for drainage.

In humid regions: Use reverse sloped type.

In arid or semi-arid regions: Use outward-sloped type (*Dennis, 2008*)

2.1.3 Objectives of bench terraces

- To reduce run-off or its velocity and to minimize soil erosion.
- To conserve soil moisture and fertility and to facilitate modern cropping operations i.e. mechanization, irrigation and transportation on sloping land.
- To promote intensive land use and permanent agriculture on slopes and reduce shifting cultivation.
2.2. Locations and conditions for use

Generally speaking, bench terraces are particularly suited to countries or communities with the following macro conditions:

- Severe erosion hazards.
- Areas with small holdings and a dense population.
- Areas where there are food shortages or high unemployment rates.
- Areas where crops require flood irrigation.

For micro or site conditions, bench terracing is suitable in the following cases:

- Where there are relatively deep soils.
- On slopes not exceeding 25 degrees.
- On sites which are not dissected by gullies and not too stony.

Bench terraces are much more cost-effective if there is potential for mechanization, irrigation and for growing high-value crops. (FAO, 2009)

2.3. Design specifications

Length: The length of a terrace is limited by the size and shape of the field the degree of dissections and the permeability and erodibility of the Soil. The longer the terraces, the more efficient they will be. But it should be borne in mind that long terraces cause accelerated run-off and greater erosion hazards. A maximum of 100 m in one draining direction is recommended for typical conditions in a humid tropical climate. The length can be slightly increased in arid and semi-arid regions.

Width: The width of the bench (flat part) is determined by soil depth, crop requirements, tools to be used for cultivation, the land owner's preferences and available resources. The wider the bench, the more cut and fill needed and hence the higher the cost. The optimum width for handmade and manual-cultivated terraces range from 2.5 to 5 m; for machine-built and tractor-cultivated terraces, the range is from 3.5 to 8 m.
Gradients: Horizontal gradients range from 0.5 to 1% depending on the climate and soils. For example, in humid regions and on clay soils, 1% is safe for draining the run-off. In arid or semi-arid regions, the horizontal gradients should be less than 0.5%. The reverse grade for a reverse-sloped terrace is 5% while the outward grade for an outwardsloped terrace is 3%.

Slope limit: If soil depths are adequate, hand-made terraces should be employed on 7 to 25 degree (12%-47%) slopes and machine-built terraces should be employed on 7 to 20 degree (12%-36%) slopes. If the soil depths are not adequate for bench terraces, hillside ditches or other types of rehabilitation measures should be used. Bench terraces are not recommended for slopes below 7 degrees. Broad-base terraces and other simple conservation measures should be used instead. (Inbar, et al. 2000)

Risers and riser slopes: Riser material can be either compacted earth -protected with grass, or rocks. In order to ensure easy maintenance, terrace riser height should not exceed 2 m, after allowing for settling, especially for earth risers. Riser slopes are calculated by the ratio of the horizontal distance to the vertical rise as follows:

- Machine-built with earth material: 1:1
- Hand-made with earth material: 0.75:1
- Hand-made with rocks: 0.5:1

For level terraces, the following formula is used for determining the riser height (for reverse-sloped terraces see Fig. 3):

\[ H_r = V_I + D_H \]

\( H_r \): height of riser, in m

\( V_I \): vertical interval, in m

\( D_H \): dyke height i.e. 15 or 20 cm.
Vertical interval: The vertical interval (VI) is the difference in height between two succeeding terraces. It gives the height of the terrace; provides basic data for calculating the cross-section and volume of soil to be cut and filled; and is used as a guide for laying out and staking on the ground. The VI is determined using the following formula:

\[ VI = \frac{S \times Wb}{100 - (S \times U)} \]

2)  

VI: vertical interval, in m

S: slope in percentage (%)

Wb: Width of bench (flat strip), in m

U: Slope of riser (using value 1 for machine-built terraces, 0.75 for hand-made earth risers and 0.5 for rock risers).

Example: The calculation of the VI of 4 m wide, hand-made benches on a 30% slope with earth risers can be done as follows:

\[ VI = \frac{30 \times 4}{100 - (30 \times 0.75)} \]

= 1.55 m

Depth of cut: The depth of cut can be calculated according to the following formula:

3)  

\[ D = \frac{Wb}{2} \tan \theta (\text{for level terrace}) \]

\[ D = \frac{Wb}{2} \tan \theta + \frac{OH}{2} \] (for reverse sloped terraces, for outward slopes, subtract outward height OH, divided by 2).

D: depth of cut

Wb: width of bench
tan 0 : tangent of the slope angle

RH : reverse height

Example: The Calculation of the the depth of cut for a 4 m-wide reverse-sloped bench terrace on a 15 degree slope:

\[ 0.64 = \frac{3}{2} \times 0.26795 + \frac{0.2}{2} \]

(RH: 4 \times 0.05 = 0.2)

Net area: This is the area in benches or flat strips which is used for cultivation. It can be calculated by the following equation:

4) \[ A = \frac{10 \times 0.001 \times Wb}{Wt} \]

A : net area per ha

Wt : width of terraces (the sum of the width of the bench and the width of the riser), in m

Wb : width of the bench, in m

When calculating the net area of level terraces, the dyke width should be subtracted.

Cross section and volume: The cross-section can be computed by the formula below:

\[ Vl = \frac{30 \times 4}{100 - (30 \times 0.75)} \]

= 1.55 m

5) \[ C = \frac{Wb \times Hr}{8} \]

C : cross-sectional area of the cut triangle, in square m

Wb : width of bench, in m

Hr : height of riser, in m
The linear length can be obtained by the following equation:

\[ L = \frac{10.00}{Wt} \]

L : linear length of terraces in a hectare, in m
Wt : width of terrace, in m

The volume (V) can be calculated by multiplying the linear length (L) by the cross-section (C).

\[ V = L \times C \] (for calculating linear length,

When calculating the volume to be cut and filled it should be noted that only one cross-section is used. This is because the same cross-section is moving downslope to form a terrace.

For level terraces, the following formulas should be used for computing cross-section:

\[ C = \frac{Wb \times VI}{8} + DC \]

C : cross-section, in square m
Wb : width of bench, in m
VI : vertical interval, in m
C : cross-section, in square m
Wb : width of bench, in m
VI : vertical interval, in m
DC : dyke cross-section, in square m

For outward-sloped terrace a modification of the riser height (Hr) is required for calculating cross-section and volume as follows:
Hr = VI - OH

Hr = VI - OH

Hr : height of riser

Hi : vertical interval

OH : outward height (equals width of bench multiplied by 0.03)

Horizontal interval (FAO,2009)

2.4 Diagrams, nomographs and tables

Figure 1 shows a diagram of reverse-sloped bench terraces and terminology, together with a set of formulas for computing the specifications of the terraces. These step-by-step computations, using only simple mathematics, should present no difficulties to field assistants. The computations are for reverse-sloped bench terraces, but they can be applied to other types of bench terraces with only minor modifications. For level terraces, the major differences are their dykes and the lack of gradients.

In the Figure below a nomograph for quick reference. It shows the volumes to be cut and filled and the width limit for both hand-made and machine-built bench terraces of the reverse-sloped type (FAO,2009)

2.5 Layout and surveying procedures

The layout of terraces should include an examination of the sites physical conditions e.g. slope, soil depth, texture, erosion, presence of rocks, wetness, vegetation cover and present land use. The layout design should include specifications of the terraces (or treatments), sites and types of waterways, sites of roads and other farm installation needs. Human factors such as the farmer's plans and resources, labour conditions, and the tools to be used, must also be considered.
FIGURE 1: Cross-sectional view and computations for reverse-sloped bench terraces

Source: FAO, 2009

9) Vertical interval $= \frac{S \times W_B}{100 - S \times U}$, where $S$: Slope in %, 

$U$: 1 or 0.75%

10) Reverse height (RH): $RH = W_b \times 0.05$
11) Height of riser (Hr): \( Hr = VI + RH \)

12) Width of riser (Wr): \( Wr = Hr \times U \)

13) Width of terrace: \( Wt = Wr + Wb \)

14) Linear length (L): \( L = \frac{43.56}{Wt} \) (per acre)

\[ L = \frac{10.00}{Wt} \] (per ha)

15) Net area of benches (A): \( A = L \times WB \)

16) Percent of benches (pb): \( Pb \% = \frac{A}{43.560} \times 100 \)

2.6 Surveying

2.6.1 Preparatory work
This entails brushing the area, preparing survey equipment, stakes, colour ribbons or markers, and deciding on survey methods and sequences.

2.6.2 Equipment
The equipment usually consists of the following:

- Dumpy level, abney level or A-level.

- Measuring tape and rod.

- Soil auger.

2.6.3 Basic techniques
- For level terraces: use contouring or levelling techniques.

- For upland bench terraces: use graded-contouring techniques.

2.6.4 Special techniques
- Setting of base-line: An up-and-down base-line should be set at the site along a representative slope.
- Use of centre-line method: When specification tables are not available, a quick calculation of the VI can be made in the field. Use a level to determine and stake the VI of the terraces along the base line. This should be followed by graded contouring or levelling surveys according to the type of terrace to be built.

After staking out all the contours or graded contours, add one line of marked stakes in between them. This line serves as the bottom line of the upper terrace and the top line of the lower one. Continue adding stakes so as to cover the whole area. A top line should be added to the first terrace on the upward slope, and a bottom line to the last terrace on the downward slope. This method is recommended for hand-made terraces where centre-lines should be kept and observed as non-cut and non-fill lines.

- Use of two-line method: Design details can be readily obtained when a set of specification tables are available. The base line should be staked out with the width of the terrace (Wt), using a tape. A contour or graded contour line should be run from each stake until the whole area is covered. These lines serve as the bottom lines of the upper terraces as well as the top lines of the succeeding terraces. This method is recommended for terrace construction using mechanical or animal power, as any centre-lines will obstruct the construction operation and should be omitted.
FIGURE 2: Volumes of soil to be cut and filled per hectare for reverse-sloped bench terraces (FAO, 2009)

The stakes should be streamlined if there are sharp turns and narrow bottlenecks as these will interfere with future operations. Streamlining the stakes entails extra cuts or fills but is worthwhile in the long run.

2.6.5 Marking stakes

Each contour line of stakes should be marked with a different colour ribbon or paint in order to avoid confusion during construction, (e.g. centre lines in red, and side lines in yellow or green, etc.).
2.7. Construction methods
The cut and fill of the terraces should be done gradually and at an equal pace so that there is neither an excess nor a lack of soil. This principle applies regardless of what kind of tools are used for the operation.

2.7.1 By manual labour
The terrace must be built when the soil is neither too dry nor too wet. Start building the terrace from the top of a hill and proceed downslope. It will not be washed away in the case of heavy rain. However, when topsoil treatment or preservation is carried out, it is necessary to start building from the bottom of the hill upwards. In this case, temporary protection measures should be undertaken. Tie cord or rope around the stakes to mark each constructed terrace in sequence. The initial cut must be made immediately below the top stakes while the fill work should be started against the bottom stakes. This is done in order to ensure that the correct grade is attained without overcutting. Sometimes, rocks or clods of earth can be placed along the bottom line of the stakes to serve as a foundation before filling.

During the filling operation, the soil should be compacted firmly by a beater every 15 cm. If the layer of soil fill is thick, the compacting process becomes difficult. Terraces which go across existing depression areas should be built particularly strong. The edge of a terrace should be built a little higher than planned because of settling. The rate of settling may be as high as 10% of the depth of the fill.

Both the reverse and horizontal grades should be checked by a level during construction work and corrections must be made promptly wherever necessary. The slope of the riser should be shaped to 0.75:1. Waterway shaping should be commenced only after the terraces are cut. Make sure all the terrace outlets are higher than the waterway bottom. (Inbar, and Al. 2000)

2.7.2 Construction using draught animals and tools
In many countries, ploughs and Fresno Scrapers, pulled by oxen, horses or buffaloes, are used to build terraces.. The Fresno scrapers, however, cannot be used to build terraces less than 3 m wide. In addition, they are not suitable for use in soils which have many rocks exceeding 25 cm in diameter. In general, Fresno Scrapers should not be used when the soils are wet and sticky,
and if the cut area of the terrace is very hard or has a lot of grass, it must first be ploughed to allow the scraper to move the soil.

To begin the operation, raise the handle of the scraper so that the rear of the floor is 10 cm higher than the cutting edge. This angle will enable the scraper to cut into the soil more easily. After the bucket is loaded, the handle should be lowered to let the scraper slide flat on its bottom to the fill area in order to dump the dirt. Always begin loading the scraper at the high point of the cutting area. As soon as it is filled, turn the animal and dump the soil parallel to the lower line of the stakes. Never load the Fresno beyond the pulling capacity of the draft animal.

When dumping dirt from the scraper, the handle should be raised to a vertical position so that the scraper rides on the runners and the dirt slides forward out of the bucket. A more efficient operation can be achieved if the cutting and filling are done by following a figure eight pattern (in which the animal is turning continuously, without stopping.

### 2.7.2 Mechanized construction

When using a caterpillar bulldozer, start cutting parallel to and about 50 cm from the top line of the stakes and push the dirt down the slope, dumping it just above the bottom line. Optimum efficiency is achieved when the bulldozer travels down a slope about three times its length or approximately 12 to 15 m, when dumping the dirt.

Attention should be paid to the load of the bulldozer blade when cutting parallel to the top line. The bulldozer should be driven down to the dumping area as soon as the blade is full (but not before). After dumping a layer about 30 cm thick along the bottom line, the dirt should be compacted by the bulldozer. Whenever the bulldozer needs to travel from one end of the terrace to another, it should always be driven along the edge of the bench for compacting purposes.

The angled blade should be used each time for cutting to a depth of about 40 to 50 cm. Continue the cut and fill until the correct vertical and horizontal grades are attained. Alternatively, mark the height of the fill with coloured ribbons at the lower line of the stakes. Do not cut or fill at the proposed waterway site, and do not overcut at the toe drain.
A dumpy level should be used for checking the grades during the construction work. Final measuring or smoothing must be done as soon as the level checking is made. The riser slope should be shaped by hand to 1:1.

2.7.3 Topsoil treatment or preservation
Bench terraces usually expose the infertile subsoil and this can result in lower production unless some prevention or improvement measures are undertaken. One such measure is topsoil treatment or preservation. When fertile topsoil exists, topsoil treatment is always worthwhile. Two alternative methods follow:

- The terraces should be built from the bottom of the slope upwards. After the bottom terrace is roughly cut, the topsoil from the slope above is then pulled down to the bench and spread on top of soil. Repeat this procedure for the next terrace up the slope and proceed uphill in this way until the top terrace is built. The top terrace will not have topsoil unless it is obtained from another place.

- The second method is to push the topsoil off horizontally to the next section before cutting the terrace. The topsoil should be pushed back when the cutting is completed. For hand-made terraces, the topsoil can be piled along the centre line provided that the bench is wide enough.

2.8. Physical output

2.8.1 By manual labour
Generally-speaking, a man can cut and fill 3 to 4 cubic m of earth desting eight hours of supervised work, although output may vary depending on the type of soil and if rocks are present. If a terrace is wider than 4 m, output will be reduced because the transporting of the earth requires extra time. A team of 3 men for narrow terraces and 4 men for wider terraces is recommended for efficient terracing work. In the case of wider terraces, two men should be employed for cutting, the third for compacting and consolidating the risers, and the fourth for transporting the dirt.
2.8.2 Using draught animals and tools

On terraces exceeding a width of 3.5 m, an animal with a plough and a Fresno Scraper can complete 12 to 16 cubic m of dirt moving in an 8-hour period.

2.8.3 By mechanized construction

A medium-sized machine, such as the Caterpillar D-6 bulldozer fitted with an angled blade can do an efficient job on slopes not exceeding 15 degrees. The average production per hour for different widths of terraces on moderate slopes is as follows:

**TABLE 1**: The average production per hour for different widths of terraces on moderate slope

<table>
<thead>
<tr>
<th>Width of bench (Wb) m</th>
<th>Production per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4</td>
<td>45.0</td>
</tr>
<tr>
<td>4.6</td>
<td>43.5</td>
</tr>
<tr>
<td>5.8</td>
<td>42.0</td>
</tr>
<tr>
<td>7.0</td>
<td>40.7</td>
</tr>
<tr>
<td>8.2</td>
<td>39.7</td>
</tr>
</tbody>
</table>

**Source**: FAO, 2009

N.B. Experiences from Smithfield, Jamaica show that on gentle slopes, the output can be up to 30% higher.

A small machine, such as a John Deer 450, can be used on slopes ranging from 15 to 20 degrees, with an output per hour, according to experiments in Taiwan (province of China), of approximately 20 cubic m.

2.9. Cost and cost relations

**Cost of the earth work**

The cost of the earth work can be calculated as follow:
Earth work, in m$^3$/ha

W : Average net width of terrace, in m

S : Average land slope in%

Cost of earth work is 250Frw/cum.

Example: To calculate the construction cost for with the following parameters:

Average land slope S:33%

Vertical interval:1.5

Average width:2.5

$HI = \frac{VI \times 100}{S} = 4.5m$

Earth work per ha : $12.5 \times W \times S = 12.5 \times 3 \times 3 = 1237$ cumec/ha say 1250 cumec/haCost ot the earth work is $1250 \times 200 = 250000$ frw

2.9.1 Cost relations

The cost of terracing per unit area depends on the following factors: slope, soil, width of bench, presence of rocks or tree stumps, and tools to be used for construction. The wider the bench (flat strip) the more costly it will be, even though the percentage of the bench remains the same.

With a fixed width, the steeper the slope, the more expensive the terracing work will be. Machine-built terraces are generally cheaper than hand-made ones in many countries. In Jamaica, for example, the ratio is 1:3 or even 1:5, depending on locations. (FAO, 2009)
2.9.2 Operation and management

Roads

Access roads are essential for the efficient use of terraces. The following factors are important when considering the road layout for terracing systems:

2.9.3 Mechanization

Road access to and from the terraced area is required for 4-wheel mechanized vehicles. On gentler slopes, the roads can be built up and down the hills but on steeper slopes, they should be built diagonally across the field. The maximum grade for this kind of tractor road is 7 to 8 degrees. There is no need for roads to traverse because the bench terraces themselves can be used as roads. Generally speaking, 200 m of road per hectare should be ample even for rugged and steep terrains. The recommended width for the road is 3.5 m.

There are three types of road systems which can be used to cope with the various field conditions and mechanization requirements:

- Two-road system: Two up-and-down roads to connect both ends of the terraces at approximately right angles. They are ideal for cultivation on gentle slopes. On large tracks of land, each road can serve two sides.
- Single road system plus U-turn: This type is recommended on moderately steep slopes, or where there is no room for the two-road system. A road is built to connect one side of the terraces while on the other side, a U-type short road connects two neighbouring terraces to enable the tractor to turn around.
- Single road system: If the benches are wide enough for the tractor to turn around, a single road connecting one end of each terrace should be sufficient. Alternatively, in the case of steeper slopes and round hills, the road can cross the terrace field diagonally. (Inbar, and al. 2000)

2.9.4 Cultivation by manual labour or using draught animals

The road requirements for these cultivation methods are less rigid. A width of 2 to 2.5 m should be ample and the road gradient can be much steeper as long as there is proper protection. About 100 to 150 m of road is required per hectare of land.
2.9.5. Protection, perception and maintenance to improve soil productivity

New terraces should be protected at their risers and outlets and should be carefully maintained, especially during the first two years. But farmers who did not construct terraces or did incomplete job said that the main reason was lack of money, lack of work group or no perception of problem. The following conclusions can be drawn based on interviews with farmers and a general discussion of the situation:

- The farmers believe that soil conservation work is not possible without employing casual labourers or working in groups.
- Poor farmers who do soil conservation work are more dependent on group work to construct the terraces than are other farmers in the area.
- The farmers who have started terracing their farms are more progressive than those who are not yet started any soil conservation work.
- The farmers who have done soil conservation have a higher cash income than those who have not yet started (David al, 1990)

2.10 Protection

After cutting a terrace, its riser should be shaped and planted with grass as soon as possible. Sod-forming, or rhizome-type grasses are better than those of the tall or bunch-type. Although tall grasses may produce considerable forage for cattle, they require frequent cutting and attention. The rhizome-type of local grass has proved very successful in protecting risers. Stones, when available, can also be used to protect and support the risers. An additional protection method is hydro-seeding. The outlet for drainage-type terraces is the point where the run-off leaves the terrace and goes into the waterway. Its gradient is usually steep and should be protected by sods of earth. A piece of rock, a brick, or a cement block, is sometimes needed to check the water flow on steeper channels. (Morgan, 1981)

Similar checks on water flow are required for level bench terraces where the water falls from the higher terraces onto those below. A piece of rock should be placed on the lower terrace to
dissipate the energy of the following water. Grasses should also be established on the area of the bench crossed by the waterway.

2.10.1 Maintenance
Bench terraces require regular care and maintenance. If a small break is neglected, large-scale damage will result. Following is a list of maintenance work that should be carried out after heavy storms and cropping, especially in the first two to three years period:

2.10.2 Benches
The toe drains should be always open and properly graded; water must not be allowed to accumulate in any part of the terrace. All run-off should be allowed to collect at the toe drains for safe disposal to the protected waterway. Obstacles such as continuous mounds or beds must be removed at regular intervals to allow water to pass to the toe drain. Grasses and weeds should be removed from the benches. Correct gradients should be maintained and reshaped immediately after crops are harvested. Ploughing must be carried out with care so as not to destroy the toe drains and the grade.

2.10.3 Risers
Keep grasses growing well on the risers. Weeds and vines which threaten the survival of the grasses should be cut back or uprooted. Grasses should not be allowed to grow too high. Any small break or fall from the riser must be repaired immediately. Cattle should not be allowed to trample on the risers or eat the grass. Run-off should not be allowed to flow over the risers on reverse-sloped terraces.

- Deep ploughing, ripping or sub-soiling is needed to improve the structure of the soils on the cut part of the bench terraces. Green manuring, compost or sludge is needed in the initial period in order to increase soil fertility. Soil productivity should be maintained by means of proper crop rotation and the use of fertilizers (David et al, 1990)

2.10.4 Outlets for drainage types of terrace
The outlets should be checked to see whether they are adequately protected. Make sure the water flows through the outlets instead of going around them. Any breaks must be mended immediately. (Morgan, 1981)
2.11 Generalities on farm economic analysis
The sustainability of farming system is a measure of internal organisation, management and performance over time, and it may be described by such “health indicators as rates of soil erosion or nutrient depletion, crop yield trends, pest and disease build up, or profitability. However, if one thinks of farming systems in an evolutionary framework, unsustainable farming systems will by definition disappear. The current concern about farming systems arises from rapid changes in forces acting on these systems, increasing limits put on adaptive response, and the geographic scope of the problem, leading to widespread resource degradation. Solutions to this situation are either to attack the problem at the level of farming system by developing more options for farmers to maintain the productivity of their systems or to try to solve the problem at higher systems level by addressing the forces that lead to unsustainable system. (Oldman, 1990).

2.13. Benefit cost ratio (BCR)
This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream.

2.14 Rules to find out the benefit cost ratio
1. All Benefit Cost Ratios are figured out by considering present year production and price
2. The cost of cultivation of crops is calculated assuming labour will be contributed by farmers

2.15 The cost–benefit study of soil conservation works

A cost–benefit analysis was made of recommended soil conservation works, attempting to isolate the costs and benefits of soil conservation per se from those of comparable agricultural improvements such as increased fertiliser application. Agricultural benefits or on-field benefits were defined as follows:

1) The prevention of falling yields per hectare which would otherwise result from the loss of topsoil,
2) An initial rise in yields consequent on implementing the works owing to less fertiliser being washed out, the use of mulch, increased soil moisture and improved soil structure, and

3) A slow gradual increase in yields as new topsoil develops on protected lands. The effects of these processes through time were modelled in terms of percentage changes in yields for each of the models.

The benefit cost ratio is found by the following formula:

\[
BCR = \frac{NPVB}{NPVC}
\]

where \( NPVB \): Present worth of the benefit stream and \( NPVC \): The present worth of the cost stream.

The total discounted benefits are divided by the total discounted costs. Projects with a benefit-cost ratio greater than 1 have greater benefits than costs; hence they have positive net benefits. The higher the ratio, the greater the benefits relative to the costs. Note that simple benefit-cost ratio is insensitive to the magnitude of net benefits and therefore may favor projects with small costs and benefits over those with higher net benefits. (This problem can be eliminated by the use of the incremental benefit-cost ratio or the net present value.) (Gittinger, 1986)

**Evaluation of BCR**

The proponents of benefit cost ratio argue that since this criterion measures net present value per unit of investment, it can discriminate between large and small investments and hence is preferable to the present value criterion.

Criterion for examination of BCR:

1. Under unconstrained conditions, the BCR criterion will accept and reject the same projects as the Net Present value (NPV).
2. When the capital budget is limited in current period, the BCR may rank projects correctly in the order of decreasingly use of capital.
3. When cash outflows occur beyond the current period, the BCR criterion is unsuitable as selection criterion.
CHAPTER 3: MATERIALS AND METHODS

3.1. Study area
The present research was conducted in CYABINGO Sector, GAKENKE District in Northern Province.

a) Description of CYABINGO Sector

b) Geographical data

CYABINGO Sector is one among 19 sectors composed by Gakenke District; it is situated at 12 km from MUSANZE Town, to reach that sector, you pass at the main road of MUSANZE-KIGALI where you cross out in GICUBA Center.

It is bordered by:
North: Remera Sector
West: Rusasa Sector
South: Busengo Sector
East: Kivuruga Sector

The population of Cyabingo Sector is about 17924 people with 724.2 people per km² of population density and the surface area is 24.75km².

c) Administrative situation

CYABINGO Sector is composed by five (5) cells which are:
Muramba cell
Muhaza cell
Muhororo cell
Mutanda cell
Rukore cell
d) Soil

The soil of Cyabingo sector is composed essentially by clay-sandy–loam soil and clay-alluvial soil in the mushlands.
e) Relief

The relief of Cyabingo Sector is composed by the mountains of high slope where the highest point is found on MUTANDA mountain.
f) Hydrographical situation

Hydrograph network is composed by BASE River and stream: tributary of river quoted above like: MUKINGA and GASEKE.

-g) Climate and precipitation

The climate of CYABINGO area is tropical temperate with four alternating seasons:
- A Short rainy season from September to December
- A Long rainy season from April to May.
- A Short dry season from January to March.
- A long dry season from July to August

The annual average rainfall is 1200 mm per year, dangerous and lots of rainfall is observed during long rainy season.

h) General description of VUP (Vision Umurenge Programm)

VUP is conceived program inaugurated to speed up the reduction of extreme poverty in Rwanda, and was positioned in the EDPRS as one of the three flagship programmers (Sustainable Growth for Jobs and Exports, Vision 2020 Umurenge and Governance).
The ambitious VUP programme was launched officially by the Prime Minister, on behalf of His Excellency the President of the Republic of Rwanda, in Mayange Millennium Village, Bugesera District on 6th March 2007. The programme’s elaboration was preceded by a study tour in Ethiopia to learn lessons from the Ethiopian Productive Safety Net Programme (PSNP). VUP design and planning was finalized in 2007, to start activities in 2008. At the beginning of 2008, VUP was linked to MINALOC as a stand alone programme, and was later attached to the former Common Development Fund (CDF). The CDF, VUP, Ubudehe and HIMO then merged to form the Rwanda Local Development Support Fund (RLDSF). Within the RLDSF, VUP is married with the Ubudehe programme to form the National Social Protection Programme. Ubudehe is one of the home grown poverty reduction initiatives with deep roots in the Rwandan culture; it is a national enabled process to help local people create social capital, nurture citizenship and build strong civil society. The process helps citizens to engage in local problem-solving using their own locally designated institution.

The VUP programme has three main components:

**Direct support (DS)** – Cash transfers for extremely poor households unable to work (inkunga y’ingoboka);

**Public Works (PW)** – Paid employment on productive community asset development projects;

**Financial Services (FS)** – Increasing access to financial services for the poor (this includes microcredit, a matching-grant challenge fund and encouraging beneficiaries to save).

These are underpinned by **training and sensitization** on community and social development issues.

### 3.2 materials

The following materials have been used during the study:

- Questionnaire for taking some data such crops grown in the area, yield obtained in different seasons for different crops and selling price.
- Human resources for data recording through the survey and monthly report
- Computer, through SPSS version 16 for data analysis and processing
3.3 Methodology

3.3.1 Data collection from farmers in terracing project under VUP by use of questionnaire.

Survey design: the choice of study area sampling design adopted for selecting the farm households and the methodology followed in the collection of farm level data are described below.

Sampling design: the multi stage purposive sampling design has been followed for this study; where 17924 people were surveyed but 68 of them were selected based on the formula of Alain Bouchard

Data about the following parameters have been found:

- Appreciation and adoption of terracing project as mechanical measures
- Different yield obtained per ha
- Selling price of crops grown
- Land exploitation size

3.3.2 Sampling method

Primary data were collected from the sample households affected by the project, with the help of well structured, pre tested interview schedules, bearing questions in relation to the objectives of the study. The secondary details like the information about study area description, population of the study area, land use pattern and cropping pattern were collected from development project in sector. The following formula was used to select the sample to be surveyed.

\[
N = \frac{(ta \times ta)PP}{d^2}, \quad N = \text{Universe size} \quad (<10^6)
\]

\[
P = \text{Frequency or probability} \quad (p=0.5)
\]

\[
n = \frac{680.6}{1 + \frac{556}{1792}} = 68
\]

\[
d = \text{error (10\%)} \quad ta = \text{student value} \quad (ta=1.65)
\]

After recording data we have calculated the weighth average production, as annual yield which allow us to find annual income at each crop. From those data the increase percentage in yield and increase percentage in income were assessed to assess economic impact of terracing project.
% increase yield =
\[
\frac{\text{Yield of crop } X \text{ in season } Y \text{ after terracing} - \text{Yield of crop } A \text{ before terracing in season } Y}{\text{Yield of crop } X \text{ Before terracing in season } Y}
\]

% increase in income
\[
= \frac{\text{Total benefit after terracing project} - \text{Total benefit before terracing project}}{\text{Total benefit before terracing project}}
\]

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Identification of surveyed farmers

TABLE 2: Repartition of household chiefs by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>35</td>
<td>51.5</td>
</tr>
<tr>
<td>Male</td>
<td>33</td>
<td>48.5</td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The project conducted in CYABINGO sector in soil conservation especially in terracing construction, has involved most female sex than male one, where the percentage of female sex involved in the project is 51% and that of male is 48.5 as shown in the table 2. This is explained by the habit of rural Rwandan population, which involves most female sex in many agricultural activities than male sex. On the other hand it indicates that the project introduced in the area facilitates the gender empowerment because more than 30% of male sex works in the project as the one way of job creation.
a) Size of family household

The family household has been studied to ensure the highest percentage of family household in the study area.

FIGURE 3: size of household

According to the figure 3 the surveyed people whose the percentage of family household size is highest, is the one which contains 5 members in the family with the percentage of 47.1%. It is followed with the household size containing 9 members with 30.9% and last containing 4 members with the percentage of 22.1%

b) Education level of farmers

Different farmers have been surveyed and their instruction levels differ from farmer to farmer the following figure shows various categories of farmers and their instructed level.
FIGURE 4: Education level of surveyed

From surveyed farmers affected by the project, the highest percentage of farmers has primary education level with 44% that percentage was the one which is highly involved in the project. It is followed by that of farmers whose education level is at least 3 years after primary education (ordinal level, senior level university education) with the percentage of 29% . The last is the percentage of farmers who didn’t even attend any year of primary education with the percentage of 26.5%. This variation in level of education of farmers; is due to the tasks accomplished by each farmer in the project. where:

- Some farmers are involved in earth cut and filling
- Others in stabilization of risers by grasses
- Other part in transporting grasses to stabilize rizers
- There is another part which constitutes the Wages technician of measuring slope.
- Other are Casual labour chefs.
C) Land exploitation and categories of farmers

**TABLE 3: Land exploitation and categories of farmer**

<table>
<thead>
<tr>
<th>Land exploitation</th>
<th>Category of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmers combining agriculture and livestock activities</td>
</tr>
<tr>
<td>0.1-0.5ha</td>
<td>11</td>
</tr>
<tr>
<td>0.5-1ha</td>
<td>13</td>
</tr>
<tr>
<td>2-5ha</td>
<td>7</td>
</tr>
<tr>
<td>more than 5ha</td>
<td>5</td>
</tr>
</tbody>
</table>

|                   | 31                                    | 24                              | 13                              | 68    |

Land exploitation by farmers in the study area varies between 0.1 to 5 ha and based on the statistical outputs given by SPSS, the highest frequency of farmers uses the land varies between 0.1 to 0.5 as shown in the table 3 where the frequency of occurrence is 30 over 68 of surveyed farmers. By combining land exploitation and category of farmers we have found that, 11 farmers combine agriculture and livestock activities, 12 Farmers do agriculture only and 7 farmers do agriculture supported by the government.
a) Adopted mechanical measures

![Bar chart showing the percentage of adopted mechanical measures for farmers in the study area]

**FIGURE 5: Percentage of adopted mechanical measures for farmers of the study area**

The most adopted mechanical measure is radical terracing in the study area followed by progressive terracing, graded bund and the last contour ditches. The highest percentage of terracing project adoption is explained by many implemented actors in the study area, which contributes to the investment project and sensitizes people to practice terraces as mechanical soil conservation measures. In addition, farmers are adepted this radical terracing because they involved in the project and the gain money in terracing construction activities.
4.2 Investment of terracing project

4.2.1 Capital cost

From appendix 2 details on investment cost is indentified in table 4, and cost at item is shown

**TABLE 4:** Capital cost of terracing project

<table>
<thead>
<tr>
<th>Working labours cost</th>
<th>Unit</th>
<th>Quantity</th>
<th>Terraced area</th>
<th>Unit cost (frw)</th>
<th>Total cost (frw)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Labour cost</strong></td>
<td>human days</td>
<td>Days</td>
<td>People</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>casual labour</td>
<td>55</td>
<td>1100</td>
<td>120</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>man power</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wages technician of measuring /month</td>
<td>55</td>
<td>40</td>
<td>120</td>
<td>1500</td>
</tr>
<tr>
<td><strong>2 Supervision cost</strong></td>
<td>Casual labour chefs</td>
<td>55</td>
<td>30</td>
<td>120</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Wages of the members of the inspection committee</td>
<td>55</td>
<td>7</td>
<td>120</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>Technicians supervisory Agronomists</td>
<td>45</td>
<td>4</td>
<td>120</td>
<td>120,000</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Contingency</td>
<td></td>
<td></td>
<td>10% of capital cost</td>
<td>6,824,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75,069,500</td>
</tr>
</tbody>
</table>

Source: VUP CYABINGO sector
The total land terraced is equal to 120 ha which will be used by farmers to grow maize and bean in the proportion of 70 ha and 50 ha respectively (CYABINGO sector report 2010 season B).

The lowest cost is spent on technicians supervisory Agronomists because their works is done temporarily where they give instructions to the members of the inspection committee for good functioning of the project. There is no cost mentioned for grasses to stabilize risers because farmers take them in their land for free either in the forests or in abandoned land.

### 4.2.2 operating cost

From appendix 3 the operating cost is detailed in the table 5, this cost is detailed based on crop to be grown.

**TABLE 5**: operating cost for maize

<table>
<thead>
<tr>
<th>№</th>
<th>Agricultural inputs</th>
<th>Unit</th>
<th>Quantity</th>
<th>Land area (Ha)</th>
<th>Unit cost (rwf)</th>
<th>Total cost (rwf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>liming material (Quicklime)</td>
<td>Kg</td>
<td>320833</td>
<td>70</td>
<td>50</td>
<td>5,250,000</td>
</tr>
<tr>
<td>2</td>
<td>Maize seed</td>
<td>Kg</td>
<td>2800</td>
<td>70</td>
<td>350</td>
<td>980,000</td>
</tr>
<tr>
<td>3</td>
<td>DAP</td>
<td>Kg</td>
<td>7000</td>
<td>70</td>
<td>420</td>
<td>2,940,000</td>
</tr>
<tr>
<td>4</td>
<td>Urea</td>
<td>Kg</td>
<td>3150</td>
<td>70</td>
<td>340</td>
<td>1,071,000</td>
</tr>
<tr>
<td>5</td>
<td>Organic manure</td>
<td>Kg</td>
<td>70,000</td>
<td>70</td>
<td>20</td>
<td>14,000,000</td>
</tr>
<tr>
<td>6</td>
<td>Durban as pesticides</td>
<td>L</td>
<td>113.75</td>
<td>70</td>
<td>5000</td>
<td>56,875</td>
</tr>
<tr>
<td>7</td>
<td>Maintenance cost for terrace</td>
<td></td>
<td></td>
<td>70</td>
<td>50,000</td>
<td>350,000</td>
</tr>
<tr>
<td>8</td>
<td>Contingency</td>
<td>Rwf</td>
<td>10% of operating cost</td>
<td>70</td>
<td>2464787.5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Total</td>
<td>Rwf</td>
<td></td>
<td></td>
<td></td>
<td><strong>27,112,663</strong></td>
</tr>
</tbody>
</table>
The total operating cost for growing maize is equal to 27,112,663, farmers do not have adequate livestocks necessary for providing organic manure nor the compost for increasing organic manure is not contracted. That why the highest cost is spent on organic manure.

**TABLE 6**: operating cost for bean

<table>
<thead>
<tr>
<th>No</th>
<th>Agricultural inputs</th>
<th>Unit</th>
<th>Quantity</th>
<th>Land area (Ha)</th>
<th>Unit cost (rwf)</th>
<th>Total cost (rwf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>liming material (Quicklime)</td>
<td>Kg</td>
<td>-</td>
<td>-</td>
<td>--</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Bean seed</td>
<td>Kg</td>
<td>2500</td>
<td>50</td>
<td>350</td>
<td>875,000</td>
</tr>
<tr>
<td>3</td>
<td>DAP</td>
<td>Kg</td>
<td>7000</td>
<td>50</td>
<td>490</td>
<td>3,430,000</td>
</tr>
<tr>
<td>4</td>
<td>NPK</td>
<td>Kg</td>
<td>1000</td>
<td>50</td>
<td>400</td>
<td>400,000</td>
</tr>
<tr>
<td>5</td>
<td>Organic manure</td>
<td>Kg</td>
<td>500000</td>
<td>50</td>
<td>20</td>
<td>10,000,000</td>
</tr>
<tr>
<td>6</td>
<td>Maintenance cost for terrace</td>
<td>Rwf</td>
<td></td>
<td></td>
<td>50,000</td>
<td>250,000</td>
</tr>
<tr>
<td>7</td>
<td>Contingency</td>
<td>Rwf</td>
<td>10% of operating cost</td>
<td>50</td>
<td>-</td>
<td>1495500</td>
</tr>
<tr>
<td>8</td>
<td>Total</td>
<td>Rwf</td>
<td></td>
<td></td>
<td></td>
<td><strong>16450500</strong></td>
</tr>
</tbody>
</table>

The cost of weeding, land preparation is not mentioned because farmers work in their own plots. The difference of total cost required for growing maize and bean is due 2 reasons:

- The liming is done once for one year, hence it is used for 4 seasons because the effect of increasing
- The land under maize crop is superior to the land under bean crop thus operating cost increases as the land also increases.

The total cost is divided into two types:

- Money required to pay labour as their salary per month or capital cost
- Money required to buy agricultural inputs, necessary for crop production or operating cost
Investment cost / ha = 625579. rwf
Operation cost/ha for maize = 387323.75 rwf
Operating cost/ha for bean = 329010 rwf

4.3 Yield obtained per season on selected crops

4.3.1 Yield obtained on maize
From surveyed farmers on the field, the yield data on maize have been found and analysed as they are shown, separately in different seasons in figure 6 and 7.

**FIGURE 6:** Yield of maize before radical terracing

By comparing the yield of 2 seasons before terracing, we find that at the season B the yield increases because farmers improve their ways of farming by use of fertilizers, and control soil by other measures rather than terracing. Hence soil becomes more fertile, in season B than in season A as soil fertility status manifests its effect most in season B than in season A.
Yield after terracing –Season A

FIGURE 7: Yield of maize after radical terracing

The increase in yield after radical terracing is higher than the increase in yield before radical terracing project as indicated in table 11, where the increase is 13.2 and 20.8% respectively for season A and B. This is due to the soil nutrients retention caused by terraces.

4.3.2 Yield obtained on bean

After taking the data on different yields obtained by farmers on bean, results have been compared before radical terracing and after it thereby figure 7 and 8 show the results found
Before radical terracing project farmers grow bean with soil erosion control rather than radical terracing and fertilize their land as they do after terracing project, the combination of those practices give the average yield of 1.83 and 2.32 tons/ha respectively for season A and B.

After radical terracing the adoption of bean crop manifests a problem in season B, because of the increase in yield which lesser than the increase in yield before terracing project, as crops respond differently to the soil requirement, the soil fertility status after radical terracing project was not suitable for bean as it is for maize that it is pooved by the difference in % increase in yield which is identified between those two crops. In addition there other production factors that have influenced rather than soil factores such rainfall dtribution, pest diseases, etc.

4.4 price of selling

The selling price is an important paramater used to calculate the income generated by the crops grown in the study area which are Maize and Bean. Different farmers sell their production on different price, depending on their needs in food security, the data of selling
price on bean and maize are shown in Figure 10 and 11 based on statistical analysis made through SPSS.

**FIGURE 10**: unit of selling price for maize both seasons

The analysis of statistical outputs reveal that the average of selling price of maize for both season when they are grain, as 300 rwf. This price will be used to calculate the income generated by maize both seasons.
Based on statistical outputs which reveal that the average of selling price of bean for both season as 350 rwf, we calculate the income generated by bean both seasons.

4.5. Yield and annual income generated by selected crops

4.5.1 Yield and annual income of maize

Yield has been calculated as the Weight average production, and the income generated is obtained by multiplying the yield and selling price of maize or bean.
Before radical terracing, farmers get the annual average yield of 5.41 tons/ha, which is less compared to standard average production of maize in Rwanda, which is 2 to 5 tons/ha/season (Farmer’s diary, 2010). The low annual average yield of maize is due to many constraints, and soil erosion is the major one followed by others like insufficient fertilizers inputs, etc.

**TABLE 7: Yield and income of maize before terracing both seasons**

<table>
<thead>
<tr>
<th>Season</th>
<th>Weight annual average production (t/ha)</th>
<th>Annual gross income generated (rwf/ha)</th>
<th>Net Income in (rwf/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.43</td>
<td>729,000</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2.98</td>
<td>893,250</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.41</td>
<td>1,622,250</td>
<td>847,602.5</td>
</tr>
</tbody>
</table>

After terracing project, the improvement of soil erosion control is ensured, thus, there is a small increase in annual average yield, where it arrives at 6.35 tons/ha. This justifies the use of terraces in soil productivity and as the yield increases the income generated by maize also increases where it comes from 847,602.5 to 1,133,921.5 rwf/ha.

**TABLE 8: Yield and income of maize after terracing both seasons**

<table>
<thead>
<tr>
<th>Season</th>
<th>Weight annual average production (t/ha)</th>
<th>Gross income generated (rwf/ha)</th>
<th>Net income in (rwf/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.75</td>
<td>828,570</td>
<td>1,133,921.5</td>
</tr>
<tr>
<td>B</td>
<td>3.60</td>
<td>1,080,000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6.35</td>
<td>1,908,570</td>
<td></td>
</tr>
</tbody>
</table>
4.5.2 Yield and annual income of bean

TABLE 9: Yield and income of bean before terracing both seasons

<table>
<thead>
<tr>
<th>Season</th>
<th>Weight average production (t/ha)</th>
<th>Gross income generated (rwf/ha)</th>
<th>Net income in (rwf/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.833346</td>
<td>641671.1</td>
<td>797,980</td>
</tr>
<tr>
<td>B</td>
<td>2.3253</td>
<td>839615</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.16</td>
<td>1,456,000</td>
<td></td>
</tr>
</tbody>
</table>

For bean Crop , before radical terracing project, the annual average yield is 4.16 tons/ha, with the annual income of rwf. This yield obtained by farmers does not satisfy the need of farmers in food security, so they search how to improve bean production by making radical terraces to minimize the use of organic manure and mineral fertilizers.

TABLE 10: Yield and income of bean after terracing both seasons

<table>
<thead>
<tr>
<th>Season</th>
<th>Weight annual average production (t/ha)</th>
<th>Gross income generated (rwf/ha)</th>
<th>Net income in (rwf/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.2208</td>
<td>770700</td>
<td>942,565</td>
</tr>
<tr>
<td>B</td>
<td>2.3523</td>
<td>869680</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.5731</td>
<td>1600585</td>
<td></td>
</tr>
</tbody>
</table>

After radical terracing project the small increase in yield has obtained on bean but, as terraces are still new, the production increases slowly in the function of nutrients supply into the soil. The small increase in annual average yield causes also the increase in income generated by bean where it pass to rwf and becomes 942,565rwf.
TABLE 11: Increase in yield and income

<table>
<thead>
<tr>
<th>% increase in yield (%)</th>
<th>% increase in income(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Bean</td>
</tr>
<tr>
<td>Season A</td>
<td>Season B</td>
</tr>
<tr>
<td>13.2</td>
<td>20.8</td>
</tr>
</tbody>
</table>

The increases in yield and in income generated by maize and by bean have been calculated and results show that the increase in maize is greater than the increase in bean this is because beans have not adopted well after radical terracing as for maize crop. In addition for season B there was contraints in bean production, related to heavy rainfall, which have domaged bean crop that it why there is small increase in yield for season B compared to the season A.

4.6 Benefit cost ratio

After calculation of all required data the benefit cost ratio has been calculated for both crop and both season and the table 12 shows the results

Table 12: benefit cost ratio before and after terracing

<table>
<thead>
<tr>
<th>Maize</th>
<th>Bean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before radical terracing</td>
<td>After radical terracing</td>
</tr>
<tr>
<td>2.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Before radical terracing</td>
<td>Before radical terracing</td>
</tr>
<tr>
<td>2.4</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Based on the results found in the calculation of BCR maize crop brings the benefit at the greater rate than bean crop, where the results show that the increase of BCR comes from 2.4 to 2.9 for maize, while for bean it comes from 2.4 to 2.8 after terracing.
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The study conducted in GAKENYE District CYABINGO sector focusing on economic impact analysis of radical terracing project has successfully achieved. The hypotheses have been responded the investment cost of radical is higher than the operating cost because terracing construction requires much inputs than the inputs required to grow crops in terms of money. The results show that as we continue to use terraces the productivity increases; the use of radical terraces is shown through the increase in yield after radical terracing, thereby the results show that the percentage increase in yield is 13.2% for season A and 20.8% for season B while the increase in yield for bean is 21.3% for season A and 1.32 for season B. This less percentage increase is due to other factors of production which are not related to the soil factors such rainfall distribution, pest management. For both crops annual income generated is higher than the one generated before terracing project, this is the justification of importance of terraces in soil productivity and hence 39.86% and 23.42% were the percentage increase in annual income respectively for Maize and bean crop. After all analyses made, the project of radical terracing conducted in CYABINGO Sector of GAKENKE District, was feasible, because the results show that, after terracing project BCR increases, where it
increases up to 2,9 when farmers grow maize and up to 2,8 when farmers grow bean. Some recommendations are to addressed to different stakeholders of radical terracing project:

- To the farmers:
  - To minimize the investment cost and operating cost in order to maximize the benefit by exploiting all available resources like optimum use of household wastes to minimize much use of organic manure.
  - To form the cooperatives for easy provision of agricultural input for better use of
  - To combine radical terracing with other mechanical measure of soil conservation to minimise the cost of soil conservation.

- To the local government: To evaluate economic feasibility of soil conservation techniques in order to predict the techniques that highly generate the income for farmer.
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Gittenger J.P Economic analysis of Agricultural projects, World Bank, Washington DC, USA, 1986
LIST OF APPENDICES

Appendix 1: SURVEY QUESTIONNAIRE

I. IDENTIFICATION

1. Names of household chef

2. Residences:

   Cell:

   Sector: class CYABINGO.

   District: GAKENYE

   Province: northern Province

3. Repartition of household chiefs by sex

   - Feminine
   - masculine

4. Marital status:

   - Married
   - Single
   - Window
   - divorced

5. Size of house hold

   - 4 Members
   - 5 Members
   - 9 Members
6. Class repartition of age
- Below 20 years old
- Between 21 and 30 years old
- Between 31 and 40 years old
- Between 41 and 50 years old
- More than 51 years old

7. Instruction level of surveyed
- Not instructed
- Primary level
- 3 years of study after primary
- Between 3 and 6 years of secondary
- University formation

II LAND EXPLOITATION DETAILS OF FARMERS

2.1 What is the size of your land under agriculture practices?
- Between 0.1 and 0.5 ha
- Between 0.5 and 1 ha
- Between 2 and 5 ha
- More than 5 ha

2.2 Do you practice erosion control measures in your farms?
- Yes
- No

2.3 If yes enumerate mechanical measures for soil conservation do you use?
- Radical terracing
- Progressive terracing
- Graded bund and contour bund
- Contour ditches

2.4 In which of the following category of farmers are you belonged in?
- Farmers combining agriculture and livestock activities
- Farmers doing only agriculture
2.5 What are the selected crops do you grow in your exploitation land
   Maize
   Bean

2.6 What are the fertilizers, pesticides and amendments used in your land?
   o liming material
   o Mineral manure (DAP)
   o NPK
   o pesticides

III. ADOPTION OF TERRACING TECHNIQUE

3.1 Is there any necessity of making terracing project in your agricultural exploitation?
   - Yes
   - No

3.2 If yes what are the advantages do you suspect to get?
   - Increase in agricultural productivity
   - Fertilizers management
   - Soil erosion control
   - Soil moisture conservation

3.3 Do you remark any social economic impacts of terracing project in your agricultural exploitation?
   Yes
   No

   If yes what are they?
   - Increase in income generation
   - Job creation while terracing
   - Facilitate land use consolidation

3.4 What are the implementation actors of terracing project?
   - Ubudehe
   - Common works(ubudehe, imiganda)
   - Local government
3.5 How do you appreciate bench terraces techniques?
- Good  
- Very good  
- Bad  
- Neutral  

3.6 Do you have adequate capacity and knowledge to create terraces without intervention of project?
- Yes  
- No  

3.7 Is there any improvement of production after terracing project?
- Terracing project brings the improvement  
- The situation is better before the project than after the project  
- The situation is better after the project than before it.  

3.8 If no any improvement what are the constraints?
- Low knowledge  
- Financial problems and insufficiency of agricultural tools  
- Low motivation of leaders  

3.9 Are there any disadvantages of bench terraces?
- Loss of arable land  
- Reduction of productivity in first years of cultivation  
- Hard work (installation) and time consuming  

IV. COST ANALYSIS OF TERRRACING PROJECT
3.1 What is the expected yield before terracing project?

<table>
<thead>
<tr>
<th>Expected Crop yield</th>
<th>Maize</th>
<th>Bean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ton/Ha Season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>- 2 tons</td>
<td>- 1.6tons</td>
</tr>
<tr>
<td></td>
<td>- 2.5 tons</td>
<td>- 2.5 ton</td>
</tr>
<tr>
<td></td>
<td>-3. tons</td>
<td>- 2.6 tons</td>
</tr>
</tbody>
</table>
3.2 How much money is paid for one labour per day?

- 1000 rwf □
- 800rwf □
- Between 800 and 1500 rwf □

3.3 What is the expected yield per hectare after terracing project?

<table>
<thead>
<tr>
<th>Expected Crop yield</th>
<th>Maize</th>
<th>Bean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ton/Ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Season</td>
<td>2.3 tons</td>
<td>1.7 tones</td>
</tr>
<tr>
<td></td>
<td>2.6 tons</td>
<td>2.9 tons</td>
</tr>
<tr>
<td></td>
<td>3.6 ton</td>
<td></td>
</tr>
</tbody>
</table>

| B                   |                |     |
|                     | 3.4ton         | 1.8 tons |
|                     | 3.4ton         | 2.3 tons |
|                     | 4 tons         | 3.1 tons |

3.4 What do you use your production after harvesting?
3.5 If your production is for selling cost what unit cost of sale both two seasons?

<table>
<thead>
<tr>
<th>Unit selling Price (rwf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>Bean</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>350</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>
Appendix 2: Investment cost of terracing project

<table>
<thead>
<tr>
<th>No</th>
<th>Working Labours</th>
<th>Unit</th>
<th>Quantity</th>
<th>Terraed Area</th>
<th>Unit Cost/ FRW</th>
<th>Total Cost/FRW</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Salary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Casual Labour</td>
<td>Days</td>
<td>55</td>
<td>1100</td>
<td>120</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Manpower/Pers/Day/Persons/Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Casuared Labour</td>
<td>Days</td>
<td>55</td>
<td>30</td>
<td>120</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Chefs/Pers/Day/Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Wages Technician</td>
<td>Days</td>
<td>55</td>
<td>30</td>
<td>120</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Of Measuring/Persons/Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Wages of the Members of the Inspection Committee</td>
<td>Days</td>
<td>55</td>
<td>7</td>
<td>120</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>Technicians</td>
<td>Month</td>
<td>2.5</td>
<td>2</td>
<td>120</td>
<td>120000</td>
</tr>
</tbody>
</table>
Supervisory Agronomists

S/TOTAL 1 66,820,000

Source: VUP CYABINGO sector

Appendix 3: Operating cost

<table>
<thead>
<tr>
<th>B. Agricultural tools</th>
<th>The wording</th>
<th>Unit</th>
<th>Quantity</th>
<th>Terraced area</th>
<th>Unit rwf</th>
<th>Total Cost (rwf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>liming</td>
<td>Kg</td>
<td>550,000</td>
<td>120</td>
<td>30</td>
<td>16,500,000</td>
</tr>
<tr>
<td></td>
<td>material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Quicklime)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bean seed</td>
<td>Kg</td>
<td>6,400</td>
<td>120</td>
<td>400</td>
<td>2,160,000</td>
</tr>
<tr>
<td>3</td>
<td>Maize seed</td>
<td>Kg</td>
<td>5400</td>
<td>120</td>
<td>300</td>
<td>1,620,000</td>
</tr>
<tr>
<td>4</td>
<td>DAP</td>
<td>Kg</td>
<td>12,000</td>
<td>120</td>
<td>490</td>
<td>5,880,000</td>
</tr>
<tr>
<td>5</td>
<td>Urea</td>
<td>Kg</td>
<td>5400</td>
<td>120</td>
<td>340</td>
<td>1,836,000</td>
</tr>
<tr>
<td>6</td>
<td>Organic</td>
<td>Kg</td>
<td>1,200,000</td>
<td>120</td>
<td>20</td>
<td>24,000,000</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Durban</td>
<td>L</td>
<td>195</td>
<td>120</td>
<td>500</td>
<td>97500</td>
</tr>
<tr>
<td>8</td>
<td>NPK</td>
<td>Kg</td>
<td>30000</td>
<td>120</td>
<td>400</td>
<td>12,000,000</td>
</tr>
<tr>
<td>S/TOTAL 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64,093,500</td>
</tr>
<tr>
<td>9</td>
<td>contingency(=10% of Stotal 1and 2)</td>
<td>Kg</td>
<td>30000</td>
<td>120</td>
<td>400</td>
<td>13,091,350</td>
</tr>
</tbody>
</table>

OVERALL TOTAL 144,004,850
Source: VUP CYABINGO sector