PEOPLE AND BANANAS ON STEEP SLOPES: AGRICULTURAL INTENSIFICATION AND FOOD SECURITY UNDER DEMOGRAPHIC PRESSURE AND ENVIRONMENTAL DEGRADATION IN RWANDA

By

Jaakko Kangasniemi

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ABSTRACT

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This research uses national farm survey data and other information to investigate agricultural intensification in Rwanda. The main focus is on how farmers are changing their land use in response to population growth.

The study shows that under demographic pressure, Rwandan households are expanding cultivation at the expense of pasture and fallow and relying increasingly on four crops: bananas, beans, sweet potatoes, and maize. While beans, sweet potatoes and maize are staples grown mostly for subsistence consumption, the expansion of bananas is largely a market-driven process. In 1990, bananas brought more cash to Rwandan farm households than coffee. The exchange of banana beer for food helped many poor households achieve food security. In part, this strategy is based on high taxes on industrially produced beer and low barriers for the informal imports of beans and cereals.

The results also show that land scarcity pushes Rwanda's smallholders to grow bananas in dense multi-layered associations with other crops rather than on separate fields. In much of Rwanda, banana intercropping already accounts for more than half of the erosion-prone hillsides. Soil losses on fields intercropped with bananas vary greatly

depending on crop management practices, but are generally well below those recorded on fields without bananas.

Population growth itself need not push Rwandan farmers to replace their beer bananas with food crops, but restrictions on food imports or declining banana yields due to pests or diseases could do so. However, if Rwanda's economy recovers and if policies target food security rather than food self-sufficiency, market-oriented intensification with bananas, perennial export crops, agroforestry, and mixed farming is likely to continue.

The large and expanding role of banana intercropping suggests that research and extension to make banana associations more productive and sustainable deserve high priority. Especially increases in the productivity of food bananas would contribute greatly to food security. Both environmental and food security concerns argue for policies that invest in rural infrastructure and tax consumption rather than trade, thereby allowing farmers to specialize increasingly in high-value cash crops that in Rwanda happen to be also less degrading than the staple food crops.

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LIST OF ABBREVIATIONS

AE	Adult equivalent
CNA	National Agricultural Commission (of Rwanda)
C-value	Index of crop cover
DAI	Development Alternatives Inc.
DSA	Division of Agricultural Statistics (of Rwanda's Ministry of Agriculture)
FAO	Food and Agriculture Organization of United Nations
FRw	Rwandan francs
MINAGRI	(Rwanda's) Ministry of Agriculture and Livestock)
MINIPLAN	(Rwanda's) Ministry of Planning
MSU	Michigan State University
RPF	Rwandan Patriotic Front
TLU	Tropical livestock unit
USAID	United States Agency for International Development

Chapter 1

INTRODUCTION

1.1 Intensification and Commercialization

During the next quarter of a century, the population of sub-Saharan Africa[1] is projected to double (World Bank 1995). As a result, hundreds of millions of rural Africans will not be able to survive by expanding cultivation as their parents and grandparents had done. Instead, they will have to increase production by substituting other inputs for land. If food security is to improve under demographic pressure, farming systems need to undergo major changes. This requires public policies and investments that facilitate sustainable intensification.

Africa already has several pockets of high population density, where land is scarce and where farmers are intensifying by inventing and adopting new agricultural practices, by adjusting their crop mix, and by purchasing new inputs (Kates, Hyden, and Turner II 1994). In addition to being a home to tens of millions of people, these intensively farmed areas are pioneers, struggling now with many of the problems that other areas will face soon as their population grows.

As the most densely populated country in continental Africa, Rwanda is in the forefront of agricultural intensification. Like most other densely inhabited areas in Africa, Rwanda has found that the fast transition from extensive growth to intensification is difficult. After being one of the few African countries where food production increased faster than population in 1960-1980 (Harrison 1987), Rwanda's agriculture apparently failed to keep pace with population growth after the mid-1980s, when the land frontier

[1] Hereafter, "Africa" is used to denote sub-Saharan Africa.

became virtually exhausted (MINAGRI 1992). The resulting impoverishment and declines in food access also contributed to the genocide of 1994 (Grosse 1994; Olson 1994; Sellström and Wohlgemuth 1996).

Four years later, Rwanda's agriculture has largely recovered from the events of 1994 (Economist Intelligence Unit 1996a, 1996b, 1997), but the challenge of intensification remains unsolved. To feed the expanding population without destroying their resource base, Rwandan farmers need support for their intensification efforts from appropriate public investments and policies. The design of appropriate interventions requires information on how the farming system is changing under population pressure. Policymakers need to know how farmers are using their increasingly scarce land and what are the factors that determine whether they resort to unsustainable practices to survive on their tiny farms. Since many of the public policies affect farmers via markets, the relationship between intensification and commercialization is of particular interest.

General literature on semi-subsistence agriculture provides important insights and hypotheses, but cannot give specific answers. For instance, theory has no unequivocal conclusion on whether agriculture will become more or less commercialized as it intensifies during demographic pressure. On the one hand, population growth can push farmers to specialize in cash crops that give highest returns to scarce land (von Braun, de Haen and Blanken 1991; Hillman 1981). Moreover, since very small farms do not have enough land to restore fertility via fallowing, they may need to produce cash crops to be able to buy fertilizer and other inputs (Ruthenberg 1976; von Braun and Kennedy 1994). On the other hand, many researchers have pointed out that due to high transaction costs and unreliable markets for food and for cash crops, poor rural households may have good reasons to prioritize subsistence production and produce for the market only after most of their subsistence food needs have been met (de Janvry, Fafchamps and Sadoulet 1991; Fafchamps, de Janvry, and Sadoulet 1995; von Braun and Kennedy 1994). Where the rational for "food first-strategy" prevails, land scarcity brought about by population growth can reduce cash crop production and push households back towards subsistence production. On the other hand, population growth could also undermine the rational by helping to reduce transaction costs and make markets more reliable.

Empirical studies on Rwanda's agricultural intensification also have considerable gaps. Many have focused on small, unrepresentative areas. In most of Rwanda, farming systems are dominated by bananas, mostly grown for beer[2], but in attempting to select areas where the pressure on resources is greatest, many of the best studies of the intensification process have focused entirely or mostly on high-altitude and/or marginal areas where few bananas are grown (von Braun, de Haen and Blanken 1991; Olson 1994; Ford 1994; Charlery de la Masselière 1989, 1992, 1993a). While there are good reasons to study the most food insecure or the most densely populated areas, the past studies can cast little light on the ongoing intensification process in the banana-growing areas that cover most of Rwanda. The focus of the present study is on these areas and specifically on the role of bananas in Rwanda's agricultural intensification.

When empirical studies have looked nationally at the questions discussed above, they have often done so on the basis of quite limited evidence and come up with contradictory answers. The ongoing and expected crop mix changes are a case in point. The conventional wisdom is that the transition to roots and tubers that has been going on for decades will continue in the future. However, in one of the most detailed studies of rural Rwanda, Bart (1993) predicts that the current peri-urban cooking banana gardens

[2] Banana beer is a rapidly fermented, poorly storable drink with a low (and varying) alcohol content. In Rwanda, it is typically produced artisanally out of beer bananas (plus small amounts of sorghum) that are distinct from cooking bananas. Because it is mostly fruit-based, banana beer is occasionally called "wine," but this risks creating confusion with another product, a long-fermentation more storable beverage known as wine ("vin") that is also made artisanally out of bananas in Rwanda, but is not nearly as important as the ubiquitous beer (Miklavcic 1995). Also distilled hard liqueurs can be made out of bananas, both industrially and artisanally, but they play only a minimal role in rural Rwanda.

give a preview of tomorrow's agriculture in Rwanda[3]. Several researchers have argued that if population growth reduces per capita food production, farmers will substitute food crops for their beer bananas (Jones and Egli 1984; Cambrezy 1984). However, the land use statistics for 1984-1990 indicate that while per capita food production declined, farmers planted more beer bananas and coffee (MINAGRI 1992).

Regarding commercialization, there is a wide consensus among researchers (e.g., Charlery de la Masselière 1992; Jones and Egli 1984; Cambrezy 1984) and policymakers in Rwanda and in donor agencies (Ntezilyayo 1986; CNA 1992a; World Bank 1991) that under demographic pressure Rwandan farmers are reverting back to subsistence. However, the land use statistics for 1984-1990 cited above do not show any such trend. Moreover, many of those warning about declining cash crop production in fact focus on export crops, ignoring bananas and other non-export crops that are frequently grown for sale.

The purpose of this study is to inform agricultural policies in Rwanda by looking specifically at ongoing changes in land use and at the participation of rural households in agricultural product markets in the context of demographic change and environmental degradation. More specifically, we ask what explains households' land use and marketing decisions, how households are responding to demographic change, and why some households are more successful in finding sustainable solutions to the increasing land scarcity than others. In less detail, we also review literature and some data on other agricultural and non-farm responses, seeking to put the land use and marketing decision in a wider perspective on what are households' strategies to cope with the increasing demographic pressure on resources.

[3] Although Bart's book was published in 1993, his statistics on the "current" situation were mostly from the 1984 national agricultural survey.

Although the focus is on Rwanda, the study may also have wider relevance for the highlands in eastern and central Africa. Together these areas cover close to 100 million hectares and are home to perhaps 100 million people (Lewis and Berry 1988). Most of these highlands have much higher population densities than the surrounding lowlands. Like Rwanda, they typically have sufficient rainfall for cultivation and steep slopes, some of which are fertile and volcanic, but most relatively poor and prone to erosion. Many of the highlands have sedentary farming systems that resemble much more Rwanda's farming systems than those of their surrounding lowlands. With population growth, many of these areas are rapidly approaching the problems that Rwanda is struggling with today. Just as this study repeatedly refers to the experiences documented in the highlands of Kenya, Tanzania, Burundi, Uganda, Democratic Republic of Congo[4], and Ethiopia, those working on these highlands may find the observations and conclusions of this study useful. The findings should be of particular interest for those focusing on Burundi, which is very similar to Rwanda in many respects.

In Rwanda, intensification is a key food security question. In a predominantly agricultural, landlocked country with almost no unused cultivable land and limited hope for rapid increases in non-farm employment, it is only a slight exaggeration to say that food security succeeds or fails with agricultural intensification. But intensification is also an environmental issue, particularly in the less densely populated countries like Tanzania. Failed intensification may not lead to starvation there as easily as in Rwanda, but may instead force farmers to expand to new areas.[5] Whether the remaining forests and wetlands on the East African highlands and many of the species endemic to these areas can be saved depends largely on how well agricultural intensification succeeds in the

[4] Former Zaire, hereafter referred to as "Congo."

[5] Examples of outmigration in the context of failed intensification abound in the literature. Ruthenberg (1968 and 1976) discusses several cases and Kajumulo-Tibaijuka (1984) reports of one case that has much relevance for Rwanda and is discussed in some detail below.

currently farmed areas. By informing policies on agricultural intensification, this study also hopes to contribute to environmentally sound development.

1.2 Organization of the Study

This study comprises nine chapters. Chapter 2 provides a brief overview of the geography and history of Rwanda as well as a somewhat more detailed review of agricultural developments in this century. Since the main issue in Rwanda's agriculture in this century is the expansion of population from 1-2 million to about 8 million in 1994, much of the discussion looks at the long-term trends in agricultural intensification.

In chapter 3, the literature of agricultural intensification is reviewed. Although the theoretical starting point is on the writings of Thomas Malthus, Esther Boserup and their followers, the main focus is on empirically based studies on the African continent.

Chapter 4 describes the surveys which form the empirical basis of this study and discusses the methods used in transforming raw survey data into analytically meaningful numbers.

The results of the study are presented in chapters 5, 6, and 7. Chapter 5 examines the patterns and determinants of land use, focussing on how the most land-scarce farmers differ in their land use from that of their neighbors with more land per person. Chapter 6 studies the patterns and determinants of market participation. The main focus is on how and to what extent Rwanda's poor rural households use markets to survive with their limited land resources. In chapter 7, we look in some detail at the contribution of bananas for food security.

Chapter 8 draws from other literature and somewhat also from DSA data to look on other aspects of agricultural intensification, including soil conservation investments, livestock practices, and the use of agricultural inputs. The purpose is to put the results of this study into a wider perspective.

Finally, in chapter 9, we summarize the results of the study and discuss their implications for agricultural policy in Rwanda and similar countries.

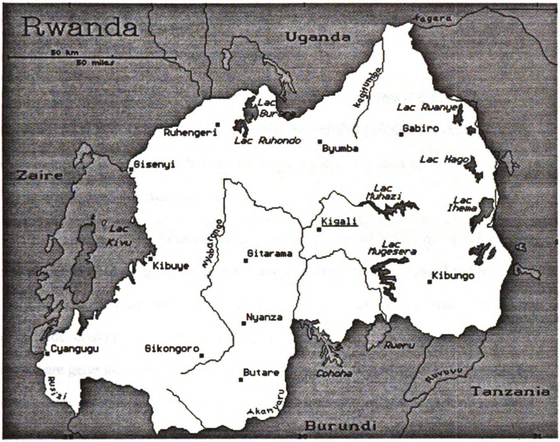
Chapter 2

BACKGROUND ON RWANDA

2.1 Geography and Climate

Rwanda is a small, landlocked country located close to the equator in the highland region of east-central Africa (Figure 2-1). It is bordered by Tanzania to the east, Uganda to the north, Congo to the west, and Burundi to the south. Most international trade normally flows through Uganda and Kenya, whose port town Mombassa lies about 1700 kilometers to the east by road (Sirven, Gotanegre, and Prioul 1974).

With a land area of 26,338 square kilometers (2.6 million hectares), Rwanda is slightly smaller than Belgium, its former colonial ruler. Almost the entire country is over 1000 meters above sea level and about 1.5 million hectares are over 1500 meters, the altitude often used to define highlands (Lewis and Berry 1988). Due to the high altitude, Rwanda enjoys a mild temperature, averaging about 19 degrees Celsius. While temperature shows little seasonal variation, rainfall follows a bimodal pattern. The longer rainy (and hence growing) season ranges from February to May, and the shorter one from October to December (Nduwayezu 1990). Summer months are dry and little agricultural work is done in August.



Source: The World Bank

Figure 2-1: Map of Rwanda

Despite its small size, Rwanda contains substantial climatic variation, largely attributable to altitude. The eastern third of the country is relatively low (1000-1500 meters) , warm (above 21 degrees Celsius), and, except for the swamps, dry (800-1000 mm). The natural vegetation consists mostly of woody savannah, not closed forests as elsewhere. The landscape is hilly, but not as mountainous as elsewhere. By Rwandan standards, the East is a drought-prone region, much of which has only recently become settled, and still is relatively sparsely inhabited.

The central plateau lies between 1500 and 1900 meters and has milder temperatures (17-20 degrees Celsius) and higher rainfall (1000-1300 mm) than the eastern lowlands. This is the historic core of Rwanda, "the land of thousand hills" , and has a long history of dense settlement.

To the west of the central plateau lies the Congo-Nile Divide, which consists of a mountainous chain running north-south and separates the Nile watershead to the east and Lake Kivu to the west. Much of the mountain chain is between two and three kilometers of altitude, cool (15-17 degrees Celsius) and rainy (more than 1200 mm rainfall). The slopes are generally steep and highly prone to erosion. In northwestern Rwanda, the divide consists of a chain of volcanic mountains, several of which peak above 3500 meters. The volcanic soils are much more fertile and less prone to erosion than the soils elsewhere on the Divide.

The shores of Lake Kivu resemble the Congo-Nile Divide in rainfall but central plateau in temperature.

Administratively rural Rwanda is divided into ten *prefectures*, named for their respective capitals (Sirven, Gotanegre, and Prioul 1974; Grosse 1994). In addition, there is one urban prefecture consisting of Kigali, the capital city. Much of the rural Kigali, as well as Byumba in the north-east and Kibungo in the south-east cover eastern lowlands and have large farms by the standards of Rwanda. Gitarama and Butare on the high plateau are the historic center of the country. Also Gikongoro and Kibuye on the Congo-Nile Divide belonged to the core but had a lower agricultural potential and were partly cleared for cultivation only in this century. Cyangugu in the south-west is separated from the rest of Rwanda by a large national park, Nyungwe forest, and relies much on cross-border trade with Congo and Burundi. The northwestern prefectures of Ruhengeri and Gisenyi are very densely populated, but were historically somewhat separate from the core.

For analytic and policy purposes, several agricultural classification schemes have been devised for Rwanda. The most widely used is the division of Rwanda into 12 *agricultural regions* (Delepierre 1982). Producing representative survey data for 12 regions, some of which are quite small, would either require very large national samples or result in unreliable statistics for some of the regions. Therefore, the Division of Agricultural Statistics (DSA) of Rwanda's Ministry of Agriculture used in its survey work another classification, which divides the country into five agroclimatic zones: *North-West, South-West, Center-North, Center-South,* and *East*. The problem with this scheme is the great variation within the zones. North-West, for instance, includes both some of Rwanda's most productive banana groves by Lake Kivu, temperate volcanic highlands that are too cool for bananas but highly productive under potatoes, marginal farming systems on the non-volcanic and erosion-prone parts of the cool highlands, and warmer mid-altitude areas typical for much of the rest of the country. Agroclimatic differences between Center-North and Center-South are probably much smaller than those within North-West. When referring to these five zones below, we call them *geographic regions*.

A third scheme, used in some form by Jones and Egli (1984), Ange (1987) and Nduwayezu (1990), separates three large zones mostly based on altitude: *Central* (or *High*) *Plateau* consists of the historic "land of thousand hills" between 1400 and 2000 meters, *East* includes the warmer and drier regions at lower altitudes to the east of the High Plateau, and *Congo-Nile Divide* covers the high-altitude watershed lands on the mountain chain to the west of the Plateau. In addition, there are two smaller zones:

Volcanic Highlands on the northern edge of the Congo-Nile Divide and *Kivu*, a narrow strip between the Divide and Lake Kivu. This is the classification used implicitly in the beginning of this section. However, nationally representative farm surveys have not been designed to provide reliable information for each of these five zones. Therefore, statistics computed for each of the two small zones have large margins of error.

2.2 People and History

Rwanda is the most densely populated country on the African continent. In early 1994, its population was about 7.9 million, which translates into a density of roughly 300 inhabitants per square kilometer or three per hectare (Grosse 1994). The density relative to cultivable land (outside national parks) was about double this, and the most densely inhabited regions of the country had rural population densities close to 1000 per square kilometer. Although not exceptionally high by the standards of many rice-growing areas of Asia, such densities are rare in Africa (Kates, Hyden, and Turner II 1993).

In part, Rwanda's high population density is related to its altitude. Also in Tanzania, Burundi, Congo, Uganda, Kenya, and Ethiopia, highlands tend to have much higher population densities than the surrounding lowlands. Highlands are generally more suitable for agriculture due to higher rainfall and more fertile soils and they also provide some protection from tropical vector-born diseases such as malaria and sleeping sickness (Lewis and Berry 1988). Moreover, the isolation promoted both by geography and by the precolonial kingdoms protected the populations of Rwanda and Burundi from the great epidemics (cholera and smallpox) of the nineteenth century (Gourou 1953).

At the turn of the century, colonial administrators estimated Rwanda's population to be about two million (Guichaoua 1989), but some later estimates for that period are barely above one million (Nzisabira 1989a, 1989b). Since the estimate for 1949 is below two million, interpretations of what happened in between vary widely. Grosse (1994) considers the higher initial figures to be more credible and sees no population growth, whereas Olson (1994) states that population doubled between 1920 and 1950 due to advances in health care and food production. In any case, there were considerable fluctuations. A series of famines occurred in the late 1920s, probably decreasing population through death and outmigration. Population increased in the 1930s, perhaps to almost two million, only to be reduced to some 1.5 million by a major famine during World War II. The period of rapid growth started after the war. Between 1950 and 1994 the population increased fourfold, starting from about two million, reaching three million in 1964, four million less than ten years later, five million before the end of 1970s, and climbing to almost eight million by April 1994 (Hamand 1982; Lalou 1993; Grosse 1994).

According to the 1991 census, 95 percent of the population is rural. Even allowing for some urban undercounting and misclassification of both individual people and locations as rural when they in fact were urban (Grosse 1996), it remains true that Rwanda is one of the most rural countries in the world, with more than 90 percent of its population living in rural areas.

The only sizable city is the capital, Kigali, with about 300,000 residents in 1988 (Nduwayezu 1990). The other 11 officially recognized towns were estimated to have a total population of about 200,000. Beyond that, there are few hamlets or even large villages, since Rwandan farmers usually have their dwellings in the middle of their fields.

Unlike most African countries, Rwanda has a long history as a "nation" that shares a single territory, language, and culture. Yet, there are three ethnic groups, Hutu (88-90% of the population), Tutsi (9-11%), and Twa (less than 1%). The Twa presumably descend from the original hunter-gatherers, the Hutus are descendants of the Bantu farmers that migrated to Rwanda perhaps 1000 years ago, and the Tutsis are believed to descend from the pastoralists who came some 500 years ago establishing a feudalistic control over the others (Vidal 1985). By 1900, the kingdom of Rwanda encompassed much of what is today Rwanda. The kingdom was a highly stratified society, where Tutsis were rulers and herders, while Hutus were primarily cultivators and the Twa hunters and artisans. However, some fluidity existed in ethnic identity. Some Hutus accumulated cattle and became regarded as Tutsis, while some Tutsis who lost their herds assumed Hutu identity.

Rwanda and neighboring Burundi, which resembles it in many respects, were occupied by German colonial troops at the turn of the century, but the presence of the Germans was minimal. During the World War I, Belgium seized the territory and started to administer it through the existing Tutsi monarchy. This "indirect rule" favored the Tutsis and made the feudalistic relationships between Tutsi chiefs and Hutu peasants more exploitative and the ethnic identities more rigid (Newbury 1988). At the same time, colonialists promoted Christianity and other new ideas that undermined the legitimacy of the Tutsi rule. In the 1950s, educated Hutus started to mobilize and articulate the discontent. A violent rebellion ensued in 1959, and tens of thousands of Tutsis left as refugees. Belgian administrators decided to promote majority rule, organizing elections in 1960-61, abolishing monarchy, and transferring power to a Hutu-dominated government in 1962. In the southern part of the colony, and later in independent Burundi, Tutsis remained in power.

Rwanda's first government under president Gregoire *Kayibanda* was explicitly pro-Hutu. Inter-ethnic violence escalated and almost 200,000 more Tutsis left for neighboring countries (Grosse 1994). The remaining Tutsis lost their privileges, including exclusive rights to grazing lands. Increasingly, Hutus and Tutsis alike were farmers.

In 1973, Major General Juvenal Habyarimana replaced Kayibanda in a bloodless coup. President Habyarimana preached reconciliation between ethnic groups and allocated government positions proportionally to them. Intermarriage became common and Habyarimana was widely credited for creating ethnic peace in Rwanda. This view was not, however, shared by most of the exiled Tutsis, few of whom returned. Moreover, a regional split developed, as president Habyarimana, a northener, channelled government jobs, educational opportunities, and development funds disproportionately to the northwestern prefectures of Ruhengeri and Gisenyi.

In late 1990 and again in early 1993, the Rwandan Patriotic Front (RPF), dominated by the exiled Tutsis, attacked Rwanda from Uganda. The war greatly increased ethnic tensions and further weakened the economy, already suffering from low coffee prices and agricultural stagnation. Under pressure from donors, Habyarimana was forced to legalize opposition parties in 1991. Groups close to Habyarimana started to mobilize support among the Hutus by vilifying the Tutsis and by labeling the more conciliatory opposition parties as RPF collaborators (Prunier 1995).

In August 1993, President Habyarimana, opposition parties, and RPF reached an agreement on power sharing, transitional government, and multi-party elections. The implementation of this "Arusha Accord" was repeatedly delayed. In April 1994, the assassination of President Habyarimana unleashed simultaneously a genocide and a civil war. In the genocide, between half a million and one million Tutsis and mostly southern Hutus were killed by extremist Hutus associated with the regime. In the war, the RPF invaded the country, which ended the killings of the Tutsis by August 1994, but also caused a mass exodus of almost two million Rwandans (mostly Hutus) to neighboring countries.

For two and a half years most of the (new) refugees stayed in the camps in Congo, Tanzania, and Burundi. Meanwhile, hundreds of thousands of earlier "old caseload" refugees (mostly Tutsis who had left in and after 1959) returned to Rwanda. Some of the "old caseload" refugees returned fearing the genocidal campaign that was continuing in and around the refugee camps, especially in Congo. The situation remained tense also in Rwanda, where dozens of killings and revenge killings were reported monthly and where tens of thousands of suspected genociders were kept without trial in overcrowded prisons.

In November 1996, a (largely Tutsi) rebellion in Eastern Congo triggered a sudden return of more than half-a-million (Hutu) refugees, followed by further repatriations of most of the remaining refugees in 1997. In December 1996, hundreds of thousands of refugees were repatriated from Tanzania. After these returns, the total number of people inside Rwanda's borders exceeds that of 1990, when most of the statistics used in this study were collected, and is probably close to the pre-genocide level of 7.8 million (World Bank 1998). Within few years, Rwanda's population density will climb to unprecedented levels. Despite the genocide of close to one million people, adaptation to high population pressure remains a central issue in rural Rwanda.

2.3 Agricultural Developments

2.3.1 Pre-Colonial Practices: Extensive Grazing and Small Plots

When the Europeans arrived at the turn of the century, much of the "country of thousand hills" was covered by almost treeless grasslands. Except for small areas in the dry eastern savannas, the grasslands were created by centuries of grazing and frequent burnings. While the burnings favored grasses that the cattle could utilize, they also reduced the amount of organic matter in the soil, thereby decreasing its capacity to hold water and nutrients. Over time, the grasslands became degraded, producing much less biomass than the vigorous forests that once had covered the hills. The forests still covered higher mountains and steeper slopes, especially those on the Congo-Nile Divide. These slopes and watersheds had less fertile soils, were partly too temperate for the crops, and degraded fast if cleared for grazing or cultivation.

Cultivation was limited to small plots on the hilltops and upper slopes that were easiest to cultivate and clear with fire (Meschy 1985, 1989). Wet valleys were mostly reserved for grazing during the dry season. Some of the plots were permanently cropped; others were periodically left fallow. The fertility of the cultivated plots was based on fallowing, household refuse, and especially on cattle manure. Livestock played a key role in fertility management by transporting nutrients and organic matter from the grasslands to the cultivated plots. Although most livestock and all land was owned by the Tutsi and most cultivation done by the Hutu, the two groups were integrated through the *ubuhake* contractual system. In the system, Hutu clients guarded the cattle of Tutsi patrons and gave them a portion of their crops, receiving in return male calves, milk, blood, manure and protection against outsiders (Olson 1994).

The main crops were sorghum, finger millet (eleusine), taro (colocase) and traditional legumes (peas, cowpeas). Beer bananas were also grown widely, although most beer may have been made out of sorghum. Farmers had also started to grow beans, sweet potatoes, and maize, but none of these was yet a major staple (Jones and Egli 1984; Martin 1987).

This picture of pre-colonial agriculture holds for the historical core of Rwanda, the central plateau, where bulk of the population lived. Most of the savannas of the East had very low population densities and almost no cultivation. The large marshes in southeastern Rwanda and the montane forests on the Congo-Nile watershed were largely uninhabited.

2.3.2 Colonial Changes: New Crops and More Cattle

To fight the famines that had periodically devasted the country, Rwanda's Belgian administors enacted several policies that were supposed to increase or stabilize the availability of food (Guichaoua 1989; Vis 1975; Olson 1994). In 1924, they passed a law requiring all farmers to plant and maintain 15 ares of famine crops and 35 ares of other food crops *per adult*. The required fields were much larger than the plots cultivated before. The implementation of the law would have increased dramatically the work load of the farmers and the amount of land exposed to erosion by cultivation, while decreasing soil fertility due to shorter fallow periods and reduced availability of manure. Moreover, the rule would have reduced the availability of grazing lands. Consequently, the law was widely resisted, and it is unclear whether the *total* acreage requirement had much direct impact.

In contrast, the requirement to grow famine crops was enforced rigorously by the colonial administration, especially after the famines in the late 1920s (Guichaoua 1989; Leurquin 1963). The famine crops were non-seasonal roots (sweet potato and cassava) and tubers (white potato), that were supposed to feed the families if cereals and other seasonal crops failed. Cassava was promoted at low altitudes, particularly in the East, white potatoes at the high altitudes of the Northwest, and sweet potatoes throughout the country. Farmers' responses were mixed. White potatoes were well received on the volcanic highlands of the Northwest, where farmers had been lacking crops that do well in temperate climates. Sweet potatoes provided high yields in terms of calories, had been gaining ground already before, and continued to expand. The situation was entirely different for cassava, which was actively opposed by farmers. In addition to the new taste they did not like (yet), farmers may have resented the crop because it did not do particularly well in much of Rwanda. Cassava is a lowland crop and its yields are much lower in the cool highlands. Its superiority on badly degraded fields was not needed yet and its resistance to drought was valuable mostly in those parts of the country that were still under pasture.

Another influential colonial policy was to give farmers rights to cultivate land in valleys (Olson 1994). The Tutsi herders who depended on the valleys for dry-season pasture, especially in drought years, resisted the conversion to crops, but nevertheless some valleys were cleared for cultivation. Belgians also promoted cultivation in uninhabited areas at high elevations and in the east through the *paysannat* resettlement scheme, which emphasized heavily export crops. Despite these policies, the Tutsi by and large were successful in opposing the conversion of grazing lands into cropping lands. Consequently, the new crops had to increase mostly at the expense of old crops and fallow, particularly in the 1950s, when the population exceeded the pre-famine levels and continued to grow fast. In addition to the actively promoted roots and tubers, farmers planted more bananas and switched away from low-yielding peas and finger millet (Leurquin 1963). Thanks to the new crops and improved varieties introduced by the Belgians, living conditions remained stable or improved despite the population pressure (Leurquin 1960). Especially the volcanic highlands in the Northwest, which were fertile but too cool for Rwanda's old crops, benefitted from the temperate crops (white potato and wheat) introduced and promoted during the colonial period.

Two other influential land use policies were enacted and enforced rigorously by the Belgians. In 1931, Rwandans were obligated to plant communal forests, and in 1933, each farmer was required to plant a certain number of coffee trees (Olson 1994). The former policy was intended to produce construction wood and fuel, reduce erosion, and fight famines by increasing rainfall, while the purpose of the coffee requirement was to provide revenue for the colonial administration.

The colonial rulers failed to realize the key role of cattle manure in Rwandan agriculture or the role of milk and blood in diets. They felt that cattle contributed little to human nutrition, caused erosion, and were owned for little else than prestige. They wanted to reduce livestock numbers and rationalize livestock management by slaughtering more animals and by improving veterinary services. The net impact of the measures was the opposite of what was intended. Citing Jean-Paul Harroy (1954), who became the Resident Governor of Ruanda-Urundi in 1955, Olson (1994) reports that cattle population increased tenfold between 1920 and 1950 due to veterinary services. As a leading advocate of the colonial policies to reduce cattle numbers, Harroy had an interest in creating alarming numbers, and his "cattle explosion" appears grossly exaggerated. Nevertheless, it is clear that Belgians not only failed to reduce cattle numbers but even contributed to an increase.

After the famines of the late 1920s, Belgians identified erosion as one of the main causes leading to famine and wrote alarming reports on vast ravines and gullies everywhere on the densely populated central plateau (Scaetta 1932). Although many of the grass lands were quite degraded already before the Belgians, their policies that expanded cropping at the expense of fallow and increased livestock populations apparently made things much worse (Olson 1994). In 1934, colonial authorities introduced anti-erosive measures coercing farmers to dig infiltration ditches on their fields (Gatera 1980). After the severe famines of the 1940s, the policy was greatly expanded. Throughout the colony, farmers were mandated to participate in *umuganda,* forced communal labor to dig erosion ditches, plant grass strips on contour lines (typically on the upper banks of the ditches), and to plant trees on erosion-prone lands. Burning of pasture was outlawed (Olson 1994). By 1960, 40 percent of cultivated lands and 8 percent of pastures had been protected (Nduwayezu 1990; Sirven, Gotanegre, and Prioul 1974). The laborous works were bitterly resented by farmers.

2.3.3 Revolution and Independence: More People and More Crops

As the authority of the Belgians started to wane in the end of the 1950s, the enforcement of the unpopular agricultural policies weakened and finally stopped. During the first decade of independence, almost no anti-erosion structures were built, some of the old structures were actively destroyed and most of the rest gradually disappeared due to lack of maintenance (Brondeau 1991).

In rural Rwanda, the principal consequence of the "social revolution" was to make lands previously reserved for pasture available for cultivation. Together with the accelerating population growth, this led to a fast increase in cultivation both locally in the densely populated heartlands and through the settlement of the uninhabited areas, particularly in the East. Thus, the process of agricultural intensification under population pressure that characterized the 1950s was ended by the social revolution and replaced by extensification for almost two decades (Olson 1994; Bezy 1990). Also the exodus or death of large numbers of Tutsi and even larger numbers of their cattle made room for those that remained. It was only after mid-1970s that Rwanda's agriculture again faced population pressure.

During the period of extensive growth, farmers eagerly planted more bananas and beans (Delepierre 1970; Bart 1993). This form of expansion can be interpreted to be a sign of relative prosperity, since banana beer, cooking bananas, and beans are relatively expensive foods, whereas root crops are poor man's food. Bananas could also be grown extensively on the relatively large farms of the East, and both bananas and beans grew much better on the newly cleared fields than on the old overcultivated lands. Sorghum was favored in the drought-prone eastern savannas but elsewhere lost ground to maize, which typically yields better in well-watered areas. Coffee was promoted heavily and at times coercively throughout the country and tea was promoted in small areas around the factories (Chapuis 1986). Potato production in the Northwest benefitted greatly from externally funded agricultural research and extension (Haverkort 1986a, 1986b). Although the potato success story was an exception to the general pattern of technical stagnation and modest investments in agriculture, economic policies in Rwanda were not nearly as anti-agricultural than they were in many other African countries (Azam 1989). In the 1960s and 1970s Rwanda was one of the few countries in Africa where food production grew faster than population (Harrison 1987).

As cultivation expanded and soil conservation was neglected, erosion rates increased. In the mid-1970s, Habyarimana's government re-launched the colonial anti-erosion policies, with the same soil conservation techniques and similar or even stricter enforcement (Brondeau 1991; Olson 1994). By the end of the decade, 17 percent of the cultivated lands were "protected against erosion" (Musema-Uwimana 1979), and in the early 1980s, Habyarimana's government started to push even harder to achieve 100 percent by 1988. Communal authorities were required to report quarterly on their activities, with progress linked to development activities (Guichaoua 1991). In 1988, 38 of 133 rural communes were over 90 percent protected and even Kibungo with its gentle slopes and lower rainfall was estimated to be 74 percent covered (Olson 1994). As in the colonial period, farmers resented the forced labor and the inflexible design of the soil conservation works.

2.3.4 Recent Stagnation: More People and More Trouble

By the end of the 1970s, almost all cultivable land outside the national parks had been opened up for cultivation. Communal pastures were mostly gone, private pastures were largely marginal lands on steep slopes and on leached hilltops, and the remaining valleys were mostly large wetlands that were difficult to drain on farmers' own initiative and often had an important role in the water system (Bart 1993). During the 1980s, farmers could expand cultivation only on marginal lands and at the expense of fallow. Without offsetting measures, both options were likely to increase degradation and erosion. In a 1991 national survey, 47 percent of field blocks were reported by their cultivators as degraded (Clay 1994).

To cope with the rapid population growth, farmers planted more sweet potatoes and bananas, which gave high caloric yields, or, in the case of beer bananas, superior monetary returns to land. In the late 1980s, these and other adjustments were merely enough to offset the impacts of degradation and pest attacks that may have been partly caused by it. Food production stagnated and per capita food production declined considerably. The degraded western highlands were particularly hard hit. The droughts in 1989 and 1993 lead to starvation in the poorest areas, especially in the prefectures of Gikongoro and Kibuye.

In the early 1990s, the authoritarian control of Habyarimana's government on farmers started to wane. Forced communal labor came to an end, and the construction of anti-erosion works stopped, just as it had done 35 years earlier in the last days of the colonial government. While some farmers continued to maintain the structures, others actively destroyed theirs. Centralized control remained longer on coffee, which provided the government with desperately needed export earnings. By 1994, many farmers had started to neglect their coffee trees and some had altogether abandoned theirs, but few had dared to uproot their coffee trees.[6]

After the genocide and war in 1994, large areas of Rwanda, particularly in the East were almost empty of people. Since then, much of the East has been inhabited by the "old caseload refugees", that is, the Tutsi who left the country more than 30 years ago, and their descendants. Along with the people, large herds of cattle have arrived, implying

[6] In January 1994, we asked a farmer in the prefecture of Byumba what she would do, if she could uproot her coffee trees. She replied that she would uproot and grow sorghum and beans instead. Although the prohibition against uprooting had officially been repealed, the local agricultural extensionist who was with us rapidly reminded her that she would not be allowed to do so. Some other farmers, however, told us that they were happy with their coffee trees and might even plant more.

that parts of the East were again reserved for pasture. The return of hundreds of thousands of refugees in late 1996 brought man-land ratios back to the pre-genocide level in most parts of Rwanda.

Chapter 3

REVIEW OF AGRICULTURAL INTENSIFICATION LITERATURE

3.1 Malthusian Fears and Boserupian Hopes

Much of the literature on how rural societies respond to population growth is colored either by pessimistic fears or by optimistic hopes. The gloomy view sees population pressure leading to declining living standards and ultimately to poverty and famine. As desperate people resort to unsustainable responses, they mine their lands, thereby destroying their environment. In contrast, the optimists perceive additional people as the "ultimate resource" (Simon 1981) that not only is sufficient to maintain the standard of living but also may be needed for economic progress and environmental recovery (Kates, Hyden, and Turner II 1993).

The pessimistic view is usually labelled "neo-Malthusian", after Thomas Malthus, the classical economist who popularized the idea that human populations constantly tend to grow beyond their means of subsistence (Blaug 1985). To avoid misery and starvation caused by population growth, people should apply "preventive checks:" moral restraint and contraception.[7]

The key assumption of the Malthusian view was the idea of diminishing returns. Along with David Ricardo and other classical economists, Malthus believed that best lands generally were opened up for cultivation first. If population grew, farmers would have to increase production either by cultivating poor lands (extensive margin) or by adopting practices previously considered too laborous (intensive margin). Both options would reduce returns to labor and, hence, wages and access to food.

[7] Malthus, unlike most present-day neo-Malthusians, advocated moral restraint and condemned contraception as "improper."

Today, the neo-Malthusian view often goes with the term "human carrying capacity." The idea is borrowed from ecology, and increasingly neo-Malthusians worry that population growth undermines ecological sustainability, not just that it reduces human welfare (Lambert 1982). Angelsen and Fjelstad (1995), for instance, present a simple model of a farm household, in which farming becomes more intensive and soil erosion increases if marginal returns to labor decline due to population growth.[8]

Some pessimists would reject both the neo-Malthusian label and the prescriptions that emphasize birth control (Kates, Hyden, and Turner II 1993). Whether calling themselves neo-Marxist or something else, they typically see either local population growth itself or the associated negative results (human misery, environmental degradation) as resulting from external exploitation (Blaikie 1985; Blaikie and Brookfield 1987). For instance, the capture of good agricultural lands for export crop production may force the displaced smallholders to farm unsustainably on marginal lands. The suggested solutions include land reform, local empowerment, self-reliance and variously defined forms of "alternative development".

The optimistic view is usually associated with Esther Boserup, a contemporary Danish economist, although it also has deep roots in classical political economy. Malthus himself talked about "the optimal population" and starting from Adam Smith classical economists had emphasized the progressive role of specialization and its dependence on the size of the market (Blaug 1985). Classical economists were well aware that among sparse populations "rude devices of production" could be more profitable than "the most efficient instruments" and that as population densities grew, people would innovate and adopt more productive methods.

[8] This arises from a formulation that does not allow the costs of soil conservation to be a function of wage rates. Neither is there any induced technical change in the model. If either of these complications were introduced, the model would no more yield simple Malthusian conclusions.

Yet, classical economists saw technical progress mostly in industry and transportation, underestimating its scope in agriculture. Above all, they failed to appreciate how technical progress could help to increase the frequency of cropping (Boserup 1989). Drawing from the economic history of Europe and somewhat also from developments elsewhere, Boserup (1965, 1981) concluded that while population pressure first leads to diminishing returns, inducing people to adopt more labor-intensive practices that they could avoid before, it also enables and encourages them to develop and adopt innovations that mitigate or even reverse the decline in labor productivity that would otherwise follow.

The key variable in Boserup's virtuous cycle is the frequency of cultivation. Under low population pressure, people usually practice shifting cultivation and use long (bush) fallows to restore fertility and control weeds. With population growth, fallow periods get shorter (grass fallows) and eventually give way to permanent cultivation or even to carefully controlled irrigated farming with two or more cropping cycles per year. As fallows disappear, households start to maintain fertility by manuring their fields and adopt better hand tools or animal traction to control the weeds. Investments in land become worthwhile. Increasing population density reduces the per capita costs of roads, irrigation systems, and other forms of infrastructure, expands markets, and promotes specialization. Further innovation follows and purchased inputs become ubiquitous in agriculture.

For Boserup, the beneficial upward spiral of population growth and technological improvements is a possibility that many societies have been able to achieve, not something that is guaranteed to happen. In particular, if people fail to invent or adopt other measures of fertility restoration when they shorten the period of fallow, they may mine their lands and be left with "the choice between starvation and migration" (Boserup 1965).

In the historical cases referred to by Boserup, population growth rates had been low, often below 0.1 percent per annum (Boserup 1985). Consequently, the populations involved had had centuries to invent and adopt appropriate intensification responses. Boserup herself stated (1965: 118) that the intensification process may not work if population densities are very high or grow very fast. More recently several authors have claimed that sustainable intensification is failing to take place in much of Africa, where population growth rates often exceed three percent and where population densities double from one generation to the next (Ho 1985; Lele and Stone 1989; Binswanger 1988; Ehui, Williams, and Swallow 1995).

On the other hand, cases of sustainable intensification do exist, even in places where both population densities and growth rates have been high. Based on their comparative study of ten densely populated areas in western and eastern Africa, Hyden, Kates, and Turner II (1993) had some doubts on how much further these areas can adapt to population growth, but they were convinced that outside the pockets of high population density much scope for intensification exists in Africa. Moreover, in four of the ten cases, intensification had been accompanied by "increases in food availability or improvements in general material well-being." Tiffen and Mortimore (1992) and Tiffen, Mortimore, and Gichuki (1994) report on a highly successful intensification in Machakos, Kenya. Although population increased five-fold between 1930 and 1990, erosion rates declined, the landscape became greener, and the per capita value of agricultural production increased considerably.

3.2 Conditioning Factors

3.2.1 Introduction

Basically Boserup studied how one variable, population density, had affected agriculture in human history. She demonstrated how changes in population density in a wide variety of environments had pushed agricultural societies from one farming system to another. While not denying the role of other factors, she considered population density pivotal and warned against assuming that low production in sparsely inhabited areas indicates low potential (Boserup 1989). In her view, Africa produced less food than India because it had fewer people, not because it had less fertile land. She also emphasized that while labor-saving tools and techniques promote intensification, lack of them has not prevented some societies (like the Mayas) from intensifying. Moreover, Boserup emphasized that many of the changes in institutions and policies that promoted agricultural intensification were in fact responses induced by population growth. Private land tenure, for instance, generally emerged where investments in land were needed to feed the growing population. Similarly, the development of high-yield rice and wheat varieties was a political response to population pressure in Asia.

Other researchers have focused on how factors other than population affect intensification. Kates, Hyden, and Turner II (1993) differentiate between intensification theories that emphasize (subsistence) consumption needs and those that emphasize market demand. Chayanov and Boserup supposedly exemplify the former, whereas many economists from Schultz (1964) to Hayami and Ruttan (1985) have been proponents of the latter, arguing that small farmers respond to market incentives. Kates, Hyden, and Turner II lament that each side has largely ignored the other, although evidence is accumulating that neither approach alone can tell the whole story. In their own study, Kates, Hyden and Turner II perceive the relationship between population and agricultural intensification as being modified by two sets of variables: market access and environmental conditions. Thus, they hypothesize that the success of agricultural intensification in responding to demographic change depends crucially on the environmental and market conditions in which it is taking place.

That intensifying farmers are responding both to market incentives and subsistence needs is undoubtedly true but in implying that most others had missed this elementary fact, Kates, Hyden and Turner II are largely creating a strawman that is easy to knock down. Far from ignoring markets, Boserup (1989) wrote that commercial farmers respond primarily to markets and warned that if food prices are kept artificially low by food aid or subsidized imports, intensification may not be forthcoming. Similarly, the economists emphasizing responses to prices typically did so in order to attack the myth of an "irrational tradition-bound peasant", not because they saw market prices as the only things that matter. Moreover, much of what Schultz (1964) and other economists wrote emphasized economic incentives that were more than just market incentives and clearly included on-farm endowments and subsistence needs.

Along with market incentives and environmental conditions, several researchers have emphasized the availability of tools, methods, varieties and inputs needed for intensification, farmers' knowledge about them, land tenure and other institutions governing the use of land and water, government policies affecting all these, and cultural and social factors including the norms regarding the sexual division of labor. Bilsborrow (1987) casts the net even wider, suggesting that the scope for migration and that for fertility decline should also be considered, since people may fail to intensify if they have easy access to lucrative jobs or uncultivated fertile land elsewhere. This, however, is a framework for a different question, namely how households choose between the three options: coping on less land per person, moving out, and restricting their fertility. Our focus here is on the scope and strategies of the first option.

Before discussing in detail how each of the above factors affects intensification, we turn briefly into a more general question on how these factors should be structured in the framework of analysis. Most researchers have explicitly or implicitly conceptualized them as factors that either together with demographic change affect agriculture or condition how farmers respond to demographic change. In contrast, Clay, Guizlo, and Wallace (1993) argue that the impacts of population growth depend crucially on the set of intermediate variables they label as *the structure of landholding* and define to include four key variables: size, fragmentation, fragility, and land tenure. In their framework, population growth changes the structure of landholdings, which in turn changes farmers' behavior regarding land use and investment decisions and, through them, may cause land degradation. Population growth not merely increases the pressure on resources but also may create obstacles for sustainable intensification. If, for instance, population growth contributes to the concentration of land holdings, lands may increasingly be cultivated by tenant farmers, who may not have as good incentives as owner-operators to invest in land. And if population growth pushes farmers to cultivate fragile lands, this may also cause degradation.

The argument that demographic changes affects behavior through tenure and other intervening factors is undoubtedly true, but the "structure of landholdings" -framework is problematic in not showing the influence of outside factors. For instance, although the authors discuss in detail how different crops have very different environmental consequences, the market incentives that induce households to grow protective rather than erosive crops or vice versa do not fit easily in their framework. The framework of Clay, Guizlo and Wallace (1993) appears to be designed for the purpose of tracing the various direct and indirect impacts of population growth in a given context, not for analyzing how the impacts differ as the context varies. Since the latter is the main focus here, we proceed by discussing how each of the factors conditions the impact of demographic growth on agricultural change.

3.2.2 Environmental Conditions

For Boserup, one of the key questions in intensification is how to maintain or even improve land fertility without unacceptably high labor inputs. Another main question is how to make water available for progressively higher frequencies of cropping. While the questions were much the same everywhere, the answers naturally varied with environments. Ruthenberg's classical study on tropical farming systems (1976) provides many of the answers. It shows that while population growth is pushing rural areas from one farming system to another, environment limits the options.

Farmers in temperate climates have typically responded to population growth by moving from fallow systems to permanent upland (non-irrigated) cultivation, but in the humid tropics dense populations have more often resorted to either irrigation (mostly wet rice) or perennial crops (Ruthenberg 1976, chapter 6). Without mineral or organic fertilizer, most tropical soils rapidly lose much of their fertility under permanent upland cultivation. The warmer and more humid the climate, the greater the problem: high temperature promotes rapid decomposition and high rainfall contributes to leaching and erosion. Permanent production of annual crops typically provides neither much additional organic matter nor much protection from the sun to slow down decomposition nor much uptake of nutrients from the subsoil. The loss of organic matter increases the leaching of nutrients to the subsoil, while reducing water infiltration. Land degradation caused by leaching, the loss or organic matter, and periodic water scarcity is often augmented by erosion. Soils poor in organic matter and water infiltration capacity, loosened periodically by cultivation, and not protected by crops against the erosive impact of raindrops are vulnerable to large soil losses, particularly if they are located on steep slopes and on impermeable soils.

The fertility loss is generally less severe on the cool, tropical highlands, in semi-arid climates, and on fertile volcanic soils. If excessive erosion is prevented, continuous cultivation of annual crops can often be sustainable in these environments even without fertilizer. In contrast, for permanent cultivation in humid and semi-humid climates to be sustainable without either irrigation or large quantities of external inputs, it typically must "mimic rainforest" (Altieri, Letourneau, and Davis 1984). Examples include tree and bush crops, such as oil palm and coffee, home-gardens such as the banana-based farming systems in much of East African highlands, and various agroforestry systems. Another possibility is to bring either large quantities of manure and other organic matter from elsewhere, or to use mineral fertilizer to grow the crops and the organic fertilizer (green manure) needed to maintain the organic matter content of the soil. Where modern inputs are unavailable or expensive, intensification typically reduces returns to labor, which is why it only occurs when sufficient land for more extensive forms of production is no longer available.

The island of Ukara on Lake Victoria in Tanzania is a well-known example of the very low productivity of permanent farming on poor soils in semi-humid tropics (Ludwig 1968; Ruthenberg 1964, 1976). For more than a century, the population density on Ukara has exceeded 500 persons per hectare, which is too high to allow the restoration of fertility through fallowing. Farmers practice careful soil husbandry with manuring, leguminous green manure/cover crops, and labor-intensive methods of erosion control. Yet, yields are modest and returns to labor are extremely low. While quite sustainable environmentally, Ukara has been a case of poverty agriculture. Whenever possible, young people have left the island to practice more extensive agriculture on the mainland. According to Ruthenberg (1964: 31), Ukara shows that "only an extreme emergency situation can induce the inhabitants to take up pre-technical measures to preserve the fertility of the soil."

Eastern Nigeria is an example of intensification toward permanent farming in humid climates. Population densities are now higher in Eastern Nigeria than on Ukara, but two or three generations ago they were still low enough for fallow systems. Consequently, farmers have not yet adopted as careful and laborous soil husbandry practices as in Ukara. Lageman's (1977) study of three villages suggests that land fertility and yields are drastically lower in the village with the highest population density (nearly thousand persons per square kilometer). Despite much stronger efforts to maintain soil fertility, farmers in the densest village are mining their lands, albeit not in the sense of taking nutrients from the soil with the crops and selling them in the market. Increasing frequency of cultivation lowers yields primarily by reducing the contents of organic matter and nitrogen in the soil. Traditionally fertility management has focused on importing nutrients and organic matter from outer fields and pastures to the compounds (in-fields) that produce most of the output, but with population growth there are too many compounds and too few out-fields for this to work.

The book edited by Turner II, Hyden, and Kates (1993) includes three case studies from Eastern Nigeria. Unfortunately, they shed little light on whether workable responses to continued population growth have been found in the pockets with the extremely high rural population densities, like the one studied by Lageman in 1974-75. In one case (Awka-Nnewi), total production is decreasing and in another (Imo State), yields are declining (Hyden, Kates, and Turner II 1993). The third case (Ngwa-Igbo) has a much lower population density and has thus far intensified successfully. In all three cases, some farmers are responding to the fertility crisis by using mineral fertilizer, financed in part by market gardening, which is becoming more important. Farmers have also planted more oil palms and other trees and shifted to less demanding and higher-yielding crops, particularly from yams to cassava. Land husbandry is improving and irrigation is expanding.

In sum, permanent upland cultivation of annual crops is so problematic in the tropics that farmers tend to opt either for irrigation or for perennial crops. In general, the transition to irrigation farming is a major intensification option in humid climates and also in semi-humid and semi-arid areas provided that water sources can be found (Ruthenberg 1976; Bray 1986; Ishikawa 1967). Irrigation allows higher frequencies of cultivation and can provide much productive employment. Typically farmers start to regulate water flows first in the valleys where irregular flooding is a problem and irrigation is easy. In fallow systems such valleys have often been marginal lands, and among the last areas to be cleared for cultivation. With increasingly skillful irrigation they become prime rice fields. The widely credited fertility of rice fields (e.g., Pearce, Barbier, and Markandya 1990) actually is often created by decades of careful husbandry on soils that may originally have been quite poor (Bray 1986). Where population growth continues, farmers start the laborous conversion of lower slopes into rice terraces. Improvements in water control, fertility management, and crop husbandry can typically increase output greatly with modest or no declines in labor productivity (Geertz 1963; Bray 1986). Fertilizer, pesticides, and improved varieties tend to have higher payoffs than in most other farming systems (Ruthenberg 1976; Byerlee 1990). In much of Asia, wet rice systems support very high rural population densities, often exceeding 3000 persons per square kilometer.

In contrast to humid and semi-humid climates, where the transition to permanent upland cultivation is difficult but irrigation has great potential, farmers in semi-arid climates can more easily intensify from fallow systems to continuous cultivation, but tend to have great difficulties in intensifying further, except in the vicinity of irrigable water sources. On the other hand, the Machakos success story mentioned above (Tiffen, Mortimore, and Gichuki 1994) comes from a semi-arid area, showing that considerable intensification within the system of permanent cultivation is possible. Soil and water conservation works can reduce erosion and nutrient losses and increase the availability of water for plants. The development of animal traction is often the bottleneck. Physical responses to mineral fertilizer are often stronger than in more humid regions, but the profitability of fertilizer naturally depends on relative prices. The semi-arid cases included in Turner II, Hyden, and Kates (1993) were not particularly successful, experiencing both environmental degradation and declining per capita production levels.

Although cooler climates make tropical highlands more conducive to permanent cultivation than the lowlands, suggesting better prospects for intensification, many of the highlands already have high population densities. Moreover, highlands often have steep slopes and poor, shallow soils, which make them vulnerable to erosion. In Rwanda and Burundi, for instance, the chain of mountains that form the divide between the basins of the Congo and the Nile is a particularly poor and degraded region. Verhaegen and Degand (1993) report how intensification is failing on Congo-Nile Divide in northern Burundi. Soil fertility is low and declining, and pests are attacking beans and sweet potatoes, the main staples. Marginal returns to labor are collapsing with population growth. No innovations capable of bringing about sustainable intensification have been widely adopted. Uwizeyiama (1991) describes similar problems in Rwanda, concluding that agricultural intensification there is reaching a dead end.

Some highlands have much better prospects due to their volcanic soils that tend to be highly fertile, impermeable and hence not very prone to erosion (Ruthenberg 1976; Pearce, Barbier, and Markandya 1990). For instance, in contrast to the generally impoverished Congo-Nile Divide highlands, the volcanic part of the divide, including much of the Ruhengeri prefecture, is Rwanda's potato basket with high yields, reasonable incomes and moderate levels of soil losses. Ford (1993) concludes that Ruhengeri is "marginally coping" with population growth, and Hyden, Kates, and Turner II (1993) label it a qualified success story.

Outside the highest altitudes that are too cool for bananas, tropical highlands often can intensify sustainably with banana groves. A well-documented case is that of Bukoba, Tanzania. On relatively poor soils, "0.3 hectares of bananas mixed with beans are sufficient to cover the basic food requirements of one family" (Ruthenberg 1976: 239). Although the high productivity of banana gardens was in part achieved by importing nutrients from degraded pastures, the system appeared capable of supporting very high population densities (Friedrich 1968). Some of the banana gardens had existed for a century or more, had virtually no erosion, and showed stable or increasing yields. In the 1970s, however, the banana groves were attacked severely by new pests, which undermined the viability of the system (Kajumulo-Tibaijuka 1984).

In sum, the scope for agricultural intensification in the tropics depends greatly on environmental conditions such as rainfall, soil type, steepness of slope, and temperature. Prospects are good on volcanic highlands that enjoy fertile soils, abundant rainfall and modest rates of decomposition. Also farmers in semi-arid tropics can often intensify relatively sustainably from fallow systems to permanent cultivation. In most of humid and semi-humid tropics and on the steep slopes of tropical highlands, sustainable intensification from fallow systems to permanent upland cultivation of annual crops is extraordinarily difficult. Technically, soil fertility can be maintained either with industrially produced inputs or with an organic approach based on very large labor inputs, but returns on these inputs tend to be low. In these conditions, sustainable intensification has typically been based either on irrigation or on perennial crops.

3.2.3 Market Incentives

Market conditions can influence intensification in multiple ways. First, market production can make intensification profitable and provide farmers with the resources to invest in land. Second, access to markets and relative market prices influence crop choice. Third, input markets may promote or discourage specific forms of intensification.

In the case of perennial crops, the crucial role of market access is well understood (Ruthenberg 1976). Most perennial crops represent intensification: they provide high returns to land and much employment per hectare, thereby supporting high population densities. Most provide better crop cover against erosion than annual crops. Most are produced entirely or mostly for sale, often to overseas markets. Many need local processing, and for some, production is feasible only in the neighborhood of the processing facilities. This description applies to tree crops such as oil palm, rubber, cocoa, coconuts, and cloves, to shrub crops such as coffee and tea, and to perennial field crops such as sugar cane, pineapples and sisal. Bananas are a partial exception in being also a major subsistence crop.

When farmers facing increasing land scarcities voluntarily choose perennial cash crops over subsistence food crops, the choice typically helps them in coping with the scarcities. Examples include smallholder tea in Meru, Kenya (Hyden, Kates, and Turner II 1993), coffee in Bukoba, Tanzania (Friedrich 1968), and beer bananas in Rwanda (Bart 1993). No such positive presumption can be made if farmers have been forced to grow perennials. Laure (1986) and Braun, Haen, and Blanken (1991) found that tea produced lower returns to land and labor in Gisenyi, Rwanda than the most lucrative alternative crops.[9]

Similarly, in Clay et al. (1995) we found that at the prices that prevailed in 1990, coffee was not an attractive crop for many of the Rwandan smallholders who had coffee bushes, which they were not allowed to uproot.

In several of the cases included in Turner II, Hyden, and Kates (1993), market gardening for nearby urban areas was instrumental in justifying and financing purchased inputs and labor-intensive investments in land. The Machakos success story reported by Tiffen, Mortimore, and Gichuki (1994) was largely based on terracing and other investments and inputs paid for and made lucrative by the production of non-food and horticultural products for the Nairobi market. Both Hyden, Kates, and Turner II (1993)

[9] This conclusion probably only holds for tea grown on high-quality fields, especially in the wet valleys suitable for sweet or white potatoes. The opportunity cost of tea is much lower on the thin soils of acidic hills, where bananas do not grow at all and where annual food crops would grow only poorly and lead to massive erosion. Moreover, the private profitability of tea appears to have been poor in Rwanda at least in part because

and Pearce, Barbier, and Markandya (1990) conclude that further intensification in densely inhabited highland areas is likely to involve more fruits, vegetables and other special products. Increased imports of starchy staples from elsewhere are typically essential for intensification in the highlands.

In contrast to perennials that typically provide good crop cover against erosion, vegetables and other annual crops produced for urban markets are often highly erosive. Pearce, Barbier, and Markandya (1990) report how the lucrative market for temperate vegetables has encouraged upland farmers in Java to cultivate steep volcanic slopes high on the mountains. Since volcanic soils are inherently fertile and not very prone to erosion, the losses of topsoil appear to have little impact on yields. Although erosion imposes significant off-site costs, its real on-farm costs are modest and perceived costs even smaller. Hence, farmers see no reason to invest in soil conservation. The authors, however, see this as an exception to the normal rule that good farm prices are a key to soil conservation and sustainable intensification.

The argument for good overall incentives does not apply for areas where farmers would respond primarily by expanding agriculture to new areas. Neither does it carry to individual crops. Improved incentives to grow erosive crops can clearly make agriculture less sustainable. In Java, Pearce, Barbier, and Markandya (1990) were worried about the substantial price increases for cassava, a highly erosive cash crop.[10] Similarly, Verhaegen and Degand (1993) lament that the most lucrative cash crops in Burundi (tobacco and potato) are highly erosive.

When important quantities of purchased inputs are used in agriculture, input prices play a key role in determining incentives. When discussing the development

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of the indirect taxation of farmers through overvalued exchange rate, distorted pricing structure, and inefficient parastatals (World Bank 1991).

options of various tropical farming systems, Ruthenberg (1976) repeatedly refers to relative prices, especially to the price ratios between fertilizer and farm products.

Although almost all input use can contribute to intensification, some inputs may be unsustainable, bringing short-term gains at the expense of long-term production losses. Fertilizer is often regarded such an input. Unlike in the industrialized countries and in parts of Asia, excessive nutrients are seldom the problem in Africa, Instead, the concern is about the loss of organic matter, which may ensue if cheap fertilizer encourages farmers to neglect soil conservation or the organic fertilizers that would provide both the nutrients and the humus. With this reasoning, Pearce, Barbier, and Markandya (1990) suggest that fertilizer subsidies in Indonesia should be abolished. McIntire, Bourzat and Pingali (1992) argue that impediments for the use of mineral fertilizer are encouraging the use of manure and other organic fertilizers in sub-Saharan Africa.

On the other hand, mineral fertilizer increases crop growth, which means better crop cover against erosion and provides more organic matter that can be used to improve soil quality. Ruthenberg (1976) believes that fertilizer generally increases the stability of tropical agriculture. McCown et al. (1992) started their research in semi-arid Kenya by focussing on biological fixation of nitrogen by legumes but ended up advocating the fertilizer-augmented soil enrichment (FASE) strategy that emphasizes the importance of using both organic and mineral fertilizer. Similarly, a German project (PAP) that sponsored research on "ecofarming" in Rwanda and originally had been quite critical towards "artificial fertilizer," found that the leguminous plants that were central on their agenda were difficult to establish on degraded lands without mineral fertilizer (Egger and Rottach 1983; Adelhelm and Kotschi 1985; Egger and Martens 1987; Kotschi, Pfeiffer, and Grosser 1983). Kotschi (1991) concluded that improved fallow complements but

[10] Unlike in Africa, where cassava is usually a subsistence food crop, it is grown in Java primarily for export to Europe as animal feed.

cannot substitute other forms of fertilization. This conclusion is also shared by Balasubramanian and Blaise (1993).

Comparable arguments can be presented for and against other agricultural chemicals. While the standard argument against "environmentally unsustainable" pesticides that supposedly destroy the ecological balance (Buchholtz 1984) has merit in many cases, certain forms of sustainable intensification can be highly dependent on industrially produced chemicals. For instance, zero-tillage, which is increasingly used in mechanized agriculture to save fuel and/or to conserve water and which might have substantial potential for soil conservation in the tropics is highly dependent on herbicides and insecticides (Ruthenberg 1976: 159; Byerlee 1996).

In sum, sustainable intensification is most likely in market conditions that reward farmers for investing in their land, for using inputs and methods that increase and maintain productivity, and for choosing crops that provide high returns without mining the soil. In general, good access to well-functioning markets allows farmers to specialize based on their comparative advantage. With markets, land-scarce farmers can deviate from their consumption needs towards products that give higher returns to land, and farmers on steep slopes can focus on crops that provide good protection against erosion. Lucrative agricultural terms of trade promote input use and investments in soil conservation, but may also encourage expansion to new areas.

3.2.4 Availability of Intensification Techniques

Boserup (1965) recognized that failure to invent or adopt appropriate methods of intensification may lead to severe problems, but nevertheless assumed that most farmers have several options and can respond to population growth by choosing more labor-intensive practices. However, Ruthenberg (1976) described in detail how some populations had a variety of attractive intensification techniques to choose from, whereas others had no viable techniques available and were either getting poorer or migrating elsewhere as population grew. Although migration may indicate superior opportunities elsewhere rather than dearth of intensification options in the current location (Bilsborrow 1987), it is clear that the availability of intensification techniques varies considerably in time and place. Lipton (1990) argues forcefully that the principal constraint of agricultural growth in much of Africa is the poor supply of improved agricultural technologies.

While some agricultural intensification techniques can be invented by farmers themselves or borrowed from elsewhere, many are results of organized agricultural research. Although such research can be seen as just another form of the Boserupian population-induced intensification process (Boserup 1989; Hayami and Ruttan 1985), time lags in agricultural research are long and the results available to farmers depend on a large number of factors, only one of which is the population growth that may have pushed governments, donors, or private companies to invest in agricultural research. Hence, when analyzing the responses of rural households to population pressure, the availability of intensification techniques is often most usefully treated as an independent factor that conditions the responses. A further argument for this approach is the fact that agricultural research is one of the key policy levers that donors and governments can pull in order to make intensification more successful or sustainable.

In nine of the ten densely populated districts examined by Hyden, Kates, and Turner II (1993), including all the successful cases of intensification, new crops or improved varieties had played an important role. In Ruhengeri, Rwanda, for instance, progress had been partly based on the development of improved potato varieties, the provision of fungicides they needed, and the construction of a paved road from the region to the capital, the main market for potatoes (Ford 1993). When the temperate crops (potato and wheat) had originally been introduced during the colonial period, the intensification prospects at the high altitudes had greatly improved. Previously intensification even on the fertile volcanic lands had been hampered by lack of suitable crops, because the crops that yielded well at lower altitudes (bananas, beans, sweet potato) did not grow well on the cool highlands (Nduwayezu 1990).

In Machakos, Kenya the "inflows of ideas from external sources" were crucial for successful intensification (Tiffen, Mortimore and Gichuki 1994). The sources included not only extension agents and development projects but also many other sources. Indian customers in Nairobi, for instance, provided farmers with the seeds of the Indian vegetables that they wanted to buy.

In sum, sustainable intensification is made more likely by the availability of appropriate technologies. Over time, the development of new technologies is a key issue, whereas in cross-sectional analysis differences in information about the available technologies can explain differences in intensification.

3.2.5 Land Tenure

For Boserup (1965; 1989), the emergence of individualized land tenure was an integral part of the intensification process induced by population growth. In long-fallow systems individual tenure of land during the fallow period is neither necessary nor easy; enforcing such property rights is seldom worth the trouble. Since virtually all farm work is oriented towards short-term benefits during the short cultivation period, communities generally recognize and enforce only use rights during cultivation. As population grows and fallow periods get shorter and finally disappear, investments in land improvements become economically attractive for the community. They are also privately profitable for households if those who invested can count on getting the benefits. To ensure this, farmers generally claim and communities recognize stronger property rights on land, which gradually lead to individualization.

As already mentioned, Boserup studied slow changes that gave societies hundreds of years to adapt to new situations. She fully recognized that where populations double in 20-30 years institutions such as land tenure may fail to change fast enough, and inadequate security of tenure may constrain intensification. Not surprisingly, the population explosion of the past decades has created a lively debate on whether or to what extent lacking security of tenure is causing inappropriate incentives, and what, if anything, governments should do to provide security of tenure. At one extreme are those who assume that the lack of individual property rights leads to the "tragedy of commons" (Hardin 1968) and advocate rapid privatization and formal registration. At the other extreme are those who attribute problems primarily to externally caused disruptions in the local governance of the commons and advocate measures to strengthen it (Blaikie and Brookfield 1987).

Empirical evidence from Africa suggests that while land tenure in many parts of Africa is gradually becoming more individual and less communal, an abrupt transition to freehold tenure has only limited benefits and often contributes to landlessness (Bruce 1986). Moreover, a wholesale transfer of the land tenure administration from traditional institutions to the government is very costly and may decrease rather than increase the security of tenure. Therefore, the emerging consensus on land tenure calls for policies that prevent outsiders (including government officials) from grabbing land, establish some ground rules for the fair functioning of local traditional institutions of land tenure administration without trying to take over the entire operation, and promote the gradual individualization, recognizing that communities will differ in what they privatize. For example, communities may move at their own pace from a situation where cultivation rights are private but grazing rights during fallows are communal into a situation where those planting trees or leguminous fodder crops on their fallows are allowed to exclude others' livestock by constructing fences, and ultimately into a situation where livestock owners are required to keep their animals out.

Another incentive problem associated with tenure arises when owners do not farm their lands themselves. According to the usual argument, the tenant has no security of tenure and therefore no incentive to invest in rented land. However, this does not explain why the landlord would not find it profitable to pay for the investment and then increase the rent to reflect the higher productivity of the field. Alternatively, landlords and tenants could agree that in the end of the lease period landlords would compensate the tenants for any improvements made. That these options are not entirely unrealistic can be seen in that the Asian lowlands with their extraordinarily high investments in the creation and the maintenance of irrigation systems are often operated by tenants and owned by absentee landlords. Thus, the usual argument must be replaced by a more complex one that emphasizes the costs of designing and enforcing contracts. Two related approaches known as the information-theoretic approach (Stiglitz 1986) and the transaction costs approach (Williamson 1985) offer different terms and techniques, but both see the problem as one in which costs related to uncertain or asymmetric information prevent landlords and tenants from having contracts that would give tenants the same incentives to invest as an owner-operator would have.[11] For instance, the costs of supervising how much tenants use manure on rented fields may be so high that landlords and tenants may find it advantageous to specify nothing even if the result were that no manure will be used on the field.

In sum, investments in soil conservation, water control, and perennial crops are typically crucial for sustainable intensification and are more likely to happen when land tenure arrangements and other institutions are such that those who invest in land can also reap the benefits. To some extent, evolution towards such institutions is induced by the pressures to intensify.

3.2.6 Capacity to Invest

Even when physical and economic incentives to invest in land and to adopt the appropriate intensification techniques are in place, households may not have the resources to invest (Reardon and Islam 1989; Clay and Reardon 1994). Fundamentally, this may also be seen to result from high transaction and information costs that lead to failing credit markets. The practical implication is that wealth and incomes influence intensification.

As intensification measures themselves can increase incomes or arrest declines that would otherwise occur, the intensification process is characterized by "multiple equilibria." In other words, relatively small differences in initial conditions may put households and communities on diverging paths towards strikingly dissimilar outcomes. For instance, a household fortunate enough to own a head of cattle may reach higher incomes with the manure, may therefore be able to invest in water control and, with the additional income, enter a virtuous cycle. Meanwhile, a neighbor without the animal may

[11] Also in the privatization debate above the root cause of the problem is transaction costs. In their absence, the degradation of and underinvestment in the commons could be avoided by appropriate contracts between communities and their members.

be forced to "mine the soil" in an increasingly vicious cycle. Similarly, off-farm incomes may be the source of liquidity that allows households to invest in intenfication (Reardon 1997).

3.3 Chapter Summary

Although much of the literature is vague or careless about the multitude of factors affecting the responses of rural populations on demographic change, and although many scholars make sweeping generalizations without spelling out the specific conditions under which the generalizations were observed or would be expected to hold, there nevertheless seems to be a wide consensus on the factors that matter. The prospects of intensification depend on environmental conditions, market incentives, availability of intensification techniques, on institutional arrangements such as land tenure, and on the capacity of the households to invest in intensification.

Chapter 4

DATA AND THEIR LIMITATIONS

4.1 Introduction

The empirical analysis in this study is based on national farm survey data mostly from agricultural year 1990[12]. The farm surveys were carried out by the Division of Agricultural Statistics (DSA) of Rwanda's Ministry of Agriculture and Livestock (MINAGRI) with assistance from the United States Agency for International Development (USAID) through a cooperative agreement with Development Alternatives Inc. (DAI) and Michigan State University (MSU).

4.2 Sampling Design

The sampling procedures of the DSA were designed primarily to provide nationally representative statistics on Rwanda's agricultural economy at reasonable costs. A secondary objective was to provide information on regional variation. To achieve these objectives, DSA used stratified random sampling with 21 strata. Each stratum corresponds to a unique combination of agro-ecological zone and prefecture. The idea was to design a sample that would give reasonably accurate estimates for each or Rwanda's five main agro-ecological zones[13], and hence, for Rwanda as a whole, while also allowing for disaggregation of national aggregates by prefecture, which was inevitably less reliable but nevertheless wanted by policymakers.

[12] The definition of "agricultural year" used by DSA has varied over time; in 1990, the agricultural year ran from September 1989 to August 1990.

[13] These were called geographic regions in section 2.1., where also the limitations of this scheme of regionalization are discussed.

Depending on the size of the strata, 2 to 8 administrative sectors were randomly selected within each.[14] Altogether, 78 sectors out of the 1,490 in the country were chosen. Next, to reduce further the costs of travelling by enumerators, primary sampling units were selected by choosing randomly one census district from within each sector. Finally, samplers resorted to cells, the smallest administrative units, corresponding roughly to 100 families. Four cells were randomly selected from within each district. Only after these steps were households selected randomly from within each cell.

The selection was made out of a list of all farm households. Since the intent of the survey was to cover all agricultural production, the definition of farm households was broad. All rural families that engaged in agricultural activities on their own account were considered farm households. In rural Rwanda, this definition includes most but not all established households and excludes mostly young wage laborers and salaried employees who no more live with their parents. The sample included a handful of households that had household members employed in skilled (school teachers, masons) or unskilled (laborers) occupations and earned most of their income from off-farm activities.

Within each cell, four households were randomly selected for the intensive sample. In addition, four households were selected for the extensive sample and four more for the reserve sample. The purpose of the extensive sample was to test whether less frequent interviews and hence less costly data collection could yield sufficiently reliable results. No data on the extensive sample have been used in this study.

The sample included 78 primary sampling units ("villages"[15]), each covered by one full-time enumerator. Each enumerator visited four households every week in each of

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[14] More precisely, the random selection of sectors had been made for the 1986-1988 sample and was largely kept in place for the 1989-1992 sample so that the enumerators would not have to relocate.

[15] "Village" is a somewhat problematic term since rural Rwandans live scattered on the hills, not in clusters clearly separated from one another. This, of course, is also true for many "villagers" of the world.

the four cells ("sub-villages") chosen from his sector. Whenever households dropped out of the intensive sample for whatever reasons, they were immediately replaced by households taken from the reserve sample. While the replacement in data collection was immediate (so as to avoid distorting the incentives of enumerators), both the new and the replaced households were typically dropped out of the analysis for the season when the replacement happened.

The sample is not self-weighting. Although the number of sectors chosen from each strata were roughly proportional with population, this adjustment was not perfect. More importantly, within strata, households from sectors with smaller populations were more likely to be selected than households from elsewhere. Sample weights to adjust for these biases were computed based on the population estimates from the 1978 census. Whenever a household was dropped from the analysis because of missing or poor data, the weights were adjusted accordingly.

The sample used in this study was selected in 1988, and data on it were collected for the crop years of 1989, 1990, 1991, and 1992. Since late 1990 (crop year 1991), data collection in parts of northern Rwanda has been disrupted by the civil war. Hence, the most complete data is for crop year 1990.

Despite the disruptions and the intensive nature of the survey, most households remained in the sample throughout the period. Four out of five households included in the beginning of crop year 1989 were still interviewed weekly three years later.

4.3 Surveys Conducted

The basic task of agricultural sample surveys in most developing countries is to collect data on agricultural production. In Rwanda, the first nationally representative farm survey was carried out in 1983-1984, and since crop year 1986 DSA had collected production data annually. Surveys on land use were added in 1989 and those on agricultural transactions a year later.

Despite the expansion, production surveys remained a core activity and the only survey requiring each enumerator to visit and interview each household every week. This was deemed necessary in an environment where crops are harvested throughout the year and not just once or twice a year. Farmers were provided with standardized buckets and asked to report harvested output in terms of buckets.

Data on revenues and expenditures (and gifts) were collected monthly. Despite its name, the revenue and expenditure survey was not a comprehensive household budget survey. While the revenue side covered also wages and salaries and not just agricultural sales, the expenditure side focused exclusively on the purchases of agricultural products, labor and inputs. Even with this omission, the survey was very laborous, and included more numbers to key in than all the other surveys combined. For most transactions, both physical quantities transacted and amounts of money paid or received (if any) were recorded.

Land use data were collected twice a year (once per season). Unlike production and transaction data, the land use data were based on direct observation. Enumerators measured the dimensions and angles of each field. If the field was intercropped, enumerators estimated the planting densities of all the principal crops, using the local densities of pure stands as a yardsticks. The focus was on operational holdings, including both owned and rented fields, but excluding fields that were rented out for others. Only one-half of the fields were included in the 1989A season and three-quarters during the next two seasons. Complete land use data for the entire intensive sample is available for seasons 1990B, 1991A and 1991B.

Two types of livestock surveys were fielded regularly by DSA. Livestock inventory data were collected once a year, while animal production surveys were conducted quartely.

Demographic information on household members was collected once in 1989 and again during the 1991A cropping season. The demographic survey included questions on age, sex, literacy, education, and occupation.

In addition to the regular surveys, DSA conducted some special surveys. For our purposes, the most important is the survey of agroforestry fielded in 1991. Despite its name, the agroforestry survey had a broad focus, including questions on farm productivity, soil conservation, and farming practices. The agroforestry survey also asked whether each parcel was owned or rented.

No data were collected on the use of family labor on the farms. The demographic data sets tells how many members were primarily farming in each household, but there is no information on who did what and how much labor was devoted for agriculture, not to speak of how much was devoted to each crop.

Another significant omission concerns wealth. While data were collected on the two most important asset classes in rural Rwanda, land and livestock, the focus was on operational holdings. No information was gathered on land rented out or livestock lent to others.[16] Further, no listings were made of possessions such as bicycles or radios or of other potential proxies of wealth such as the type of roof on or the number of windows in the house.

No community-level data on agroclimatic conditions, health facilities, market places or roads were collected as part of DSA's regular survey program. However, on the basis of detailed maps and with the assistance of Jean Bosco Sibomana, the former national supervisor of DSA, we were able to add to the data set sector-level estimates of altitude, rainfall, and distance to paved road.

4.4 Quality Control and Data Cleaning

To ensure the quality of data collected, DSA relied primarily on continual training and close supervision of its 78 enumerators. It had full-time supervisors in each prefecture, so that the performance of each enumerator could be monitored weekly. The supervisors visited enumerators weekly, collected filled questionnaires from them, screened for inconsistencies and anomalies, and went back to the farms with the enumerators if needed. Supervisors themselves were monitored by a national supervisor, and also DSA's analysts frequently made field visits to see how their questionnaires were understood and interpreted and how enumerators adhered to the standard operating procedures.

In the DSA's office, questionnaires were again inspected visually before data entry. However, most data cleaning occurred after data entry. Complicated data cleaning programs were used to screen for anomalies and to print out listings of suspicious cases (Lassiter, 1992; Kangasniemi, Riley, and Peters, 1993). With the list in hand, data cleaners rechecked the questionnaires and reentered data. Decision rules for anomalies

[16] It is common in Rwanda for poor households to borrow livestock from their better-off neighbors. In exchange for taking care of the animals, the poor get manure, which helps them to maintain soil fertility.

not attributable to data entry errors were unclear and little or no documentation exists for how or whether anomalies were corrected.

All data cleaning in the DSA office was done survey by survey. No formal procedures were in place to ensure that information gathered in one survey was consistent with that gathered in another. Although supervisors and enumerators informally could weed out extreme inconsistencies, many anomalies remained.

As many of the computations made for this study were based on many surveys, they inevitably revealed inconsistencies such as sales of a given crop by households that had neither produced nor bought the product. Although it was not possible to address all or even most of the anomalies, some cleaning was made and a handful of households with very anomalous data was dropped out of analysis.

4.5 Data Transformations and Resulting Variables

4.5.1 Overview

The creation of analytically interesting variables out of the raw data collected by enumerators requires complex transformations based on numerous definitions and assumptions. While the transformations can be understood fully only by studying what the hundreds of lines of transformation algorithms actually do, this section seeks to describe some of the key definitions and assumptions needed to assess the potential and the limits of the data. Most of the transformation algorithms used by DSA were created by Greg Lassiter.

4.5.2 Production, Land use and Yield Data

The raw production data were in terms of buckets by crop and form of the product. Using standard conversion factors, quantities were converted into kilograms and non-typical forms were converted into the equivalents of the preferred form (e.g., green beans were converted into dry-bean equivalents). Note that all production data were collected at farm level; there is no way of telling how much beans or bananas came from any one field or whether fields close to the compound were more productive than more distant fields.

Land use data, in contrast, was originally at the field level. The raw data on land area consisted of measurements of angles and lengths of each side of each field, which were quite straightforward to convert into ares (100 ares = 1 hectare). Aggregated over the fields of each household, this gave an estimate of operational holdings.

Estimating land use by crop was more complex because of the prevalence of intercropping. The raw data included planting densities of the associated crops for each field, expressed as a percentage of the typical planting densities of these crops on purely cropped fields. These "unstandardized densities" typically added up to more than 100 percent. To allocate the estimated area of the field between the associated crops, the densities were scaled down (divided by their sum) to create "standardized densities" or shares that added up to 100 percent. If, for instance, the unstandardized densities of a 10 are plot were 60 percent for beans, 60 percent for sweet potatoes and 30 percent for maize, the standardized densities (shares) were 40 percent, 40 percent and 20 percent, respectively, and the household was considered to have 4 ares of this field under beans, 4 ares under sweet potatoes, and 2 ares under maize.

With farm-level estimates of output and area by each crop at hand, yields can in principle be computed. In practice, there are several reasons why household-level yield estimates are highly unreliable. First, although the use of most fields remains constant over the season, some crops are harvested throughout the year, implying that a significant minority of the fields change from one use to another during the season. For instance, a sweet potato field may be harvested and replanted with cassava just before the enumerator arrives to observe land use. Thus, the recorded sweet potato output for the season can be hundreds of kilograms, even though the recorded area under sweet potato is zero. If the farmer in this case had sweet potato on no other fields, the computed yield would be infinite. And since the cassava that replaced sweet potato would not be harvested during the season, its estimated yield would be zero.

Another explanation for the extremely noisy farm-level yield data has to do with minor crops on associated fields. For simplicity, enumerators were advised to ignore crops with unstandardized densities below five percent. Because of this simplification, areas under minor crops are understated on many farms and, if calculated, household-level yields would be overstated (and infinite in some cases).

While these problems cause anomalies at the household level, there is little reason to think that they systematically bias either land use or production data. Therefore, these problems do not distort national or other aggregated yield estimates computed by aggregating hectares and kilograms first and then dividing.[17]

Thus, the frequent allegation that the prevalence of intercropping leads to a significant across-the-board underestimation of yields and land productivity, is not true for DSA's data. It is an argument that holds for farm surveys that altogether ignore significant minor crops. In DSA's system, the output of minor crops is included even when these crops were left out from land use statistics. At most, the errors in the measurement of land use caused by intercropping can increase the estimated areas and

[17] Note that the aggregation of household-level yield estimates leads to aggregate estimates that are biased downward, since it effectively excludes the "anomalous" kilograms (infinite yields) but includes the analogously "anomalous" hectares (zero yields). All yield estimates computed for this study were made by aggregating first kilograms and hectares and then dividing. Some DSA publications, though, include estimates computed by the incorrect method, underestimating yields slightly (0-8%, depending on the crop).

hence depress the estimated yields of some major crops by reducing the area estimates and inflating the yield estimates of some minor crops.[18]

It is most likely to be true that DSA's numbers underestimate agricultural production, yields and food availability, but the reason is not because the data collection procedures failed to account for intercropping. Instead, the principal culprit is likely to be underreporting, especially of those products that are harvested in small quantities throughout the season.

4.5.3 Market Transactions and Rural Exports

The raw data on market transactions included numerous units and several forms of many products. As in the case of production data, the first step was to convert non-standard units into kilograms and several product forms into one per each crop.

One problem with the rural transaction data is the fact that some farm households are also part-time traders, buying products in order to sell. At the same time, many households buy and sell the same crop without being traders, for instance because they run out of their own supplies before the harvest. To study the degree of rural commercialization, the transactions of the latter should be included, whereas those of traders should be excluded in order to avoid doublecounting. In practice, we sought to separate the two by netting purchases and sales monthly. For instance, a household that bought 300 kilograms of potatoes in March and sold 500 kilograms during the same month was assumed to be trading 300 kilograms and selling 200 kilograms from his own production. In contrast, a household which bought 40 kilograms of beans in November and sold 50 kilograms of beans in January was assumed to be selling the full amount.

[18] At the national level, this appears to be a theoretical curiosity with little impact on the estimates. At sub-national levels, maize yields could be somewhat affected, because maize is frequently grown as a minor component in intercropped fields.

The monthly netting adjusts gross sales only modestly to eliminate trading. If netting is done over the year and over many or all surveyed households, the results are called "net sales and gifts" or "rural exports."[19] These no more indicate the importance of markets for producers or consumers but instead estimate the quantities of farm products moved from rural areas.

4.5.4 Income and Its Components

Since total household income is such a comprehensive concept, using farm survey data to compute estimates for total household income in semi-subsistence agriculture requires many conceptual decisions on the definition of income, a large number of computations and transformations, and numerous shortcuts and assumptions to deal with data limitations and computational constraints. Subsistence consumption must be valued, and adjustments may be needed for seeds and other inputs and for cross-household differences in the purchasing power of money.

The complex computations used to derive income estimates from the DSA survey data were originally created by Scott Loveridge (1992), and later substantially modified by the present author. Despite many changes that appeared quite significant, our revised income estimates were highly correlated with those of Loveridge.

Definition of income. Income is defined as a sum of the value of home consumption of main crops net of purchased inputs, sales of agricultural products net of purchased inputs, net gifts received, wages earned, and other incomes such as land rents received.[20] Among the items that conceptually should be part of the definition but are not included in the estimates due to unavailability of data are (1) home consumption of minor

[19] Thus, our terminology differs from that used by Loveridge (1992). His "net sales" is close to our "adjusted gross sales", although his adjustments moved more transactions from sales and purchases to trading than did ours.

[20] Home consumption is defined as production minus sales and gifts given (both adjusted monthly to account for trading and reciprocal exchanges). Thus, the income estimates exclude in-kind gifts given and include in-kind gifts received.

crops, (2) home consumption of livestock products, and (3) the value of the meals provided by employers and relatives.

Production of minor crops such as cabbages and tomatoes was not asked in the DSA surveys, although all sales, including those of minor crops were recorded. Hence, home consumption cannot be estimated for minor crops. Collecting information on the minor crops would have increased costs, and might even have reduced the quality of income estimates by adding to the complexity of the farm survey. An earlier national household budget survey (ENBC Rural) found that the 15 main crops (or 17, if the three types of bananas were considered separate crops) included in the DSA survey accounted in the mid-1980s for more than 97 percent of all calories consumed with much of the rest coming from industrial products like sugar and edible oils (MINIPLAN 1988).

Livestock products are like minor crops in that only transactions were recorded, implying that production for home consumption was not included in income estimates. The omission is not as important as it appears, since while most rural households practice mixed farming, livestock is kept largely for manure and for cash income, not for home consumption. Most rural Rwandans are too poor to consume sizable amounts of meat, eggs or milk. According to the ENBC rural budget survey the 15 main crops accounted for more than 96 percent of all proteins consumed (MINIPLAN 1988).

More significant is the omission of the meals provided by employers and relatives. These are clearly important, since especially the poorest households are known to send their children to eat with the relatives or to work for richer households, often primarily for wages in kind. In some parts of the country, particularly in the Northwest, it is customary for the employer to feed the employees during the working day. The omission of these meals presumably is one reason why the food availability estimates for the very poorest households are often impossibly low (<1000 kcal/day/adult equivalent on average). Unfortunately, little is known of the magnitude of this omission.

Valuation. A common procedure in farm surveys is to use national producer price estimates to value production and home consumption, whereas household budget surveys frequently value home consumption by using national consumer price estimates. In other words, farm surveys effectively assume that the alternative for home consumption is to sell at the national producer price, whereas consumption surveys assume that the alternative is to buy at the national consumer price. Both approaches are simplifications in that they overestimate the relative importance of home consumption of a given product in areas where its price is low and underestimate it in areas where its price is high. For instance, if we used the national mean potato price to value the home consumption of potatoes in Rwanda's northwestern potato zone, where potato prices are low, we could be claiming that a farmer who sold half of his potatoes got much more income from the other half that was consumed at home and valued higher. Even more anomalously, a subsistence-oriented potato farmer who consumed all his potatoes at home could appear more prosperous than a market-oriented potato farmer who sold all his potatoes and then bought potatoes for food at the low local prices.

In theory, computations should use prices that are as close as possible to the opportunity costs that households face and then adjust for price differences to ensure comparability. Since the DSA surveys have collected price and quantity information on tens of thousands of transactions in different locations at different times, we have tried to get a little closer to this ideal than is common in farm household surveys. Given the fact that most rural households in Rwanda both buy and sell farm products, and many even buy the same crop during some months they sell at other times, we valued home consumption by using the average of local purchase and sales prices. We estimated monthly producer and consumer prices for each of Rwanda's ten rural prefectures by first aggregating values and quantities and then dividing. Where only few transactions were made, annual prefectural or even annual national prices were computed instead.[21]

While the use of local prices ensures that the estimated relative roles of home consumption and sales are not very biased, they distort regional income comparisons by exaggerating incomes in the areas of high prices and understating incomes in the areas of low prices. To correct for this, all income components, not just home consumption, need to be adjusted up in low-price areas and down in high-price areas. Our approach was to compute household-level food price indices based on what was the estimated value of food availability (whether produced at home or purchased) at local prices and at national prices. Consider, for instance, a household that lives in a low-price area and was estimated to have earned 60,000 Frw in cash from sales and 40,000 Frw in kind from home consumption (at the low prefectural prices). Suppose that 20,000 Frw of the cash earnings were used to buy food at the low local prices so that the estimated value of food availability was 60,000 Frw. If the value of these quantities at national prices would have been 70,000 Frw instead, our method would adjust for the low local prices by adjusting incomes up by 10,000 Frw (10 percent). To avoid distorting numbers on market-orientation, we would adjust both sales and home consumption up by 10 percent. Since the DSA data base had no information on non-agricultural prices, we only corrected for differences in (the most important) agricultural prices.

As important as the use of local prices and the corrections for differences in purchasing power may appear in a context where regional price variation is substantial, their quantitative significance turned out to be quite limited. The overall picture painted

[21] Annual prefectural rather than monthly national prices were used, since prices varied more across prefectures than across months. Prefectural rather than sectoral prices were estimated, since a vast majority of sector-month-product combinations had no or only few transactions on which to base the computations.

by our estimates is essentially the same as that presented by the numbers computed by Scott Loveridge, who did not adjust for differences in the purchasing power of money.

Conversion factors. Most rural households grow either bananas or sorghum or both and sell at least some traditional beer made out of these ingredients. The amount of bananas and sorghum estimated to be left for home consumption depends crucially on how much ingredients are estimated to be needed for the beer that was sold. Very little is known on the actual conversion factors. Relying on the mid-point estimates for small beer brewers by Hagblade (1987) we assume that 3.41 kilograms of bananas and 0.11 kilograms of sorghum are needed to produce one liter of banana beer and that 0.36 kilograms of sorghum are needed to brew one liter of sorghum beer.

Unfortunately, neither the beers nor the ingredients are of standard quality. More bananas are probably needed at higher altitudes where bananas have lower sugar contents. Anecdotal evidence suggests that beer produced for sale is more diluted and hence requires less ingredients than beer produced for own consumption. Consequently, the conversions associated with beer brewing introduce considerable uncertainty to income estimates.

No change in assets. Our simplified assumption that sales plus consumption minus inputs equal production implies that changes in assets were ignored. Implicitly we assume that there were no changes in inventories and that labor was hired to plant and weed, not to invest in long-term biological capital or land improvements. Both assumptions are probably reasonable simplifications: Rwanda's main farm products are poorly storable and therefore crop inventories and changes in them are minimal (Loveridge 1988). Alhough investments in soil conservation, trees, and perennials are sizable, most labor is hired to participate in current production.

One important part of the omission of capital accounts is the simplified treatment of livestock sales. For simplicity, all livestock sales revenues were considered current income, whereas the weight gains of the animals not sold during the year were ignored altogether. Moreover, livestock purchases which conceptually are inputs, were not deducted from the sales. In the absence of capital accounts deducting livestock purchases would artificially reduce the incomes of some of the wealthier households. On the aggregate, the omission of livestock purchases biases livestock incomes upwards, but since home consumption of livestock products is ignored altogether, the overall bias is probably downward. The real problem is that income estimates for any year are highly dependent on whether households happened to sell livestock during the year. Income statistics overestimate the incomes and the role of livestock for some households, while underestimating them for most others. As a result, the statistics exaggerate the concentration of livestock incomes.[22]

4.5.5 Food Availability

Food availability was defined as production minus sales minus gifts given plus purchases plus gifts received. As was the case with income computations, the definition effectively assumes that there were no change in inventories. As discussed above, estimates of bananas and sorghum left for home consumption were based on the somewhat arbitrary assumptions on how much bananas and sorghum were needed for the recorded beer sales.

Kilograms were converted into kilocalories by applying the conversion factors from MINAGRI (1988). The availability of calories from bananas (that is, bananas not sold either as such or as beer) was computed as such, despite the fact that most bananas were brewed into beer. Thus, the estimated availability of kilocalories overstates the

[22] An alternative approach not used here would be to ignore livestock sales and instead simply assume that the income from livestock is proportional to livestock holdings.

likely consumption of calories. A more detailed discussion of the implications is provided in Chapter Seven.

Availability was computed for the 16 main crops. According to a nationwide consumption survey in the mid-1980s, these crops accounted for more than 97 percent of all calories and 96 percent of all proteins consumed in rural Rwanda. More important than the omission of minor crops, milk and other livestock products and industrially produced food products such as sugar and vegetable oil is probably the omission of meals provided by employers. Especially for the very poorest households, who sometimes even send their children to work for food wages, this omission can greatly understate food availability.

4.6 Limitations and Their Implications for Analysis

Detailed inspection of small samples of households by Scott Grosse and the present author have showed that the quality of the data set is quite uneven. Despite the various efforts to control data quality, numerous data entry and other errors exist in the data.

For many variables, the tails of distributions are not very meaningful. For instance, the estimates of food availability per adult equivalent are impossibly low for a significant minority of households. In some of these cases households have probably understated their production or purchases or overstated sales, in other cases a data entry error may have been the problem, in still others household members may have been fed by their employers or may have been consuming their inventories. At the same time some households have impossibly high availability estimates of perishable products. Income estimates suffer from similar problems.

Excluding outliers from analysis often helps but seldom solves the problem, since the cut-off points for outliers are arbitrary and can easily bias results. In some cases, aggegation over time, products, or households is necessary. Yield estimates discussed above are one example; food availability estimates are another. In principle, DSA's data are detailed enough that food availability could be estimated month by month, so as to study how different household groups change their diets over time and which are the crops that carry the food insecure households over the lean season. In practice, however, such estimates would be noisy and not particularly informative. Above all, the absence of inventory data means that monthly disaggregation could not shed much light on whether the food insecure households survive without storable products (beans and cereals) during the lean period. Therefore, our analysis of food availability is based on aggregation over 12 months.

One possibility is to use methods that give less weight to extreme observations. Throughout this study we rank households to quartiles based on income or farm size and base discussion largely on these rankings. No reference is made to the "poorest five percent," or "the worst nourished one percent" since many households in these categories would be there only because of data errors.

Finally, analyses have been repeated for several subsets, although only one or a few have been reported here. Throuhgout, the aim has been to focus on robust findings that do not change due to minor variations in definitions, specifications or samples.

Chapter 5

INTENSIFICATION OF LAND USE

5.1 Main Land Use Options

In this section we compare the main agricultural land use options available to Rwandan smallholders. We review national statistics on yields (returns to land), whether measured in terms of subsistence (nutritive) or market value. We also discuss labor requirements of the main crops and the degree of protective crop cover that each crop provides against erosion.

Rwandan smallholders cultivate on average two-thirds of their cultivable lands. The rest consists of fallows, pastures, and woodlots. Fallows are the traditional way of restoring land fertility. Along with pastures they yield benefits through grazing. Woodlots provide increasingly valuable forest products. In general, uncultivated land uses give low returns to land, which explains why they over time have lost ground to crops. Some recent studies suggest, however, that trees already are highly attractive cash crops in certain parts of the country (Cook and Grut 1990). Unfortunately, no data are available on the typical returns to pasture and woodlots.

The main crops in Rwanda are, in the order of the land share, bananas, beans, sweet potato, cassava, sorghum, maize, coffee, white potato, peas and taro (colocase). Together, the main crops cover over 90 percent of the cultivated land area. Minor crops include soybeans, peanuts, wheat, finger millet (eleusine), rice, cocoyams, tea, pyrethrum, as well as various fruits such as papaya and avocado and many vegetables, including cabbages and tomatoes.

Rwanda has two main agricultural seasons per year, although bananas, roots and tubers, and to some extent also other crops are harvested throughout the year. Table 5-1 shows the national mean yield estimates of major crops during the six seasons of 1989-1991. For cross-crop comparability, all yields are expressed per six-month seasons.[23] Since beer bananas and cooking bananas are not separated in land use statistics, only the average yield estimate for total bananas can be computed.

In terms of market value, white potatoes have highest yields, followed by bananas, sweet potato, and beans. However, the high national figure for potatoes is due to the volcanic highlands in northwestern Rwanda, where yields are more than twice as high as elsewhere. For most Rwandan farmers, bananas are by far the most remunerative cash crop, whereas coffee was not particularly attractive at the prices that prevailed in the late 1980s and early 1990s.

[23] Note that this differs from the FAO practice of expressing yields per growing period for annuals and per year for perennials.

Table 5-1: Characteristics of Main Crops (National Averages)

	Yield per hectare per season: Weight (kg)	Value ('000 FRw)	Energy (mill. kcal)	Proteins (kg)	Index of Crop Cover (C-value) (%)	Sales price (FRw/kg)	Caloric cost (FRw/ 1000 kcal)
Beans	838	29	2.50	164	19	31	13
Peas	272	16	.90	56	15	62	19
Sorghum	1016	23	3.10	73	40	19	9
Maize	1010	23	3.30	86	35	19	9
Sweet Potato	4527	40	4.20	65	23	8	9
Cassava	2185	17	2.20	11	26	9	7
White Potato	6102	78	3.50	73	22	10	26
Taro	1580	20	1.30	22	35	12	15
Cooking Banana	6788	51	5.40	48	4	7	10
Beer Banana	6788	31	5.40	48	4	4	6
Banana Beer	6788	47	1.30	9	4	27	41
Coffee	256	21	N.A.	N.A.	2	83	N.A.

Note: Mean banana yield used for all bananas.

Sources: Yields: 1989-1991 means computed from DSA/MINAGRI farm survey data; C-values: Lewis (1986); Prices: 1990 means computed from DSA/MINAGRI data.

In terms of food energy, sweet potatoes and cooking bananas are far ahead of the others, followed by white potatoes, maize, sorghum, and beans. Beans are superior providers of proteins. Cassava, taro, and peas are low-yielding by every measure. Bananas are high-yielding subsistence crops if consumed directly, but if they are turned into beer, their yields in terms of calories or proteins are low.

Data on labor use are notoriously laborous and costly to collect. They were not collected by the Division of Agricultural Statistics (DSA) of Rwanda's Ministry of Agriculture and Livestock (MINAGRI), whose data we used above to compute returns to land. Hence, no comparable figures on returns to labor can be presented. Experts on Rwandan agriculture generally believe that coffee is the most laborous crop (Bart 1993;

Graaff 1986). Pure banana groves do not require much work if grown extensively, but intensive production that often involves intercropping with annual food crops can be laborous. Beans require more labor per hectare than cereals, and cereals more than root crops. Cassava, especially, requires little labor (Holden 1993). Thus, it appears that cash returns to labor are high for potatoes in the northwestern highlands and for extensively cropped bananas in much of the rest of the country. Coffee is not nearly as attractive (at the low prices that prevailed in late 1980s and early 1990s). The rankings of the main food crops—sweet potato, beans, sorghum, maize, and cassava—in terms of their returns to labor apparently vary greatly depending on local agroclimatic conditions and prices.

Crop-specific returns on land and labor vary considerably depending on agroclimatic conditions. The higher the altitude, the cooler the climate and the lower the yields of cassava, which grows best on the warm lowlands found in Rwanda only on the soutwestern and southeastern edges. Bananas yield well at the mid-altitudes (around 1500 meters) that cover much of the country. At higher altitudes they grow more slowly and have a lower sugar content, which reduces their value for beer-brewing. Few bananas are grown above 2000 meters altitude. The range of sweet potatoes, beans, and maize reaches somewhat higher, but at the temperate highlands (around 2500 meters), sweet potatoes are typically outyielded by potatoes, beans by peas, and maize by wheat. Of export crops, coffee grows better at lower and tea at higher altitudes.

Rainfall increases in Rwanda from east to west and the difference matters mostly for cereals. Maize is the dominant cereal in the well-watered western provinces, whereas sorghum thrives in the dryer eastern savannas. Although bananas in general are vulnerable to droughts, only a very small area in eastern Rwanda is too dry for bananas. Most of the East is very suitable for bananas. Cassava, sweet potato, and tea are known to grow relatively well on degraded lands, whereas cereals, beans, and bananas suffer considerably from degradation (Barampama 1993). Cooking bananas are more demanding than beer bananas.

Producer prices per kilogram can be interpreted as proxies for transportability. At the 1990 prices, coffee was by far the most transportable crop, followed by peas, beans, banana beer, and cereals. Root crops and bananas have low values per weight, which implies that their production for non-local use depends crucially on transportation costs. The relative prices of beer bananas and banana beer shows how brewing increases transportability. If brewing is considered part of banana production, beer bananas are a labor-intensive crop with high market returns per hectare. The fact that cooking bananas are almost twice as expensive as beer bananas suggests that on similar land cooking bananas yield considerably less than beer bananas. Thus, our second column cannot be interpreted to mean that farmers could earn higher income by switching from beer bananas to cooking bananas.

The last column of Table 5-1 reports consumer prices relative to caloric content. Of the products normally eaten, cassava provides cheapest calories. Beer bananas would be even cheaper, but are considered famine food and are usually eaten only after serious crop failures. Brewing increases price and destroys many calories, making banana beer a very expensive source of food energy. Cooking bananas are relatively expensive food, which suggests that in consumers' view, they are a very different product from beer bananas. Cereals provide as cheap calories as sweet potatoes despite much lower returns to land. White potatoes are quite expensive food, although this does not hold for the prime potato production areas.

Since Rwanda is a hilly country, with an average field slope of 16.7 degrees, erosion is a major concern. Erosion depends on a number of factors, including the degree of protective cover provided by the vegetation. Crop cover, in turn, depends on the crop species and varieties grown, on the timing and density of planting, on the crop management practices followed, etc. In general, perennials that are kept mulched throughout the year provide best protection against erosion, whereas annuals that establish slowly leaving much of the ground bare during the early rainy season, are most erosive.

Table 5-1 also presents the crop cover indices (C-values) estimated for Rwandan conditions by Lewis et al. using the Universal Soil Loss Equation (USLE). These estimates are specific to the prevailing agronomic practices and are based on empirical measurements in Rwanda and Kenya. Coffee fields that are usually mulched carefully in Rwanda are least vulnerable to erosion. Also tea, Rwanda's second most important export crop, provides good crop cover. Pure banana groves are typically covered by mulch (banana leaves and trunks), which protects them well against erosion. However, farmers are officially urged to thin their banana groves to get more productive banana trees, which means less mulch and more erosion. Moreover, when bananas are intercropped with annuals, most of the crop residues are typically removed or turned under the soil, making land much more vulnerable to erosion. Of the annual crops, beans and roots and tubers typically provide more crop cover against erosion than maize and sorghum, the main cereals.

In sum, outside the northwestern potato zone, market incentives are typically tilted towards bananas, subsistence incentives towards sweet potatoes, beans and bananas, followed by cereals. On degraded lands, cassava and sweet potatoes often produce most food; on better lands, beans, cereals, and especially bananas produce more food or market value. On steep slopes, concern for soil conservation might induce households to prefer bananas, coffee, or woodlots over annual food crops.

5.2 Land Use Trends in Recent Past

Between 1944 and 1994, Rwanda's population grew from less than two million to almost eight million. Changes in land use and cropping patterns have been the central mechanism through which agriculture has been able to respond to population growth.

One hundred years ago most cultivation took place on the gently sloping hillsides that were easiest to clear with fire and cultivate with hoes (Bart 1993). Over the past century, cultivation has gradually expanded to the wet valleys, steep slopes, dry savannas, and temperate highlands previously reserved for grazing or left under natural forests. Frequency of cultivation has increased; fallowing has declined.

In the beginning of this century, sorghum, which was grown both for food and for beer, was the dominant staple and other important crops included beer bananas, finger millet (eleusine), and traditional legumes (Jones and Egli 1984, Martin 1987). New world crops, including beans, sweet potatoes, and maize had been introduced but had not yet challenged the reliance on traditional cereals and legumes.

A series of famines in the late 1920s provoked the Belgian authorities to promote non-seasonal crops: cassava in low-altitude areas, sweet potatoes in medium-altitude areas, and potatoes in high-altitude areas (Vis 1975, Guichaoua 1989). Cultivation of coffee was made compulsory in 1927 (Guichaoua 1989) and in the 1930s also the cultivation of the non-seasonal famine crops became mandatory (Leurquin 1963). Sweet potato gained ground rapidly, but was soon attacked by a disease, which greatly contributed to the 1943-44 famine (Vis 1975). Colonial administrators responded by emphasizing more cassava, which was originally bitterly resented by farmers, and by introducing more resistant sweet potato varieties (Leurquin 1960). Farmers also responded to famines by planting more beer bananas, which can be eaten during times of distress (Bart 1993; Leurquin 1963; Close 1955).

By 1967, cereals were still believed to take nearly one-third of cultivated land (Bart 1993). Roots and tubers had increased to 14 percents and provided more calories than cereals. Leguminous plants with 37 percent of cultivated land provided enough proteins. One-fifth of cultivated lands was believed to be under bananas.

In the 1960s and 1970s, cultivated area grew approximately as fast as population. The area under and the production of roots and tubers and coffee may have increased by more than three-fold, while cereals and beans grew more slowly and lost ground relative to roots and tubers (Cambrezy 1984; Bart 1993; World Bank 1991; CNA 1991b). Banana production expanded fast in the 1960s, as most of the colonial restrictions on bananas were discontinued after independence (Delepierre 1970). Thereafter, banana groves continued to expand slightly faster than cultivated area, but since many of the new groves were planted on marginal lands, production increased more slowly, failing to match increases in population (Bart 1993; CNA 1991b).

The above numbers were based on various expert opinions. Agricultural surveys with nationally representative sampling started in 1984, and only in 1989 a systematic approach was introduced to deal with intercropping, which is a pervasive feature of Rwandan agriculture (DSA 1991). This suggests caution when discussing the long-term trends in land use.

According to the national agricultural survey for agricultural year 1991, cereals have lost their dominance and only covered 14 percent of cultivated land. Their role in food consumption, whether measured in terms of food energy or proteins, had dropped to below 20 percent. Finger millet had almost disappeared and sorghum had lost ground nationally, despite its suitability for and popularity in the dry eastern lowlands, where cultivation had expanded most (Bart 1993). In beer brewing, sorghum had been increasingly replaced by beer bananas (Jones and Egli 1984; Bart 1993). Rice had been expensively promoted for the drained marshes (Rushemeza 1991), but nationally it was still a minor crop.

Roots and tubers that cover 29 percent of the cultivated area and bananas with 24 percent provide almost two-thirds of the food energy, while legumes (primarily beans) with 24 percent provide half of the proteins. Sweet potato is by far the most important root crop and is grown almost throughout Rwanda. Cassava is grown mostly in areas that are too dry or degraded for sweet potato. White potatoes are a minor, low-yielding subsistence crop in most of Rwanda, but a major, high-yielding cash crop in the cool northwestern highlands. Their prominence is partly due to climatic conditions, and partly dependent on effective research, extension, and input supply. Bananas are mostly beer bananas, but especially in eastern Rwanda and around cities also cooking bananas are a major crop. Legumes are mostly beans, and increasingly climbing beans rather than bush beans (Sperling et al. 1994). Except for some high-altitude areas, peas have almost disappeared. Soybeans are starting to gain ground, primarily on degraded lands and in areas where beans have suffered greatly from diseases (Olson 1992; World Bank 1991).

Compared to the first agricultural survey in 1984, the 1990 survey suggested that the area under bananas had increased by 27 percent and that under sweet potatoes by 33 percent. Also coffee, cassava, potato and soybean acreages had increased, while beans, peas, and cereals had declined.

In sum, three main trends in land use over this century in Rwanda can be identified. First, annual and perennial crops have expanded at the expense of pasture, fallow, and forest. Second, the shares of cultivated fields under roots and tubers, bananas, and coffee have increased at the expense of cereals, and, more recently, legumes. Third, traditional cereals (finger millet and sorghum) have been replaced by maize and traditional legumes (cowpeas and peas) by bush beans and these in turn by climbing beans and soybeans. Despite quite heavy-handed promotion of some crops at the expense of others at times, the trends are probably mostly voluntary choices by farmers. Sweet potatoes and cassava continued to expand after colonial promotion ended, and official discouragement did not prevent the expansion of bananas, although it may have slowed it somewhat during the late colonial period.

Above we have simplified by averaging over the two seasons. Most land uses in Rwanda are quite stable, with little difference between the seasons. The main exception is sorghum, which in much of Rwanda is grown exclusively during the second (longer) season. The offsetting change concerns mostly beans and maize, which nationally cover about twice as much land during the first season than during the second season. Seasonal differences are least important in the North-West, where the rainfall is higher and more evenly distributed than elsewhere in Rwanda (Nduwayezu 1990).

5.3 Patterns of Land Use by Farm Size

The main difference in land use between small and large farmers is the much larger share of small farms that is under the crops. Using data from the national agricultural survey of 1991 and averaging over the two seasons, Table 5-2 reports that the quartile of households with least cultivable land relative to the size of the family (hereafter "small farmers") cultivated 90 percent of their cultivable land, while the quartile with most land per adult equivalent (hereafter "large farmers") had crops on only 69 percent of their agricultural land. Large farmers had three times as large a share under fallow than small farmers, and also had much more pasture.

Table 5-2: Land Use by Farm Size

% OF CULTIVABLE LAND	FARM SIZE QUARTILE (Ares/AE)				All Farms
	<9	9-14	14-24	>24	
Bananas	19	20	18	19	19
Roots and Tubers	28	26	23	18	24
Legumes	22	19	19	16	19
Cereals	13	13	12	11	12
Coffee	6	5	5	4	5
Other	2	2	3	2	2
TOTAL CULTIVATED	90	85	80	69	81
Fallow	10	14	18	25	17
Pasture	1	1	2	5	2
Woodlot	8	10	13	8	10

Source: DSA/MINAGRI, Agricultural Survey 1991; 1095 households

To a large extent, the disappearance of fallow and pasture reflects the Boserupian intensification process in which farmers respond to population pressure by increasing the frequency of cultivation. Notably, woodlots do not show the same pattern. Unlike pasture and fallow, which in Rwanda are often "luxuries" of large farmers, the woodlots that remain on farms are largely located on steep slopes and on other marginal lands. Regionally disaggregated tabulations not reproduced here indicate that the relatively rich and large farmers in the East have almost no woodlots, whereas the impoverished farmers on the Congo-Nile Divide allocate much land for trees. Our definition of cultivable land used in grouping farmers to farm size quartiles excludes woodlots but includes pasture and fallow. Even the inclusion of pasture and fallow is debatable, since while most of these lands undoubtedly can be and periodically are cultivated, some farmers resort to fallowing not because they have much land but because their fields are so poor that they yield little without fallowing.[24]

Regarding the crop mix, the table is less clear, showing mainly that small farmers have higher shares of most crops. To better identify patterns in the crop mix, we focus on the allocation of cultivated land in Table 5-3. As the historical developments would suggest small farmers have higher shares of white potatoes and root crops. But the historic expansion of bananas at the expense of other crops is nowhere to be seen, and the decline of bean cultivation in the 1980s under strong demographic pressure clearly does not mean that small farmers would shun beans. Overall, the crop choices of the small farmers are not strikingly different from those of the large farmers. Some observers even refer to the "considerable stability" of the crop mix (MINAGRI 1992).

[24] In regional comparisons, cultivated rather than cultivable land would probably be a better basis for assessing land scarcity, since much of the regional variation in fallowing and pasture appears to be associated with land quality. Within each region, however, larger and richer households generally have much more fallow and pasture than their less fortunate neighbors. This suggest that in household-level analysis like ours, cultivable land should be defined to include pasture and fallow.

Table 5-3: Crop Shares by Farm Size

% OF CULTIVATED LAND	FARM SIZE QUARTILE (Ares/AE)				All Farms
	<9	9-14	14-24	>24	
Banana	21	23	22	27	23
Sweet Potato	15	14	13	11	13
Cassava	8	9	10	10	9
White Potato	6	4	3	2	4
Total Roots and Tubers	32	31	29	26	29
Beans	18	16	17	16	17
Peas	3	3	3	4	3
Total Legumes	24	22	23	22	23
Sorghum	5	8	9	9	8
Maize	9	7	5	6	6
Total Cereals	15	16	16	16	16
Coffee	6	6	6	6	6
Other Crops	2	2	3	3	3

Source: DSA/MINAGRI, Agricultural Survey 1991; 1095 households

The differences between the longitudinal and cross-sectional results suggest that the associations between land scarcity and land use may be lost because small and large farmers differ also by agroclimatic or other factors. A key agroclimatic distinction in Rwanda is between highlands, where bananas do not grow well, and the rest of the country. Part of the non-banana highland area enjoys fertile volcanic soils and specializes in white potatoes. Outside the potato zone, the highlands are mostly marginal and degraded. In our sample, the distinctions between the zones are clear. Ten of the 78 enumerators worked outside the banana zone, four of them in the potato zone. Within the banana zone, there were some households with almost no bananas, but in all the clusters of four households bananas covered at least 10 percent of cultivable land. In the potato zone, bananas were almost non-existent. In the marginal zone, both bananas and white potatoes were rare.

Table 5-4: Comparison of Cropping Zones

	Banana Zone	Potato Zone	Marginal Zone
Altitude (m)	1710	2214	2184
Rainfall (mm)	1083	1161	1574
Farm Size (ares/AE)	19	11	22
% Cultivated	82	90	60
% under Banana	21	0	2
% under Sweet Potato	11	1	13
% under White Potato	1	38	3
Households in sample	N=960	N=57	N=78

Source:DSA/MINAGRI, Agricultural Survey 1991; 1095 households

Table 5-4 shows that the cropping zones are closely associated with farm size: farms in the potato zone are tiny, whereas those in the marginal zone are relatively large. This suggests that despite the strong national cross-sectional correlation between land scarcity and potato production, potatoes are a significant response to population pressure only for a small minority of Rwandan farmers. More generally, the table hints that the national patterns on land use may give little guidance on how Rwandan farmers are intensifying. Moreover, intensification strategies are likely to differ by zone.

Hereafter, we focus on the banana zone, which covers some 85 percent of our sample and presumably roughly the same share of Rwanda. Table 5-5 shows that the strong association between farm size and white potatoes seen above indeed does not hold for the banana zone. Otherwise, the results do not change much. Land scarcity appears to be associated primarily with beans and sweet potatoes, but not with bananas, which cover only slightly smaller shares of cultivable land on smaller farms and, relative to the cultivated land area, are no more important on small farms than on larger farms.

To the extent that intercropping is a way to increase returns to land, it can be hypothesized to be one intensification strategy. Table 5-6 shows that intercropping indeed

Table 5-5: Land Use by Farm Size in Banana Zone (% of cultivable land)

	FARM SIZE QUARTILE (Ares/AE)				All Farms
	<9	9-14	14-24	>24	
Banana	22	23	20	20	21
Roots and Tubers	27	26	22	18	23
Sweet Potato	14	13	10	7	11
Cassava	8	9	9	7	8
White Potato	1	1	1	1	1
Legumes	23	19	19	15	19
Beans	19	14	14	12	15
Peas	2	2	2	2	2
Cereals	11	11	12	10	11
Maize	5	4	3	3	4
Sorghum	5	7	7	7	6
Coffee	7	5	5	5	6
Other	2	2	3	2	2
TOTAL CULTIVATED	91	86	81	71	82
Fallow	8	13	16	24	16
Pasture	0	1	3	5	2

Source: DSA/MINAGRI, Agricultural Survey 1991; 960 households

is associated with land scarcity, with smaller farmers having much higher shares of their land under various crop associations. Half of the difference arises because small farmers have less fallow, woodlots and pasture, but even if we look at only the cultivated fields, small farmers clearly practice more intercropping.

Moreover, small farmers intercrop differently. Their associations include more crops, and have more often bananas, beans and sweet potatoes among the associated crops. Thus, it appears that land scarcity is pushing households towards multistorey banana gardens where food crops are grown under banana trees (Conway 1983).

5.4 Multivariate Analysis of Land Use

The cropping patterns discussed above show how the land uses of land-scarce farmers differ from those of their larger neighbors, but they do not go very far in

Table 5-6: Intercropping by Farm Size in Banana Zone

	FARM SIZE QUARTILE (Ares/AE)				All farms
	<9	9-14	14-24	>24	
% of cultivable intercropped	63	54	48	41	51
% of cultivated intercropped	68	62	58	58	62
with bananas	45	38	33	30	36
with beans	40	32	29	27	32
with sweet potatoes	23	22	17	14	19
with cassava	19	18	16	15	17
with sorghum	9	10	11	11	10
with maize	24	19	18	18	20
with coffee	2	2	1	2	2
Crops/association	2.4	2.3	2.2	2.1	2.2

Source: DSA/MINAGRI, Agricultural Survey 1991; 957 households

explaining whether the differences arise because land scarcity pushes small farmers to behave differently. We next study the association between land scarcity and land use by controlling for a number of other factors. Since the patterns were found to be highly different on the highlands, it is likely that also the relationships between land use and other factors vary by cropping zone. Access to markets, for instance, is likely to provide very different incentives for land use depending on which are the most lucrative cash crops in the area. We therefore restrict our study to Rwanda's banana zone, which covers roughly 85 percent of the rural households.

5.4.1 General Model

Semi-subsistence smallholder agriculture like that in Rwanda is characterized by very high transportation and transaction costs (Binswanger and Rosenzweig 1986). As explained by Coase (1937) and elaborated by Williamson (1985), North (1990), and Fafchamps, de Janvry, and Sadoulet (1995), the presence of such costs makes resource allocation dependent on who owns the assets. Land, labor, and credit markets cannot be assumed to equate factor costs across farm households. Consequently, resource allocation decisions, including those on land use, cannot be modelled merely as a function of relative prices and the physical input-output relations. Instead, the opportunity costs (shadow prices) of using land tend to be higher and those of using labor tend to be lower on the farms that have less land per person. Instead, models should also include relative factor endowments as well as household subsistence needs and consumption preferences.

In practice, many of the theoretical determinants are not observable and various proxies need to be used. Given our focus on the impacts of increasing land scarcity associated with demographic pressure we sketch a model with four sets of variables:

Land use = f (market incentives, physical conditions, person/land ratio, other household characteristics).

Market incentives refer to prices or to other measures of how lucrative it is to produce certain crops for sale while relying on markets for other crops. Physical conditions are proxies for land productivity, that is, for the yields farmers can expect on their fields from each crop. Physical conditions are likely to have strong correlations both with land use and with other determinants, which makes them crucial control variables for the model. Person/land ratio measures both subsistence needs and the relative endowments of land and labor. Other household characteristics are proxies for preferences and non-land endowments.

5.4.2 Explanatory Variables and Hypotheses

Land scarcity. We expect that land scarcity (high person-to-land ratio in terms of adult equivalents per cultivable hectare) is associated with more land being allocated to uses that give high returns to land at the expense of uses that give low returns to land. Based on the characteristics of the major crops in Rwanda (Table 5-1), we expect land scarcity to be associated with high shares for bananas and sweet potato, which nationally have superior productivity both in terms of market value and in terms of food energy. We expect low shares for sorghum, peas, taro, and cassava, which are nationally quite low-yielding by every measure.

No unambiguous hypothesis can be made for beans, since while their land productivity is considerably below that of sweet potato and bananas in terms of market value and food energy, they are superior to all other crops in terms of proteins. In a commercialized setting, we could expect the market value to matter most and small farms to specialize in bananas and sweet potato, and purchase rather than grow beans. But in Rwanda's still quite subsistence-oriented rural economy where diets are very deficient in proteins, subsistence production of proteins clearly must be very important. Also the value of the nitrogen fixed by leguminous plants such as beans may increase as land becomes scarcer and fallowing no longer can be relied on to restore fertility.

Also the expectation for maize is ambiguous, since while maize does not provide very high returns to land in Rwanda, it produces more food per hectare than sorghum, especially in the well-watered western regions. To the extent that cereals are subsistence foods and substitutes for each other, maize can be hypothesized to gain ground from sorghum as land becomes more scarce.

Overall, the share of cultivated land can be expected to increase with higher land scarcity and that of pasture and fallow to decline. Little can be said about woodlots, since no data is available on returns to trees. While cultivation has historically expanded at the expense of forests, some results suggest that in many land-scarce areas trees could be highly remunerative cash crops (Cook and Grut 1990; Current, Lutz, and Scherr 1995).

Market incentives. In theory, market incentives could be expressed in terms of (the expected levels and variances of) prices faced by farm households at the farm gate, but in practice we observe only market prices. Since Rwanda's main agricultural products are bulky (Table 5-1) and local infrastructure is often poor, the unobserved farmgate shadow prices are likely to be quite different from the observed prices[25]. Moreover, local market prices reflect both local demand and local supply. Instead of indicating good economic incentives (strong demand), high prices may be a sign that the crop in question just does not grow well in the area (weak supply). When agroclimatic and other factors affecting supply are imperfectly controlled for, regression analyses often seem to suggest that farmers react to high prices by producing less. Since data on local prices are also quite noisy, we do not attempt to measure market incentives by prices.

Instead, we use distance to paved road as a proxy for the incentives to produce for the market and to rely on it for food. The point, of course, is not that only roads matter for commercialization. While proximity to road may be the key determinant of whether a given farmer has access to wider markets, the overall commercialization of Rwandan agriculture may depend more on the growth of urban economy and on trade policies than on road construction. Thus, what our analysis finds about the "impacts" of good access may also suggest what are some of the rural consequences of growing urban demand for food and other agricultural products.

We expect that good market access encourages households to specialize in cash crops that yield well in terms of market value. We expect this to happen at the expense of less remunerative land uses, including food crops with low monetary returns. We expect

[25] In Kagera, on Tanzanian side of Rwanda's eastern border, large quantities of cooking bananas are thrown away or fed to livestock in good harvest years (Kajumulo-Tibaijuka 1984). This suggests that transportation costs exceeded market prices and the perceived farmgate producer prices were close to zero. DSA data suggest that some households in eastern Rwanda may do the same.

also changes towards bulky cash crops at the expense of crops with lower yields but higher value per unit of weight.

In Rwanda's banana zone, this implies above all that bananas should benefit from good access to paved roads. Whether sold for food or as beer, their transportability as measured by value-to-weight ratio is far below that of coffee, the other main cash crop in Rwanda. The land uses that can be hypothesized to lose ground are pasture, fallow, cereals, cassava, taro, peas, and coffee. For beans the expectation is again ambiguous, since, as discussed above, their role in fertility management can offset the consequences of modest yields in terms of market value. While the latter is an argument for expecting that households close to roads might take advantage of markets and buy rather than produce beans, the latter suggests that market access which increases the value of the increased soil fertility could promote bean production.[26] In other words, in a farming systems perspective beans may not be a low-yielding crop that farmers are tempted to give up if they can buy beans instead.

Physical conditions. Rwanda is a mountainous country, where agroclimatic conditions vary primarily with altitude. Most of the country is between one and two kilometers above sea level, but roughly a quarter of agricultural land is located above 2000 meters and some areas in eastern and southwestern parts of the country are below 1000 meters. Highlands are cool and well-watered, lowlands much dryer, especially on the eastern side of the Congo-Nile Divide. Soils also vary considerably, but no estimates of the soil types or of degradation on the surveyed farms were available in the data set. Estimates obtained from soil maps were not helpful, presumably because they were much too crude. Instead, we have computed an index of land quality, based on the estimated

[26] In many countries a reasonable assumption would be that good road access implies improved access to fertilizer and reduced incentive to grow beans. As discussed below, fertilizer consumption in Rwanda in 1990 was so minimal that variation in fertilizer access hardly played any significant role in crop choice. Neither farmers close to roads nor those in more remote areas used notable quantities of fertilizer for beans.

yields of major crops (weighted by national prices) in each sector. Since not all differences in physical conditions are captured by rainfall, altitude, and land quality, we also have included dummy variables for agroclimatic zones. To the extent that the impacts of rainfall, altitude, and land quality are non-linear, such impacts also can get captured by zone dummies.

Multicollinearity among the indicators of physical conditions creates problems for the estimation and interpretation of regression coefficients. Fortunately, these coefficient estimates as such are of minor interest. Since our main focus is on demographic change and on factors that are changing or could be changed by policy, the role of rainfall, altitude, land quality, and zone dummies is primarily to control for physical conditions. This role is not compromised by high correlations among the indicators of physical conditions.

The general hypothesis, of course, is that each crop claims larger shares in those conditions that are more suitable for it. Of Rwanda's major crops, bananas and cassava are known to thrive at lower altitudes and sorghum does better in dry conditions than maize. White potatoes are known to grow best at the very high altitudes, whereas sweet potatoes and beans grow better at lower altitudes. Cassava and sweet potato are known to suffer relatively modestly from degradation, whereas cereals are considered quite demanding.

*Household characteristics.*Two key characteristics that can be hypothesized to be associated with land use are the age of the household head and off-farm incomes. As population growth has greatly increased the number of agricultural households during the past decades, young people have often settled either on previously uncultivated lands or on the outer fields of their parents' farms. We expect that households with older heads devote higher shares of their land to perennial crops such as bananas and coffee.

Off-farm incomes are a proxy for liquidity and can be hypothesized to be associated with lucrative crops that require large cash outlays or long payback periods. In Rwanda's volcanic highlands, white potatoes might be such a crop, but in the banana zone studied here none of the main crops requires many purchased inputs other than labor. Since both coffee and (intercropped) bananas are labor-intensive and take years to reach their full production, we hypothesize that these are associated with high off-farm incomes.

Education is highly correlated with off-farm incomes, either because high incomes are needed to pay for education or because education raises earnings. Only off-farm incomes were used in our specification.

5.4.3 Regression Results on Land Use

Two sets of Ordinary Least Squares regressions on land use are estimated using the variables described in the previous section. In the first set of OLS regressions, the dependent variables are percentages of *cultivable* land under each land use and in the second set, they are percentages of *cultivated* land under each crop. The first set focusses on how farmers respond to demographic change by expanding cultivation at the expense of fallow and pasture, while the second set looks specifically at variation within the crop mix. Table 5-7 reports the results for the first set, and Table 5-8 for the second one.

Table 5-7: Land Use Model I: Shares of Cultivable Land under Each Use

	Banana	Sw.Pot	Cassava	Beans	Sorghum	Maize	Coffee	Fallow	Pasture
Man/land,farm	.18**	.02	-.06	.17**	-.05	.11**	-.11**	-.13**	-.13**
Man/land,vill	-.04	.24**	-.02	.12**	.00	.27**	.10*	-.29**	.04
Dist. to road	-.17**	.02	.06	.02	.09*	.08*	.02	.04	.07
Altitude	-.11*	.33	-.49**	.11*	.21**	.12**	-.26**	.19**	-.07
Rainfall	-.06	.04	.20**	-.37**	-.14**	.04	.06	-.01	-.13**
Land quality	-.01	-.22**	-.04	-.07*	.15**	.06	.00	.09*	-.13**
Age of head	.12**	-.04	-.13**	.00	.07*	.06	-.07*	-.02	.03
Off-farm inc.	.04	-.02	-.07*	.04	-.04	.04	-.08**	-.02	.02
East	.14**	-.02	-.24**	.14**	.16**	.24**	-.12**	-.10*	-.04
Congo-Nile	.03	-.06	-.13*	.00	.07	.15**	-.09*	-.04	.02
Volcanic	-.03	-.14**	-.01	.26**	.01	.12**	-.03	-.10**	.00
Lake Kivu	-.05	-.06	-.12**	.26**	-.12**	.08*	.28**	-.09*	-.04
ADJ. R2	.11	.28	.22	.28	.14	.17	.23	.18	.04

Source: DSA/MINAGRI, Agricultural Survey 1991; 960 households
* = significant at 5% or better, ** = significant at 1% or better

Population pressure. Table 5-7 confirms that small farmers indeed cultivate a higher share of their cultivable land by allocating less land for fallow and pasture. In other words, the pattern observed in the cross-tabulations above, appears to hold when rainfall, altitude and the other factors in the regression specification are controlled for.

Both Table 5-7 and Table 5-8 show that land-scarce households allocate more land to bananas, beans and maize than others on the average. The relationship between sweet potatoes and population pressure is more complex. The results show that while more sweet potatoes are grown in *secteurs* with higher population pressure, no significant association was found within *secteurs* between sweet potato and land scarcity. If the sectoral association arose only because some unmeasured factors (such as soil type) are linked to both population pressure and land use, we could not conclude that population pressure is pushing land-scarce farmers to grow more sweet potatoes. Yet, the post-World War II expansion of sweet potatoes during the period when Rwanda's population grew

Table 5-8: Land Use Model II: Shares of Cultivated Land under Each Crop

	Banana	Sw.Pot.	Cassava	Wh.Pot.	Beans	Sorhum	Maize	Coffee
Man/land,farm	.12**	-.02	-.09**	-.05	.13**	-.07*	.07*	-.12**
Man/land,vill	-.15**	.20**	-.06	.18**	.08	-.05	.23**	.05
Dist. to road	-.17**	.04	.06*	.05	.00	.09*	.12**	.02
Altitude	-.07	.37**	-.49**	.04	.17**	.25**	.17**	-.27**
Rainfall	-.08	.02	.19**	.00	-.43**	-.17**	.01	.05
Land quality	.03	-.22**	-.05	-.03	-.07	.18**	.07	-.02
Age of head	.12**	-.05	-.12**	.01	.00	.06	.06	-.07*
Off-farm inc.	.04	-.01	-.08	.00	.04	-.04	.06	-.07*
East	.11*	-.07	-.28**	.01	.14**	.16**	.24**	-.14**
Congo-Nile	.03	-.06	-.14**	.03	.00	.09*	.16**	-.10**
Volcanic	-.06	-.15**	-.01	.14**	.24**	-.03	.10**	-.03
Lake Kivu	-.07	-.09**	-.14**	-.04	.25**	-.10*	.07	.25**
ADJ. R2	.12	.32	.22	.04	.27	.18	.15	.19

Source: DSA/MINAGRI, Agricultural Survey 1991; 960 households
* = significant at 5% or better, ** = significant at 1% or better

four-fold suggests a link between the two trends. One possible explanation is that population pressure pushes small farmers to *consume* sweet potatoes (which provide cheap calories) but not to *produce* them (because other crops provide higher returns to land). This would explain why the sectoral association exists while the farm-level association does not and this would also be compatible with the trend towards sweet potatoes over time. We will examine this question below using data on sales and purchases for the same set of households.

Although small farmers clearly allocate a higher share of their land to bananas than their neighbors with more land, *sectoral* land scarcity is associated with *less* bananas in the crop mix. Just as above in the case of sweet potatoes, there are two possible explanations for the paradox. First, there may be omitted or poorly measured factors that explain why densely inhabited areas have less bananas than their other characteristics would suggest. Potential candidates include soil type, prevalence of banana diseases, or market demand for bananas. Second, land scarcity may push farmers to *produce more* bananas (which provide high returns to land) but *consume less* (because bananas and banana beer provide relatively expensive calories), in which case the small size of the neighbors would be an argument to grow food rather than bananas. Again, this hypothesis is something we will study more thoroughly in the next chapter.

Table 5-7 shows that none of the main food crops significantly loses ground as pressure on land increases. In other words, the expansion of bananas, beans, and maize occurs primarily at the expense of pasture and fallow. However, as Table 5-8 shows, the relative importance of sorghum and cassava declines significantly in the crop mix. Coffee is favored on the larger farms of the more densely populated areas. One possible explanation is that the official persuasion to grow coffee has been strongest in these areas, but either has not been enforced equally strictly on the smaller farms, or has been resisted more actively by the small farmers desperate to grow more food instead.

The results are broadly compatible with the hypotheses stated above. Sorghum and cassava are less labor intensive and lower-yielding than the other major crops and all crops require more labor than fallow and pasture.

Market access. Banana production is significantly associated with short distance to paved roads. In contrast, cereals and cassava are more important in more remote areas than in areas close to paved roads. This suggests that improvements in roads and presumably also in other forms of marketing infrastructure would encourage farmers to substitute bananas for cereals and cassava. These results are compatible with the hypothesis that good market access encourages specialization in bulky but otherwise profitable cash crops and reduces reliance on low-yielding subsistence crops.

Land quality and agroclimatic factors. As discussed above, our proxies for the physical environment, especially for soil quality, are quite imperfect and highly collinear. Consequently, the coefficients for them are difficult to interpret and often not significant.

Nevertheless, the hypothesis that low land quality would be associated with higher shares of land devoted to less demanding crops got strong support in the case of sweet potato. The hypothesis also got some indirect support in the case of cassava, since the dummy variables show that cassava was associated with location on the central plateau, which is known to be quite degraded. Since land productivity is affected by labor use, inputs, skills, and other factors in addition to land quality, the dummies for zones may capture some land quality and degradation impacts.

The other side of the hypothesis is that demanding crops should be favored on highly productive fields. This was supported for sorghum but not for bananas, maize, or beans. In the case of bananas, the explanation may be historical, since both the high share of bananas and low yields may result from a long history of frequent cultivation in the area. The explanation for beans may be that while they grow poorly on poor fields, their ability to fix nitrogen is most needed there.

The associations between land use and agroclimatic conditions are generally strong, although the high correlation between altitude and rainfall create some surprises. For instance, the association of banana production with the warm and relatively dry conditions outside the high-altitude areas was captured by rainfall rather than altitude in our model, whereas the opposite was true for the association of sweet potato and higher-altitude areas.

Household characteristics. The age of the household head is positively associated with banana production. This is what we expected for a perennial that takes years to reach its full productive potential. The association with the other main perennial, coffee, is to the opposite direction. This shows that coffee trees are not a similar investment of embodied labor as banana trees and suggests that other considerations, including government policies to promote coffee, have been more important for the decision to grow coffee. Of the annual crops, cassava is grown more frequently by younger households. This was not hypothesized, and might be related to unmeasured differences in land quality. Many young households occupy poor lands that until recently were considered marginal for cultivation and reserved for pasture. Cassava may be the only food crop that gives decent yields on such fields.

The hypothesis that perennials are investments that households with high off-farm cash incomes are more capable of doing was not supported. Apparently, the fact that banana groves can be intercropped throughout the establishment period makes the investment so small that cash is a minor constraint. Coffee, in turn, is related to *low* off-farm incomes. This may be related to farmer interest (or official persuasion) to plant coffee in places where few alternative sources of cash have been available. In principle, coffee is also a source of liquidity that could be hypothesized to reduce farmers' interest in off-farm employment, but given how poor cash source coffee was around 1990 compared to most other land uses, this explanation does not appear to be very credible.

5.5 Environmental Impacts of Intensification

As shown above, increasing land-scarcity forces Rwandan farmers to cultivate a larger share of their land at the expense of forest, pasture, and fallow. Since non-cropping uses of land provide more vegetative cover against erosion (have lower C-values) than most food crops (Table 5-1), the expansion of cultivation increases erosion in Rwanda. On the other hand, demographic pressure also pushes farmers to grow more perennials, which protect soils better than annual food crops and can even exceed the level of crop cover provided by degraded pastures and woodlots planted with non-protective trees such as eucalyptus. Moreover, farmers also respond to increasing land scarcity by relying more on dense crop associations, which may increase vegetative cover on cultivated fields.

Accurate assessment of the net result of all these offsetting impacts would require detailed field experiments on soil losses and statistical analysis on their determinants, with land scarcity as one of the explanatory factors. Since data on soil losses tend to be too costly to collect in regular farm surveys, researchers are left with the option of combining farm survey data on land use with empirical information on the average degree of protective crop cover provided by each land use. If there exists a relatively small number of relatively uniform land use types, this approach should provide reasonably accurate approximations at low cost.

Unfortunately, this assumption is questionable in Rwanda. Although a handful of crops dominate Rwanda's agriculture, more than one-half of cultivated fields are covered by crop associations, with numerous crop combinations and infinite variation with respect to the relative importance of each crop in the association. Few empirically-based crop cover estimates are available for crop associations, and there is little empirical basis for computing estimates for them on the basis of crop cover estimates of the constituent crops and on the densities of each crop.

Despite these caveats, we computed two sets of field-level crop cover estimates in Kangasniemi and Reardon (1995). Our *unadjusted C-value* was an average of crop-specific C-values weighted by the estimated land shares of each crop in a given association. There were three reasons to think that this typically represents the lower bound for the true C-value. First, DSA's land use data show that planting densities on intercropped fields are higher than on purely cropped fields, which suggest that there is more vegetation, and thus more crop cover against erosion. Second, the few empirical measurements available indicate that the average C-value of the crops grown in the associations overstates the C-value (understates protective crop cover) of the association (Lewis 1986). Third, in the literature, reduced erosion is frequently mentioned as one of the reasons why farmers choose to intercrop (Fussel and Serafini 1985; Koponen 1988; Ruthenberg 1976; Lewis and Berry 1988; Richards 1983, 1985).

Our second set of estimates therefore was computed assuming that the higher the planting densities on intercropped fields, the better the crop cover and the lower the C-value that measures the exposure to erosion. The exact form of the adjustment was arbitrary: we divided the unadjusted C-value by the sum of the densities of the crops grown in the association.

With these assumptions, our data analysis gave one clear conclusion. At high altitudes (above 1900 meters), small farms were significantly more exposed to erosion than large ones. Elsewhere, results depended on how the measure of vegetative cover was adjusted to account for high cropping densities. Without any adjustment, small farms appeared to have less vegetative cover; with our adjustment, there appeared to be no association between farm size and exposure to erosion.

The key difference between high and low altitudes was the dominance of bananas in the latter areas. Essentially, the result shows that if intercropped banana groves provide as good protection against soil losses as our adjustment implies, the expansion of banana intercropping offsets the increases in erosion that otherwise would arise from the land use changes brought about by agricultural intensification.

There are two reasons to think that this result is too optimistic, even if the expansion of bananas would continue. First, the idea of comparing planting densities in crop associations with those in pure stands, for which we have C-value estimates, fails for bananas. Traditional pure banana groves are typically dense, at least if they are old. The officially recommended density, which is used as the benchmark pure density in the data collection, is much lower than the traditional density (CNA 1990). While thinning supposedly increases banana production, at least in the short term, it reduces the production of crop residues and increases erosion. In the collection of land use data, the benchmark density for bananas refers to the thinned groves, but the only available C-value estimates refer to "typical" pure groves which presumably are quite dense.

To illustrate, consider a bean/banana field with unstandardized densities of 80 percent for beans (C=19%) and 80 percent for bananas (C=4%). Our unadjusted C-value estimate for this field was simply the average (C=11.5%), while the adjusted C-value was much lower (C=11.5/1.6=7%). However, notwithstanding the recorded high density, this field probably has less than half of the number of bananas trees of the typical pure banana grove.

Second, the key explanation for minimal erosion (low C-values) in the traditional banana groves is mulch: typically the soil is fully covered by crop residues. The mulch protects the soil from the direct erosive impact of raindrops and, more importantly, slows down the movement of water, thereby increasing infiltration and taming the downhill flow into a non-erosive trickling that does not take the topsoil with it. To grow annual food crops with bananas, farmers typically remove the crop residues from much of the soil. While densities clearly influence crop cover by affecting the amount of vegetative material available for mulching, this impact is probably dwarfed by variations in how the mulch is used. Thus, the 80/80 bean/banana grove discussed above could easily provide crop cover that is closer to that of a bean field than that of a dense, fully mulched banana grove. Where this is the case, both the adjusted and the unadjusted C-value estimates could exaggerate the degree of protective cover and understate the exposure to erosion.

The dramatic increase in erosion is not inevitable, though. Preliminary research results from Burundi suggest that if crop residues are put into small contour lines 2-3 meters apart they provide better protection in thinned banana groves against soil erosion than the traditional practice of simply leaving crop residues cover the soil more or less haphazardly (Rishirumuhirwa 1992, 1993a and 1993b). If confirmed by further studies, this suggests that intercropped bananas can be a highly sustainable form of agricultural intensification on the steep hillsides of the Great Lakes Region.

In sum, except for the high altitudes, where population growth is increasing erosion, it is not clear whether demographic pressure is making land uses more erosive in Rwanda. The expansion of bananas is offsetting some of the damage done by the expansion of annual crops, but the net impact depends on the details of how farmers intercrop.

From the sustainability point of view, agricultural land uses differ from each other not only in how well they protect the soil against erosion but also in how much organic matter they produce. In the tropics where decomposition rates are high, low production of organic matter can easily reduce the organic matter content of the top soil and thereby compromise its capacity to hold water and nutrients, especially nitrogen (Ruthenberg 1976). Most annual crops produce so little organic matter that lands degrade unless fallowed periodically. Also coffee produces only modest amounts of organic matter, but soil fertility is typically maintained by bringing in mulch from elsewhere. Among the principal crops of Rwanda, bananas are superior producers of organic matter, which, along with the low rates of erosion, explains how banana groves can remain highly productive for several decades without fallowing (Kajumulo-Tibaijuka 1984). Trees, bushes and anti-erosion grass lines also produce organic matter which can be used to improve soils.

Thus, even if we consider degradation associated with the loss of organic matter rather than merely that associated with erosion, the bottom line is broadly similar: The expansion of annual crops at the expense of fallow and pasture is making the situation worse, whereas the expansion of bananas is making it better.

5.6 Conclusions

In this chapter we have presented household-level survey data showing how land-scarce Rwandan farmers allocate a higher share of their land to cultivation in general and to roots and tubers in particular than do farmers with relatively large amounts of cultivable land per adult equivalent. We have further shown that the national pattern of small farmers relying heavily on white potatoes only arises because farms are small on the volcanic soils of the cool northwestern highlands, where potatoes thrive. In most of Rwanda, farming systems are banana-based and the key difference between farm size categories is the heavy reliance of small farmers on sweet potatoes.

Controlling for a set of other factors, we have shown evidence suggesting that small farmers respond to land scarcity by growing more bananas, beans, and maize. Notably, bananas are among these crops but sweet potatoes are not. In light of the longitudinal trend towards roots and tubers, we hypothesize that smallholders may be responding to population pressure by growing more bananas, and exchanging them for sweet potatoes. Thus, population growth would be increasing the importance of sweet potatoes in the diets and the role of bananas on the fields of small farmers. We will study these hypotheses below.

The results also show that in areas close to paved roads, farmers grow more bananas and less cereals and cassava. Since bananas protect the soils much better against erosion than cereals and cassava do, the specialization made possible by infrastructure development, urban demand and food imports appears to increase the environmental sustainability of agricultural intensification in Rwanda.

We have found no evidence that lack of liquidity would be a constraint that prevents poor households from choosing profitable or sustainable land uses. For most Rwandan households, the principal intensification option, and the one that also happens to be a clear step towards environmental sustainability, is increased reliance on bananas, and this option is characterized neither by large start-up costs nor by long payback periods.

Environmentally, the land use changes associated with population growth are a mixed bag. The expansion of annual crops at the expense of fallow and pasture increases erosion and reduces the production of organic matter. Both trends contribute to degradation. On the other hand, the expansion of bananas and, to a lesser extent, of coffee and tea, makes agriculture somewhat more sustainable. The net impacts are unclear, except for the high-altitude areas, where land use is becoming less sustainable due to demographic pressure.

Chapter 6

PARTICIPATION IN AGRICULTURAL PRODUCT MARKETS

6.1 Income Patterns

In this section we briefly look at the overall patterns of incomes. The purpose is to provide the background for the more detailed analysis of market participation.

Using farm survey data to compute estimates for total household income in semi-subsistence agriculture requires many conceptual decisions on the definition of income, a large number of computations and transformations, and numerous shortcuts and assumptions to deal with data limitations and computational constraints. Subsistence consumption must be valued, and adjustments may be needed for seeds and other inputs and for cross-household differences in the purchasing power of money. In Rwanda, the importance of traditional beers means that the estimates on how much ingredients are needed for beers are among the most important parameters in income computations. Our definition of income in principle includes implicit income from subsistence food production (that is, food production for home consumption), sales of agricultural products and beer, off-farm wages and salaries, gifts received and some minor items. The main issues in how the definition was operationalized and what auxiliary assumptions and shortcuts were made were discussed above in chapter four. The details are available in the transformation programs, which consist of thousands of lines of SPSS code.

Table 6-1: Gross Household Income Sources by Income Quartiles

Rwandan Francs	Income Quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Home Consumption	11,161	19,323	28,044	45,396	25,757
Farm Sales	4,125	9,568	16,250	26,135	13,881
Crops	1,541	3,643	7,360	13,271	6,372
Beer	1,834	4,004	5,805	8,272	4,943
Livestock	750	1,921	3,085	4,592	2,565
Purchased Inputs	-707	-1,486	-2,600	-7,653	-3,054
Ag. Labor	-342	-909	-1,749	-6,944	-2,429
Other Ag.	-19	-45	-131	-141	-84
Beer Inputs	-346	-532	-719	-567	-542
Labor Sales	3,097	4,609	6,551	31,118	11,088
Agricultural	1,659	1,891	1,794	1,308	1,669
Other Unskilled	602	873	1,453	1,815	1,179
Skilled	836	1,845	3,303	27,996	8,241
Gifts Received	771	830	1,273	2,279	1,275
Other	401	222	705	2,696	983
Net Income	18,847	33,066	50,223	99,971	49,930

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Table 6-1 shows the estimated gross household incomes by source, costs of purchased inputs, and total net incomes both for rural Rwandan households on average and for income quartiles computed by ranking households in terms of income per adult equivalent. The "pre-industrial" nature of Rwanda's agriculture can be seen in that the use of fertilizer and other external inputs is minimal. The only inputs purchased in significant quantities are agricultural labor and ingredients (sorghum and bananas) for traditional beer brewing.[27] The fact that households prefer to use their cash for labor rather than for chemical inputs, along with the fact that households with highest incomes

[27] In addition, some farmers purchase seeds and capital inputs (primarily livestock) and pay cash rents, but due to data problems, these are not included in income computations. Other DSA data show that less than 10% of agricultural land is rented, often at no or low charge (perhaps because it is often rented from relatives).

Table 6-2: Net Household Income Sources by Income Quartiles

Francs/household	Income Quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Home Consumption	10,904	18,755	26,911	40,872	24,174
Farm Sales	3,675	8,651	14,783	23,006	12,410
Crops	1,501	3,505	7,007	11,911	5,911
Beer	1,438	3,307	4,841	6,904	4,093
Livestock	736	1,840	2,934	4,191	2,406
Labor Sales	3,097	4,609	6,551	31,118	11,088
Agricultural	1,659	1,891	1,794	1,308	1,669
Other Unskilled	602	873	1,453	1,815	1,179
Skilled	836	1,845	3,303	27,996	8,241
Gifts Received	771	830	1,273	2,279	1,275
Other	401	222	705	2,696	983
Net Income	18,847	33,066	50,223	99,971	49,930

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

use only a fraction of a percent of their cash outlays for purchased inputs, suggests that liquidity is not the primary contraint of input use. Instead, inputs are either unavailable or considered unprofitable by most farmers.[28]

The inequality of income distribution in rural Rwanda can be seen in that the estimated mean net income is five times as high in the richest quartile of households (hereafter "the rich") as it is in the poorest quartile (hereafter "the poor"). Although the tails of the estimated income distribution probably are strongly affected by data errors and although the rich have somewhat larger families than the poor, rural differentiation is undoubtedly a major issue in Rwanda.

[28] A notable exception to this is the fungicide used to control mildew in potatoes and tomatoes.

In Table 6-2 the purchases of beer inputs are deducted from beer sales and the costs of labor and other inputs are allocated proportionally to home consumption and farm sales. Note that the beer sales revenue is net of purchased inputs, and not net of the imputed values of home-grown ingredients. In other words, it includes returns to both farming of bananas and sorghum for beer, and brewing for sale.[29] As discussed below, the market value of ingredients accounts for most of the market value of beer. Rather than being a separate income-generating activity, traditional brewing (at least that of banana beer) is more correctly seen as the last phase of agricultural production needed to process products for transportation and sale. Its role is close to that of peeling and drying cassava for sale. Table 6-3 shows the shares of net income sources.[30]

[29] To avoid double-counting the estimated quantities of bananas and sorghum used for beer sales were deducted from home consumption.

[30] The percentages in table 6-3 were computed at household-level and then aggregated, not the other way round. Instead of reporting the shares of total income coming from each source, they show how much households on average get income from each source without giving more weight to the more prosperous households. Thus, skilled labor is reported in Table 6-3 to account for 7% of *average* rural incomes, although its share of *aggregate* rural incomes, implicit in Table 6-2, is 16%. The difference arises since incomes from skilled labor are highly concentrated among the high-income households. *Both* percentages would obviously be much lower if the sample excluded teachers, masons and others employed in off-farm activities and instead covered only households earning a bulk of their income from agriculture.

Table 6-3: Net Household Income Shares by Income Quartiles

Percent	Income Quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Home Consumption	58	58	54	49	55
Farm Sales	18	24	28	27	24
Crops	8	10	13	14	11
Beer	7	9	9	8	8
Livestock	3	5	6	5	5
Labor Sales	16	14	13	19	16
Agricultural	9	7	5	2	6
Other Unskilled	3	2	3	2	3
Skilled	4	5	5	15	7
Gifts Received	5	3	3	3	3
Other	2	1	1	3	2
Net Income	100	100	100	100	100

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Tables 6-1 to 6-3 show that households in rural Rwanda are still quite subsistence-oriented, earning on average just above half of their income in the form of food crops grown for home consumption. Sales of agricultural products and labor account for most of the other half. Poor households are typically somewhat more subsistence-oriented than those in the other end of the income distribution. Sales of crops and livestock are more important for better-off households, whereas beer incomes on average account for almost one-tenth of the estimated incomes in all income quartiles. Wage labor supplements on-farm incomes in all quartiles, but while the better-off households sell primarily skilled labor at high wages, the poorest households work primarily in agriculture at low wages. Gifts, land rents and other off-farm sources of income are relatively unimportant in rural Rwanda.

Table 6-4: Net Household Income Shares in Banana Zone

Percent	Income Quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Home Consumption	60	58	55	48	55
Farm Sales	18	25	29	27	25
Crops	8	10	13	14	11
Beer	8	10	11	8	9
Livestock	2	5	5	5	4
Labor Sales	15	14	12	20	15
Agricultural	9	5	4	1	5
Other Unskilled	3	3	3	2	3
Skilled	4	5	5	16	8
Gifts Received	4	3	3	3	3
Other	2	1	1	2	2
Net Income	100	100	100	100	100

Source:DSA/MINAGRI, Agricultural Survey 1990; 955 households

In the preceding chapter we showed that on the temperate highlands ("potato zone" and "marginal zone"), where roughly 15 percent of Rwanda's farmers reside, farming systems are quite different from the rest of Rwanda, which we called "banana zone." In accordance with our focus on banana zone in chapter five, we tabulate also income shares for just this area. Table 6-4 shows that the income patterns do not change much if one leaves out the temperate highlands. The explanation lies in that the two zones of the temperate highlands diverge from the national patterns into opposite directions. The volcanic potato zone is relatively highly commercialized and has few livestock, while the marginal zone relies more on subsistence food production and has more livestock.

Finally, we take a look at the relationship between farm size and household income within the banana zone. Table 6-5 shows that only on-farm incomes are closely associated with farm size. On average, households in the bottom farm size quartile get more income from labor sales than those in the top quartile. However, labor incomes are dominated by earnings from skilled employment, which, as discussed above, are highly concentrated among a handful of households with members who work as teachers, masons and other skilled employees. While skilled jobs have allowed a small number of land-scarce households to escape poverty, most small farmers are poor.

Nevertheless, the mean on-farm income in the bottom *farm size quartile* is nearly twice as high as that in the bottom *income quartile* (Table 6-2). This suggests that many of the smallest farmers have relatively high yields, whereas many of the poorest households are poor not just because of land scarcity, but also because of the low productivity of their land. The simple correlation coefficient between farm size and income, both scaled by family size expressed in adult (consumer) equivalents, is .43, implying that variation in farm size "explains" only one-fifth of the variation in income. The association between farm size and income would obviously be tighter, if the survey had excluded those earning most of their income from outside agriculture.

Table 6-5: Net Household Income Sources by Farm Size in Banana Zone

Francs/household	FARM SIZE QUARTILE (Ares/AE)				All Farms
	<9	9-14	14-24	>24	
Home Consumption	16,432	21,715	29,281	34,104	25,549
Farm Sales	7,913	10,954	13,937	18,721	12,990
Crops	4,117	4,497	5,779	9,449	6,012
Beer	2,564	4,096	5,661	5,895	4,585
Livestock	1,233	2,362	2,497	3,377	2,392
Labor Sales	16,032	7,017	14,746	9,143	11,606
Agricultural	2,301	1,867	1,097	507	1,426
Other Unskilled	2,389	1,127	726	498	1,164
Skilled	11,342	4,024	12,923	8,137	9,016
Gifts Received	882	1,196	1,232	1,677	1,256
Other	703	550	1,359	1,085	924
Net Income	41,962	41,433	60,555	64,730	52,325

Source:DSA/MINAGRI, Agricultural Survey 1990; 960 households

6.2 Patterns of Agricultural Transactions

6.2.1 National Patterns

Despite the importance of subsistence production, Rwanda's rural households sell and buy large quantities of agricultural products. Much of the trade occurs within the rural sector, allowing households to exchange their surpluses of some products for those that they do not produce in sufficient quantities. But rural areas also export significant quantities of some products to urban areas and neighboring countries, while relying on imports of other products.

Table 6-6 reports the estimated sales, gifts given, purchases, gifts received, and net outflows in (exports from) the rural sector in agricultural year 1990. Since some households are also trading (buying in order to sell), the first four measures are adjusted by netting monthly and recording only the sums of non-negative monthly net figures for each household.[31] The adjustment has no impact on the fifth column, which we primarily focus on below. Negative net sales and gifts indicate that rural areas were importing products from elsewhere. The estimates are based on DSA's nationally representative rural household survey sample. Statistics on beer bananas and sorghum include only transactions as such, not those in the form of traditional beers.

[31] The monthly netting admittedly is an imperfect way of eliminating trading. It fails to exclude trading when purchases and sales do not occur during the same calendar month and it incorrectly excludes some purchases for consumption and sales from own production, especially in the case of perishable products such as beer.

Table 6-6: Rural Transaction Quantities

Millions of Units	Sales	Gifts Given	Purchases	Gifts Received	Net Sales and Gifts
Beans	16.11	5.47	75.91	5.39	-59.71
Peas	.63	.21	2.35	.30	-1.81
Peanuts	.86	.11	1.03	.07	-.13
Soybeans	1.07	.25	1.50	.25	-.44
Sorghum	25.42	1.93	50.57	3.31	-26.53
Maize	4.84	3.62	7.71	2.82	-2.07
Wheat	2.11	.19	.98	.15	1.16
Finger Millet	.11	.09	.05	.08	.07
Rice	2.23	.24	3.54	.22	-1.29
Cassava	42.71	4.57	68.25	2.80	-23.77
White Potato	77.95	5.99	52.85	3.23	27.86
Sweet Potato	58.04	17.22	48.15	8.60	18.51
Taro	4.96	1.48	6.06	1.11	-.74
Cocoyam	.05	.02	.11	.04	-.08
Cooking Banana	47.02	7.63	16.99	4.87	32.80
Beer Banana	59.01	10.42	61.71	5.93	1.79
Fruit Banana	7.26	.54	2.53	.41	4.86
Coffee	41.13	.00	.00	.00	41.13
Banana Beer	207.08	39.97	6.99	12.71	227.35
Sorghum Beer	67.62	15.32	8.75	11.05	63.13
Milk	.06	.00	.00	.00	.05
Cattle	.13	.02	.05	.03	.07
Pigs	.19	.01	.07	.01	.12
Sheep	.28	.02	.09	.02	.20
Goats	.65	.05	.20	.07	.43
Chicken	.64	.10	.38	.14	.22
Ag. Labor	23.68	N.R.	34.30	N.R.	-10.63
Non-Ag. Unsk. L.	15.02	N.R.	8.20	N.R.	6.82
Skilled Labor	41.43	N.R.	4.12	N.R.	37.31

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer (litres), milk (litres), livestock (heads), and labor (mandays). N.R.= Data not recorded.

According to Table 6-6, Rwanda's rural sector sells very large quantities of traditional beers, especially banana beer. In part, this reflects underreporting of beer purchases by the respondents of the rural sample.[32] Nevertheless, rural households sell very large quantities of beer to urban areas. Other crops exported from rural areas in large quantities include coffee, cooking bananas, white potato, and sweet potato. Large rural trade occurs in beer bananas, but there are almost no rural exports. Beer brewing is characteristically batch production and requires some rural assembly, but long-distance transportation typically occurs after brewing, which greatly increases value to weight. Also root crops are largely traded within the rural sector.

[32] If we assume that Rwanda's urban population (or, more accurately, the non-farm population not covered by DSA's farm household survey) in 1990 was 700,000 and that 400,000 of this population was in the age groups that consumed beer, taking the rural exports reported in Table 6-6 at face value and assuming no net exports would imply that each urban beer drinker on average consumes nearly two liters of beer per day. This is clearly not credible and suggests that most rural purchases were not reported by the respondents.

Table 6-7: Rural Transaction Values

FRw/household	Sales	Gifts Given	Purchases	Gifts Received	Net Sales and Gifts
Beans	387	154	2,362	178	-1,998
Peas	31	12	100	19	-76
Peanuts	56	7	74	6	-17
Soybeans	32	8	47	8	-15
Sorghum	382	30	1,038	67	-692
Maize	72	69	168	65	-91
Wheat	61	5	24	4	37
Finger Millet	4	3	3	4	-0
Rice	67	7	224	12	-162
Cassava	292	29	375	19	-73
White Potato	634	49	618	40	25
Sweet Potato	384	113	354	63	81
Taro	47	14	61	10	-10
Cocoyam	1	0	1	0	-1
Cooking Banana	264	41	103	30	173
Beer Banana	191	34	244	22	-41
Fruit Banana	33	2	8	1	27
Coffee	2,684	0	0	0	2,684
Other Ind.Crops	413	0	36	0	377
Beef	14	0	620	0	-606
Other Meat	6	0	224	0	-218
Fish	15	0	212	0	-197
Banana Beer	4,271	821	163	323	4,607
Sorghum Beer	754	169	100	123	701
Milk	147	0	80	0	68
Vegetables	117	0	172	0	-55
Fruits	25	0	15	0	10
Fertilizer	0	0	7	0	-7
Pesticides	0	0	68	0	-68
Forest Prod.	232	0	50	0	182
Fodder Crops	6	0	7	0	-1
Cattle	1,037	151	351	223	615
Pigs	297	15	61	19	232
Sheep	220	17	70	18	148
Goats	733	57	203	78	509
Chicken	104	16	57	22	40
Ag. Labor	1,702	N.R.	2,428	N.R.	-725
Non-Ag. Unsk. L.	1,228	N.R.	327	N.R.	901
Skilled Labor	8,285	N.R.	498	N.R.	7,787
Total	25,287	1,825	11,571	1,353	14,188

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
N.R.= Data not recorded

Rural Rwanda imports large quantities of beans, sorghum, and cassava, although much of the sorghum is used for beer, and sold further. It is particularly noteworthy that Rwandan farmers not only fail to supply urban areas with beans, the main source of proteins in Rwandan diets, but also supply only a fraction of the rural market demand for beans.

In contrast to beans, rural Rwanda does supply cities with meat. Table 6-7 reports the estimated transactions in money terms and also includes products such as meat, for which data was collected on the cash values of the transactions but not·on the quantities transacted. A comparison of meat purchases and livestock sales indicates that rural Rwanda exports large numbers of livestock to urban areas and neighboring countries.

Table 6-7 shows that none of the main food crops brings significant amounts of cash to rural Rwanda. Although white potatoes, sweet potatoes, cooking bananas, beans, cassava, and sorghum are important sources of cash for some farmers, most of the trade is intra-rural. Moreover, the three food crops exported from rural Rwanda in notable quantities (cooking bananas, white potatoes, and sweet potatoes) are much cheaper products than the beans imported from neighboring countries.

To finance the imports of beans and all the industrial products, rural Rwanda sells labor, beer, coffee, and livestock, in this order. The role of unskilled labor resembles that of food crops in that both are important sources of cash for some households but neither brings significant amounts of cash to rural areas.[33] However, as discussed in detail below, the roles differ in that the poor are net sellers of unskilled labor but net buyers of all food crops.

[33] That the farm households on the aggregate appear to be net importers of agricultural labor should not be interpreted to indicate migratory labor from the cities or neighboring countries. Indeed, migratory labor probably flowed from rural areas to cities and not vice versa (Olson, 1994). Instead, the numbers probably reflect the sampling design that sought to cover farm households and excluded farm workers that did not have their own farms.

Interestingly, the single most important flow of cash to agricultural households consists of the wages of skilled workers, such as teachers, soldiers, and employees of development projects. However, as we will see below, labor incomes, especially those from skilled employment, are highly concentrated.

6.2.2 Agricultural Transactions in Banana Zone

In this section we tabulate the estimates of the net sales and gifts given (rural exports) by cropping zone. Much of the discussion deals with the banana zone, which covers 85 percent of the observations and is the primary focus of this study. Table 6-8 presents the quantities of crop and labor sales per household and Table 6-9 shows the summaries for all the recorded transactions in monetary terms.

Table 6-8: Net Household Sales by Cropping Zone

Units/household	Cropping Zone			Rwanda
	Banana Zone	Potato Zone	Marginal Zone	
Beans	-44	-97	-57	-48
Peas	-1	-5	-2	-1
Peanuts	-0	-0	-0	-0
Soybeans	-0	0	-0	-0
Sorghum	-16	-67	-65	-22
Maize	-2	-21	7	-2
Wheat	1	-0	1	1
Finger Millet	0	0	0	0
Rice	-1	-2	-1	-1
Cassava	-17	-52	-23	-19
White Potato	-37	1,158	-22	23
Sweet Potato	23	-53	-54	14
Taro	-1	0	0	-1
Cocoyam	-0	0	0	-0
Cooking Banana	30	-5	-1	26
Beer Banana	5	0	-37	2
Fruit Banana	5	-6	-1	4
Coffee	37	0	3	33
Banana Beer	199	-3	40	178
Sorghum Beer	48	62	60	50
Ag. Labor	-12	20	17	-8
Non-Ag. Unsk. L.	5	7	11	5
Skilled Labor	30	22	22	29

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer (litres)and labor(mandays).

Although the three zones are strikingly different in their trading patterns, the two high-altitude zones are so small that the national patterns largely hold for the banana zone. Like Rwandan households on average, households in the banana zone exchange skilled labor, banana beer, coffee, and livestock for beans and cereals. Some agricultural laborers from the high-altitude zones are employed in the banana zone and some white potatoes are imported from the potato zone.

Table 6-9: Net Household Sales in Frw by Cropping Zone

FRw/household	Cropping Zone			Rwanda
	Banana Zone	Potato Zone	Marginal Zone	
Beans	-1,885	-3,913	-2,305	-2,015
Peas	-56	-266	-152	-73
Peanuts	-21	-3	-18	-20
Soybeans	-15	0	-21	-15
Sorghum	-550	-1,984	-1,842	-715
Maize	-69	-825	84	-95
Wheat	42	-16	39	38
Finger Millet	-1	-0	15	-0
Rice	-169	-237	-43	-163
Cassava	-52	-294	-199	-75
White Potato	-568	11,214	-239	38
Sweet Potato	160	-561	-530	74
Taro	-11	0	-4	-10
Cocoyam	-1	0	0	-1
Cooking Banana	200	-46	-8	173
Beer Banana	-23	0	-265	-39
Fruit Banana	33	-22	-3	27
Coffee	3,062	0	215	2,704
Other Ind.Crops	416	-112	296	381
Beef	-654	-528	-99	-608
Other Meat	-242	-17	-46	-216
Fish	-226	-12	-8	-199
Eggs	32	4	22	30
Honey	10	0	16	10
Banana Beer	5,142	-104	982	4,581
Sorghum Beer	680	916	824	702
Milk	77	25	0	68
Vegetables	-59	-213	67	-57
Fruits	11	-5	12	11
Fertilizer	-5	-24	-26	-7
Pesticides	-17	-1,035	-41	-69
Forest Prod.	164	-99	614	184
Fodder Crops	-1	-10	1	-1
Cattle	597	931	717	622
Pigs	244	0	215	230
Sheep	130	167	388	151
Goats	494	699	641	515
Chicken	42	-4	14	38
Ag. Labor	-1,101	2,081	1,888	-727
Non-Ag. Unsk. L.	860	1,259	1,296	911
Skilled Labor	8,319	4,671	4,179	7,838
Total	14,989	11,636	6,676	14,219

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

True to its name, the potato zone is highly dependent on white potato exports. It also relies heavily on pesticides, primarily fungicides for potatoes, whereas most farmers in other zones do not use industrially produced agricultural chemicals. Because of their profitable potato sales, potato farmers can both augment the output of their tiny farms by purchasing large quantities of beans and sorghum and have almost as much cash left for their non-staple needs as farmers in the banana zone, where farms are much larger.

Also households in the marginal zone buy significant amounts of beans and sorghum, but because they lack profitable cash crops, their incomes from sales are small and hence they have very little left for their other needs.

6.2.3 Crop Transactions by Income in Banana Zone

This section focusses on how the patterns of crop transactions vary by household income within the banana zone. Table 6-10 shows the estimates for crop and labor sales quantities per household by income quartile, and Table 6-11 presents the summaries for all the recorded transactions in monetary terms.

The tables show that food transactions are strongly associated with poverty and that the nature of this association varies by crop. On average, households in all but the richest quartile buy significant amounts of beans and sorghum. The rich are roughly self-sufficient, imports being the source of supply for the poor. In contrast, cassava, the third important food purchased by poor households, is a minor cash crop for the rich. The regional analysis in the Appendix A suggests that the poor buyers are nevertheless largely dependent on imports, since the rich sellers are located mostly in eastern Rwanda and supply mostly urban consumers in Kigali, whereas the poor buyers are found mostly in western Rwanda, especially in the south-western prefecture of Cyangugu, where most cassava in the market is presumably supplied by imports from Congo.

Table 6-10: Net Household Sales Quantities by Income Quartile in Banana Zone

Units/household	Income quartile (FRw/AE)				All Farms
	<5350	5350-8020	8020-13230	>13230	
Beans	-53	-60	-57	-5	-44
Peas	-1	-1	-1	-2	-1
Peanuts	-0	-0	-1	1	-0
Soybeans	-2	-0	-0	0	-0
Sorghum	-26	-24	-23	8	-16
Maize	-5	-5	-3	7	-2
Wheat	-0	1	3	-0	1
Finger Millet	-0	-0	0	-0	0
Rice	-1	0	-1	-2	-1
Cassava	-44	-52	-17	46	-17
White Potato	-17	-29	-37	-64	-37
Sweet Potato	-43	7	35	89	23
Taro	-6	-7	1	10	-1
Cocoyam	-0	-0	-0	-0	-0
Cooking Banana	-5	-1	-6	132	30
Beer Banana	19	4	-33	32	5
Fruit Banana	1	4	7	6	5
Coffee	10	22	49	66	37
Banana Beer	64	148	224	355	199
Sorghum Beer	47	49	64	32	48
Ag. Labor	14	10	-4	-69	-12
Non-Ag. Unsk. L.	9	8	13	-11	5
Skilled Labor	7	16	19	77	30

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer(litres) and labor(mandays).

Sweet potato, Rwanda's single most important staple food, is another minor cash crop for richer households and another food crop purchased by the poor. Since bean, sorghum, and cassava supplies come primarily from neighboring countries, sweet potato is the only major crop bought primarily by the poor Rwandans from their better-off neighbors. This is in clear contrast to white potatoes, which are relatively expensive and are purchased primarily by better-off households.

Cooking banana is another relatively expensive food crop, but unlike white potato, it is sold rather than purchased by the better-off rural households. As shown in

Appendix A, much of the explanation is regional: the main production area and the only region where cooking bananas are an important cash crop is in eastern Rwanda, where farms are large and households relatively prosperous.

In the banana zone, two items, beer and coffee, dominate agricultural sales revenues in all income quartiles. Although the net sales are concentrated strongly among the rich households, beer and coffee sales are relatively more important for the poor, since while the rich also sell modest amounts of food crops and cattle, the poor rely more exclusively on beer and coffee. While the income tabulations above showed that even the poorest get some income from food crop sales, the net flow tabulations here indicate that as a group the poor are net buyers and would be hurt rather than helped by higher prices. This naturally is only the direct impact and indirect impacts, especially those transmitted through labor markets, could alleviate or aggravate the situation, depending on what brought about the higher food prices.

Table 6-11: Net Household Sales Values by Income Quartile in Banana Zone

FRw/household	Income quartile (FRw/AE)				All Farms
	<5350	5350-8020	8020-13230	>13230	
Beans	-2,127	-2,467	-2,306	-610	-1,885
Peas	-34	-54	-49	-86	-56
Peanuts	-17	-35	-65	36	-21
Soybeans	-59	-15	2	7	-15
Sorghum	-732	-735	-715	-15	-550
Maize	-154	-151	-88	118	-69
Wheat	4	38	119	0	42
Finger Millet	-3	-3	2	-2	-1
Rice	-82	-35	-167	-395	-169
Cassava	-317	-294	-64	465	-52
White Potato	-273	-450	-564	-973	-568
Sweet Potato	-396	19	247	740	160
Taro	-93	-87	19	113	-11
Cocoyam	-1	-2	-0	-0	-1
Cooking Banana	-28	1	-42	875	200
Beer Banana	54	-52	-177	96	-23
Fruit Banana	14	29	49	37	33
Coffee	796	1,830	4,035	5,487	3,062
Other Ind.Crops	50	408	376	811	416
Beef	-131	-301	-663	-1,509	-654
Other Meat	-55	-119	-254	-534	-242
Fish	-131	-207	-228	-333	-226
Eggs	17	54	52	3	32
Honey	0	41	-1	-3	10
Banana Beer	1,716	3,950	5,914	8,826	5,142
Sorghum Beer	628	672	921	488	680
Milk	21	87	111	82	77
Vegetables	-44	-53	42	-182	-59
Fruits	5	8	48	-18	11
Fertilizer	-6	0	-11	-2	-5
Pesticides	-0	-18	-45	-3	-17
Forest Prod.	119	44	96	404	164
Fodder Crops	0	8	12	-23	-1
Cattle	-106	390	622	1,449	597
Pigs	34	347	316	258	244
Sheep	56	137	143	179	130
Goats	176	237	597	957	494
Chicken	30	49	107	-20	42
Ag. Labor	1,221	814	-272	-6,158	-1,101
Non-Ag. Unsk. L.	614	891	1,282	625	860
Skilled Labor	616	1,803	3,130	27,784	8,319
Total	1,381	6,778	12,532	38,978	14,989

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

The poorest households sell very little skilled labor (otherwise they would not be poor) but augment their farm product sales revenues by working for richer farmers. Important as these incomes are, they do not match the sales revenues from beer. The poorest use most of their sales revenues to buy beans and other staple foods. The bottom line in Table 6-11 shows that the richest quartile accounts for almost two-thirds of the rural demand for non-agricultural products.

6.2.4 Crop Transactions by Farm Size in the Banana Zone

As discussed above, poverty in rural Rwanda is only loosely associated with farm size, primarily for two reasons. First, off-farm incomes are important also in rural areas and make income distribution less dependent on land endowments. Second, land quality varies and while some of the large farms, especially those in eastern Rwanda, are relatively prosperous, others, especially those on the Congo-Nile Divide, are among the poorest due to the low productivity of their fields.

While transaction patterns by income categories are valuable for understanding how the benefits and costs of price changes would be distributed, patterns by farm size are the first approximation of how population growth in rural areas would affect rural supply and demand. Table 6-12 tabulates net sales quantities by farm size and Table 6-13 presents the transactions in monetary terms.

Table 6-12: Net Household Sales Quantities by Farm Size in Banana Zone

Units/household	Farm size quartile (ares/AE)				All Farms
	<9	9-14	14-24	>24	
Beans	-65	-58	-52	-13	-46
Peas	-1	-2	-1	1	-1
Peanuts	-1	-0	-1	2	-0
Soybeans	-0	-1	0	-0	-0
Sorghum	-16	-29	-17	4	-15
Maize	-8	-4	1	6	-1
Wheat	0	1	2	1	1
Finger Millet	-0	-0	0	-0	0
Rice	-6	-2	-2	5	-1
Cassava	-101	-11	-20	64	-15
White Potato	-66	-25	-31	-29	-37
Sweet Potato	-37	5	58	67	24
Taro	-8	-3	-1	9	-1
Cocoyam	-0	-0	0	-0	-0
Cooking Banana	-10	1	15	113	31
Beer Banana	-10	-20	-7	53	4
Fruit Banana	-1	7	4	12	6
Coffee	38	31	29	50	37
Banana Beer	113	171	248	275	203
Sorghum Beer	27	62	63	48	50
Ag. Labor	13	5	-18	-53	-14
Non-Ag. Unsk. L.	15	10	-4	0	5
Skilled Labor	40	18	40	26	31

Source:DSA/MINAGRI, Agricultural Survey 1990; 1095 households
Units are kilograms, except for beer (litres) and labor (mandays).

Regarding food crops, the big picture is still that the top quartile purchases less or sells more farm products than the bottom quartile. Small farms, just as the poor ones, are net buyers of beans, sorghum, white potato, cassava and sweet potato, whereas large farms, as the rich ones, are net sellers of cassava and sweet potato. The large difference between the two rankings comes in the main cash crops and in labor incomes. Whereas the coffee and beer sales of the bottom income quartile were only a small fraction of those of the top income quartile, the differences between the farm size quartiles are less extreme. Labor sales are even higher in the bottom farm size quartile than they are in the top quartile.

Table 6-13: Net Household Sales Values by Farm Size in Banana Zone

FRw/household	Farm size quartile (ares/AE)				All Farms
	<9	9-14	14-24	>24	
Beans	-2,628	-2,355	-2,157	-753	-1,953
Peas	-67	-98	-56	36	-45
Peanuts	-73	-32	-81	95	-21
Soybeans	-21	-35	14	-7	-13
Sorghum	-545	-848	-628	-107	-529
Maize	-251	-112	10	83	-64
Wheat	-0	61	78	25	41
Finger Millet	-1	-3	4	-5	-1
Rice	-460	-202	-160	85	-178
Cassava	-677	-7	-113	572	-41
White Potato	-959	-415	-512	-435	-573
Sweet Potato	-380	41	460	527	171
Taro	-106	-48	-13	118	-10
Cocoyam	-1	-3	1	0	-1
Cooking Banana	-64	4	117	743	208
Beer Banana	-153	-144	-20	198	-26
Fruit Banana	-0	46	20	78	37
Coffee	3,139	2,583	2,428	4,196	3,097
Other Ind.Crops	15	88	654	867	413
Beef	-748	-389	-681	-852	-666
Other Meat	-188	-150	-313	-364	-255
Fish	-561	-40	-211	-104	-223
Eggs	61	23	16	39	34
Honey	41	-11	3	-8	5
Banana Beer	3,022	4,514	6,381	6,862	5,230
Sorghum Beer	377	857	846	728	707
Milk	-123	116	-27	321	78
Vegetables	-161	30	-139	37	-55
Fruits	-1	18	23	9	12
Fertilizer	0	-6	-4	-8	-5
Pesticides	-3	-10	-40	-21	-18
Forest Prod.	37	92	439	125	173
Fodder Crops	-13	16	-0	-3	0
Cattle	32	310	899	844	528
Pigs	150	365	178	302	251
Sheep	125	109	146	138	130
Goats	338	362	455	856	508
Chicken	1	86	65	37	48
Ag. Labor	1,186	556	-1,646	-4,915	-1,261
Non-Ag. Unsk. L.	2,106	1,030	164	185	852
Skilled Labor	11,366	3,810	12,176	7,095	8,511
Total	13,812	10,209	18,775	17,620	15,098

Source:DSA/MINAGRI, Agricultural Survey 1990; 1095 households

While the above tables show clearly that small farmers rely more on markets for their food, the message regarding cash crops is less clear. Both farm size and cash crop sales are much smaller in the household quartiles with less land per person. To find out whether two small farms typically sell more cash crops than one large farm operating the same amount of farm land, we next tabulate farm transactions per hectare, again restricting the analysis to Rwanda's banana zone. Moreover, to understand the role of sorghum, which is both a staple food product and an ingredient of sorghum and banana beer, we convert beer transactions into the estimated ingredient needs included in those transactions.[34]

[34] Beer and fruit bananas are combined, since fruit bananas are frequently used in beer brewing along with beer bananas.

Table 6-14: Net Sales per Household by Farm Size in Banana Zone

Kg/household	Quartiles of C-ABLE/AE				All Farms
	<9 ares/AE	9-14	14-24	>24 ares/AE	
Beans	-65	-58	-52	-13	-46
Peas	-1	-2	-1	1	-1
Peanuts	-1	0	-1	2	0
Soybeans	0	-1	0	0	0
Sorghum	6	12	33	52	26
Maize	-8	-4	1	6	-1
Wheat	0	1	2	1	1
Finger Millet	0	0	0	0	0
Rice	-6	-2	-2	5	-1
Cassava	-101	-11	-20	64	-15
White Potato	-66	-25	-31	-29	-37
Sweet Potato	-37	5	58	67	24
Taro	-8	-3	-1	9	-1
Cocoyam	0	0	0	0	0
Cooking Banana	-10	1	15	113	31
Other Banana	374	570	841	1001	702
Coffee	38	31	29	50	37

Source:DSA/MINAGRI, Agricultural Survey 1990; 960 households
Banana and sorghum sales also include sales as beer.

Table 6-14 indicates that when transactions in the form of banana and sorghum beer are included, all farm size quartiles in Rwanda's banana zone are net sellers of sorghum. The sizable sorghum imports discussed above are not for food but for transformation into beer. Primarily, sorghum purchases are needed to process beer bananas for sale, a transformation that increases value to weight six-fold and thereby greatly reduces transportation costs. Accounting for sales as beer, sorghum is one of the cash crops.

In Table 6-15, the transaction quantities are scaled by the hectares of cultivable land. The purpose of the table is to shed light on what happens to the aggregate rural exports (net sales) when population growth makes farms increasingly small. Even if small farmers sold less of everything, their sales per hectare could be higher, suggesting that as farms get subdivided under demographic pressure, marketed supply will increase rather than decrease. According to Table 6-15, this holds for bananas and for coffee, but not for sorghum. In other words, unless these associations are spurious results caused by agroclimatic or other variation, demographic change should increase the marketed supplies of bananas and coffee, but reduce those of sorghum. In the next section we will study this further, controlling for agroclimatic and other variation.

Table 6-15: Net Sales per Hectare by Farm Size in Banana Zone

Kg/hectar	Quartiles of C-ABLE/AE				All Farms
	<9 ares/AE	9-14	14-24	>24 ares/AE	
Beans	-297	-102	-58	-19	-116
Peas	-8	-5	-1	1	-3
Peanuts	-4	-1	-1	1	-1
Soybeans	-4	-2	0	0	-1
Sorghum	10	25	35	30	25
Maize	-35	-7	-1	2	-10
Wheat	0	2	3	1	1
Finger Millet	0	0	0	0	0
Rice	-31	-3	-2	4	-8
Cassava	-498	-6	-27	28	-119
White Potato	-317	-49	-42	-22	-104
Sweet Potato	-214	10	64	44	-21
Taro	-42	-9	-2	7	-11
Cocoyam	0	0	0	0	0
Cooking Banana	-65	6	6	64	4
Other Banana	1218	932	937	678	935
Coffee	140	51	33	46	66

Source:DSA/MINAGRI, Agricultural Survey 1990; 960 households
Banana and sorghum sales also include sales as beer.

6.2.5 Some Concluding Remarks

The transaction patterns presented above show that the partially but not fully overlapping categories of small (land-scarce) and poor households are net buyers of food. The national average pattern—the exchange of labor, beer and coffee for imported beans and sorghum—holds for the mid-quartiles, but large and rich farmers also sell bulky food crops to their neighbors (sweet potatoes) and to urban consumers (cooking bananas).

Finally, as discussed above, it should be noted that the survey covered not just full-time farmers but also households with members employed in off-farm occupations. If the definition of farm households were more exclusive, the role of labor sales would appear much smaller than what the tables above suggest. Above all, the average numbers tabulated for the smallest households would change. In our tables, the inclusion of the relatively high-income semi-farmers, who can afford to eat better than their neighbors and drink their banana beer instead of selling it, increases the net purchases of food and decreases the net sales of banana beer, especially in the bottom farm size category.

6.3 Multivariate Analysis of Crop Transactions

The transactions patterns discussed above show that land-scarce households on average are simultaneously net buyers of food and net sellers of beer bananas (mostly in the form of beer) and coffee. Relative to farm size, small farmers produce more beer and coffee for sale than their neighbors with more land. The patterns do not, however, go very far in explaining whether land scarcity actually pushes households to buy more food (per hectare) and sell more cash crops (per hectare). Thus, based on the patterns only, little can be said on whether increasing land scarcity brought about by demographic change tends to increase the supply of cash crops to the market. To be able to illuminate this question, we next study the association between land scarcity and net sales by controlling for a number of other factors. Like above, we argue that relationships are likely to be quite different in the high-altitude areas, and therefore focus on Rwanda's banana zone.

6.3.1 General Model, Explanatory Variables, and Hypotheses

The approach used here is analogous to the one used above to model land use. Decisions on market participation and those on land use are obviously closely associated. In a cross-sectional analysis they are determined simultaneously. Both market conditions that affect households through market transactions and on-farm conditions that affect households through the agricultural input-output relationships influence land use and market participation.

Thus, we see market participation as a function of market incentives, physical conditions, land scarcity, and other household characteristics. Market participation is defined as net sales in kilograms per hectare.

Land scarcity or "man/land ratio" is measured in terms of adult equivalents per cultivable hectares. As discussed above, no unequivocal hypoheses regarding the impact of land scarcity on market participation can be made on the basis of economic reasoning. Instead, theory suggests that the association between net sales and land scarcity is determined by the interplay of two objectives. On the one hand, land scarcity pushes households to grow and sell crops that give high returns to land and to purchase those that give only low returns to the scarce resource. Based on the characteristics of the major crops in Rwanda (Table 5-1), this would imply more specialization in (beer) bananas and sweet potatoes and less in coffee. On the other hand, the existence of transactions and transportation costs and the associated failures in the markets for food and other products may make households subsistence-oriented. Where this prevails, cash crop sales should be closely associated with farm size, since only those with some land left after subsistence needs are met, would produce cash crops for sale. However, also food crop sales would decline with farm size, since large farmers would be able to have a margin of safety and would produce marketable surpluses in most years, whereas small farmers could have deficits despite their single-minded focus on food crops.

In Rwanda, both arguments suggest that coffee sales per unit of land should decline with farm size. Coffee is neither a subsistence food crop nor provides high returns to land (at the prices that prevailed in 1990). Therefore, we expect that coffee sales per unit of land decline with farm size. This hypothesis implies that the apparent association between land scarcity and coffee sales per hectare that was seen in the cross-tabulations above should not hold under multivariate analysis.

For bananas the implications are less clear. If the costs and uncertainties of relying on the market are indeed high enough to justify a strategy that gives priority to subsistence food crops, bananas could decline as land gets scarce. On the other hand, if market transactions are not prohibitively expensive, one could expect that land-scarce farmers would rely more on bananas, which, when turned into beer, provide high returns on their scarce land.

Since none of the food crops can match the high returns to land provided by bananas, our hypothesis is that the net sales of all food crops per unit of land should decline as land gets more scarce. The decline can be expected to be stronger for cassava, cereals, and beans, which are more transportable and provide lower returns to land than sweet potatoes.

Market incentives are again problematic, since, as discussed in the previous chapter, our measures of agroclimatic conditions are so imperfect that if prices were used to measure market incentives, they would actually capture much of the variation associated with agroclimatic variation. In other words, high prices for a given crop would be associated with lower sales—not because farmers do not behave economically but because high prices are associated with poor growing conditions. Thus, we only use distance to paved road as a proxy for market access, hypothesizing that households with good market access rely more on the sales of profitable but bulky cash crops, particularly bananas, and also rely more on the purchases of food crops that are not very lucrative in terms of returns to land and labor. For coffee, the hypothesis is that proximity to roads should reduce farmers' reliance on coffee, which is less profitable and more transportable than banana.

Physical conditions are again measured by rainfall, altitude, and land quality index, and are used primarily to control for other factors. The proxies, especially rainfall and altitude, are highly collinear, and the coefficients themselves have little relevance. The general hypothesis is that the net sales of each crop are higher in those conditions that are more suitable for the crop. For instance, net sales of bananas are expected to be lower at higher altitudes.

Household characteristics used in the model are the age of household head and off-farm incomes (which are highly correlated with education). In accordance with the hypotheses of the previous chapter, we could hypothesize that households with older heads as well as those with higher off-farm incomes produce and sell more bananas and coffee. However, households with large off-farm incomes can afford to consume more, which should reduce the net sales of most products, especially those of beer, which has a high income elasticity of demand (Ansoanuur 1991).

6.3.2 Regression Results on Crop Transactions

The results of the OLS regressions on net sales per hectare are presented in Table 6-16. The key results concerning the association between land scarcity and net sales controlled for other factors are found on the first line of the table.

The numbers confirm our hypothesis concerning cash crops. As expected, the coefficient for beer bananas is positive and that for coffee is negative, suggesting that, other things being equal, increasing land scarcity brought about by population growth is associated with expanding market supply of banana beer but declining market supply of coffee.

Table 6-16: Net Household Sales Model

	Beer Banana	Cooking Banana	Sweet Potato	Cassava	Beans	Sorghum	Maize	Coffee
Man/land, farm	.17**	-.26**	-.48**	-.50**	-.73**	-.10**	-.18**	-.15**
Man/land, vill	.08*	-.08*	.09*	-.12**	-.04	.00	-.07*	.07
Dist. to road	-.09*	-.04	-.03	.05	.03	-.01	.03	.02
Altitude	-.14**	.03	.04	.07	-.12**	-.05	-.16**	-.16**
Rainfall	-.15**	.01	-.02	.00	.14**	-.14**	.10*	-.04
Land quality	.03	.08*	.02	.10**	.03	.04	.14**	.09*
Age of head	.04	-.01	-.05	.01	.03	-.06	.06	.00
Off-farm inc.	-.09*	-.03	.07	-.13**	.19**	-.06	.05	-.02
East	.02	.01	-.04	.06	.12**	.14**	-.05	-.06
Congo-Nile	.03	.05	-.05	.01	-.01	.05	-.08*	-.02
Volcanic	.14**	-.01	-.10*	.00	.03	.12	-.05	-.04
Lake Kivu	-.05	.11	-.03	.06	-.03	.05	-.30**	.31**
ADJ. R2	.12	.07	.17	.40	.56	.10	.17	.17

Source: DSA/MINAGRI, Agricultural Survey 1991; 960 households
* = significant at 5% or better, ** = significant at 1% or better

The result for coffee suggests that the positive correlation between land scarcity and coffee sales shown in Table 6-15 is spurious, reflecting the impact of intervening variables and not specialization in coffee as a response to population pressure. Table 6-16 suggests that agroclimatic conditions might be the explanation. Not only are coffee sales associated with land quality but they are also much more important on the shores of lake Kivu, which is characterized by small farms and good soils. Moreover, coffee sales have a weak positive association with the man-land ratio of the village, which also correlates with high land quality. But within villages, small farmers sell less coffee per hectare than their neighbors with more land.

The result that land scarcity is positively correlated with beer banana sales (as such or as beer) but negatively with cooking banana sales, is consistent with the fact that beer bananas require much more work per unit of land than cooking bananas when brewing labor is also considered. While the agronomic suitability of Eastern Rwanda for cooking bananas is clearly one reason why farmers there rely so much on cooking bananas, our findings suggest that large farm size in the East is another explanation. Within villages large farmers rely more on cooking banana sales and less on beer banana sales than do their smaller neighbors.

The net sales of all the main food crops decline with farm size. The longitudinal implication of this cross-sectional result is that as population grows and farms get smaller, the market demand for all food crops will increase.

Unlike the coefficient for the man-land ratio of the farm itself, the coefficient for the man-land ratio of the village is significantly positive in the case of sweet potato. Together these two numbers suggest that in densely inhabited villages many large farmers are net sellers of sweet potatoes. As demographic pressure increases, the market demand for sweet potatoes, this crop is gaining ground as a cash crop. None of the other major food crops is doing so, which is consistent with the fact that sweet potatoes provide higher returns to land than any other food crops.[35]

Market access, represented in the model by distance to paved road, had a significant coefficient only in the case of beer bananas. As expected, farmers sold more beer bananas in areas close to paved roads. The coefficients for cassava, beans, maize, coffee, and cooking bananas had the hypothesized signs, but were not statistically significant at the 5 percent level.

As expected, high off-farm incomes were associated with small sales of beer bananas. The same was true for cassava. The net sales of beans, in contrast, were found to increase with off-farm incomes. Since the net sales of beans are typically negative, this means that those with above-average off-farm incomes bought below-average quantities

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[35] In the potato zone on Rwanda's temperate highlands, white potatoes already are a major cash crop. With few exceptions, white potatoes are a minor, low-yield subsistence crop in the banana zone.

of beans. This is an anomalous result with no clear explanation. The fact that employees are sometimes fed by their employers may be a partial explanation. Another partial explanation is the fact that some of the households with large off-farm incomes bought meat, eggs or fish instead of beans.

In sum, the regression results presented in this section show that in Rwanda's banana zone households with less land per adult equivalent sell more bananas per hectare and buy more food per hectare. This suggests that as population grows and farms get smaller, the practice of growing bananas and exchanging banana beer for food is becoming an increasingly important part of the food security strategies of the poor.

6.4 Conclusions

The tabulations presented in this chapter show that while bananas and coffee are the main cash crops for all farm size categories in Rwanda, food crops are sold in significant quantities only by relatively large farmers. Throughout the country large farmers achieve and exceed self-sufficiency in sweet potatoes, maize, cassava, and cooking bananas, and in the sparsely inhabited eastern lowlands they also succeed in producing marketable surpluses of beans. Small farmers, in contrast, often need to purchase food to supplement their own production. In the case of beans their own production only accounts for half of the consumption. Many small farmers could produce more food by giving up cash crops but have instead opted for a partial specialization in cash crops.

Poorest farmers are more subsistence-oriented than smallest farmers. They sell little banana beer and coffee, produce primarily cheap root crops, purchase only minimal amounts of beans and have extremely low consumption levels. While this may in part show the dead end of the subsistence farming under demographic pressure, a more important explanation is agroclimatic. Subsistence-orientation and poverty are linked largely because soil degradation contributes to both. This is associated with the fact that in Rwanda, the principal cash crops (bananas and coffee) are more demanding than some of the main food crops (sweet potatoes and cassava).

Multivariate analysis that controls for agroclimatic and other factors shows that in Rwanda's banana zone, households with less land per adult equivalent sell more beer bananas per hectare. In this respect bananas are different from any other major crop, including coffee. This suggests that Rwandan farmers are not substituting food crops for cash crops to cope with land scarcity caused by population growth. While households with less and less land per person are not making any dramatic transition to cash crops either, they clearly prefer to keep their bananas and to rely on the exchange of banana beer for food. "Food first" is not their strategy of achieving food security.

Chapter 7

BANANAS AND FOOD SECURITY

7.1 Introduction

In the previous two chapters we have seen that bananas are central in Rwanda's agriculture. In most of the country it is not an exaggeration to call the farming system banana-based. The relative importance of bananas has increased during the past decades and the cross-sectional evidence we have presented above shows that, controlling for other factors, bananas seem to be associated with land scarcity. This suggests that the relative role of bananas should increase further with population growth. However, we have also shown that for many households bananas are largely a cash crop, implying that the expansion in supply associated with population growth is contingent on changes in market demand.

In this chapter we take a more detailed look at the contribution of bananas for food security in rural Rwanda. We examine why so many food insecure households grow bananas for beer rather than food for themselves and discuss the factors that affect the future role of bananas in Rwanda's food security equation. To put the survey results in perspective, we start by reviewing literature on bananas and banana-based farming systems in the highlands of central and eastern Africa.

7.2 Background Information on Bananas

7.2.1 General Characteristics of Bananas

Banana is one of the most important food crops of the world, and it is grown throughout the tropics (Stover and Simmonds 1987). Botanically, banana (genus Musa) is not a tree, but a gigantic herb. The plant springs from an underground stem, forming a false trunk. Each trunk produces only one bunch of fruit, and is then cut down. The stem can live for decades.

Most bananas are starchy when green and sweet at maturity (Montcel 1985). Most bananas grown for export and eaten uncooked when ripe belong to the AAA triploid group, whereas most bananas that are cooked when green and that are typically known as plantains belong to the AAB triploid group (Perrault 1978). Nevertheless, the distinction between sweet bananas and plantains does not always correspond to botanical classification.

In Africa, plantains belonging to the AAB triploid group dominate West African lowlands and the Congo drainage basin in central Africa. Plantains are mostly cooked for food, and provide very low yields (about 2 tons per hectare per year), but do not require much labor either (Perrault 1978). In the highlands of Central and East Africa, varieties of the AAA triploid group predominate, most of them belonging to a subgroup that is found nowhere else (Perrault 1978). In Rwanda, 90 percent of bananas were estimated to be AAA triploids (Delepierre 1970). Yields are considerably higher than for plantains in Zairian lowlands, usually exceeding ten tons per hectare per year. In Rwanda and Burundi, bananas are mostly grown for beer; in Uganda and Tanzania mostly for food (Perrault 1978).

Bananas grow best on deep soils with abundant rainfall and temperature that varies between 25 and 30 centigrades. However, hundreds of varieties exist, and as a group, bananas can grow satisfactorily on a wide variety of soils, as long as the climate is sufficiently warm and not subject to prolonged dry spells (Champion 1963, Stover and Simmonds 1987). In much of Central and East Africa, mid-altitude highlands provide the best conditions, since the surrounding lowlands are often too dry for bananas, whereas the high mountains are too cold (Stover and Simmonds 1987). Although the absolute altitude limit due to low temperature is quite high, bananas grow so slowly in cool areas and have so low sugar contents that few bananas are grown above 2000 or 2100 meters.

Bananas thrive on soils that are high in organic matter, but at least on the more fertile soils banana groves can effectively mulch themselves and gradually build up the contents of organic matter (Perrault 1978, Kajumulo-Tibaijuka 1984). Neither fallowing nor nutrients imported from elsewhere in the form of chemical or organic fertilizer are needed to maintain fertility in subsistence-oriented banana groves, although both can be used to increase yields on poor soils, or to replace nutrients exported in the form of bananas or banana leaves.

Nutrient uptakes by bananas are modest and little leaching of nutrients or volatilization of nitrogen occurs in well-mulched banana groves (Champion 1963). Compared to cereals, bananas have particularly low uptakes of phosphorus. Fertilizers designed to be used on cereals are usually not suitable for bananas.

On small farms, pests such as weevils and nematodes and diseases such as black Sigatoka (black leaf streak) and Fusarium vilt (Panama disease) typically keep average banana yields at a fraction of the genetic potential. Until the 1950s, this was true also on most export-oriented banana plantations, but during the subsequent 30 years average yields on plantations almost tripled to 40-60 tons per hectare per year (Stover and Simmonds 1987). Improved pest and disease control along with breeding for higher yields were the keys to the spectacular yield increase. The impact of these advances on semi-subsistence production has been relatively modest, both because pest control has relied heavily on frequent applications of costly pesticides and because banana research and extension has mostly focused on high-input production on commercial plantations. Among smallholders the adoption of improved varieties and external inputs is sporadic. Combined with the rapid spread of banana diseases and pests over the past decades, this means that average yields in smallholder conditions have stagnated or decreased in many parts of the world. This is in great contrast to the broadly shared benefits of technical progress in wheat, rice, and maize over the past decades in most of the developing world.

Bananas are often intercropped with coffee, timber trees, and food crops such as beans, maize, or sweet potatoes. The relative densities of the crops vary widely and cultural practices range from deep hoeing to zero-tillage. Typically none of the associated crops yields as well as it would on pure stands, but the total production per hectare is higher (and so are the "standardized" yields computed by allocating the intercropped fields among the associated crops). Occasionally intercropping is a temporary phase during the establishment period of perennials. In Papua New Guinea highlands, for instance, mixed vegetable gardens are gradually converted into coffee/banana gardens and eventually into coffee/casuarina stands, and the point of intercropping is to minimize the need for weeding (Bourke 1989). In eastern Kivu, close to Rwanda's western border, intercropped banana groves became pure as they matured (Perrault 1978). More often, however, intercropping is a permanent feature of banana groves. In much of eastern and central Africa, albeit not in Rwanda, coffee is the main crop associated with bananas. At least at lower altitudes and warmer temperatures, coffee bushes benefit from the shade and the mulch provided by banana trees.

The uses of bananas are not limited to beer brewing and direct consumption as such, although these typically dominate. Numerous processed food products (flour, flakes, chips, puree, juice, vinegar), as well as non-foods ranging from glue to cloth, can be made out of various parts of banana plants (Stover and Simmonds 1987). Some of the processing techniques are cheap and simple and are used by small-scale operators, particularly in India, Sri Lanka, and the Philippines. Also in Tanzania the practice of drying bananas and pounding them to flour has a long history (Koponen 1988).

As such, bananas are bulky and perishable products, which greatly reduces their value for food security and makes their potential as cash crops crucially dependent on access to roads and markets (Perrault 1978). Processing can often solve one or both of these problems. Drying increases both transportability (value-to-weight ratio) and storability; brewing only the former, since traditional banana beer is highly perishable.

7.2.2 Bananas on East African Highlands

In eastern and central Africa, bananas have been one of the main staples since the precolonial period. In precolonial Tanzania, for instance, "grain cultivation with a fallow period was practiced in the lowlands and plateaus with moderate rainfall whereas banana was predominantly the crop of well-watered volcanic highlands and other pockets of exceptional soil fertility"[36] (Koponen 1988). Some of the banana-based systems supported very high population densities, maintained fertility through manuring and mulch, and practiced irrigation and soil conservation. Bananas were used in many forms (fresh, cooked, dried and pounded to flour, mashed for brewing, etc.).

Quantitatively, the historical role of bananas is difficult to estimate. One German settler claimed early this century that three-quarters of African crops consisted of bananas (Koponen 1988), but this may refer to quite a limited geographic area in Tanzania and it may also underestimate crops intercropped with bananas.

In the mountains of Usambara, banana lost its role as the chief staple after 1900, primarily to maize and secondarily to cassava (Fleuret and Fleuret 1980; Koponen 1988). The reasons for the shift are unclear, as is the extent to which such a transition occurred

[36] It is likely that many of these fertile "pockets" were results of farming systems that concentrated nutrients and organic matter in the banana groves around the compounds (Perrault 1978, Kajumulo-Tibaijuka 1984, Olson 1994). The contrast between the banana growing "in-fields" and the annually cultivated or grazed "out-fields" was often great both because nutrients and organic matter were brought from out-fields for consumption and recycling in and around compounds, and because out-fields were typically more exposed to sun, fire, and water, and hence had higher levels of

elsewhere. Nevertheless, banana continues to be an important crop, often the main staple, in the well-watered highlands of the region.

The Chagga (or Wachagga) homegardens on the slopes of Mount Kilimanjaro are one of the present-day banana-based systems (Ruthenberg 1964; Fernandes, O'Kting'ati and Maghembe 1989). They support a population density that exceeds 500 persons per square kilometer, and are regarded as a relatively sustainable system. The homegardens are dominated by bananas and intercropped with coffee and beans. Most households also have a lowland plot, mostly allocated to maize and beans. Most farmers keep permanently stabled cattle and goats, mostly fed with leaves and stalks from bananas, supplemented with hay and grass brought from the drier lowlands. In the early 1960s, Ruthenberg (1964) saw the system as improving; yields were increasing as farmers were starting to use fertilizer and pesticides and adopting "rational" milk production practices. By the late 1980s, little progress had occurred. Fernandes, O'Kting'ati and Maghembe (1989) reported that little fertilizer was used and included fertilizer and intensified milk production among their recommended improvement options. They pointed out that the system had a low productivity and was failing to deal with population growth, which had resulted in considerable outmigration. Nevertheless, they suggested that the gardens were relatively sustainable and productive, and therefore worth extending elsewhere, including the uplands of South-West Rwanda.

Another well-documented banana-based system is that of the Bahaya in Bukoba, Kagera, the region of Tanzania that borders Rwanda. The system relies on intensive manuring and mulching and is credited not only for arresting erosion but also for building up fertility on soils that initially were badly leached (Friedrich 1968; Ruthenberg 1976). However, the poor grass lands that each farm has in addition to its fertile banana groves

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decomposition, volatilization of nitrogen, leaching of nutrients to sub-soil, and soil erosion.

may not offer a valid comparison, since the system is partly based on the transfer of nutrients and organic matter from the poor pastures to the intensively cropped infields.

In the early 1960s, farmers produced primarily cooking bananas for home consumption, and secondarily robusta coffee and cooking bananas for sale. Perennials were intercropped with beans and maize, which were grown with zero-tillage (Friedrich 1968). Returns to land and labor were relatively high compared to many other African farming systems (Ruthenberg 1976).

Twenty years later, the farming systems around Bukoba were reported to be under severe stress (Kajumulo-Tibaijuka 1984). In the 1970s, cooking bananas had been attacked by weevils and nematodes, causing yield declines of 20-95 percent. Also beans, the main source of proteins, had been under severe pest attacks. Farmers had responded by increasing root crop production in banana groves, or by replacing cooking bananas altogether by cassava and sweet potatoes. They also had planted more beer bananas that are higher-yielding and less susceptible to the pests. Beer bananas were replacing both cooking bananas and coffee as sources of cash, and beer had also become a much more important part of subsistence consumption. Some farmers even had migrated to more remote parts of the region to avoid the banana pests. Kajumulo-Tibaijuka (1984) concluded that coffee production will not recover unless the pest problem of cooking bananas can be solved and suggested that bananas should be "number one priority crop" in the area.

The problems faced by banana growers in Bukoba apparently reflect the situation in many other parts of the East African highlands as well: Due to pests and diseases, and, in some cases, due to the impoverishment of the land, yields of bananas, in particular those of cooking bananas, are stagnating or declining. In the most severely affected areas farmers are substituting roots and cereals for bananas. At the same, prices relative to other crops are increasing. In response to the high prices and to population growth, farmers in less affected (and typically less fertile) areas are planting more bananas. In Uganda, agricultural statistics suggest that the area under cooking bananas (matoke) increased by some 50 percent from the early 1970s to the early 1990s, whereas production barely increased (World Bank 1993: Uganda: Agriculture; FAO/WFP 1997). Although the shorter-term fluctuations in yields are dominated by the collapse due to civil strife and recovery thereafter, the long-term picture is one of declining productivity and yields.

7.2.3 Role of Bananas in Rwanda's Farming System

Bananas have a long history in Rwanda, but it is not clear how important they were in the past. Jones and Egli (1984) report that before 1900 most beer was made out of sorghum, not out of bananas. Bart (1993) claims that bananas dominated farming already at the turn of the century, albeit only in the central region. As permanent cultivation later expanded to valley bottoms and swamps, towards the Congo-Nile Divide, and towards the dryer Eastern savannas formerly used for pasture, bananas conquered new territory.

In 1966-67, bananas were estimated to cover some 130,000 hectares (Nyabyenda 1988; Bart 1993). Delepierre (1970) reports that during the 1960s the area planted to bananas increased by 7.6 percent per year, more than three times as fast as the population. He attributed the increase to the superior profitability of beer bananas compared to other crops.

During the 1970s, the area under bananas continued to expand (Gotanègre 1983). Bart reports an estimate of 249,000 hectares for 1982, and Nyabuenda an estimate of 253,000 hectares for 1985. Charlery de la Masselière (1993) sees the expansion of bananas to as high as 2,200 meters altitude in places as a sign of strong pressure on traditionally settled lands at lower elevations.

On most Rwandan farms, bananas are the main crop of the intensively cropped in-fields around the compound. Virtually all manure and household waste are used on bananas, which respond well to organic matter (Raquet 1991; Kotschi et al. 1991). In recent years, also the vulnerability of banana groves to thefts has encouraged farmers to plant bananas on their closest fields that are easiest to supervise (Bart 1993).

Jones and Egli (1984) claim that "banana groves tend to nest in small folds in hillsides down to which soil nutrients have been washed from the annual-cropped soils above. Thus banana groves tend to occupy the more fertile and less steep hillside land." The claim is not supported by DSA data, except for the prefecture of Gisenyi, where many of the hilltops and upper slopes are too high and cool for bananas. Elsewhere, bananas play their biggest role on hilltops, followed by upper slopes. In the valleys, the share of land under bananas is much smaller.

7.3 Bananas for Food

Since most bananas produced in Rwanda are beer bananas and are typically consumed as beer, the role of bananas in human nutrition depends crucially on how much nutrients are lost in the conversion to beer. Unfortunately, the estimates found in the literature vary substantially. Perrault (1978: 336) gives the highest estimate, claiming that 90 percent of the calories are lost in the brewing process. According to Loveridge (1989: 226), who refers to MINAGRI (1985) "a kilo of beer bananas provide only 17 percent of the calories that a human obtains from a kilo of cooking bananas because calories are lost in the brewing process." Jones and Egli (1984: 67) suggest that the alleged high losses are exaggerations associated with the official anti-beer policies that consider beer drinking anti-social and beer brewing wasteful. Referring to FAO statistics, they claim that "every kilogram of bananas consumed directly furnishes 751 calories," whereas "every kilo of banana fermented into beer furnishes 438 calories." This implies that only 42 percent of calories would be lost in the conversion to beer. In its annual statistical report, DSA uses the estimates of 802 kcal/kg, 196 kcal/kg, and 523 kcal/kg for cooking bananas, beer bananas (after brewing) and fruit bananas, respectively. The conversion factors are taken from MINAGRI (1988) and suggest that if the beer bananas consumed as such were comparable to cooking bananas, the implied loss would be 75 percent, and if they were more like fruit bananas, it would be 62 percent.[37]

While Jones and Egli may be right in that the highest estimates of the fermentation losses are biased for political reasons, much of the wide variation, from 42 to 90 percent, in estimated losses probably results from the fact that estimates are based on small samples of heterogenous goods. Neither beer nor bananas are products of standard quality. Recipes for making beer are known to vary, and the highest loss estimates probably come from computations in which the caloric content of "more diluted" beer is divided by the amount of bananas used for "less diluted" beer. Moreover, also small amounts of cereals (mostly sorghum) are used for making banana beer. The studies may have differed in how they divided the caloric losses between cereals and bananas.

In the tables below, we present estimates on the (potential) availability of calories. For each crop, availability is defined as own production plus purchases plus gifts received minus sales (either as such or as beer) minus gifts given. Beer bananas consumed as such are assumed to be comparable to fruit bananas in their caloric content. No adjustment is made for calories lost in brewing for home consumption.[38] One argument for this approach is that the destruction of calories by brewing is the producers' choice and if food is unusually scarce, farmers may eat bananas instead of brewing them for home

[37] While some of the calories are indeed lost in the brewing process, others are included in the by-products of brewing. Apparently none of the estimates makes any attempts to account for how these by-products are used. To the extent that the byproducts are used for fodder and contribute to the availability of animal products, the estimates overstate losses.

consumption.[39] Thus, while the numbers below do not show the best estimate for calories actually consumed, they might tell more about food security. Moreover, given the huge variation in the estimated brewing losses, it may be more informative to give the numbers on availability and then establish what the various estimates on brewing losses would suggest for consumption. A third argument is that the numbers for all the other crops are estimates of availability rather than consumption. Sorghum, finger millet, and wheat are used partly for beer, too. In remote areas where transportation costs make bulky products non-tradable, occasional surpluses of cooking bananas and sweet potatoes are probably fed to animals.[40] No quantitative information on the caloric losses caused by these factors is available. Thus, it can be argued, the only way to be consistent is to focus on availability and not on consumption.

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[38] Calories lost in brewing for sale is accounted for by the conversion of beer sales into banana and sorghum sales.

[39] Brewing for sale is a different story, since, depending on prices, brewing and exchanging beer for food may be exactly what food scarcity calls for. Therefore, calories lost in brewing for sale cannot be assumed to be potentially available for the household.

[40] In Kagera, on Tanzania's side of Rwanda's eastern border, farmers were found to seek food security for poor years by producing more bananas than they needed in normal years (Kajumulo-Tibaijuka 1984). Consequently, bananas had almost no market value in good years and in remote areas farmers at times threw away large quantities. Also DSA's numbers show that many farmers in Eastern Rwanda have much more cooking bananas available than they possibly can eat. In some cases this probably results from data errors (underreported sales or overreported production) or from unrecorded consumption by relatives or employees, in others it probably indicates that surpluses were fed to animals.

Table 7-1: Caloric Availability by Crop and Income Quartile

1000 kcal/hh	Income quartile (FRw/AE)				All Farms
	<5350	5350-8020	8020-13230	>13230	
Beans	325	481	675	924	598
Peas	17	25	30	46	29
Peanuts	2	6	13	41	15
Soybeans	30	57	54	96	59
Sorghum	148	194	320	645	323
Maize	115	176	254	363	225
Wheat	8	7	18	15	12
Eleusine	3	3	3	3	3
Rice	3	9	13	21	11
Cassava	130	210	277	320	233
White Potato	32	50	94	153	81
Sweet Potato	539	735	739	714	682
Taro	28	48	60	65	50
Cocoyam	1	2	3	4	2
Cooking Banana	100	199	359	799	359
Other Banana	193	372	629	1144	578
Total	1672	2574	3542	5352	3261

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Table 7-1 shows mean food energy availabilities from each crop by income quartile in kilocalories and Table 7-2 indicates what is the average share of each crop of the total amount of calories available from the 16 main crops. According to a nationwide consumption survey in the mid-1980s, these crops accounted for more than 97 percent of all calories consumed in rural Rwanda. Fruit bananas, which account for about one-tenth of the volume of all bananas and are used both for food and for beer, are combined in the tables with beer bananas.

Table 7-2 shows that if bananas (and other crops) available were consumed as such, they could provide almost one-quarter of all the calories for an average household.[41] In practice, most beer and some fruit bananas are brewed, which probably reduces the average share of bananas in caloric consumption to somewhere between 17 and 20 percent.[42] Although traditional brewing probably destroys more than one-tenth of all calories available to rural Rwandans[43], which is considerable waste in a country where many people go hungry, bananas unequivocally are one of the three corner-stones of Rwanda's food supply. The old assumption that since most bananas are turned into beer, bananas do not provide many calories, is clearly unfounded.

[41] Note that the numbers in Table 7-2 are means of household-level percentages, not percentages computed from household-level means reported in Table 5-1. They tell about average households without giving more weight to households with higher availability. Since households with higher availability get a higher share of it from bananas, the percentages (9+15) reported in Table 7-2 for bananas are smaller than those (11+18) implied in Table 7-1. An average household gets 24 percent of its caloric availability from bananas but 29 percent of calories available for Rwandan households come from bananas.

[42] Assuming that 62 percent of calories were lost in brewing and that 85 percent of "other bananas" were brewed, the production of banana beer on average destroyed 305 Mcal (thousands of kilocalories) per household, which reduces total availability by 9.3 percent. Guessing that the brewing of sorghum beer destroyed one-third of calories available from sorghum, the total losses from traditional brewing would reach 412 Mcal or 12.6 percent of total availability. The reduced estimate of calories available from bananas would account for 22 percent of the reduced total. As explained in the previous footnote, this computation gives more weight to households with higher caloric availability. The average computed without such weighting is 18.4 percent.

[43] See the computations in previous footnotes. Note that this only applies to calories that were available to rural households, and availability is defined to excludes products that were sold either as such or as beer. If we add the caloric losses that apply to marketed beer and use the assumptions of the previous footnote, we can estimate that brewing destroys about 15 percent of the calories produced in Rwanda. In contrast, Jones and Egli (1984) estimated the *total* losses from banana brewing to be only 2.75 percent on the Great Lakes Highlands as a whole and only slightly more in Rwanda. In addition to using a very low estimate for the losses per kilogram, they grossly underestimated the relative importance of bananas in the farming systems, especially in the East ("Kagera Piedmont" in their terminology).

Table 7-2: Shares of Caloric Availability by Crop and Income Quartile

Percent	Income quartile (FRw/AE)				All Farms
	<5350	5350-8020	8020-13230	>13230	
Beans	20	19	19	18	19
Peas	1	1	1	1	1
Peanuts	0	0	0	1	0
Soybeans	2	2	2	2	2
Sorghum	9	7	8	10	9
Maize	7	7	7	6	7
Wheat	0	0	1	0	0
Finger Millet	0	0	0	0	0
Rice	0	0	0	0	0
Cassava	8	8	7	6	7
White Potato	2	2	3	4	3
Sweet Potato	33	30	23	16	25
Taro	2	2	2	1	2
Cocoyam	0	0	0	0	0
Cooking Banana	5	7	10	14	9
Other Banana	11	14	17	21	15
Total	100	100	100	100	100

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Nevertheless, for the poorest households which typically are among the most food-insecure, the role of bananas as direct suppliers of calories is much smaller than it is for the largest households. In the poorest quartile, only 16 percent of caloric availability comes from bananas. After adjusting for brewing losses, perhaps only 12 percent of the actual consumption of dietary energy comes from bananas. Sweet potatoes provide almost three times as many calories for the poorest quartile as bananas and beans almost twice as many. In the diets of the very poorest households in rural Rwanda, bananas are clearly secondary to sweet potatoes and beans.

As Table 7-3 shows, leaving out the areas that are too cool or otherwise unsuitable for bananas does not change the picture very much. Even in Rwanda's banana zone, bananas are twice as important in the diets of the richest quartile as in the diets of the poorest quartile.

As the multivariate analyses in the previous two chapters showed, the negative association between poverty and bananas does not mean that poverty forces households to grow and eat something else instead. Instead, the negative association results largely from agroclimatic and historical factors. Rwanda's banana basket in the East is relatively sparsely inhabited and prosperous whereas, on the watersheds of Congo-Nile Divide, most crops grow poorly and bananas almost not at all, leaving people in extreme poverty. In other words, the poor consume relatively few bananas in part because many of them live in areas where bananas do not grow well.

Table 7-3: Shares of Caloric Availability in Banana Zone

Percent	Income quartile (FRw/AE)				All Farms
	<5350	5350-8020	8020-13230	>13230	
Beans	20	19	19	19	19
Peas	1	1	1	1	1
Peanuts	0	0	0	1	0
Soybeans	2	2	2	2	2
Sorghum	9	7	8	10	8
Maize	4	4	4	3	4
Wheat	0	0	1	0	0
Finger Millet	0	0	0	0	0
Rice	0	0	0	0	0
Cassava	8	9	8	7	8
White Potato	1	1	1	1	1
Sweet Potato	33	30	24	17	26
Taro	2	2	2	1	2
Cocoyam	0	0	0	0	0
Cooking Banana	6	8	11	15	10
Other Banana	13	15	19	23	18
Total	100	100	100	100	100

Source:DSA/MINAGRI, Agricultural Survey 1990; 955 households

There are, however, three reasons to believe that the direct consumption of bananas contributes to food security more than the estimated shares in consumption suggest. First, food security depends not only on average contributions but also on their variation. In Rwanda, bananas tend to produce something even when other crops fail completely.[44] For instance, several farmers we met in January 1994 told us that their beans had died because of the drought, but their beer bananas kept on producing, albeit less than in normal years. Moreover, bananas, along with roots, are nonseasonal and

[44] Although bananas are vulnerable to droughts in the sense that they cannot tolerate long dry seasons, they are not very sensitive to the lesser irregularities that frequently cause havoc to annual crops in countries like Rwanda (Stover and Simmonds 1984).

produce also during the nutritionally critical preharvest season. Second, the poorest households probably eat more of their available beer bananas than their more fortunate neighbors and, more importantly, can in poor years convert what they normally drink into food by brewing and exchanging, or, if beer prices collapse and food prices rise, by eating the beer bananas.[45] Third, as an extreme coping mechanism during famines, farmers can uproot their bananas, dry and pound the roots and eat them the same way as dried cassava is eaten. Some 60 years ago, starving Rwandans even preferred dried banana roots to dried cassava imported by Belgian colonial administrators from Congo to prevent starvation (Bart 1993). Although cassava is now preferred, banana roots were eaten during the 1989 drought in southern Rwanda (Pottier 1993).

7.4 Bananas for Cash

In addition to supplying food for direct consumption, bananas contribute to food security as a cash crop that can be exchanged for food. In this section, we focus on the cash incomes rural Rwandans get from the banana subsector and from other sources.

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[45] As discussed below, in normal years eating beer bananas instead of brewing them into beer and exchanging for food is unlikely to improve food entitlements.

Table 7-4: Household Cash Incomes by Source and Income Quartile

Rwandan Francs	Income quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Net farm sales	3,675	8,651	14,783	23,006	12,410
Coffee	622	1,527	3,302	4,513	2,468
Banana (+ beer)	1,170	2,958	4,383	7,005	3,845
Cooking ban.	25	65	142	796	250
Sorghum (+ beer)	515	728	1,192	1,852	1,062
Other crops	632	1,599	2,971	5,446	2,629
Livestock	736	1,840	2,934	4,191	2,406
Labor sales	3,097	4,609	6,551	31,118	11,088
Agricultural	1,659	1,891	1,794	1,308	1,669
Other unskilled	602	873	1,453	1,815	1,179
Skilled	836	1,845	3,303	27,996	8,241
Cash Gifts	179	207	360	784	377
Other cash income	401	222	705	2,696	983
NET CASH INCOME	7,352	13,689	22,399	57,604	24,859
Total net income	18,847	33,066	50,223	99,971	49,930

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Table 7-4 shows the mean cash income from each source by income quartile and Table 7-5 shows the share of net cash income that households on average get from each source. In all income quartiles, bananas and banana beer bring households more cash than coffee, which has typically been considered the "predominant source of cash" in rural Rwanda (Jones and Egli 1984: 33). Moreover, the numbers are net of input costs and the imputed value of cereals sold in the form of banana beer is reported in the table with sorghum and sorghum beer. Rural Rwanda as a whole earns approximately as much cash from traditional beers and their ingredients as from all the other crops combined. Overall,

Table 7-5: Household Cash Income Shares by Income Quartile

Percent	Income quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Net farm sales	55	64	70	64	63
Coffee	10	10	13	12	11
Banana (beer)	18	24	23	20	21
Cooking ban.	0	1	1	2	1
Sorghum (beer)	7	6	6	5	6
Other crops	11	12	15	15	13
Livestock	9	13	13	10	11
Labor sales	36	31	25	29	30
Agricultural	20	15	10	4	12
Other unskilled	7	5	6	4	5
Skilled	9	11	10	21	13
Cash Gifts	4	2	2	3	3
Other cash income	5	2	3	5	4
NET CASH INCOME	100	100	100	100	100
CASH % OF TOTAL	38	40	44	49	43

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

one-half of rural incomes are in the form of cash; the other half consists of the imputed value of subsistence food production.[46]

High average incomes from an activity do not always mean that the activity contributes greatly to food security, since incomes that are highly concentrated may be of marginal benefit to the food-insecure households. The examination of distributional issues can be started by comparing income quartiles. Table 7-4 shows that the quartile with highest incomes earns six times as much income from bananas than the poorest

[46] Due to lack of data and computational limitations, several minor income components are excluded from our income estimates. An important omission is perhaps the value of the meals provided by employers. These can be important for some poor households, especially those with many teenage children. Also non-marketed non-agricultural activities such as brewing are excluded, as are livestock products produced for home consumption.

quartile, but the same kind of inequalities hold for most other sources of income as well. Table 7-5 confirms that, on average, households in the most prosperous quartile do not earn any higher share of their cash from bananas than households in the other quartiles. The real difference between the quartiles can be found in labor sales. The poor depend crucially on farm work, while the rich get most of their wages from skilled jobs.

To see whether incomes from a given source are highly concentrated within each quartile among those with highest incomes, we can compare the shares implicit in Table 7-4, where the means are disproportionately affected by higher-income households and Table 7-5, where household-level shares are averaged without giving more weight to households with higher incomes. The numbers in Table 7-4 imply that 16 percent of the aggregate cash incomes of the poorest quartile of households come from bananas, whereas Table 7-5 reports that on average, households in the poorest quartile get 18 percent of their cash incomes from bananas. The difference indicates that within this quartile, bananas are relatively more important for lower-income households. Similar reasoning can be used to show that both overall and within each quartile, cash incomes in general and labor incomes in particular are unequally distributed, contributing to income inequality.

While these averages show that banana sales on average are approximately as important for the poor as for the rich, they still leave the possibility that only a small number of people earn cash by selling bananas and banana beer. To find out whether banana sales are important for many households, we next tabulate the share of households in each quartile earning at least one-third of their cash income from each source. Table 7-6 shows that for all income quartiles, more than one in four households gets at least one-third of their cash income from bananas, whereas coffee contributes as much for only half that many households. Production of food crops for sale plays an important role for only one in ten poor households. Labor sales are important for a much larger share of

Table 7-6: Households Getting >1/3 of Cash from a Source

Percent	Income quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Coffee	11	10	14	13	12
Banana (beer)	24	30	27	25	26
Sorghum (beer)	6	4	4	3	4
Other crops	10	10	14	16	13
Livestock	8	14	14	7	11
Labor sales	46	42	31	37	39
Cash gifts	4	2	1	3	2
Other cash	6	2	2	4	3

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

households, including one-half of the households in the poorest quartile. Further computations, not shown in the tables, indicate that more than 80 percent of Rwanda's rural households get more cash from bananas than from coffee or any other single crop, and that, for 41 percent of the households, bananas are a more important source of cash than all the other crops combined. One in two households gets more cash from bananas than from wages and 15 percent of households get more than 50 percent of their cash revenues from bananas sold as such or as beer.

7.5 Cash for Food

Much of the policy-oriented literature on Rwanda's agriculture has argued that beer bananas are not a proper cash crop, since traditional beers are sold primarily in the rural areas and do not bring in cash from outside (Jones and Egli 1984). A related argument claims that cash from banana beer contributes little to food security because it is used largely to buy more beer (Miklavcic 1995). According to this argument, cash from beer bananas represents illusory earnings and should more properly be seen as a lubricant in the process in which households take turns in producing batches of beer and share the poorly storable product with their neighbors.

It is very difficult to examine the merits of these arguments. As we will see below, interviewed households did not admit to buying much beer, but numerous studies from many parts of the world have found that alcohol consumption and purchases in general are grossly underreported in household surveys (Deaton 1997). While there is no doubt that rural Rwanda exports large quantities of banana beer to Kigali and other urban centers (Miklavcic 1995), and probably also sells some banana beer to neighboring countries (Loveridge 1988, 1992), it is also clear that DSA's rural transaction data significantly underestimate rural purchases and overestimate rural exports.

With these caveats we report the cash expenditures on main crops and beer in Table 7-7. The differences between the income quartiles are striking. While the poorest quartile uses one-half of its net cash incomes for food crops, the richest quartile uses only one-tenth for the same purpose. In other words, although only a small fraction of aggregate cash income is used for food, more than one-half of the cash in the hands of the food-insecure buys food. Reported beer purchases are minimal in all quartiles, but much more money is used for sorghum and beer bananas that can be used to make beer[47]. Unfortunately, it is not clear whether the purchases of beer ingredients were resold in the form of beer. Although adjustments for beer and sorghum that only "pass through" the household were made, they were not perfect and some misclassification was bound to happen, especially for the poorest households, who rely most on purchased ingredients.

[47] In an earlier study based on the same data set, Loveridge (1992) reported banana beer purchases that were roughly 30 times as large as those in Table 7-7. This was incorrect, resulting from a typing error in the SPSS program that effectively *added* sales to purchases. The error was not carried over to numbers on rural exports (net sales) and in his text Loveridge drew no conclusions from the erroneous numbers.

Table 7-7: Household Cash Expenditures on Food Crops and Beer by Income Quartile

Francs	Income quartile (FRw/AE)				All Farms
	<5370	5370-8040	8040-13120	>13120	
Food Crops	3,558	4,243	5,037	4,818	4,414
Beans	1,830	2,327	2,565	2,055	2,194
Sweet Potato	514	333	303	194	336
Sorg.&Beer Ban.	527	552	844	776	675
Banana Beer	58	96	135	331	155
Sorghum Beer	70	89	80	156	99
Total Cash Income	7,214	13,449	21,806	53,919	24,097

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households

Although most of the aggregate cash incomes remain unaccounted for in the table, and although a significant fraction of the unaccounted share undoubtedly goes to beer, this primarily applies to those who are far from starving. Half of the cash of the poor is accounted for by recorded food crop purchases, leaving very little for industrially produced foods (e.g., vegetable oil) and for non-food items.

The higher-income households probably buy much more beer than they admit. Although these transactions bring no cash to the rural areas, they redistribute food access so that the poorest get more to eat.

If we compare net sales and production, we can see that the poorest quartile of households increases its food availability by 15 percent through market transactions and this does not yet include the meals provided by employers. Moreover, cash incomes from beer sales and other sources contribute to nutritional status and other well-being not only by financing food purchases. Indeed, the nutritional benefits of additional food decline fast and above the very low levels money often buys more nutritional benefits if it is used for medicines, soap, sanitation, health care or education instead of food (Blanken 1988; von Braun, de Haen and Blanken 1991).

7.6 Future Role of Bananas in Food Security

We have now seen that many poor households in Rwanda grow beer bananas, sell banana beer, and buy food, especially beans. Both the widespread adoption by farmers and the numbers discussed above suggest that the exchange strategy is in the best interest of the farmers, which at the very low income levels is not far from saying that it improves their food security. Using the numbers in Table 5-1, it can be computed that the cash revenue from a hectare of beer bananas sold as beer would on average have bought 1446 kilograms of beans[48]. This is 72 percent more than the estimated average national bean yield. This shows that at the relative prices and yields that prevailed in 1990, the strategy of exchanging banana beer for beans succeeds in substituting labor for land and in improving the food entitlements of those engaged in the exchange strategy. In this section, the focus is on the factors that determine the future role of bananas in Rwanda's food security. We start by asking what the prospects are that relative prices or yields will change enough to undermine the basis of the banana beer exchange strategy.

7.6.1 Declining Terms of Trade for Banana Beer?

As discussed above, the exchange strategy is associated with land scarcity so that as population grows the market supply of banana beer can be expected to increase, while that of food should decrease. Other things being equal, banana beer prices should decline whereas food prices could increase. In principle, these changes could undermine the economic basis of the beer exchange strategy. More generally, one needs to ask what are the prospects that prices collapse if banana production increases.

[48] This uses producer price (sales price) for beer and consumer (purchase) price for beans and hence shows the advantage of exchange net of the costs charged by the traders.

Consumption studies suggest that in Rwanda banana beer is a luxury consumed primarily by households with relatively high incomes[49]. This implies that the demand for banana beer depends greatly on real incomes. If economic growth increases the purchasing power of large segments of the population, demand for banana beer increases much faster than population. Indeed, it is unlikely that banana beer supply could increase as fast as demand, if the economy grows satisfactorily. If, for instance, both population and per capita incomes grow by 2.5 percent per year, and if we, probably conservatively, use 1.0 as the expenditure elasticity of demand for banana beer, supply should increase by 5 percent per year to prevent prices from rising.

If, however, real incomes decline, demand stagnates or even declines. Market prices can react dramatically, since stagnation in incomes not only reduces demand but also increases marketed supply as some of the impoverished producers exchange a higher share of their output for food. In part, the profitability of beer bananas in 1990 reflected Rwanda's economic growth that until 1980s had been sufficiently fast to allow a large share of the rapidly growing population to maintain the traditional diet that includes large quantities of beer.

Thus, the future of Rwandan smallholders' exchange strategy depends largely on how the overall economy develops. If real incomes increase, additional net sales coming from the increasing number of small farms specializing in beer need not depress prices, since demand will also grow rapidly. But if the stagnation of the late 1980s and the early 1990s continues in the nearby future, prices could decline and thereby force some farmers to revert from banana-based specialization towards subsistence food production.

[49] Although industrially produced beer is preferred to traditional beers, it is too expensive for most Rwandans. Both in urban and rural areas, the demand for banana beer is estimated to increase fast with incomes, in rural areas more than proportionally (that is, it is estimated to be a luxury) (Ansoanuur 1991).

Apart from economic stagnation, changes in taxes on industrially produced beer could depress banana beer prices. In the past, industrially produced beer has been taxed heavily in Rwanda, whereas traditional beer has mostly escaped taxes (Haggblade 1987). The choice has largely been dictated by fiscal needs and administrative feasibility. Since nearly all households manufacture some beer, taxes on traditional beers have been thought impossible to administer. With the increased commercialization and rural-to-urban transportation of traditional beers, the administrative feasibility of taxing them has improved and the fiscal gain from doing so has increased. Thus, although radical cuts of taxes on industrially produced beer may be unlikely for fiscal reasons, the same fiscal considerations make new taxes on banana beer a distinct possibility.

The scenario where higher bean and cereal prices would choke off the banana-based specialization on Rwanda's land-scarce farms would be most likely in a situation where Rwanda's borders were more effectively closed to informal imports of beans and cereals. In the early 1990s, most of the beans bought by Rwanda's land-scarce farmers were imported from neighboring countries, mostly from Congo (Loveridge 1992). Without higher trade barriers major increases in long-term average bean and cereal prices are unlikely, since the relatively high transportability and storability of beans and cereals suggests that supply is quite elastic. In other words, small increases in relative bean and cereal prices would be sufficient to expand the areas in Congo and Uganda that supply beans to Rwanda.

The opposite scenario is that of lower food prices brought about by more open borders, improved infrastructure, lower transportation costs, higher agricultural productivity in the supplying areas, or food aid. These obviously would encourage more specialization in banana beer at the expense of food crops. One of the unintended consequences of the massive food aid Rwanda has received since 1994 has been to encourage Rwandan farmers to produce beer rather than food.

7.6.2 Declining Yield Advantage of Beer Bananas?

Just as the decline in relative banana beer prices could make specialization in beer bananas unattractive, lower yields for bananas or higher yields for food crops could destroy the economic basis of the exchange strategy. Whether this will happen depends largely on policies affecting agricultural research, extension, and input supply.

All of Rwanda's main food crops have average yields that are only a fraction of those achieved in agronomic trials in Rwanda and are also far behind the yields harvested by smallholders in the well-watered areas of Zimbabwe and Kenya (CNA 1990). This suggests that with concerted efforts in research, extension and input supply, the yields of any of the main crops could be increased significantly, with major implications on what farmers would choose to grow.

The potential of agricultural research in changing cropping patterns is illustrated by Rwanda's experience with white potatoes. By introducing local varieties resistant to late blight (the main problem limiting potato production in Rwanda) and by supplying pesticides to control mildew, the national potato improvement program (PNAP) has greatly increased yields and production. Between mid-1970s and mid-1980s the area area under potatoes more than doubled (Bart 1993). The initial success was limited to high altitudes but the great interest of farmers elsewhere suggests that if improved planting materials, technical advice and pesticides were made more widely available, the area under potatoes could expand further (Little and Horowitz 1988).

Another recent change in cropping patterns has been a shift from bush beans to climbing beans (CNA 1990). The latter require much more labor per unit of land, but have much higher yield potential in favorable conditions, are less susceptible for the damage caused by excessive rain and thrive at higher altitudes. More importantly, some new climbing bean varieties are resistant to root rots, which had become a major constraint in the production of the traditional bush bean varieties. Where climbing beans grow well, farmers can get more beans by growing climbing beans than by growing bananas and exchanging beer for beans. By the late 1980s climbing beans had become popular in some fertile, well-watered densely inhabited areas, particularly in Gisenyi, and in the 1990s they have spread throughout much of the country (Sperling and Munyaneza 1995). In the areas most affected by root rots, many farmers had stopped producing beans before the introduction of the new varieties resistant to root rots.

However, these two success stories are exceptions to the general picture which is one of minimal technical progress associated with underinvestment in agricultural research. Relative to the size of agricultural output, few countries in the world have invested as little in agricultural research as Rwanda. In terms of funding, the neglect has not always been visible in international statistical comparisons, since agricultural research in Rwanda, like in many other African countries, is funded mostly by donors. As a result, the level of funding has been highly volatile. Moreover, a large share of the recorded expenditures has been spent on a handful of expatriate researchers.

Even a quite limited effort could be effective, if it is focused tightly on a sufficiently small number of key constraints and concentrated on selecting, adapting and transferring technologies developed elsewhere, provided that appropriate technologies exist. The success of the national potato improvement program was based on a tight focus on two problems (late blight and mildew) and two solutions (varieties resistant to late blight and pesticide to control mildew) (Amani and Haverkort 1986; Haverkort 1986a, 1986b, Wilcock and Ndoreyaho 1986). Moreover, the program targeted an inherently fertile volcanic small area where potato was the cash crop (Durr 1983). Hence, land fertility was much less of a problem than in most other parts of Rwanda, and getting inputs and advice into the hands of the farmers was relatively easy. Much of the push for creating a critical mass behind the program came from the International Potato Center (CIP), which was eager to demonstrate impact by capitalizing on its success with late blight resistant varieties. In the case of climbing beans, the keys to success were improved varieties and strong support from CIAT (Sperling and Munyaneza 1995). However, outside these two programs the situation is quite different. In general, the limited resources of Rwanda's national agricultural research institute (ISAR) have been spread extremely thinly on tens of commodities and hundreds of production constraints (ISAR 1989; Eicher, 1990).

In light of the limited resources and lack of focus, it appears unlikely that research alone could increase food crop yields in the nearby future so dramatically that specialization in bananas would lose its appeal. More likely challenges for the banana-based intensification include declining banana yields due to pests and diseases, and higher food crop yields brought about by large fertilizer subsidies.

7.6.3 Fertilizer Subsidies?

One policy change that could change the role of bananas in Rwanda is the introduction of major subsidies on mineral fertilizer. While fertilizer subsidies have not played a large role in Rwanda's past, they may soon become a major issue in Rwanda's food policy.

In pre-genocide Rwanda, fertilizer use was minimal and mostly limited to export crops. Several projects distributed free or heavily subsidized fertilizer, but quantities remained small. The main deterrant was the extremely high international transport cost of "more than $270 per ton from Kigali to Europe," which alone was enough to more than double the cost of fertilizer in Rwanda (World Bank 1991).[50]

Yet, it is precisely the costly international transportation that may push Rwanda or its donors to subsidize fertilizer. Even if Rwanda's farmers fell short of the "rule-of-

[50] It is unclear whether this refers to the shortest, and the only fully asphalted route to the sea via Uganda to Mombasa. In the 1980s, a political blockade by Uganda often forced Rwanda to use more costly routes (Bart 1987).

thumb" response ratio of ten kilograms of cereals per one kilogram of fertilizer (Pinstrup-Andersen 1982), costly transportation means that it is less expensive to increase food supply in Rwanda by importing fertilizer from international markets than by importing cereals from there.

Since the genocide, the focus in and around Rwanda has been on emergency relief, and hundreds of thousands of tons of food aid have been trucked or flown in without much concern for costs. However, the return of hundreds of thousands of refugees in late 1996 made it clear that food aid would be needed for years to come and increased interest in alternatives that would be financially more sustainable in the long term. In 1997 and 1998, the Government of Rwanda and USAID officials were discussing whether donors could "jump-start Rwanda's rural economy" by shipping in large quanties of fertilizer.

In pre-genocide Rwanda, the idea of increasing food production by promoting the use of fertilizer was already part of the conventional wisdom. In the early 1980s, increased use of fertilizer and other external inputs was declared one of the corner stones of the official food security strategy (MINIPLAN 1983; Bart 1987). Ten years later, Rwanda's National Agricultural Commission went further, stating that increased use of fertilizer was "a question of life and death" (CNA 1992a). The commission computed that to make fertilizer use "financially viable," farmgate prices should be subsidized by 40 percent. For fertilizer use to achieve the level deemed necessary by the commission, the total subsidy should be more than ten million dollars per year, which is far more than what has been used for agricultural research. Fertilizer needs were computed by adding the estimated uptakes of nutrients by crops to the estimated losses of nutrients caused by soil erosion.[51]

[51] This, of course, leads to a great overestimation of nutrient outflows since in Rwanda most crops are used and recycled on the farms and most of the topsoil lost due to

Also many donor documents emphasized the importance of fertilizer (Jones and Egli 1984; Wilcock and Ndoreyaho 1986; World Bank 1991). Instead of advocating costly subsidies, donor experts argued that fertilizer either is already profitable or could be made so by appropriate investments in agricultural research and extension. Hence, they called for research on more fertilizer-responsive crop varieties and for the development of easy-to-extend packages that would incorporate fertilizer.

To substantiate their claims that fertilizer pays or at least could increase production if promoted with subsidies and supported by relevant research, some of the above documents summarize the results of agronomic trials on fertilizer response. The computations carried out for the National Agricultural Commission suggest that bush beans, bananas and sorghum are so unresponsive that fertilizer use would remain unprofitable in all reasonable price scenarios (CNA 1992a). In contrast, climbing beans, soybeans, potatoes, and wheat, along with Rwanda's main export crops, coffee and tea, have given high returns to fertilizer in the trials (CNA 1992a; World Bank 1991). Results for sweet potatoes, cassava, and maize were also somewhat encouraging (CNA 1992a; Wilcock and Ndoreyaho 1986). More importantly, combining fertilizer with varieties that are highly responsive to it, could increase yields dramatically. In particular, the combination of fertilizer and hybrid maize is assumed to have much potential, as it has in parts of Kenya and Uganda. In the World Bank studies one of the key arguments was that research on fertilizer response deserves high priority (Jones and Egli 1984; World Bank 1991).

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erosion is deposited on the fields lower on the hillside. On the other hand, many fields in Rwanda are so degraded that merely replacing current nutrient outflows could not make them productive (König 1992).

In Rwanda, fertilizer subsidies would probably encourage the production of high-response crops at the expense of bush beans, sorghum, and bananas.[52] The relative importance of these three traditional crops would decline, while the role of newer crops such as soybeans and potatoes would increase. Since sorghum has been losing its relative role for the past forty years or more and since there already has been a clear trend from bush beans to climbing beans and soybeans, fertilizer subsidies would only hasten the trends. In the case of bananas, however, a major reversal could happen. Bananas have expanded secularly for several decades, but could decline if bypassed by the production increases brought about by subsidized fertilizer.[53]

Much depends on the results of the associated research agenda. The combination of major fertilizer subsidies and locally adapted highly responsive maize, cassava, and sweet potato varieties could stop the expansion of bananas and gradually transform much of Rwanda from a system based on banana intercropping into a system dominated by monocropped cereals or roots and tubers.

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[52] In theory, the acreage under the responsive crops could decrease if higher yields and production brought about by cheap fertilizer dramatically reduce prices. However, as discussed above, beans, cereals, and cassava are traded regionally, which reduces the impact of national fertilizer subsidies on prices. The disincentive effect would be felt mostly in the surplus areas of Congo and Uganda, where slightly lower food prices would not be offset by significantly lower fertilizer prices.

[53] Two major caveats for these conclusions should be noted. First, most of the fertilizer trials noted above have examined responses to commonly available compound fertilizer types containing nitrogen, phosphorus and potassium. While this may be a reasonable starting point and the most cost-effective fertilizer application for some crops and some soils, more profitable fertilizer applications could certainly be found by better tailoring the application of chemical fertilizer to soil conditions and to the nutrient uptakes of each crop. For instance, banana groves that failed to give attractive returns to compound fertilizer might have economically interesting responses to potassium. Second, fertilizer response trials typically focus on short-term direct impacts of the nutrients and ignore long-term impacts through changes in soil structure. Given that bananas thrive on deep soils with much organic matter and that increased biomass production brought about by fertilizer can be used to build up the organic matter content of the soil, it is possible that certain fertilizer-augmented soil enrichment strategies could be profitable for bananas, although the straightforward fertilizer trials fail to show sufficient impact.

7.6.4 Transition to Edible Bananas?

The numbers in Table 5-1 show that in addition to being highly profitable cash crops, bananas produce more calories per hectare than any other main crop in Rwanda. Moreover, cooking bananas supposedly yield even higher cash returns to land than beer bananas. Yet, as we have seen, cooking bananas are not a particularly popular food for the poorest farmers.

The solution to the paradox lies in the yield gap between beer and cooking bananas. Since beer, cooking and fruit bananas were not separated in land use statistics, Table 5-1 includes only the aggregate banana yield. Although our data set cannot show the gap directly, we can indirectly conclude that cooking banana yields must be considerably higher than beer banana yields. Only a large yield gap can explain the fact that cooking bananas are much more expensive than beer bananas and yet small farmers prefer beer bananas.

Cooking bananas are grown mostly in the East, where banana yields are much higher, and nationally their mean yield may well be close to that of beer bananas. Even on many farms, cooking bananas may yield as well as beer bananas, since they are more demanding and grown usually on the most fertile fields just around the compound[54]. But on similar land, cooking bananas must yield considerably less than beer bananas, so that farmers could not increase their cash incomes simply by substituting cooking bananas for beer bananas.

Across Rwanda's eastern border, in Kagera, Tanzania, the superior yields of beer bananas are well documented. According to Kajumulo-Tibaijuka (1984) farmers in this area had substituted beer bananas for cooking bananas because the former are higher-yielding and less susceptible to pests, which had become a major problem in the 1970s.

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[54] Jean-Bosco Sibomana, personal communication.

Pest problems were particularly severe in areas which had been covered by banana groves for several decades. This gives the hint of an alarming prospect that the important role of of cooking bananas in eastern Rwanda may be only temporary. Until independence, much of Kibungo was reserved for pasture and most of the banana groves in the area have been planted quite recently. Thus, the pests which have devastated cooking banana groves in Kagera may become a much more severe problem in eastern Rwanda in the near future.

Technically, beer bananas are just as edible as cooking and fruit bananas, but the taste is different and, as Table 5-1 shows, consumers are willing to pay nearly twice as much for cooking bananas as for beer bananas. Indeed, while beer bananas are a famine food eaten usually only under extreme deprivation, cooking bananas are a highly appreciated food crop. A more expensive source of calories than sweet potato, maize, sorghum, or cassava, cooking bananas are consumed primarily by the better-off households. Eastern Rwanda, especially Kibungo prefecture where cooking bananas grow best and are cheap, is a partial exception in that cooking bananas are the main staple there for poor and rich alike.

In addition to parts of Kibungo, cooking bananas increasingly dominate in Rwanda's peri-urban areas. Based on this tendency, Bart (1993) predicts that peri-urban cooking banana gardens may show the path for the rest of the country. However, the evidence presented above on prices and consumption patterns suggests another explanation. Instead of being a response to land scarcity, the peri-urban cooking banana gardens probably reflect proximity to high-income consumers. Urban consumers demand both cooking bananas and banana beer. Since the latter is much more transportable (has four times more value per weight) than the former, peri-urban and other well-connected areas specialize in cooking bananas while the more remote areas specialize in banana beer.

The prices and consumption patterns of bananas suggest that depending on economy-wide trends, two entirely different developments for edible bananas are possible. If Rwanda prospers, the demand for cooking bananas increases fast, inducing increased production, especially in peri-urban areas, along roads and in Kibungo. But if Rwanda stagnates, and if both the demand for banana beer and beer banana prices collapse, millions of poor Rwandans may be forced to eat beer bananas more regularly, and not just during famines, as in the past. Depending on how much and how persistently they dislike beer bananas, producers may either start substituting root crops for bananas or learn to accept beer bananas as a food crop.

Obviously, the above scenarios hold only if the price and yield gaps between beer and edible bananas persist or become even wider due to pest attacks. If agricultural research succeeds in narrowing the gap, by improving edible banana varieties or their management practices or by developing new varieties which yield as much as beer bananas but are appreciated as food, the entire picture changes. Based on such achievements, edible bananas could expand independent of what happens to incomes, improving considerably food security and environmental sustainability in Rwanda.

7.7 Chapter Summary

In Rwanda, the grass-roots view on bananas is strikingly different from the aggregate view. From the aggregate point of view, the brewing of bananas into beer represents an important waste of food. In theory, a reduction in the waste and a redistribution of the saved food to the needy could significantly reduce undernutrition in Rwanda, if not eliminate it altogether. But from the point of view of hundreds of thousands of poor households, bananas are crucial for their food security, not least via the exchange of banana beer for cheap staples.

The evidence presented in this chapter indicates that (1) despite the nutritional losses associated with brewing, bananas provide more than one-fifth of the calories consumed in rural Rwanda; (2) bananas are the single most important cash crop and second only to labor sales as a source of cash; (3) cash incomes from bananas are widely distributed in rural Rwanda and no more concentrated among the better-off households than other sources of income; (4) the poorest households use half of their cash income to buy staple foods, especially beans imported informally from neighboring countries; (5) food purchases are essential for food security, since subsistence production is seriously deficient in proteins and lipids; and (6) beer banana yields are so high that land-scarce households typically can get more beans by growing bananas and exchanging beer for beans than by growing beans themselves.

The key role of bananas in the food security equation of rural Rwandans is based primarily on two ratios: the yields of bananas are relatively high compared to those of other major crops and the prices farmers can get for banana beer they sell are relatively high compared to the prices they need to pay for the beans and cereals they buy. In several plausible scenarios these ratios could change sufficiently to undermine the basis of banana-based specialization on Rwanda's hillsides. A tax cut on industrially produced beer that would reduce banana beer prices, import restrictions that would increase food prices, fertilizer subsidies that would increase food crop yields, and pests that would reduce banana yields are among the possibilities. Obviously, reverse scenarios that could increase the contribution of bananas for food security also exist. Technical progress that would increase the yields of cooking bananas close to the current yield levels of beer bananas is one such scenario.

The purpose of exploring the above scenarios is not to predict the future of Rwanda's banana-based intensification process. Instead, the scenarios can illuminate some of the consequences of selected policy choices and thereby provide the background for the policy discussion in the concluding chapter.

Chapter 8

OTHER RESPONSES TO DEMOGRAPHIC PRESSURE

8.1 Introduction

In the preceding chapters we have focused on how farmers with different amounts of land per person differ in their land use and participation in agricultural product markets. We have found that in most of Rwanda, land scarcity is strongly associated with more intensive cropping patterns, dominated by the intercropping of bananas and food crops. This suggests that banana-based intensification of cropping patterns is a major response to demographic pressure in Rwanda.

The purpose of this chapter is to put the banana-based intensification into a wider perspective by looking at the other forms of agricultural intensification and the bigger picture of how agricultural households respond to population pressure on and off their farms. Drawing from existing literature and from DSA data, we look at agricultural and non-farm income strategies. This is followed by a very brief review of the demographic responses.

8.2 Other Agricultural Responses

8.2.1 Investments in Erosion Control

As mentioned in section 2.3., strictly enforced policies to fight soil erosion were introduced in Rwanda during the colonial era, discontinued at independence, re-launched in the 1970s, and intensified during the 1980s. Most often farmers were advised and forced to dig infiltration ditches and plant grass strips, both on the contours. On steeper slopes, contour hedgerows rather than grass strips were usually the recommended method. Since the result of well-maintained grass lines or hedgerows is a gradual build-up of terraces, contour lines with vegetative barriers are often called (progressive) terraces. By 1990, most sloping fields were "protected" by at least some anti-erosion structures. According to the DSA data set discussed in the preceding chapters, Rwandan fields had on average 205 meters of grass strip per hectare, 161 meters of anti-erosion ditches, and 56 meters of hedgerows (Clay, Reardon, and Kangasniemi 1995).[55]

Many observers have praised Rwanda's beautifully "protected" hillsides and Harrison (1987) even argues that diligent soil conservation is one of the key reasons why Rwanda was among the few African countries that until mid-1980s could increased food production fast enough to match the rate of population growth. However, both the poor performance of Rwanda's agriculture since the mid-1980s and detailed studies on how the soil conservation investments work on Rwanda's steep hillsides cast doubt on these conclusions.

The anti-erosive measures promoted during the colonial period and again after 1973 were developed in the 1940s to reduce soil erosion on slopes of less than ten degrees (Moeyersons 1989). By Rwandan standards these are gentle slopes. One-half of Rwanda's fields have slopes that exceed 11 degrees, the mean slope of fields is estimated to be 16.7 degrees, and two-thirds of the soil losses occur on slopes that exceed 21 degrees (SESA 1986).

Several researchers argue that on steeper slopes official measures can be ineffective or even harmful. Bidou (1989) argues that the anti-erosion ditches promoted in Burundi and Rwanda by the Belgians were not able to deal with heavy rains, and if not properly maintained, could lead to gullying. Nduwayezu (1990) shares these allegations

[55] Hedgerows were not necessarily woody perennials. In the survey, pennisetum purpureum lines were classified as hedgerows, unless they were kept short by cutting regularly for fodder (Jean Bosco Sibomana, personal communication).

and also criticizes infiltration ditches for being costly to make, requiring lots of maintenance, not increasing production, and not reducing erosion between the ditches.

Nduwayezu (1990) advocates grass lines, claiming that if made according to the official recommendation, they reduce soil losses to one-tenth of what they would otherwise be. However, on steep slopes this apparently is neither quite true nor good enough. Byers (1990), Brondeau (1991), and Lewis (1992) report average annual soil losses of 54 t/ha, 83 t/ha, and 62 t/ha, respectively, even with vegetated barriers. While much lower than those achieved on similar conditions without barriers, they are too high to allow continuous cropping in the long term. Moreover, as pointed out by Ndayizigiye (1989, 1992), among others, grasses and hedges take up nutrients which, if not replaced with fertilizers, reduces crop yields. Unless the grasses and hedges themselves can be converted into valuable products by feeding them to livestock, farmers may not be able to reap any benefits.

The key problem is that just as infiltration ditches fail to arrest erosion between ditches, grass lines do little to reduce erosion between the lines. Instead, they lead to the accumulation of topsoil from the top of the interline area to the bottom, as the terrace progressively is formed. In much of Rwanda, the loss of topsoil from the upper sides of the terraces is a serious problem. Rwandan soils are fertile but the fertility resides only in the topmost layers, which are fairly thin (Moyersons 1989). Subsoils are often acid, poor in main nutrients, and have potentially toxic levels of aluminium (Zaag et al. 1984). At least on fragile highlands, terracing has reduced fertility and increased soil acidity (Lewis 1992).

Farmers often cultivate too close or even under the progressive terrace to make it collapse and then spread the accumulated fertile topsoil more widely (Lewis 1992; Bart 1993). But even without such man-made soil losses the formation of progressive terraces can destabilize steep hillsides and lead to gullying (Webster and Wilson 1980). Where soils are deep, even landslides can follow (Ndayirukiye 1989), as many Rwandan farmers experienced during the unusually heavy rains in May 1988 (Byers 1988).

To some extent, the problems experienced on steeper slopes could be addressed by reducing the distance between grass lines and increasing the width of the vegetative barrier, as is the official recommendation (Nduwayezu 1990). However, this would leave less space for crops and reduce current incomes, unless the plants grown on the barriers have considerable value as fodder, fuel, or food.

The key message from the literature is that Rwanda's anti-erosion campaign was rigid and simplistic. It has advised and at times forced farmers to adopt practices with little regard to their physical environment (rainfall, soil type, slope) and almost no regard to the economic environment and to what farmers were growing on their fields and whether they owned any livestock. Little attention was paid to indigenous practices already used by farmers in many parts of the country (Derenne 1989). It stands to reason that the interests of and benefits for farmers varied widely, ranging from those who were clearly hurt by the measures to those whose needs were so well met by the measures that they did even more than was required. In between the extremes must be some who were initially reluctant but then were persuaded by the benefits they saw and others whose efforts would have been better spent on other activities but who nevertheless decided to maintain the structures when the most laborous task of putting them in place was done. Not much information exists on where in this range most farmers were and what they would have done in the absence of the compulsion. Guichaoua (1991) who interviewed farmers in 1989, reports that the anti-erosion campaign was bitterly resented and mistrusted, with measures generally seen as either useless or even harmful. Yet, many farmers agreed that soil conservation in some form was needed. What they resented were the specific things they were asked to do and the degree of compulsion that was used.

Even in a context of a government campaign to promote soil conservation, one could argue that the large variations between households reflect the economic, social, and environmental incentives faced by farmers and therefore could be used to get some understanding on what is going to happen now that the enforcement of the soil conservation policies has (temporarily?) ceased. This is the approach taken by Clay and Reardon (1994) and Clay, Reardon, and Kangasniemi (1995), who used the DSA data set to examine the determinants of soil conservation investments.

The dependent variable in the analysis is the amount (meters) of three types of conservation investments (grass strips, anti-erosion ditches, and hedgerows) per hectare on the farm. Independent variables include measures of monetary and physical incentives to invest, risk of investment, wealth and liquidity and other household characteristics. No proxies of the degree to which the policies were actually enforced in the area were used.

Some of the results supported the hypotheses: off-farm employment, small farm size, and large household labor force appeared to promote investments, whereas insecurity of land tenure appeared to discourage them. However, also statistically significant anomalous results were found: The index of agricultural profitability had a statistically significant positive association with grass strips and anti-erosion ditches, but a statistically significant negative association with hedgerows. Also price variation and knowledge of conservation techniques had coefficients that were positive for some forms of soil conservation investments and negative for others. High agricultural wages, which make investments more costly and could be hypothesized to discourage conservation, appeared to encourage it.

The regression equations explained only a small fraction (6-13%) of the variation in the investments. This is not surprising in light of the claims that much of the variation may have been related to differences in how rigorously the policies were enforced

(Guichaoua 1991). Neither does it necessarily invalidate the results, if the unmeasured degree of enforcement is not correlated with the explanatory variables used. Thus, the key question is whether the implicit assumption that enforcement is uncorrelated with the other determinants is warranted.

If, for instance, all adults were mandated to construct a certain quantity of terraces on their fields, this would imply that enforcement was correlated positively with family size and negatively with farm size. Thus, the key result suggesting that households with much labor and little land indeed intensify by investing in soil conservation could be a result of enforcement rather than of voluntary responses.

In sum, although the result that land scarcity is associated with investments in soil conservation appears plausible, the evidence to support this assertion is not very strong. Further, although the degree to which farmers invested in soil conservation because they were forced to do so is unclear, the evidence is strong that compulsion was an important factor in the 1980s. The additional incentives that population growth may create for the construction of progressive terraces in the nearby future are likely to be more than offset by the fact that the enforcement of the rules requiring farmers to conserve their soils effectively ended in the early 1990s.

More importantly from the point of view of this study, even if population pressure brought about significant increases (or decreases) in how farmers invest in and maintain their progressive terraces, it is not clear how such changes would affect their incentives to intensify through banana-based intercropping. To the extent that progressive terraces reduce soil erosion, they may reduce the need to plant bananas for soil conservation purposes. On the other hand, the profitability of bananas along with their sensitivity to variations in soil fertility suggests that if progressive terraces work as intended, the payoffs to planting bananas could increase.

In conclusion, while investments in soil conservation in principle can change farming systems and cropping patterns, we have found little evidence to suggest that soil conservation in Rwanda is fundamentally changing the basis of the banana-based intensification patterns discussed in the preceding chapters. Neither the prospects of soil conservation nor its impacts on cropping patterns are clear.

8.2.2 Agricultural Inputs

Increased use of external and on-farm inputs is another way of coping with increasing land pressure that potentially could change cropping patterns and modify Rwanda's ongoing banana-based intensification. This section briefly reviews the evidence on input use in Rwanda to explore whether ongoing changes in input use could be modifying the basis on which Rwanda now is heading towards labor-intensive banana-based intensification.

In the early 1990s, Rwandan farmers used only minimal quantities of external inputs. The only significant exceptions were the use of pesticides to control mildew on potatoes in the northeastern part of the country and the use of fertilizer on tea plantations. Apart from these cases and occasional distributions of free or heavily subsidized fertilizer by externally funded development projects, farmers largely ignored the fertilizer recommendations of the research and extension systems. According to DSA's national survey, less than five percent of parcels received any purchased inputs in 1991 (Clay, Reardon, and Kangasniemi 1995).

As shown above in Table 6-1, according to the 1990 transaction survey, Rwanda's rural households spent on average only 84 francs on purchased inputs (other than labor). Roughly 30 times more were spent on the purchases of agricultural labor, suggesting that liquidity is not be the principal constraint on low input use. Instead, farmers choose to allocate their cash to labor rather than to fertilizer and pesticides, either because chemical inputs are not available, because returns on them are low, or because farmers fail to appreciate the returns. The fertilizer trials discussed above found that, on most of Rwanda's major crops, fertilizer use was not particularly profitable at the prices that prevailed in the late 1980s.

In contrast to purchased inputs, on-farm organic inputs are widely used in Rwanda. According to DSA's national survey, almost 70 percent of parcels received manure, compost, and/or mulch in 1991 (Clay, Reardon, and Kangasniemi 1995). As discussed below in more detail, most livestock are kept in stalls at least during the nights and the resulting manure is applied to nearby fields. Mulching is common on fields covered by bananas and coffee, and much of household waste along with some crop residues is composted and spread on the fields.[56] The recycling of the human "nightsoil" is less rigorous, but banana trees are often planted on top of former latrine pits.

Given the central role of organic inputs in fertility management on Rwanda's farms, understanding how that role is changing would be valuable. General literature on intensification provides no clear guidance. As discussed in Chapter 3, the use of organic inputs can be highly labor-intensive and therefore increasingly careful mulching and manuring is typically a key part of labor-based intensification associated with land scarcity (Goodland, Watson, and Ledec 1984). On the other hand, land scarcity can reduce the availability of organic inputs. Noting that much of the mulch used on coffee fields comes from uncultivated (or fallowed) valley bottoms that are being cleared for cultivation, Jones and Egli (1984) predicted that mulching will decrease in Rwanda.

[56] There is an important difference in how coffee and banana fields are mulched. The former involves hard work by farmers to bring in the mulch, whereas the latter occurs naturally on established banana groves, unless farmers remove the crop residues either to cultivate other crops with bananas or to use the residues for other purposes such as the (mandatory) mulching of coffee.

Empirical evidence provides little support for this prediction. Using DSA's national survey data, Clay, Reardon, and Kangasniemi (1995) examined the determinants of organic input use on the parcels of Rwandan households. The results on this topic are subject to similar caveats as those on soil conservation investments discussed above. Most notably, both the production of coffee and the nearly universal mulching of it were strongly influenced by government policies and their enforcement. Variation of these was not measured and little is known about how enforcement was correlated with the socioeconomic factors studied.

With these caveats we can note that the use of organic inputs was significantly and negatively associated with farm size. In other words, large farmers were less likely to use organic inputs on any given parcel than their neighbors with less land. Further, organic input use favored fields that were close to the residence, owned rather than rented, flat rather than steep, and located on the hill rather than in the valley.[57]

The result does not support the claim that organic input use is declining under demographic pressure due to the reduced availability of organic inputs. Rather, it appears that declines in fallows and pastures have been offset by the increased planting of bananas, trees, and hedgerows. In conclusion, there is little evidence to suggest that the direction of Rwanda's intensification is fundamentally changing as a result of ongoing changes in input use.

8.2.3 Livestock Practices

Although it is frequently assumed that the role of livestock must inevitably decline when demographic pressure forces households to grow food for themselves rather than

[57] The results also included a statistically significant positive association between the size of the parcel and the likelihood of input use, but this cannot be interpreted to suggest that a plant growing on a large parcel was be more likely to enjoy organic inputs than a plant growing on a small parcel. Input use was not quantified and it is rather obvious that a large parcel (that in Rwanda typically consists of several differently cropped

grass for their animals, empirically based literature paints a quite different picture (Ruthenberg 1976, Jahnke 1982). While large herds are not compatible with high population density, mixed farming often is. In low-income and low-input conditions, moderately dense livestock populations are often used to convert crop residues and weeds into animal products, draft power, and manure, which plays a key role in fertility management (McIntire, Bourzat, and Pingali 1992; Decuyepere et al 1982). Where local incomes are higher or larger markets easily accessible so that farmers face a strong demand for animal products, intensification with purchased inputs and specialized fodder crop production can lead to very high livestock densities. On parts of Kenyan highlands, for instance, a shift to intensive dairy production has allowed households to earn higher incomes on increasingly small farms (Jahnke 1982).

In Rwanda, total livestock numbers increased during the post-World War II period but much more slowly than population. As a result, the relative importance of livestock, especially that of cattle, in Rwanda's rural economy declined. Large herds disappeared and increasingly farmers have substituted small ruminants for cattle. While Rwanda had .29 cattle, .12 sheep and .40 goats per person in 1953, the numbers in 1989 were .10, .10, and .26, respectively (Rwamasirabo 1990).

Expert opinions on the current and future role of livestock in Rwanda's rural economy vary widely. Before the events of 1994 fundamentally changed the situation, most observers believed that Rwanda was overstocked with animals. For instance, Rwamasirabo (1990:66) estimated that Rwandan farmers have "roughly three times the amount of livestock recommended for adequate animal nutrition and ecological sustainability". He referred to the "uncontrolled expansion" and asked whether livestock in Rwanda has been "transformed from a resource that generates income and helps

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fields) is more likely to receive inputs and be therefore classified as organically fertilized than a small parcel.

improve nutrition to a destroyer of natural resources". At the same time some other observers saw room for expansion and argued that soil conservation with vegetative barriers can only succeed if farmers can turn the grasses and hedges into valuable products with livestock.

In Table 8-1, we use the DSA 1990 data set to take a cross-sectional look at lifestock holdings. The last column gives the national averages: While only 31 percent households have cattle, 50 percent have goats and 24 percent have sheep. The holdings overlap so that 28 percent of households have neither ruminants nor pigs (but many of them have chicken or rabbits). To get a measure of livestock pressure on land, we compute stocking rates (livestock densities) by converting each species into tropical livestock units (TLU) and dividing by farm size. If we aggregate over all farms, the average stocking rate is .89 TLU/ha; excluding households without livestock gives an average rate of 1.23 TLU/ha.[58]

Comparing farm size quartiles, we see that as the population density increases and farm size decreases, the share of households with cattle decreases as does the average herd size. However, among those who do have cattle, farm size declines more than herd size so that average stocking rate increases. The same applies also for goats and sheep. More importantly, the overall stocking rate is highest on the smallest farms even if we average over all households, not just over those with animals.

[58] These numbers are considerably lower than those computed by Rwamasirabo (1990) using the essentially comparable data from 1989 Agricultural Survey. The difference arises primarily from how livestock numbers are converted into TLUs. Rwamasirabo assumed that *all* cattle on average were 250 kg, goats one-sixth of that, etc., whereas we assume that these apply only to *adult* animals, and that the conversion factors for young animals should be smaller. The question is empirical and not trivial since our conversion factors lead to stocking rates that are only two-thirds of those used by Rwamasirabo. In the absence of measurements from Rwanda we chose to use conversion factors that are compatible with those of the International Livestock Center for Africa (ILCA) as reported by Jahnke (1982).

Table 8-1: Household Livestock Holdings by Farm Size

	FARM SIZE QUARTILE (Ares/AE)				All Farms
	<9.5	9.5-15.0	15.0-25.5	>25.5	
CATTLE					
% with cattle	13%	24%	37%	48%	31%
average herd	1.88	1.92	2.40	2.91	2.44
density (TLU[1]/ha)	4.61	2.31	1.44	1.11	1.83
% keep in corral	70%	64%	62%	53%	60%
% permanently in[2]	25%	19%	28%	14%	20%
% cut&carry[3]	78%	64%	61%	55%	61%
GOATS					
% with goats	42%	45%	54%	59%	50%
average herd	2.51	2.50	3.02	3.27	2.86
density (TLU[1]/ha)	.86	.40	.29	.21	.41
% keep in corral	55%	52%	38%	37%	44%
% permanently in[2]	35%	22%	21%	21%	24%
% cut&carry[3]	58%	46%	40%	37%	45%
SHEEP					
% with sheep	18%	22%	28%	31%	24%
average herd	2.15	2.02	2.61	2.87	2.47
density (TLU[1]/ha)	.66	.33	.27	.17	.32
% keep in corral	62%	60%	45%	47%	52%
% permanently in[2]	44%	24%	27%	16%	26%
% cut&carry[3]	61%	49%	49%	45%	50%
TOTAL LIVESTOCK					
% with livestock	60%	67%	78%	83%	72%
average herd (TLU[1])	.55	.75	1.13	1.55	1.04
density (TLU[1]/ha)	1.94	1.28	1.03	.88	1.23
% with corral	57%	55%	51%	52%	54%
% keep all in[2]	39%	26%	24%	20%	27%
% mostly cut&carry[3]	57%	49%	47%	49%	50%
TLU/ha (ALL FARMS)	1.16	.86	.80	.73	.89

[1] TLU=Tropical Livestock Units, [2] % keep animals *permanently* in corral,
[3] % rely primarily on stall-feeding (cut&carry), not grazing
Source:DSA/MINAGRI, Agricultural Survey 1990; 1035 households

Some of the stocking rates on small farms are very high, suggesting that the fodder for these animals may have come from outside the farms. Another possible explanation is that small farmers have adopted livestock management practices that substitute labor for land. Results from elsewhere show that a given area can support more animals, if it is not grazed, but instead farmers keep their livestock in corrals (stables, stalls), cut grass, leaves, and other fodder, and carry it to the animals. This cut and carry system or stall-feeding is more labor-intensive than grazing, but more compatible with crop production, especially if the crops are perennials. Moreover, it helps conserve nutrients. Much of the effectiveness of manure is based on nitrogen which is easily lost under exposure to sun (McIntire, Bourzat, and Pingali, 1992). While stall-feeding does not guarantee effective use of manure, it makes it much easier.

Table 8-1presents three indicators of stall-feeding: percentage of households who report that they keep their animals fully or partly in stables, percentage reporting that they have adopted permanent stabulation, and percentage reporting that they rely more on fodder that they cut and carry to their animals than on natural pasture. Each of these indicators shows more stabulation on small farms. But even on the largest farms one-half stabulate partly, and one-fifth keep all their animals permanently in stable.

Longitudinal evidence about the trend from grazing to stall-feeding is also clear. During the colonial period cattle were nearly always grazed and no tradition of fodder crop production exists (Bart 1993). In the 1984 survey, one-fourth of cattle-owners reported that they kept their cattle in stable (corral), which suggests that stall-feeding has been increasing also during the 1980s. Bart (1993) reports that stables, especially those with tin roofs, have become signs of modernity, in part because of the increasing risk that cattle that are not kept confined damage crops.

While small farmers on average have more livestock per unit of land even when averaging over all households and not just those with animals, two out of five households in the smallest farm size category did not have any livestock in 1990. Clearly, lack of fodder is not the reason for not having even one goat. Literature provides two other explanations. First, due to poor veterinary services, livestock mortality in Rwanda is exceptionally high, making animals quite risky investment for very poor households (Rwamasirabo 1990).

Second, many households in Rwanda are probably too poor to buy livestock and have no access to credit, except possibly at excessively high rates (Bart 1993). That lack of liquidity rather than lack of fodder or poor profitability of livestock plays the key role is illustrated by the common practice in which poor households agree to take care of the animals of their neighbors with no other compensation than the manure.

The trend towards stall-feeding is compatible with the banana-based intensification pattern discussed in the preceding chapters. Banana groves produce large quantities of leaves that can be used for fodder. Moreover, the supply of banana by-products is not nearly as seasonal as that of most other fodder resources. This matters, since typically it is not the total annual fodder availability but instead the dry-season minimum that limits livestock production.

On the other hand, the use of banana leaves for fodder competes with their use as mulch, which is the key to the environmental sustainability of banana groves. The tradeoff is obviously less severe, if banana leaves are fed to animals only during the dry season, when grass availability is at the minimum.

Another link between stall-fed animals and bananas is through manure, which in Rwanda is most often used for bananas and crops intercropped with them (Bart 1993; Kotschi et al. 1991).

In sum, intensification based on labor and not on purchased inputs characterized both what smallholders in pre-genocide Rwanda did in their livestock practices and what they did in their cropping practices. The trends were compatible, even mutually reinforcing. The much-lamented overstocking appears to have had been oversold, in part because both the intensification of cropping patterns (banana gardens, tree planting) and the establishment of vegetative anti-erosion structures were increasing the availability of fodder.

8.3 Income Diversification

In the two preceding chapters we have already presented some data on the role of rural off-farm incomes. In this section we revisit these findings to ask how continued population growth will affect households' opportunities to find off-farm employment, and what, in turn, are the implications for the agricultural intensification process discussed in the preceding chapters.

Several previous studies that have looked at some regions of Rwanda have emphasized that off-farm employment already is an important source of income for rural households (von Braun, de Haen and Blanken 1991). The numbers presented above show that this is also true for rural Rwanda as a whole. According to Table 6-5, labor sales accounted in 1990 for 22 percent of aggregate net household incomes in Rwanda's banana zone (22 percent in rural Rwanda on average) and for almost 40 percent of the net household incomes of the quartile with least land per adult equivalent. However, as discussed above, these numbers are effectively weighted by income, and therefore are strongly influenced by a small number of high-income households with members employed as teachers or other civil servants.[59] Most households rely much less on labor sales, and, as shown in Table 6-3, the mean share of income coming from labor sales was only 16 percent in 1990.

For all but the richest quartile of households, unskilled labor was a larger source of income than skilled labor, and in the poorest quartile agricultural wage labor was typically more important than all skilled and unskilled non-agricultural jobs combined. Thus, for the poorest households, access to agricultural wage employment is crucial for food security.

[59] By the standards of rural households, civil servants were well paid in Rwanda in 1990. According to the DSA data set, the mean daily wage for civil servants was approximately five times that for unskilled farm and non-farm workers. Also masons and carpenters earned 2-4 times as much as unskilled laborers.

Unfortunately, this access is likely to decline under demographic change. As shown in Table 6-12, sales and purchases of agricultural labor are strongly associated with farm size. The bulk of the demand for agricultural labor comes from the top farm size quartile, whereas households with the least land per person are typically net sellers of unskilled labor. The longitudinal implication of this cross-sectional observation is that, other things being equal, the subdivision of farms under population pressure reduces the demand for and increases the supply of unskilled labor. Without either major land-saving and labor-using innovations in agriculture or rapid increases in non-agricultural employment to offset these trends, either real wages for unskilled workers will decline or rural un(der)employment will increase.

Moreover, many of the non-agricultural jobs directly or indirectly face the same predicament. To the extent that subdivision of farms makes households poorer and less self-sufficient in food, it reduces the rural demand for the services of masons, carpenters, and tailors, among others. And to the extent that smaller farms pay less direct and indirect taxes, the capacity of the state to employ teachers and other civil servants may decline. In other words, without technical progress in agriculture, population growth threatens to impoverish poor households not only by allocating them less land but also by turning the process of agricultural growth multipliers in reverse (Haggblade, Hazell, and Brown 1989; Mellor 1986; Mellor and Desai 1985).

Reduced opportunities for wage labor increase further the pressure for labor-based intensification in agriculture. The cross-sectional intensification patterns discussed above may well understate the upcoming changes. To the extent that tomorrow's land-scarce farmers have less access to off-farm incomes than today's small farmers, they will be forced to practice more intensive agriculture than is found today on tiny farms. Thus, the second-round impacts of demographic change through labor markets make the story of labor-based intensification towards banana intercropping even more credible. However, as discussed above, this is not the only second-round impact; another one is felt through prices. To the extent that demographic change reduces incomes not just among the rural poor but also among the urban consumers, thereby forcing them to cut back on their consumption of banana beer and cooking bananas, it may reduce banana prices and undermine the scope for banana-based intensification.

8.4 Demographic Responses

Apart from agricultural intensification and the expansion of the non-farm economy, rural populations can also respond to increasing demographic pressure by migrating elsewhere or by adopting measures to limit population growth. These demographic responses interact with the economic responses in different ways. Therefore, we review here very briefly the nature of demographic responses in Rwanda, drawing primarily on Olson (1994), and discuss the implications for agricultural intensification and for the development of the non-farm economy.

Migration from densely inhabited highland areas to surrounding lowlands has been a central response throughout the region. Rwanda has a long history of sending permanent and temporary migrants to less densely populated areas in neighboring countries. During the early colonial period such emigration was frequently encouraged by the colonial administrators, who considered Rwanda overpopulated. After independence Rwandan politicians continued to talk about the need to find more land for Rwandans in neighboring countries, but as the neighbors were reluctant to host immigrants, little international migration occurred.[60]

Most migration during the post-World War II period has been internal and, until the 1980s, mostly rural-to-rural. The big picture was that young men and women moved

[60] Although some 200,000 tutsis left the country in the 1960s, most of them considered themselves refugees, declared their intention to return, and eventually did so after the 1994 genocide.

eastward from the densely inhabited high plateau. In 1945-61 the large movements were from Gikongoro to Butare and from Ruhengeri to Byumba. After independence, most migrants went to the rural areas of Kigali prefecture, often to areas that had previously been reserved to the tutsi pastoralists. Since the end of the 1970s, the eastern province of Kibungo became the main destination for the rural-to-rural migrants. Rural-to-urban migration was limited to the capital city, and between 1978 and 1991, the estimated population of Kigali more than doubled to 230,000.

Also temporary migration plays an important role in Rwanda. Using the men-to-women ratios of the 1991 census, Olson (1994) estimates that the main destinations of short-term migration are the city of Kigali and Bugesera in the south of Kigali (rural) prefecture. Interestingly, Kibungo, the most sparsely inhabited region, did not appear to have as many temporary migrants as the earlier migration destinations. In part, this may be associated with the strong reliance of Kibungo on cooking bananas, which require less labor per hectare than most other crops.

Fertility rates remained high until until the late 1970s, but then started to fall rapidly. According to the 1991 census, Rwanda's total fertility rate had declined to 6.2, which is about 30 percent below the rate computed based on the 1978 census results (Grosse 1994).

While the spread of modern methods of contraception undoubtedly contributed to Rwanda's fast fertility decline, the main explanation was the increasing scarcity of land and other opportunities, which postponed the marriages of the young and raised the interest in family planning. The steepest fertility declines were recorded in the western prefectures (Gisenye and Kibuye), where the pressure on resources is strongest. In contrast, fertility rates had barely declined in the relatively sparsely inhabited eastern prefectures (Byumba and Kibungo). News from the post-genocide Rwanda reports that birth rates are up again, presumably because many households are responding to the losses of family members by having more children (The Economist 1997). Together with the return of hundreds of thousands of "old-caseload" refugees, this suggests that demographic pressure in most of Rwanda is about as high as it was before the genocide and increasing faster.

In sum, demographic responses have clearly reduced the pressure on resources in the most densely inhabited parts of Rwanda and given households more time to intensify their farming and diversify outside agriculture. In many areas of Rwanda's historic core, migration has fully compensated for natural population growth, keeping local pressure on resources at bay. However, now that the unoccupied frontiers have been settled, the pressures to intensify and diversify are getting stronger. Even if fertility rates resumed soon their rapid downward trend, Rwanda's young population would continue to grow fast.

The key agricultural implication of the past demographic responses has been a shift towards banana-based farming systems. Hundreds of thousands of people have moved to areas where beer bananas are the main cash crop and, less universally, cooking bananas the main food crop.

Although the eastern frontiers are now settled, the trend towards the areas dominated by bananas is likely to continue. Farms in these areas are still larger and more fertile than those in most other parts of Rwanda. As a result of above-average birth rates, some immigration from more densely populated areas, and less outmigration to cities than from other rural areas, the share of Rwanda's rural population living in these areas will increase.

8.5 Conclusions

In this chapter, we have seen that although there are number of other responses to demographic change in addition to the land use and marketing responses discussed in the previous chapters, they do not appear to change the situation fundamentally. The big picture is still that of labor-based intensification and increased reliance on banana intercropping and on the market for food. Despite all the gradual changes, farmers are losing their battle to survive on the hills of Rwanda. Without significant technical progress in agriculture and/or major increases in non-agricultural income earning opportunities, food security in rural Rwanda is set to deteriorate.

Chapter 9

POLICY IMPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

9.1 Summary of Results

None of the findings summarized below is entirely new. All of them have been stated, guessed or documented somewhere in the literature on Rwanda's agricultural development. However, the main findings are contrary to what some of the most knowledgeable observers of rural Rwanda have recently stated or what is the conventional wisdom based on which policies have been or are formulated.

9.1.1 Land Use

The key finding of this study is the association of beer bananas and banana intercropping with land scarcity. National cross-tabulations fail to show this link because farms for various reasons happen to be large in the areas most suitable for bananas. But within regions, small farmers rely more on beer bananas than large farmers. The conventional wisdom that land scarcity pushes farmers to switch from beer bananas to sweet potatoes and other food crops gets no support from cross-sectional data. Instead, population growth is increasingly converting Rwanda's hills into intercropped banana gardens, where food production occurs under bananas. While some types of intercropping are labor-saving methods used in land-abundant conditions, Rwanda's intercropped banana groves are not. Instead, they are a form of agricultural intensification, helping people to substitute labor and biological capital for increasingly scarce land.

In a complete contrast to bananas, sweet potatoes are favored in densely inhabited areas, but within the areas small farmers allocate no more land to sweet potatoes than do their neighbors with more land. This occurs despite the fact that sweet potatoes have high caloric yields and are the main staple for the poor. Clearly, small farmers do not seek food self-sufficiency at all cost but instead respond to the superior returns that beer bananas can provide to their increasingly scarce resource.

Apart from bananas and sweet potatoes, our results confirm the conventional wisdom. Land scarcity pushes households to expand cultivation at the expense of fallow and pasture. Beans and maize, along with bananas are the crops that expand most.

One policy lever that appears to have a significant impact on land use is physical infrastructure. In areas close to paved roads, farmers grow more bananas and less cereals and cassava.

Although the expansion of cultivation at the expense of fallow and pasture increases the exposure of Rwandan hillsides to water erosion, the expansion of bananas offsets the negative impact at least in part. It is not clear whether population growth is making land uses more or less erosive. Dense pure banana groves protect the soil well against erosion, but the protective cover provided by banana intercropping varies greatly depending on management practices. The officially promoted practices have clearly been more erosive than the traditional practices followed by farmers.

The transition of Rwandan smallholders to banana intercropping only applies to the agroclimatic areas that are suitable for bananas. It does not hold for the highest altitudes (above 2000-2100 meters) that are too cool for bananas. On temperate highlands, population growth is unequivocally making agriculture more erosive and less sustainable.

9.1.2 Market Participation

The findings on market participation are corollary to those on land use. Most significantly, when agroclimatic variation is controlled for, the net sales of bananas (as such or as beer) per unit of land are higher on small farms than on large farms. This suggests that as population growth increases land scarcity, the market supply of banana beer will increase, not decrease as is commonly assumed. Coffee sales per unit of land, in contrast, tend to decline with farm size when agroclimatic variation is controlled for. This implies that, other things being equal, demographic pressure would tend to reduce Rwanda's coffee exports.

The sales and purchases of all food crops are strongly associated with land scarcity. On average, small farmers are net buyers and large farmers net sellers. Other things being equal, population growth reduces market supply and increases market demand for all food crops.

In other words, the cross-sectional patterns show that farmers are not responding to land scarcity by giving priority to food. They are intensifying production by intercropping bananas and food crops. As a result of this intensification, both subsistence food production and beer production for sale increase per unit of land, while both decline per person and per household.

As expected, households with better access to markets were found to rely more on the exchange of banana beer for food.

9.1.3 Bananas and Food Security

Despite the waste of calories associated with the brewing of bananas into beer, bananas provide more than one-fifth of the calories consumed in rural Rwanda. Although the most food-insecure rural households rely more on sweet potatoes and other cheaper sources of calories, the direct consumption of cooking bananas and banana beer is not unimportant for them. On average, bananas account for more than one in ten calories consumed by the poorest households. In the eastern parts of the country cooking bananas are the principal staple food for most households.

Much of the contribution of bananas to food security comes through the exchange of banana beer for food. Bananas are the single most important cash crop and second only to labor sales as a source of cash. The cash incomes from bananas are widely distributed and no more concentrated among the better-off households than incomes in general. The poorest households use much of their cash incomes to buy food, especially beans, which are a valuable supplement to their protein-deficient diets.

Our computations suggest, given existing prices and yields, that many land-scarce households can get more beans by growing bananas, brewing beer and exchanging beer for beans than by growing beans themselves. Moreover, bananas are less vulnerable to droughts than annual food crops and protect the soils better against erosion. In other words, while the use of scarce land for beer bananas reduces food availability at the national level, it improves the food security of many households by increasing their incomes and "exchange entitlements" to food.

The argument that demographic pressure is pushing households to substitute cooking bananas for beer bananas gets no support from our data. Unlike beer bananas which have high yields and trade at low prices, cooking bananas are a much more expensive staple, presumably because they are more demanding and/or yield less. Effective demand rather than land scarcity appears to be the explanation for the expansion of cooking bananas in peri-urban areas.

Since independence, population has grown much faster in eastern Rwanda where bananas are the main staple, than in the rest of the country. As eastern Rwanda still has much larger farms and higher household incomes and therefore can cope with additional people better than other parts of the country, the trend is likely to continue. This will tend to increase the national importance of bananas. Apart from that, the future role of bananas in Rwanda's food security equation will depend crucially on what Rwandans can afford to consume. If Rwanda's economy grows and if the benefits of the growth are shared broadly, cooking bananas and banana beer will in the medium term become more important than they are now. If, however, population growth is accompanied by economic stagnation, the demand for traditional banana products will decline, eroding the economic basis of the strategy of exchanging banana beer for food. Depending on how much and how persistently poor Rwandans dislike beer bananas, they would either substitute root crops for bananas or learn to accept beer bananas as a food crop.

9.2 Update on Recent Developments

The results summarized above were obtained primarily from the analysis of a large nation-wide survey data set collected in 1989-1991. Although no comparable data set exists for later years, Rwanda has undergone so dramatic events in the 1990s that we cannot go from 1990 data to 1998 policy implications without examining how the situation may have changed since 1990. Drawing primarily from World Bank (1998), we list the following developments:

1. Although close to one million lives were lost during the events of 1994, Rwanda's 1998 population is back to the pre-genocide levels. Consequently, rural population densities are now considerably higher than they were in 1990, when the data set used above was collected. Hence, the question of how households respond to increasing land scarcity remains relevant.

2. In contrast to the population, agriculture has not recovered fully. A large part of the physical and organizational infrastructure for agricultural services was destroyed in 1994 (Kumar et al. 1996). In early 1998, production was estimated to be at some 70 percent of the pre-genocide level. Large quantities of food aid are brought in to fill the gap and distributed primarily through food-for-work projects. Although many relief and

development projects have distributed farm tools and seeds, the shortage of sweet potato vines and other planting materials is still acute in many areas.

3. Agriculture suffers from a severe labor shortage, primarily because hundreds of thousands of adults were killed in 1994, and because some 100,000 Rwandans are still in prison, most of them suspected genociders awaiting trial. Restrictions on labor movements limit the ability of labor-deficient areas from getting workers from labor-surplus areas. Further, food-for-work projects draw labor from agriculture. Much land lies fallow because households do not have enough labor to cultivate it or because they participate in food-for-work projects. However, the entry of young people into the labor force can be expected to turn the labor shortage into a labor surplus in a few years.

4. The security of land tenure remains uncertain, and few households have started to make long-term investments such as the planting of perennial crops (coffee and bananas).

5. Cropping systems are largely similar to what they were in 1990. The most significant difference may be the expansion of root-rot-resistant bean varieties. Relative to most other crops bean prices have somewhat declined. Sweet potatoes are still the dominant cheap staple for the poor, and cooking bananas are still a more expensive source of calories than cereals. Information on beer bananas or on banana beer has not been collected.

6. World coffee prices have increased, but higher prices have not been passed on to farmers. Like in 1990, coffee does not appear to be a lucrative cash crop, except for those who could not get bulkier products to the market. Many vehicles used to transport agricultural products were destroyed in 1994 and have not been replaced.

7. Large cattle heards were brought by returning "old-caseload" refugees from Uganda to Eastern Rwanda, but elsewhere livestock were decimated by the genocide and the ensuing war and dislocations, and have not recovered.

9.3 Implications for Policy

In a predominantly rural country, almost all areas of public policy have some connections to how farming systems are coping with rapid demographic change. The focus here is on implications for agricultural policies, broadly understood.

9.3.1 Agricultural Research and Extension

The main policy implication of this study concerns the very high contribution that *technical progress on bananas, especially on edible bananas, would make to food security and environmental sustainability in rural Rwanda.* As summarized above, bananas are the single most important crop in terms of land use and income and a key to soil conservation on the steep hillsides of Rwanda. Since bananas can produce more income and food per hectare than any other crop in most parts of Rwanda, their role has expanded with population growth and could potentially increase much further. However, banana production suffers from severe pest and disease problems and without new solutions to these problems, banana production in general and cooking banana production in particular could decline dramatically, as it has done in some nearby areas in neighboring countries. This would have dire consequences to food security and environmental sustainability.

The substantial benefits of technical progress are a strong argument for giving bananas a high priority in agricultural research and extension, provided that agricultural research and extension on bananas are neither much more costly nor less likely to produce results than research and extension on other crops. Experiences from other countries suggest that research and extension on bananas have a high likelihood of producing significant results at reasonable costs. Technical progress in the export-oriented banana plantations in Central America and elsewhere has been spectacular. The stock of methods and results (including germplasm) that researchers focussing on the semi-subsistence banana groves of African highlands can apply and adapt is substantial. Researchers in the region already have some interesting results in the pipeline. Moreover, technical progress in smallholder banana production does not rely on industrially produced fertilizer to the extent that productivity increases in cereals typically do. Given the high costs of importing fertilizer to Rwanda, this is a significant advantage and one argument for prioritizing bananas in technology development and transfer.

Apart from bananas, Rwandan agriculture is increasingly dominated by two crops: sweet potatoes are the most important source of calories while beans are the main source of proteins. Together, these three crops provide more than two-thirds of calories, proteins and cropping incomes in rural Rwanda, and for the poorest households, their shares are even higher. To a large extent, the stagnation of Rwandan agriculture and the deterioration of the food security situation in the 1980s and early 1990s resulted from the lack of technical progress in these three crops. Although detailed appraisals of research projects are needed before definitive conclusions can be drawn, it is a good first approximation that returns to research investments are likely to be large when they focus on widely grown crops so that innovations can potentially have much impact. Moreover, the gap between current average yields and on-station experimental yields is huge in Rwanda, suggesting that much potential for technical progress may exist (Ndamake 1984a, 1984b). Thus, our findings suggest that Rwandan *policymakers could increase the contribution of agricultural research to food security by ensuring that it has a strong focus on the three main food crops*.

Note that the argument here is based on expected payoffs, not on any anti-market "food first" approach. Both sweet potatoes and cooking bananas are bulky and poorly transportable products and therefore essentially non-tradable wage goods. If their productivity stagnates in the context of rapid population growth, the ensuing higher prices will not only hurt the net buyers, including most poor rural households, but can also choke off growth in other parts of the economy, especially in the coffee sector. Major increases in productivity, in turn, could release resources for other industries, including export crop production. To a lesser extent, the argument also applies to beans, since although they are more tradable, transportation of imported beans to rural areas is expensive and a shift from locally importable to locally exportable entails substantially lower local prices.

The other side of the coin is that none of the three main crops can pull Rwanda out of poverty. All three are essentially local wage goods with little direct potential for export earnings. The better the research and extension efforts targeted at them succeed, the more will the prices of the bulky food products decline, and the stronger becomes the case for promoting productivity increases not only in the main food crops but also in export-oriented activities that could take advantage of the resources released from food crop production (Pearce 1990). Above all, this reasoning puts coffee on the agenda of agricultural research and extension. Although not nearly as important for rural households as the three main food crops, coffee is Rwanda's main source of export earnings and the only widely grown export crop in the country. In the conditions that prevailed in 1990 (as well as in those that prevailed in 1998) coffee was not a particularly profitable crop, which raises questions on whether farmer interest in replanting coffee could be sufficiently high to bring improved technologies to the fields and to justify investments in research and extension. Obviously, the payoffs depend crucially on how good the improved coffee technologies are, but positive returns are also more likely if the efforts advocated above are already bringing major productivity increases (and price decreases) to the poorly tradable bulky food crops (e.g., sweet potato and bananas), if open borders help to lower the prices of the more tradable food crops (e.g., cereals and cassava flour), and if policies do not discriminate against the coffee sector.

Apart from coffee, similar arguments hold for many other agricultural activities that currently play little role compared to the main food crops, but eventually will become local or even national engines of rural growth. These range from tea and horticultural products to dairy operations and fish ponds. Each of these sub-sectors is more likely to emerge and respond positively to investments if productivity in the food crops that now employ and feed bulk of the population increases.

The suggestion to focus research more tightly on the three main food crops and on coffee is not an argument for cutting funding on other lines of research. As the success of white potato research in Rwanda shows, research on crops that are nationally of minor importance can have high returns and contribute significantly to food security (Amani and Haverkort 1986; Haverkort 1986a, 1986b; Blanken, von Braun, and de Haen 1994; Monares 1984, 1987). In a predominantly agricultural country with poor prospects for non-agricultural exports to pay for massive food imports, investments in the generation and dissemination of agricultural innovations should probably be much larger and the research agenda should even in the future include more than just the 3-4 main crops. Nevertheless, the risk for spreading research resources too thinly is real.

In most of Rwanda, the main competitors to the three main crops on the research agenda are probably cereals (maize and sorghum) and cassava.[61] Any of these crops could probably become much more productive and gain ground if concerted efforts were targeted at it.[62] Unfortunately, the expansion of maize and cassava could increase soil

[61] Also white potatoes and wheat compete for the same funds, but they mostly target the high-altitude areas, where none of the three main crops grows well.

[62] The ensuing price reduction obviously would offset part of the increased incentive to grow these crops, but as discussed below, the extensive informal cross-border trade in these crops limits price changes.

losses on the steep hillsides of Rwanda, since neither crop provides much protection against erosion. Although hedgerow intercropping systems, terraces or herbicide-dependent minimum-tillage methods may solve the problem in the future, it is questionable whether any of these will have much impact for many years to come. In the nearby future, bananas will continue to play a central role in soil conservation, while cereals and cassava will remain highly erosive. It should also be noted that cereals and (dried) cassava are more tradable than sweet potatoes and cooking bananas. This suggests that productivity gains in cereals and cassava would tend to have less impact on prices and more impact on cropping patterns than those in sweet potatoes and cooking bananas. Consequently, research on tradable food crops could hurt coffee production, wherease research on non-tradable food crops is more likely to help it.

Another, closely related policy implication of our findings is that *agricultural research and extension should emphasize intercropping*. As summarized above, intercropping, especially with bananas, is widespread, is expanding with population growth, and apparently is making the farming system somewhat more sustainable. Yet, agricultural research in the past has done relatively little to improve intercropping systems and agricultural extension has even discouraged some forms of intercropping. Moreover, when intercropping has been studied, the focus has often been on non-banana associations, none of which have not been adopted as widely as associations with bananas.

Emphasis on intercropping implies focusing on the performance of the system rather than on that of individual components in artificial isolation. This requires more than adjustments to the "downstream" on-farm trials. Breeders, for instance, need to seek varieties that make good components for the associations, rather than individual "star players" intended to replace entire "teams". If farmers typically grow their beans under bananas, the screening trials of beans should happen in similar conditions, so that tolerance to shading and other interactions get included among the the selection criteria.

One important crop association that has almost completely been neglected in research and discouraged in extension, is the intercropping of coffee and bananas. Belgian colonial administrators banned coffee intercropping in Ruanda-Urundi, arguing that coffee does not need shading at high altitudes. However, farmer practices in the highlands of neighboring countries suggest that declines in coffee yields are more than offset by the value of bananas and by the labor savings achieved when mulching materials are produced right next to the coffee bushes. Farmers clearly are convinced that coffee and bananas perform better in combination than on separate fields. Both in Kagera in Tanzania, in Kivu in Congo, and in southern Uganda farmers intercrop most of their coffee with bananas, some of it at altitudes comparable to Rwanda. Indeed, to the extent that the policies forcing farmers to monocrop coffee have now come to an end, intercropping may well be already returning and, depending on prices, may in the long term be the only form of coffee production attractive to farmers.[63] Thus, research on and extension of coffee-banana intercropping may be crucially important for Rwanda's export earnings.[64] Or, if the government of Rwanda is to rehabilitate coffee production in one way or another, intercropping may be an option that provides the needed export earnings at lower opportunity costs than forced monocropping of coffee.

[63] In early 1994, we observed how farmers in Butare and Byumba were starting to intercrop food crops with coffee. We did not see any bananas planted between coffee trees, but this may reflect mostly the fear of farmers that the ban on intercropping might soon be reintroduced and the bananas planted between coffee trees destroyed.

[64] Given that (1) coffee trees suffers greatly from excessive shading but can actually benefit from a modest degree of shading, and that (2) the amount of work needed to transfer mulching materials from banana groves to coffee fields depends largely on distance, an option that appears worth exploring is a compromise in which bananas and coffee are not fully mixed but spaced in alleys.

9.3.2 Soil Conservation

Our results suggest that *enhancing the contribution of bananas for soil conservation deserves high priority in Rwanda's soil conservation policy.* Although the shortcomings of the old engineering-based soil conservation approach as well as the key role of bananas in protecting Rwandan soils are widely acknowledged in literature and although several researchers have advocated greater reliance on vegetative measures, there has been surprisingly little interest in how the environmental contributions of bananas could be increased. In part, bananas may have been neglected because of the incorrect assumption that they would (or, in the case of beer bananas, should) inevitably lose ground under demographic pressure. Another reason may simply be the failure to realize that although the traditional dense banana groves conserve soils well, the mulch produced by bananas often contributes little to erosion control on intercropped banana groves.

This study has noted many developments that argue for focussing on bananas in soil conservation. First, the old approach that relied on ditches, grass lines, and hedges leading to the formation of "progressive terraces" was unpopular, ineffective on steeper slopes, and largely ended in the early 1990s as the government lost its ability to enforce it. Second, bananas in general and intercropped bananas in particular are gaining ground under demographic pressure. Third, cultivation is expanding on steep slopes, where perennial crops may be the only way of protecting the soils. Fourth, declining land fertility rather than erosion is the main soil conservation issue in Rwanda, and bananas can alleviate both problems. This is in great contrast to the engineering solutions that at best do little to maintain fertility and at worst make the problem worse.

In principle, the contribution of bananas for soil conservation can be increased in three different ways. First, the expansion of bananas can be promoted by research and extension as discussed above, or by favorable prices as discussed in the next section.

Second, better use could be made of the mulch produced by bananas, especially in the intercropped banana groves. Although research on this has been minimal and only preliminary results (from Burundi) are at hand, it appears that relatively small changes in banana management practices could greatly reduce soil erosion in intercropped banana groves (Rishirumuhirwa 1992; 1993). The proposed changes may not be ready for nationwide extension, but they are sufficiently promising to warrant further research efforts.

Third, banana production can be targeted at areas where the good vegetative cover it provides is most valuable. This has implications for priority setting in research, extension, and rural infrastructure. Improved banana varieties would contribute most to soil conservation if they were targeted at the erosion-prone hillsides, where soils are often degraded and acidic and temperatures often too low for current banana varieties to do well. Soil conservation is an argument for focusing banana research and extension on the production constraints that prevail on the hills. The same argument suggests that cereal and root crop research should focus on the constraints that matter most in the valleys and flatter fields.

Naturally, soil conservation is only one argument among many others. Since cooking bananas are more demanding than beer bananas and since Rwanda's prime cooking banana areas (Kibungo) are relatively flat and not very vulnerable to erosion, there may be a trade-off between soil conservation and food production objectives. Banana research that targets erosion-prone hills, for instance by screening for edible banana varieties that are less demanding or more tolerant to acidity, may not be the best strategy to boost banana production, but it may be the most cost-effective method of conserving soils on steep hillsides.[65]

[65] Comparable tradeoffs may also exist for other crops. For instance, preliminary results suggest that researchers could break through the altitude (and temperature) barriers that

The suggestion to make a better use of bananas in soil conservation efforts can be seen as a component of a broader approach of basing soil conservation more on vegetative cover and less on labor-intensive structures. Under a variety of names this approach is being studied and extended in many parts of the world (Fujisaka and Garrity 1988, 1989; Garrity 1989; Getahun 1991; König 1992a, 1992b; Nair 1989b, 1989c; Shepherd et al. 1996; Osiname and Tonye 1996; Palmer 1992; Paningbatan 1994; Roose et al. 1988; Roose et al. 1992; Stark 1996; Tacio 1993; Young 1989, 1995). While the economic viability of alley cropping and other forms of agroforestry may often be questionable on level land, the potential of vegetative soil conservation measures on sloping lands is considerable (Young 1989; Garrity 1989; Hoekstra 1994; Kessler and Wiersum 1995; Jabbar, Larbi, and Reynolds 1994). And on steep slopes, perennial crops or multi-storey "home gardens" rather than annual crops accompanied by vegetative barriers are increasingly seen as the best option (Young 1995).

The principal alternative for soil conservation based on bananas and other perennials is a return to the engineering approach, probably with a strong focus on proper ("radical") terraces. In the early 1990s, Rwanda's National Agricultural Commission saw terraces, along with fertilizer subsidies, as the key to soil conservation and higher agricultural productivity (CNA 1992a).

In contrast to intercropped bananas that have expanded spontaneously on hundreds of thousands of farms, no Rwandan farmers have voluntarily adopted radical terraces, which require large inputs of labor to build and maintain (Nduwayezu 1990). Except perhaps for the volcanic highlands where bananas do not grow and where potatoes

now constraining cassava production on the mountains of Rwanda (Mulindangabo and Rollin1989). The immediate gains for food security could be significant, since many of the high-altitude areas are degraded watersheds where other crops perform very poorly and where many households are extremely poor. However, given that cassava provides much poorer vegetative cover than sweet potato, the gains might not be sustainable.

are a lucrative cash crop, it is highly questionable whether radical terraces could spread significantly without massive subsidies or strong coercion.

9.3.3 Tax and Trade Policy

A second set of policy implications arises from the findings that Rwandan smallholders, especially those with least land per person, are highly dependent on food purchases financed by the sales of labor, banana beer, and coffee. These food security strategies are contingent on certain relative prices, and adverse changes in the policies that affect those prices would undermine the access of some food insecure households to food. On the other hand, appropriate policy changes informed by these strategies could be of considerable help to the poor.

The most straightforward implication concerns the direct and indirect taxes on industrially produced beer. Although the primary justifications for high beer taxes in developing countries are typically fiscal and administrative, in Rwanda their distributional and allocative impacts have much merit compared to most other sources of public finance. Beer taxes are paid by the relatively affluent drinkers of industrial beer, but by increasing the demand for and the prices of traditional beers, they also transfer incomes from the (mostly urban) drinkers of traditional beer to the (mostly rural) brewers, banana growers, and their employees, thereby improving the food access of the poorest rural households.[66] They subsidize environmentally benign forms of land use and discourage the use of alcohol.[67]

[66] Note that our results are specific to Rwanda's banana zone, where most traditional beer is made out of bananas that are a lucrative cash crop for most rural households, including the poor. The distributional impacts of taxes on industrial beer are less equitable in places where traditional beers are made mostly out of cereals and where the poor are net buyers of cereals. Thus, the conclusions are likely to hold also for much of Burundi and for the neighboring mid-altitude regions in Tanzania, Congo, and Uganda, but not to areas that are either too cool (high altitudes) or too dry for bananas.

[67] It is not clear, however, whether taxes on industrially produced beer promote public health. Traditional beers sometimes include alarming quantities of hazardous substances. The advocates of development assistance for the construction of public

On the other hand, high taxes on industrially produced beer discourage coffee production by making beer bananas a more profitable crop. High beer banana prices have been an unintended consequence of fiscally motivated taxation of industrial beer. The heavy-handed promotion of coffee in Rwanda during the past decades can be seen in part as a way of offsetting this disincentive. As Rwandan policymakers seek to liberalize agricultural policies, they are likely to pay more attention to economic incentives and question the indirect subsidies of beer bananas created by high beer taxes.

However, lower taxes on industrially produced beer or new taxes on banana beer would be not just a distributionally and environmentally questionable policy change but also a rather blunt tool to promote coffee. At the relative prices that prevailed in 1990 as well as at those that prevailed in 1998, many other crops besides bananas appeared to provide higher returns to land and labor than were available in coffee production.

No similar case exists for the taxation of most other industrially produced or imported goods. Sugar and vegetable oil, for instance, rather than competing with environmentally benign crops sold by most poor farmers are themselves products that most poor households buy. Taxes on gasoline and vehicles are also partly paid by the rural poor, since they increase marketing margins, thereby reducing the prices farmers receive for their products and increasing those they pay for the non-local products they buy. Border taxes in general change the terms of trade against export producers, which suggests that many of the poor coffee growers are adversely affected. All these taxes may be justified on fiscal grounds, but beer taxes are unique in that the majority of the rural poor who are net sellers of banana beer gain from them. It is true, though, that the biggest gainers from the higher banana beer prices brought about by taxes on industrially

breweries in Africa and elsewhere have often depicted traditional brewing as a public health hazard, but this may be exaggerated (Kortteinen 1989a, 1989b). Nevertheless, the health benefits of lower total alcohol consumption brought about by high beer taxes are partially offset by the shift in consumption from industrial brews to traditional ones with more variable quality.

produced beer are relatively affluent rural households with large farms that are suitable for bananas and well connected to wider markets.

Being net buyers of beans, cereals, and cassava flour, the poorest segments of rural Rwanda depended in the early 1990s crucially on trade policies. Since the cross-border food imports were largely informal, trade policies influenced prices not so much through the formal tariff rates but through the decisions that allowed the borders to be relatively porous so that the traders could import food from the neighboring countries, primarily Congo. During the 1990s, eastern Congo may have lost much of its ability to produce surpluses for export, but at the same time maize and cassava production in southern Uganda has increased dramatically. *Open borders to the imports of basic staples and to the exports of the goods that pay for them contribute significantly to food security in rural Rwanda, and also promote environmentally sustainable land uses on the steep hillsides by lowering the prices of erosive crops (cereals and cassava).*

As discussed above, fertilizer subsidies would probably trigger environmentally unfavorable land use changes, since highly erosive crops, such as maize, happen to be more responsive to fertilizer than less responsive crops, such as bananas and sweet potato. This is not to say that chemical fertilizer is environmentally harmful in Rwanda. On the contrary, chemical fertilizer can increase vegetative cover on impoverished hillsides and thereby reduce erosion. The success of introducing agroforestry on degraded lands may depend on access to fertilizer.[68] Moreover, yield increases brought about by fertilizer may reduce the pressure to bring new land under cultivation. Nevertheless, the

[68] More precisely, the payoffs to trees and cover crops should increase with improved access to or reduced price of nutrients other than nitrogen. With respect to nitrogen, the picture is more complex, since if the trees and cover crops are leguminous and if the ability to fix nitrogen plays an important role in their benefits, payoffs to agroforestry could actually decline with improved access to (reduced price of) nitrogen fertilizer (Akyeampong and Hitimana 1996).

prospect of adverse environmental impacts through unfavorable land use changes weakens the case for fertilizer subsidies.

9.3.4 Infrastructure

The findings of this study on farm-level land use patterns support the argument that could be made a priori based on economic reasoning and information on rural and urban consumption patterns: *In Rwanda, investments in rural infrastructure can promote environmentally sustainable agricultural intensification.*

The key to this conclusion is the association of banana production with roads. Given the bulkyness of bananas and the perishability of banana beer as well as the role of bananas as the main cash crop, it is not surprising that farmers with good access to roads and hence to urban markets are more likely to produce bananas for sale and rely more on markets for beans and cereals that would give lower returns to their scarce land. This specialization increases farmers' incomes and reduces erosion on their sloping lands.

Investments in rural roads and bridges would not merely allocate banana fields from previously connected but more distant areas to the newly connected areas. Also food consumption patterns would change. Urban diets in Rwanda are now strikingly different from rural ones. Urban consumers eat much less sweet potatoes and bananas than their rural counterparts, and much more cereals and white potatoes. Even controlling for income, a large gap exists, presumably because bananas and sweet potatoes are more expensive relative to cereals and white potatoes in urban areas than in the rural areas. This, in turn, depends largely on costly transportation, which is reflected in wide marketing (gross) margins (Tardif-Douglin 1991). Investments in rural roads would reduce the prices of the rural staples in urban areas, but would have little impact on the prices of beans and cereals that are imported from abroad. As a result, there would be some substitution of locally produced sweet potatoes and bananas for imported cereals in urban areas, and small shifts from the bulky staples to cereals and beans in rural areas. Since sweet potatoes and bananas have much higher yields than cereals and beans, the reallocation of land from the latter to the former would increase total food production and reduce food imports.

Since Rwanda already has good paved roads connecting prefectural capitals to Kigali, the highest priority is likely to lie in feeder roads. By neglecting feeder roads while investing heavily in highways, policymakers in Rwanda and in donor agencies have favored food imports (via the good paved roads from Congo and Uganda) as well as market-oriented food production in relatively distant areas along the paved highways (bananas in the southwestern part of the country (Kibungo) and white potatoes in northwestern Rwanda).

9.3.5 Off-Farm Employment

Literature on rural Rwanda has repeatedly emphasized the need to promote off-farm employment, not just to provide additional income but also to encourage farmers to invest, commercialize and take risks in their agricultural activities (Ezemenari, 1993). Our findings confirm that for the households with smallest farms and/or most impoverished fields, labor sales play a crucial role in helping them to bridge the gap between what they produce and what they need to survive. Unfortunately, the poorest sell mostly agricultural labor, and as farms get smaller with populationg growth, the demand for it is declining. Finding ways to reverse that trend and/or to increase the demand for unskilled labor outside agriculture is vital for the welfare of the rural poor.

Most of the discussion on how various policies and programs can best create non-farm jobs is beyond our scope. Here we only focus on four issues suggested by our results.

First, *the viability of banana-based processing activities in rural Rwanda should be assessed.* The processing of bananas and banana byproducts in Rwanda is almost exclusively limited to brewing. The other small-scale processing activities that are widespread in parts of Asia and also used in Africa, are almost non-existent in Rwanda. Bananas are seldom dried into flakes or chips or pounded into flower, although drying could greatly improve storability and transportability. Yet, survey results suggest that at least in Eastern Rwanda, surplus cooking bananas are sold at very low prices, and sometimes even thrown away or fed to livestock. As Rwanda's urban population grows, the potential for processing activities that improve storability and transportability is clearly improving. Although it may be premature to advocate the promotion of processing activities, the opportunities appear worth exploring.

It might also be possible to reduce the use of scarce resources for banana beer by improving the transformation process (Haggblade and Minot 1987). If combined with taxes on banana beer, such an intervention, if successful, could improve the performance of the sub-sector without increasing beer consumption.

Second, the dependence of the poorest quartile of rural households on the sales of unskilled labor together with the disappearence of employment opportunities outside the main agricultural seasons suggests a useful role for *labor-intensive public works during the summer months.* At sufficiently low wages such works can be self-targeting and cost-effective means of improving food security among the working poor (Braun, Teklu, and Webb 1991). They cannot, however, target assistance to those who cannot work.

If properly planned and implemented, public works are not only social safety nets but also productive investments. The list of possible activities range from the construction of roads and fish ponds to soil conservation and tree-planting (Engle, Brewster, and Hitayezu 1993). A particularly interesting target for the public works consists of various investments in water control. In addition to employment during construction, such investments could permanently increase the demand for labor during the season when additional employment is most needed. Large-scale irrigation schemes in Rwanda and elsewhere in Africa have been expensive and performed poorly, but the experiences from smaller schemes are often encouraging. Public works that use manual labor and simple tools rather than heavy machinery to level land and to build dams, canals and reservoirs are worth studying.

Third, *the government of Rwanda should avoid high and rigid agricultural minimum wages*. Outside the busy seasons, Rwanda's rural minimum wage was in 1990 far above the opportunity cost of most people's time and also above the value of the work for the employer. Although not universally enforced, minimum wage appears to have had some impact, often limiting rural employment to those activities and periods where labor productivity exceeded the minimum wage. This slowed down labor-based intensification, which typically involvs low-return investment activities during periods when the opportunity cost of labor is low.

As population growth reduces the average farm size, an increasing share of the more productive work will be done by owner-operators, leaving less for the laborers. If intensification activities combine labor inputs and (other) cash outlays, they may appeal neither to the poor households who face a credit constraint nor to their wealthier neighbors who face an artificially high price of labor. More generally, a minimum wage and the limits it implies on what is worth doing send a fundamentally wrong signal in a situation where the combination of demographic pressure, environmental degradation, and technical stagnation means that only harder work can prevent food consumption levels from falling.

Undoubtedly some employees were earning higher *daily* wages because of the minimum wage laws, but their *total* earnings may have been lower. Full-time year-round employment at minimum wage is a rare anomaly in Rwandan agriculture; instead of having regular jobs, farm laborers get temporary assignments that often take only days and seldom more than weeks. Thus, during less productive periods employers can flexibly cut days worked if the law prevents them from cutting wages. It follows that lower agricultural minimum wages, at least outside the busy months, would probably increase employment, encourage intensification and promote food security in rural Rwanda.

Fourth, *more investment in the development of skills should be considered.* Wage premiums for skills are high in rural Rwanda. Much of the premium is due to the relatively high salaries paid to teachers, soldiers, and other civil servants, but also rural households themselves pay often high wages for employees with specific skills. Masons and carpenters, for example, typically earn two to four times as much as unskilled laborers. The high private returns to formal education and on-the-job training implied by the wage differentials also suggest that social returns are high. The creation of rural non-farm employment depends crucially on the viability of enterprises that combine the efforts of skilled and unskilled employees and the high skill premiums suggest that in Rwanda the availability of skilled employees is a serious constraint.

9.4 Suggestions for Future Research

Our discussion above on policy implications already covered the implications for agricultural research and extension, emphasizing the great social value that technical progress on the three major crops would have and arguing that also the case for coffee research may be strong, especially if substantial technical progress in food crops releases resources from the production of bananas, sweet potatoes, and beans. The suggestions in this section focus on policy-relevant socioeconomic research. In other words, we ask what are the researchable knowledge gaps that should be filled in order to inform policies related to agricultural intensification in Rwanda. Some of these gaps have been mentioned above as limitations and caveats of the results of the present study, while others stem from anecdotal evidence encountered in the field, from major changes that have taken place since the data used in this study was collected, or from unsuccessful attempts to use existing data to illuminate important issues.

Timely information on production and prices. This study has repeatedly highlighted the dependence of rural households on the exchange of labor, banana beer, and coffee for food. This implies that the ability of households to command food depends not just on their food production but also on the prices they face. An illustrative case is the one we observed in early 1994 in southern Rwanda, where the influx of refugees from Burundi had reduced rural unskilled wages at the same time as a drought had increased bean prices. Neither trend alone looked particularly alarming, but their combined impact was that the amount of beans food deficit households could get in exchange of their labor had declined to less than half the normal level. This shows that efforts to alert policymakers to dangerous declines in household food entitlements must include timely collection, processing, analysis and dissemination of data on production, prices, and wages. Although the focus on timeliness that is vital for early warning monitoring is rare in nationally representative farm surveys, combining the two efforts could have significant benefits, not least because timely data processing can improve quality in data collection.

Cooking bananas versus beer bananas. A major question raised by this study is whether pest problems are forcing Rwandan farmers to replace their cooking bananas by beer bananas. Pests have devastated many cooking banana-based communities in Kagera, Tanzania, on the other side of Rwanda's eastern border, but we have not found evidence of any major transition from cooking bananas to beer bananas in Rwanda. Perhaps the best guess is that whatever shifts to beer bananas may have taken place in some areas have been offset at the national level by the expansion of cultivation in Eastern Rwanda, where cooking bananas grow well. As these relatively recently established cooking banana groves are maturing, the pest problems are probably increasing, but just how severe the problem is and whether it is forcing farmers to replace their cooking bananas by beer bananas or other crops is not clear. One constraint for analysis is that the land use statistics used in this study do not differentiate between cooking bananas and beer bananas. Given the key role of bananas in Rwanda, especially in the eastern parts of the country, improved understanding of the magnitude and the nature of the banana pest problems in Rwanda is needed. This calls for collaboration between social scientists engaged in nationally representative surveys and agricultural scientists working on the pest problems in Rwanda.

A related issue concerns the direct use of beer bananas for food. As discussed above, anecdotal evidence suggests that, in some parts of Rwanda, beer bananas have become an accepted part of the regular diet. In part, this may be a reaction to extreme poverty, but is this the whole story? Are there other explanations such as innovations in preparation? Are there policy interventions that could promote the use of beer bananas as food. Given that beer bananas are considerably cheaper than cooking bananas and, if considered edible, would provide cheaper calories than any other staple and more food per unit of land than any other food crop, the answers to these questions might have significant implications for food security. A case study on "the emerging custom of eating rather than drinking beer bananas" is clearly warranted.

Rural income patterns. Numerous externally funded projects are seeking to alleviate poverty in post-genocide Rwanda, and some of these have been designed with an explicit assumption that efforts to target projects at poorest areas or at the poorest households are not warranted, because rural poverty is rather universal. The income and food availability computations used in this study as well cast considerable doubt on this assumption as do many earlier studies (McAllister 1994). While most rural Rwandans admittedly are poor by the standards of most outsiders, households with small farms, poor soils, many dependents and little access to off-farm incomes are far more likely to suffer from deprivation than others. In 1990, most households on the degraded hills in the prefectures of Gikongoro and Kibuye were much more food insecure than most households in the prefecture of Kibungo. While the main patterns are likely to hold still, much has changed during and after the genocide and new work on rural income distribution and income patterns is warranted. Given the great complexity and cost involved in collecting data on household income, it might be advisable to develop "relatively quick and relatively clean" methods that are sufficiently inexpensive so that their use for the targeting of poverty alleviation efforts is feasible.

Impact of AIDS on agriculture. Population growth, increasing land scarcity, declining farm size, and the increasing need to substitute labor for land were the starting points of this study. While the expansion of AIDS in rural Rwanda is likely to somewhat slow down rural population growth, it is not expected to stop it. AIDS is, however, creating an increasing number of very poor households with both scarce land and inadequate supply of labor (Hunter, Bulirwa and Kisseka 1993). Gillespie (1989) suggests that in Rwanda increased mortality due to AIDS "might provoke a gradual shift in cropping patterns away from relatively labor-intensive legumes, to tubers such as potato, cassava and sweet potato" and is concerned about the ensuing declines in soil fertility. Thus, land *and* labor poor households are of special interest not only from the point of view of food security and the ineffectiveness of labor-intensive public works in alleviating this kind of poverty, but also matter from the point of view of environmental sustainability and land use. Given that AIDS, which in pre-genocide Rwanda was still largely an urban phenomenon has now greatly spread in rural areas, a special research focus on the affected households may be warranted.

Labor markets and labor use in agriculture. Although most Rwandans are still predominantly farmers, many rural households earn a significant share of their income from off-farm employment. In pre-genocide Rwanda, skilled employment was a major source of income for a small minority of households and the sales of unskilled labor helped many of the most land-scarce households to achieve food security. Since 1994, the situation has changed greatly. Two key policies in the current (1998) situation are severe restrictions on labor mobility and major investments in food-for-work projects. The restrictions on mobility probably hurt greatly the food security of some poor households, whereas the food-for-work projects are blamed for drawing labor from agriculture. Improved understanding of how the rural labor market functions, what are the impacts of the mobility restrictions and the employment projects, and what are the seasonal patterns of labor use in agriculture could help in designing better interventions.

Intrahousehold allocation of beer income. Although we have documented that banana beer sales are a major component of household cash incomes and that the most food insecure households spend a large share of their cash income on food, it is not clear who inside the household controls beer income, whether it is spent differently from other types of income, and how the goods and services paid for by beer income are distributed among household members. The suspicion of many is that beer income is largely controlled by men and spent on beer and other non-necessities, and therefore contributes less to household food security and children's well-being than other types of income. The assumption that incomes controlled by men tend to be less well spent than incomes controlled by women has been supported by many studies and may now be considered to be a "stylized fact" (Braun and Kennedy 1994). In contrast, the assumption that men control banana beer incomes is more questionable. The knowledge gap lies in who controls which incomes inside Rwandan households. Literature provides some guidance, suggesting that women often brew and sell beer, that they probably have more control over beer income than over coffee income, and that men generally control cash incomes much more than the imputed incomes from subsistence food crops (Bucyedusenge et al. 1990; Miklavcic 1995; Martin 1987). While somewhat helpful, this does not tell whether beer brewing mostly tranfers incomes from male beer drinkers to female beer makers or whether it more often moves resources from the female-controlled subsistence domain to the male-controlled exchange economy where children's food security gets less emphasis. Since the food security implications of policy decisions such as whether to impose taxes on banana beer sales depend on the answers, efforts to examine these issues further may be justified. Moreover, DSA might want to take another look at the consumption of banana beer. Given that consumers typically report only a fraction of their beer purchases and that also the DSA data set used in this study clearly understates rural consumption, it might be advisable to study beer transactions also from another angle by surveying traders and the keepers of rural bars.

The role of trees in agricultural intensification. Although this study has focused on changing land use, it has paid little attention to trees that increasingly are not grown on separate woodlots but on the boundaries of fields or on contour hedges and hence do not get normally accounted for in land use statistics.[69] Yet, numerous studies argue that increased planting of trees is one of the most dynamic features of the ongoing labor-based intensification in densely inhabited areas such as Rwanda, and is crucial for environmental sustainability and household food security (den Biggelaar 1994; Gahamanyi 1989; Nair 1989a, 1989b, 1989c; Shepherd 1996; Tacio 1993; Arnold 1995; Young 1989; Chambers and Leach 1989; Egli 1985). Most socioeconomic and farm

[69] DSA's Agroforestry Survey did collect information on trees but the data had many problems that greatly reduced their usefulness.

management research on agroforestry consists of case studies. Few attempts to use representative national farm household data to understand the role and the constraints of trees in agricultural intensification exist. As the capacity for collecting and analysing farm survey data is rebuilt in post-genocide Rwanda, it is probably advisable to pay more attention to trees.

Paths of intensification. Several students of Rwanda's rural economy have argued that interactions between crop choice, livestock, input use and soil conservation decisions play key roles in agricultural intensification. According to one argument, households may not be interested in investing in anti-erosion hedges or grass lines unless they have livestock that can convert grass and leaves into valuable animal products. Similarly, the profitability of input use may depend on soil conservation investments. Understanding such interactions is crucial for finding most effective interventions. For instance, if livestock really is a key to making hedges and grass lines pay, improved veterinary services might be a cost-effective way of promoting soil conservation.

Despite the strong intuitive appeal of these arguments, attempts to study such interactions with DSA's cross-sectional data set have not been very successful. As discussed above, Rwanda's strictly enforced agricultural policies provide a partial explanation. If, for instance, households are forced to plant hedges and grass lines whether or not they have animals, the observed link between livestock and soil conservation may be weak or non-existent. Another explanation can be soil quality, which obviously greatly affects land use, soil conservation, and input use, but is poorly controlled for in DSA's cross-sectional data set.

The question to ask is whether a different research approach would allow DSA to look at these interactions and the resulting intensification paths. Perhaps a detailed look at the case histories of a sample of households could cast light on the interactions. Or perhaps participatory group discussions with farmers could be useful.

Emerging success stories. While DSA's nationwide sample survey is an excellent tool for studying the state of Rwanda's rural economy and major ongoing changes such as the increasing reliance on banana intercropping examined in this study, it cannot tell much about new innovations and emerging trends that touch only few respondents in the sample. Yet, where the farming system is technically quite stagnant, policymakers are interested in and deserve to be informed about the exceptional cases where technical progress and/or investments are taking place. Apart from the well-documented success in white potatoes, some Rwandan farmers have interesting experiences with climbing beans, mixed farming, agroforestry, horticultural crops, and the development of valley bottoms. Understanding the ingredients of these limited successes and examining the preconditions for wider adoption requires that DSA's work on national surveys is supplemented by case studies of the emerging (or potential) success stories. Again, collaboration between social scientists and agricultural scientists is needed to identify the cases that are worth studying in detail.

Processing of sweet potato and banana into dried products. Two of Rwanda's three main food crops are bulky and perishable. As discussed above, processing them into more storable and transportable dried products is not common, presumably because it has not been of much interest in the past, when sweet potatoes and bananas played a smaller role in food supply and when most consumers were rural. With urbanization, the potential contribution of processing is increasing. The potential for processing is probably greatest in areas where current or potential production exceeds local demand and where prices are considerably below national levels, because costly transportation isolates the location from national markets. Promising opportunities may also exist in areas where production and prices have unusually large seasonal variation. Where are these areas and what is the magnitude of the gaps that processing could bridge? While expertise in processing is needed to evaluate and introduce innovations and investments to respond to the opportunities, national farm survey data may be useful in understanding the nature and size of the opportunities. Policies on processing could also be informed with demand-side research, including studies on the potential demand for processed products in urban areas (Boughton, Reardon, and Wooldridge 1997; Kennedy and Reardon 1994).

Liberalization of agricultural policy. The liberalization of Rwanda's coercive agricultural policy started before the genocide and presumably has continued thereafter. Relatively little is known on how farmer behavior has changed as a result. Information on the extent to which farmers have stopped mulching their coffee, are intercropping coffee with other crops or are even abandoning coffee would be relevant for the design of coffee policy. If, for instance, farmers were found to be widely abandoning coffee in some areas but not in others and if this was shown to be a voluntary response and not a reflection of differences in the extent to which coercive coffee policies continue, implications for where efforts to promote policy are likely to yield best results would be clear. Similarly, the extent to which farmers still invest in soil conservation, maintain the terraces they were once forced to build, or tear down the structures for short-term gains is not known and has major implications for policy. The higher the degree to which the old engineering approach to soil conservation has been abandoned by farmers, the more there is need to develop and promote new measures such as the planting of perennial crops on steep slopes.

Land tenure and land markets. During the field work in 1994 we repeatedly heard about land transactions, both sales and rentals. Some observers were convinced that land sales were putting (or would put) land into the hands of more effective operators and should therefore be encouraged, while others assumed, based on anecdotal evidence or literature on what had happened elsewhere (Hill 1986), that most land transactions were distress sales by the poorest rural households and were creating a class of rural landless workers. DSA's 1990 data set has some information on land tenure, but major changes have taken place since 1994 and substantial concerns exist on whether farmers now have sufficient security of tenure to invest in their land. Given that such investments are important both for household food security (bananas), export earnings (coffee) and environmental sustainability (soil conservation), improved understanding of the situation is needed to guide policy. Initial focus of data collection should probably be in examining how insecure tenure is constraining investments.[70] In the long term, efforts probably should be targeted at understanding land transactions. Policy implications obviously differ considerably depending on whether land sales are predominantly made by those with better non-farm opportunities and declining interest in farming, or by the poorest households that sell to survive when crops fail or to pay for taxes, school fees, or medicines.

[70] Farmer perceptions of the situation are crucial since lack of security may even encourage land-based investments if farmers believe that investments strengthen their claim on the land they operate. Consequently, policy details matter greatly and research to inform policies can have high payoffs.

APPENDIX A

REGIONAL PATTERNS OF RURAL EXPORTS

To disaggregate the national patterns of the net sales and gifts (rural exports) presented in Chapter 6, the regional patterns are presented in the next three tables. Three regional classifications are used. The patterns for the five geographic regions are shown in Table A-1, those for the five agroclimatic zones are shown in Table A-2, and those for Rwanda's ten rural prefectures in Table A-3. Note that the numbers of observations in some of the areas in the last two tables are quite small.[71]

[71] More precisely, the number of clusters (secteurs) from which the interviewed households were selected was small in these categories.

Table A-1: Net Household Sales and Gifts by Geographic Region

Mill. of units	North-West	South-West	Center-North	Center-South	East	Rwanda
Beans	-13	-10	-26	-10	-2	-61
Peas	-1	-0	-0	-0	-0	-2
Peanuts	-0	-0	-0	-0	0	-0
Soybeans	-0	-0	-0	0	-0	-0
Sorghum	-9	-9	-10	-6	7	-27
Maize	-2	-0	-1	-0	0	-3
Wheat	-0	0	1	-0	-0	1
Finger Millet	0	0	0	-0	0	0
Rice	-0	-1	-1	-0	1	-1
Cassava	-7	-15	-12	-2	13	-23
White Potato	58	-1	-16	-5	-6	31
Sweet Potato	-3	-3	13	7	4	18
Taro	-0	-1	0	1	-1	-1
Cocoyam	0	-0	-0	-0	-0	-0
Cooking Banana	-0	3	0	0	29	32
Beer Banana	-11	-8	1	2	16	-1
Fruit Banana	-0	0	0	2	3	5
Coffee	7	6	9	5	12	39
Banana Beer	28	16	40	38	94	216
Sorghum Beer	11	11	15	12	11	61
Ag. Labor	0	2	-2	-1	-10	-11
Non-Ag. Unsk. L.	2	3	1	1	-1	7
Skilled Labor	5	3	16	3	10	36

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer (litres) and labor (mandays).

Table A-1 and Table A-2 confirm that the relatively sparsely inhabited eastern lowlands, that are more drought-prone and were traditionally considered less productive, are now Rwanda's food basket. They produce surpluses in most crops, exporting not only banana beer and cooking bananas, but also cassava and sorghum. As Table A-3 shows, most of the surpluses come from the prefecture of Kibungo. Unlike any other prefecture, Kibungo even manages to be self-sufficient in beans. Farmers in eastern Rwanda are net buyers of labor, providing employment to temporary migrants. Nevertheless, the numbers are small, showing that even in the East most households operate family farms and hire workers only to supplement family labor.

Table A-2: Net Household Sales and Gifts by Agroclimatic Zone

Mill. of units	Agroclimatic Zone				
	East	High Plateau	Congo-Nile Divide	Kivu Lakeshore	Volcanic Highlands
Beans	1	-32	-17	-7	-6
Peas	-0	-0	-1	-0	-0
Peanuts	0	-0	-0	-0	-0
Soybeans	0	-0	-0	-0	0
Sorghum	9	-18	-14	-2	-3
Maize	1	1	-1	-2	-1
Wheat	-0	-0	1	0	-0
Finger Millet	0	-0	0	-0	0
Rice	1	-1	-0	-1	-0
Cassava	8	-12	0	-16	-4
White Potato	-7	-16	-5	-9	67
Sweet Potato	3	18	-1	2	-4
Taro	1	-1	-0	-1	0
Cocoyam	-0	-0	-0	0	0
Cooking Banana	27	1	3	2	-0
Beer Banana	17	-5	0	-19	7
Fruit Banana	3	2	1	0	-0
Coffee	11	14	1	12	0
Banana Beer	88	79	22	25	3
Sorghum Beer	8	27	21	-1	6
Ag. Labor	-10	-3	2	-0	1
Non-Ag. Unsk. L.	-1	2	1	3	0
Skilled Labor	9	15	6	3	2

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer (litres) and labor (mandays).

The historic land of a thousand hills in central Rwanda exports banana beer, coffee and some sorghum beer and sweet potatoes, and imports beans and sorghum, along with some cassava and white potatoes. Center-South is considerably poorer than Center-North, and although farmers there produce less beans and sorghum than their colleagues in Center-North, they also import much less.

Farmers cultivating the watershed lands of the Congo-Nile Divide buy large quantities of beans and cereals although their earnings from selling beer are low. None of

Table A-3: Net Household Sales and Gifts by Prefecture

Mill. of units	BUT	BYU	CYA	GIK	GIS	GIT	KGO	KBY	KIG	RUH
Beans	-6	-10	-4	-6	-9	-6	2	-3	-8	-11
Peas	0	-0	-0	0	-0	-0	-0	-0	-0	-1
Peanuts	-0	-0	-0	-0	-0	-0	0	0	0	-0
Soybeans	-0	-0	-0	0	-0	0	-0	-0	-0	-0
Sorghum	-5	-5	-1	-7	-4	-1	3	-5	1	-3
Maize	-0	-0	-1	-0	-2	-0	0	1	0	-1
Wheat	0	0	-0	0	0	-0	0	0	-0	0
Finger Millet	-0	0	0	-0	0	0	0	0	-0	0
Rice	1	-0	-0	-0	-0	-0	-0	-0	-1	-0
Cassava	-1	3	-13	-2	-4	-6	5	-0	-2	-2
White Potato	-3	-3	-0	-0	13	-5	-1	-0	-9	39
Sweet Potato	2	2	-0	-1	3	6	2	-2	-1	6
Taro	-2	0	-1	-0	-0	1	0	0	0	0
Cocoyam	0	0	-0	-0	0	-0	-0	0	-0	0
Cooking Banana	-0	2	3	0	0	-1	25	0	1	1
Beer Banana	-1	-0	-2	-6	-17	5	12	-1	4	5
Fruit Banana	1	1	0	-0	-0	1	1	0	1	-0
Coffee	3	2	5	1	8	7	5	0	7	0
Banana Beer	27	20	9	8	27	28	41	5	38	15
Sorghum Beer	14	17	-0	12	2	1	5	6	1	4
Ag. Labor	-1	1	1	2	1	-3	-6	-0	-3	-3
Non-Ag. Unsk. L.	0	0	3	1	2	1	-2	0	1	-0
Skilled Labor	1	4	1	2	4	4	5	1	8	6

Source:DSA/MINAGRI, Agricultural Survey 1990; 1184 households
Units are kilograms, except for beer (litres) and labor (mandays).
BUT=Butare, BYU=Byumba, CYA=Cyangugu, GIK=Gikongoro, GIS=Gisenyi,
GIT=Gitarama, KGO=Kibungo, KBY=Kibuye, KIG=Kigali, RUH=Ruhengeri

these crops grow well on the marginal lands, and farmers are forced to use most of their cash to buy staple foods, even if that leaves very little for everything else.

Western Rwanda imports large quantities of beans, sorghum, and cassava. Table A-3 shows that the southwestern prefecture of Cyangugu is particularly dependent on cassava imports, presumably from Congo.

The fertile volcanic highlands of the Northwest send very large quantities of white potatoes to Kigali and to lower-altitude rural areas. In exchange, potato farmers buy small amounts of crops that do not grow well at high altitudes.

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