ECONOMIC IMPACTS OF LAND FRAGMENTATION IN BUTARE, SOUTHERN RWANDA

BY

CLAUDE BIZIMANA

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I hereby certify that, unless specifically indicated to the contrary in the text, this thesis is the result of my own original work.

CLAUDE BIZIMANA

A Yannick et Annaëlle, Je dédie ce travail

ABSTRACT

Butare, where this study was conducted, exhibits one of the highest population densities in Rwanda. Agriculture is the dominant economic sector and provides employment for more than 90 per cent of the working population. As a direct result of population growth, most peasants have small fields (mean of 2.4 hectares per household) and land fragmentation is common. The purpose of this research is to examine the effect of land fragmentation on economic efficiency. This study is based on data collected during 2001 from 200 households in Rusatira and Muyira districts using a standardized questionnaire.

Regression analysis shows that area operated is primarily determined by the population-land ratio, non-agricultural employment opportunities, ownership certainty and adequate information through agricultural training. Results from a block-recursive regression analysis indicate that the level of net farm income per hectare, which indirectly reflects greater economic efficiency, is determined by area operated, use of farm information, field extension staff visits, formal education of a farm operator, and the fragmentation of land holdings. Economies of size, whereby large farms reduce their average costs are evident in the data. The results obtained using ridge regression, used to overcome the multicollinearity problem, support the findings of two-stage least squares. Better educated farm operators with large and unfragmented farm units, with access to farm information and in regular contact with field extension staff can be expected to generate higher net farm income per hectare and much higher returns to management – a fixed resource.

Factors influencing technology adoption by Rwandan coffee farmers, assessed according to extent of adoption of soil testing and use of fertilizer, are also investigated in this study. Twenty per cent of farmers surveyed have adopted both practices, however, forty-nine per cent have adopted neither practice. A chi-square test showed a strong association between the two practices, implying that a farmer who tests soils on his farm is also likely to use fertilizer. Results support expectations that farmers who adopt more recommended technologies and farming practices are more productive and more efficient producers of coffee. A discriminant analysis identified land fragmentation, availability of wealth and liquidity, and education of the principal farm decision-maker as the most important factors influencing the adoption of recommended and appropriate farming practices on coffee farms, followed by gender of farm operator, and farm information acquired by farmers.

It is concluded that transformation of Rwandan agriculture requires policies that (a) remove obstacles to the development of an efficient land market in order to reduce land fragmentation and to transfer land to more efficient farmers; (b) improve rural education, strongly associated with off-farm job opportunities, implying that improving education will improve labour mobility from agriculture; (c) improve liquidity and farmers' access to relevant information; (d) strengthen extension facilities to individual farmers; (e) reduce gender discrimination in order to improve farmers' abilities; and (f) promote adoption of recommended farming practices.

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INTRODUCTION

Rwanda, with a surface area of 26,338 Km^2, is one of Africa's smallest countries, but exhibits one of the highest population densities of all African countries (about 300 inhabitants per square kilometer) according to a World Bank (1999) report. In Rwanda, as in many other countries, the major resource is land. As the population density figures intimate, the amount of land per household is extremely small and as the rural population grows, area operated declines. The overall average area operated is 0.71 hectares per household with some variation in the average area operated between regions (MINAGRI, 2000). The high average area operated reported in this study (2.4 hectares per household) may be attributed to the fact that most of the sample farmers operated on lands belonging to relatives who died during the 1994 genocide.

In Rwanda, agriculture contributes around 40 per cent of Gross Domestic Product (GDP), provides employment for about 90 per cent of the working population and accounts for 85 per cent of foreign exchange earnings (World Bank, 2002). Coffee is the most important crop, accounting for three-quarters of these foreign exchange earnings (MINAGRI and OCIR, 1998). However, Rwandan agriculture, including coffee farming, is beset by many problems, including obsolete technology, land fragmentation, inadequate infrastructure and a shortage of skilled manpower (Waller, 1993).

The land tenure system in Rwanda exhibits diversity in customary rules governing access to land, utilization, and transfer (Place *et al.*, 1994). Analysis of the World Bank data revealed that little effect of government intervention is felt in Rwanda even though the government has declared some policy changes and enacted legislation affecting land rights, land transactions, size of holdings, imposed land taxes, the substance of the law, and the extent to which laws are enforced. Takeuchi and Marara (2000: 27) state that the Rwandan land tenure system has the following problems: the land tends to be excessively fractionated through heritage; settlement is generally scattered in rural areas; the written law (or "modern" law) and the customary laws co-exist about the land; and the right to land is so ambiguous that investment tends to be hindered.

Adoption of technical innovations by agricultural producers is an essential prerequisite for economic prosperity of developing countries (Manning, cited by Rauniyar, 1990). The contribution of technical innovations towards economic development can be signified by the success of innovations such as high yielding, disease and pest resistant, and stress tolerant crop varieties, pesticides, herbicides and machinery (Welch, 1978:263). Human capital capacities of farm operators are considered as important in influencing the adoption of improved farming practices among coffee farmers. Feder and Slade (1984) state that a higher endowment of human capital promotes adoption by improving resource allocation efficiency and productivity. If this relationship holds true, it is important to the on-going effort to transform Rwandan agriculture that farmers attain the critical level of knowledge in order to manage Rwanda's scarce agricultural land resources.

The primary focus of the research is to examine land fragmentation in Southern Rwanda, where land fragmentation is defined as farmers operating two or more geographically separated tracts of land, taking account of the distances between those parcels. Fragmentation arises under land scarcity as farmers look farther for whatever parcels of land may be available. Research on land fragmentation often focuses on fragmentation as the source of inefficiencies in agricultural production. The object of this research is to examine the fragmentation issue in Rwanda by examining how efficiency of resource use on farms varies with the size of a farm business and what implications variations in performance might hold for the reallocation of resources between the area operated by groups in pursuit of land redistribution. This study also seeks to provide a profile on measures of adoption ability among Rwandan coffee farmers studied, and to determine factors explaining different adoption rates of recommended farming practices and technologies. Results have implications for development of a sound agricultural policy in Rwanda.

Data for this study were collected during 2001 from 100 randomly selected households in each of Rusatira and Muyira districts using a standardized questionnaire. Farms studied are privately owned, and varied from 0.04 to 6 hectares. The size of farm only included land operated by each household (allocated land cultivated and all land rented in). Lands left idle and lands rented out were excluded.

Chapter 1 outlines the characteristics of agriculture and rural areas, and the production structure and economic importance of the coffee industry in the agricultural economy of Rwanda. Chapter 2 presents a review of the theoretical and empirical research results in analyzing economies of size and technology adoption behaviour. In this chapter, literature on theoretical considerations in the analysis of farm efficiency is reviewed, and sources of economies of scale on farm operations are discussed. The influence of human resource capital on farm performance through the adoption of better farming methods is studied. The study rests on the premise that adoption of technological innovations combined with the relevant infrastructure and institutional services could change the current situations prevalent in subsistence agriculture. The hypothesis that the adoption of agricultural technologies by farm operators is influenced by individual and farm attributes, socio-economic factors, and infrastructure and institutional facilities is tested in this study.

Chapter 3 describes the research methodology used for analyzing the socio-economic factors contributing to the economic efficiency model and the determinants of technology adoption by farmers. The overall description of the characteristics of sample population using descriptive statistics is presented in Chapter 4. Empirical analysis and results are reported and discussed in Chapter 5. Conclusions and policy implications are presented in Chapter 6, while Chapter 7 contains a summary of this research.

CHAPTER 1

CHARACTERISTICS OF AGRICULTURE AND ECONOMIC IMPORTANCE OF RWANDAN COFFEE INDUSTRY

1.1 Characteristics of Agriculture in Rwanda

1.1.1 Agricultural Sector in the Rwandan Macro-Economy

Agriculture is the most important sector of Rwanda's economy and a great part of the Rwandan population live in rural areas. It accounts for 40 per cent of GDP (Figure 1.1), about 85 per cent of total exports are agricultural, making it a leading foreign exchange earner (World Bank, 2002). More than 90 per cent of the economically active population derives its livelihood from agriculture. Further, the expanding labour force is expected to be absorbed in the agricultural sector. Undoubtedly the significance of this sector will continue in the years to come.

Figure 1.1 presents the composition of the three economic sectors in GDP. It indicates that the proportion of the agricultural sector has continued to decline. The share of the agricultural sector, which occupied around 80 per cent of the GDP at the beginning of the 1960s, is about 40 per cent today. Although the proportion of the agricultural sector in GDP has declined, its importance in employment has not changed at all. Figure 1.2 shows the proportion of the working population in the agricultural sector.

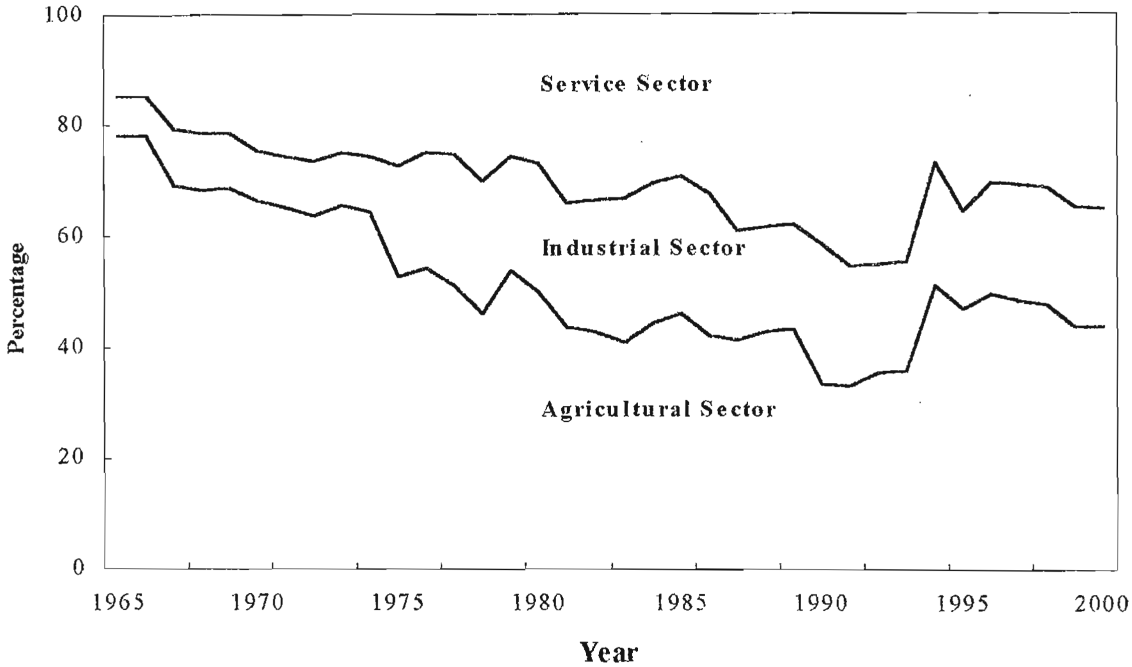

Figure 1.1 Proportion of economic sectors in Rwandan GDP (1965-2000)

Source: World Bank (2002).

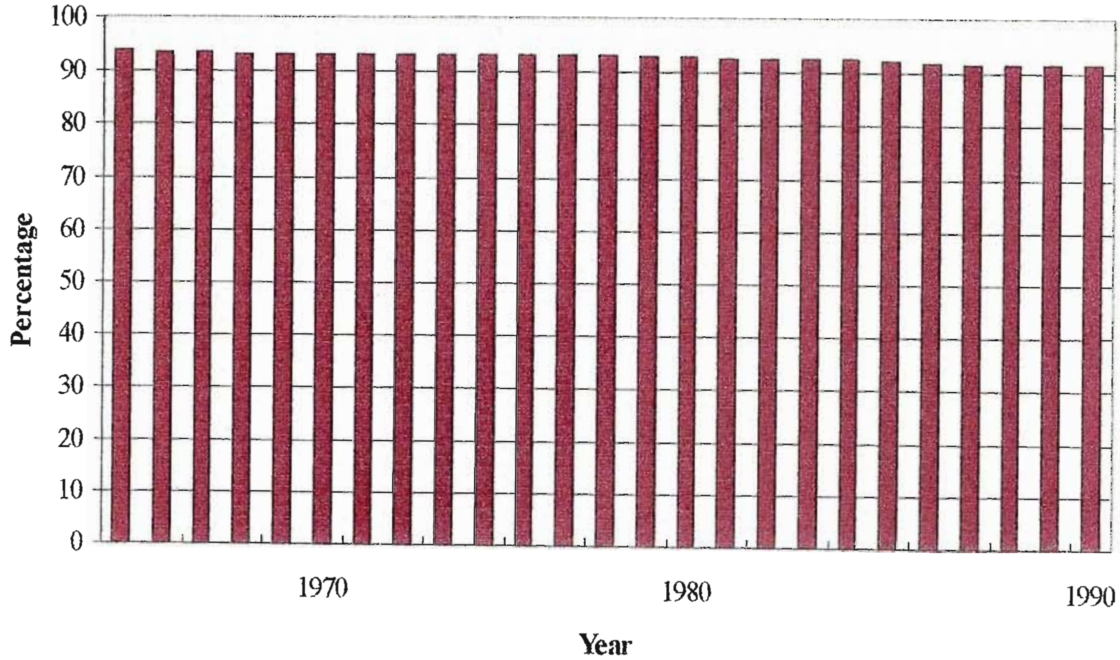

Figure 1.2 Proportion of the working population in the agricultural sector (1966-1990)

Source: World Bank (1999).

By analyzing the evolution of Rwandan real GDP growth rate in detail, it is clear that it is closely related to that of the agricultural sector. The growth rate, having increased up to the mid 1980s, declined thereafter to a level lower than the annual population growth rate. Such an evolution of GDP corresponds to the crisis of the agricultural sector. Figure 1.3 shows the evolution of real GDP growth rate.

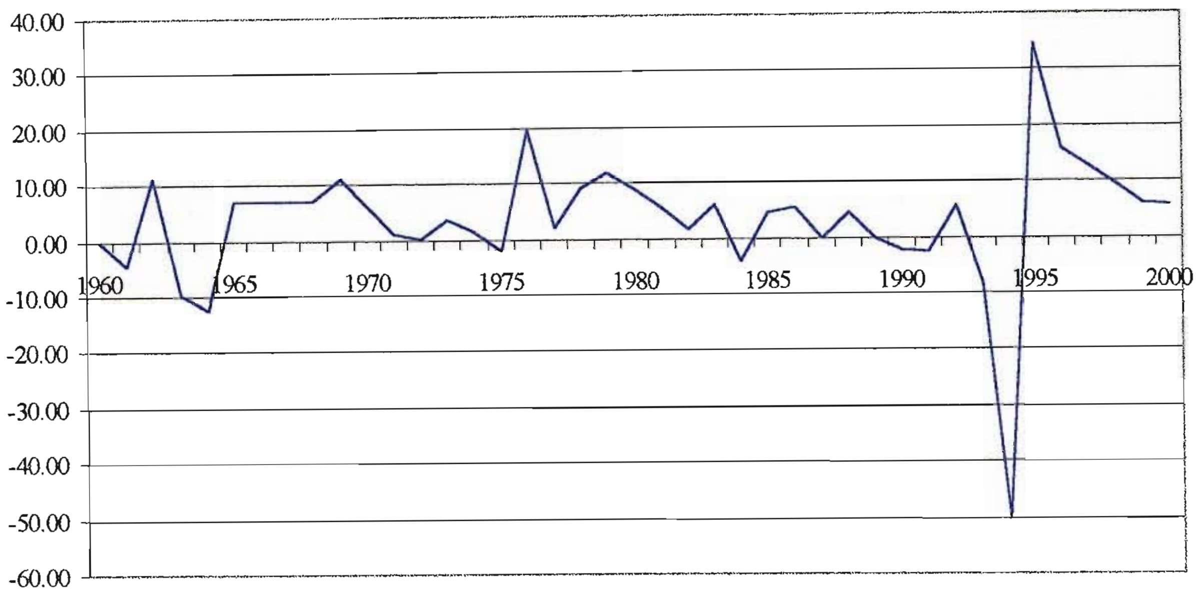

Figure 1.3 Rwandan real GDP growth rate (1960-2000)

Source: World Bank (2002).

According to Takeuchi and Marara (2000: 8), there are at least two reasons to explain the stagnation of the agricultural sector. At first, the price of coffee - the most important of export goods - in the world market fell sharply in the 1980s. This sudden decrease in coffee price, in addition to the fall of other export goods such as tin, triggered the Rwandan economic crisis. Secondly, some researchers insist that the Rwandan agricultural production system had reached its limit before the 1980s, thus causing the stagnation of food production. André (1997) argued that the cause of this food shortage could be attributed to the limit of land utilization. She further asserts that, although the agricultural method with intensive land use has developed in Rwanda, it could no longer work in the 1980s because of excessive land fragmentation.

1.1.2 Population Pressure

Rwanda remains one of Africa's most densely populated countries, with more than 290 inhabitants per square kilometer. This is certainly more than 400 if calculated from the area of cultivated land, which is undoubtedly the highest level in Africa (World Bank, 1999). The rate of population growth is very high, with the fertility rate around 8.3 and the annual population growth rate estimated at 3.1 per cent (MINECOFIN-ONAPO, 1998). Various population projections have been calculated. It is estimated that on a medium growth rate hypothesis (World Bank, 1999), the population will double over the next 20 years (to 16 million inhabitants in the year 2022). If the above-mentioned population growth estimate is correct, the density shall rise to 865 inhabitants per arable square kilometer in 20 years. There is thus considerable pressure on the land, and it is increasing at a considerable rate, making population pressure one of the country's major challenges. Figure 1.4 depicts an increasing linear curve for Rwanda's population growth for periods between 1934 and 1997.

Another important characteristic of the Rwandan population is that a large majority of the population live in rural areas: urbanization has not yet developed. The proportion of the urban population was only around 5 per cent in 1991 (MINECOFIN-ONAPO, 1998). In this sense, a strong rural population coupled with land fragmentation will have a considerable impact upon the development of Rwandan agriculture.

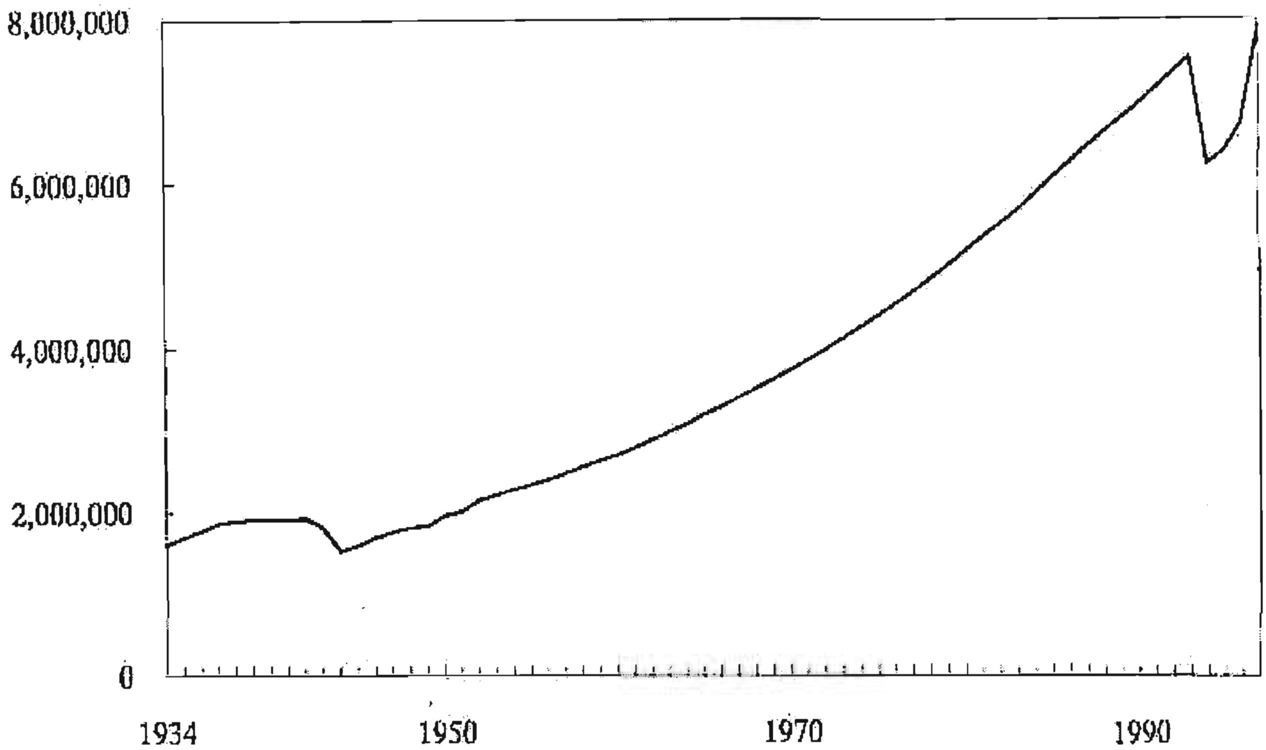

Figure 1.4 Population of Rwanda (1934-1997)

Sources: 1934-1964 : ONAPO (1990)

1965- 1997: World Bank (1999).

1.1.3 Patterns of Farm Size

In Rwanda, farms are small and often fragmented. The overall average farm size is 0.71 hectares per household (MINAGRI, 2000). There is, however, some variation in the average farm size between regions: the highest average farm size being 1.26 hectares (Gikongoro) and the lowest 0.37 hectares (Cyangugu). The average farm size in Butare is 0.48 hectares (Table 1.1). With respect to the patterns of farm size, about 79 per cent of all households in Rwanda (and about 89 per cent in Butare) have 1 hectare of land or less. Only 6 per cent of all households in Rwanda, (and 2 per cent in Butare) have two hectares or more (Table 1.2).

Table 1.1 Average farm size (in ha) in Butare compared to the national average,2000

	Farm size category (ha)							Total
	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	1.00 - 2.00	2.00 - 3.00	>3.00	
Butare (ha)	0.14	0.35	0.60	0.85	0.142	0.219	0.393	0.48
RWANDA (ha)	0.14	0.36	0.62	0.86	0.138	0.238	0.511	0.71

Source: MINAGRI (2000).

Table 1.2 Patterns of farm size in Butare compared to the national average, 2000

	Farm size category (ha)							Total
	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	1.00 - 2.00	2.00 - 3.00	>3.00	
Butare (%)	41	27	14	7	8	2	1	100
RWANDA (%)	29	26	16	8	15	4	2	100

Source: MINAGRI (2000).

1.2 Structure and Economic Importance of the Coffee Industry in Rwanda

1.2.1 Coffee Production in Rwanda

In Rwanda, coffee production has been an important source of foreign exchange, accounting for three-quarters of foreign exchange earnings, which is an important engine of growth and investments for the 50 per cent of farm households engaged in it (World Bank, 1999). Between 1965 and 1988, coffee on average contributed about 57.5 per cent to total Rwandan export value (Appendix A) and to more than 80 per cent of total agricultural exports (Appendix B). Over the years the predominating coffee policy has been to promote coffee production to ensure sufficient production and foreign exchange receipts. These estimates may understate the extent of coffee production since Loveridge (1992) contends that many Rwandans are participating in substantial informal and largely unmeasured cross-border trade.

However, the coffee sector in particular, and Rwandan agriculture in general is beset by many problems, such as obsolete technology, land fragmentation, inadequate infrastructure and a shortage of skilled manpower (Waller, 1993). The road to producing specialty coffee appears to involve a combination of improved farm-level and washing/processing quality, and better marketing, especially direct marketing to importers where trust can be established (Ponte, 2001). Rwandan coffee faces quality challenges in the size of the typical bean and in its traditional farmgate methods of initial processing (Walker, 2001). While fertilizer use is minimal, most Rwandan coffee farmers historically used chemical inputs for pest and disease control (Rwalinda *et al.*, 1992). Generally in Rwanda farming is mainly undertaken by smallholders who, although they may grow some cash crops, practice agriculture mainly for subsistence, using traditional methods which give low yields per hectare and per man.

1.2.2 Production Structure of the Coffee Industry

Coffee production in Rwanda has for a long time been unparalleled in its ability to profitably generate large amounts of hard currency for the largely agricultural population of Rwanda (Tardif-Douglin *et al.*, 1996). These amounts help the population undertake various development projects and thus improve its economy. As shown in Appendix C, each year the amount of money injected into the rural area has steadily increased.

Growth at a sectoral level is considered inclusive of the rural poor when small-scale units participate directly in the production of export crops and enjoy higher incomes generated from these activities (Carter *et al.*, 1993). Carter *et al.* (1993) further stress that the employment generated by an agricultural system largely depends on the size distribution of farms participating in the production of the crop. Despite this economically favourable outlook for coffee in Rwanda, only 4 per cent of farmland is cultivated with coffee (Table 1.3). Furthermore, production, yields and planted area are declining in sympathy with lower world prices for coffee (Loveridge *et al.*, 2002). This situation suggests that agricultural policy makers need to re-assess the future role of coffee as an earner of foreign exchange and the benefits and costs of promoting coffee production and export.

Table 1.3 Land use by group of crops in Rwanda, 2000

	Percentage
Pulses	21
Cereals	13
Tubers	25
Bananas	20
Vegetables and other food crops	1
Coffee and other industrial crops	4
Fallow and pasture	10
Forest	6
Total	100

Source: MINAGRI (2000).

1.2.3 The Coffee Industry in View of Policy Change

Rwanda coffee policy is at a cross-roads. Past coffee policy has been to promote coffee production to ensure sufficient production and foreign exchange receipts. Recently, this has grown expensive as the cyclical nature of world coffee prices of the past has given way to sharply downward trends, turning a program of price stabilization into one of price supports (Tardif-Douglin *et al.*, 1996). Viewed in the long term, prices - for the bulk low grade Arabica type of coffee produced by Rwanda - are dropping because of an endemic oversupply of coffee, brought on in part by the collapse of the International Coffee Agreement (Tardif-Douglin *et al.*, 1996; Ponte, 2001).

There is need to develop a new policy that removes or modifies laws in existence since 1978 in such a way as to reduce the burden of the State and return crop choice to farmers without bringing about a catastrophic collapse in foreign exchange inflows. Some innovative work for improving processing and marketing Rwandan coffee, and farm-level information are required to ensure that farmers become more productive and more efficient producers of coffee. Prospects for improving Rwanda's coffee harvest to facilitate a growing high value coffee market depend on supply chain considerations that begin on the farm and with inputs into coffee farming (Loveridge *et al.*, 2002). Loveridge *et al.* (2002) further point out that to be able to understand how farmers will react to new opportunities, farm level information must be developed to accompany and complement varietal, input, processing, and marketing initiatives to form a comprehensive supply chain approach. Initiatives in new varieties, processing and marketing appear to have correctly identified high value market niches.

The new policy will have to centre on another crucial constraint for the development of the coffee sector, namely the constraint related to the small size of coffee plots and their scattering which hampers coffee extension activities. Coffee plots should be consolidated in order to facilitate extension activities. This could also enable farmers to easily acquire equipment if they were grouped in associations (MINAGRI-OCIR, 1998).

This synthesis shows the need to improve household-level information on Rwanda's coffee sector, so that appropriate policies may be put into place to increase the level and diversity of smallholder and rural business income.

This brief presentation of the agriculture sector in particular, and the Rwandan economy in general describes the importance of coffee farming and the extent of land fragmentation in Rwanda. The following chapter explores theoretical and empirical literature to determine expected relationships between land fragmentation, farm efficiency and technology adoption.

CHAPTER 2

ANALYSIS OF FARM EFFICIENCY AND TECHNOLOGY ADOPTION

In this chapter, literature on theoretical considerations in the analysis of farm efficiency is reviewed, and the land fragmentation issue and adoption of recommended and improved farm practices among coffee farmers are presented. The influence of human resource capital on farm performance is also investigated, given that the potential for increasing farm output through appropriate farming practices indirectly relates to farmers' managerial abilities (Kalirajan and Shand, 1988).

Studies on efficiency in agriculture have occasionally related farm size to efficiency (Hallam, 1991), with much debate on the relative merits of different-sized farm strategies. The attempt to measure and explain differences between small and large farms in terms of relative economic efficiency is common to many studies (Pasour and Bullock, 1975). The co-existence of large and small-sized farms in the agricultural sector may suggest that different sized farms can be efficient. Ellis (1988: 192) argued that the emergence of small-scale farms is supported due to the intensive utilization of labour and capital, therefore fulfilling employment and equity goals which large farms do not meet. On the other hand, Thompson and Lyne (1991) argued that some gains from agricultural innovations are scale dependent. Likewise, adoption rates are related to farm size (Welch, 1978; Feder *et al.,* 1982; Feder, 1985; Shaw and da Costa, 1985), therefore technology is more productive the larger the scale of activities to which it is applied.

In discussing different-sized farm development strategies it is important to understand factors that could impede the attainment of policy objectives. This may relate to the nature of technology involved in production of specific crop commodities, proprietorship and managerial ability of individual farm operators. Studies on farm size efficiency relationships in Rwanda show evidence of the existence of scale efficiencies (Byiringiro and Reardon, 1996). Empirical studies indicate that for smaller farms, there is evidence of allocative inefficiency in use of land and labour, probably due to factor market access constraints. While economists may argue that given the complete set of conditions facing the farmer, including his objective function, it is impossible to call a producer inefficient as long as his behaviour is rational (Pasour, 1981).

2.1 Theoretical Considerations in the Analysis of Farm Efficiency

2.1.1 Measurement of Farm Size

Obtaining a universally accepted definition of farm size has been one of the problems encountered in farm size and efficiency studies (Mbowa, 1996). A review of literature, however, suggests that numerous definitions of farm size have been adopted, ranging from acreage, value of farm products sold, days worked off-farm (for small-scale farms), level of farm income, to the level of total family income. Many authors combine two or more of these definitions. Farm size has commonly been taken to be synonymous with farm acreage because it can easily be ascertained and is easy to understand.

However, Britton and Hill (1975:15) state that in making judgement between farm businesses, acreage is soon shown to be a rather unsatisfactory indicator of business size. This is because the proportions in which land and other factors (labour, capital and so forth) combine in production vary between types of farming, and also between farms of the same type.

Britton and Hill (1975:15), further argue that the "best" unit of measurement of farm size, and size of enterprises within farms will depend on the purpose for which the measurement is to be used. In this study area operated was used as a measure of farm size as agricultural potential appears fairly homogeneous in the area. Kay (1981:51) suggests that number of acres should be used only to compare farm sizes in a limited geographical area where farm type, soil type, and climate are very similar.

Huang (1973) questions whether average farm size variation across countries is a purely random phenomenon, primarily determined by noneconomic variables such as laws of inheritance, historical consequences of landlord-tenant relationships, or government policies restricting or increasing area operated. He further asserts that there are certain quantifiable economic determinants operating across all countries. The basic hypothesis is that area operated patterns have evolved under the influence of political, social, and economic conditions which vary greatly among countries. Social and political factors are less easily generalized and quantifiable, but the four factors selected in this study (population-land ratio, off-farm employment, tenure certainty and agricultural training) may prove to be of sufficient importance to merit their study in isolation.

2.1.2 Farm Size and Property Rights

"Property rights specify the norms of behaviour with respect to economic goods that all persons must observe in their interactions with other people or bear the penalty cost of non-observance" (Pejovich, 1990). Johnson, cited by Barrows and Roth (1990), argues that efficiency requires a clear definition of rights, meaning that these must be established and allocated to specific individuals or groups, must be easy to identify and verify, and must have legal and tenure certainty. The greater the ambiguity in property rights the higher the transaction costs in discovering the owner, in making and enforcing a lease or sale contract, and the higher the residual uncertainty remaining after any given expenditure to identify ownership (Barrows and Roth, 1990).

Variants in forms of land tenure cause a range of optimal farm size in countries at various stages of economic development (Heady, 1971). Tenancy and small-sized farms are generally related in terms of the problems that they generate (Medina, 1980). Communal land tenure creates incentive problems to invest in land improvements, and tenancy arrangements that restrict farm sizes affect farm productivity (Lyne and Nieuwoudt, 1991).

High population pressure in Rwanda is a major factor leading to scarcity of farming land, reducing farming activities to small-sized farm units (Waller, 1993). Furthermore, the inheritance laws, which divide a family's land among all the remaining sons, ensure that, as the population increases, not only does the size of holdings fall, but they are increasingly fragmented into small plots, scattered over a wide area. However, the lack of an active land market within Butare has limited the expansion of commercial farming in the region (Place and Hazell, 1993).

Some authors (Johnson, 1972; Barrows and Roth, 1990) state that the traditional African system of "communal" land tenure has been empirically demonstrated by economists as inefficient when land has scarcity value. Since property rights are not broad enough, costs and rewards are not internalized, and contracts are not legal or enforceable (Barrows and Roth, 1990). Individualized freehold tenure, on the other hand, is viewed as superior because owners are given incentives to use land efficiently and leads to the maximization of agriculture's contribution to social well being (Barrows and Roth, 1990). Johnson (1972) further argues that in situations where individuals cannot sell land, the value of investment to the farmer declines because of lost flexibility in converting a fixed-place asset into another asset form. In this study, land tenure was one of the important considerations in the selection of the study sample. Land rights are not defined according to land titles. None of the sampled farmers in the study area possessed a legal title for any parcel.

2.1.3 Farm Size and Efficiency Relationship

If it can be established beyond doubt that small farms generally use resources less efficiently than larger farms this is likely to have important implications both for the individual farm and for the national economy. Especially in Rwanda where government is encouraging large farm development, the question of efficiency and equity becomes relevant and it is not possible to simply abstract from this issue.

At the same time, if wider recognition of the economic handicaps of the small farms leads to a more rapid reduction in their numbers and their absorption into larger farms, this might bring about appreciable savings of resources. Therefore a greater awareness of the relationship between size and efficiency might, through more efficient use of resources, benefit both the individual small farmer and the community as a whole.

This line of argument, however, is based on certain assumptions which need to be mentioned. Firstly, even if it can be demonstrated that small farms are generally less efficient than larger farmers in terms of output obtained from a given amount resources, this alone does not prove that the difference in size is the main cause of the difference in efficiency. For instance, it could well be the managerial ability of the present holders of small farms is significantly lower than that of the present holders of larger farms. If they were to change places, the relative efficiency of small and large farms might de reversed.

Secondly, it could be argued that the difference in efficiency exaggerates the apparent cause of for farm enlargement. The reason is that should small farm operators acquire more land and join the larger farm operators, it may not follow that they would then manage their businesses at a higher level of efficiency currently observed among holders of the larger holdings. Some of them might find that the challenge of the new managerial tasks is beyond their capacity. A farmer as entrepreneur is usually the largest indivisible factor of production, meaning that in practice the external limit of the size of the economic unit is determined by the management ability of the farmer. Many economists (Friedman, 1962; Pasour, 1981), contend that it is difficult to measure efficiency, because individual decision makers have different attitudes to risk. Different managers' subjective evaluation of the cost value of time, managerial input as well as of revenue also vary (Bradford and Johnson, 1964). Such perpetual differences can also be expected to influence an individual's scale of operation, contributing to divergence in size of business (Groenewald, 1991).

In general, differences in efficiency might well be attributable not simply to differences in size but to a whole range of other factors which happen to be associated in different degrees with small and large farms.

The relationship between farm size and economic efficiency exists either because there are economies of scale in the physical production function of the farm or because relative prices are such that cost savings result from increasing size. Efficiency associated with physical economies of scale can be characterized as technical efficiency, while efficiency associated with adjusting factor use and output mix to relative prices can be characterized as price efficiency - allocative efficiency (Hall and Le Veen, 1978). Overall economic efficiency is, therefore, a function of both price and technical efficiency. In the following section, sources of economies of scale on farm operations are discussed.

2.1.4 Sources of Efficiency

Experience in agriculture as well as in manufacturing industry and retail distribution has frequently confirmed that average costs per unit produced or sold decline as fixed costs are spread over a greater output. This means that the small farm or firm with a limited output but with certain unavoidable costs, finds itself at a disadvantage (Britton and Hill, 1975:7). Fixed costs such as management, supervision, information and machinery can be spread over more units of output (Krause and Kyle, 1970), resulting in reductions in cost per unit of output (increasing returns to scale or size). Returns to scale are defined as the proportionate change in output when all inputs are increased in the same proportion (Hallam, 1991). The term "economies of size" is used to describe the fall in total cost per unit of production found on larger farms. The expressions returns to *scale* and *size* are used almost interchangeably by some economists (Stanton, 1978).

The concept of economic efficiency may be divided into two distinct components, technical efficiency and allocative efficiency.

Technical efficiency is an engineering concept which measures the efficiency with which a firm converts inputs into output. The firm that is able to convert a given quantity of inputs into a greater quantity of output, using scale-neutral technology, is said to be more technically efficient.

Allocative efficiency, on the other hand, is dependent upon economic principles based on profit maximization. If one considers the ratios of the Values of Marginal Product (VMP) of inputs to those inputs' prices, then a firm is said to be perfectly allocatively efficient (or price efficient) if all ratios are equal to one (i.e. $VMP_x / P_x = 1$, for all inputs x). In comparing a number of firms, the one with the ratios most nearly equal to one is relatively more price efficient.

2.1.5 Present Study Approaches

In this study the term "efficient farm" refers to a farm utilizing less resources than other farms to generate a given quantity of output. This superior performance is manifested in higher efficiency ratios (output per unit of input), and a lower cost per unit of production. Therefore, agricultural efficiency is measured through net farm income per hectare reflecting returns to management, rent earned on land and other fixed inputs. Britton and Hill (1975: 45) recommend that any study of relative efficiency of different sizes of farm business must impute values of factors of production where no cash payment is involved. They suggest two principal methods of arriving at imputed costs: (1) to use what is paid to similar factors of production in similar occupations where actual payments are made; and (2) to consider what the inputs in question could earn in their best-paid alternative employment (their transfer earnings or opportunity costs). Therefore, as suggested by Britton and Hill (1975: 50), in this study family labour price is imputed by costing operations performed by family labour based on what is paid to similar factors of production in similar occupations. As for input costs, they include farm variable costs.

2.2 Land Fragmentation Issue

2.2.1 Land Fragmentation and Efficiency

Research on land fragmentation often focuses on fragmentation as the source of many problems in the agricultural sector with fragmentation identified as the source of significant inefficiencies in agricultural production. Land fragmentation, farming two or more separate and perhaps widely scattered plots, is a characteristic of farms throughout the world . The 1970 Food and Agriculture Organization's *World Census of Agriculture* estimates that 80 per cent of the world's farmland is fragmented. This is based on fragmentation defined as farmers having two or more plots of land per operational holding.

The literature concerning land fragmentation may be divided into two broad categories, namely one that deals with fragmentation as it currently exists in the world and the other with fragmentation in Europe when lands were held in common or open fields (Scott, 1987). The two categories of literature treat land fragmentation with differing overall approaches and differing basic assumptions. Consequently, the conclusions analysts reach in each literature are divergent. For instance, the former treats land fragmentation as an important source of inefficiency in the agricultural sector while the latter emphasizes beneficial aspects of fragmentation.

The negative impact of fragmentation on the agricultural sector as a whole is stressed by several studies. The most often cited cause of fragmentation is that holdings are fragmented when farms are divided among heirs. Farmers inherit fragmented farms and inheritance laws ensure that, as the population density figures intimate, not only the amount of land per household falls, but it is increasingly fragmented into small plots, scattered over a wide area (Gebeyehu, 1995). Few studies omit inheritance as one of the key sources of land fragmentation. Jacoby (1961) in Malaysia, Lawrance (1963) in Uganda, Vanderpol (1956) in Netherlands, Nazeer (1985) in Pakistan and OECD (1969) in Turkey all cite equitable inheritance customs as the primary cause of land fragmentation. A second cause of fragmentation focuses on the settlement or expansion of farms. In contrast to the inheritance explanation, the settlement explanation is intuitively appealing and is supported to a degree by field studies and land surveys (Scott, 1987: 18). Mosher (1966) states that depending on local conditions, fragmentation is often a serious obstacle to agricultural development. In summarizing a number of works, Henning, as cited by Scott (1987:21), observes, "it is a commonplace description about African agriculture that fragmentation of holdings is the biggest single obstacle to better farming".

According to Scott (1987: 22), problems of land fragmentation discussed in the literature may be categorized into four categories:

Physical problems arising from scattered plots, with issues including the "wastage" of labour time and of land, fencing costs, added transportation costs to move materials between plots, and limited access to lands. Loss of labour time is due to the need to travel between plots of land. In the Nyeri District of Kenya's Central Province where farms average ten plots per holding, the average total distance from the farmstead visiting each plot and back is ten miles (Henning, as quoted by Scott (1987)). Of course, farmers may not need to visit each plot daily but several plots frequently will be visited in a day. Land wastage is based on the loss of land under boundary barriers and on land in corners and edges of plots which is not cultivated as effectively as interior space. The quantity of under-utilized land increases with the number of plots. For instance, using data from Jamaica, Igbozurike (1971) calculates a 5 per cent loss of productive space from fencing and footpaths between plots in comparing two 20 acre farms, one split in 11 parcels and one contiguous. Costs of enclosing plots with fences or other barriers rise with perimeter size which increases with the number of plots. Igbozurike (1971) in Jamaica found fencing costs for the fragmented farm to be 116 per cent greater than costs for the consolidated farm. Transportation costs rise due to extra movement between plots. Both the number of plots and inter-plot distances add to time and expenses consumed in transportation. Lastly, access to individual plots also may be impeded with fragmentation.

Problems in achieving operational efficiency on the farm, including problems associated with farm equipment, with farming techniques and systems, with management and supervision of production, with pest control, and with the abandonment of distant or small plots. Due to both the reduced size of individual parcels and their frequently irregular shapes, introduction of new farm machinery may be inhibited. Waller (1993) in Rwanda suggests that if land were consolidated into holdings of at least two hectares, it would be possible to introduce modern mechanized techniques that would increase overall productivity.

Problems in improving the land. Three types of land improvement raised in the literature are development of irrigation sources and systems, land drainage, and curtailment of soil erosion. Since each type of improvement requires a fixed investment cost for each parcel, the total investment cost for a farm of several plots will exceed that of improving an equivalent sized contiguous farm. This may dissuade farmers from improving some plots, if not the entire farm.

Problems external to the farm. This category of problems arising from land fragmentation are external to individual farmers. Most important are problems on the community or regional level such as in designing and developing road and irrigation systems when plots are scattered. Attempts to plan and coordinate aggregate crop and livestock production and development activities on regional and national levels are complicated. Production losses with fragmentation may have national trade of foreign exchange ramifications too.

Another problem arising from land fragmentation cited by Dahlman (1980:95) is the complication of keeping property rights to a multitude of scattered plots clearly defined. Dahlman found that court records of quarrels regarding plots of land are prolific. This indicates that losses may have been considerable due to time lost in such struggles and to uncertainty of ownership. The conclusion that analysts inevitably reach with this approach is that lands should be consolidated.

Among the benefits of land fragmentation found in the literature, the risk reduction theory has probably gained the most widespread acceptance (Scott, 1987). Fragmentation of holdings is used as a risk averting mechanism against the unpredictable impact of weather, pests, diseases and other natural calamities on crop yield (Gebeyehu, 1995). In addition, subsistence farmers can get access to varied soil types of different fertility status which enable them to grow a variety of crops.

A second benefit of land fragmentation focuses on labour market imperfections. Fenoaltea (1976) points out that fragmentation could increase output by increasing available labour. Farmers sought to get as much labour time as possible from family members before hiring outside workers because of the high information costs and incentive problems in labour market transactions. McCloskey, as cited by Scott (1987: 31), states that labour demand redistribution is possible due to land heterogeneity. The optimal timing of cultivation activities will differ on lands with different physical characteristics. Thus, farms composed of single contiguous plots will tend to have labour demand concentrated at one time. With family labour inputs only, insufficient labour may be available or the timing of labour inputs may be sub-optimal. However, with several plots which have different times of labour demand, family labour use can be extended without efficiency losses from poor timing. Thus, farmers may avoid the high cost labour markets by cultivating scattered plots.

A third benefit of land fragmentation that has gained recognition in the literature focuses on land needs in both crop production and livestock. According to Dahlam (1980: 125), land fragmentation was a means of enforcing participation in the common grazing of livestock while maintaining independent crop production. With farmers' lands merged, the costs of raising livestock independently would have been prohibitively high.

2.2.2 Land Fragmentation and Technology Adoption

Several studies argue that land fragmentation may play an important role in the adoption decision. Views are almost unanimous as to the negative impact of land fragmentation on technology adoption. Gebeyehu (1995) in Ethiopia reports the fragmentation and diminution of land as a result of continuous land distributions and growing population create a sense of insecurity among farmers, hence preventing them from making additional investments to increase production. The smallness of farms and plots has an adverse effect on technology adoption. Grigg (1966) describes how technical change bypassed farmers with scattered lands in 18th Century England. Adoption of the Norfolk system which incorporated crop rotation techniques, alternative cultivation practices, and new crop varieties was only feasible on consolidated farms. In fact, Grigg (1966) suggests that the relative losses were so great that access to new technologies was a principal motivation for voluntary land consolidation. Gebeyehu (1995) also points out that the fact that most of the conservation structures are space consuming and the relative size of plots is very small, the adoption of soil conservation structures is seen as a factor reducing the size of farms. As a result farmers were not willing to construct conservation structures on their plots.

Aside from the direct costs of more inputs needed in production, fragmentation may prevent farmers from operating with plots of optimal sizes and may slow the pace of technological innovation or investment (Scott, 1987: 24). These effects of fragmentation raise production costs indirectly in the sense that farmers fail to obtain potential benefits. For instance, fragmented farms may prevent some new cost reducing technologies from being adopted. In other words, by restricting the flexibility of farmers, fragmented lands constrain optimization in the operation of farms.

In this study, both the number of plots and inter-plot distances are considered in analyzing the impact of land fragmentation on economic efficiency and adoption of appropriate farm practices.

2.3 Adoption of Recommended Farm Practices

The adoption of technical innovations by agricultural producers is an essential prerequisite for the economic prosperity of developing countries. This section provides a profile on measures of adoption rates among Rwandan coffee farmers studied. Adoption of improved technologies and farming practices has for many years been a major contributing factor to agricultural productivity growth achieved in developing countries (Manning, cited by Rauniyar, 1990). Improved technologies may be packaged in, for example, seeds, pesticides, fertilizers, equipment or resource-management schemes (Welch, 1978:263). The potential for increasing farm output through appropriate farming practices indirectly relates to farmers' managerial qualities (Kalirajan and Shand, 1988). If this relationship holds true, it is important to the on-going effort to transform Rwandan agriculture that farmers become more proficient, and that relatively more proficient farmers increasingly manage Rwanda's scarce agricultural land resources.

2.3.1 Assessments of Technology Adoption

In this study, soil testing to determine the suitability of regions for the coffee crop, and the adoption of fertilizer, are used to measure adoption of improved farm practices among coffee producers. The adoption of the two farm practices (soil analysis and use of fertilizer) is also used to reflect on the ability of individual coffee farmers. Coffee is an efficient user of a combination of nitrogen (N), phosphorus (P) and potassium (K), known as NPK 20-10-10, and its timing and placement is critical for the production of high yields of coffee. This necessitates soil analysis to determine application rates (MINAGRI and OCIR, 1998). In general, coffee grows well and gives a sufficient production in regions with soils' acidity levels (pH) between 4.5 and 6, and soils which are fertile, friable, and quite permeable (Kavamahanga, 1987; Coste, 1989). Temperature and rainfall are other important factors which govern the regional adaptability of the coffee (Altitude: between 1400 and 1900 meters; Rainfall: between 1500 and 1600 mm; and Temperature: between 18 and 22 ^{0}C) (Kavamahanga, 1987; Coste, 1989).

2.3.2 Factors Influencing Technology Adoption

(a) Farm size

Land is an important asset in the farming business and a major source of wealth of the farm operator. Farm size is one of the first factors on which the empirical adoption literature focuses. Feder *et al.* (1985) report that farm size is a substitute for a large number of important factors such as access to credit, information, inputs, capacity to bear risk and the wealth of a farmer which are likely to influence adoption behaviour. As the influence of these factors varies in different areas and over time, so does the relationship between farm size and adoption. Therefore, large farmers may tend to adopt quickly due to the proxy factors rather than to the large farm size per se. Empirical evidence from the former KwaZulu homeland in South Africa, suggests that both the adoption of farm technology and the production of surpluses are positively correlated with farm size and renting or borrowing of land (Kleynhans and Lyne, 1984; Nieuwoudt and Vink, 1989; Thomson and Lyne, 1991). Welch (1978) states that large farm sizes enhance technology adoption because management and information costs are fixed but returns to information and technology are proportional to scale.

On the other hand, an inverse relationship between farm size and the adoption of modern inputs is reported by several researchers. The rationale for this argument is that small-scale farmers may farm more intensively to meet subsistence needs. Byiringiro and Reardon (1996) in Rwanda reported a strong inverse relationship between farm size and land productivity, and the opposite for labour productivity. Feder *et al.* (1985) report that small farmers have been observed to irrigate more efficiently and to use more low-cost family labour. Norman *et al.* (1982) in Nigeria and Nkonya *et al.* (1997) in Tanzania reported a negative correlation between farm size and the rate of nitrogen fertilizer applied. The alleged reason was that farmers with more land tended to grow their crops on more fertile lands and fallowed areas with less natural fertility (i.e., when land is not constrained, a positive relationship might hold). Perhaps the inverse relationship between technology adoption and farm size is attributed to the fact that government reduced private fixed transaction costs by providing information, credit and extension. Or else there are special resources (such as irrigation, cheap labour, and subsidies) at the disposal of small scale farmers. Otherwise, very small farm sizes tend to preclude scale economies and limit potential returns to innovation and higher product prices (Nieuwoudt and Vink, 1989; Lyne and Niewoudt, 1991).

Ruttan and Binswanger, cited by Ruthenberg (1985: 51), state that although differential rates of adoption by farm size and tenure have been observed, available data show that within a short time of a technological introduction, lags in adoption rates associate with farm size or tenure have typically disappeared. On the basis of evidence obtained from the Indian Punjab and rice farms in Phillippines, they conclude that no serious adoption differences have caused any significant yield differences between small and large farmers.

(b) Information Factors

Factors such extension support and other sources of information are hypothesized as influencing farmers' technology adoption decisions. Feder and Slade (1984) reported that improved knowledge regarding a new technology through the accumulation of a stock of information over time is hypothesized to be one of the main dynamic elements of the technology adoption process.

Basabrain (1983) reports that the level of knowledge about the innovation, extension contact and contact with other sources of information influence adoption of innovations. Kislev and Shchori-Bacharch (1973) more explicitly argue that the production function associated with new technology incorporates an efficiency factor which is positively related to the level of knowledge. Hiebert (1974) states that an adoption decision is a decision made under uncertainty, where the farm operators have different and incomplete information about the new techniques and hence are uncertain about the techniques. As the adoption process proceeds, farm operators obtain additional information which reduces uncertainty and the possibility of making allocation mistakes. Skills which enable the recipient to "decode" information are thus shown to increase the likelihood of adoption. Farmers who are visited regularly by extension agents adopt faster because they attain the critical level of knowledge (Feder and Slade, 1984). Moor and Nieuwoudt (1998) found that access to extension and training positively influenced yield (total output). This suggests that better informed farmers are more likely to make yield-enhancing management decisions. Farmers with better access to information have higher levels of cumulative information, and will therefore adopt earlier than other farmers, *ceteris paribus* (Feder and Slade, 1984).

In the coffee industry, farmers have access to several sources of farm information. These include; (i) economic advisors from the Rwandan coffee authority (OCIR), (ii) experiment research station, (iii) field extension officers, (iv) farmer participation in field day-demonstrations and practical training workshops in coffee growing, (v) interaction with other farmers, and (vi) the use of farm magazines.

(c) Human Capital

Human capital abilities of farm operators are considered as important in influencing the adoption of improved farming practices among coffee farmers. Human capital is the cumulative knowledge acquired in the form of informal or formal education, and experience. Farmer education plays an important role in influencing the rate at which farmers adopt improved production processes or techniques (Brien *et al.,* 1965; Jamison and Lau, 1982; Feder *et al.,* 1985; Strauss *et al.,* 1991). Better educated farmers can assimilate and interpret information at lower costs than less educated farmers. Welch (1978) contends that education reduces costs of information and improves allocation efficiency, while demand for education increases with farm size as returns to education are scale proportional (large scale implies broader scope for applying information). Feder and Slade (1984), Sanders *et al.* (1996), Chilot *et al.* (1996), Nkonya *et al.* (1997) and Hassan (1998) have found that better formal education, concrete experience, and exposure to extension services are important sources of information gathering in that they contribute to comprehensive knowledge about the innovation and thereby stimulate technology adoption. Feder *et al.* (1985) report that educated farmers adjust to input price change, their input levels approach optimal levels faster, and they apply modern inputs efficiently. This suggests that more educated farmers are early adopters.

(d) Economic Status

Economic status of farm operators has an important influence on adoption behaviour (Feder *et al.,* cited by Wheeler, 1989). Voh and Monu, cited by Wheeler (1989), reported that economic status referred to as "level of living" has positively affected the adoption of a technology. It is hypothesized that healthy economic status will result in an increased capacity to bear the potential risk associated with the new technology and in this way will stimulate adoption. It is also more likely that wealthier farmers are able to finance the cost of a new technology. Off-farm activities provide finance for implementing and maintaining the new technology whereas an asset base (herd size or any other asset) represents an increased capacity to take risk. Savadogo *et al.*, and Adesina, cited by Adesina *et al.* (2000), have shown that non-farm income positively influences adoption of technologies. This is because having non-farm income may allow farmers to meet capital costs, and may also reduce adverse consequences of risks in experimenting with new technologies.

(e) Personal Characteristics

Personal characteristics of farm operators are considered as important in influencing the adoption of improved farming practices among coffee farmers. The gender of the farm operator is hypothesized as influencing the decision to adopt a given technology. Women have the problems of legal ownership of land (in case they have ownership, it is biased in favour of men), low social status and cultural barriers, and lack of education (Lipton and Longhrust, 1989: 338) A MINAGRI/PNUD (1996) report has shown that social customs in Rwanda tend to discriminate against women, reducing their access to information and new technologies. Similarly, Delgado (1997) reports that although most women and men have land use rights, women unlike men are not directly involved in the allocation of use rights. The tenure insecurity of women reduces their incentive to invest in time and resources, and adopt more sustainable practices. He also states that women face higher transaction costs (i.e., a market and information), receive less education than men, face mobility restrictions and less credit accessibility, which in turn may have implications for their adoption of new technologies. Abdulkadir (1992) in Kenya found that since female households are more attached to and rely on the land, and receive less income and support from non-farm sources, they would be more inclined to adopt farming practices to safeguard their farm, which is their main source of livelihood. Similarly, Hassan (1998) claims that female headed households are expected to place more emphasis on the post harvest qualities of new varieties than men do, because women usually perform post harvest operations.

As for age of the farm operator, empirical evidence indicates a positive, negative or no relationship between age and the adoption of farm practices (Basabrain, 1983). Considering attitude towards risk, older farmers may be more conservative or resistant to change than younger ones. Celis *et al.* (1991:196) report a negative relationship between the age of household head and modern technology. Bagi, Gould *et al.*, and Polson and Spencer, as quoted by Adesina *et al.* (2000), have shown that younger farmers tend to be more innovative because of their long-term planning horizons and lower risk aversion. On the other hand, age may, however, mean that a farmer has accumulated enough information through longer experience and experimentation, and hence age is thought to increase the likelihood of adopting a new technology (Hassan, 1998). Matungul *et al.* (2001) similarly reported that older and more experienced household heads tend to have more contacts, face lower transaction costs and use more marketing channels. Nkonya *et al.* (1997) report that farmer age does not significantly influence the adoption of improved maize seed and nitrogen fertilizer in Tanzania.

(f) Tenure Issues

Several studies argue that tenure issues may play an important role in the adoption decision. A review of literature, however, suggests that views are not unanimous and the subject is one of considerable controversy, due to the fact that the relationship of tenure and adoption are in accordance with the unsettled debate in the theoretical literature about the relationship between tenancy and adoption (Feder *et al.,* 1985).

In general, as hypothesized by Place and Hazell (1993), farmers are more likely to improve parcels over which they have a long-term interest, both in terms of their rights to cultivate the land on a continuous basis and to dispose of the land in ways that provide adequate compensation for the value of any improvements. Hayes *et al.* (1997) in Gambia, and Moor and Nieuwoudt (1998) in Zimbabwe report that tenure security positively enhances long-term investments, the planting of trees on plots and the application of higher levels of inputs. It is contended that the increasing individualization of land rights (i.e., rights to sale and the use rights it implies) even under customary tenure is associated with a higher propensity to make investments, which in turn has a positive effect on yields. Place and Hazell (1993) report that tenure security directly affects variable input use because of improved access to cheaper institutional credit. Feder *et al.* (1988) and Barrows and Roth (1990) argue that more secure property rights increase credit use by providing greater incentives for investment and enhance collateral value of land; promote more land transactions due to contract certainty and lower transaction costs; lead to less land disputes and increase agricultural output. Kille (1993) reports that on-farm investment and farm productivity are determined by exclusive and secure property rights.

Issues of previous empirical analyses must be jointly viewed with description of variables and methods to facilitate specification of a research methodology that is both feasible and appropriate. Consequently, the analysis in the next chapter proceeds to consider the description of variables and research method.

CHAPTER 3

DESCRIPTION OF VARIABLES AND RESEARCH METHOD

This chapter specifies econometric models for the analysis of factors affecting both the economic efficiency and technology adoption models. Section 3.1.1 presents a short justification of the dependent variables while the hypotheses about independent variables are presented in section 3.1.2. Section 3.2 outlines a survey which includes a description of study areas, data collection and sampling techniques. Section 3.3 provides the research methodology adopted in this study, which includes the analytical techniques such as two-stage least squares (2SLS), ridge regression (RR), linear discriminant analysis (LDA) and principal component analysis (PCA).

3.1 Selection of Variables

Selection of the explanatory variables is based on the extensive literature review done in chapter two of this study. The results of previous economic efficiency studies of small-scale farmers in Rwanda as well as outside Rwanda were considered. The first section of the present chapter describes the dependent variables followed by explanatory variables influencing both the economic efficiency and technology adoption models.

3.1.1 Dependent Variables

3.1.1.1 Net Farm Income per Hectare

Net farm income per hectare is a continuous dependent variable reflecting returns to management, rent earned on land and other fixed inputs and was specified to reflect greater economic efficiency.

3.1.1.2 Adoption of Recommended Farm Practices

This is a dichotomous dependent variable indicating whether a farm operator adopted soil testing and used fertilizer. Two dummy variables were specified to account for individual adoption decisions when adopting soil testing and use of fertilizer. Firstly, soil testing on coffee farms was measured as a dichotomous variable, equal to one if the practice is adopted, and zero otherwise. Secondly, use of fertilizer on coffee farms was measured as a dichotomous variable, equal to one if the practice is adopted, otherwise zero. In the latter case, the adopters of a single practice (i.e., either soil testing or fertilizer) are excluded from the analysis. On the basis of the decision to adopt soil testing and use fertilizer as a measure of farmer adoption abilities, sample households can be classified as:

Non- adopters : Farm operators who did not have soils tested or did not use fertilizer;

Partial- adopters : Farm operators who either adopted soil testing or used fertilizer;

Full- adopters : Farm operators who used both practices simultaneously.

3.1.2 Explanatory Variables

This section describes the selected socio-economic variables influencing the economic efficiency model and affecting the adoption of improved farm practices. The explanatory variables could be classified as either quantitative or qualitative, depending on the method of approaching or measuring a variable. For example, a variable describing access to training can be specified by the number of training workshops attended in two years or whether or not a farm operator has received practical training. The following explanatory variables were used as predictors contributing to the economic efficiency model and adoption of improved farm practices.

3.1.2.1. Quantitative Variables

These variables take a numerical value in a real interval when measured accurately (Ramanathan, as cited by Nell, 1998). They include the farming experience and education of the farm operator; farm size; number of plots cultivated; distance between parcels; non-farm income; monetary value of livestock and number of training workshops attended.

3.1.2.2. Qualitative Variables

These variables may take a numerical value one or zero and are often called nominal or categorical variables. They are the agricultural training status of the farm operator, tenure certainty and the gender of the household head. Qualitative variables may also take a numerical value of zero, one, two and more and are scores created by summing one or more dummy variables. They are scores for the use of extension and other farm information sources.

Table 3.1 Variable definitions and measurements

Farm size	(FMS) :	Hectares
Area under coffee	(ACO) :	Hectares
Gender	(GDR) :	Dichotomous (1,0) one for male, zero otherwise
Education	(EDU) :	Scale ranging from zero to three to symbolize; no education, grade 6 and below, grade 7 to grade 12 (matric), and tertiary education, respectively.
Farming occupation	(OCU) :	Dichotomous (1,0) one for full-time, zero otherwise
Soil analysis	(SOIL) :	Dichotomous (1,0) one if farm operator ever had farm soils tested, zero otherwise
Use of fertilizer	(FERT) :	Dichotomous (1,0) one if fertilizer is used, zero otherwise
Training	(TRG) :	Dichotomous (1,0) one for training, zero otherwise
Workshops attended in two years	(WSP) :	Continuous number
Field extension officer visits	(VST) :	Scale ranging from zero to four (i.e., none, 1-3 times, 4-6 times, 7-9 times, and 10+ times, respectively)
Assessment of farm information sources	(INFO) :	Likert-type scale ranging from zero to three representing rankings; not useful, less useful, useful, and very useful; respectively:
(1) Economic advisors (ECA) (2) Experiment stations (ERS) (3) Field extension officers (EXO) (4) Field demonstrations (FLD) (5) Other farmers (OTF) (6) Farm magazines (FMG)		

3.2 The Survey

3.2.1 Description of the Study Area

The study area chosen for this research was Butare province[1], Southern Rwanda. Butare is located about 148 kilometers South of Kigali (the capital city). It covers an area of 1690 square kilometers. It has a population of approximately 627,000 inhabitants (MINECOFIN-ONAPO, 1998). As Rwandan farm operator activities were homogeneous the investigation was limited to two districts, Rusatira and Muyira. These districts are respectively 97 and 135 square kilometers in extent and have respective population densities of 289 and 255 inhabitants per square kilometer (Figure 3.1). The annual population growth rate is estimated at 3.1 per cent (MINECOFIN-ONAPO, 1998). Four sectors were chosen as survey sites in each district. Rusatira, Kinazi, Kabona and Buremera were chosen from Rusatira district and Matara, Mulinja, Kibirizi and Mbuye from Muyira district. These study areas were chosen because they have the highest population densities in the central plateau.

Geographically the two districts are similar. They have similar climates. Temperatures vary little, ranging from 18 ^{0}C to 24 ^{0}C. Annual rainfall averages between 1500 mm and 2000 mm and is well distributed throughout the year. Both districts have a mountainous landscape, with altitude ranging from 1400 m to 2000 m above sea level but differ in that Muyira is a planned district whereas Rusatira is not, which accounts for farms being on average larger in Muyira (3.30 hectares) than Rusatira (1.50 hectares).

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[1]The Rwandan local administration comprises four levels: Province - District - Sector - Cell.
The sector population is generally several thousands, while the cell population is around several hundreds

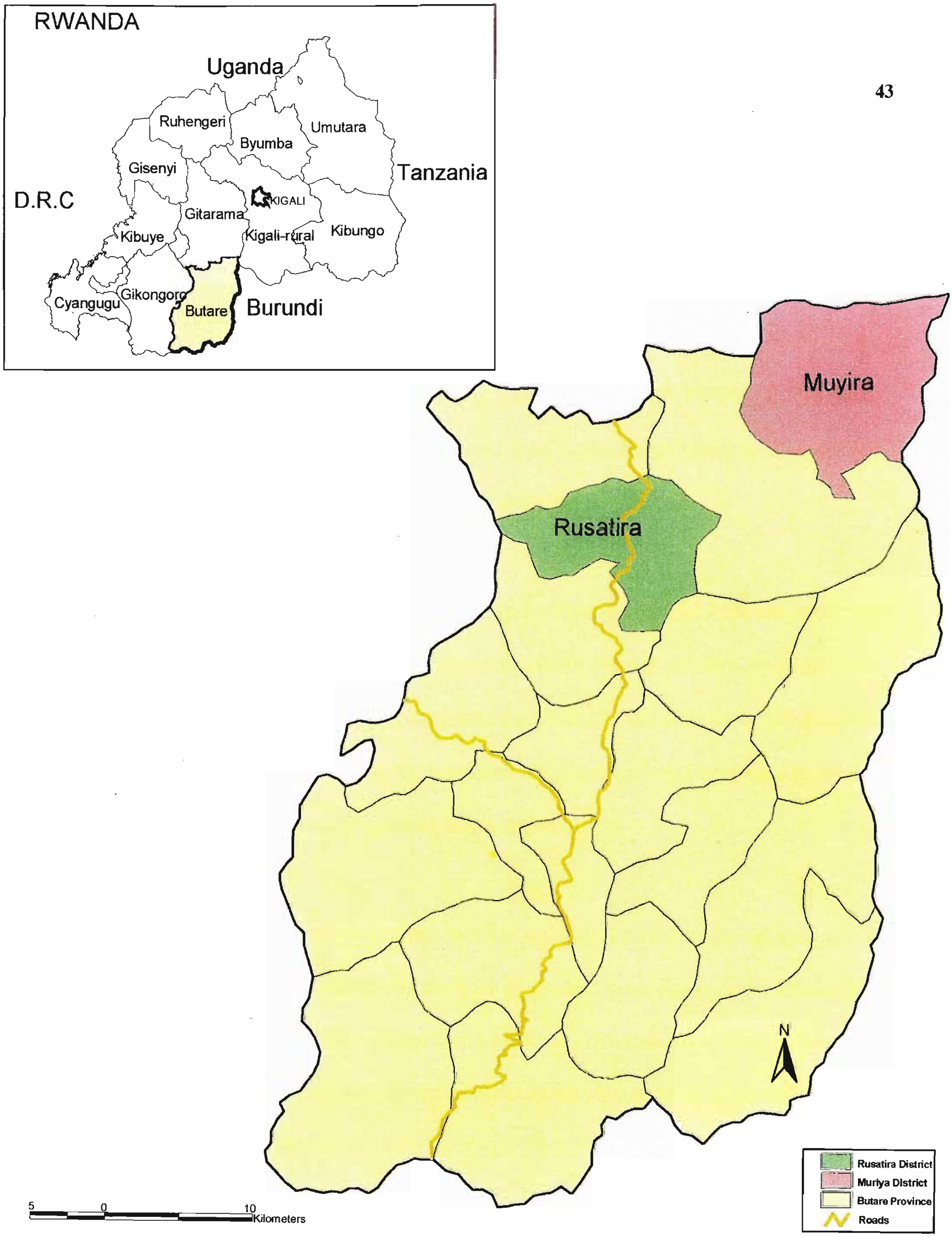

Figure 3.1 Map showing the location of Study Area in Butare.

3.2.2 Sampling Procedure and Data Collection

The main objective of this study was to collect socioeconomic data that will be useful for understanding the environment for rural farming. This study was based on primary and secondary data sources. The primary data were collected by the author using a standardized questionnaire that consisted of both pre-coded and open ended questions (Appendix F). The secondary data were obtained from various sources such as; records of Agricultural Offices in the respective study areas, published official statistics, official reports, books and maps.

The collection of data was performed in two ways: the author and trained field assistants held interviews with respondents using the standardized questionnaire. Field observations were made and open discussions were held with farm operators both individually and collectively as well as with agricultural officials on issues such as the magnitude of agricultural land fragmentation, average costs per unit of production and degrees of technology adoption.

The survey collected information on farm operator and farm business characteristics, and in particular details of coffee production on these farms. Questions were designed to be answered by household heads who typically manage farm operations in Rwanda. In addition to the survey of households, some questions were posed to agricultural officials in order to obtain data at regional and national levels.

Data for this research were collected from December 2000 to February 2001 from one hundred randomly selected households in each of Rusatira and Muyira districts. The sample was selected at random from a population list provided by extension officers in the two study areas.

3.3 Data Analysis

The SPSS (1995) computer software was used for data processing in order to determine farm operator characteristics and possible predictors and to identify the influential variables of the specified dependent variables in the various models used. All variables were tested using the Pearson correlations test. Other techniques such as Condition Index and Variance Inflation Factors were also used to detect multicollinearity between variables.

The explanatory (independent) variables hypothesized to influence the economic efficiency model and the adoption of appropriate farming practices were placed in two categories, continuous and categorical. The identified possible predictors for each specified dependent variable (economic efficiency and adoption models) were included in the most adequate discrete choice model. Those variables were tested for statistically significant differences between study areas, using one of the following statistical tests depending on their type and distribution as described by Siegal (1956):

The **t-test** to determine significant differences between two continuous variables with normal distributions;

The **Mann-Whitney test** to determine significant differences between two continuous variables with skewed distributions;

The **Chi-square test** in the analysis of categorical variables with larger frequencies.

3.3.1 Analytical Techniques

A set of four techniques was used to analyze the survey data. Two-Stage Least Squares (2SLS) was employed to produce consistent estimates of parameters when one or more predictor variables might be correlated with the disturbance. Ridge Regression (RR) was used as a remedy for the multicollinearity problem from the explanatory variables. Linear Discriminant Analysis (LDA) was used to identify factors that influence the different degrees of adoption of appropriate farming practices among coffee farmers. Principal Component Analysis (PCA) was used to condense the variables into fewer orthogonal variables.

3.3.1.1 Two-Stage Least Squares Analysis

Two-Stage Least Squares (2SLS) is an important regression technique for models in which one (or more) of the predictor variables is thought to be correlated with the error term. The 2SLS strategy is to replace the troublesome endogenous predictor variables with similar variables that are almost as good as the first ones at predicting the endogenous variable and are not correlated with the theoretical error term in the prediction of the endogenous variable (Norušis, 1990c: 238). A replacement variable is obtained by ordinary regression, using the instruments to predict the endogenous variable. Instrumental variables, or simply instruments, are variables that are not influenced by other variables in the model but that do influence those variables (Norušis, 1990c: 237). To be effective, instruments should be highly correlated with the endogenous variables and not correlated with the error terms. With these two instruments' properties, the predicted value of the endogenous variable will be a good predictor of the dependent variable and uncorrelated with the error term for the dependent variable.

3.3.1.2 Ridge Regression

Ridge Regression (RR) is one of several methods that have been proposed to remedy multicollinearity problems by modifying the method of least squares to allow biased estimators of the regression coefficients. When an estimator has only a small bias and is substantially more precise than an unbiased estimator, it may well be the preferred estimator, since it will have a larger probability of being close to the true parameter (Neter *et al.*, 1996: 411). Figure 3.2 shows that estimator **b** is imprecise, whereas estimator $\mathbf{b}^R$ is much more precise but has a small bias. The probability that $\mathbf{b}^R$ falls near the true value of β is much greater than for the unbiased estimator **b**.

The ridge standardized regression estimators are obtained by introducing into the least squares normal equations a biasing constant $K \geq 0$ as shown in Appendix D. The constant K reflects the magnitude of bias in the estimators and usually varies between 0 and 1. When $K > 0$, the ridge regression coefficients are biased but tend to be more stable than ordinary least squares estimators (Neter *et al.*, 1996:412). The bias component of the total mean squared error (MSE) of the RR estimator $\mathbf{b}^R$ increases as K gets larger (with all $\mathbf{b}_k^R$ tending toward zero) while the variance component becomes smaller. There always exists some value of K for which the RR estimator $\mathbf{b}^R$ has a smaller total MSE than the ordinary least squares estimator **b**.

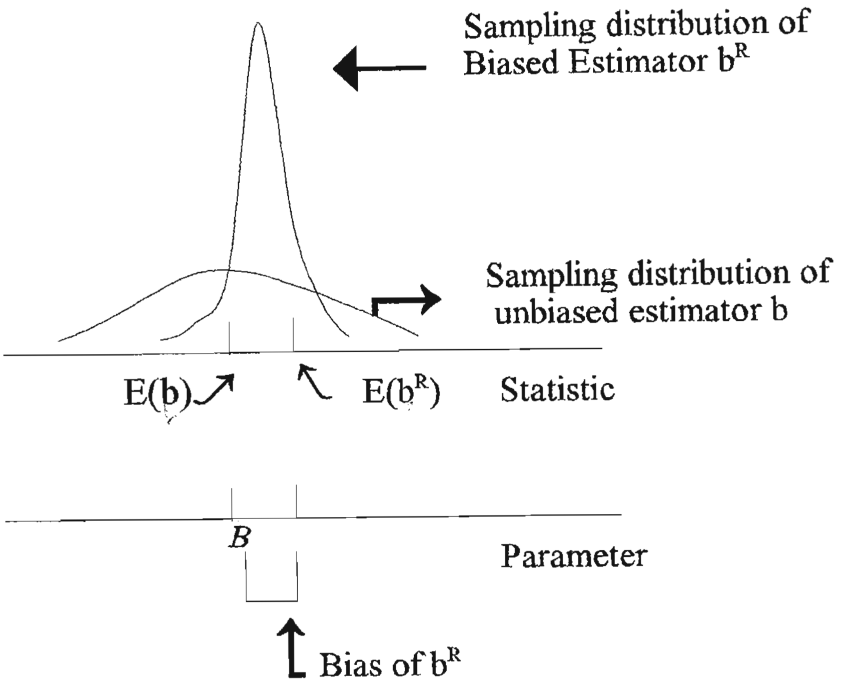

Figure 3.2 Biased estimator with small variance may be preferable to unbiased estimator with large variance.

A commonly used method of determining the optimal biasing constant K is based on the *ridge trace* and the *variance inflation factors* (VIF) as presented in Appendix E. The former is a simultaneous plot of the values of the p-1 estimated ridge standardized regression coefficients for the different values of K while the latter are the diagonal elements of the inverse of the simple correlation matrix for dependent variables. Therefore, by examining the ridge trace and VIF values, the smallest value of K will be chosen where the regression coefficients first become stable in the ridge trace and the VIF values become sufficiently small. In this study the appropriate biasing constant and hence the final model RR coefficients were derived by examining the ridge trace and VIF, using SPSS and Mathematica computer software programmes, respectively.

3.3.1.3 Linear Discriminant Analysis

Linear Discriminant Analysis (LDA) was used to identify factors that influence the different degrees of adoption of appropriate farming practices among coffee farmers. Discriminant analysis attempts to separate two or more groups of individuals, given measurements for the individuals on several variables (Manly, 1994: 107). The objective of linear discriminant analysis is to find a linear function that distinguishes between groups using discriminant variables which measure characteristics on which the groups are expected to differ. The discriminant function includes *n* variables, X_1, ..., X_n, that will separate the two groups as well as possible. The method employed in group separation is canonical variate analysis (Manly, 1994: 109). This is conducted by an analysis of variance which maximizes the between-group variance, while minimizing the within-group variance. The LDA model takes the form:

$$D_i = \sum_{j=1}^{n} B_j X_{ij} \qquad \textbf{(3.1)}$$

The standardized weighting coefficient estimates ($\boldsymbol{B_j}$) are particularly important for policy analysis, since each shows the relative contribution of its associated variable ($\boldsymbol{X_j}$) to the linear function. Discriminant scores $\boldsymbol{D_i}$ estimated for each group are compared to the mean score for each classified group and group membership is classified into the group with the score most similar to his own. Success in discrimination between groups is assessed by observing the proportion of correct group classifications and the Wilk's Lambda statistics (Klecka, 1980: 38). Wilk's Lambda is an inverse likelihood measure of the discriminating power of the variables. Thus, the smaller the value of Wilk's Lambda, the better is the discriminating power of the variables.

3.3.1.4 Principal Component Analysis

Principal Component Analysis (PCA) was used to condense the variables into fewer orthogonal variables. Perfectly correlated variables cannot be used in a discriminant function at the same time (Klecka, 1980: 9). The lack of correlation between explanatory variables is a useful property because it means that the indices are measuring different "dimensions" in the data (Manly, 1986: 59). PCs can then be substituted instead of the original **(x)** variables in the derivation of a discriminant rule, thus reducing the dimensionality problem (Jolliffe, 1986: 157).

Variables studied were measured on varying scales, hence components were derived from the correlation matrix. Each variable is initially standardized to have a zero mean and unit variance. This caters for the differences in scales, and avoids any undue influence of scales on the components (Manly,1986: 63). The object of component factor analysis, therefore, is to economize on the number of explanatory variables $X_1, X_2, ..., X_p$ (Crabtree, 1971; Nieuwoudt, 1977; Manly, 1986: 58) by seeking linear transformations of the type:

$$PC_{ij} = \alpha_{1j} X_{i1} + \alpha_{2j} X_{i2} + \alpha_{3j} X_{i3} + \dots\dots\dots\dots + \alpha_{pj} X_{ip} \qquad \textbf{(3.2)}$$

In this approach new uncorrelated indices (components) PC_{ij} are constructed that explain as much of the variance in the original data as possible, in descending order. The *first* principal component is a linear function of highly correlated variables which accounts for the greatest possible part of total variance in the data (Ehrenberg, 1982: 207). The coefficient (α_{pj}) indicates the relative importance of each variable in the component.

This description of variables and methods must be jointly considered with socio-economic characteristics of the sample households to better understand and draw implications about the potential of developing the agricultural sector. This is likely to have important implications both for the individual farm and for the national economy.

CHAPTER 4

SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS

The objective of this chapter is to provide a context in which to understand and draw implications about the potential of developing the agricultural sector in the study area. A single variable test (i.e., t, Mann-Whitney and Chi-square) of mean difference (Siegal, 1956) of selected characteristics in the study area is presented hereafter.

4.1 Household Characteristics

Households characteristics illustrating a demographic profile of respondents in the sample are presented in Table 4.1. Table 4.2 illustrates characteristics specific to land use and performance indicators in the two study areas. Table 4.3 shows adoption rates of improved farm practices, and evaluation of farm information by farm operators in the two study areas. Table 4.4 illustrates land tenure and rights, while Table 4.5 shows prevalence of land rights in the study areas.

4.1.1 Demographic Characteristics

Table 4.1 compares personal and demographic characteristics between study areas. The farm operators in Muyira appear to be younger (44 years) compared to 52 years for Rusatira. With regards to gender of the household head, there is a difference between the two areas, with Muyira recording 79 per cent male heads of household, compared to 71 per cent for Rusatira. Gender was captured as a dichotomous variable, 1 for male head and 0 otherwise. With regards to formal education[1], there is a difference between the two areas, with Muyira recording an education level of above grade 7, compared to grade 6 and below in Rusatira. Data on farmers' education were captured using the scale ranging from zero to three to symbolize; no education, grade 6 and below, grade 7 to grade 12 (matric), and tertiary education, respectively. Such categorization in the different levels of education had to be followed due to difficulties experienced by respondents in stating the exact number of years taken to attain a certain standard of education. A difference in the mean years of farming experience between farm operators in Muyira and Rusatira was observed (with 20 years for Muyira compared to 24 years for Rusatira). The mean size of sample households for Muyira was 4.5 members, while Rusatira had an average size of 5.0 members.

Table 4.1 Mean difference in farmers' personal and demographic characteristics in Rusatira and Muyira, 2001

Characteristics	Rusatira (n=100)	Muyira (n=100)	Significance
Age (years)	52	44	.000[2]
Gender (% male)	71	79	.000[3]
Education	0.8	1.3	.000[2]
Farming Experience (years)	24	20	.006[1]
Household Size (people)	5.0	4.5	.053[1]
Full-time Farming (%)	85	76	.000[3]
Training	0.60	0.92	.000[3]
Training workshops attended in two years	1.72	3.52	.000[2]

where [1] t-Test, [2] Mann-Whitney Test, [3] Chi-square Test. Figures in parenthesis represent valid cases.

[1] In Rwanda, formal education comprises six years for primary school, six years for secondary school, and four to five years for University.

Farming is a full-time occupation to 76 per cent of farm operators in Muyira with 92 per cent having received practical training in coffee growing, attending over three training sessions on average in two years. Eighty five per cent of farmers in Rusatira are full-time farmers, and 60 per cent have been trained in coffee growing with an attendance rate of one training session on average in two years.

4.2 Land Use and Performance Indicators

From Table 4.2 significant differences in the means of selected land use characteristics and performance indicators are visible between the study areas. Average area operated is 1.5 hectares and 3.3 hectares for Rusatira and Muyira [2], respectively. The ratio of rented land is relatively higher in Rusatira with 17.6 per cent, compared to 12.2 per cent in Muyira. However, the difference is not significant but demonstrates that the proportion of land rented falls with increase in size of farm operated. This is evidence on the other hand that land transactions take place in both districts, an indication that the sample was drawn from farm operators possessing secure land tenure rights. Muyira has a relatively high percentage of land under coffee, utilizing 37.2 per cent of operated land as compared to the 33.9 per cent in Rusatira. Coffee production contributed about 75 per cent of gross total farm income in both Rusatira and Muyira. Even if no significant difference in the average coffee income per gross farm income between the two study areas was recorded, this shows that coffee growing is the most important farm activity on farms studied in both areas. Average number of plots cultivated - characteristic of land fragmentation - is 3.1 and 1.8 for Rusatira and Muyira, respectively. The geographic dispersion of land parcels, another dimension of land fragmentation, is here operationalized as the total

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[2] The relatively high average farm size reported in the study areas may be attributed to the fact that most of the sample farmers operated on lands belonging to relatives who died during the 1994 genocide.

"distance" (in kilometers) between each parcel cultivated and the household residence. The average distance traveled varied from 1.35 kms for Rusatira to 0.95 kms for Muyira.

Table 4.2 Mean difference in land use and performance indicators between Rusatira and Muyira, 2001

Land Use	Rusatira (n=100)	Muyira (n=100)	Significance
Farm size (Ha)	1.5	3.3	.000[1]
Rented land per total area operated (%)	17.6	12.2	.270[2]
% of area under coffee	33.9	37.2	.059[1]
Coffee income per gross farm income (%)	75.4	75.0	.246[2]
Number of plots cultivated	3.1	1.8	.000[2]
Distance between parcels (km)	1.35	0.95	.000[2]
Performance Indicators			
Average Yield of coffee (Tons/Ha)	0.54	0.69	.000[2]
Net Income (RWF/Ha)[(i)]	1728	3808	.000[2]
Input costs (RWF/Ha)[(ii)]	525	456	.000[2]
Labour costs (RWF/Ha)[(iii)]	1358	1385	.808[2]

where [1] t-Test, [2] Mann-Whitney Test. RWF denotes Rwandan Franc (During January 2001, 1ZAR = 52.5RWF) [(i)] Net income reflects returns to management, rent earned on land and other fixed inputs. [(ii)] Includes farm variable costs. [(iii)] Includes family and hired labour costs. Figures in parenthesis represent valid cases.

With regards to measures of economic performance considered, the average yield of coffee on farms in the two study areas was relatively lower in Rusatira (0.54 tons/ha), compared to Muyira (0.69 tons/ha). Net farm income per hectare is substantially higher in Muyira (3808 RWF) compared to Rusatira (1728 RWF). Input costs per hectare are lower in Muyira (456 RWF), compared to Rusatira (525 RWF). Quantity discounts on bulk purchase of inputs like fertilizers and herbicides may explain the lower input costs per hectare on the larger-scale farms.

No significant difference in labour costs per hectare between the two study areas was recorded. Labour costs per hectare (including family labour costs) were found to be 1358 RWF in Rusatira and 1385 RWF in Muyira.

4.3 Technology Adoption and Evaluation of Farm Information

Table 4.3 shows significant differences in mean adoption rates of improved farm practices, and evaluation of farm information sources between the study areas. Data on farm information sources available in the Rwandan coffee industry were captured on a Likert-type scale ranging from zero to three representing rankings; not useful, less useful, useful, and very useful, respectively, indicating the farm operators' assessment of the usefulness of farm information sources (Table 3.1). This reflects the relevance of issues discussed when farm operators seek external extension assistance (Zinnah *et al.,* 1993). Information (INFO) is the average score of the ratings for all the farm information source data.

Visit by field extension officer (VST) is an index ranging from zero to four (i.e., none, 1-3 times, 4-6 times, 7-9 times, and 10 + times, respectively) positively related to the number of field extension officer visits received by the farm operator in the last two seasons. The categories of the variable VST were determined after a means test showed significant changes in adoption of farm practices and farm visits by extension officers at the above intervals.

Table 4.3 **Mean difference in technology adoption and farmer's evaluation of sources of farm information in Rusatira and Muyira, 2001**

Farm Practice		**Rusatira (n=94)**	**Muyira (n=89)**	**Significance**
Adoption of soil analysis	(SOIL)	0.16	0.5	.000[3]
Adoption of fertilizer	(FERT)	0.15	0.62	.001[3]
Adoption of farm practices	(ADOPT)[(i)]	0.31	1.12	.000[3]
Farm Information Sources		**Rusatira (n=100)**	**Muyira (n=100)**	**Significance**
Field extension visits	(VST)	1.01	2.25	.000[1]
Economic advisors	(ECA)	0.32	1.15	.000[2]
Experiment station	(ERS)	0.46	0.93	.001[2]
Field extension officer	(EXO)	1.49	1.58	.511[1]
Field demonstration	(FLD)	0.65	0.98	.027[2]
Other farmers	(OTF)	1.37	1.2	.261[1]
Farm magazines	(FMG)	0.08	0.62	.000[2]
Information	(INFO)	0.73	1.08	.000[1]

where [1] t-Test, [2] Mann-Whitney Test, [3] Chi-square Test. [(i)] ADOPT is derived from combining the response scores on the rate of soil analysis and use of fertilizer by each farmer (see section 5.2 for details). Figures in parenthesis represent valid cases.

The adoption rate of appropriate farm practices is relatively higher amongst farm operators in Muyira. Direct interaction with extension officers (EXO) is the most important source of farm information, due probably to the high frequency of seasonal visits (VST) by extension officers. Overall, farm operators in Muyira turn to a relatively wider source of information (INFO) for technical advice.

4.4 Land Tenure and Rights

Table 4.4 shows significant differences in means of selected tenure characteristics between study areas. All these selected variables were captured as dichotomous variables, equal to one for yes, otherwise zero. None of the sample farmers in the study areas possessed a legal title for any parcel. With regards of tenure certainty, 42 per cent of farm operators in Rusatira felt assured of their long-term tenure, compared to 54 per cent of farm operators in Muyira. The percentage of farm operators who made any fixed improvements on their land is relatively higher in Muyira 51 per cent, compared to 40 per cent in Rusatira. Land purchases (and sales) are much less common, accounting for 18 per cent (3 per cent) and 10 per cent (7 per cent) of operated parcels in Rusatira and Muyira, respectively. Land disputes over ownership of boundaries (in the past five years) reported in the sample correspond with 11 per cent in Rusatira, compared to 9 per cent in Muyira.

Table 4.4 Mean difference in land tenure characteristics between Rusatira and Muyira, 2001

Tenure Characteristics	Rusatira (n=100)	Muyira (n=100)	Significance
Possession of title deed for land (% yes)	0	0	
Tenure certainty (% yes)	42	54	.090[3]
Make improvements on land (% yes)	40	51	.103[3]
Sale of land (% yes)	3	7	.000[3]
Buy additional land (% yes)	18	10	.000[3]
Land disputes (% yes)	11	9	.000[3]

where [3] Chi-square Test. Figures in parenthesis represent valid cases.

With regards to land rights, Table 4.5 shows that the right to sell is prevalent with 42 per cent and 54 per cent of all parcels in Rusatira and Muyira, respectively. Nevertheless, restrictions on transfer rights do exist in the study areas, and they are even greater when the need to obtain family approval is taken into account[3]. For example, only 18 per cent and 16 per cent of the permanently held parcels can be sold without approval, whereas 24 per cent and 38 per cent can be sold with approval in Rusatira and Muyira, respectively.

Table 4.5 Prevalence of land rights in Rusatira and Muyira, 2001

Land Rights	Rusatira	Muyira
	(Percentage)	
Permanently held parcels		
No right to sell	58	46
Right to sell with approval	24	38
Right to sell without approval	18	16

Although not shown in the table, there is considerable variation within the study areas in land rights across parcels and often across parcels operated by the same farm operator. Land rights are not defined according to land titles. None of the sampled farmers in the study areas possessed a legal title for any parcels.

The majority of parcels in both study areas were acquired through non-market channels such as inheritance, gift, government allocation, and appropriation. Inheritance is by far the most common method of land acquisition (93 per cent and 69 per cent in Rusatira and Muyira, respectively),

[3] Transfer rights were subdivided depending on whether or not the farm operators needed to obtain family approval before selling.

while appropriation is becoming rare as unused land disappears (Figure 4.1). Figures of land acquisition refer to the main farm unit of farms studied.

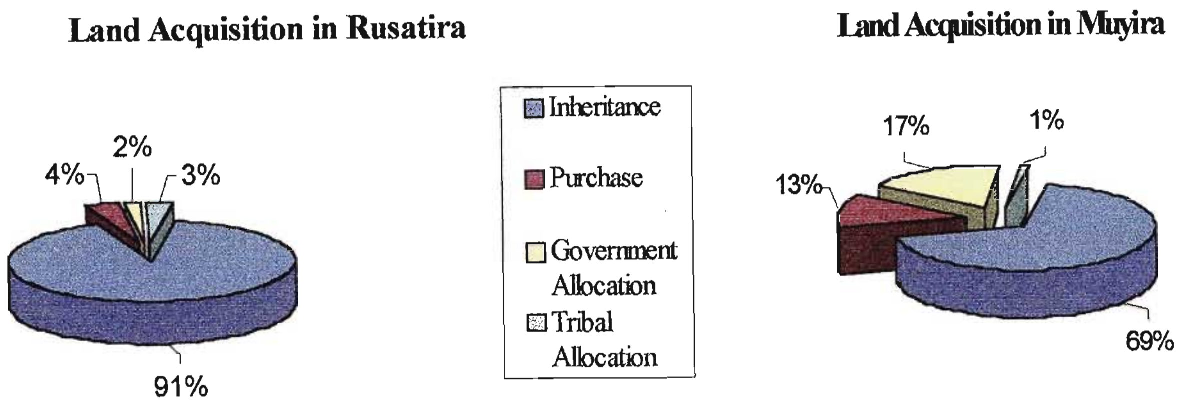

Figure 4.1 Methods of land acquisition in Rusatira and Muyira, 2001

4.5 Credit Use and Sources

Formal rural banking institutions are poorly developed. Less than 11 per cent of farm operators in Rusatira and 27 per cent of farm operators in Muyira used credit for the purchase of agricultural inputs in the past two years. Owing to the importance of collateral to the functioning of credit markets, the absence of well-defined and enforced private property rights in land may effectively prohibit the successful operation of formal credit markets in rural areas (Feder and Feeny, 1991). The absence of formal credit institutions within the two districts might explain the lack of credit use. A question was asked to assess whether sample farmers would consider borrowing capital to expand their farming activities if formal credit institutions were available. Almost all farm operators knew about borrowing and would consider this option. However, as shown in Figure 4.2, their preferred sources of credit differed considerably and favoured informal sources of lending rather than formal sources, such as banks and farm organizations. Co-operatives, neighbours and relatives were the most mentioned and preferred sources of credit by sample farm operators in Rusatira, while in Muyira 30 per cent and over 20 per cent of respondents would prefer formal banks and farm organizations, respectively. These findings suggest that borrowers face much lower transaction costs in informal credit markets.

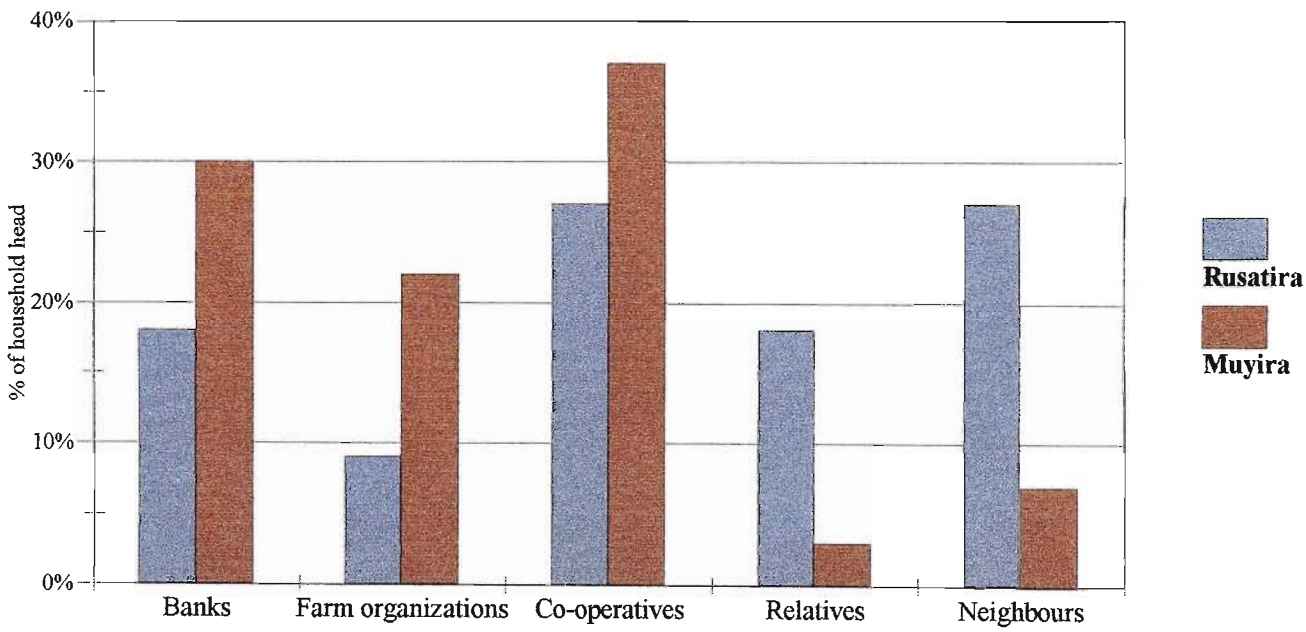

Figure 4.2 Preferred source of credit by farm operators sampled in Rusatira and Muyira, 2001

Households characteristics illustrating a demographic profile of respondents in the sample; land use and performance indicators; adoption rates of improved farm practices, and evaluation of farm information; land tenure and rights; and credit use and sources show marked variation in the study areas. Consequently, it is expected that the data elicited in the survey is suitable for analysis of land fragmentation's economic impacts. Results of the statistical analyses are presented in the next chapter.

CHAPTER 5

EMPIRICAL ANALYSIS AND RESULTS

This chapter presents the empirical findings of the study with concurrent discussion. Results are presented in the sequence prescribed by the methodology that is presented in chapter two: specification of the economic efficiency model is analyzed in section 5.1 followed by an assessment and analysis of technology adoption in sections 5.2 and 5.3.

5.1 Specification of the Model

A two-stage least squares (2SLS) regression analysis was found suitable for determining the socio-economic factors contributing to the economic efficiency model. To this end, the model developed explains the relationship between area operated, land fragmentation and economic efficiency. In this study, area operated was used as a measure of farm size as agricultural potential appears fairly homogeneous in the area, as suggested by Kay (1981). The model is specified as follows:

Area Operated (ha) (AREA) = f_1 (demographic characteristics, non-agricultural employment, tenure certainty, and agricultural training). **(5.1)**

Net Farm Income per ha (NFI) = f_2 (area operated, farmers' characteristics, contact with field extension staff, usefulness of farm information, land fragmentation, input and labour costs). **(5.2)**

The model hypothesizes that factors affecting area operated include demographic characteristics, non-agricultural employment opportunities, tenure certainty and access to training. In turn, net farm income per hectare is dependent on area operated, farmers' characteristics, contact with field extension staff, usefulness of farm information, land fragmentation, and input and labour costs. Empirically, the two equations constitute a block-recursive model (Gujarati, 1995: 680).

5.1.1 Factors Influencing Area Operated

Exogenous regressors include population-land ratio (PLR), off-farm employment (OFE), tenure certainty (TNR), and agriculture training status (TRG) of the farm operator. Equation (5.1) was generalized as:

Area operated = f (PLR, OFE, TNR, TRG) **(5.3)**

Area operated is measured in hectares and the explanatory variables; their measurement and their expected signs are defined in Table 5.1.

Rwanda is a country in the very early stages of development with the overwhelming majority of the population economically dependent on land (Waller, 1993). There are negligible employment opportunities in the non-agricultural sector. Aside from the effects of particular social and political factors, according to Huang (1973), the average area operated is primarily determined by the population-land ratio in such a situation. The greater the population-land ratio the smaller the expected average area operated. The population-land ratio (PLR) was thus included in the empirical model explaining area operated (Table 5.1).

Table 5.1 Hypothesized variables associated with different sized farms in Rusatira and Muyira, 2001

Variable	Code	Description	Expected sign
Population-land ratio	PLR	Dummy variable representing the ratio of the total population in the study areas in 1998 to the total area in hectares	-
Off-farm employment	OFE	Dummy variable representing a proxy for off-farm employment available in the area (one if farmer has off-farm employment, zero otherwise)	+
Tenure certainty	TNR	Dichotomous (1,0) one if farmer feels assured of his long-term tenure, zero otherwise	+
Training	TRG	Dichotomous (1,0) one if farmer had received agricultural training, zero otherwise	+
Dependent variable: Area operated (hectare) (AREA)			

Off-farm employment exposes the farm operator and other members of farm households to outside opportunities, and so influences off-farm migration (Huang, 1973). This migration will release land to be used by the remaining farmers, thus increasing area operated. Off-farm employment, following Huang (1973), was thus included as an independent variable in the empirical model explaining area operated. The information for this variable was obtained from the survey. Different off-farm employment opportunities could arise because (a) of an improvement in off-farm income or (b) an improvement in the farmer training or education which enables him to obtain a job outside of agriculture. If it is due to (a) then it needs to be hypothesized that labour is not perfectly mobile otherwise the difference in off-farm income will disappear in different areas. Off-farm job opportunities in the study appear largely a function of education of the head of the household (Pearson Correlation = 0.55)[4], which differ in the two

[4] Correlation is significant at the one per cent level of probability.

areas (Table 4.1). This implies that improving education will improve labour mobility from agriculture.

Agricultural training status of the farm operator is expected to have a positive relationship with area operated (Berger *et al.*, 1984: 33). The higher the level of farmers' training the larger the area operated. Training may assist off-farm migration while it may enable the farm to operate larger acreages.

Tenure certainty was measured through farmers' judgment as to whether they feel assured of their long-term tenure or not. Tenure certainty is expected to be positively related to area operated, given that farmers are more likely to improve parcels over which they have a long-term interest, in terms of their rights to cultivate the land on a continuous basis, to make and enforce a lease or sale contract, and to dispose of the land in ways that provide adequate compensation for the value of any improvements (Place and Hazell, 1993). Thomson (1996) argues that tenure security depends on both the actual and the perceived rights of individuals. These include whether or not farmers perceive rights to cultivate for the whole year, fence-off their arable land, and claim compensation for crops damaged by stray animals. Results of the Ordinary Least Squares (OLS) regression analysis of the area operated equation are presented in Table 5.2.

According to the results, population-land ratio has a strong negative impact on determination of area operated. t-values and beta-coefficients (standardized coefficients), indicating the relative importance or impact of each variable in the model, suggest that population-land ratio has the greatest impact on area operated (i.e. the increase of population is the major factor leading to scarcity of farming land, reducing farming activities to small-sized and fragmented farm units).

Table 5.2 Results of OLS regression analysis of the area operated equation (n=179)

Variable	Expected sign	Coefficient	Beta	t-value
PLR	-	-0.996	-0.635	-12.939**
OFE	+	0.525	0.321	7.137**
TNR	+	0.413	0.276	5.725**
TRG	+	0.104	0.066	1.363*
CONSTANT		2.82		14.065**

Dependent variable: AREA
F-statistic: 82.083**
R^2: 0.654
Adjusted R^2: 0.646

Note: **, * denote statistical significance at the one and twenty per cent probability levels, respectively.

Likewise, whether or not the farm operator has off-farm employment influences positively the area operated. Off-farm employment is also seen as a proxy for off-farm jobs. As job opportunities are created in the non-agricultural sector, migration out of agriculture will occur. All of these relationships are consistent with *a priori* expectations and agree with findings of previous research (e.g., Huang, 1973; Abdulkadir, 1992).

Tenure certainty is significant at the one per cent level of probability and, according to the beta-coefficients and t-values, is the third most important determinant of area operated after population-land ratio and off-farm employment. Heady (1971) reported a similar result that variants in forms of land tenure cause a range of optimal farm sizes in countries at various stages of economic development. Heady (1971) further argues that while conditions of development and resource suppliers or markets do relate to farm size, tenure conditions also pose differences in the opportunity cost of capital for landowners.

Access to agricultural training is related positively to area operated. Removing obstacles to small-scale farmers' access to training, will give them the opportunity to engage in market transactions, thus supporting the findings of Berger *et al.* (1984: 34).

5.1.2 Factors Influencing Economic Efficiency

The variables used to estimate equation (5.2) are presented in Table 5.3, along with their expected signs. Economic efficiency is measured by net farm income per hectare, and is dependent on area operated, education of the farm operator, visits by field extension officer, usefulness of farm information, number of plots cultivated, distance between parcels, input and labour costs per hectare. Area operated is seen as endogenous and estimated from equation (5.3). Thus, equation (5.2) was estimated as:

$$NFI = f(\hat{AREA}, EDU, VST, INFO, PLT, DST, INP, LAB) \qquad \textbf{(5.4)}$$

The dependent variable - net farm income per hectare – reflects returns to management, rent earned on land and other fixed inputs.

Table 5.3 Hypothesized variables for the economic efficiency model, Rusatira and Muyira, 2001

Variable	Code	Description	Expected sign
Area operated	$\hat{AREA}$	Predicted value for area operated	+
Education	EDU	Formal education of farm operator	+
Extension visits	VST	Number of times a farmer was visited by field extension staff in the last two seasons	+
Farm information	INFO	The assessment of the usefulness of farm information in assisting farmers to improve farm productivity	+
Number of plots	PLT	Number of arable plots cultivated	-
Distance between parcels	DST	Total distance in kilometers between each plot cultivated and the household residence	-
Input costs	INP	Input costs per hectare (RWF/Ha)	
Labour cost	LAB	Labour costs per hectare (RWF/Ha)	
Dependent variable: Net Farm Income per hectare (NFI)			

It is expected that area operated, formal education of farm operators, visits by field extension officer, and tenure certainty are expected to bear positively on net farm income per hectare, while number of plots cultivated and distance between parcels, characteristics of land fragmentation, are expected to have a negative impact on economic efficiency. The results of two-stage least squares regression analysis (2SLS) are presented in Table 5.4.

Equation (5.2) could be estimated using OLS if it is assumed that the error term is not correlated with the stochastic variable "area operated". However, to account for possible correlation with the error term, the stochastic variable was replaced with an instrumental variable (estimated area operated). 2SLS involves the application of OLS in two stages.

Table 5.4 Results of 2SLS and ridge regression analysis of economic efficiency model (n=179)

		2SLS Regression			Ridge Regression		
Variable	**Expected sign**	**Coefficient**	**Beta**	**t-value**	**Coefficient**	**Beta**	**t-value**
$\hat{AREA}$	+	475.153	0.402	7.125***	454.596	0.385	8.323***
INFO	+	628.777	0.424	6.414***	445.971	0.301	6.167***
VST	+	591.959	0.398	5.652***	423.194	0.284	5.637***
EDU	+	401.293	0.253	5.553***	386.634	0.244	5.938***
PLT	-	-340.445	-0.223	-3.958***	-331.291	-0.217	-4.683***
LAB		-305.137	-0.151	-3.402**	-275.490	-0.136	-3.388**
DST	-	-100.934	-0.067	-1.434	-104.651	-0.070	-1.675*
INP		-75.521	-0.050	-1.098	-51.937	-0.034	-0.849
CONSTANT		1328.824		6.648***	1385.738		8.266***
		F-statistic: 48.296*** R^2: 0.694 Adjusted R^2: 0.680			K = 0.10 F-statistic: 46.480*** R^2: 0.686 Adjusted R^2: 0.671		

Note: ***, **, * denote statistical significance at the one, five and ten per cent probability levels, respectively.

Table 5.4 summarizes the results of the economic efficiency equation. Again, the results from the 2SLS regression analysis are consistent with the hypothesized relationships. This is particularly true with respect to the significant and strongly positive effects of area operated (AREA), farm information (INFO), extension visits (VST), and education (EDU); and the strong negative effect of number of plots (PLT) on net farm income per hectare. Area operated has the strongest positive impact on net farm income per hectare, which indirectly reflects greater economic efficiency. In absolute terms, the results suggest that a unit (hectare) increase in area operated will increase net farm income per hectare by 475 RWF.

The number of arable plots cultivated is negatively and significantly correlated with net farm income per hectare, indicating that land fragmentation leads to small and uneconomic holdings (Gebeyehu, 1995). This implies that efficiency of very small-scale farms can be enhanced by land consolidation. Likewise, distance between parcels negatively influences the level of net farm income. According to King and Burtons (1982), the long distances between parcels reduce the level of crop income.

As regards farm indicators, results indicate an economy of scale within the farming process itself (internal economies), due to better utilization of labour and other inputs (technical economies). Labour cost per hectare is negatively and statistically significant at the five per cent level of probability, and according to its relative importance in the model, the results show that it has a significant impact on economic efficiency. Variable input costs per hectare are also negatively but not statistically significantly associated with net farm income per hectare, due probably to the fact that inputs used in the two study areas are mainly confined to small projects.

Even though R^2 is high and the regression coefficients individually significant as revealed by the higher t values, the Condition Index of 20.6 indicates the presence of a moderate to high multicollinearity in the regression equation (5.2) (Gujarati, 1995: 338). The Condition Index is the square root of the ratio of the largest eigenvalue to the minimum eigenvalue. Therefore, ridge regression was used as an alternative procedure to 2SLS to deal with the problem of multicollinearity. The variance inflation factor, however, indicates that multicollinearity is mild.

5.1.3 Ridge Regression for the Economic Efficiency Model

Following Maddala (1992: 280) and Neter *et al.* (1996: 411) ridge regression was used as an alternative procedure to 2SLS to deal with the problem of multicollinearity in the original equation (5.2). RR overcomes the multicollinearity problem by adding a biasing constant, K ≥0 to the least squares normal equations and then by estimating the standardized ridge estimators (Neter *et al.*, 1996: 412). A careful examination of the *ridge trace*, which is a graph of the beta coefficients against the biasing constant, K, and the values of variance inflation factors (VIF) help to determine the value of K which stabilizes the beta coefficients. The results are presented in Table 5.5.

Table 5.5 R-square and the Beta coefficients for different values of the biasing constant, K

K	R^2	$\hat{AREA}$	INFO	VST	EDU	PLT	LAB	DST	INP
.00	.6944	.4023	.4241	.3975	.2535	-.2229	-.1513	-.0673	-.0503
.05	.6917	.3950	.3518	.3298	.2493	-.2194	-.1433	-.0686	-.0405
.10	.6863	.3849	.3008	.2842	.2442	-.2169	-.1366	-.0698	-.0346
.15	.6797	.3740	.2625	.2513	.2388	-.2147	-.1308	-.0709	-.0308
.20	.6729	.3630	.2326	.2265	.2334	-.2126	-.1257	-.0718	-.0284
.25	.6659	.3524	.2085	.2071	.2279	-.2103	-.1211	-.0726	-.0267
.30	.6589	.3423	.1885	.1915	.2227	-.2079	-.1169	-.0732	-.0255
.35	.6519	.3327	.1717	.1787	.2176	-.2054	-.1132	-.0737	-.0246
.40	.6451	.3236	.1574	.1679	.2127	-.2028	-.1097	-.0740	-.0240
.45	.6383	.3150	.1450	.1588	.2079	-.2002	-.1065	-.0742	-.0235
.50	.6316	.3069	.1341	.1509	.2034	-.1975	-.1035	-.0743	-.0232
.55	.6251	.2992	.1245	.1441	.1991	-.1949	-.1008	-.0743	-.0229
.60	.6186	.2920	.1160	.1380	.1949	-.1922	-.0982	-.0742	-.0226
.65	.6122	.2851	.1084	.1326	.1909	-.1896	-.0958	-.0741	-.0224
.70	.6060	.2786	.1016	.1278	.1871	-.1870	-.0935	-.0739	-.0222
.75	.5998	.2724	.0954	.1234	.1834	-.1844	-.0913	-.0736	-.0221
.80	.5938	.2665	.0897	.1195	.1799	-.1818	-.0893	-.0733	-.0219
.85	.5878	.2608	.0846	.1159	.1765	-.1793	-.0873	-.0730	-.0218
.90	.5819	.2555	.0799	.1126	.1732	-.1769	-.0855	-.0726	-.0216
.95	.5762	.2503	.0756	.1095	.1701	-.1744	-.0837	-.0722	-.0215
1.00	.5705	.2454	.0717	.1067	.1670	-.1721	-.0821	-.0717	-.0213

The results in Table 5.5 show that the ridge estimators first stabilized when the value of the biasing constant, K, equals 0.10 and the values of VIF for the regression coefficients are close to one (unity) as shown in Table 5.6. The small K value (K = 0.10) implies that the bias introduced through the use of RR is small.

Table 5.6 VIF values for regression coefficients for different values of the biasing constant, K

K	$\hat{AREA}$	INFO	VST	EDU	PLT	LAB	DST	INP
.00	1.7740	2.4330	2.7520	1.1590	1.7650	1.1000	1.2260	1.1650
.05	1.4079	1.7040	1.8696	1.0267	1.4102	.9806	1.0675	1.0141
.10	**1.1587**	**1.2883**	**1.3767**	**.9168**	**1.1624**	**.8806**	**.9410**	**.8977**
.15	.9780	1.0244	1.0707	.8243	.9807	.7958	.8380	.8039
.20	.8413	.8445	.8665	.7456	.8425	.7232	.7525	.7260
.25	.7345	.7149	.7224	.6781	.7345	.6605	.6804	.6602
.30	.6490	.6178	.6164	.6196	.6481	.6059	.6190	.6038
.35	.5792	.5425	.5356	.5685	.5776	.5581	.5661	.5549
.40	.5212	.4825	.4723	.5237	.5192	.5159	.5201	.5121
.45	.4723	.4337	.4215	.4842	.4702	.4784	.4798	.4743
.50	.4307	.3933	.3799	.4490	.4285	.4450	.4443	.4408
.55	.3949	.3592	.3453	.4177	.3927	.4151	.4127	.4110
.60	.3638	3302	.3161	.3866	.3617	.3882	.3846	.3842
.65	.3366	.3051	.2912	.3643	.3345	.3638	.3594	.3600
.70	.3126	.2833	.2696	.3415	.3107	.3418	.3367	.3381
.75	.2913	.2641	.2508	.3208	.2895	.3222	.3162	.3183
.80	.2723	.2470	.2342	.3019	.2707	.3034	.2976	.3002
.85	.2553	.2319	.2195	.2848	.2538	.2867	.2806	.2836
.90	.2399	.2183	.2064	.2690	.2386	.2713	.2651	.2685
.95	.2261	.2060	.1946	.2546	.2248	.2572	.2509	.2545
1.00	.2134	.1948	.1840	.2414	.2123	.2442	.2378	.2417

The value of K= 0.10 was then used to determine the final beta coefficients. The results of ridge regression of socio-economic variables on net farm income per hectare (NFI) are presented in Table 5.4. The signs of the explanatory variables retained in the final model agree with a *priori* expectations. All the variables were included in the final RR model. The standardized coefficients of the ridge regression in Table 5.4 suggest that area operated (AREA) is the most important variable influencing net farm income per hectare (NFI) followed by farm information (INFO), visits by field extension staff (VST), education (EDU), number of plots (PLT), labour cost per hectare (LAB), distance between parcels (DST), and input costs per hectare (INP).

Comparing 2SLS and RR results, the beta coefficients of RR are generally smaller in magnitude than the beta coefficients obtained by using 2SLS, while t-values of RR are a bit higher than the ones obtained from 2SLS. The adjusted R^2 obtained using RR is only a bit smaller than when using 2SLS, as the biasing coefficient ($K = 0.10$) is small. The RR results in general support the findings of 2SLS.

5.2 Assessment of Technology Adoption

5.2.1 Cross-tabulation Analysis between Soil Testing and Use of Fertilizer

A measure of association between soil testing and use of fertilizer was performed in a cross-tabulation analysis. The tested hypothesis postulates that a farmer who adopts soil analysis is most likely to make use of fertilizer on his farm (thus assuming a relationship between the two farm practices). A test of *independence* between the two farm practices was performed with an objective of assessing if the two farm practices could be combined into a single variable as a measure of farmer technology adoption ability.

The hypothesis that two variables of a cross-tabulation are *independent* of each other is often of interest to researchers (Norušis, 1990b: 129). Two variables are by definition independent if the probability that a case falls into a given cell is simply the product of the marginal probabilities of the two categories defining the cell. The probability (***P***) under independence of an observation falling into cell (*ij*) is estimated (Norušis, 1990b: 129) by:

$$P(\text{row} = i \text{ and column} = j) = \left(\frac{count \quad in \quad row \quad i}{N}\right)\left(\frac{count \quad in \quad column \quad j}{N}\right) \qquad \textbf{(5.5)}$$

If the probability, also known as the *observed significance level* of the test is small enough (usually less than 0.05 or 0.01), the hypothesis that the two variables are independent is rejected.

To obtain the expected number of observations in cell (*ij*), the probability is multiplied by the total sample size (***N***), that is;

$$\mathbf{E}_{ij} = \boldsymbol{N}\left(\frac{count \quad in \quad row \quad i}{N}\right)\left(\frac{count \quad in \quad column \quad j}{N}\right)$$

$$= \frac{(count \quad in \quad row \quad i)(count \quad in \quad column \quad i)}{N} \qquad \textbf{(5.6)}$$

A statistic often used to test the hypothesis that the row and column variables are independent is the *Pearson chi-square* (Norušis, 1990b: 130) . It's calculated by summing over all cells the squared residuals divided by the expected frequencies.

$$X^2 = \sum_i \sum_j \frac{(Oi_j - Ei_j)^2}{Ei_j}$$ Where: O_{ij} = observed frequencies and E_{ij} = expected frequencies **(5.7)**

The chi-square test provides little information about the strength or form of the association between two variables because it is sensitive to sample size, degrees of freedom, and scale measurements of variables studied (Norušis, 1990b: 132). The use of measures of association based upon it has been encouraged, like *phi-coefficient*, which modifies the *Pearson chi-square* by dividing it by the sample size and taking the square root of the result (Norušis, 1990b: 132).

$$\Phi = \sqrt{\frac{X^2}{N}} \tag{5.8}$$

Soil testing on coffee farms was measured as dichotomous, equal to one if farmers have had farm soils tested, and zero otherwise. Likewise, use of fertilizer was captured as dichotomous, equal one if fertilizer is used, and zero otherwise. Results of the cross-tabulation are given in Table 5.7.

Table 5.7 Cross-tabulations of soil testing by use of fertilizer

Soil testing	**Use of fertilizer** 0	1	**Row Total**
0	90 (49.2%)	33 (18.0%)	123 (67.2%)
1	24 (13.1%)	36 (19.7%)	60 (32.8%)
Column Total	114 (62.3%)	69 (37.7%)	183 (100.0%)

	Value
Chi-square:	
Pearson	18.9*
Statistic:	
Phi	0.321*

* Statistically significant at one per cent level.

According to Table 5.7, a *Phi-coefficient* of 0.321 and *Pearson chi-square* value of 18.9 (both statistically significant at one per cent level), indicated that the *chi-square* test showed a strong association between the two practices, therefore the hypothesis that adoption of soil testing and use of fertilizer on a coffee farm are independent was rejected, implying that a farmer who tests soils on his farm is most likely to use fertilizer.

From a total of 200 farm operators surveyed, 183 valid cases were retained of which 90 (49.2 %) neither had soils tested nor used fertilizer, 33 (18.0 %) used fertilizer but never had soils tested, 24 (13.1 %) adopted soil testing but never used fertilizer, and 36 (19.7 %) adopted soil testing and used fertilizer. The other 17 cases remaining were excluded from the final model because of lack of sufficient information. The four groups were re-classified into three groups, that is of (i) *non-adoption,* (in group one), (ii) *partial-adoption* (in group two and three) and (iii) *full-adoption* (in group four). The characteristics of the three farm groups with different magnitudes of adopting improved and appropriate farm practices were then analyzed using the SPSS test of means procedure (Norušis, 1990a: 457). Averages of some of the social and economic farmer characteristics studied within the three defined groups were calculated. The results are presented in Table 5.8.

Table 5.8 Mean farm operator and farm business characteristics by adoption rates, in Rusatira and Muyira, 2001

Variable	Technology Adoption			F-value
	Non-adopters (90)	*Partial-adopters* (57)	*Full-adopters* (36)	
Age of farm operator	50.08	47.58	44.92	3.22**
Education	0.54	1.21	1.78	48.58***
Farm size (ha)	1.88	3.4	3.99	42.87***
% Of arable land under coffee	33.48	38.46	38.59	3.94**
Average yield (tons/ha)	0.57	0.64	0.73	17.02***
Net farm income/ha	1858.88	3132.71	3722.71	32.39***
Off-farm income (RWF)	1861.11	2696.49	8727.78	11.90***
Monetary value of livestock (RWF)	117311.1	89929.82	210166.7	4.72**
% Farmers confident of secure tenure	57	67	89	6.28**
Number of plots cultivated	2.94	2.21	1.89	17.44***
Distance between parcels (km)	1.48	0.89	0.59	10.63***
Labour costs/ha	1352.78	1265.79	1305.55	1.27
Input costs/ha	557.89	510.09	524.58	0.07

*** and ** denote statistical significance at the one and five per cent levels of confidence, respectively.
Figures in parenthesis represent valid cases.

Descriptive statistics, presented in Table 5.8, indicate that, on average, farmers who have adopted relatively more recommended technologies tend to produce significantly higher yields per hectare and achieve significantly higher net farm income per hectare than farmers who have adopted less and/or have not adopted at all recommended technologies, despite having similar per hectare labour and variable input costs.

These trends are consistent with *a priori* expectations that farmers who adopt relatively more recommended technologies tend to be more productive and more efficient coffee farmers. Adopters of recommended technologies also tend to be younger and better educated; operate larger, less fragmented farms; have greater liquidity; perceive greater tenure certainty; and they allocate a greater proportion of their arable land to coffee production.

5.3 Analysis of Technology Adoption

5.3.1 Linear Discriminant Analysis (LDA)

Technology adoption behaviour of farmers may be conceptualized as a function of farm and farmer attributes, the technology itself and the farming objective (Mafuru *et al.,* 1999), as well as the existing institutions and infrastructure. Accordingly, a linear discriminant analysis (LDA) was conducted to identify factors associated with adoption of soil testing and use of fertilizer by coffee farmers in Southern Rwanda.

LDA is a statistical technique that distinguishes between groups using characteristics on which the groups are expected to differ (Manly, 1994:107). A LDA model was specified to discriminate between *full-adopters*, *partial-adopters* and *non-adopters* of soil testing and use of fertilizer. Table 5.9 lists the explanatory variables specified in the LDA together with theoretical explanations of why each is included in the model.

Table 5.9 Variables that discriminate between adoption of soil testing and use of fertilizer by coffee farmers in Rwanda

Farm size (FMS)	Returns to information, technology and management are scale dependent (Welch, 1978: 184), consequently, relatively smaller farm businesses have less incentive to adopt new technologies.
Age (AGE)	Younger farmers tend to be more willing to adopt new technologies due to longer planning horizons (Celis *et al.,* 1991).
Gender (GDR)	Social customs in Rwanda tend to discriminate against women in Rwanda (MINAGRI/PNUD, 1996), reducing their access to information and new technologies.
Education (EDU)	Formal education and training in agriculture improves farmers' abilities to acquire accurate information, evaluate new production processes, and use new agricultural inputs and practices efficiently (Ashby, 1981; Mbowa, 1996).
Information (INFO)	Usefulness of farm information is likely to promote adoption of appropriate agricultural practices. For example, training workshops expose farmers to new technology and information sources outside their farms (Adesina and Baidu-Forson, 1995); and contact with extension staff is expected to promote adoption of recommended farm practices (Abdulkadir, 1992).
Off-farm income (OFI)	Increased off-farm income earnings could alleviate on-farm liquidity constraints, since labour has close substitutes (Lyne and Nieuwoudt, 1991).
Value of livestock (LVT)	Farmers who have more wealth in the form of livestock may be better able to finance the cost of technology adoption (Essa and Nieuwoudt, 2001).
Tenure certainty (TNR)	Farmers are more likely to improve parcels over which they have a long-term interest (Place and Hazell, 1993), hence increasing the probability of a farm adopting modern production methods.
Land fragmentation	Land fragmentation, as a result of continuous land distributions and growing population, creates a sense of insecurity among farmers, hence preventing them from making additional investment to increase production (Gebeyehu, 1995).

The following LDA model was postulated to identify factors associated with adoption of recommended farm practices:

$$Z_i = a_1 FMS + a_2 AGE + a_3 GDR + a_4 EDU + a_5 TRG + a_6 WSP + a_7 VST + a_8 INFO + a_9 OFI + a_{10} LVT + a_{11} TNR + a_{12} PLT + a_{13} DST + a_{14} ACO \quad (5.9)$$

Where, Z_i is the discriminant score for each group category of *non-adopters*, *partial-adopters* and *full-adopters*; and $a_1,\ldots,\ a_n$ are the weighting (standardized discriminant function) coefficients.

5.3.2 Results of the farm practices LDA Adoption Model

Factors that could influence the different degrees of adoption and non-adoption of improved farm practices on a coffee farm were included in the discriminant function as independent variables. Statistically significant collinearity was identified within this set of explanatory variables (Table 5.10). Because collinearity between the explanatory variables may lead to biased parameter estimates (Norušis, 1990b: 53), Principal Components Analysis (PCA) was used to condense the variables into fewer orthogonal variables, each measuring different dimensions in the data (Manly, 1994:59). PCA generated four components (PC's) that accounted for the variability between farmers on the 14 variables used to reflect the different degrees of adoption of appropriate and improved farm practices. Kaiser's criterion was used whereby only PC's with eigenvalues greater than one (1.0) are retained (Stevens, 1986: 341; Norušis, 1990b: 319). The value of 1.0 represents the variance of the original variables (Johnston, 1980: 190). Hence, a PC with an eigenvalue of less than 1.0 accounts for less of the total variance than any of the original variables. The criterion was followed in this study because it is particularly accurate when the number of variables is small (Stevens, 1986: 341).

5.10 Correlation matrix of social and economic characteristics of coffee farms studied

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Farm information	X_1	1.000													
Training workshops	X_2	.612**	1.000												
Extension visits	X_3	.747**	.531**	1.000											
Agricultural training	X_4	.542**	.534**	.359**	1.000										
Number of plots	X_5	-.162*	-.267**	-.203**	-.289**	1.000									
Distance between parcels	X_6	-0.045	-0.031	-0.029	-.151*	.347**	1.000								
Age of farm operator	X_7	-.137	-.177*	-.088	-0.134	.308**	.155*	1.000							
Farm size	X_8	.099	.215**	.188**	.196**	-.522**	-.303**	-.297**	1.000						
Monetary value of livestock	X_9	.105	0.053	.189**	0.085	-.196**	0.049	-0.073	.272**	1.000					
Off-farm income	X_{10}	0.106	.169*	.192**	.029	-.200**	-.136	-0.118	.239**	.424**	1.000				
Education of farm operator	X_{11}	.156*	0.133	.222**	.011	-.315**	-.131	-.228**	.241**	.230**	.344**	1.000			
Tenure certainty	X_{12}	0.098	.245**	0.119	0.133	-.236**	-.145*	.009	.399**	-0.069	-0.022	.055	1.000		
Gender of farm operator	X_{13}	-.024	0.013	0.082	-0.08	-0.125	-0.128	0.014	.293**	0.134	0.017	.130	.231**	1.000	
% of arable land under coffee	X_{14}	0.081	.170*	0.074	0.098	-0.092	-0.081	-0.017	.170*	-0.076	0.063	0.107	.309**	0.136	1.000

** and * denote significance at the one and five per cent levels of probability, respectively, (2-tailed).

Components were rotated using *equamax* rotation to more easily define groups of related dimensions (Rummel, 1970). Factor loadings, analogous to correlation coefficients, represent the degree and direction of the relationship between the original variables measured and the newly defined factors. Variables with factor loadings greater than 0.5 were used to interpret the PCs. The objective is to attach an economic interpretation to the PC's (Stevens, 1986: 339). If the PC's can be meaningfully interpreted, this leads to a greater understanding of the variation in the data (Crabtree, 1971). Table 5.11 shows extracted PC's.

Table 5.11 Loadings and eigenvalues of the elicited principal components

Variable	PC_1	PC_2	PC_3	PC_4
Farm information	0.893			
Training workshops	0.804			
Farm visits by field extension officers	0.784			
Agricultural training	0.705			
Number of plots		0.709		
Distance between parcels		0.666		
Age of farm operator		0.649		
Farm size		-0.578		
Monetary value of livestock			0.790	
Off-farm income			0.736	
Education of farm operator			0.583	
Tenure certainty				0.750
Gender of farm operator				0.643
% of arable land under coffee				0.610
Eigenvalue	3.49	1.92	1.56	1.20
Percentage variability	24.9	13.7	11.2	8.6

The first principal component, PC_1, captures information accessible to farmers from extension support and therefore, can be interpreted as an *index positively related to usefulness of information*. PC_2 is an *index of farm operator's age*, reflecting that older farmers tend to operate relatively smaller and more fragmented farms. PC_3, has high loadings for monetary value of livestock, off-farm income, and education of the farm operator, which are all related to liquidity. Accordingly it is interpreted as an *index positively related to ability to finance agricultural inputs.* The monthly cash income earned is a variable which shows the availability of a reliable income source and the ownership of livestock signifies wealth status and a source of finance. PC_4 has high loadings for tenure certainty, gender of the farm operator and proportion of arable land under coffee. It is interpreted as an *index of access to agricultural resources*, reflecting that men tend to have better access to agricultural resources and perceive greater tenure certainty than women.

These four orthogonal PCs were substituted for the original (x) variables in the LDA model, thus averting the collinearity problem (Jolliffe, 1986: 157). Initially the discriminant model was based on the three groups, namely *non-adopters*, *partial-adopters* and *full-adopters*. The separation between the three groups was poor; therefore the two extreme groups of *non-adopters* and *full-adopters* were used to get better results. The variable classifying both groups was captured as dichotomous, equal to one for *full-adopters*, and zero for *non-adopters*. The discriminant function was therefore estimated based on 126 respondents from the two extreme groups. Results of the LDA model are presented in Table 5.12.

Table 5.12 Estimated discriminant functions for *non-adopters* and *full-adopters* of recommended farm practices, Rusatira and Muyira, 2001

Explanatory variable	Standardized coefficient	t-value	Component score group means		
			non-adopters	*full-adopters*	F value
PC_2	-0.790	-6.293**	1.033	-1.467	25.791**
PC_3	0.647	5.136**	-0.768	1.770	24.147**
PC_4	0.566	4.278**	-0.820	0.764	10.656**
PC_1	0.424	3.148*	-0.396	0.602	4.348*
Number of valid cases			90	36	
F value		71.3**			
Wilk's Lambda		0.55			
Canonical correlation		0.66			
Classifications:					
	non-adopters	83.30 %			
	full-adopters	88.90 %			
	Total	84.90 %			

** and * denote statistical significance at one and five per cent levels of confidence, respectively.

The LDA model correctly identifies 83.3 % of *non-adopters* and 88.9 % of *full-adopters*, respectively. A Wilk's lambda value of 0.55, and 84.9 % overall correct classification of adoption indicates an effective classification ability of the estimated discriminant function. Frequency distributions of the discriminant scores are shown in Tables 5.13 and 5.14 along with their accompanying histograms (Figures 5.1 and 5.2). Both groups (non-adopters and adopters) have an approximately univariate normal distribution, the estimates therefore can be accepted with reasonable confidence.

Table 5.13 Frequency distribution of discriminant scores estimated for non-adopters

Code	Discriminant score range	Frequency	Frequency as Percentages
1	(-2.577 to -1.787)	11	12
2	(-1.787 to -1.017)	25	28
3	(-1.017 to 0.247)	32	36
4	(0.247 to 0.523)	10	11
5	(0.523 to 1.293)	8	9
6	(1.293 to 2.063)	3	3
7	(2.063 to 2.823)	1	1
		90	100

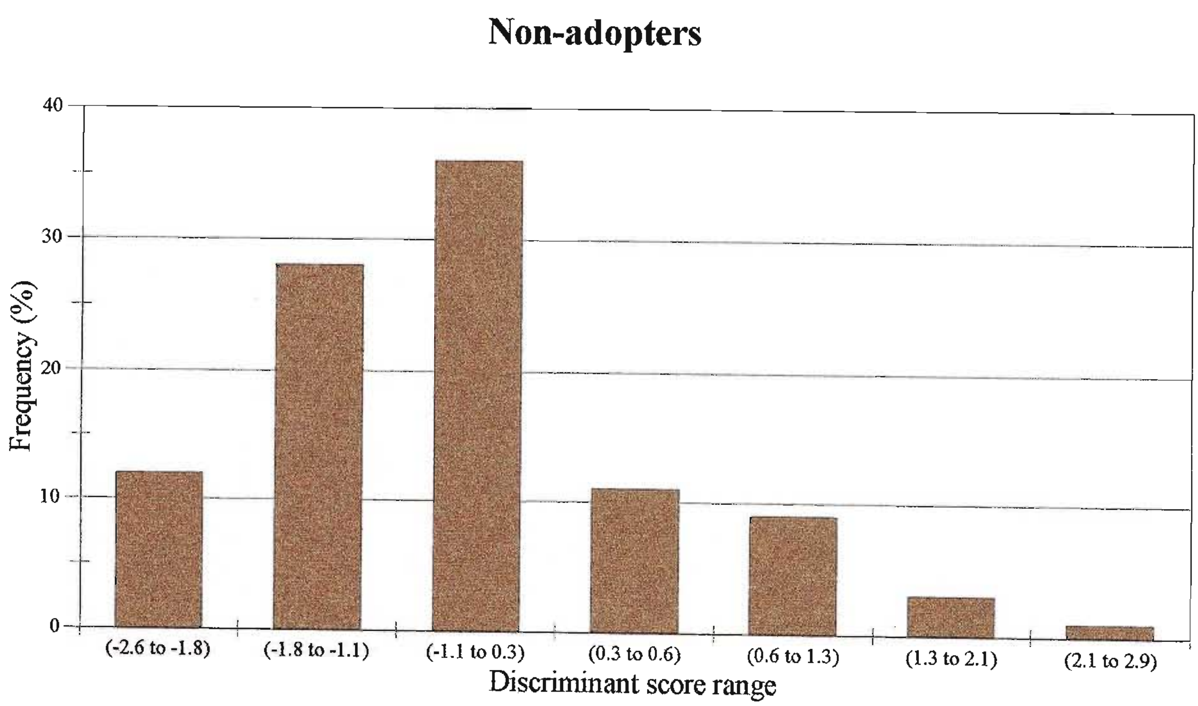

Figure 5.1 Histogram for discriminant scores for non-adopters

Table 5.14 Frequency distribution of discriminant scores estimated for adopters

Code	Discriminant score range	Frequency	Frequency as Percentage
1	(-0.187 to 0.554)	7	19
2	(0.554 to 1.295)	11	31
3	(1.295 to 2.036)	9	25
4	(2.036 to 2.777)	7	19
5	(2.777 to 3.517)	2	6
		36	100

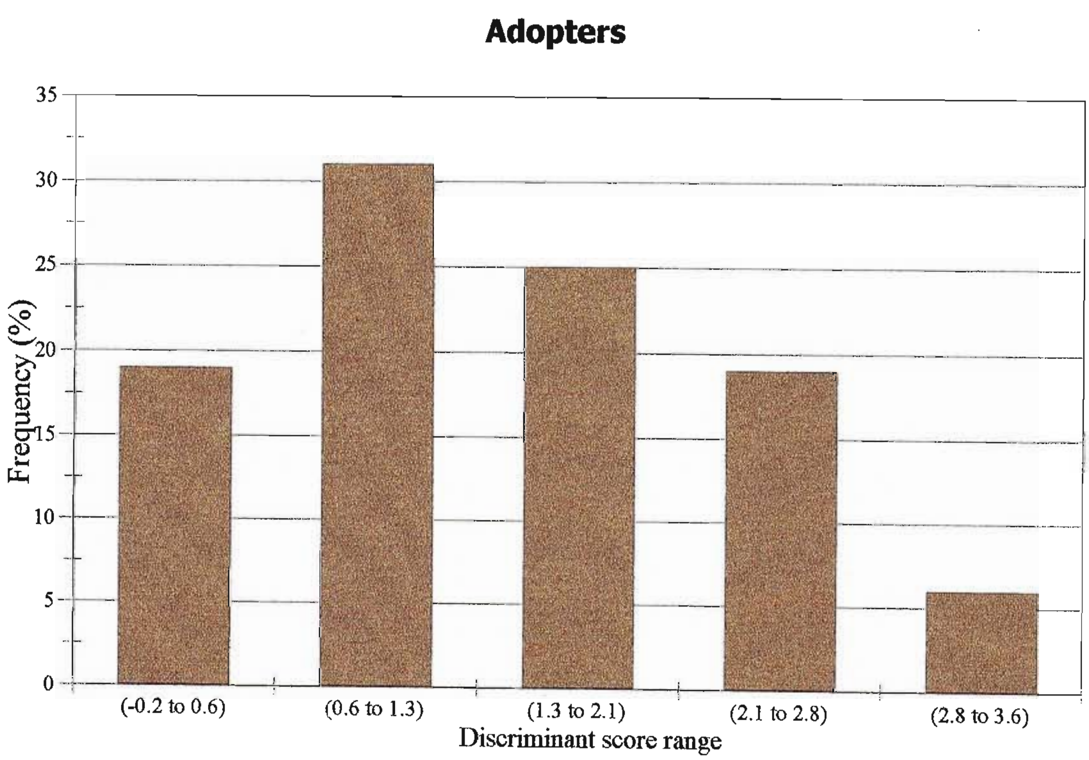

Figure 5.2 Histogram for discriminant scores for adopters

Results indicate that wealthier, younger, better educated, male farmers, with relatively less fragmented farms, greater tenure certainty, and good access to agricultural training and information sources are relatively more likely to adopt appropriate and improved farming practices on coffee farms. All of these relationships are consistent with *a priori* expectations and agree with findings of previous research (e.g., Strauss, *et al.,* 1991; Celis *et al.,*1991, Essa and Nieuwoudt, 2001; and Abdulkadir, 1992).

PC_2 and PC_3 (age of the farm operator and wealth/liquidity, respectively) are statistically the two most important dimensions discriminating between *non-adopters* and *full-adopters* of the two recommended farming practices, followed by PC_4 (access to agricultural resources) and PC_1 (access to agricultural information). This finding does not necessarily imply a diminished role for provision of agricultural information in promoting adoption of recommended farming practices. Rather, it may reflect that concurrent policies are required to ensure that farm operators can efficiently use this information to assess agricultural practices, have training to effectively implement these practices, have access to sufficient resources (large farms) to provide the incentive to adopt new technologies, and have the ability (e.g. wealth and liquidity) to adopt these practices. This points towards the need for a strong collaborative link between the *Rwandan Industrial Crops Authority* (OCIR), which serves the entire coffee industry of improved coffee varieties, control of pests and diseases, effective extension services and cultivation practices, with field extension staff who are mainly in close contact with farmers to facilitate the dissemination of relevant information on better farming methods.

The negative relationship identified between age and adoption indicates that younger farmers may be more innovative and quick learners of new techniques, have longer planning horizons and are less risk averse. Furthermore, the fragmentation and diminution of land as a result of continuous land distributions and growing population create a sense of insecurity among farmers (Gebeyehu, 1995). This insecurity deters farmers from adopting new technologies. The negative impact of fragmentation may reflect recent Rwandan policy to reallocate relatively larger farms to more efficient farmers through a villagization policy, which aims at reducing the present dispersed distribution of land (MINAGRI, 1997).

The combined results of the two analyses provide considerable insight towards factors influencing economic efficiency and technology adoption models. Analysis of both models identified a negative relationship between land fragmentation and net farm income per hectare, which indirectly reflects greater economic efficiency, on the one hand, and between land fragmentation and technology adoption on the other hand. The next chapter proceeds to draw conclusions and policy implications from this research.

CHAPTER 6

CONCLUSIONS AND POLICY IMPLICATIONS

Agriculture is the most important sector of Rwanda's economy. It accounts for around 40 per cent of GDP, and about 85 per cent of total exports are agricultural. This makes it a leading foreign exchange earner. Ninety per cent of the population derives its livelihood from agriculture, and it's the biggest wage employer. Further, the rapidly expanding labour force is expected to be absorbed into the agricultural sector. Undoubtedly the significance of this sector will continue in the years to come. However, Rwandan agriculture is beset by many problems, including land fragmentation and obsolete technology.

Effect of fragmentation on economic efficiency is examined based on information collected from a sample of 200 individually (privately) owned farms in the Rusatira and Muyira districts in Butare Province during 2001. Farms studied ranged from 0.04 to 6 hectares. The sample was selected randomly from a population list provided by extension officers in the two areas.

Investigations of characteristics of the sample farmers using regression analysis revealed that, within a "stage of development" framework, the area operated can be viewed as being initially determined by a country's resource endowment, which over time may change with population growth and clearing of land (Huang, 1973). With development, increases in nonagricultural employment opportunities, changes in customary tenure security and provision of adequate information through training will cause pressures for the area operated to increase. An implication of the findings of this study is that the area operated will be constantly changing in response to dynamic conditions.

Results from a block-recursive regression analysis indicate that the level of net farm income per hectare, which indirectly reflects greater economic efficiency, is determined by the area operated, use of farm information, field extension staff visits, formal education of a farm operator, and the fragmentation of land holdings. The model developed employs the behavioral assumption of utility maximization by farmers focusing on farm profit and risk aversion components of the utility function. Principal channels through which fragmentation affects utility are: the increase in input costs, the loss of scale economies, and the stifling of technical change. In the empirical application, two measures of fragmentation were retained. One corresponding to the simple definition of fragmentation found in the literature, number of plots (PLT), and a second which incorporates an associated characteristic of land dispersion, distance between parcels (DST).

Study results on factors influencing economic efficiency identified area operated as the most important factor influencing net farm income per hectare, followed by farm information acquired by farmers, farm visits by field extension officers, and education of the principal farm decision-maker. As expected, the number of arable plots cultivated and distance between parcels are negatively and significantly associated with net farm income per hectare, suggesting that land fragmentation results in small and uneconomic size of operational holdings (Gebeyehu, 1995). Land fragmentation therefore appears to affect the level of efficiency attainable in farm operation. As regards farm indicators, results indicate an economy of scale within the farming process itself due to better utilization of labour and other inputs.

The conclusion drawn from this research is that the need for consolidating land, allocating land to more efficient farmers, and enabling efficient farmers to access relatively larger land holdings can be attained through institutions and policies promoting efficiency in human resources and an efficient land (rental) market; although some positive level of land fragmentation may be optimal for farmers given the conditions in which they operate. The negative impact of fragmentation may reflect recent Rwandan policy to reallocate relatively larger holdings to farmers in order to reduce the present dispersed distribution of land (MINAGRI, 1997).

Factors influencing the adoption of recommended and improved farming practices on coffee farms were studied with the objective of making policy recommendations towards the development of sound agricultural policy in Rwanda. A negative relationship was identified between land fragmentation and technology adoption, suggesting that policies that promote consolidation of land are important to achieving improved agricultural performance in Rwanda. An interaction index of age of farm operator, farm size, and number of plots and distance between parcels (characteristics of land fragmentation) is the most important discriminating variable in classifying farmers as non-adopters and adopters. The negative relationship identified between age and adoption indicates that younger farmers tend to be more willing to adopt new technologies due to longer planning horizons (Celis *et al.*, 1991). Furthermore, land fragmentation, as a result of continuous land distributions and growing population, creates a sense of insecurity among farmers, hence preventing them from making additional investment to increase production (Gebeyehu, 1995).

The second most important discriminating variable shows that liquidity significantly influences the farmer's ability to adopt better farming methods. Better educated farmers were more likely to have soils analyzed and use fertilizer. These conclusions are consistent with the evidence concerning the adoption of recommended cultural practices on farms in (Feder and Slade, 1984; Strauss *et al.*, 1991; Celis *et al.*, 1991; Abdulkadir, 1992; and Essa and Nieuwoudt, 2001). This points towards a policy direction of designing extension provision strategies that will target farmers of varying resource base (human and capital) in order to improve the current productivity levels in the coffee industry.

Results also indicate that farmers who have adopted relatively more recommended technologies also tend to enjoy greater tenure certainty. This supports the finding of Place and Hazell (1993) that farmers are more likely to improve parcels over which they have a long-term interest, in terms of their rights to cultivate the land on a continuous basis, to make and enforce a lease or sale contract, and to dispose of the land in ways that provide adequate compensation for the value of any improvements. Gender of the farm operator is an important determinant of the likelihood of adoption, which supports the expectation that female heads of household have poor access to new technologies compared to their male counterparts. Policies in Rwanda should seek to address issues of rural gender discrimination.

Study results on factors influencing the adoption of recommended and appropriate cultural practices on coffee farms reveal that an interaction index of use of farm information, contact with field extension staff and information acquired by farmers (through training in agriculture, particularly coffee growing, and participation in information transmitting activities like seasonal field training workshops) is the fourth and final most important dimension discriminating between non-adopters and adopters. This indicates that proper training and extension support services aimed at increasing farmers' managerial ability should form part of the agricultural restructuring process in the Rwandan agricultural sector. The findings of this study point towards the need for a strong collaborative link between the *Rwandan Industrial Crops Authority* (OCIR) with field extension staff who are mainly in close contact with farmers to facilitate the dissemination of relevant information on better farming methods that is lacking in the majority of small-scale farmers.

Since the subject of this study is to examine the fragmentation issue, several aspects of the issue have been simplified for the purpose of developing the research methodology. These simplifications represent limitations of the work and are avenues for meaningful further research. In spite of the limitations of this study, its approach can lead to new directions in research on the issues of land fragmentation and technology adoption. This study is important to individual coffee farmers by providing an understanding of their economic position in relation to the sizes of farms they operate. It could enhance management decision making processes of coffee producers by enabling farmers to determine probable areas that could be restructured to increase efficiency in coffee production. This is likely to have important implications for the national economy, given that coffee is the most important cash crop, accounting for three-quarters of total Rwandan foreign exchange earnings. The new insights provided by this study are hoped to contribute to the ongoing effort to transform Rwandan agriculture.

CHAPTER 7

SUMMARY

In Rwanda in general and particularly in Butare, the most important feature of land fragmentation is its temporal dimension - the decrease in farm size per household over generations, and much more important is the spatial dimension - plots scattered at great distances. The object of this study is to examine the fragmentation issue in Rwanda by examining how efficiency of resource use on farms varies with the size of a farm business and what implications' variations in performance might hold for the reallocation of resources between area operated groups in pursuit of land redistribution.

Data for this study were collected during 2001 from 100 randomly selected households in each of Rusatira and Muyira districts using a standardized questionnaire. Farms studied are privately owned, and varied from 0.04 to 6 hectares. The size of farm only included land operated by each household.

Agriculture is the mainstay of the Rwandan economy. It contributes around 40 per cent of GDP, and accounts for 85 per cent of foreign exchange earnings. Coffee is the most important crop, accounting for three-quarters of foreign exchange earnings. However, Rwandan agriculture, including coffee farming, is beset by many problems, including land fragmentation, obsolete technology, inadequate infrastructure and a shortage of skilled manpower.

Investigations of characteristics of the sample farmers using regression analysis revealed that, in the early stages of development, the majority of inhabitants of a developing country like Rwanda are dependent on the land. This results in competition for agricultural land. With the process of development, job opportunities are created in the non-agricultural sector and an outflow of labour from agriculture will occur. Such migration will release land which can then be used by the remaining farmers. Tenure certainty and access to agricultural training are also considered as factors influencing change of area operated, basically due to the fact that variants in forms of land tenure cause a range of optimal farm sizes in countries at various stages of economic development and the higher the level of farmers' training the larger the area operated.

The analysis of economic efficiency model shows a strong positive effect of area operated on net farm income per hectare, which indirectly reflects greater economic efficiency. Therefore a greater awareness of the relationship between size and efficiency might, through more efficient use of resources, benefit both the individual small farmer and the community as a whole. In general, differences in efficiency might well be attributable not simply to differences in size but to a whole range of other factors which happen to be associated in different degrees with different sized farms. A negative relationship was identified between land fragmentation and net farm income per hectare, suggesting that land fragmentation results in small and uneconomic size of operational holdings. Economies of size, whereby large farms reduce their average costs, are evident in the data. Conclusions drawn from this research is that the need for consolidating land, allocating land to more efficient farmers and enabling them to access relatively larger land holdings can be attained through institutions and policies promoting efficiency in human resources and an efficient land rental market.

This study has analyzed factors influencing the adoption of appropriate and improved farming practices on coffee farms with the objective of making policy recommendations towards the development of sound agricultural policy in Rwanda. Results indicate a strong relationship between technology adoption and farm performance. Farmers who have adopted relatively more recommended technologies also tend to enjoy greater tenure certainty. It is concluded that agricultural policy in Rwanda should seek to increase farmers' abilities to adopt new technologies, and seek to allocate more land to more efficient farmers. A negative relationship was identified between land fragmentation and technology adoption, suggesting that policies that promote consolidation of land are important to achieving improved agricultural performance in Rwanda.

Another important conclusion of the research is that provision of information alone is not sufficient to promote adoption of recommended farming practices by Rwandan coffee farmers. It is important that policies are in place that improve rural education to improve farmers' abilities to effectively use information provided; policies should be in place to reduce farmers' financial constraints to adopting new technologies and to provide farmers with sufficient access to agricultural resources to spread fixed costs associated with adoption of new technologies and practices. Gender of the farm operator is an important determinant of the likelihood of adoption, supporting the expectation that female heads of household have poor access to new technologies compared to their male counterparts. Policies in Rwanda should reduce gender discrimination in order to improve farmers' abilities and promote adoption of recommended farming practices.

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APPENDICES

Performance of Rwanda's Commodity Exports (1965-1996)

Years	Coffee trading (tons)	Value (x 1000000) RWF	Value of trading exported (x 1000000) RWF	Value of coffee in comparison with all other products trading (%)
1965	9998.00	368.00	692.00	53.18
1966	8738.00	658.00	1190.00	55.28
1967	10127.00	818.00	1575.00	51.94
1968	12055.00	945.00	1613.00	53.59
1969	11894.00	782.00	1439.00	54.34
1970	14729.00	1423.00	2380.00	55.79
1971	15264.00	1211.00	2156.00	56.17
1972	10646.00	980.00	1860.00	52.69
1973	20365.00	1702.00	4287.00	39.70
1974	25077.00	2334.00	4980.00	46.87
1975	26683.00	2790.00	5255.00	53.30
1976	36690.00	6475.00	10456.00	61.93
1977	19159.00	6537.00	11622.00	56.66
1978	19319.00	4533.00	10350.00	43.80
1979	39113.00	12820.00	18838.00	68.05
1980	22418.00	5813.00	12402.00	46.87
1981	30044.00	6342.00	10520.00	60.29
1982	25082.00	6344.00	10069.00	63.10
1983	30075.00	7150.80	10246.10	69.80
1984	31418.00	8810.00	13476.00	65.00
1985	33299.00	9711.00	13476.00	70.00
1986	46933.00	13903.00	16481.00	84.00
1987	29930.00	7725.60	9917.00	77.90
1988	34617.00	7707.00	9850.00	78.20
1989	29340.00	5543.00	8777.00	63.10
1990	42403.00	5763.00	8209.00	70.20
1991	43541.00	9292.00	13763.00	67.50
1992	31946.00	4931.00	9781.00	50.40
1993	33578.00	6667.00	10971.00	60.70
1994	5778.00	1358.30	2641.40	51.40
1995	8972.00	8248.10	11302.40	72.90
1996	22841.00	15143.90	19605.40	77.20

Sources: OCIR CAFÉ (1984); BNR Reports (1997).

APPENDIX B

Commercial Value of Crops Exported By Rwanda (1990-1996)

Crops	1990			1991			1992			1993		
	Quantity (tons)	Value millions (RWF)	Value of each crop (%)	Quantity (tons)	Value millions (RWF)	Value of each crop (%)	Quantity (tons)	Value millions (RWF)	Value of each crop (%)	Quantity (tons)	Value millions (RWF)	Value of each crop (%)
Coffee	43551	5894	70.65	43957	9288	73.78	31909	4924	57.15	33579	6667	70.30
Tea	12600	2225	26.68	12527	2984	23.70	14280	3391	39.36	10237	2695	28.42
Pyrethrum	39.9	212	2.54	33.9	304.6	2.42	30.4	276.9	3.21	23.1	97.2	1.02
Beans	84.8	11.1	0.13	71	12.6	0.10	170.4	23.3	0.27	143.2	20.5	0.22
Bananas	---	---	---	---	---	---	6.2	0.1	0.00	23.7	3.5	0.04
TOTAL	56275.7	8343.1	100.00	56588.9	12589.2	100.00	46396	8615.3	100.00	44006	9483.2	100.00

Source: MINAGRI - OCIR (1998).

APPENDIX B (continued)

Commercial Value of Crops Exported By Rwanda (1990-1996)

Crops	1994			1995			1996		
	Quantity (tons)	Value millions (RWF)	Value of each crop (%)	Quantity (tons)	Value millions (RWF)	Value of each crop (%)	Quantity (tons)	Value millions (RWF)	Value of each crop (%)
Coffee	5778	1358	60.77	8972	8248	81.28	22841	15144	83.64
Tea	3384	854	38.22	4889	1640	16.16	7196	2869	15.85
Pyrethrum	2.0	16.5	0.74	14	259.1	2.55	6.0	92.3	0.51
Beans	21.7	1.4	0.06	---	---	---	---	---	---
Bananas	30.8	4.8	0.21	---	---	---	1.0	0.4	0.00
TOTAL	9216.5	2234.7	100.00	13875	10147.1	100.00	30044	18105.7	100.00

Source: MINAGRI - OCIR (1998).

APPENDIX C

Money Revenues Generated by Coffee in the Rural Area (1965-1996)

Years	Production (tons)		Value (RWF)	
	Parchment coffee	Green coffee	Per kilo	of total production
1965	13330	9979	25	333 250 000
1966	11430	8525	35	400 050 000
1967	15255	9931	35	533 925 000
1968	16296	11975	35	570 360 000
1969	16740	9214	35	585 900 000
1970	19240	14240	35	673 400 000
1971	20870	15245	35	730 450 000
1972	14140	10599	35	494 900 000
1973	19135	14160	40	765 400 000
1974	19002	14061	45	855 090 000
1975	24385	18045	45	1 097 325 000
1976	27478	20344	65	1 786 070 000
1977	20684	16307	120	2 482 080 000
1978	29774	21735	120	3 572 880 000
1979	34315	25050	120	4 117 800 000
1980	27616	20160	120	3 313 920 000
1981	41633	30392	120	4 995 960 000
1982	33528	26541	120	4 023 360 000
1983	33528	26541	120	4 023 360 000
1984	43749	32374	120	5 249 880 000
1985	48027	35539	120	5 763 240 000
1986	47876	35424	125	5 984 500 000
1987	55933	43026	125	6 991 625 000
1988	53782	37647	125	6 722 750 000
1989	39526.5	30405	115	4 545 547 500
1990	50025.3	38481	115	5 752 909 500
1991	35504.3	27311	115	4 082 994 500
1992	47030.1	36177	115	5 408 461 500
1993	37043.5	28495	115	4 260 002 500
1994	---	---	---	---
1995	28377.7	21829	300	8 513 310 000
1996	19810.7	15239	300	5 943 210 000

Source: OCIR-CAFÉ (1989).

APPENDIX D

RIDGE REGRESSION AND ESTIMATORS

Consider the following least squares normal equations for the ordinary multiple regression model:

$$\mathbf{X'X\,b = X'Y} \qquad (1)$$

The least squares estimators are obtained from:

$$\mathbf{b = (X'X)^{-1}\,X'Y} \qquad (2)$$

Following (Neter *et al.*, 1996: 278-279), after standardizing and transforming using a correlation transformation of the Y and X's, equation **(1)** can be expressed as follows:

$$\underset{(p-1)}{X}\,'\underset{(p-1)}{X} = \underset{(p-1)x(p-1)}{r_{xx}} \qquad (3)$$

where $\mathbf{r_{xx}}$ is a correlation matrix of the X variables, whereas

$$\underset{(p-1)x}{X}\,'\underset{1}{Y} = r_{YX} = \begin{bmatrix} r_{y1} \\ r_{y2} \\ \cdot \\ r_{y,\,p-1} \end{bmatrix} \qquad (4)$$

$\mathbf{r}_{yx}$ is the vector of the coefficients of simple correlation between Y and each X variable. It now follows from **(3)** and **(4)** that the least squares normal equations and estimators of the regressions coefficients of the standardized regression model (Neter *et al.*, 1996: 279) are as follows:

$$r_{XX}\, \mathrm{b} = \mathbf{r}_{\mathrm{YX}} \tag{5}$$

$$\mathrm{b} = \mathbf{r}_{\mathrm{XX}}^{-1}\, r_{YX} \tag{6}$$

where

$$\underset{(p-1)\times 1}{b} = \begin{bmatrix} b'_1 \\ b'_2 \\ . \\ b'_{p-1} \end{bmatrix} \tag{7}$$

The regression coefficients b'_1, ... b'_{p-1} are called *standardized regression coefficients*. The ridge standardized regression estimators are obtained by introducing into the least squares normal equations a biasing constant K ≥0 in the following form

$$(\boldsymbol{r}_{\mathrm{xx}} + \mathbf{KI})\, \mathbf{b}^{\mathrm{R}} = \boldsymbol{r}_{\mathrm{YX}} \tag{8}$$

where **I** is the (p-1) x (p-1) identity matrix while $\mathbf{b}^{R}$ is the vector of the *standardized ridge regression coefficients* b_k^R:

$$b^R = \begin{bmatrix} b_1^R \\ b_2^R \\ \cdot \\ b_{p-1}^R \end{bmatrix} \qquad \textbf{(9)}$$

Solving the normal equations in **(8)** yields the ridge standardized regression coefficients:

$$\mathbf{b}^{R} = (r_{XX} + \mathbf{KI})^{-1}\, r_{YX} \qquad \textbf{(10)}$$

APPENDIX E

VARIANCE INFLATION FACTORS (VIF)

The Tolerance for variable X_k is $\mathbf{(TOL)_k = 1 - R_k^2 \quad k = 1,2,3 \ldots, \mathit{p}-1.}$ **(11)**

where R_k^2 is the R-square when X_k is regressed on the other independent variables in the model including the constant. The variance inflation factor in the ordinary least equation for variable X_k is the inverse of the tolerance and measures how much the variance of the standard regression coefficient, b_k is inflated by collinearity. That is,

$$\mathbf{(VIF)_k = 1/(TOL)_k} \qquad \mathbf{(12)}$$

The VIF value for $\mathbf{b}_k^{\mathbf{R}}$ measures how large the variance of $\mathbf{b}_k^{\mathbf{R}}$ is relative to what the variance would be if the predictor variables were uncorrelated. Following Neter *et al* (1996:415), VIF values for the ridge regression coefficients $\mathbf{b}_k^{\mathbf{R}}$ are the *diagonal elements* of the following (p-1) x (p-1) matrix:

$$\mathbf{(\mathit{r}\,xx + KI)^{-1}\ \mathit{r}_{XX}\ (\mathit{r}\,xx + KI)^{-1}} \qquad \mathbf{(13)}$$

A sufficiently small value of VIF for $\mathbf{b}_k^{\mathbf{R}}$ is desirable when choosing the stable coefficients (Neter *et al.*, 1996). Further, the smallest value of the biasing constant, K, where the regression coefficients first become stable in the *ridge trace* should also be examined for decision.

APPENDIX F

HOUSEHOLD SURVEY QUESTIONNAIRE, 2000

This questionnaire is to be completed for each parcel used (owned, allocated, borrowed, or rented in) by the household. Questions will be addressed to the Land Holder of the parcel (the person who maintains overall control of the parcel) and to the Land Users of the parcel (those who use the parcel for agricultural production). The information recorded during this interview is strictly confidential. The respondent should be a male or female head. Respondents are not required to answer questions if they do not wish to do so.

Date : ----------------------------

Place : ----------------------------

Region : ----------------------------

Land Holder's name : ----------------------------

Respondent : ----------------------------

Relation to Land Holder : ----------------------------

Household No : ----------------------------

Section 1: Household characteristics

A. Household composition

Household member	Gender (M or F)	Age (years)	Occupation [1]	Cash income (Frw/month)	Cash remitted (Frw/month)	Disability and pension payments (Frw/month)	School standard passed[2]
1. Male head							
2. Female head							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

1. Occupation should be categorized as: Wage Employed (WE); Farmer (F); Self- Employed (SE - e.g. builder, works in town, taxi driver, etc); Housekeeper (H); Pensioner (P) if in receipt of pension; Disabled (D); if paid a disability grant; Unemployed (U) if seeking work; Infant (I) if too young to attend school; or vagrant (V).
2. Education should be categorized as: (0) No Education; (1) Grade 6 and below; (2) Grade 7 to Grade 12; and (3) Tertiary education.

2. If the household head is female, is she widowed? ------------------- **Yes/No**

3. How many family members work on the farm at planting time? -------------------

B. Background Information

1. For how long have you been growing coffee? ------------- **years**

2. Have you ever had **practical training** (i.e. field day demonstrations, group meetings, or any other form of training) relating to coffee growing? ------------- **Yes/No**

3. State the number of times you have attended such **training programs** (i.e. field days demonstrations and other forms of training) in last **two** seasons ------------ **times**

4. Please **rank, how useful** you have found the following in assisting you to **improve the productivity** of your farm? Please **circle** the number that best indicates your judgment as indicated by the scale below.

Not Useful	Less Useful	Useful	Very Useful
0	1	2	3

Economic advisors from the coffees' Association	0	1	2	3
Coffee Experiment Station(s)	0	1	2	3
Extension officer(s)	0	1	2	3
Training during Field Days-Demonstrations	0	1	2	3
Other Farmers	0	1	2	3
Farm Magazines	0	1	2	3

5. Approximately, **how many times** did the extension officer(s) visit your coffee farm in the last **two** seasons?

10 +	
7-9	
4-6	
1-3	
None	

6. How do you **rate** your Field lay-out plan on your coffee farm relative to other farmers in your district? (tick where appropriate)

Very Good	
Good	
Satisfactory	
Fair	
Uncertain	

7. What would you **comment** about your coffee growing **under normal weather Conditions** relative to other farmers in your district? (tick where appropriate)

Very successful	
Successful	
Not successful	
Failure	

8. Have you ever had **farm soils** tested on your coffee farm? ---------------- **Yes/No**

Section 2: Farm Characteristics

	Arable land						
	Allocated land cultivated	**Allocated land leased/lent out**	**Allocated land left idle**	**All arable land**	**Land rented in ***		
					1	**2**	**3**
No of arable plots cultivated now and in the past							
Size (ha)							
Slope							
Aspect							
Distance between arable and residence (Km)							
Distance to nearest irrigation water (Km)							
Waterlogging problems **(Y or N)**							
Arable land quality**							
Have the farm boundaries changed since acquisition?							
If **Yes**, is the farm **larger** or **smaller** than before?							

* Record the lessee's 3 most important rental contracts
** 1 Poor; 2 Below; 3 Average; 4 Good; 5 Excellent
Missing values score –1

2.1 Did you plant all your own arable land last season? -------------- **Yes/No**

If **no,** what portion of your arable land did you plant? (tick where appropriate)

Portion	Arable land
All (100 %)	
Most (75 %)	
Half (50 %)	
Some (25 %)	
None	

2.2 List the main reasons for not cultivating all of the arable land

1. --
2. --
3. --
4. --

Section 3: Crop Production during Past Year

Crop	**Hectares**	**Total Harvested**	**Quantity Sold**	**Gross Income (RWF)**
Coffee				
1.				
2.				
3.				
4.				
5.				
Grazing		**************	**************	**************
Forestry				
Other (Specify)				

3.1 What was the **average price** paid for each Kg of coffee? ------------- RWF

3.2 Over the last years, what has been the **average yield** on your coffee farm?

---------------------- Kg/hectare

3.3 From your **personal judgement**, what size of farm can you **operate** efficiently, with your present resources? ------------------------ Hectares.

3.4 How many Kg of coffee would you have to cut to lead a **decent life?**

-------------------- Kg/Season

3.5 What is the next **alternative crop activity** you would consider investing in if are to **switch** farm resources from coffee production? ------------------------

3.6 Please indicate what you think are the major **limiting factors** to coffee farm expansion, by circling the number that **best** expresses your **judgement** as indicated by the scale below

Not Limiting	Limiting	Quite Limiting	Very Limiting
0	1	2	3

Lack of land to extend on Farm operation	0	1	2	3
Lack of capital to purchase inputs	0	1	2	3
Lack of labor	0	1	2	3
Lack of extension Services	0	1	2	3
Low prices paid for surplus	0	1	2	3

Livestock

Livestock	Number Owned	Number Sold	Gross Income (RWF)
Oxen			
Cows			
Bulls			
Goats			
Pigs			
Chicken			

Section 4: Farming Expenses on inputs (past season)

Inputs	Used (Yes/No)	Quantity Purchased	Quantity Used	Total Cost
Chemical fertilizer		/ (50Kg Bags)	/ (50Kg Bags)	

Section 5:Credit Use

5.1 Have you **used** credit for agricultural inputs in the past two years? ------------ **Yes/No**

If **Yes,** go to question 5.2 If **No**, go to question 5.4

5.2 What was the source of the credit used in the past two years?

Source of credit	Used (Year)	Collateral required (Y or N)	Collateral used		Used for [1]	Amount borrowed (RWF)
			Land	Other (group)		
Commercial Bank						
Farm organization						
Co-operative						
Relative						
Friend / Neighbour						
Informal lender						

[1] Production credit, purchase machinery, purchase land, finance land improvements, no-farm use (housing, education) etc

5.3 After how long were you expected to repay the loan? (tick were appropriate):

1 year --------------

2 - 5 years --------------

5.4 If you **didn't** use credit, would you like to? ---------------- **Yes/No**

If **Yes**, what have prevented you from using credit? (tick where appropriate):

a) There is no credit available -----------
b) Credit is too expensive ------------
c) You cannot use land as collateral for credit -----------
d) Creditors will not accept land as collateral -----------
e) Credit is too risky -----------

Section 6: Land Transactions

6.1 Tenure Characteristics

6.1.1 How long has the land been farmed by this household? ---------- **years**

6.1.2 How did you acquire the land? (tick where appropriate)

a) By inheritance -----------
b) By purchase -----------
c) Long term lease (option to purchase) -----------
d) Government allocation (e.g. district council) ----------
e) Tribal allocation (e.g. chief) ----------
f) Other methods (specify)

6.1.3 Who owns this land?	**Arable:**	**Grazing:**
a) Family	------------	-----------
b) Chief	-----------	-----------
c) Government	-----------	-----------
d) Other (specify)	----------	-----------

6.1.3.1 If your family owns the land, does it possess a registered title deed to the land ------------- **Yes/No**

If **Yes**, in who's name is the title registered? (tick where appropriate)

a) Present household -----------------
b) Previous household head (ancestor) -----------------

6.1.3.2 Do you feel secured of your long-term tenure? --------- **Yes/No**

If **No**, why? (specify) ---

6.1.3.3 Have you made any fixed improvements on your land? ----------- **Yes/No**

6.2 Transfer rights

6.2.1 Can you specify the heir to this land? -------------- **Yes/No**

6.2.2 Are there rules that prevent you from renting out or lending surplus land to other individuals? -------------- **Yes/No**

6.2.3 Can you sell your land? **Arable:** ------------- **Grazing:** -------------

If **Yes**, does the household require permission from others?

a) Permission not required ------------
b) Family members ------------
c) Tribal authority ------------
d) Government official ------------

6.3 Use Rights

Land Rights [1]	Land Types	
	Arable	Grazing
Can you crop this land throughout the year?		**********
Can you fence off this land?		**********
Can the rest of the community use your unused land? (e.g. for planting or gathering thatch and firewood)		
Can you gather natural resources (e.g. thatch, firewood) on land that is not being cultivated by the community?		
Are there any rules controlling this? (**Yes** or **No**)		
Can you exclude other peoples' livestock from grazing on the land?		**********

[1] **Code**	**0**	**No**
	1	**Yes, without authorization**
	2	**Yes, with Household head's approval**
	3	**Yes, with Tribal Authority approval**
	4	**Yes, with Government approval**
	5	**Don't Know**

6.4 Land Sales

6.4.1 Have you ever **bought** additional land? ------------- **Yes/No**

If **No**, would you like to **buy** more land? ------------ **Yes/No**

If **Yes**, motive for purchase (tick where appropriate):

a) place of residence ------------- b) land for children ------------

c) investment ------------- d) farming and/or grazing -----------

e) establish enterprise ------------ f) other ------------

6.4.2 If you **do** want to buy more land but have not, what have prevented you from doing so? (tick where appropriate):

a) There is no land to buy ------------
b) Land is too expensive ------------
c) Tribal authorities do not allow land to be bought ------------
d) Government does not allow land to be bought ------------

6.4.3 Have you ever **sold** any land? ------------- **Yes/No**

6.5 Land Disputes

6.5.1 Have you or any members of your family ever had a dispute over land ownership or boundaries in the past 5 years? ------------- **Yes/No**

If **Yes**, with whom? (tick where appropriate):

Family	------------	Neighbours	------------
Tribal Authority	------------	Government	------------
Others (specify)	------------		

If **Yes**, has the dispute been resolved? ----------- **Yes/No**

If the dispute **has been resolved**, who was involved in resolving it? (tick where appropriate):

Resolved ourselves	---------------	Religious Leader	----------------
Tribal Authority	---------------	Witnesses	----------------
Magistrate	---------------	Other (specify)	---------------

6.5.2 Are land disputes? (tick where appropriate):

More serious now than in the past --------------------

Not as serious as in the past --------------------

Not a problem -------------------

6.5.3 What are the most frequent types of land disputes farmers face in the area?

6.5.4 Do you know a household that has been dispossessed of its land after a land dispute? -------------- **Yes/No**

Section 7: Extension and Information

7.1 Estimating the rural and urban population in the study areas.

Urban: -------------- (%)

Rural: -------------- (%)

7.2 Opportunities of peasant households getting a job in non-agricultural activities.

Industrial: --------------- (%)

Services: --------------- (%)

7.3 Farmers' viewpoint on advantages and disadvantages of fragmentation.

Advantages: --------------------------- Disadvantages: -----------------------

--------------------------- ------------------------

THANK YOU FOR PARTICIPATING IN THIS STUDY