National University of Rwanda
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The Determinants of Agricultural Production and Profitability in Musanze District, Rwanda

A thesis submitted to the National University of Rwanda in partial fulfillment of the requirements for the award of the degree of Master of Science in Economics

by

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Dedication

To

My parents

My wife Marie Assumpta Uwimpuhwe

My daughter Ange Carine Tabita

The memory of my brother Late Angelo Nzayisenga

The memory of the family of Late Charles Twagirimana

My brothers and sisters

My relatives and friends

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I wish to express my love and gratitude to my beloved families for their understanding, endless love, patience and encouragement when it was most required, through the duration of my studies. I also wanted to thank them for their support in every trial that came my way. Also, I thank them for giving me not only financial, but also moral and spiritual support.

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Abstract

This study considered the determinants of agricultural production and profitability with special reference to crop production in Musanze District. Data collection was conducted through well structured questionnaire administered on 107 respondents selected purposively. The methods of data presentation used were descriptive statistics, and the methods of analysis were production function analysis using the Ordinary Least Square (OLS) approach to estimate the parameters of the Cobb-Douglas production function and the gross margin, the financial sustainability and the BC ratio to analyse the profitability of agricultural production. The results revealed that majority of the farmers' organizations (53.27%) grow Irish potato, bean (27.10%) and corn (11.21%). The overall agricultural production is positively related to inputs used which include labour, fertilizers, seeds and pesticides. The test of significance of estimated parameters shows that inputs in the form of labour, fertilizers and seeds are statistically significant at the 5% level. The estimated R^2 shows that 66% of the variations in agricultural production are explained by the specified independent variables. Also the significance test and the normality test of residuals show that the estimated model is reliable. The sum of input coefficients (0.99) shows that agriculture records decreasing returns to scale. In the short run, the profitability analysis shows that agricultural production is a profitable business in the study area. This is reflected by the gross margin of RwF 3,289, the net income of RwF 2,273, the BC ratio of 1.47, and the return to labour of RwF 1,287 given the daily minimum wage of 700 RwF paid to the worker. Likewise, the analysis shows that all individual crops (potato, wheat, corn, tomato, onion, and cabbage) are profitable except for bean. Similarly, the results of the long run profitability analysis show that the BC ratio is 1.003102. The corresponding NPV is RwF 4,912.84; the IRR is 17.046% with the discount rate (the prevailing lending interest rate) of 16.749%. The sensitivity analysis shows that the agricultural profitability is responsive to the increase of total operating costs, the decrease in average price, the decrease in total production, as well to the increase in the discount rate. Consequently, farmers should improve their equipment and allocate rationally the inputs to attain the least-cost combination. Besides, the government and other stakeholders in agriculture should guarantee markets to farmers and enhance all necessary extension services. These were reported as restraining factors to materialize the agricultural benefits.

Key words: Cobb-Douglas agricultural production function, agricultural profitability, Musanze District, Rwanda

List of acronyms, signs and abbreviations

%	: per cent
a.m	: *ante meridiem* (between midnight and midday)
BC ratio	: benefit-cost ratio
CEPEX	: Centre de promotion des exportations
DC	: District Centre
DERN	: Développement Rural du Nord
Dr.	: Doctor
et al.	: and others
EViews	: Econometric Views (software)
F/LF	: Fertilizers
FAO	: United Nations Food and Agricultural Organization
GDP	: Gross Domestic Product
GI	: Gross Income
GM	: Gross Margin
GoR	: Government of Rwanda
GRP	: Genuine Researchers and Publishers
ha	: hectare
INES	: Institut d'Enseignement Supérieur (de Ruhengeri)
K/LK	: Equipment or equipment expenditure
Kg	: Kilogramme
km	: kilometre
km^2	: square kilometre
L/LL	: Labour
LD/LLD	: Land
LDC	: Less Developed Country
Ltd	: Limited
MINAGRI	: Ministry of Agriculture and Animal Resources (Rwanda)
MINECOFIN	: Ministry of Finance and Economic Planning (Rwanda)
NAPC	: National Agricultural Policy Center (Syria)
NFI	: Net Farm Income
NIS	: National Investment Strategy
No	: Number
NOUN	: National Open University of Nigeria
^oC	: Celcius degree
OLS	: Ordinary Least Squares
P/LP	: Pesticides
p.m	: *post meridiem* (between midday and midnight)
pp.	: pages
REMA	: Rwanda Environment Management Authority
RTS	: Returns to scale
RwF	: Rwandan Franc
S/LS	: Seeds
Std. Dev.	: Standard Deviation
TVC	: Total Variable Costs
UNEP	: United Nations Environment Programme
Y/LY	: Agricultural production/output

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Chapter 1: General Introduction

This chapter highlights the background, the problem statement, the objectives, the questions and hypotheses as well as the structure of this research.

1.1 Background to the study

In economics, a production function describes the technical relationship that transforms inputs (resources) into outputs (commodities) (Debertin, 2012). Bhujel and Ghimire (2006) have estimated the production function of Hiunde rice in Morang District (Nepal) by using data collected through face to face interview during 2002/2003 by administering a semi-structured questionnaire. The result of the empirical model of Cobb-Douglas production revealed the model significant at 1% level and showed that 95% of variation in Hiunde rice production is due to variation in cultivated area, nitrogen, phosphorous, potash, tractor hour, human labour, bullock labour, and irrigation. The net benefit from Hiunde rice was found to be Rs. 14 507.41 per hectare. As the corresponding variable costs were Rs. 19 878.49, the benefit cost ratio was 1.73. The authors concluded that rice production was profitable in the study area.

In the same way, Olujenyo (2008) has conducted a research to define the determinants of agricultural production and profitability with reference to maize production in Nigeria. The results of his study were that the majority of farmers were ageing and quite experienced in maize farming. Farming was still on subsistence level with the low mean size of 0.39 hectares. Maize farming was profitable in the study area, Akoko North East and South West Local Government Areas of Ondo-State. In case of Rwanda, the research conducted by Mpawenimana (2005) analysed the socioeconomic factors affecting the production of bananas in Kanama District. The results showed that land, physical capital, fertilizer and price have positive relationship with banana output. But this research did not analyse the profitability.

Besides the above authors, there are also a number of scholars who have empirically worked on the estimation of agricultural production function all around the world without analyzing the profitability. These include for instance Hoch (1962), Ike (1977), Ecchevaria (1998), Kudaligama and Yanagida (2000), Hussain and Saed (2001), Hu and McAleer (2005), Olubanjo and Oyebano (2005), Arene and Mbata (2008), Mussavi-Haghighi *et al.* (2008), Poudel *et al.* (2010), and Onoja and Herbert (2012).

Theoretically, Picard (2002), Ahuja (2006a, 2006b) and Saleemi (2008) defined production as all activities involving the combination of factors of production like labour, capital, etc. to create goods and services. These authors said that the quality and the quantity of production depend on the quality and quantity of the factors of production available. This means that the bigger is the amounts of the factors of production, the higher is the level of output. In this respect, Picard (2002) classifies the inputs in fixed inputs and variable inputs. In addition, Barthwal (2000) defined the determinants of profitability. These include the total revenue, the fixed cost, the variable cost, and the total cost. The higher is the amount of cost, the lower is the profitability; and the higher is the revenue, the higher is the profitability. Alternatively, for farming business, Oseni said that Gross Margin is one of the most commonly used financial indicators in farm management, whereas Gietema (2006) stated that the main indicator of farm profitability is the Net Farm Income (NFI) which is derived from the Profit and Loss Account. In the same way, Corselius *et al.* (2001) justified the necessity of farming profitability. He emphasized that profitability enables farmers to meet increasing levels of demand and to support an acceptable standard of living while also underwriting the annual investments needed to improve progressively the productivity of resources.

Conceptually, Picard (2002) and Descamps (2005) described the production function as the relationship between amounts used of various inputs and the maximum level of output to be produced. The production function represents the set of technical constraints that a firm is facing. He states that the output is achieved by combining certain amounts of different inputs. This hypothesis is depicted in Figure 1 below.

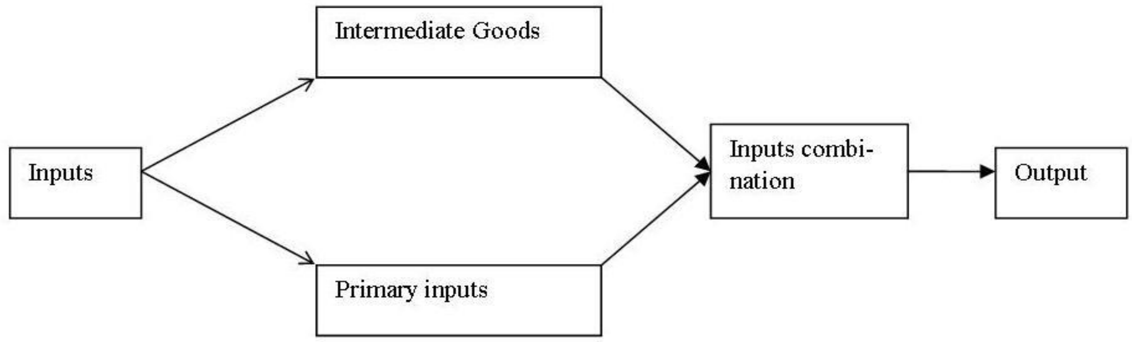

Figure 1: Production process

Mudida (2003) stated that a simple agricultural production function is obtained by using labour and land as inputs and by recording alternative outputs per unit of time. Ahuja (2006a, 2006b) precised that a production function, especially agricultural production, can be extended to include more than two factors like land, irrigation, and fertilizers.

In the current context, the Government of Rwanda (MINECOFIN, 2002) considers highly the agricultural sector both for survival and commercial purposes. It supplies mainly foodstuff and, in case of sufficient production, farmers manage to sell their excess products on markets to get money. Like many governments, the Government of Rwanda (GoR) has subsidized agriculture to ensure an adequate food supply. These agricultural subsidies are often linked to the production of certain commodities such as wheat, corn (maize), rice, soybeans, and milk (Cantore, 2011).

In the past century, agriculture has been characterized by enhanced productivity, the use of synthetic fertilizers and pesticides, selective breeding, mechanization, water contamination, and farm subsidies (Howard, 1943). Proponents of organic farming such as Howard (1943) argued in the early 20th century that the overuse of pesticides and synthetic fertilizers damages the long-term fertility of the soil. While this feeling lay dormant for decades as environmental awareness has increased in the 21st century, there has been a movement towards sustainable agriculture by some farmers, consumers, and policymakers. In Rwanda, this appeals the controversies between MINAGRI and Rwanda Environmental Management Authority (REMA). While MINAGRI (2004) supports the intensive use of fertilizers, use of marshlands to increase the land surface for agriculture in order to achieve high agricultural productivity, REMA (undated) highlights that the use of fertilizers and agricultural chemicals has polluted water, and agricultural activities and general mismanagement of the wetlands have further degraded and destroyed the natural resources by provoking soil erosion and vulnerability to climatic shocks.

As one of the development priorities of Rwanda, agriculture was recognised as the engine of the primary growth (Republic of Rwanda, 2004; IMF, 2008). It has been chosen as the first and strongest leverage to put the country on a sustainable development process and to fight against poverty" and the investment policy in agricultural sector "will contribute to change in the structures, methods, marketing and efficiency of agricultural activities with a very high impact on the revenue of the majority of the population and most of the poor, on exports and on the GDP".

The major agricultural policies adopted by the Government of Rwanda to transform and mechanize the agriculture through the development of modern agriculture include the promotion of more intensive agricultural practices through the increased use of agricultural inputs, agricultural professionalization that promotes high enterprise profitability, the promotion of soil fertility and protection, improved marketing initiatives, and the reinforcement of agricultural research and advisory including a greater role for farmer cooperatives and associations (Bingen and Munyankusi, 2002). Another government policy known as Economic Development and Poverty Reduction Strategy, EDPRS (Government of Rwanda, 2007) identifies the agricultural sector as a crucial area for a growth and calls for energetic public action in collaboration with private and nongovernmental development partners to encourage greater input use and to assist in the provision of services and their monitoring. Yet another government policy, the National Decentralized Policy, supports the MINAGRI policy in its priority on empowering local populations to fight poverty by participating in planning and management of their development process (Bingen and Munyankusi, 2002).

It is well remarkable that Rwanda authorities have made many efforts to pursue sustainable development in making strong strategies in all sectors and particularly in agricultural sector. All these efforts have improved the Rwandan economy in general and the agricultural status in particular. All undertaken strategies by the Government of Rwanda have improved the current situation of Rwandan agriculture. But the question is to know to what extent this improvement has contributed to the development of agricultural sector. In part of response to this question, the study aims at analysis the agricultural production function in a sample District. Results will inform the policy where further efforts are needed to sustain the on-going agricultural development process in Rwanda.

1.2 Problem Statement

Making appropriate economic policies is still of current interest. In the agriculture sector, farmers do not know how to measure the relationship between inputs and output. Alternatively, they need knowledge of differential effects of inputs used as well as the profitability of their cropping system. Another problem regards the effects of agricultural government policies on the poverty alleviation. Yet the profitability of crops planned for each region in the context of crop intensification programme still requires more explanations considering each region’s specificities. Part of contribution of this study is also to give light on the benefits of crop intensification with focus to land use consolidation.

The implementation of Crop Intensification Program goes together with government subsidies for the purchase of fertilizers and seeds by small holder farmers. The question remains obtaining proper exit strategy to ensure sustainability of premises already achieved as well as the overall agro-input business sustainability by involving the private sector.

1.3 Research objectives

The general objective of this study is to estimate the agricultural production function and analyze its profitability in Musanze District, Rwanda. Specifically, the study aims to:

1. Define the determinants of the agricultural production in Musanze District;
2. Analyse the profitability of agricultural production in Musanze District;
3. Formulate practical strategies to address problems related to agriculture in Musanze District.

1.4 Research Questions and Hypotheses

To validate the above objectives, the study will make an attempt to respond to the following questions:

1. What is the influence of inputs on agricultural output in Musanze District?
2. What kind of returns to scale are there in the agricultural sector in Musanze District?
3. How are CIP crops profitable for smallholder farmers in Musanze District?

The leading assumptions of this study include:

1. The agricultural output is positively related to the inputs used in the production process in Musanze District.
2. The agriculture in Musanze District scores increasing returns to scale.
3. The CIP crops in Musanze District are profitable both in the short run and in the long run for smallholder farmers.

The first hypothesis was motivated by the fact that, according to economic theory, the level of production depends positively upon the level of inputs used. The researcher is willing to verify the validity of this theory in agricultural sector in the sample sectors. The second hypothesis is based on the results of the voucher system which state that in some areas of Rwanda, the harvest has been multiplied by two, three, four, even more. The researcher wants to know how this practice is performing in the study area. As for the third, it is justified by the question about the suitability and the profitability of the CIP crops in different regions of Rwanda. The research would like to help the policymakers, farmers and investors to know how well the crops have been chosen as well as how profitable these crops are in the sample District.

1.5 Justification and the scope of the study

Agriculture is the backbone of Rwandan economy. Besides, this sector has more problems than others. These problems need solutions from specialists. As an Agricultural Economist, the researcher is eligible to contribute to the development of the agricultural sector in Rwanda.

This study is necessary to state at what extent the agricultural business is profitable. It is expected that the results of this study will be used by agricultural decision makers, agriculture planners and farmers when planning for inputs and outputs. Knowing the main determinants and profitability of agricultural production, decision makers shall know where more efforts are needed and planners hall be able to predict both inputs and output for a specific future period. Similarly, farmers will use the estimated econometric model to plan for inputs and output. They will also use the results of this study to compare their crops in order to know their degree of profitability. In regards of researchers and academicians, the results of this study shall contribute to the set of knowledge related to agricultural economics in Rwanda.

As far as the scope is concerned, this study is delimited in the domain, in the space as well as in the time. In the domain, this study is limited to farm business organisation where the econometric model stating the relationship between inputs and agricultural output in Musanze District is estimated. The first dimension is concerned with the agricultural sector of economy. The second dimension is just the application of econometrics in measuring the impact of different activities undertaken in the agricultural sector on the production. The model chosen to estimate this relationship is the Cobb-Douglas production model. The results associated to this dimension will help the researcher to define the determinants of the agricultural production (objective 1). The third dimension is concerned with the farm accounting where the profitability of agricultural production is analyzed. The results linked to this dimension will be necessary to analyse the agricultural profitability (objective 2). Spatially, this research is concerned with the estimation of agricultural production function and profitability analysis in Musanze District. Temporally**,** the researcher will use agricultural statistics collected during

August and September 2012. The overall results will be referred to in formulating policy recommendations (objective 3).

1.6 Structure of the study

The remaining part of this study is concerned with 5 chapters from chapter 2 to chapter 6. The second chapter provides the literature review. The third chapter illustrates the research methodology. The fourth chapter includes the data presentation. The fifth chapter concentrates on presentation, discussions and evaluation of results. Finally, the conclusions and recommendations are the contents of the sixth chapter.

Chapter 2: Literature Review

This chapter presents different economic theories on agricultural production and its specific characteristics, the role of agriculture in economic development as well as the production function. The agricultural production function is mainly represented by the Cobb-Douglas production function. All these points have been described in the first section which is entitled as theoretical literature review. The second section whose title is empirical literature review presents the results achieved by different researchers by using Cobb-Douglas production function to define the determinants of agricultural production function and the gross margin analysis to state the agricultural profitability in different areas throughout the world.

2.1 Theoretical Literature Review

Tayebwa (2007) defined and extended agriculture to include crop and livestock production, production and marketing and farm products, as well as inland fisheries and forestry. According to Cafiero (2003), agriculture is broadly conceived as the set of activities that use land and other natural resources to produce food, fiber and animal products that can be used for direct consumption (self consumption) or for sale, either as food or as input to the manufacturing industry. Forestry, fishing and hunting are usually included in the agricultural sector.

Corsi (2002; 2003) defined specific technological and socioeconomic characteristics of agriculture as well as characteristics concerning the heterogeneity, the specificity of the demand for the agricultural products as well as the risks and uncertainties in agricultural sector. In addition, he underlined the sources of risks in this sector. In the same way, Nehme (2007) has completed Corsi in distinguishing between the impact on farmers and the society as a whole (the consumers).

Concerning the role agriculture, Rukuni (2006) and Tayebwa (2007) stated that it evolves as the economy of a country develops. In developing countries, the agriculture is almost always the foundation and backbones of the economy since most people rely on it for food and employment. He precised that agriculture plays several traditional roles essential in overall economic growth.

Specifically in Western countries, agricultural development has been a prerequisite for the industrial revolution: it provides food for the industrial labour force, it supplies raw materials for the industry (cotton, wool, etc.), it provides labour for the industry, it gives the capitals for the first industries, and it serves as a market for industrial goods (tools, machinery, chemical fertilizers). In the other countries, agricultural development has important roles too: provides labour for the other sectors, creates an internal market, may be a source of capital formation, may provide raw materials for a domestic processing industry, and may provide foreign currency when the agricultural output is exported (Corsi, 2002). In addition, Todaro and Smith (2009) underlined that the integrated rural development is achieved in developing economies if the agriculture played its basic complementary elements namely accelerated output growth, rising domestic demand for agricultural output derived from an employment-oriented urban development, and diversified non-agricultural labour-intensive rural development activities that support and are supported by the farming community, and this after completing its primary purpose of providing sufficient low-priced food and man-power to the expanding industrial economy.

As consequence of above mentioned characteristics of agriculture, Corsi (2002) and Mudida (2003) listed the problems of agricultural sector: price fluctuations (due to weather, diseases, etc.), effects of international production changes on the local market, time lags between the decision to produce and the realization of the final output, income fluctuations, declining long-term terms of trade, food demand scarcely responsive to income, less concentration in agriculture than in many other sectors and little market power, sectors outside agriculture (input production, food industry, marketing sectors) are more concentrated and have more market power, scarce factor mobility (land, machinery, labour) and adjustment to market changes are slow, hence agricultural incomes are often lower than in other sectors. Tayebwa (2007) identified a number of bottlenecks in agricultural development particularly in less developed countries (LDCs) considering the case of Uganda.

About the agricultural production function, Ellis (1992) described it as the physical relationship between agricultural output and inputs considering the example of the response of rice (paddy) output to changes in the application of nitrogen fertilizer. He defined the output (Y) and any number of production inputs (X_1, X_2, …, X_n) and presented the production function as:

$$Y=f\,(X_1,X_2,\ldots,X_n).$$

The relationship between paddy output and fertilizer input is a production function. This production function is described as the total physical product (TPP). The same relationship can also of course be described mathematically, either in a general form which says that paddy output (Y) is some function of different levels of a variable input (X_1), or $Y=f(X_1)$; or in a specific form which tries to give the exact relationship between output and input.

The most used form of an agricultural production function is a Cobb-Douglas production function. This application is preferred for it is easy to apply and its fit is almost a certainty. Moreover, it produces output elasticities with respect to independent variables included in the model, and gives better results comparing to other forms (Hussain and Saed, 2001). Debertin (2012) stated that the concept of Cobb-Douglas production function was used for the first time in 1928 in an empirical study to define the comparative productivity of capital versus labour in the economy of the United Sates. The function has been used in agriculture because of its simplicity. The function was assumed to contain two inputs, capital and labour, and to be homogeneous of degree 1 or to score constant returns to scale. He added that this function can have different shapes bearing to the independent variables included in the function.

Beside different theories on the estimation of agricultural production function, economists show that the agriculture must impact on the farmer's life. That is, the agricultural activities must be profitable. According to Oseni (undated) and Olukosi *et al.* (undated), the agricultural profitability can be measured by using the Gross Margin (GM) or the Net Farm Income (NFI). The GM is the difference between the Gross Farm Income (GFI) and the Total Variable Costs (TVC), whereas the NFI is the difference between the GFI and the Total Costs (TC), or the difference between GM and Total Fixed Costs (TFC). Both Oseni and Olukosi said that the GM can be used to appraise and evaluate the performance of a farm business. To serve effectively for this purpose, all GM calculations must be checked very carefully for consistency and accuracy. In the same sense, Brown (1979) stated that the Gross Margin (GM) is one of the most commonly used financial indicators in farm management. GM is gross return after all variable costs have been accounted for. It means that it is return on variable costs only, and it does not include fixed costs. Also Johnson, Lessley and Hanson (1998) defined the GM as the surplus or deficit remaining after variable costs have been deducted from the value of total production or gross income. However, the GM is not the only indicator of farm profitability. Another farm performance indicator is the Net Farm Income, NFI (Brown, 1979; Gietema, 2006; Oyebanji *et al.*; 2012).

In Rwanda, agriculture is a dominant economic activity (as the majority of the population live in the rural areas) with enough number of development potentials like climate and fertile soil especially in the volcanic mountains in the Northwest (Republic of Rwanda, 2004).

As the agricultural sector has continued to perform poorly with consistently declining productivity associated with traditional peasant-based subsistence farming, the Vision 2020 (Republic of Rwanda, 2000) targeted to replace subsistence farming by a fully monetized, commercial agricultural sector by the year 2020. The agricultural policy orientation was to be overhauled, promoting intensification so as to increase productivity and achieve the annual growth rates of 4.5 to 5%.

For the purpose of implementation of the Vision 2020 Planning, the Economic Development and Poverty Reduction Strategy, EDPRS (Republic of Rwanda, 2007) was put in place. In agricultural domain, EDPRS aimed at adopting an export-oriented growth. Besides, other programmes like GIRINKA and CIP, and different projects like Agricultural Information and Communication (CICA), Rural Income through Exports (PRICE), Bugesera Natural Region Rural Infrastructure Support Project (PAIRB), Livestock Infrastructure Support Programme (LISP), Kirehe community-based Watershed Management Project (KWAMP), etc. have been put in place by the Ministry of Agriculture and Animal Resources (MINAGRI) in order to enhance the agricultural development. All of these programs and projects aimed at enhancing sustainability of agricultural practices to help the sector to fulfill its potential for increasing GDP and reducing poverty.

2.2 Empirical Literature Review

Several researches have been conducted on agricultural production using the production function model to estimate the impact of various factors on output changes. In any case, the Cobb-Douglas production function has been used to define the determinants of agricultural production function.

Poudel et al. (2010) used a Cobb-Douglas production function to estimate the production function and resource use condition of organic cultivation in different farm size and altitude categories in the Hill Region of Nepal. By using the OLS method and cross section data collected in 2010 on 280 coffee farming households selected randomly from 400 households in 12 Village Development Committee (VDC) in the Gulmi District. The data was for the 2009 normal coffee growing year and organic farms were classified according to farm size and farm altitudes. The variables included in the model are the coffee output, farm size, labour used, fertilizer, inter/shade crops, the number of coffee trees, the sex of the coffee farm manager, household size, the extension training of the coffee farm manger, the age of the coffee farm manager, the farm experience, and the labour cost. The results showed the greater significance of labour employed and organic fertilizer application. Increasing returns to scale was observed in all categories while summing of elasticities. Labour was found overutilized while remaining factors were underutilized. Therefore, available inputs should be rearranged effectively to enhance the technical efficiency.

In Iran, Mousavi-Haghighi, Kowsar and Shamsuddin (2008) used the Cobb-Douglas production function to estimate the production technology in agricultural sector. In addition, both translog and transcendental production functions were used. Data from 1966/67 to 2000/01 were used, and the variables included in the models are agricultural production, capital, labour, irrigated and non-irrigated land, total land and time. The findings of the study indicated the declining RTS because of the negative effect of labour in production process. It was also shown that the marginal products increased except the marginal product of labour. Hence, it was concluded that the production was on the phase one or two on the production surface of land and capital, and the improper combination of the labour and other inputs has remained unchanged. Thus it was suggested that policies should be formulated to reduce labour in the agricultural sector in order to increase output and productivity.

In China, panel data were used by Hu and McAleer (2005) to estimate the agricultural production efficiencies. A panel data set from 30 provinces for the seven year period (1991-1997) was used based on the Cobb-Douglas production function. The data were taken from various issues of the China Statistical Yearbook comprising agricultural input and output data for 1991-1997 for 30 provinces, with the subscripts i and t ranging from 1 to 30 and 1 to 7 respectively. The variables included in the model are the capital (with its different forms: land, machinery, fertilizers), labour as well as the agricultural production output (products of farming, forestry, animal husbandry, and fishery). Individual effects were tested to determine if pooled estimation is preferred to unpooled (panel) estimation to represent the production frontier and to compute technical efficiency at the provincial level.

In Nigeria, Ike (1977) used the Cobb-Douglas production function to estimate agricultural production functions for some farm families in Western Nigeria by using cross section data collected in February 1973 from two hundred farmers. A questionnaire was used for the interview. The data collected were the value of farm equipments, the areage of land brought under cultivation, the number of families and hired labour, the value of fertilizers, and the value of output for the year 1972. The value magnitudes were estimated using prevailing market prices. The data were stratified in several ways in such a way that ten production functions were estimated. The estimated production functions are used to predict the output effect of factor transfers from small-scale to medium-scale holdings and from medium-scale to large-scale holdings. The main results show that farmers with more consolidated holdings were more efficient in the use of labour and land than farmers with less consolidated holdings. The equations estimated for both groups are good and as such comparable. It was shown that a movement towards consolidated holdings would help the attainment of more efficient input mix and hence increased output in the agricultural sector. The emphasis placed on fertilizers in governmental input subsidy schemes could be reaching suboptimal limits. Better hoes could be experimented with like hoes that reduce the amount of motive power applied to them for traction. The introduction of motor driven equipment should be made in highly consolidated holdings.

Yet in Nigeria, elements of agriculture include forestry, livestock, food and cash crops such as yams, cassava, maize, cocoa, groundnut and oil palm. Through his work, Olujenyo (2008) aimed at defining the determinants of agricultural production and profitability in Ondo-State. His methods included the Ordinary Least Squares (OLS) criterion. The variables included in the model are the output of maize (Y), age (X_1), farm size (X_2), education (X_3), sex (X_4), labour man day (X_5), cost of input (X_6), season (X_7, dry=1, wet=2). The model has been estimated by using data collected with the aid of structured questionnaire from 100 respondents selected through random sampling technique.

The results show the positive relationship between total output and age, education, labour, non-labour input cost and type of season. That is, the increase in one or all of these variables implies the increase in total output. On the other hand, there is an inverse relationship between output and farm size, years of experience and sex of respondents. The same as the negative sign of farm size and years of experience was unexpected; the same the sign of education is unexpected but is due to the generally small number of years of formal education observed throughout the sample. The results show that only labour has significant impact on maize production. Yet the profitability analysis showed that maize farming was profitable in the study area with gross margin and net returns of N 2,637.00 and N 2,141.00 respectively.

Another similar study was conducted by Bravo-Ureta and Pinheiro (1997) in Dajabon region in the Dominican Republic, with the objective of assessing the possibilities for productivity gains by improving the efficiency of small-scale agriculture. The Cobb-Douglas functional form is chosen because it has been widely used in farm efficiency analyses for both developing and developed countries.

Based on a sample of sixty small farmers from Dajabon and on the model specified, the results of the ordinary least square (OLS) and maximum likelihood (ML) estimates of the production function show that all parameter estimates are statistically significant at the 1 per cent level for the two models with the exception of the parameter estimates for labour (X_2) and seeds and draft power (X_5), both of which are statistically significant at the 5 per cent level.

In Turkey, the study conducted in the province of Aydin by Armagan and Ozden (2007), the authors wanted to reveal the Total Factor Productivity (TFP) of the enterprises engaged in production of agricultural products in a comparative manner considering the size of the enterprises. Besides, the efficiency and the yields of each inputs involved in this process is concerned. The authors have used the conventional Cobb-Douglas production function to determine the relation between the gross production and the inputs used.

To achieve their objectives, the authors have dealt with three sample groups. As the main goal of this study was the analysis of TFP, the TFP coefficient was found only significant in the third group enterprises.

While conducting a research on production function of rice in Morang district in Nepal, Bhujel and Ghimire (2006) have used a semi-structured questionnaire through face-to-face interview to collect information necessary to estimate this function. Considering the results of this study, human labour and bullock labour have not any significant effect in production. The nitrogen effect on production is significant at 1% level and has negative value which indicates the excess application and the variety which is not much responsive to higher dose of nitrogen, however the dose of phosphorous and potash can be increased.

Hussain and Saed (2001) aimed at assessing and evaluating the crop production function parameters in Jordanian's agricultural sector during the period 1981-1996. The main objectives of this research are to estimate the relationship between the output per tones and the level of inputs (area, labour, and capital), and to test the hypothesis that reallocation of resources with farm capital intensity bias will promote growth, employment potential growth and agricultural productivity in Jordan. To estimate this production function, the author has used the usual Cobb-Douglas production function. The estimated production function show the increasing returns to scale. The analysis indicates that agriculture is characterized by the intensive labour method since the elasticity of labour was greater than that of capital, respectively of 0.455 and 0.130.

In Canada, a study was conducted by Echevarria (1998) with the aim of the estimation of value added in agriculture as a constant returns to scale function of the three factors of production (land, labour and capital) using Canadian data on the period 1971-1991. After a constant returns to scale production function is estimated, the author has calculated the average of the factor of change of the Solow residuals using a Cobb-Douglas function. The results show that agricultural production functions in Canada, both at provincial and national levels register constant returns to scale, because the sum of partial elasticities is unity.

In Rwanda, similar researches have been conducted with the aim of defining the determinants of the banana production function (Mpawenimana, 2005) and the profitability analysis and strategic planning of coffee processing and marketing of coffee growers’ association in Rwanda (Murekezi, 2003). Comparatively, Mpawenimana ignored the banana profitability analysis whereas Murekezi did not include the definition of the determinants of the coffee production function. Another research in Rwandan context which analysed the agricultural profitability with reference to bench terraces was conducted by Bizoza and de Graaff (2010) by using the financial benefit cost analysis.

Chapter 3: Research Methodology

This chapter provides the respondents, the presentation of the study area, the data collection method, the data presentation methods as well as the data analysis methods.

3.1 Determination of the number of the respondents

The respondents in this research are the farmers' organizations operating in eight sectors of Musanze District and that are coached by DERN (*Développement Rural du Nord*). This is an organisation of Ruhengeri Catholic Diocese, created in 1981 with the mission of improving the socioeconomic conditions of the population of the same Catholic Diocese of Ruhengeri. Specifically, the Programme aims at increasing money income of agricultural production for rural households. The beneficiary group is made of poor families who mostly depend on income assistance by DERN Program. The areas of intervention include the sectors of Busogo, Muko, Rwaza, Gataraga, Nkotsi, Muhoza, Musanze, Nyange and Kinigi of Musanze District. In this District, DERN program does not cover all sectors; the Program does not intervene in the sectors of Gacaca, Gashaki, Kimonyi, Muhoza, Remera and Shingiro. The sample area of this study is made of the sectors which lay in the intervention zone of DERN Program. In the study area, the number of these farmers' organizations assisted by DERN is 107. The farmers' organizations were purposively targeted (Amin, 2005; Rukwaru, 2007) since they are coached in such a way that they register all expenses they incur in their daily farming activities and, therefore, it was very easy for the researcher to identify them. Before the researcher decided to target the farmers' associations coached by the Programme DERN, a reconnaissance survey was conducted in June and July 2012 to identify the respondents who are poor and smallholder farmers, and who are able to communicate what and how they manage their farming activities. It is just in this way that the sample was determined.

3.2 Presentation of the study area

With special reference to the District Development Plan 2008-2012 (District de Musanze, 2007), the paragraphs of this section describe briefly the study area.

Musanze District is one of the five Districts of the Northern Province. It has a surface of 530.4 km^2 of which 60 km^2 for the Volcano National Park and 28 km^2 of the Ruhondo Lake. Musanze District is surrounded by Uganda in North and by the Democratic Republic of Congo

(D.R.C), the Volcano National Park, in the South by Gakenke District, in the East by the Burera District, and in the West by Nyabihu District.

The average altitude is of 2,000 m including the chain of the volcanoes Kalisimbi (4,507 km), Muhabura (4,127 km), Bisoke (3,711 km), Sabyinyo (3,574 km), Gahinga (3,474 km) which offers beautiful and attractive touristic site.
Musanze District faces tropical climate of highlands with has mean temperature of 20ºC. Generally with enough rain the whole year, the precipitations vary between 1,400 mm and 1,800 mm.

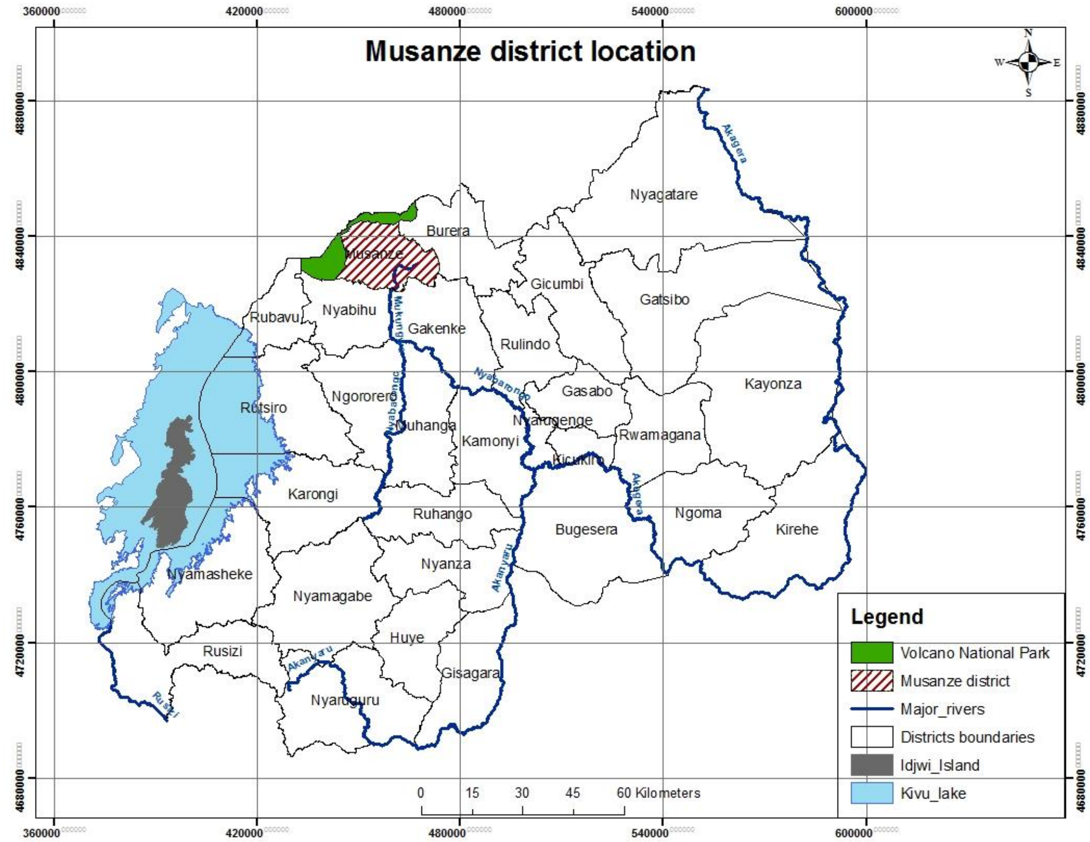

Figure 2: Location of Musanze District on the map of Rwanda

Two main and two small seasons characterize the study area namely the rainy and the dry seasons: from June to mid-September, we have the great dry season; from January to mid-March, the small dry season; from mid-March at the end of May, the great rainy season; and from mid-September to the end of December, the small rainy season.

In terms of physical characteristics of the study area, the soil of Musanze District is dominated by volcanic soil which is essentially fertile. The main crops of Musanze District are Irish potato, bean, corn and wheat. The horticulture experiences a slow development, limited to vegetables and fruits. As for the industrial crops, in 2006 the production of the pyrethrum reached 220 tons of dry flowers whereas the coffee farming relates to 86,128 coffee-trees (District de Musanze, 2007).

According to current statistics, the population of Musanze District rises to an average density of 592.6 inhabitants per km^2. The population composition shows that the female manpower (166,763) is higher than that of the men (147,479), that is to say the respective proportions of 53% and 47%, for the whole of the District. The overpopulated sectors are Muhoza and Cyuve, with respective densities of 1,722.3 inhabitants per km^2 and 903 inhabitants per km^2. Kinigi is the sector the least populated with 274.8 inhabitants per km^2.

The population of Musanze District is in general young, since less than 25 years represents approximately 60% of the total active people. The habitat differs according to zones: the urban zone where the habitat is planned and spontaneous and the rural zone where the habitat is dominated by agglomerations and dispersed habitat. The current estimates identify two rural sectors namely Kinigi and Nyange which experience a notorious development with more than 90% of the population living in agglomeration. To increase cultivable surface and to facilitate the access to the basic infrastructures (drinking water, management of the environment, roads, station of health…), it proves to be pressing to identify the sites of habitat gathered for their development.

Table 1: Musanze population in 2012 (projections)

Sector	Remera	Kimonyi	Muhoza	Musanze	Muko	Nkotsi	Gataraga	Busogo
Population	21,984	14,107	41,786	30,842	18,432	14,651	23,083	17,958
Percentage	6.15	3.95	11.70	8.63	5.16	4.10	6.46	5.03
Sector	Shingiro	Cyuve	Kinigi	Nyange	Gashaki	Rwaza	Gacaca	**Total**
Population	20,641	34,669	25,321	27,554	15,225	26,215	24,807	**357,275**
Percentage	5.78	9.70	7.09	7.71	4.26	7.34	6.94	**100.00**

Source : District de Musanze, *Plan de Développement du District de Musanze: 2008-2012,* District de Musanze, Musanze, 2007

The schooling population dominates in Musanze District since 26% of the whole population are still at primary school. Ranging between 20 and 59 years, the working population is distributed in different branches of industry which are mainly agriculture and husbandry, craft industry, trade, and liberal profession.

The households of Musanze District remain slightly capitalized in cattle. The animal livestock comprises the bovines, the sheep, the caprines, the porcines, the rabbits, the poultries as well as the bee-keeping, smaller live-stock having a significant place. In addition, it has noted that each family on 4 has at least one cow. Such a situation is not comfortable in a primarily agricultural economy.

3.3 Data Collection Method

For the purpose of data collection, a field survey was conducted in Musanze District during August and September 2012 from a purpose sample of 107 farmers' organizations assisted by the Programme DERN in Musanze District. The sample was judged representative because these organizations are homogeneous both in terms of the socioeconomic characteristics of members and the size. In the intervention zone, DERN assists farmers' associations are provided with fertilizers, improved seeds, as well as technical assistance. The CIP crops are promoted by the DERN assisted farmers' organizations. DERN wants the assisted organizations' members to learn the modern farming techniques and apply them in their individual households' farms. This last aspect is out of the concern of this study. Data collected from the survey include the crop production in kilograms, the number of workers used, the equipment expenditure, the size of the cultivated land, the quantity of seeds grown, the quantity of pesticides used, the quantity of fertilizers used as well as the unit selling price of each product and for each farmer organization. Questionnaire forms (Rukwaru, 2007) were administered to the respondents who fulfilled them. All questionnaire forms were fully completed and taken back by the respondents to the researcher.

Besides the field survey, the documentary method (Amin, 2005) has been used in collecting data. This method involves information delivery by studying carefully written documents, or visual information from various sources called documents. These documents include textbooks, newspapers, articles, speeches, advertisements, pictures, and many others.

In this research, the documentary method has been used to deal with primary data which concern primarily the literature review.

3.4 Data presentation method

Descriptive Statistics (Francis, 1998; Francis, 2004) were used to present data collected (mean, minimum, maximum, standard deviation, tables, totals, percentages and figures).

Francis (1998) and Rukwaru (2007) define the mean of a set of values as the sum of the values divided by the number of the values. The significance of the mean is understood as the standard average and regarded as truly representative of the data since all values are taken into account in its calculation.

For these authors, the standard deviation is defined as the root of the mean of the squares of the deviations from the common mean of a set of values. It is a number which gives a measure of spread about its mean. It is used as a measure of dispersion of a set of values. It is related to the mean deviation which is also a measure of deviation that gives the average absolute difference (that is, ignoring the negative signs) between each item and the mean.

Like the standard deviation, the variance gives an indication of how closely or widely the individual X values are spread around their mean value. The standard error is simply the standard deviation of the values about the estimated regression line and is often used as a summary measure of the goodness of fit of the estimated regression line (Gujarati and Sangeetha, 2007).

Lind, Marshal and Wathen (2005) compared standard deviation to standard error. Whereas the standard deviation measures the dispersion around the mean, the standard error of estimate measures the dispersion about the regression line.

Rukwaru (2007) defined a range as the difference between the highest and the lowest values of the set. That is, subtracting the lowest value from the highest value will give us the range. He defines the mode as the value or category of the scale which occurs most frequently. It is corresponds to the maximum of its frequency distribution. This is also called the mode or the modal value of the distribution. Yet for this author, the median is the value which divides a distribution into two equal parts. It means that this value divides a distribution so that an equal number of values lie on either side of it.

King'Oriah (2004) defined and compared skewness and kurtosis coefficients. He stated the existence of a few very large values in a population has a tendency to pull the mean value upwards, which is beyond the position of the median. In this case, the modes of the data are also positioned below the mean. The mean then ceases to be the centre of gravity of observations because the largest proportion of data lies below the mean to conform to the position of the mode and the median. Under such circumstances, we conclude that the resulting distribution has a skew and it is skewed to the right. A skew is a long tail of the distribution caused by the existence of a few very large or very small values. Gujarati and Sangeetha (2007) define briefly skewness as the lack of symmetry, and the kurtosis as the flatness or the tallness. For a normally distributed variable, the skewness coefficient (s) is equal to 0 and the kurtosis coefficient (k) is equal to 3. Both s and k are important elements used in the test of normality. If the computed p value of the JB statistic in an application is sufficiently low, which will happen if the value of the statistic is very different from 0, one can reject the hypothesis that the residuals are normally distributed. But if the p value is reasonably high, which will happen if the value of the statistic is close to zero, we do not reject the normality assumption.

3.5 Definition of variables and Specification of the Model

The table 2 below summarizes the definition, the symbol and the measurement of both dependent and independent variables. The dependent variable is the agricultural output, and the independent variables include the labour used, the fertilizers, the pesticides, and the seeds. Each independent variable is positively related to the dependent variable. This means that the signs of the coefficients are expected to be positive.

Table 2: Definition and measurement of variables

Variables	Symbol	Measurement	Definitions
Agricultural output	Y	Kilograms	Agricultural produce for one crop
Labour	L	Man days	Number of workers used
Fertilizers used	F	Kilograms	Minerals and organic manure used
Pesticides used	P	Litres	Value of pesticides used in RwF
Seeds	S	Kilograms	Seeds used in RwF

Source: Definition and measurement of variables by the researcher

Before estimating the model, data on these variables have been collected. Equipment expenditures and rent were not considered when estimating the production functions because they are fixed inputs in nature. However, these were used for the profitability analysis. The variable inputs (labour cost, value of fertilizers, pesticides cost, and seed cost) were included in the model to see the extent to which they affect the agricultural production.

In the intent of the model specification, Gujarati (1995) and Gujarati and Sangeetha (2007) classify the Cobb-Douglas production function as the best production function besides constant elasticity of substitution production function. Its stochastic form and its log-linear form are below presented respectively:

$$Y = \beta_1 X_{2i}^{\beta_2} X_{3i}^{\beta_3} e^{u_i}$$

$LogY = \beta_0 + \beta_2 LogX_{2i} + \beta_3 LogX_{3i} + u_i$ ---Equation (1)

where Y is a dependent variable, Xs are independent variables, u_i is a disturbance term, β s are parameters to be estimated and $\beta_0 = Log\beta_1$ are the intercepts. Following Gujarati, the model to be estimated for this case study is below described:

$LogY = \beta_0 + \beta_1 LogL + \beta_2 LogF + \beta_3 LogS + \beta_4 LogP + U$ -----------------------------Equation (2)

where *LogY* stands for agricultural output in RwF, *LogA* is the TFP that represents technological level, *LogL* is labour in RwF, *LogF* is the value of fertilizers in RwF, *LogP* is the value of pesticides in RwF, *LogS* is the value of seeds in RwF, *Log* means natural logarithm, U stands for the disturbance term, e is the Neperian number, and β_0 to β_4 are parameters to be estimated. The above equation is linear in parameters and it is possible to estimate its parameters by using OLS method (Gujarati, 1995; Bourbonnais, 2005; Gujarati and Sangeetha, 2007).

The expected signs for the parameter estimates of independent variables are all positive. Thereafter, any variable whose probability is greater than 5% has less or no influence on the agricultural output.

In a Cobb-Douglas production function, the input coefficients are qualified as output elasticities with respect to inputs which express the effects of inputs on output in percentage terms (Bourbonnais, 2005). The sum of all elasticities makes the level of returns to scale (RTS). If this sum is less than one, it is the case of decreasing RTS; if it is equal to one, it is the case of constant RTS; and if this sum is greater than one, it is the case of increasing RTS (Picard, 2002).

3.6 Data analysis methods

As it was suggested by Rukwaru (2007), the results of the research were related to both the literature review to make them authoritative. As they were defined in Table 1, data collected were expressed in quantities except for equipment expenditures which were expressed in RwF. All variables were expressed in terms of money. For the agricultural production, the prevailing market prices were used. As for the inputs, the price lists of AgriNavet and AGROTECH (Agrah Care Ltd), both agricultural inputs' suppliers in Musanze, visited on September 21st 2012 were used. To estimate the land cost as an element of investment necessary for the long run profitability and sensitivity analyses, the prices stated in the Ministerial Order No 002/16.01 of 26/04/2010 determining the reference land price outside the Kigali City were used, whereas the rent were estimated by the respondents when data were collected. The rent was used in the short run profitability analysis as an element of fixed costs.

The Ordinary Least Squares method, OLS method was used to estimate the agricultural production functions in the sample District with reference to Cobb-Douglas production function. The overall production function and the individual production functions for Irish potato and bean were estimated. The decision rule was mainly the probability value linked to the student ratio: an input was qualified significant if the probability value is less than 5%. In addition, other tests were conducted. These include the R^2, Fisher test and the normality test of errors to measure the reliability of the model estimated. The related decision rule was that if R^2 is greater than or equal to 0.20 (as cross section data are concerned), if the probability of Fisher statistic is less than 5% and if the errors are normally distributed, the model was qualified as reliable.

About the profitability analysis for the short run, the main indicator was the gross margin. An enterprise is considered as profitable is the gross margin is positive. Other indicators were computed: the benefit-cost ratio and the returns to labour. For these indicators, an enterprise is considered profitable if the benefit cost ratio is greater than 1 and the return to labour is greater than the minimum daily wage paid to the worker.

As for the long run profitability analysis, the benefit-cost ratio was defined. An investment is said to be profitable if this ratio is greater than 1. In this case, further indicators were calculated: the financial sustainability, the net present value (NPV) as well as the internal rate of return (IRR). If the financial sustainability is concerned, an investment is profitable if the cumulated cash flow is positive on the period specified. In case of NPV or IRR, a project is profitable if its NPV is positive or its IRR is greater than the current discount rate.

Chapter 4: Presentation of Data

This chapter is concerned with the distribution of respondents in sample sectors and in crops grown. In addition, the socioeconomic characteristics of overall and individual agricultural production functions in the sample sectors are hereby presented through the descriptive statistics.

4.1 Distribution of the respondents

Respondents are distributed in sectors and according to the crops. The table below describes the sector distribution of respondents in the study area. This table shows that 107 respondents are distributed differently in the sample sectors. The sector of Musanze is the first with 14.95% of respondents, Rwaza the second with 14.02%, Busogo the third with 13.08%, Gataraga the fourth with 12.15%, up to Kinigi the last with 6.54%. As the table shows, the numbers of respondents are distributed in sectors from 7 to 16.

Table 3: Distribution of respondents in sample sectors

Sector	Number of organizations	Percentage
Busogo	14	13.08
Cyuve	9	8.41
Gataraga	13	12.15
Kinigi	7	6.54
Muko	11	10.28
Musanze	16	14.95
Nkotsi	13	12.15
Nyange	9	8.41
Rwaza	15	14.02
Total	**107**	**100.00**

Source: Field survey, August and September 2012

Not only were the respondents distributed in sectors, but also according to the crop as it is described by the table below. The crop distribution of respondents was also presented in order to know in which importance the CIP crops are grown in sample sectors. This table shows that 53.27% of the respondents grow Irish potato, 27.10% grow bean, 11.21% grow corn, 5.61% grow wheat, 0.93% grow cabbage, 0.93% grow tomato, and the remaining 0.93% grow onion.

Table 4: Crop distribution of respondents

Crop	Number of organizations	Percentage
Bean	29	27.10
Cabbage	1	0.93
Corn	12	11.21
Irish potato	57	53.27
Onion	1	0.93
Tomato	1	0.93
Wheat	6	5.61
Total	**107**	**100.00**

Source: Field survey, August and September 2012

4.2 Descriptive statistics

The data collected for the purpose of this research have been summarized in tables in money value. The tables comprising data (from table 5 up to table 9) include the mean, the median, the maximum, the minimum, the standard deviation, the skewness, the kurtosis, the Jarque Bera (JB) statistic and its probability as well as the number of observations for each variable. Tables have been dressed globally for all variables both in real terms and money value. In addition, individual tables for bean, Irish potato, corn and wheat in money value have been dressed.

The following table describes the agricultural production in Musanze District. It presents the socioeconomic characteristics of main crops produced in the study area. This table shows that, on the land of 18.01 ares, the production is RwF 185,905 worth, and it costs RwF 6,649 for equipment, RwF 39,140 for labour, RwF 16,019 for land, RwF 28,464 for fertilizers, RwF 48,408 for seeds, and RwF 10,626 for pesticides. This comes to the production of RwF 10,317, and the costs of 380 RwF for equipment, RwF 2,172 for labour, RwF 1,580 for fertilizers, RwF 2,686 for seeds, and RwF 590 for pesticides per are. The cost of 1 are of land is RwF 889.

Table 5: Description of crop production in RwF in Musanze District

	Y	K	L	LD	F	S	P
Mean	185,905.3	6,848.598	39,139.72	16,018.69	28,463.87	48,407.99	10,626.24
Median	116,400.0	3,000.000	25,500.00	12,000.00	19,720.00	24500.00	4,000.000
Maximum	1,200,000.	51,000.00	170,000.0	80,000.00	23,3950.0	450,000.0	184,000.0
Minimum	7,500.000	0.000000	4,250.000	3,000.000	1,000.000	100.0000	0.000000
Std. Dev.	235,228.4	11,360.22	38,283.55	12,154.26	35,018.29	71,806.90	22,360.21
Skewness	2.947173	2.514302	2.010700	2.669577	3.737338	3.054826	4.953687
Kurtosis	12.34640	8.688639	6.416958	12.00963	19.34468	14.53104	35.64035
Jarque-Bera	544.3558	257.0117	124.1523	488.9902	1,440.128	759.2220	5,187.487
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	107	107	107	107	107	107	107

Source: Field survey, August and September 2012 (Summarized by using EViews)

In the above paragraphs, the socioeconomic characteristics of the crops grown in Musanze District have been presented. In the following paragraphs, the same characteristics are presented but for individual crops.

The socioeconomic characteristics of potato production in Musanze District are summarized in the following table. This table shows that the production of potato on average is RwF 251,739, and its cost is RwF 11,270 for equipment (K), RwF 30,078 for labour, RwF 17,526 for land (LD), RwF 39,178 for fertilizers, RwF 83,226 for seeds, and RwF 16,872 for pesticides. As the average cultivated area is 16.46 ares, this counts for the production of RwF 15,294 and the cost of RwF 685 for equipment, RwF 1,827 for labour, RwF 2,380 for fertilizers, RwF 4,996 for seeds, and RwF 1,025 for pesticides per are.

Table 6: Description of Irish potato production in RwF in Musanze District

	Y	**K**	**L**	**LD**	**F**	**S**	**P**
Mean	251,738.9	11,270.46	30,078.07	17,526.32	39,178.37	83,226.32	16,871.72
Median	144,000.0	6,848.000	25,500.00	12,000.00	27,395.00	60,000.00	8,880.000
Maximum	1,200,000.	51,000.00	85,000.00	80,000.00	23,3950.0	450,000.0	184,000.0
Minimum	12,000.00	2,500.000	6,800.000	5,000.000	3,965.000	1,500.000	160.0000
Std. Dev.	293,751.0	12,840.93	17,904.67	15,165.58	44,436.64	83,973.48	27,307.77
Skewness	2.223371	1.943421	0.921597	2.220113	2.779717	2.409925	4.400399
Kurtosis	7.325618	5.647638	3.383450	8.290228	11.15174	9.659957	26.04362
Jarque-Bera	91.40064	52.52912	8.417940	113.2925	231.2258	160.5167	1,445.098
Probability	0.000000	0.000000	0.014862	0.000000	0.000000	0.000000	0.000000
Observations	57	57	57	57	57	57	57

Source: Field survey, August and September 2012 (Summarized by using EViews)

The table 7 below table summarizes the characteristics of bean production in Musanze District. This table shows that the production of bean on average is RwF 75,853, and its cost is RwF 5,856 for equipment, RwF 46,838 for labour, RwF 14,276 for land, RwF 14,572 for fertilizers, RwF 7,054 for seeds, and RwF 10,102 for pesticides. As the average cultivated area is 18.66 ares, this counts for the production of RwF 4065 and the cost of RwF 314 for equipment, RwF 2,510 for labour, RwF 781 for fertilizers, RwF 378 for seeds, and RwF 541 for pesticides per are.

Table 7: Description of bean production in RwF in Musanze District

	Y	K	L	LD	F	S	P
Mean	75,853.45	5,856.138	46,837.93	14,275.86	14,571.97	7,054.310	10,102.83
Median	62,500.00	6,848.000	27,200.00	14,000.00	12,325.00	3,500.000	10,626.00
Maximum	250,000.0	20,000.00	170,000.0	35,000.00	47,888.00	24,500.00	10,626.00
Minimum	7,500.000	1,000.000	5,100.000	7,000.000	2,000.000	1,050.000	80.00000
Std. Dev.	60,938.48	3,807.324	45,418.13	6,299.924	9,311.677	6,743.115	2,110.183
Skewness	1.579982	1.744180	1.203364	1.633881	1.550091	0.883086	-4.146878
Kurtosis	5.292990	7.784033	3.381695	6.077992	6.662904	2.616212	19.35858
Jarque-Bera	18.41885	42.35889	7.175119	24.35070	27.82549	3.947214	406.4705
Probability	0.000100	0.000000	0.027666	0.000005	0.000001	0.138955	0.000000
Observations	29	29	29	29	29	29	29

Source: Field survey, August and September 2012 (Summarized by using EViews)

The characteristics of corn production in Musanze District are contained in the table below. This table shows that the production of bean on average is RwF 190,417, and its cost is RwF 8,171 for equipment, RwF 76,075 for labour, RwF 15,000 for land, RwF 22,548 for fertilizers, RwF 12,821 for seeds, and RwF 6,795 for pesticides. As the average cultivated area is 30.42 ares, this counts for the production of RwF 6,260 and the cost of RwF 269 for equipment, RwF 2,501 for labour, RwF 741 for fertilizers, RwF 421 for seeds, and RwF 223 for pesticides per are.

Table 8: Description of the value of corn production in RwF in Musanze District

	Y	K	L	LD	F	S	P
Mean	190,416.7	8,170.667	76,075.00	15,000.00	22,548.42	12,820.83	6,795.000
Median	100,000.0	5,700.000	28,475.00	10,000.00	20,000.00	7,500.000	0.000000
Maximum	412,500.0	41,800.00	170,000.0	40,000.00	36,975.00	35,000.00	40,000.00
Minimum	25,000.00	2,000.000	4,250.000	3,000.000	1,000.000	1,050.000	0.000000
Std. Dev.	156,604.0	10,809.92	70,006.06	11,045.36	14,209.43	12,235.69	15,515.94
Skewness	0.326823	2.803812	0.325200	1.176170	-0.242220	0.874113	1.785855
Kurtosis	1.269262	9.317356	1.180970	3.217943	1.605743	2.420908	4.194421
Jarque-Bera	1.711353	35.67722	1.865945	2.790503	1.089317	1.695823	7.091874
Probability	0.424996	0.000000	0.393383	0.247771	0.580040	0.428309	0.028842
Observations	12	12	12	12	12	12	12

Source: Field survey, August and September 2012 (Summarized by using EViews)

The characteristics of wheat production in Musanze District are described by the following table. This table shows that the production of bean on average is RwF 97,500, and its cost is RwF 5,924 for equipment, RwF 24,083 for labour, RwF 13,500 for land, RwF 12,861 for fertilizers, RwF 7,408 for seeds, and RwF 13,757 for pesticides. As the average cultivated area is 30.42 ares, this counts for the production of RwF 8,729 and the cost of RwF 530 for equipment, RwF 2,156 for labour, RwF 1,151 for fertilizers, RwF 663 for seeds, and RwF 1,232 for pesticides per are.

Table 9: Description of the value of wheat production in RwF in Musanze District

	Y	K	L	LD	F	S	P
Mean	97,500.00	5,924.000	24,083.33	13,500.00	12,860.67	7,408.333	13,757.33
Median	90,000.00	6,424.000	21,250.00	13,000.00	13,937.00	7,875.000	10,626.00
Maximum	120,000.0	6,848.000	36,550.00	17,000.00	15,000.00	10,500.00	40,000.00
Minimum	90,000.00	3,600.000	17,000.00	12,000.00	7,395.000	3,500.000	40.00000
Std. Dev.	12,549.90	1,283.951	8,511.326	1,974.842	2,984.508	3,432.261	13,535.61
Skewness	1.122263	-1.069099	0.452676	0.938723	-1.110990	-0.076536	1.357772
Kurtosis	2.632653	2.775873	1.584891	2.609467	2.892277	1.098279	3.646930
Jarque-Bera	1.293211	1.155531	0.705549	0.919331	1.237200	0.909993	1.948175
Probability	0.523821	0.561151	0.702736	0.631495	0.538698	0.634450	0.377537
Observations	6	6	6	6	6	6	6

Source: Field survey, August and September 2012 (Summarized by using EViews)

Among the 107 respondents, tomato, cabbage and onion is each grown by 1 farmer organization. The production of tomato is RwF 225,000, and its cost is RwF 2,500 for equipment, RwF 25,500 for labour, RwF 15,000 for land, RwF 13,916 for fertilizers, RwF 29,280 for seeds and RwF 47,500 for pesticides. As the cultivated land is 4 ares, this counts for the production of RwF 56,250 and the cost of RwF 625 for equipment, RwF 6,375 for labour, RwF 3,479 for fertilizers, RwF 7,320 for seeds and RwF 11,875 for pesticides per are. The land cost is RwF 3,750 per are.

The production of cabbage is RwF 80,000, and its cost is RwF 3,600 for equipment, RwF 17,000 for labour, RwF 10,000 for land, RwF 20,000 for fertilizers, RwF 100 for seeds and RwF 160 for pesticides. As the cultivated land is 10 ares, this counts for the production of RwF 8,000 and the cost of RwF 360 for equipment, RwF 1,700 for labour, RwF 2,000 for fertilizers, RwF 100 for seeds and RwF 16 for pesticides per are. The land cost is RwF 1,000 per are.

The production of onion is RwF 168,000, and its cost is RwF 15,300 for labour, RwF 15,000 for land, RwF 8,219 for fertilizers, and RwF 3,500 for seeds. As the cultivated land is 2.5 ares, this counts for the production of RwF 67,200 and the cost of RwF 6,120 for labour, RwF 6,000 for land, RwF 3,288 for fertilizers, and RwF 1,400 for seeds per are.

After the detailed presentation of data, the next chapter focuses on the presentation, discussion and evaluation of results.

Chapter 5: Presentation, Discussion and Evaluation of Results

This chapter is firstly devoted to the presentation of the results by estimating overall and individual production function of crops in the sample sectors of Musanze District, Rwanda. Secondly, the profitability analysis for both the short run and the long run were undertaken. Thirdly, the response of the profitability to the changes in different factors (changes in total operating costs, in selling prices, in total output, and in discount rate) were conducted under the sensitivity analysis. Lastly, the results were discussed and the hypotheses verified.

5.1 Estimation of agricultural production functions in Musanze District

In this point, the overall agricultural production function was estimated. Individual production function for bean and potato were also estimated.

The following table concerns the analysis of estimates of agricultural production function of main crops grown in Musanze District. These crops are Irish potato, bean, corn, wheat, tomato, onion and cabbage. This table shows that positive relationship exists between agricultural production (LY) and cultivated land (LL), fertilizers (LF), seeds (LS), and pesticides (LP). This implies that as more of these inputs are used, there is an increase in agricultural production. The sum of coefficients is 0.99 which shows decreasing returns to scale. The test of significance shows that land, fertilizers, and seeds are statistically significant at 5% level of significance. The R^2 estimated as 0.66 shows that 66% of variations in agricultural production are explained by the explanatory variables included in the model.

Table 10: Estimates of agricultural production function in Musanze District

Dependent Variable: LY				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.773846	0.879471	2.016947	0.0463
LL	0.235565	0.081082	2.905266	0.0045
LF	0.493556	0.084081	5.870036	0.0000
LS	0.239079	0.046996	5.087212	0.0000
LP	0.024414	0.043813	0.557222	0.5786
R-squared	0.668593	F-statistic		51.44459
Adjusted R-squared	0.655596	Prob(F-statistic)		0.000000
Durbin-Watson stat	1.946314	Observations		107

Source: Estimation of agricultural production function by using EViews

As far as the analysis of determinants of bean production in Musanze District is concerned, the results in the table 11 here below show positive relationship between bean output and fertilizers and seeds. This means that the bean production increases with the increase in fertilizers and seeds. On the other hand, negative relationship exists between bean production and labour and pesticides. This negative relationship is unexpected. It could be due to poor mix of labour and pesticides with other inputs. The sum of coefficients is 0.48 which shows decreasing returns to scale. The test of significance shows that only seeds are statistically significant at 5% level of significance. The R^2 estimated as 0.67 shows that 67% of variations in bean production are explained by the explanatory variables included in the model.

Table 11: Estimates of bean production function in Musanze District

Dependent Variable: LY				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.114207	1.800357	3.951554	0.0006
LL	-0.061536	0.216016	-0.284867	0.7782
LF	0.064238	0.173136	0.371024	0.7139
LS	0.624093	0.200962	3.105526	0.0048
LP	-0.149238	0.116931	-1.276295	0.2141
R-squared	0.677625	F-statistic		12.61185
Adjusted R-squared	0.623896	Prob(F-statistic)		0.000012
Durbin-Watson stat	1.098353	Observations		29

Source: Estimation of bean production function by using EViews

The table 12 describes the estimates of bean production function in Musanze District. This table shows positive relationship between potato output and labour, fertilizers, seeds and pesticides. This means that the potato production increases with the increase in labour, fertilizers, seeds and pesticides. The sum of coefficients is 1.25 which shows increasing returns to scale. The test of significance shows that fertilisers and seeds are statistically significant at 5% level of significance. The R^2 estimated as 0.77 shows that 77% of variations in potato production are explained by the explanatory variables included in the model.

Table 12: Estimates of Irish potato production function in Musanze District

Dependent Variable: LY				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.051648	1.302492	-0.807412	0.4231
LL	0.110544	0.142062	0.778138	0.4400
LF	0.549744	0.100531	5.468407	0.0000
LS	0.507781	0.101079	5.023619	0.0000
LP	0.077987	0.067624	1.153243	0.2541
R-squared	0.775833	F-statistic		44.99260
Adjusted R-squared	0.758590	Prob(F-statistic)		0.000000
Durbin-Watson stat	1.882819	Observations		57

Source: Estimation of potato production function by using EViews

From the three estimations above, both overall and bean production functions record decreasing returns to scale whereas the potato productions function records increasing returns to scale. The equations estimated (including the overall estimation of production function) can be considered as reliable on the basis that at least one of the input coefficients are significantly different from zero at the 5% level of confidence.

In addition, the reliability of the estimated model of crop production (overall estimation) is also guaranteed by the results of the test of normality of errors given by the figure 3 below. This figure shows that the JB statistic (1.377011) is not significantly different from zero at 5% level of significance since its probability (0.502326) is greater than the level of significance. This implies that the errors of the estimated agricultural production function are normally distributed. Consequently, the model estimated is reliable.

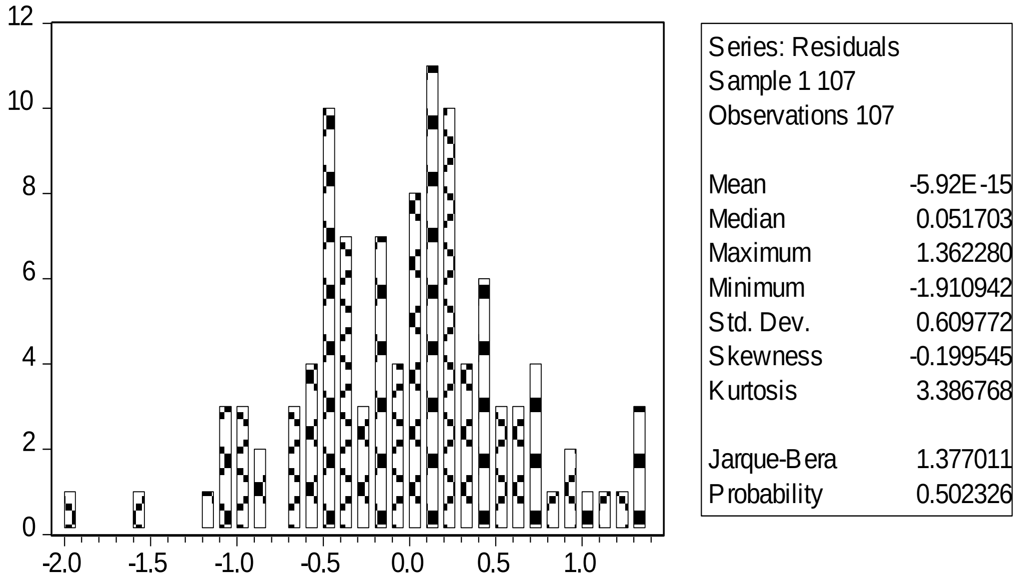

Figure 3: Histogram of residuals of estimated agricultural production function in Musanze District

5.2 Short run profitability analysis of agricultural production in Musanze District

The following paragraphs are concerned with the computation of the GM. Even though the land cost has used, it was only to give an idea about the net farm income (NFI). This is why GM has been still considered more than GM because almost all farmers' organizations have their own land and less of them pay the rent. Therefore, in any case, the preferable indicator of profitability has been the GM. Both the overall and individual GMs have been computed for potato, bean, wheat, corn, tomato, onion, and cabbage.

The table 13 below contains the analysis of main crops grown in Musanze District. In the study area, these crops are namely Irish potato, bean, corn, wheat, tomato, onion and cabbage. This table shows that the gross margin (GM) which is the difference between the gross income (GI) and total variable costs (TVC), that is, GM=GI-TVC, is positive. In the same sense, the benefit-cost ratio (BC ratio) which is the ratio of GI to TVC is equal to 1.47 which is greater than 1. This implies that the crop production is profitable. Given the fact that it requires around 3 (that is 2.56) labour units, the calculations also show that the return to labour is RwF 1,287 which is greater than the daily minimum wage of 700 RwF paid to the worker in Musanze District.

Table 13: Profitability analysis of crop production in Musanze District

Items	Revenue/Cost in RwF per are	Percentage
Revenue		
Total revenue	**10,317**	
Variable costs		
Labour expenses	2,172	30.90
Fertilizers	1,580	22.48
Seeds	2,686	38.22
Pesticide expenses	590	8.39
Total variable costs	**7,028**	**100.00**
Gross Margin	**3,289**	
Depreciation	127	
Rent	889	
Total Fixed Costs	1,016	
Net farm income	**2,273**	

Source: Computation of the gross margin by using Microsoft Excel

Even though crop production is profitable, it is better to analyse the cost components in order to know the importance of each of them. The cost components of crop production are given by the figure 4 below. This figure shows that, from the most to the least important, seeds covers 38% of TVC, labour 30%, fertilizers 22%, and pesticides 8% of TVC. If the farmer happens to reduce the big components of TVC, seed expenses by producing them themselves, this will increase the GM. The same result should be achieved if the farmers master the labour expenses or the fertilizer expenses.

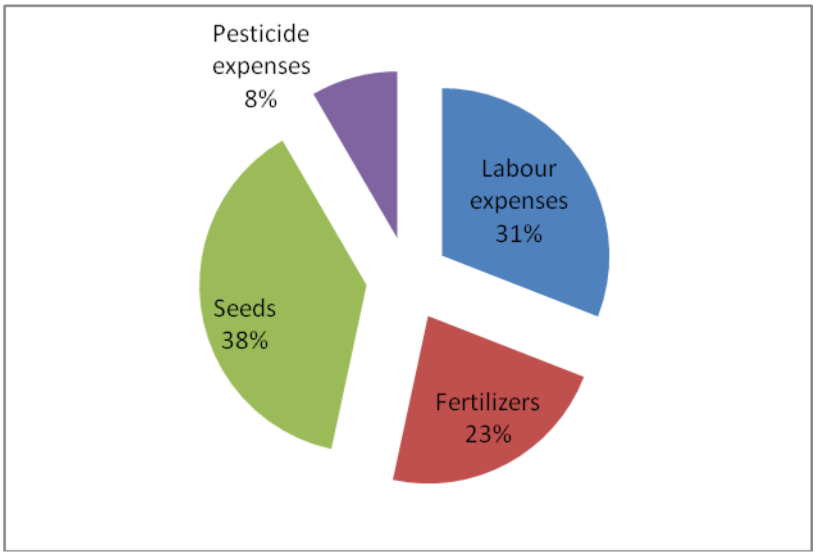

Figure 4: Variable costs incurred in agricultural production in Musanze District

Now that the profitability of main crops grown in Musanze District has been analysed, it is better to do so for different crops individually.

The profitability analysis of Irish potato is summarized in the table 14 below. This table shows that the GM is positive and the BC ratio equal to 1.50 is greater than 1, which implies that the potato production is profitable. The calculations also show that the return to labour is RwF 2,356 (given the requirement of 2.15 units of labour per are) which is greater than the daily minimum wage of RwF 700 paid to the worker in Musanze District.

Table 14: Profitability analysis of Irish potato production in Musanze District

Items	Revenue/ Costs in RwF per are	Percentage
Revenue		
Total revenue	**15,294**	
Variable costs		
Labour expenses	1,827	17.86
Fertilizers	2,380	23.27
Seeds	4,996	48.85
Pesticide expenses	1,025	10.02
Total variable costs	**10,228**	**100.00**
Gross Margin	**5,066**	
Depreciation	228	
Rent	1,065	
Total Fixed Costs	1,293	
Net farm income	**4,001**	

Source: Computation of the gross margin of potato by using Microsoft Excel

After the profitability analysis of Irish potato, the cost components of potato production are given by the figure 5 below. This figure shows that most cost components to be mastered (reduced) in order to increase the GM are seed expenses, fertilizer expenses and labour expenses which cover respectively 49, 23 and 18% of TVC.

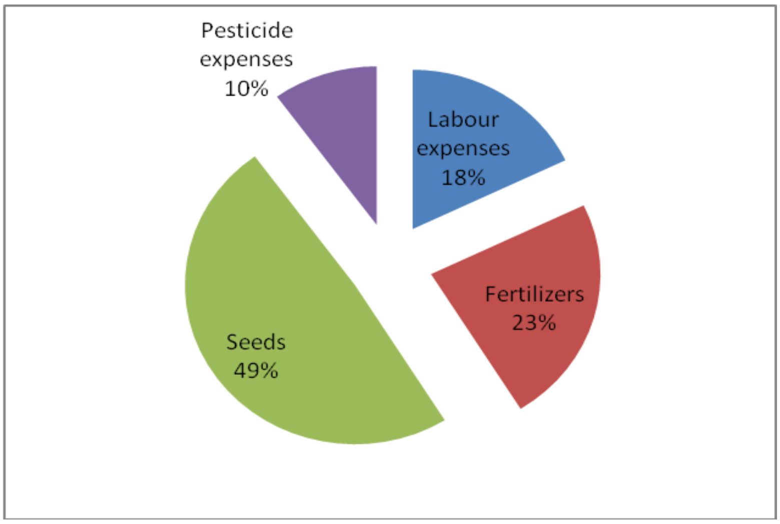

Figure 5: Variable costs incurred in Irish potato production in Musanze District

The profitability analysis of bean production is shortly presented in the table 15 below. This table shows that the GM is negative and the BC ratio equal to 0.966 is less than 1, which implies that the bean production is not profitable. Considering the requirement of around 3 (that is 2.95) units of labour per are, the calculations also show that the return to labour is RwF - 49 which is strictly less than the daily minimum wage of RwF 700 paid to the worker in Musanze District.

Table 15: Profitability analysis of bean production in Musanze District

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**4,065**	
Variable costs		
Labour expenses	2,510	59.62
Fertilizers	781	18.55
Seeds	378	8.98
Pesticide expenses	541	12.85
Total variable costs	**4,210**	100.00
Gross Margin	**(145)**	
Depreciation	105	
Rent	765	
Total Fixed Costs	870	
Net farm income	**(1,015)**	

Source: Computation of the gross margin of bean by using Microsoft Excel

After the bean profitability analysis, the cost components of bean production are described by the figure 6 below. This figure shows that main cost components to be mastered (reduced) in order to increase the GM are labour expenses, fertilizer expenses and pesticide expenses which cover respectively 60, 18 and 13% of TVC.

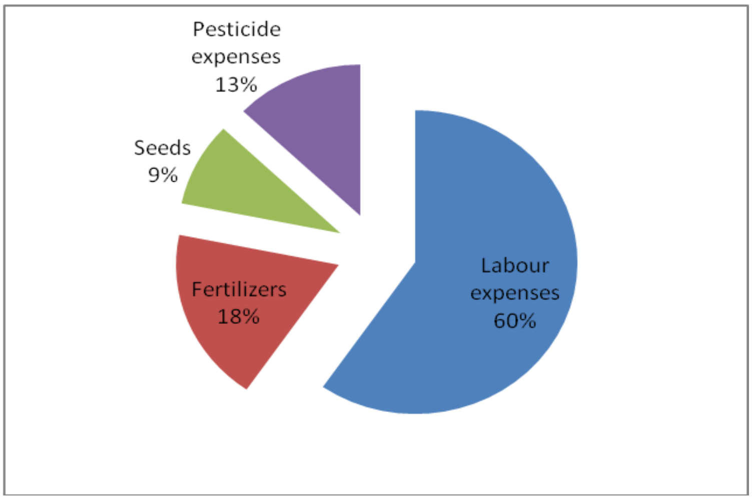

Figure 6: Variable costs incurred in bean production in Musanze District

The profitability of wheat production in Musanze District is described in the table 16 here below presented. This table shows that the GM is RwF 3,527 and the BC ratio is 1.68, which implies that wheat production is profitable. The calculations also show that the return to labour is RwF 1,391 (given the requirement of 2.54 units of labour per are) which is greater than the daily minimum wage of 700 RwF paid to the worker in Musanze District.

Table 16: Profitability analysis of wheat production in Rwanda

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**8,729**	
Variable costs		
Labour expenses	2,156	41.45
Fertilizers	1,151	22.13
Seeds	663	12.75
Pesticide expenses	1,232	23.68
Total variable costs	**5,202**	**100.00**
Gross Margin	**3,527**	
Depreciation	177	
Rent	1,209	
Total Fixed Costs	1,386	
Net farm income	**2,141**	

Source: Computation of the gross margin of wheat by using Microsoft Excel

For the purpose of cost analysis, the figure 7 below presents the components of the TVC incurred in wheat production. This figure shows that main cost components to be mastered (reduced) in order to increase the GM are labour expenses, pesticide expenses and fertilizer expenses which cover respectively 41, 24 and 22% of TVC.

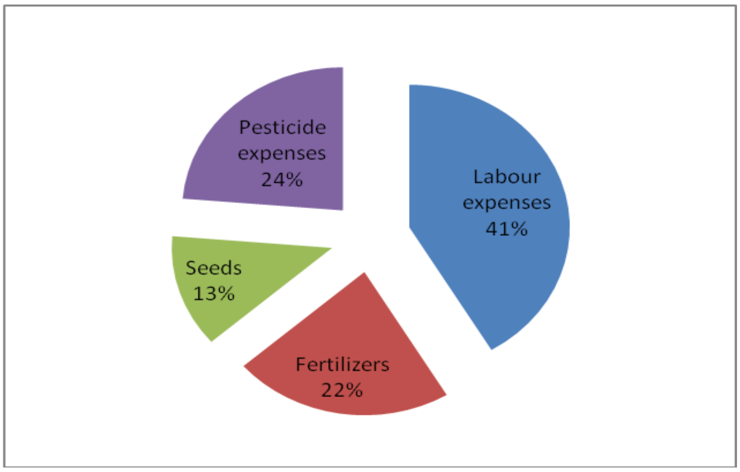

Figure 7: Variable costs incurred in wheat production in Musanze District

The table 17 presented below summarizes shortly the profitability analysis of corn production in Musanze District. The table here above shows that the GM of corn is RwF 2,374 and the computed BC ratio is 1.61. Both indicators show that corn is profitable. The calculations also show that the return to labour is RwF 807 (considering that it requires 2.94 units of labour per are) which is greater than the daily minimum wage of 700 RwF paid to the worker in Musanze District.

Table 17: Profitability analysis of corn production in Musanze District

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**6,260**	
Variable costs		
Labour expenses	2,501	64.36
Fertilizers	741	19.07
Seeds	421	10.83
Pesticide expenses	223	5.74
Total variable costs	**3,886**	**100.00**
Gross Margin	**2,374**	
Depreciation	90	
Rent	493	
Total Fixed Costs	583	
Net farm income	**1,791**	

Source: Computation of the gross margin of corn by using Microsoft Excel

The corresponding cost analysis is contained in the figure 8 below. This shows that main cost components should be controlled (reduced) in order to increase the GM are labour expenses, fertilizer expenses and pesticide expenses which cover respectively 64, 19 and 11% of TVC.

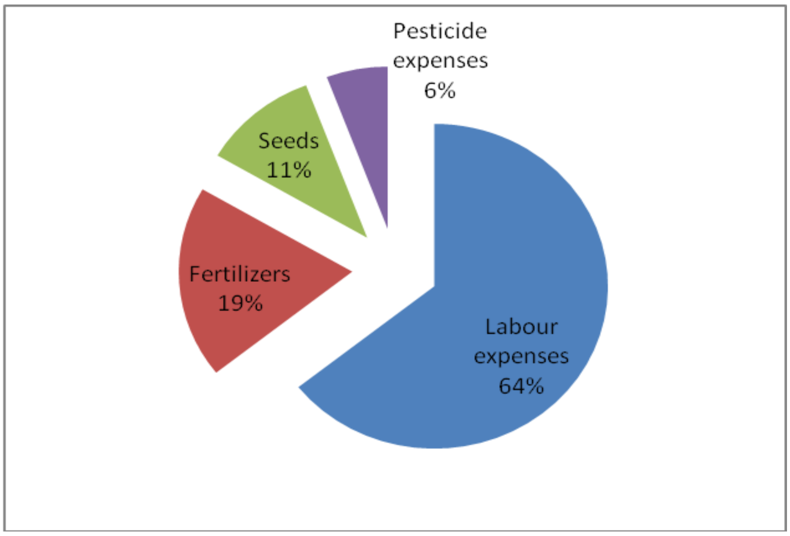

Figure 8: Variable costs incurred in corn production in Musanze District

The profitability analysis of tomato production in Musanze District is presented in the table 18. This table shows that the GM of tomato is RwF 27,201 and the computed BC ratio is 1.936, which implies that tomato production is profitable in Musanze District. The calculations also show that the return to labour is RwF 3,627 (given the requirement of 7.50 labour units per are) which is greater than the daily minimum wage of RwF 700 paid to the worker in Musanze District.

Table 18: Profitability analysis of tomato production in Musanze District

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**56,250**	
Variable costs		
Labour expenses	6,375	21.95
Fertilizers	3,479	11.98
Seeds	7,320	25.20
Pesticide expenses	11,875	40.88
Total variable costs	**29,049**	**100.00**
Gross Margin	**27,201**	
Depreciation	208	
Rent	3,750	
Total Fixed Costs	3,958	
Net farm income	**23,243**	

Source: Computation of the gross margin of tomato by using Microsoft Excel

The following figure describes the cost composition of tomato production. This figure shows that most cost components to be mastered in order to increase the GM are pesticide expenses, seed expenses, labour expenses and fertilizers which cover respectively 41, 25, 22 and 12% of TVC of tomato production in Musanze District.

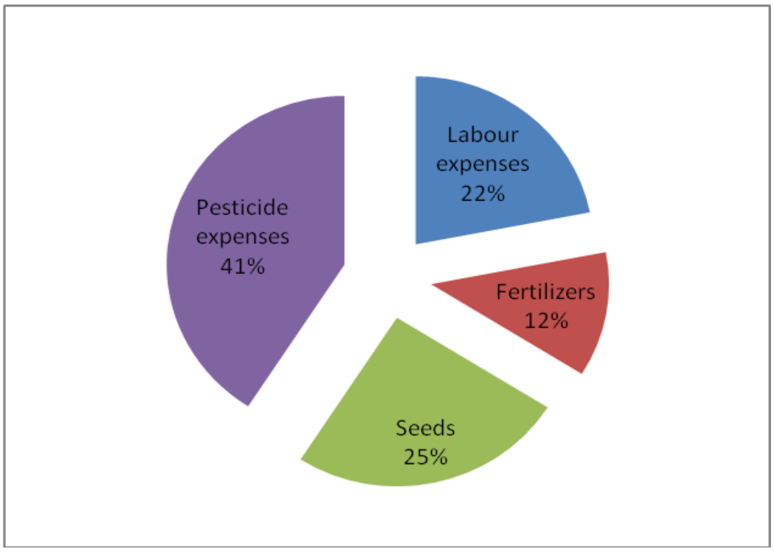

Figure 9: Variable costs incurred in tomato production in Musanze District

The profitability of onion production in Musanze District is shown in the table 19 below. This table shows that the GM of onion is RwF 56,392 and the computed BC ratio is 6.22, which implies that onion production is highly profitable in Musanze District. The calculations also show that the return to labour is RwF 7,832 (which is greater than the daily minimum wage of RwF 700 paid to the worker in Musanze District.

Table 19: Profitability analysis of onion production in Musanze District

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**67,200**	
Variable costs		
Labour expenses	6,120	56.62
Fertilizers	3,288	30.42
Seeds	1,400	12.95
Pesticide expenses	-	0.00
Total variable costs	**10,808**	**100.00**
Gross Margin	**56,392**	
Depreciation	0	
Rent	6,000	
Total Fixed Costs	6,000	

Net farm income	**50,392**

Source: Computation of the gross margin of onion by using Microsoft Excel

The cost composition of onion production in Musanze District is presented by the figure below. This figure shows that only three types of costs are incurred in onion production. These are labour expenses, fertilizer expenses and seed expenses which represent respectively 57, 30 and 13% of TVC.

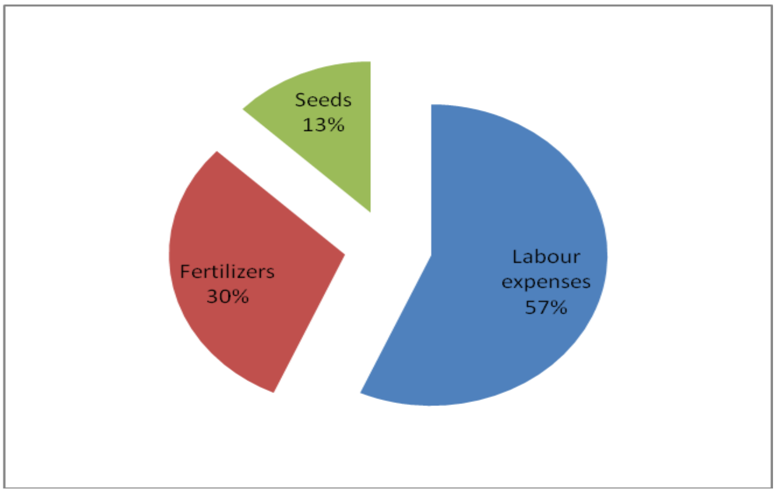

Figure 10: Variable costs incurred in onion production in Musanze District

Cabbage is also among the crops grown in Musanze District. Its profitability is analysed briefly by using the table below. It is shown in this table that the GM of cabbage is RwF 4,184 and the computed BC ratio is 2.10, which implies that cabbage production is profitable in Musanze District. The calculations also show that the return to labour is RwF 2,092 which is greater than the daily minimum wage of RwF 700 paid to the worker in Musanze District.

Table 20: Profitability analysis of cabbage production in Musanze District

Items	Revenue/Costs in RwF per are	Percentage
Revenue		
Total revenue	**8,000**	
Variable costs		
Labour expenses	1,700	44.55
Fertilizers	2,000	52.41
Seeds	100	2.62
Pesticide expenses	16	0.42
Total variable costs	**3,816**	**100.00**
Gross Margin	**4,184**	
Depreciation	120	
Rent	1,000	
Total Fixed Costs	**1,120**	

Net farm income	3,064

Source: Computation of the gross margin of cabbage by using Microsoft excel

The cost analysis of cabbage production is contained in the figure below. This figure shows that costs incurred in cabbage production in Musanze District include fertilizer expenses, labour expenses, and seed expenses which represent respectively 52, 45, and 3% of TVC.

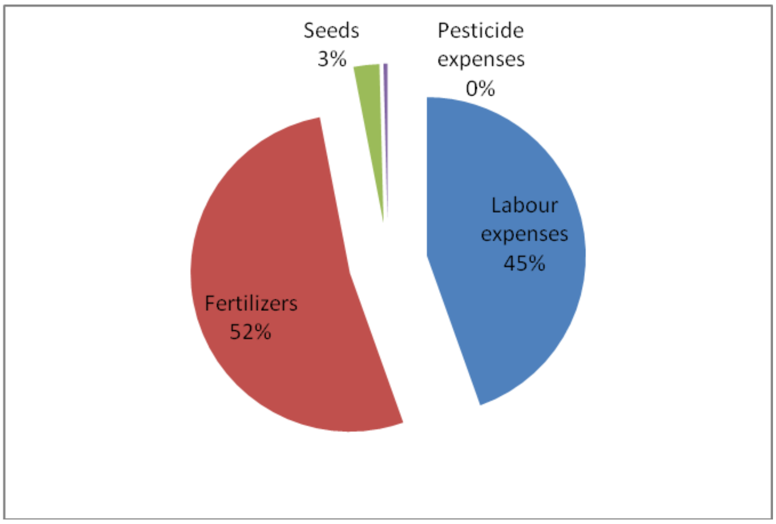

Figure 11: Variable costs incurred in cabbage production in Musanze District

Through the profitability analysis of crop production here above conducted, considering their BC ratios that are greater than 1, it has been shown that potato production, corn production, wheat production, tomato production, onion production and cabbage production are all profitable. In contrast, the bean production was qualified unprofitable as its BC ratio is less than 1. For the purpose of profit improvement, costs should be mastered, since there is inverse relationship between profitability and costs: the less the cost, the more the profit, and the higher the cost, the lower the profit. This justifies the cost composition analysis of different crops grown in Musanze District.

5.3 Long-run profitability analysis of agricultural production in Musanze District

Besides the short run profitability analysis contained in the previous section, the long run profitability analysis was undertaken. To do so, it was necessary to distinguish the investment costs, the revenues and the operating costs for a period relatively long. The period of ten years was fixed.

The investments include the land cost and the equipment costs. The land cost was calculated by multiplying the cultivated area (in ares) by the land prices as they are defined in the Ministerial Order No 002/16.01 of 26/04/2010 determining the reference land price outside the Kigali City. The average land cost was RwF 412,593. Another element of investment is equipments. The estimated average cost of equipments is RwF 9,903. As the equipment is not used for one year, the annual depreciation amount was calculated by fixing the duration of the agricultural equipments to 3 years on average. The corresponding annual depreciation amount was RwF 3,301, and the equipments are replaced each three-year period.

About the revenues, the average agricultural production was RwF 185,905 per season. This comes to RwF 371,810 per year (two seasons). Assuming the same production capacity alongside the ten year period, the annual production is fixed to RwF 371,810. Concerning the costs, the average amount for a season is RwF 39,140, RwF 1,651, RwF 28,464, RwF 48,408, and RwF 16,970 for labour, depreciation, fertilizers, seeds, and pesticides respectively. This comes to the annual total of RwF 78,280, RwF 3,301, RwF 56,928, RwF 96,816, and RwF 33,940 for labour, depreciation, fertilizers, seeds, and pesticides respectively. These totals are also assumed to prevail alongside the ten-year period.

The discount rate was chosen by averaging the monthly lending rates for the period from January to October 2012 as they were published by the National Bank of Rwanda (www.bnr.rw/statistics.aspx, accessed on October 23, 2012 at 10:11 a.m). The discount rate used in this research is then 16.749%.

The financial sustainability is measured by the accumulation of the cash flows generated by an investment during a specified period of time. An investment is financially sustainable if the cumulated cash flow at the end of the period concerned is positive. This research shows that the agricultural investment is financially sustainable in the study area as the cumulated cash flow is RwF 521,973 for a ten-year period of time as it is stated in the table 21 below.

Table 21: Calculation basis of financial sustainability

Years		**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**20210**
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**
Produce sales	0	185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land costs	412,593	0	0	0	0	0	0	0	0		0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour	0	39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation	0	1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers	0	28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds	0	48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides	0	16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Cash flows	**(422,496)**	**51,273**	**102,545**	**102,545**	**92,642**	**102,545**	**102,545**	**92,642**	**102,545**	**102,545**	**92,642**
Cumulated cash flows	**(422,496)**	**(371,224)**	**(268,679)**	**(166,134)**	**(73,492)**	**29,054**	**131,599**	**224,241**	**326,786**	**429,331**	**521,973**

The parentheses indicate a negative number.

The benefit-cost ratio (BC ratio) is the ratio of the discounted revenues to the discounted total costs of an investment during a specified period. When this ratio is equal to 1, the discounted revenues are equal to the discounted costs, and the corresponding net present value (NPV) is zero. Under such circumstances, the corresponding discount rate is qualified as the internal rate of return (IRR). An investment is profitable if its BC ratio is equal to or greater than 1. This means that its NPV is equal to or greater than zero, and the corresponding discount rate is lower than the IRR.

In such a way, the discounted revenues amount to RwF 1,588,812.73 and the discounted costs totalize RwF 1,583,899.88. Therefore, the BC ratio is 1.003102. The corresponding NPV is RwF 4,912.84. The IRR of such an investment is 17.046%. The details on these indicators are summarized in the table 22 here below.

Table 22: Calculation basis of BC ratio, NPV and IRR

Years		**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810.0**	**371,810**	**371,810**	**371,810**
Produce sales	0	185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land cost	412,593	0	0	0	0	0	0	0	0	0	0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour	0	39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation	0	1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers	0	28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds	0	48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides	0	16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Discount factors at 16.749%	1.00	1.17	1.36	1.59	1.86	2.17	2.53	2.96	3.45	4.03	4.70
Present values of revenues	**0**	**159,234.77**	**272,781.38**	**233,647.73**	**200,128.25**	**171,417.52**	**146,825.69**	**125,761.84**	**107,719.84**	**92,266.18**	**79,029.53**
Present values of total costs	**422,496**	**115,317.90**	**197,548.42**	**169,207.81**	**150,263.31**	**124,140.66**	**106,331.24**	**94,426.40**	**78,010.77**	**66,819.22**	**59,338.14**

5.4 Sensitivity analysis

Sensitivity analysis is carried out by changing total operating costs, the average price and the total production in order to identify the variables that most affect the level of profitability of agricultural production in the study area in the long run.

The GoR has recently decided to give up the voucher system which aims mainly at subsidizing the corn farming through the fertilizers' price reduction by 50%. Assuming this decision will cause a 10% increase in total operating costs, the long run profitability of agricultural production is questionable. The main problem is here about the capacity of farmers to meet themselves their costs and maintain their activities profitable. Under such circumstances, the results of this study show that the BC ratio is 0.94 and the NPV is negative, NPV= - 99 366.34. The IRR is 10.4% which is lower than the discount rate of 16.749%. These results show that the agricultural production is sensitive to the change in total operating costs. Therefore, if the total operating costs increase by 10%, the agricultural investments in the study area are not profitable. The details about these calculations are included in the table in 23 presented below.

Table 23: Sensitivity analysis of the profitability to the increase of 10% in total operating costs

Years		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810.0**	**371,810**	**371,810**	**371,810**
Produce sales		185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Changed costs	**422,496**	**148,096**	**296,192**	**296,192**	**296,192**	**296,192**	**296,192**	**296,192**	**296,192**	**296,192**	**296,192**
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land cost	412,593	0	0	0	0	0	0	0	0	0	0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour	0	39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation	0	1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers	0	28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds	0	48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides	0	16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Discount factors at 16.749%	1.00	1.17	1.36	1.59	1.86	2.17	2.53	2.96	3.45	4.03	4.70
Present values of revenues		**159,234.77**	**272,781.38**	**233,647.73**	**200,128.25**	**171,417.52**	**146,825.69**	**125,761.84**	**107,719.84**	**92,266.18**	**79,029.53**
Present values of total costs	**422,496**	**126,849.91**	**217,303.63**	**186,128.90**	**159,426.55**	**136,554.96**	**116,964.56**	**100,184.64**	**85,811.99**	**73,501.26**	**62,956.65**

The sensitivity analysis shows that agricultural profitability is sensitive to a decrease in the average price. With the average farmer's income of RwF 185,905 and the average quantity produced is 1,333.32 Kgs. The corresponding average price is RwF 139.43. A reduction of the average price by 10% makes a 10% decrease in revenues. The sensitivity results show that agricultural investment in the study area is unprofitable since the BC ratio comes to 0.903, VAN of – 153,969.88, the discount rate of 16.749% and the IRR of 6.372%. The table 24 below gives the details on the calculations of these indicators.

Table 24: Sensitivity analysis of the profitability to the decrease of 10% in the average price

Years		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Decreased revenues	**0**	**167,314.5**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**	**334,629.0**
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810.0**	**371,810**	**371,810**	**371,810**
Produce sales		185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land purchase	412,593	0	0	0	0	0	0	0	0	0	0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour	0	39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation	0	1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers	0	28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds	0	48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides	0	16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Discount factors at 16.749%	1.00	1.17	1.36	1.59	1.86	2.17	2.53	2.96	3.45	4.03	4.70
PV of revenues	**0**	**143,311**	**245,503**	**210,283**	**180,115**	**154,276**	**132,143**	**113,186**	**96,948**	**83,040**	**71,127**
PV of total costs	**422,496**	**115,317.90**	**197,548.42**	**169,207.81**	**150,263.31**	**124,140.66**	**106,331.24**	**94,426.40**	**78,010.77**	**66,819.22**	**59,338.14**

The sensitivity analysis of the decrease in total production shows the similar results as in case of the decrease in the average price. That is, if both the average price and the total production decrease by 10%, the BC ratio comes to 0.903, VAN of – 153,969.88, the discount rate of 16.749% and the IRR of 6.372%. The details on the related calculations are summarized in the table 25.

Table 25: Sensitivity analysis of the profitability to the decrease of 10% in total production

Years		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Changed revenues	**0**	**167,314**	**334,629**	**334,629**	**334,629**	**334,629**	**334,629**	**334,629**	**334,629**	**334,629**	**334,629**
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810.0**	**371,810**	**371,810**	**371,810**
Produce sales		185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land cost	412,593	0	0	0	0	0	0	0	0	0	0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour		39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation		1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers		28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds		48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides		16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Discount factors at 16.749%	1.00	1.17	1.36	1.59	1.86	2.17	2.53	2.96	3.45	4.03	4.70
Present values of revenues	**0**	**143,311**	**245,503**	**210,283**	**180,115**	**154,276**	**132,143**	**113,186**	**96,948**	**83,039**	**71,127**
Present values of total costs	**422,496**	**115,317.90**	**197,548.42**	**169,207.81**	**150,263.31**	**124,140.66**	**106,331.24**	**94,426.40**	**78,010.77**	**66,819.22**	**59,338.14**

A 10% increase in lending interest rate makes ipso facto the discount rate to increase in the same proportion. That is, if the discount rate increases from 16.749 to 18.424%, the BC ratio comes to 0.99, VAN to – 21,696.84, the discount rate to 18.424% and the IRR amounts to 17.0458%. The calculation basis about these indicators is contained in the table 26.

Table 26: Sensitivity analysis of the profitability to the increase of 10% in interest rate

Years		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Revenues	**0**	**185,905**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810**	**371,810.0**	**371,810**	**371,810**	**371,810**
Produce sales	0	185,905	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810	371,810
Total costs	**422,496**	**134,633**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**	**269,265**	**269,265**	**279,168**
Investment costs	**422,496**	**0**	**0**	**0**	**9,903**	**0**	**0**	**9,903**	**0**	**0**	**9,903**
Land cost	412,593	0	0	0	0	0	0	0	0	0	0
Equipment purchases	9,903	0	0	0	9,903	0	0	9,903	0	0	9,903
Operating costs	**0**	**134,633**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**	**269,265**
Labour	0	39,140	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280	78,280
Depreciation	0	1,651	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301	3,301
Fertilizers	0	28,464	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928	56,928
Seeds	0	48,408	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816	96,816
Pesticides	0	16,970	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940	33,940
Diacount factors at 18.4%	1.00	1.18	1.40	1.66	1.97	2.33	2.76	3.27	3.87	4.58	5.42
Present values of revenues	**0**	**156,982.54**	**265,119.46**	**223,873.09**	**189,043.68**	**159,632.91**	**134,797.77**	**113,826.40**	**96,117.68**	**81,164.02**	**68,536.80**
Present values of total costs	**422,496**	**113,686.84**	**191,999.66**	**162,129.01**	**141,940.63**	**115,606.24**	**97,620.62**	**85,464.85**	**69,608.47**	**58,779.02**	**51,459.83**

In all four cases of sensitivity analysis, the BC ratios are less than 1, the NPVs are negative, and the IRRs are less than the corresponding discount rates. But by importance, the agricultural profitability is mostly sensitive to both the decrease in the average price and the decrease in the total production. After the decrease in both the average price and the total production come the increase in total operating costs and the increase in the lending interest rate respectively.

5.5 Discussion of the Results and Verification of hypotheses

Three equations were estimated to analyse the determinants of agricultural production function in Musanze District. These concern the overall estimation of agricultural production function, the bean production function and the potato production function respectively. For the overall production function, all independent variables included in the model (labour, fertilizers, seeds, and pesticides) are positively related to total production which means that the production increases with the increase in the use of these inputs, but three of them (labour, fertilizers and seeds) are significantly contributing to the change in the total production as their coefficients are statistically different from zero at 5% level of significance. The R^2 of 0.668593 means that 66.86% of the variations in agricultural production are explained by the explanatory variables included in the model. Concerning the potato production, the production is positively related to the inputs (labour, fertilizers, seeds and pesticides), but only fertilizers and seeds are significant. The corresponding R^2 is 0.775833. As for bean production, the total output is positively explained by fertilizers and seeds, but negatively by labour and pesticides. The R^2 is equal to 0.677625. Therefore, the first hypothesis stating that agricultural output is positively related to the inputs used in the production process in Musanze District was accepted.

Concerning the measurement of the returns to scale (RTS), the sums of the production elasticities with respect to all inputs are 0.99, 0.48 and 1.25 respectively for the overall production function, bean production function and potato production function. The overall and bean production functions register decreasing returns to scale, which means that the individual farmers' organizations have not attained the least-cost combination of inputs. Only the potato production function scores increasing returns to scale. This led the researcher to reject the second hypothesis stating that agriculture in Musanze District scores increasing returns to scale.

The process of profitability analysis has gone through the profitability of all crops after the overall profitability analysis. The short run profitability analysis of the overall crop production shows that it is profitable since the GM is RwF 3,289, and the BC ratio is 1.47. As the GM is positive and BC ratio greater than 1, this shows that the agricultural activities are profitable. At individual level, the analysis has shown that the GMs of potato, wheat, corn, onion, tomato and cabbage are RwF 5,066, RwF 3,527, RwF 2,374, RwF 56,392, RwF 27,201, RwF 4,184 respectively. The corresponding BC ratios are 1.50, 1.68, 1.61, 6.22, 1.936 and 2.10 respectively. It is remarkable that all GMs are positive and all BC ratios are greater than 1. However, only the GM of bean is RwF - 145 (negative) and the BC ratio is 0.966 (less than 1). These figures indicate that the agricultural investments are profitable in the short run. In addition, the long run profitability analysis shows that the discounted revenues amount to RwF 1,588,812.73, the discounted costs totalize RwF 1,583,899.88 and the BC ratio is 1.003102. The corresponding NPV is RwF 4,912.84 and the IRR of such an investment is 17.046%. The BC ratio is greater than 1, the NPV positive, and the IRR is greater than the discount rate (which is really the prevailing market lending interest rate). This implies that the agricultural investments in the study area are profitable in the long run. Hence, the third hypothesis stating that it is positively profitable to invest in agriculture in Musanze District was accepted.

Grosso modo, the results of this research show that the agricultural output is positively related to inputs used, the agriculture records decreasing returns to scale and agricultural investments are profitable both in the short run and in the long run. Therefore, the first and the third hypotheses were accepted whereas the second hypothesis was rejected. The research objectives were also achieved.

Chapter 6: Conclusions and Recommendations

The research examined the determinants of agricultural production function and profitability with special focus on crops grown by farmers' organizations assisted by the Project DERN in Musanze District. The Cobb-Douglas production function and the ordinary least squares (OLS) technique have been used to estimate the agricultural production function and the gross margin has been used to analyse the profitability. Data were collected through a field survey conducted in Musanze District during August and September 2012 from a purposive sample of 107 farmers' organizations assisted by the Programme DERN. The parameter estimates of the production function were estimated by using the OLS technique. The values of the estimates have been used to compute the returns to scale. In addition, the BC ratio, the gross margins, net farm income and the returns to labour were computed to estimate the profitability of potato, bean, wheat, corn, onion, tomato and cabbage, individually and collectively, in the study area.

The distribution of the respondents shows that they are concentrated mostly in the sectors of Musanze (14.95%), Rwaza (14.02%), Busogo (13.08%), Gataraga (12.15%), Nkotsi 12.15%) and Muko (10.28%). In addition, most of them grow potato (53.27%), bean (27.10%) and corn (11.21%).

The overall agricultural production is positively related to inputs used which include labour, fertilizers, seeds, and pesticides. The test of significance shows that the significant inputs are labour, fertilizers and seeds at the 5% level of significance. The individual production function for potato shows a positive relationship between output and labour, fertilizers, seeds and pesticides, and the test of significance shows that the significant inputs are fertilizers and seeds at the 5% level of significance. In the same way, the individual production function for bean shows a positive relationship between bean output and fertilizers and seeds, and a negative relationship between output and labour and pesticides. These negative signs are unexpected. The negative relationship between bean output and fertilizers could be due to the low use of fertilizers in bean production whereas the negative relationship between bean output and seeds could be explained by the use of traditional seeds instead of high-yielding varieties. The test of significance shows that the significant input is only seeds.

As some inputs are statistically significant, the estimated production functions are considered reliable. In addition, all estimated production functions record increasing returns to scale of

0.99, 0.48 and 1.25 for the overall production function, the bean production function and potato production function respectively. The decreasing returns to scale imply that the individual farmers' organizations have not achieved the least-cost combination of inputs.

The agricultural production is generally profitable in the study area in the short run as it is reflected in the gross margin of RwF 3,289, the net income of RwF 2,273, the BC ratio of 1.47, and the return to labour of RwF 1,287 given the daily minimum wage of 700 RwF paid to the work. The individual profitability analysis has shown that the GMs per are of potato, wheat, corn, onion, tomato and cabbage are RwF 5,066, RwF 3,527, RwF 2,374, RwF 56,392, RwF 27,201, and RwF 4,184 respectively. Their corresponding BC ratios are 1.50, 1.68, 1.61, 6.22, 1.50 and 2.10 respectively; the individual returns to labour are RwF 2,356, RwF 1,391, RwF 807, RwF 7,832, RwF 3,627, and RwF 2,092 respectively. The net farm incomes per are are RwF 4,001, RwF 2,141, RwF 1,791, RwF 50,392, RwF 23,243, and RwF 3,064 respectively for potato, wheat, corn, onion, tomato and cabbage. It is remarkable that all GMs are positive and all BC ratios are greater than 1. However, only the GM per are of bean is RwF - 145 (negative), the BC ratio is 0.966 (less than 1), the return to labour of RwF - 49 and the net income of RwF – 1,224 per are. Considering these indicators, all individual crops (potato, wheat, corn, tomato, onion, and cabbage) are profitable in the short run except for bean as it is reflected by the results.

In the long run, the results of the profitability analysis show that the discounted revenues amount to RwF 1,588,812.73 and the discounted costs totalize RwF 1,583,899.88. The BC ratio is 1.003102, the corresponding NPV is RwF 4,912.84, and the corresponding IRR is 17.046%. In addition, the results of the sensitivity analysis show that the BC ratios are less than 1, the NPVs are negative, and the IRRs are less than the corresponding discount rates. The ordering shows that, by importance, the agricultural profitability is mostly sensitive to both the decrease in the average price and the decrease in the total production. After the decrease in both the average price and the total production come the increase in total operating costs and the increase in the lending interest rate respectively.

All these results led the researcher to accept the three research hypotheses. The first hypothesis stating that agricultural output is highly sensitive to the inputs used in the production process in Musanze District has been accepted. In contrast, the second hypothesis stating that agriculture in Musanze District scores increasing returns to scale was rejected. The third hypothesis stating that the CIP crops in Musanze District are profitable both in the short run and in the long run was accepted.

For further increase in agricultural production and profitability improvements, some recommendations have been formulated:

1. Farmers and farmers' organizations should improve their equipment by adopting modern agricultural tools and new technological methods through the introduction of motor driven equipment where applicable;
2. Farmers and farmers' organizations should reallocate rationally the inputs so as to attain the least-cost input combination. They should have more access to extension services in order to improve their knowledge of farm management;
3. The government and the partners in agriculture sector should encourage the adult literacy education mainly through demonstration farms for the farmers to be able to record all farm operations and to calculate their profitability;
4. The government should enhance and extend the services of subsidized fertilizers;
5. The government should guarantee the access to market to farmers for their products;
6. The land protection should be enhanced in order to maintain or to increase its productivity.

Even though good results have been achieved, an interesting extension of this research should rely on the following topics:

1. Determinants of production and profitability analysis of individual smallholder famers in Rwanda;
2. Determinants of agricultural production function and profitability with time series data in Rwanda;
3. Determinants of agricultural production function and profitability with panel data in Rwanda;
4. Technical, economic and allocative efficiency of agriculture in Rwanda;
5. Determination of total factor productivity of agriculture in Rwanda;
6. Analysis of agricultural vulnerability in Rwanda.

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Appendix 1a. Questionnaire Addressed to Farmer Organizations in Musanze District coached by DERN in Musanze District

I. Respondent Identification:

Name of the farm organization: …………………...

Sector: ………………… District: Musanze

Crop: ………………………………………………

Year of creation: …………………………………..

Number of members: ……………………………...

II. Questions Directly Related to the Research

A. Question related to crop production

Question 1. What is the quantity in kilos of your crop yield for the recent harvest?

Answer: [ ] Kilogrammes.

B. Questions related to inputs

Question 2. Fill in the table below to indicate the amount of each input used to achieve the harvest mentioned in the answer to the Question 1 above:

No	Input used	Measurement	Number/Amount/Quantity	
1	Labour	Number of workers used (man-days) to get the produce stated in the answer to the question 1		
2	Tools/Equipment	All equipment/tools used	Nature of tools	Number
3	Size of the cultivated area	Land cultivated in ares to get the produce stated in answering the question 1		
4	Seeds	Quantity of seeds in kilos to get the produce stated in answering		

		the question 1		
5	Pesticides used	Quantity of pesticides used	Nature of pesticide	Quantity
6	Fertilizers used	Quantity of fertilizers used	Nature of fertilizer	Quantity

C. Question related to market access

Question 4. Is it easy for you to market your produce? Explain clearly.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Question 5. At what price, on average, have you sold your produce considering the selling place?

Gate unit price in RwF	Unit price on market in RwF

D. Questions related to the agriculture sector in general

Question 6. What does encourage/motivate you in the farming environment? (Please do be specific and brief) ………………………………..…………………………………………

…………………………………………………………………………………………………

Question 7. What main problems are you currently facing in agriculture? (Do be specific and brief, please) ……………..……………………………………..………………….

………………………………………………………………………………………………….

Question 8. What are your main suggestions to address problems identified in response to Question 7 above? (Do be specific and brief, please) ....……………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Thank you very much for your contribution to my research!

Appendix 1b. Urutonde rw'ibibazo bigenewe Amakoperative y'Abahinzi akorana na DERN mu Karere ka Musanze

A. AMABWIRIZA:

- **Ni byiza gusubiza ibibazo byose kandi mu mwanya wabigenewe: ku turongo cyangwa mu kazu**
- **Mu gihe muhinga ibihingwa byinshi, buri gihinwa kigira urupapuro rw'ibisubizo rwihariye**

B. UMWIRONDORO WA KOPERATIVE:

Izina rya Koperative: ……………………………………………………………………………

Umubare w'Abanyamuryango: ………………………………………………………….……..

Igihe yashingiwe (umwaka): ………………………………………..

Umurenge: …………………   Akarere: Musanze

Igihingwa cya Koperative: ……………………………………………..

C. URUTONDE RW'IBIBAZO

a. Ibibazo birebana n'umusaruro

Ikibazo cya 1. Igihe muherukira gusarura, umusaruro wanyu wanganaga iki?

[ ] Kilogarama.

b. Ibibazo bireba inyongeramusaruro n'ibikoresho

Ikibazo cya 2. Uzuza imbonerahamwe ikurikira werekana ubwoko n'ingano y'ibyakenewe kugira ngo haboneke umusaruro mwagaragaje ku kibazo cya mbere:

<table>
<tr><th>Nimero</th><th>Ubwoko bw'Ibyakenewe</th><th colspan="2">Ingano yabyo</th></tr>
<tr><td>1</td><td>Abakozi (Garagaza umubare w'abakozi bose mwakoresheje kugira ngo mubone umusaruro mwagaragaje mu kibazo cya mbere)</td><td colspan="2"></td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Ibikoresho byose mukoresha (urugero: amasuka 3, amapiki 7, ingorofani 1, …)</td><td>Ibikoresho</td><td>Ingano/umubare</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>3</td><td>Umusaruro muheruka kubona wavuye mu murima ungana iki? (Garagaza ubuso bwawo</td><td colspan="2"></td></tr>
</table>

	muri ari)		
4	Imbuto mwahinze yanganaga iki? Garagaza ibiro		
5	Mwakoresheje umuti wica udukoko/urwanya indwara ungana iki? (Niba mwarakoresheje imiti inyuranye, garagaza ingano ya buri bwoko)	Umuti wica udukoko (ubwoko)	Ingano/Umubare
6	Mwakoresheje inyongeramusaruro zingana iki? (Niba mwarakoresheje inyongeramusaruro zinyuranye, garagaza ingano ya buri bwoko)	Inyongeramusaruro (ubwoko)	Ingano/Umubare

c. Ibibazo birebana n'isoko

Ibibazo 4. Byaba biborohera kubona amasoko y'umusaruro wanyu? Sobanura neza

………………………………………………………………………………………………..

Ibibazo 5. Ni ku kihe giciro mwagurishirijeho umusaruro wanyu ukurikije aho wagurishirijwe?

Igiciro cyo mu murima (FRW) ku kiro	Igiciro cyo ku isoko (FRW) ku kiro

d. Ibibazo birebana n'ubuhinzi muri rusange

Ikibazo cya 6. Ni iki mwishimira mu buhinzi bwanyu? (Sobanura neza)

…………………………………………………………………………………………………

Ikibazo cya 7. Ese haba hari ibibazo muhura nabyo mu murimo w'ubuhinzi? (Sobanura neza)

……………………………………………………..…………………………………

Ibibazo cya 8. Niba hari ibibazo wagaragaje haruguru, hari ibyifuzo/ibitekerezo watanga byafasha gusubiza ibyo bibazo? (Sobanura neza) ....……………………………….

……………………………………………………………………………………………………

Murakoze cyane!

Appendix 2a. Raw data in RwF

An Nbr of respondents	Agr production in RwF	Equipement expenditure in RwF	Labour expenses in RwF	Cultivated area (Ld)		Fertilizers expenses in RwF	Seeds expenses in RwF	Pesticides expenses in RwF	Product	Sector
No	Y	K	L	Ld (Rent)	Ld (Land cost in RwF)	F	S	P	Product	Sector
1	12,000	8,000	11,050	5,000	126,500	17,888	15,000	4,400	Irish potato	Gataraga
2	37,500	9,900	4,250	25,000	126,500	1,000	2,800	1,500	Corn	Gataraga
3	48,000	9,903	12,750	12,000	101,200	7,916	42,000	4,000	Irish potato	Gataraga
4	216,000	23,300	34,000	50,000	379,500	52,185	112,500	16,350	Irish potato	Gataraga
5	96,000	6,100	8,500	6,000	101,200	12,860	30,000	6,210	Irish potato	Gataraga
6	480,000	47,500	51,000	35,000	1,821,600	173,950	225,000	69,500	Irish potato	Gataraga
7	24,000	9,903	9,350	12,000	6,325	20,000	9,000	48,000	Irish potato	Gataraga
8	1,200,000	43,000	68,000	50,000	1,391,500	233,950	180,000	20,000	Irish potato	Gataraga
9	600,000	28,800	17,000	10,000	506,000	59,160	120,000	60,000	Irish potato	Gataraga
10	360,000	12,400	53,550	20,000	1,138,500	111,555	135,000	184,000	Irish potato	Gataraga
11	1,200,000	24,900	38,250	27,000	759,000	62,370	225,000	45,000	Irish potato	Gataraga
12	1,200,000	24,800	29,750	25,000	632,500	43,225	187,500	50,000	Irish potato	Gataraga
13	28,800	3,600	8,500	25,000	202,400	26,832	1,500	1,000	Irish potato	Gataraga
14	37,500	12,500	27,200	17,000	141,000	15,000	2,450	6,000	Bean	Nkotsi
15	37,500	9,000	14,450	16,000	84,600	4,000	1,050	16,970	Bean	Nkotsi
16	105,000	9,903	31,450	14,000	169,200	12,874	4,200	16,970	Wheat	Nkotsi
17	168,000	9,903	15,300	15,000	35,250	8,219	3,500	16,970	Onion	Nkotsi
18	70,000	2,100	15,300	14,000	126,900	12,000	1,750	16,970	Bean	Nkotsi
19	120,000	9,903	36,550	17,000	211,500	7,395	5,250	16,970	Wheat	Nkotsi
20	31,250	3,000	15,300	18,000	84,600	10,950	1,050	16,970	Bean	Nkotsi
21	30,000	1,500	9,350	18,000	84,600	7,500	1,225	16,970	Bean	Nkotsi
22	90,000	9,903	25,500	14,000	141,000	11,895	3,500	16,970	Wheat	Nkotsi
23	225,000	2,500	25,500	15,000	56,400	13,916	29,280	47,500	Tomato	Nkotsi
24	87,500	3,000	16,150	12,000	169,200	12,000	2,625	16,970	Bean	Nkotsi
25	50,000	3,000	12,750	8,000	112,800	12,000	1,575	16,970	Bean	Nkotsi
26	67,500	9,903	13,600	10,000	141,000	15,000	1,400	16,970	Bean	Nkotsi
27	90,000	3,600	17,000	12,000	371,000	15,000	10,500	40,000	Wheat	Busogo
28	75,000	3,000	25,500	10,000	371,000	20,000	6,000	40,000	Corn	Busogo
29	75,000	6,000	25,500	10,000	371,000	20,000	6,000	40,000	Corn	Busogo
30	240,000	3,000	17,000	10,000	333,900	34,790	111,000	12,000	Irish potato	Busogo
31	240,000	3,000	17,000	10,000	333,900	34,790	60,000	12,000	Irish potato	Busogo
32	720,000	3,000	85,000	67,000	2,226,000	73,950	450,000	160	Irish potato	Busogo
33	75,000	3,600	17,000	40,000	556,500	14,790	3,000	40	Corn	Busogo

34	80,000	3,600	17,000	10,000	371,000	20,000	100	160	Cabage	Busogo
35	125,000	5,400	25,500	10,000	742,000	20,000	9,000	16,970	Corn	Busogo
36	250,000	5,400	34,000	17,000	1,484,000	20,000	14,000	80	Bean	Busogo
37	480,000	4,200	51,000	35,000	1,484,000	79,300	240,000	20,000	Irish potato	Busogo
38	276,000	3,600	25,500	15,000	371,000	34,720	90,000	12,000	Irish potato	Busogo
39	90,000	5,400	17,000	12,000	371,000	15,000	10,500	40	Wheat	Busogo
40	90,000	6,000	17,000	12,000	371,000	15,000	10,500	16,970	Wheat	Busogo
41	137,280	3,000	30,600	7,000	864,000	34,790	39,000	4,060	Irish potato	Kinigi
42	135,000	9,903	11,900	7,000	278,000	37,255	39,000	4,600	Irish potato	Musanze
43	180,000	9,903	56,100	17,000	278,000	16,990	84,000	8,000	Irish potato	Musanze
44	12,000	9,903	12,750	7,000	139,000	9,130	15,000	900	Irish potato	Musanze
45	144,000	9,903	33,150	17,000	333,600	15,325	78,000	6,008	Irish potato	Musanze
46	60,000	9,903	30,600	12,000	222,400	8,895	30,000	6,020	Irish potato	Musanze
47	96,000	9,903	29,750	14,000	250,200	11,374	45,000	4,000	Irish potato	Musanze
48	108,000	9,903	17,000	14,000	250,200	8,874	60,000	14,000	Irish potato	Musanze
49	143,520	4,000	46,750	7,000	278,000	27,395	24,900	6,000	Irish potato	Musanze
50	324,720	4,000	45,900	14,000	556,000	12,560	69,000	11,000	Irish potato	Musanze
51	192,000	2,500	21,250	12,000	432,000	30,650	60,000	11,000	Irish potato	Kinigi
52	120,000	9,903	40,800	7,000	278,000	22,325	72,000	8,000	Irish potato	Musanze
53	126,240	4,000	29,750	7,000	278,000	10,000	75,000	8,600	Irish potato	Musanze
54	240,000	2,500	57,800	14,000	432,000	27,325	75,000	8,000	Irish potato	Kinigi
55	120,000	9,903	7,650	7,000	194,600	27,255	36,900	15,000	Irish potato	Musanze
56	120,000	2,500	51,000	8,500	333,600	15,325	42,000	17,500	Irish potato	Musanze
57	78,000	9,903	40,800	8,500	556,000	9,860	45,000	600	Irish potato	Musanze
58	241,200	9,903	17,850	7,000	278,000	38,311	54,000	7,500	Irish potato	Nyange
59	25,000	9,903	10,200	10,000	139,000	2,000	1,050	16,970	Corn	Musanze
60	50,000	9,903	34,850	17,000	467,000	20,000	3,500	16,970	Bean	Cyuve
61	18,750	9,903	8,500	12,000	140,100	9,000	1,050	16,970	Bean	Cyuve
62	59,250	9,903	34,000	14,000	747,200	47,888	5,600	16,970	Bean	Cyuve
63	250,000	9,903	17,000	8,500	233,500	10,000	17,500	16,970	Bean	Cyuve
64	7,500	9,903	5,100	7,000	140,100	6,000	1,050	16,970	Bean	Cyuve
65	10,250	9,903	8,500	8,500	186,800	8,000	1,400	16,970	Bean	Cyuve
66	25,500	9,903	45,900	16,000	560,400	6,000	4,200	16,970	Bean	Cyuve
67	15,000	9,903	6,800	15,000	140,100	9,000	1,050	16,970	Bean	Cyuve
68	120,000	9,903	21,250	25,000	373,600	11,832	48,000	2,070	Irish potato	Cyuve
69	240,000	9,903	10,200	14,000	556,000	69,580	3,600	16,060	Irish potato	Musanze
70	127,200	2,500	23,800	34,000	416,000	54,510	120,000	18,400	Irish potato	Nyange
71	180,000	2,500	12,750	20,000	208,000	37,255	66,000	10,900	Irish potato	Nyange

72	180,000	4,900	20,400	7,000	208,000	29,790	48,000	4,070	Irish potato	Nyange
73	96,000	9,903	34,000	17,000	208,000	26,720	36,000	9,800	Irish potato	Kinigi
74	1,080,000	8,000	72,250	80,000	1,248,000	193,950	366,000	53,800	Irish potato	Nyange
75	62,400	2,500	21,250	15,000	208,000	37,255	36,000	9,600	Irish potato	Nyange
76	360,000	7,500	25,500	12,000	728,000	47,255	112,500	14,800	Irish potato	Nyange
77	180,000	5,000	10,200	17,000	432,000	39,790	51,000	8,800	Irish potato	Kinigi
78	420,000	5,000	18,700	27,000	416,000	34,790	126,000	16,400	Irish potato	Nyange
79	116,400	5,000	6,800	8,000	648,000	29,720	60,000	600	Irish potato	Kinigi
80	360,000	2,500	19,550	27,000	416,000	44,650	126,000	17,000	Irish potato	Nyange
81	188,760	9,903	55,250	7,000	864,000	59,300	69,000	12,100	Irish potato	Kinigi
82	234,000	51,000	45,900	35,000	244,000	24,790	105,000	29,000	Irish potato	Muko
83	55,000	20,000	18,700	10,000	85,400	2,000	2,800	16,970	Bean	Muko
84	30,000	5,200	25,500	7,000	61,000	7,430	28,500	4,600	Irish potato	Muko
85	36,000	4,600	28,900	7,000	61,000	5,000	27,000	4,000	Irish potato	Muko
86	18,000	20,600	22,950	5,000	48,800	3,965	18,000	2,000	Irish potato	Muko
87	45,000	4,500	20,400	12,000	73,200	2,500	2,450	16,970	Bean	Muko
88	105,600	42,500	30,600	7,000	61,000	7,694	27,000	4,600	Irish potato	Muko
89	52,500	41,800	31,450	17,000	97,600	7,916	1,750	16,970	Corn	Muko
90	24,000	23,700	25,500	5,000	48,800	6,465	21,000	4,000	Irish potato	Muko
91	162,000	48,600	44,200	12,000	97,600	12,888	45,000	8,880	Irish potato	Muko
92	30,000	22,700	20,400	10,000	73,200	5,458	27,000	4,800	Irish potato	Muko
93	125,000	7,500	53,550	17,000	660,000	24,650	15,750	16,970	Bean	Rwaza
94	325,000	6,000	153,000	7,000	924,000	36,975	35,000	16,970	Corn	Rwaza
95	75,000	1,500	76,500	10,000	343,200	14,790	14,000	16,970	Bean	Rwaza
96	62,500	4,500	76,500	9,000	330,000	14,790	7,000	16,970	Bean	Rwaza
97	332,500	6,000	170,000	7,000	924,000	36,975	35,000	16,970	Corn	Rwaza
98	125,000	2,000	127,500	30,000	660,000	24,650	14,000	16,970	Bean	Rwaza
99	375,000	2,500	144,500	30,000	660,000	36,975	21,000	16,970	Corn	Rwaza
100	112,500	4,500	102,000	14,000	594,000	21,199	14,000	16,970	Bean	Rwaza
101	150,000	7,500	170,000	20,000	660,000	24,650	24,500	16,970	Bean	Rwaza
102	120,000	2,000	127,500	35,000	660,000	24,650	17,500	16,970	Bean	Rwaza
103	100,000	9,903	127,500	13,000	264,000	19,720	13,300	16,970	Bean	Rwaza
104	67,500	9,903	69,700	8,000	316,800	12,325	8,400	16,970	Bean	Rwaza
105	412,500	5,000	153,000	11,000	686,400	36,975	15,750	16,970	Corn	Rwaza
106	64,750	1,000	69,700	8,000	330,000	12,325	8,400	16,970	Bean	Rwaza
107	375,000	2,000	153,000	3,000	660,000	36,975	17,500	16,970	Corn	Rwaza
Average	**185,905**	**9,903**	**39,140**	**16,019**	**412,593**	**28,464**	**48,408**	**16,970**		

Appendix 2b. Raw data in quantities

An Nbr of respondents	Agr production in Kgs	Labour in man days	Cultivated area in ares	Fertilizers in Kgs	Seeds in Kgs	Pesticides in Litres	Product	Sector
No	Y	L	Ld	F	S	P	Product	Sector
1	100.00	13	5.00	1016.00	50.00	1.10	Irish potato	Gataraga
2	150.00	5	5.00	100.00	8.00	0.25	Corn	Gataraga
3	400.00	15	4.00	212.00	140.00	1.00	Irish potato	Gataraga
4	1800.00	40	15.00	3045.00	375.00	4.02	Irish potato	Gataraga
5	800.00	10	4.00	320.00	100.00	4.50	Irish potato	Gataraga
6	4000.00	60	72.00	10150.00	750.00	12.25	Irish potato	Gataraga
7	200.00	11	0.25	2000.00	30.00	4.50	Irish potato	Gataraga
8	10000.00	80	55.00	16150.00	600.00	5.00	Irish potato	Gataraga
9	5000.00	20	20.00	720.00	400.00	10.00	Irish potato	Gataraga
10	3000.00	63	45.00	4635.00	450.00	31.00	Irish potato	Gataraga
11	10000.00	45	30.00	1890.00	750.00	6.25	Irish potato	Gataraga
12	10000.00	35	25.00	700.00	625.00	7.50	Irish potato	Gataraga
13	240.00	10	8.00	1524.00	5.00	0.25	Corn	Gataraga
14	150.00	32	10.00	1500.00	7.00	1.50	Bean	Nkotsi
15	150.00	17	6.00	400.00	3.00	0.00	Bean	Nkotsi
16	350.00	37	12.00	418.00	12.00	0.00	Wheat	Nkotsi
17	560.00	18	2.50	604.50	0.10	0.00	Onion	Nkotsi
18	280.00	18	9.00	1200.00	5.00	0.00	Bean	Nkotsi
19	400.00	43	15.00	15.00	15.00	0.00	Wheat	Nkotsi
20	125.00	18	6.00	1095.00	3.00	0.00	Bean	Nkotsi
21	120.00	11	6.00	750.00	3.50	0.00	Bean	Nkotsi
22	300.00	30	10.00	465.00	10.00	0.00	Wheat	Nkotsi
23	1500.00	30	4.00	812.00	0.40	11.25	Tomato	Nkotsi
24	350.00	19	12.00	1200.00	7.50	0.00	Bean	Nkotsi
25	200.00	15	8.00	1200.00	4.50	0.00	Bean	Nkotsi
26	270.00	16	10.00	1500.00	4.00	0.00	Bean	Nkotsi
27	300.00	20	10.00	1500.00	30.00	0.10	Wheat	Busogo
28	300.00	30	10.00	2000.00	20.00	0.10	Corn	Busogo
29	300.00	30	10.00	2000.00	20.00	0.10	Corn	Busogo
30	2000.00	20	9.00	2030.00	370.00	3.00	Irish potato	Busogo
31	2000.00	20	9.00	2030.00	200.00	3.00	Irish potato	Busogo
32	6000.00	100	60.00	150.00	1500.00	4.00	Irish potato	Busogo
33	300.00	20	15.00	30.00	10.00	1.00	Corn	Busogo
34	1000.00	20	10.00	2000.00	0.05	4.00	Cabage	Busogo
35	500.00	30	20.00	2000.00	30.00	0.00	Corn	Busogo
36	1000.00	40	40.00	2000.00	40.00	2.00	Bean	Busogo
37	4000.00	60	40.00	3100.00	800.00	5.00	Irish potato	Busogo
38	2300.00	30	10.00	1540.00	300.00	3.00	Irish potato	Busogo
39	300.00	20	10.00	1500.00	30.00	1.00	Wheat	Busogo
40	300.00	20	10.00	1500.00	30.00	0.00	Wheat	Busogo
41	1144.00	36	20.00	2030.00	130.00	1.10	Irish potato	Kinigi
42	1125.00	14	10.00	2035.00	130.00	1.15	Irish potato	Musanze

43	1500.00	66	10.00	250.00	280.00	2.00	Irish potato	Musanze
44	100.00	15	5.00	430.00	50.00	0.15	Irish potato	Musanze
45	1200.00	39	12.00	325.00	260.00	1.70	Irish potato	Musanze
46	500.00	36	8.00	165.00	100.00	2.00	Irish potato	Musanze
47	800.00	35	9.00	268.00	150.00	1.00	Irish potato	Musanze
48	900.00	20	9.00	18.00	200.00	1.00	Irish potato	Musanze
49	1196.00	55	10.00	2015.00	83.00	1.50	Irish potato	Musanze
50	2706.00	54	20.00	290.00	230.00	1.50	Irish potato	Musanze
51	1600.00	25	10.00	650.00	200.00	1.50	Irish potato	Kinigi
52	1000.00	48	10.00	1025.00	240.00	2.00	Irish potato	Musanze
53	1052.00	35	10.00	1000.00	250.00	2.15	Irish potato	Musanze
54	2000.00	68	10.00	1525.00	250.00	2.00	Irish potato	Kinigi
55	1000.00	9	7.00	1035.00	123.00	2.50	Irish potato	Musanze
56	1000.00	60	12.00	325.00	140.00	3.40	Irish potato	Musanze
57	650.00	48	20.00	20.00	150.00	0.15	Irish potato	Musanze
58	2010.00	21	10.00	2527.00	180.00	1.25	Irish potato	Nyange
59	100.00	12	5.00	200.00	3.00	0.00	Corn	Musanze
60	200.00	41	10.00	2000.00	10.00	0.00	Bean	Cyuve
61	75.00	10	3.00	900.00	3.00	0.00	Bean	Cyuve
62	237.00	40	16.00	4016.00	16.00	0.00	Bean	Cyuve
63	1000.00	20	5.00	1000.00	50.00	0.00	Bean	Cyuve
64	30.00	6	3.00	600.00	3.00	0.00	Bean	Cyuve
65	41.00	10	4.00	800.00	4.00	0.00	Bean	Cyuve
66	102.00	54	12.00	600.00	12.00	0.00	Bean	Cyuve
67	60.00	8	3.00	900.00	3.00	0.00	Bean	Cyuve
68	1000.00	25	8.00	24.00	160.00	0.55	Irish potato	Cyuve
69	2000.00	12	20.00	4060.00	12.00	4.50	Irish potato	Musanze
70	1060.00	28	20.00	2070.00	400.00	4.60	Irish potato	Nyange
71	1500.00	15	10.00	2035.00	220.00	2.30	Irish potato	Nyange
72	1500.00	24	10.00	1530.00	160.00	1.10	Irish potato	Nyange
73	800.00	40	10.00	740.00	120.00	2.45	Irish potato	Kinigi
74	9000.00	85	60.00	12150.00	1220.0 0	17.20	Irish potato	Nyange
75	520.00	25	10.00	2035.00	120.00	2.25	Irish potato	Nyange
76	3000.00	30	35.00	3035.00	375.00	3.20	Irish potato	Nyange
77	1500.00	12	10.00	2530.00	170.00	2.20	Irish potato	Kinigi
78	3500.00	22	20.00	2030.00	420.00	4.10	Irish potato	Nyange
79	970.00	8	15.00	1040.00	200.00	0.25	Irish potato	Kinigi
80	3000.00	23	20.00	2050.00	420.00	4.50	Irish potato	Nyange
81	1573.00	65	20.00	1100.00	230.00	2.75	Irish potato	Kinigi
82	1950.00	54	20.00	1030.00	350.00	6.00	Irish potato	Muko
83	220.00	22	7.00	200.00	8.00	0.00	Bean	Muko
84	250.00	30	5.00	260.00	95.00	1.25	Irish potato	Muko
85	300.00	34	5.00	500.00	90.00	1.00	Irish potato	Muko
86	150.00	27	4.00	155.00	60.00	0.50	Irish potato	Muko
87	180.00	24	6.00	250.00	7.00	0.00	Bean	Muko
88	880.00	36	5.00	383.00	90.00	1.10	Irish potato	Muko

89	350.00	37	8.00	212.00	5.00	0.00	Corn	Muko
90	200.00	30	4.00	405.00	70.00	1.00	Irish potato	Muko
91	1350.00	52	8.00	516.00	150.00	2.45	Irish potato	Muko
92	250.00	24	6.00	256.00	90.00	1.10	Irish potato	Muko
93	500.00	63	50.00	50.00	45.00	3.00	Bean	Rwaza
94	1300.00	180	70.00	75.00	100.00	2.00	Corn	Rwaza
95	300.00	90	26.00	30.00	40.00	0.25	Bean	Rwaza
96	250.00	90	25.00	30.00	20.00	0.50	Bean	Rwaza
97	1330.00	200	70.00	75.00	100.00	0.50	Corn	Rwaza
98	500.00	150	50.00	50.00	40.00	1.00	Bean	Rwaza
99	1500.00	170	50.00	75.00	60.00	0.00	Corn	Rwaza
100	450.00	120	45.00	43.00	40.00	0.50	Bean	Rwaza
101	600.00	200	50.00	50.00	70.00	0.38	Bean	Rwaza
102	480.00	150	50.00	50.00	50.00	0.50	Bean	Rwaza
103	400.00	150	20.00	40.00	38.00	0.50	Bean	Rwaza
104	270.00	82	24.00	25.00	24.00	0.50	Bean	Rwaza
105	1650.00	180	52.00	75.00	45.00	0.00	Corn	Rwaza
106	259.00	82	25.00	25.00	24.00	0.25	Bean	Rwaza
107	1500.00	180	50.00	75.00	50.00	0.00	Corn	Rwaza
Average	**1,333.32**	**46.05**	**18.02**	**1,358.08**	**158.65**	**2.16**	**Average**	

Appendix 3. Operation zone of Programme DERN in Musanze District