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AGRICULTURE GLOBAL PRACTICE TECHNICAL ASSISTANCE PAPER

RWANDA

AGRICULTURAL SECTOR RISK ASSESSMENT

Åsa Giertz, Mohinder S. Mudahar, George Gray, Rhoda Rubaiza,
Diana Galperin, and Kilara Suit

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CONTENTS

TABLES

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
ARMT	Agricultural Risk Management Team (of the World Bank)
BBTD	Banana bunchy top disease
BBW	Banana bacterial wilt
BCMV	Bean common mosaic virus
BXW	Banana Xanthomonas wilt
CAADP	Comprehensive Africa Agriculture Development Programme
CBD	Coffee berry disease
CBPP	Contagious bovine pleuropneumonia
CBSV	Cassava brown streak virus
CIP	Crop Intensification Program
CLR	Coffee leaf rust
CMV	Cassava mosaic virus
COMESA	Common Market for Eastern and Southern Africa
CV	Coefficient of variation
DRC	Democratic Republic of Congo
EICV3	Integrated Household Living Conditions Survey 3
FAO	Food and Agriculture Organization (of the UN)
FAOSTAT	FAO Corporate Statistical Database
FMD	Foot and mouth disease
FOB	Free on board
GAPs	Good agricultural practices
GDP	Gross domestic product
G-8	Group of Eight
GoR	Government of Rwanda
ha	hectare
IFPRI	International Food Policy Research Institute

Acronym	Definition
IPCC	International Panel on Climate Change
IPM	Integrated Pest Management
ITCZ	Inter Tropical Convergence Zone
LSD	Lumpy skin disease
LWH	Land Husbandry, Water Harvesting and Hillside Irrigation Project
MCMV	Maize chlorotic mottle virus
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MLND	Maize lethal necrosis disease
MT	Metric ton
MT/ha	Metric tons per hectare
NAEB	National Agricultural Export Board
NAES	National Agricultural Extension System
NISR	National Institute of Statistics of Rwanda
OIE	World Organisation for Animal Health
PSTA III	Strategic Plan for the Transformation of Agriculture in Rwanda
RAB	Rwanda Agricultural Board
REMA	Rwanda Environment Management Authority
RF	Rwanda franc
SECO	Swiss Secretariat of Economic Affairs
SSA	Sub-Saharan Africa
TLU	Tropical livestock unit
USAID	U.S. Agency for International Development
USD	U.S. dollar
WDI	World Development Indicators
WFP	World Food Programme

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The team would like to extend its appreciation to the Rwanda Ministry of Agriculture and the stakeholders from major agricultural supply chains who participated at various moments during the field work and during the workshops to discuss the findings. Their active participation obliged the team to be realistic and practical.

Funding for this activity was provided by USAID, without which this activity would not have been possible. Supplemental financing was provided by a Multi-Donor Trust Fund (MDTF) supported by the Ministry of Foreign Affairs of the Government of the Netherlands and State Secretariat for Economic Affairs (SECO) of the Government of Switzerland.

EXECUTIVE SUMMARY

BACKGROUND

Rwanda has experienced a remarkable recovery since the civil war, with high growth since the mid-1990s; gross domestic product (GDP) has grown 10 percent per year on average. Agriculture is the dominant sector of the economy, contributing a third of the country's GDP and about half of Rwanda's export earnings. Because about 80 percent of the population lives in rural areas and is engaged in agriculture to some extent, increasing agricultural productivity is key to improving incomes and decreasing poverty. The government of Rwanda (GoR) has therefore made agricultural development a priority and allocated significant resources to improving productivity, expanding the livestock sector, promoting sustainable land management, and developing supply chains and value-added activities. As a result, the sector grew an average 5 percent per year over 2002–12, which is rather high although it fell short of both the government's own objective of 8–9 percent annual growth for the period (revised to 8.5 percent for the next years in the new Strategic Plan for the Transformation of Agriculture in Rwanda, PSTA III) and of the Comprehensive Africa Agriculture Development Programme (CAADP) commitment of 6 percent growth in the agriculture sector.

At the same time, Rwanda's agriculture sector faces a series of challenges. Agricultural land plots are very small (80 percent of land holdings are less than 1 hectare [ha], often divided into three to four plots), and over 70 percent of agricultural land is either on hills or on the side of hills. Agriculture is dominated by small-scale, subsistence farming under traditional agricultural practices and rain-fed agriculture. As a result, average crop yields are low compared with potential yields, and crops are exposed to risks such as weather-related shocks and pest and disease outbreaks. Current agricultural policies are geared to increasing productivity in the sector by achieving scale in agricultural production.

Risks can potentially have significant implications on stakeholders, investments, and development in the agriculture sector. Adverse movements in agricultural commodity and input prices, together with production-related shocks (for example, from weather, pests, and diseases), not only affect farmers and firms active in particular supply chains, but may also put severe strains on a government's resources. Rapid or significant declines in production and/or trade may reduce government tax revenues, affect balance of payments, necessitate compensatory (or recovery) expenditures, and/or otherwise adversely affect a government's fiscal position. The prevalence of "shock-recovery-shock" cycles vastly reduces the ability of many countries to plan for and concentrate on real development issues. The purpose of this report is to assess existing risks to Rwanda's agriculture sector, prioritize them according to their frequency and impacts on the sector, and identify areas of risk management solutions that need deeper specialized attention.

METHODOLOGY

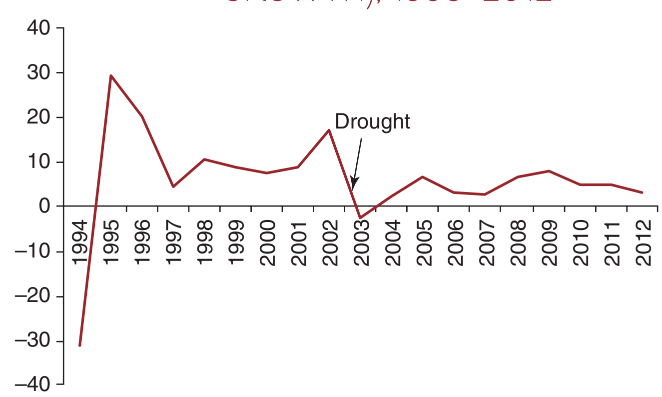
The report takes a quantitative and qualitative approach to risks and analyzes their impacts on those agricultural commodities that jointly make up the top 80 percent of agricultural production value (cassava, maize, Irish potatoes, sweet potatoes, plantain, beans, rice, and milk and beef) plus coffee and tea because of their importance as export crops. Production risks are quantified in terms of losses and then mapped by different perils. Marketing and enabling environment risks are analyzed qualitatively. For the purpose of this assessment, *risk* is defined as the possibility that an event will occur and will potentially have a negative impact on the achievement of a farm's or firm's performance objectives and/or successful functioning of the overall supply chain. In the work previously conducted by the World Bank's Agricultural Risk Management Team (ARMT) in other countries, time periods of at least 30 years are assessed to secure a proper understanding of the risks to the sector. However, because of the very different systems in Rwanda before and after the mid-1990s, as well as the interruptive civil war in 1994, it is difficult to identify distinct trends over longer time series. This assessment therefore focuses on risk to the agriculture sector over the past 20 years.

To estimate production losses, this report quantifies negative deviations from medium- to long-term yield trends that are greater than what can normally be expected in agricultural production. The value of the loss is then estimated in local producer prices. A broad spectrum of stakeholders was consulted throughout this work, including the Rwandan government, farmers, traders, processors, cooperatives, agricultural institutions, and academia. A consultative stakeholder meeting organized by the Ministry of Agriculture and Animal Resources (MINAGRI) was also held in Kigali to obtain feedback on findings and to discuss areas for risk solution interventions for deeper analysis.

RISKS IN RWANDA'S AGRICULTURE SECTOR

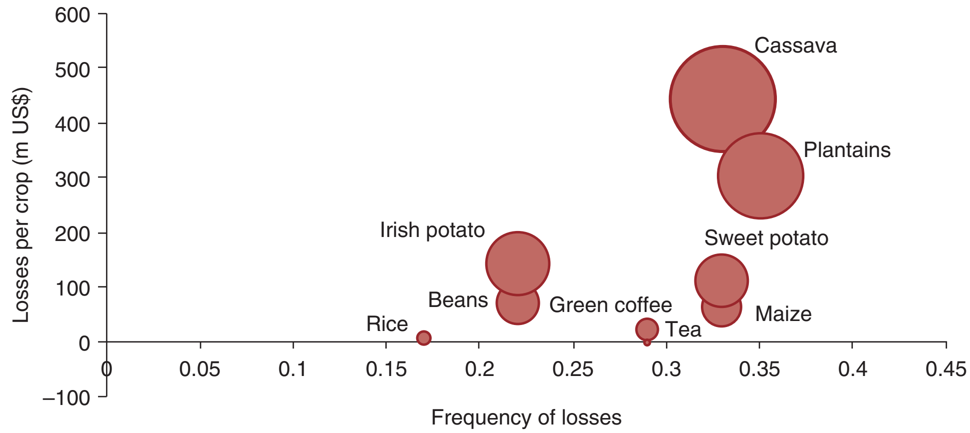
Compared with many other countries in the region, Rwanda is not subject to frequent shocks of large scale, such as national droughts or locust events. Still, risks have important consequences for agricultural productivity and growth. Although many countries in Sub-Saharan Africa (SSA) experience recurring negative agricultural growth because of various shocks, Rwanda has had only one year of negative growth in the 20 years since the war in the early 1990s (figure ES.1): in 2003, agricultural value-added growth was negative because of a drought that hit the country. On an annual basis, production losses for food and export crops averaged US$65 million between 1995 and 2012, or about 2.2 percent of Rwanda's total annual agricultural production value. Instead, risks, especially those of pests and diseases, are pervasive in Rwanda and although they don't cause large deviations from general yield trends at a national scale, their impacts on production likely explain part of Rwanda's yield gaps. Agricultural risks can thus have an important impact on growth objectives and on the government's efforts to transform the sector.

FIGURE ES.1. AGRICULTURAL VALUE ADDED (ANNUAL % GROWTH), 1995–2012



Source: WDI 2013.

FIGURE ES.2. FREQUENCY AND SCOPE OF LOSSES PER CROP, 1995–2012



Sources: FAOSTAT; Authors' calculations.

Food crops in Rwanda are mainly subject to production-related risks whereas export crops are mainly exposed to market risks. Pests and diseases pose a risk to Rwanda's food crop producers in particular because food crops have fewer organized supply chains and less access to preventive inputs than export crops. However, coffee producers especially suffer from pests and diseases that have impacts on yields and on market access. Weather-related risks are less of a concern for food crop producers and the main impacts on production are from moisture stress caused by erratic rainfall. Whereas this is true also for export crops, the risk is relatively smaller than that of market risks, because international price volatility poses a significant risk to the export sector. For food crops, marketing risks are limited, with prices responding predictably to seasonal supply and demand, and domestic prices are not affected by global prices.

Currently, the crops most exposed to risks are cassava and plantain, followed by fairly evenly distributed losses between Irish potatoes and sweet potatoes (figure ES.2). Maize has relatively frequent losses but the losses are not as large as for the first four crops. The scope of the losses are clearly in line with the importance of the crop in the total sector, because cassava, plantain, potatoes, and maize dominate agricultural production in terms of value.

Because pests and diseases are endemic in nature and outbreaks are not visible in the national-level yield data, the biggest losses tend to be correlated with difficult weather events, that is, drought or excessive rainfall (table ES.1).

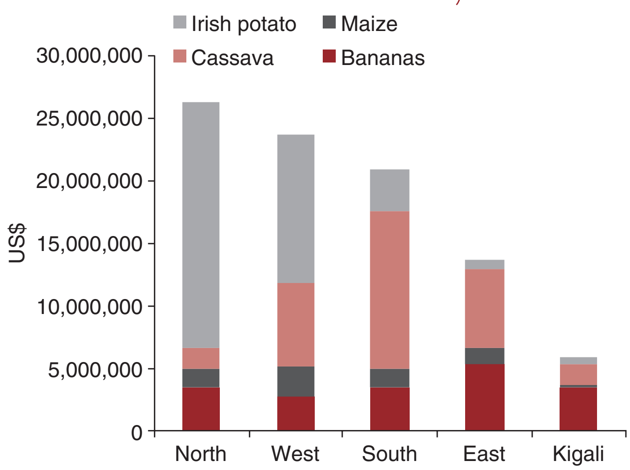
TABLE ES.1. COST OF ADVERSE EVENTS FOR CROP PRODUCTION, 1995–2012

	Indicative Loss Value		
Year	US$	% Ag. Production Value (current, average 2009–11)	Causes/Risk Events
2001	138,241,657	−4.57	Excessive rainfalls in the Northern and Western Provinces
2004	150,078,184	−4.96	Heavy rains in high altitude areas and a drought in Eastern and Southern Provinces
2006	87,062,028	−2.88	Drought/high heat in Eastern and Southern Provinces
2007	238,236,805	−7.87	Drought in Eastern Province
2008	269,030,202	−8.89	Drought in Eastern Province

Sources: FAOSTAT; Authors' calculations.
Note: Plantain, tea, and coffee were calculated from 1980 through 2011 owing to limited data. Cassava, paddy rice, sweet potatoes, maize, dry beans, and Irish potatoes were calculated from 1980 through 2012.

In years with these events, Rwanda experienced up to 9.5 percent losses of total agricultural production value. Nevertheless, omnipresent pests and diseases, including beanflies, the antestia bug, cassava mosaic virus, coffee

FIGURE ES.3. CROP LOSSES IN RWANDA BY PROVINCE (ANNUAL, US$, SUM OF SEASON A AND SEASON B)



Sources: Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.

leaf rust, and the more recently introduced banana bacterial wilt, are widely spread in Rwanda, causing yield losses ranging from a third up to 100 percent in infected plants. Thus, more systematically mitigating risks of pests and diseases would likely affect the general yield trend and narrow the yield gap for crops that currently have yields much lower than potential yields.

This report looks at indicative crop production losses for Rwanda's five provinces: Northern, Western, Eastern, Southern, and the City of Kigali. Losses were estimated for maize, bananas, cassava, and Irish potatoes for 2000–12 using MINAGRI's disaggregated data. Results indicate that losses are the greatest in absolute terms in the Northern Province and smallest in the City of Kigali (which also produces much less than the other provinces). Figure ES.3 provides an overview of the value of annual losses per province for Irish potatoes, cassava, maize, and bananas. The bulk of the losses of Irish potatoes are in the Northern Province but a large amount is also incurred in the Western Province. Most of the cassava losses take place in the Southern Province, followed by the Western and Eastern Provinces. Banana losses are more evenly distributed between provinces, but the Eastern Province has slightly higher losses than the others, whereas the Western Province has the lowest. Maize production has the lowest losses in absolute terms, whereas the Western Province sees slightly higher losses than the other provinces, followed by the Northern, Southern, and Eastern Provinces and the City of Kigali. Although the Northern Province has the highest aggregate losses in absolute amounts, it is clear that the geographic target area for any risk-management intervention will depend on the crop.

Livestock is important to Rwandan households, both in terms of income and food security and for the organic manure produced, which is applied in the fields. Half of all households own a goat, cow, and/or chicken, and of livestock units, 68 percent are cattle. Thus, this report looks at the risks to milk and beef production. The production of milk and beef has increased dramatically in Rwanda over the past two decades, in part because of government-financed livestock production programs, and in part because of increased incomes that drive consumer demand for livestock products. From being an importer, Rwanda is now essentially self-sufficient in milk products.

The key risks for the milk value chain occur first at the production level, then at the marketing level (that is, bulking/collecting and transporting), and finally at the retailing stage. The risks for meat production are mainly related to production. Since the mid-1990s, milk production has been affected by droughts and livestock disease outbreaks, such as anthrax, lumpy skin disease (LSD), and foot and mouth disease (FMD). Livestock disease outbreaks in 2008 caused a 13 percent loss in milk production in comparison with the previous year's production and cost an estimated US$10 million in lost income for farmers and US$163,000[1] in the value of destroyed, slaughtered, or dead cattle. Meat production is also affected by drought, albeit with a lagging effect, because production declines are visible only a year after the drought's occurrence. Nevertheless, the impacts are limited and cannot be compared with those on milk production.

Monthly milk prices are excessively volatile in Rwanda. In general, this kind of price volatility can occur when

[1] Based on World Organisation for Animal Health (OIE) data, the "Dairy Value Chain in Rwanda" report, and the NISR *Statistical Yearbook 2012*. The report estimates the value of an exotic bull to be RF 500,000, which is also assumed to be the average value of a milking cow. The total number of destroyed, slaughtered, and dead cattle was multiplied by the estimated value in Rwanda francs (RF) and then converted to U.S. dollars (USD).

TABLE ES.2. NATIONAL RISK PRIORITIZATION MATRIX

Impact/Probability of Event	Low	Moderate	High
Highly probable [1 year in 3]	• Potato taste (coffee) • Landslide (all crops) • Floods—local and large scale (all crops) • Milk contamination (dairy) • Milk collection center power cuts (dairy) • Counterparty risk (coffee) • Price fluctuations (food crops and milk) • Exchange rate fluctuations (export crops)	• Price volatility (export crops) • Livestock disease outbreaks	• Pests and diseases (all crops) • Drought and erratic rains (all crops and livestock)
Probable [1 year in 5]	• Hail (all crops)		
Occasional [1 year in 10]	• Glut (dairy) • Frost (tea) • Losses in transit (tea) • Aflatoxins in feed (livestock) • Maize shortage (dairy)		

daily milk consumption is fairly constant (that is, demand is relatively stable), because even small shifts away from equilibrium supply levels will lead to high price volatility. Similarly, high demand price elasticity for milk may magnify volatility at smaller changes in supply, because consumers quickly respond to price changes. Prices fluctuations are less frequent for meat and occur rather between years. Finally, especially for milk but also for fodder, the supply chains are susceptible to contamination. The milk cold chain already has problems with electricity cuts that put food safety standards at risk, and the fodder chain has sporadic problems with aflatoxin contamination.

Table ES.2 provides an overview of current risks in Rwanda according to the impact and probability of unforeseen events. When prioritizing investments in risk management, opting for mechanisms that address risks with high impact and high probability would be the first choice. The blue shadings in the table indicate the level of priority among the risks in Rwanda.

As Rwanda's agriculture sector transforms, the risk landscape will alter and, unless managed, some of these risks are likely to emerge with more important impacts on the sector. Importantly, land consolidation and monocropping facilitate the spread of pests and diseases. Similarly, Rwandan farmers' current practice of mixing local varieties for crops, which mitigates certain risks, is likely to be replaced with single-variety cultivation as output markets become more sophisticated. There are also signs of storage-related risks that are currently limited because of the limited storage in Rwanda, but these are expected to expand in scope as storage of commodities increases.

The livestock sector is predicted to grow along with consumption, which will elevate the significance of sanitary and food safety risks. An increased number of animals will lead to greater impacts associated with disease outbreaks, especially because livestock owners hold more cattle or are located in closer proximity to one another. With limited land in Rwanda, more animals are also likely to increase demand for fodder, which would imply greater impact from aflatoxins in fodder. Further, greater demand for livestock products as a result of income increases makes potential impacts from food safety risks greater as supply chains grow and products reach more consumers.

AGRICULTURAL RISK MANAGEMENT

It is important to remember that not all investments in risk management should be borne by the government, and that the private sector has an important role in managing risks. Many risks are already managed to a certain extent by public and private stakeholders in the sector. Aspects such as private versus public goods, investment gaps, and market failures should be taken into account. Although risks may emerge as the sector develops and markets grow, productivity increases are likely to give farmers better financial access to inputs and better knowledge about how to mitigate risk. However, it is important that appropriate institutions and actors are in place to facilitate this transition in the sector. Given the prioritized risks, feedback from stakeholders, and ongoing interventions, a shortlist of possible solutions areas is proposed for further assessment (table ES.3).

TABLE ES.3. PROPOSED SOLUTIONS AREAS FOR AGRICULTURAL RISK MANAGEMENT IN RWANDA

1. Improve water management for crop production

Water management in the crop sector, in particular to improve practices in preparation for dry periods and scattered rainfall, but also to better manage rainfall in the valleys to minimize flooding. Solutions areas may include:

- Expansion of on-farm water-harvesting systems
- Viable mechanisms for financing small-scale irrigation
- Expansion and rehabilitation of drainage infrastructures in valleys
- Agricultural practices to improve soil moisture and reduce flooding, including minimum tillage agriculture

2. Improve water and feed access in the livestock sector

Weather-risk management in the livestock sector, particularly as it relates to water and feed access. Solutions may include:

- Improving rural water infrastructure
- Developing existing feed supply chains to temporarily substitute for the lack of pastures in provinces where grazing is allowed
- Training of farmers in livestock management in water-scarce situations, and in good hygiene practices with special focus on practices in dry periods

3. Strengthen pest and disease management in crop production

Pest and disease management for crops, in particular as it relates to potential future risks caused by land consolidation and increased monocropping. Similarly, potential changes in pest and disease risks caused by climate change integrated in such assessment. Solutions may include:

- Improving agricultural practices and pest management, including further developing integrated pest management
- Strengthening the crop research system on pest and disease management and resilient crops
- Strengthening access to inputs, including developing a network of input dealers
- Developing information system on pests and diseases

4. Develop livestock disease management infrastructure

Developing livestock disease management infrastructure to mitigate and manage disease outbreaks to decrease the economic impact on the sector. Solutions may include:

- Developing livestock information systems, including animal registers and disease warning systems
- Developing veterinary services and vaccination programs
- Strengthening animal reference laboratory capacity
- Strengthening regional cooperation in livestock disease management

5. Strengthen sanitary institutions and practices throughout the livestock supply chain

Sanitary institutions and practices in the livestock sector, throughout the supply chain and involving both public and private actors. As incomes increase, this sector is likely to grow, so the necessary institutional infrastructure must be in place to mitigate risks and minimize losses. Solutions may include:

- Strengthening animal disease management in relevant institutions
- Introducing farm-level livestock management
- Increasing capacity of food safety institutions
- Improving hygiene practices throughout the supply chain
- Mitigating aflatoxin contamination in the feed supply chain

TABLE ES.3. PROPOSED SOLUTIONS AREAS FOR AGRICULTURAL RISK MANAGEMENT IN RWANDA (*Continued*)

6. Support improved price risk management in the export crop sector
Assessing possible price management mechanisms for actors in the export crop supply chain. Given the exposure to international prices for actors in the coffee and tea supply chains, scope exists to strengthen price management mechanisms in the sector. By analyzing the physical and financial flows on current transaction arrangements for exports, a set of options on how to reduce exposure to risk can be identified. Potential solutions areas may include: • Strengthening existing price information systems that allow for transparent price setting throughout the supply chain, and training actors throughout the chain to optimize given available information • Providing price risk management training to actors in the supply chain, for example in forwarding Price To Be Fixed (PTBF) contracting • Assessing available policy mechanisms for supporting actors in the sector against price risks • Assessing possible production and marketing investments for producers and processors that can lessen relevant actors' exposure to risk
7. Address milk price volatility
Analyze milk price volatility to better understand the reasons behind the fluctuations in milk prices. This would include proposing appropriate price risk management mechanisms depending on the identified causes behind existing price volatilities.

The GoR is already doing a lot in all of these areas. However, given the risks identified in this analysis and especially given the strategic path Rwanda has outlined for the sector, there is room for strengthening these risk management areas. The proposed solutions assessment could support Rwanda in preparing the sector for effective risk management in the coming decades.

This activity was requested by the Group of Eight (G-8) and principally financed by the U.S. Agency for International Development (USAID) and Feed the Future programs. Contributions were also received by the Multi Donor Trust Fund (MDTF) on risk management, financed by the Dutch Ministry of Foreign Affairs and the Swiss Secretariat of Economic Affairs (SECO).

CHAPTER ONE

INTRODUCTION

Rwanda is a small, landlocked, agriculture-based country of 26,338 km^2. With 12 million inhabitants, Rwanda is one of the 10 most densely populated countries in the world (MINAGRI 2010). Although Rwanda has made remarkable progress over the past two decades and is well under way to achieve its objective of becoming a middle-income country by 2020, 45 percent of the population still lives in poverty, mainly in the rural areas.[2]

Agriculture is the dominant sector of the economy, contributing a third of the country's gross domestic product (GDP) and about half of Rwanda's export earnings. Because about 80 percent of the population lives in rural areas and is engaged in agriculture to some extent, increasing agricultural productivity is key to improving incomes and decreasing poverty. The government of Rwanda has therefore made agricultural development a priority and allocated significant resources to improving productivity, expanding the livestock sector, promoting sustainable land management, and developing supply chains and value-added activities. As a result, the sector grew an average 5 percent per year over 2002–12, which is rather high although it fell short of both the government's own objective of 8–9 percent annual growth for the period (revised to 8.5 percent for the next years in the new, PSTA III) and of the CAADP commitment of 6 percent growth in the agriculture sector.

At the same time, Rwanda's agriculture sector faces a series of challenges. Agricultural land plots are very small (80 percent of land holdings are less than 1 ha, often divided into three to four plots) and over 70 percent of agricultural land is either on hills or on the side of hills. Agriculture is dominated by small-scale, subsistence farming under traditional agricultural practices and rain-fed agriculture. As a result, average crop yields are low compared with potential yields, and exposed to risks such as weather-related shocks and pest and disease outbreaks.

[2] See http://www.minagri.gov.rw/fileadmin/user_upload/documents/Publications/Agriculture%20Gender%20Strategy%20Final.pdf.

Poor groups are especially vulnerable to the impacts of risks, because risks tend to reinforce poverty traps through cycles of loss-recuperation-loss that prevent these groups from investing in productivity-enhancing measures. In Rwanda, the most vulnerable groups are heavily engaged in agriculture and the farming community's ability to bear risk is low. Farmers tend to diversify to manage risk in agriculture, which has also proven advantageous for household food security. However, whereas diversification can reduce agricultural risk for individual households, it also tends to prevent agricultural productivity increases through more efficient use of inputs and technology.

Current agricultural policies are geared to increasing productivity in the sector by achieving scale in agricultural production. Consolidation in the agriculture sector will improve use of inputs and the possibility to mechanize part of the sector, but it will also facilitate the spread of pests and diseases. Because risks often have different impacts on different crops and livestock, less diversified production also makes the actors more vulnerable to risks.

Improved agricultural risk management is one of the core enabling actions of the G-8's New Alliance for Food Security and Nutrition. To better understand dynamics of agricultural risks and identify appropriate responses, incorporate an agricultural risk perspective into decision making, and build capacity of local stakeholders in risk assessment and management, the Agricultural Risk Management Team of the Agriculture and Environment Services Department of the World Bank conducted an agriculture sector risk assessment. This activity was requested by the G-8 and principally financed by USAID and Feed the Future programs. Contributions were also received by the Multi Donor Trust Fund on risk management, financed by the Dutch Ministry of Foreign Affairs and the Swiss Secretariat of Economic Affairs (SECO).

The purpose of this report is to assess existing risks to the agriculture sector, prioritize them according to their frequency and impacts on the sector, and identify areas of risk management solutions that need deeper specialized attention. Three levels of risks are assessed: production risks, market risks, and enabling environment risks to selected supply chains. To give a sectorwide overview of the impacts of risks, the assessment looks at the largest commodities that jointly account for 80 percent of Rwanda's agricultural production value. The selected commodities are:

Food crops: cassava, maize, Irish potatoes, sweet potatoes, plantain, beans, and rice
Export/cash crops: tea and coffee
Livestock: cattle—meat and dairy

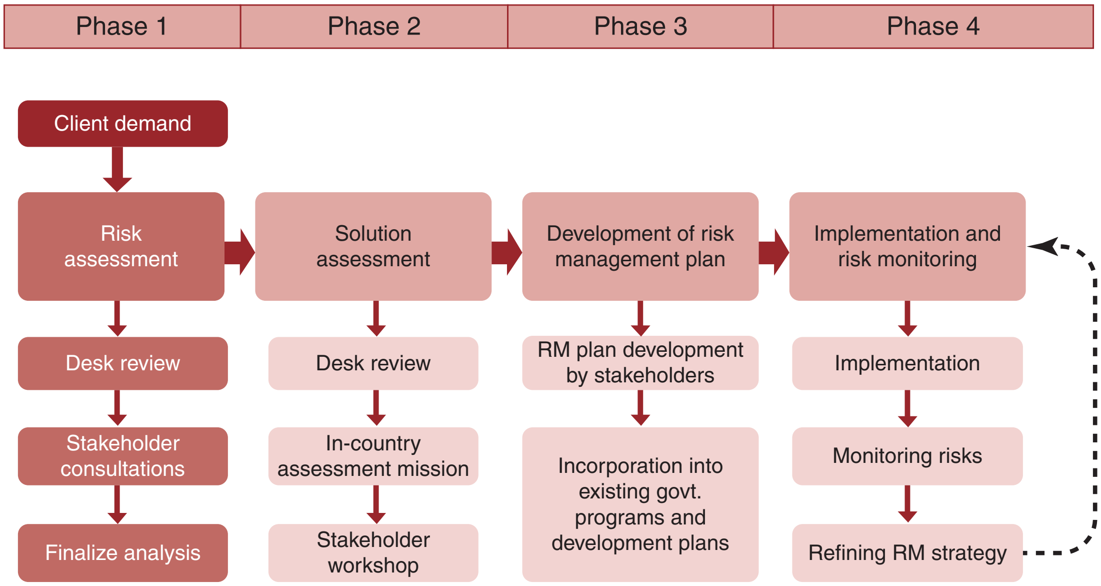
It can be noted that neither tea nor coffee technically falls into this category at production level. Nevertheless, they were included because of their contribution to gross national export earnings.

The report takes a quantitative and qualitative approach to risks. Productions risks are quantified in terms of losses and then mapped by different perils. Marketing and enabling environment risks are analyzed qualitatively. For the purpose of this assessment, *risk* is defined as the possibility that an event will occur and will potentially have a negative impact on the achievement of a farm's or firm's performance objectives and/or on the successful functioning of the overall supply chain. In the work previously conducted by ARMT in other countries, time periods of at least 30 years were assessed to secure a proper understanding of the risks to the sector. However, because of the very different systems in Rwanda before and after the mid-1990s, as well as the interruptive civil war in 1994, it is difficult to identify distinct trends over longer time series. This assessment therefore focuses on risk to the agriculture sector over the past 20 years.

A broad spectrum of stakeholders was consulted throughout this work, including the Rwandan government, farmers, traders, processors, cooperatives, agricultural institutions, and academia. A consultative stakeholder meeting organized by the Ministry of Agriculture and Animal Resources was also held in Kigali to obtain feedback on findings and to discuss areas for risk solution interventions for deeper analysis.

Figure 1.1 provides an overview of the full process applied by the ARMT in the past. The Agricultural Sector Risk Assessment in this report constitutes the first phase. Based on the results of this assessment, a solutions assessment will be conducted, under which a few potential risk

FIGURE 1.1. AGRICULTURE SECTOR RISK MANAGEMENT PROCESS FLOW



Source: World Bank ARMT.

management instruments are further assessed. Under this second phase, ongoing activities in the selected areas are assessed and gaps mapped to determine activities needed to minimize the impacts of risks on the sector.

The report is structured as follows: chapter 2 provides an overview of Rwanda's economy and the role and structure of the agriculture sector. Agriculture sector risks (production, market, and enabling environment risks) for the selected food crops, export crops, and livestock are analyzed in chapter 3. Analysis of the adverse impacts of agricultural risks at aggregate and provincial levels, along with a stakeholder risk assessment and a discussion of particularly vulnerable groups, is found in chapter 4. Chapter 5 prioritizes identified risks, discusses potential solutions areas, summarizes feedback from consulted stakeholders, and recommends solutions areas for further assessment.

CHAPTER TWO

AGRICULTURE IN THE ECONOMY

RWANDA IN THE 21ST CENTURY

Emerging from the 1994 civil war, Rwanda's economy has seen a rapid expansion over the past two decades. Overall growth has averaged 8 percent, exceeding average SSA growth rates, and Rwanda's total GDP now amounts to US$7.1 billion (2012 figure). Inflation is relatively low and the government has maintained general macroeconomic stability. In the World Bank/IFC *Doing Business 2010* report, Rwanda was the world's top reformer and now ranks 32 out of 189 countries worldwide in the "ease of doing business" (World Bank 2009). The government's vision is for Rwanda to become a middle-income country with an annual per capita GDP of US$900 by 2020. This will require annual growth of at least 7 percent.

Nevertheless, Rwanda is still relatively poor, ranking 36 out of 48 SSA countries in 2012 in terms of per capita GDP.[3] Real per capita GDP was US$390 in 2012, compared with the SSA average per capita GDP of US$1,522.[4] As shown in figure 2.1, large annual fluctuations in GDP growth rates have occurred over time.

With low per capita GDP, poverty persists in Rwanda. About 63 percent of the population lives on less than US$1.25 per day and 82 percent on less than US$2 per day. Inequality is high: the Gini coefficient is 50.8 percent and 43 percent of the income share is held by 10 percent of the population.[5,6]

The composition of GDP is 2013 was 33 percent agriculture, 14 percent industry, and 53 percent services (figure 2.2). Over time, the share of agriculture has declined and the share of services has increased. Rwanda is a relatively open economy and trade constitutes almost half of Rwanda's GDP. The value of imports is close to twice the size of exports and account for 33 percent of GDP, compared with 13 percent for exports.

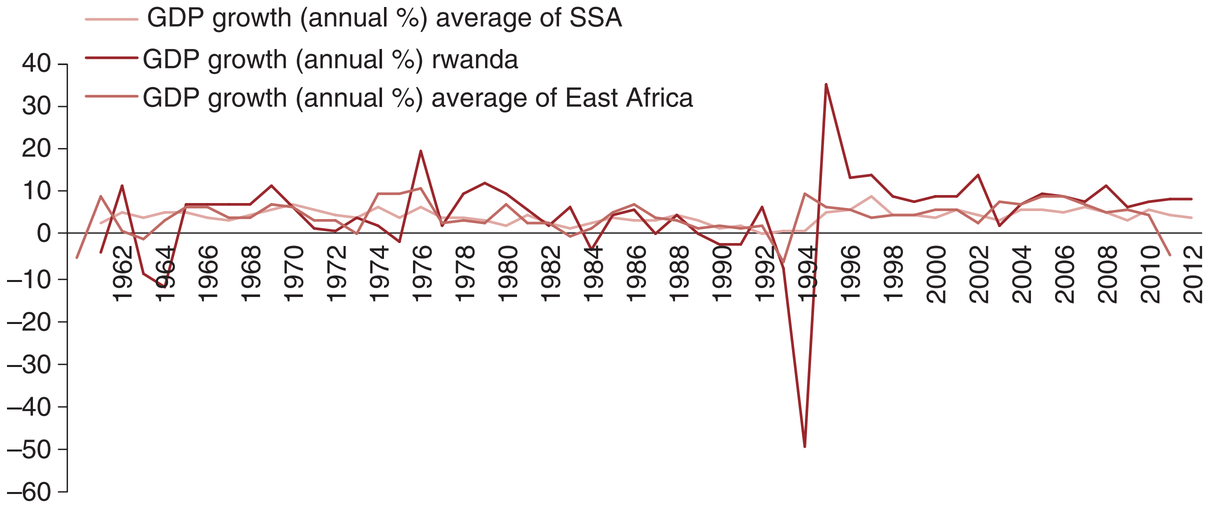
[3] Based on 2005 U.S. dollars, WDI (accessed November 6, 2013).

[4] Real GDP, 2005 prices, not including South Africa and the Seychelles.

[5] 2011 figure; http://data.worldbank.org/indicator/SI.POV.GINI (accessed December 13, 2013).

[6] WDI (accessed November 6, 2013).

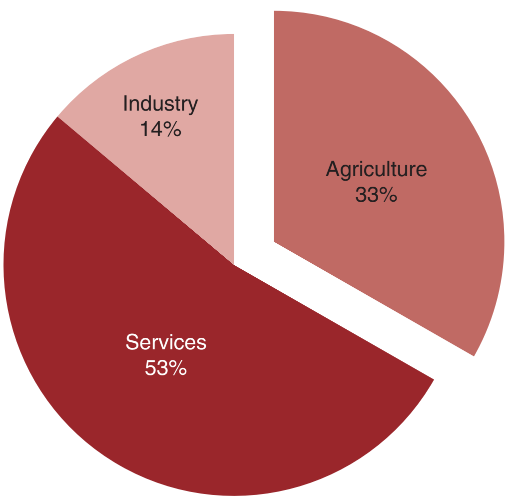
FIGURE 2.1. RWANDA'S GDP GROWTH COMPARED WITH SSA AND EAST AFRICA



Source: WDI 2013.

Note: East Africa follows the definition set out by Food and Agriculture Organization (FAO) and includes the following countries: Burundi, Djibouti, Ethiopia, Kenya, Rwanda, Somalia, Sudan, and Uganda. See http://www.fao.org/africa/sfe/en/.

FIGURE 2.2. GDP COMPOSITION, 2013



Source: WDI 2013.

ROLE OF AGRICULTURE IN THE ECONOMY

Agriculture plays an important role in the overall economy. As discussed above, agriculture contributes 33 percent of GDP and 80 percent of population is engaged in the sector. At the aggregate level, domestic food production almost equals domestic demand and farmers' own production is an important source of food at the household level. Agriculture is also a major source of export earnings. Despite this, poverty is high in rural areas, where 49 percent live below the poverty line compared with 22 percent in urban areas.

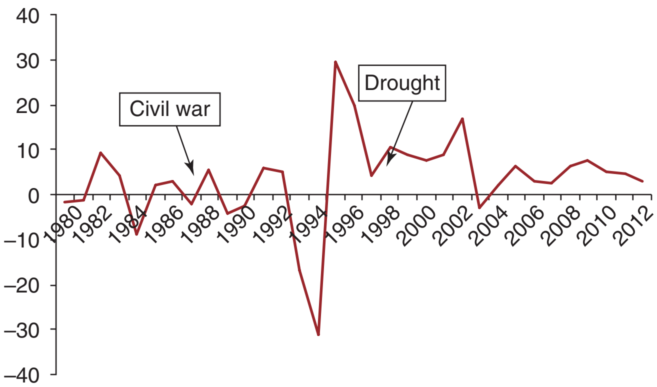
SECTOR COMPOSITION AND AGRICULTURAL VALUE ADDED

Rwanda's agriculture sector has experienced two growth trends over the past 30 years, with high volatility pre-1994 and almost uninterrupted growth from 1995 onward. Agricultural value added per worker has increased since 1999 and, consequently, agricultural employment and the rural population have declined. In 2007, the productivity of an agricultural worker was about US$263; by 2012, it had reached US$294. However, the overall growth rate of agricultural value added has not been linear (figure 2.3). For instance, it went from 2.6 percent in 2007 to 7.7 percent in 2009, followed by another decline to 4.68 percent in 2011.[7] The last time that agricultural value added growth rates were negative was in 2003, when Rwanda experienced a drought that affected more than 1 million people.[8]

[7] Ibid.

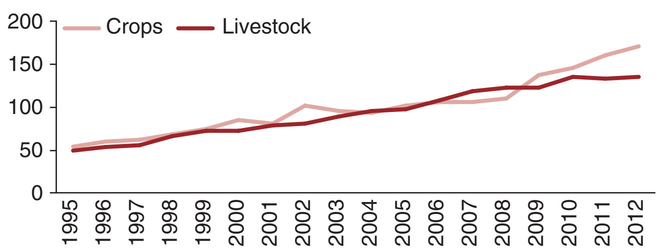
[8] Ibid.

FIGURE 2.3. AGRICULTURAL VALUE ADDED (ANNUAL PERCENT GROWTH), 1980–2012



Source: WDI November 2013.

FIGURE 2.4. GROSS PRODUCTION INDEX NUMBER, CROPS AND LIVESTOCK (2004–06 = 100), 1995–2012

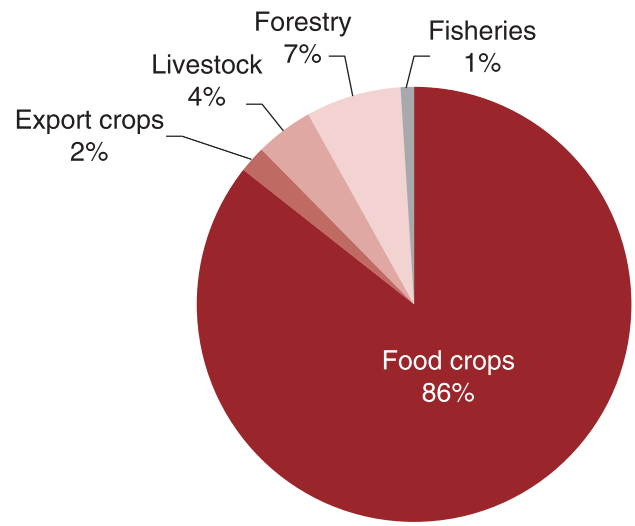


Source: FAOSTAT 2014.

Looking at production indexes for crops and livestock over the past 20 years confirms this smooth, positive growth trend in agriculture. Overall, there has been little volatility in the sector, which is good from a macroeconomic perspective and indicates limited systemic risks to the sector. This sets Rwanda apart from many other countries in SSA, where growth trends are often highly volatile. The few slight drops in Rwanda's crop production were recorded in 2001, 2004, and 2007 compared with the respective previous years; livestock production drops occurred in 2000 and in 2011–12 compared with 2010 (figure 2.4). All of these years had either deficit or excessive rainfalls, but with the exception of 2004 (when leguminous production showed a marked decline), it is not clear that these actually affected aggregate production.

However, aggregated data mask volatility; hence, to better understand the real losses it is necessary to analyze the

FIGURE 2.5. SECTORAL COMPOSITION OF RWANDA'S AGRICULTURE SECTOR GDP



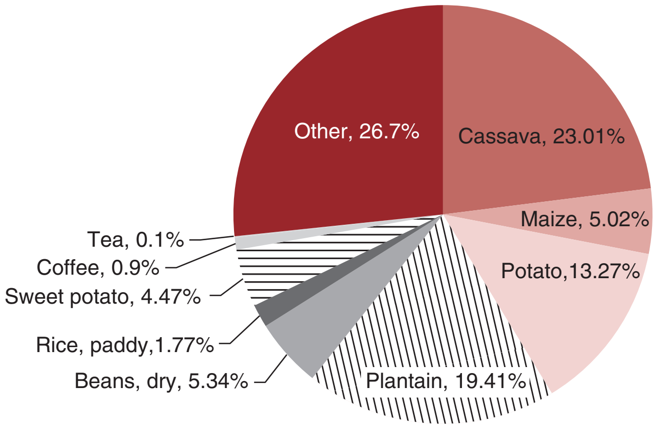
Source: MINECOFIN 2013a; Authors' calculations.

impacts of risks at provincial and commodity levels. This disaggregated analysis might reveal that losses are significant for one or two provinces and/or for certain commodities, or that agricultural risks lead to significant losses for certain groups engaged in the sector. The agriculture sector in Rwanda consists of four subsectors: crops, livestock, fisheries, and forestry. The crops subsector is further divided into two groups: food crops and export crops. Figure 2.5 shows the composition of agricultural GDP. Within agriculture, food crops account for 86 percent of agricultural GDP. The role of other subsectors is relatively small and the relative shares of export crops and livestock have been declining.[9]

Plantain, cassava, Irish potatoes, sweet potatoes, and maize dominate agricultural production (figure 2.6). In particular, cassava, potato, and maize production has increased rapidly since the turn of the century. Rice and beans are potentially important crops. Production increase is largely a result of targeted agricultural policies and expansion of production areas. The share of export crops is much smaller. However, their contribution to overall exports is important and agricultural exports are a major source of foreign exchange earnings in Rwanda.

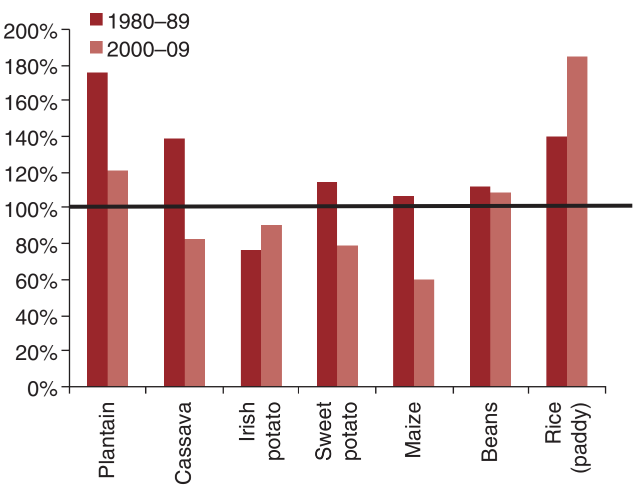
[9] The relative share of fisheries has remained constant, whereas the relative share of forestry has been increasing.

FIGURE 2.6. CROPS' SHARES OF GROSS AGRICULTURAL PRODUCTION VALUE (CURRENT, AVERAGE 2009–11)



Source: FAOSTAT 2013.

FIGURE 2.7. YIELD GAPS COMPARED WITH SSA, 1980–89 AND 2000–09

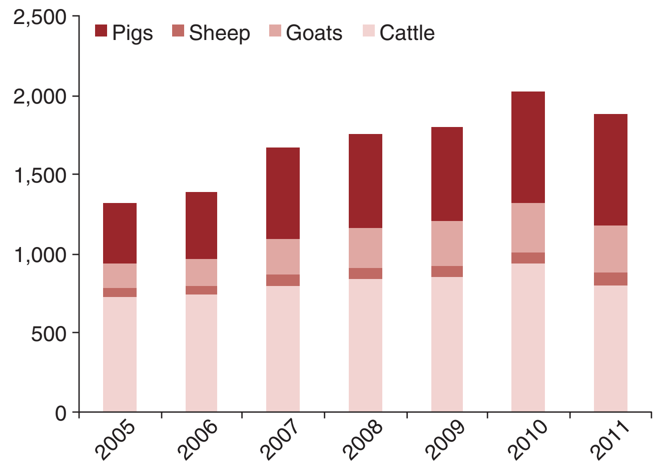


Sources: FAOSTAT 2013; Authors' calculations.

Longer-term time series of crop yields show a more varied trend.[10] Yield decreased significantly in the late 1980s and early 1990s because of instability in the country. Although yields for most crops have now returned to prewar levels, the yield growth varies between crops. Several crops have yields below the SSA average and the gap between actual yield and production potential is large (figure 2.7; postwar crop yield trends are given in figures 3.4–3.8).

[10] Average yield of crops from 2009 through 2011 was calculated to make the comparison (FAOSTAT 2013).

FIGURE 2.8. NATIONAL HERD PROFILE OF LIVESTOCK (TLUs,* '000 OF ANIMALS), 2005–11



Source: Rwanda Agriculture Board (RAB).[1]

Note: Cattle, sheep, and goats are in TLUs. No estimates for pigs were available for 2011 so 2010 figures were used.

*TLU = Tropical Livestock Units. 1 TLU = 1.0 Camels; 0.7 Cattle; 0.1 Sheep/Goats. See http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Mixed1/TLU.htm

[1] Data obtained in 2014 from RAB files during field mission.

The livestock sector is growing, although less than the overall agriculture sector (figure 2.8). According to the National Institute of Statistics (NISR), half of all households own a goat, cow, and/or chicken. This is partly attributable to government initiatives such as the "One Cow per Poor Family" (Girinka) program (which has distributed 134,548 cows and another 40,352 heifers passed by beneficiary households onto other poor households [MINAGRI 2013a]) and UBUDEHE (a rural development program that has distributed different types of livestock). As a result, milk production has increased nine times since 1999, and meat production three times in the same period. From being a major milk importer, Rwanda is now more or less self-sufficient in milk production. Livestock production accounts for just over 9 percent (2010–12 average) of total production value, and the demand for livestock products is likely to increase further as incomes rise in Rwanda. Milk and meat consumption increased from 20 l/person/year and 5.7 kg/person/year in 2006 to 50 l/person/year and 6.8 kg/person/year in 2012, respectively (FAO Corporate Statistical Database [FAOSTAT] 2014; 2004–2006 prices).

Food and agricultural export make up almost half of Rwanda's export. The top five agricultural export commodities in terms of value contribute 92 percent of

TABLE 2.1. VALUE OF THE TOP FIVE AGRICULTURAL EXPORT COMMODITIES, 2008–10 (AVERAGE)

	Share of Agricultural Exports (%)	Total Value (USD '000s)	Share of Agricultural Production (%)*	Share of GDP (%)**
Tea	45.56	63,605	3.48	1.78
Coffee	35.47	49,514	2.71	1.38
Beer of barley	4.72	6,585	0.36	0.18
Beverages, nonalcoholic	3.72	5,192	0.28	0.15
Cattle	2.53	3,531	0.19	0.10

Source: FAOSTAT 2014.

* Constant 2004–06 prices; ** constant 2005 prices.

agricultural exports (table 2.1). Remaining exports are mainly ores and metals. Food and agriculture constitute a much smaller share of imports (18.5 percent), whereas manufactured goods, food, and fuel constitute the bulk of imports (WDI 2013).

CLIMATE AND AGRO-ECOLOGY

Situated on mountainous terrain in the East African Rift Valley, Rwanda has a tropical temperate climate (Rwanda Environment Management Authority [REMA] 2009, 97). Temperatures in the country vary with altitude, but average annual temperatures range between 16°C and 20°C (REMA 2009, 97). Rainfall in the country is shaped by the effect of the Inter Tropical Convergence Zone (ITCZ), where the weather systems of the Northern and Southern Hemispheres meet. The progression of the ITCZ results in two types of seasons: dry and rainy.

Four seasons divide a calendar year in Rwanda (table 2.2): two rainy seasons from September to November and from March to May, and two dry seasons from December to February and June to August. The crop calendar has essentially three seasons, though the most important are September to January (Season A) and February to June (Season B).

Because of the topography of the country and the existence of large bodies of water, the eastern and southeastern parts of the country experience more frequent prolonged droughts, whereas the northern and western regions get more rainfall (REMA 2009, 97). Over the past 20 years, both floods and rainfall deficits or droughts have been fairly frequent but are often incurred locally or regionally. Therefore, as seen earlier, droughts and floods more often than not do not have significant impacts on the agriculture sector as a whole. Similarly, hailstorms are relatively common in Rwanda, but their impacts are highly localized.

TABLE 2.2. WEATHER AND CROP SEASONS IN RWANDA

Crop Seasons	Period
Season A	September–January
Season B	February–June
Season C	July–September
Rainy Seasons	
Season A	Mid-September–December
Season B	Mid-February–Mid-May
Dry Seasons	
	December–February
	June–August

Source: MINAGRI 2011a.

Certain changes in both rainfall and temperature patterns are already apparent, indicating that Rwanda is affected by global climate change. Temperature and rainfall data over the past 30 years show that the rainy season is becoming shorter with higher intensity, leading to both more droughts and floods simultaneously (REMA 2009, 97). However, different parts of the country are affected differently. The Northern and Western Provinces are seeing heavier rains and floods whereas the Eastern Province is seeing more rainfall deficits (REMA 2009, 98).

Despite these observed patterns, climate models are in disagreement over rainfall changes projected in Rwanda over the next 30 years. For East Africa as a whole, high rainfall extremes (events typically occurring once in every 10 years) are expected to increase in frequency (van de Steeg et al. 2009, 27).

Climate models are in more agreement regarding temperature increases. Three different climate change models[11] forecast a 1°C to 2.5°C increase in maximum temperatures. It is projected that higher and more variable temperature will lead to more frequent and severe droughts and floods in Africa. Because most of Rwanda's agriculture is rain fed and thus exposed to weather events, it is vulnerable to the climate changes projected. For crops that also require cooler temperatures to grow, such as beans and potatoes, temperature increases pose a particular threat.[12] In addition, higher temperatures are expected to increase the prevalence of pests and diseases. However, no studies have been conducted on how global climate change will affect key crops in Rwanda. Appendix B gives a more detailed overview of projected global climate change in Rwanda.

AGRICULTURAL LAND AND INPUT USE

About 50.6 percent of Rwanda's land area is agricultural, of which about 73 percent is actually used to grow crops (food crops, cash crops, and forages); the remaining 27 percent is either kept fallow or used for pastures and afforestation. The Eastern Province has the most agricultural land (439,000 ha) and the Northern Province has the least (212,000 ha) (not including the City of Kigali) (table 2.3). The share of land covered by agricultural holdings also varies by province: 46 percent in the Eastern Province and 65 percent in the Northern Province.

TABLE 2.3. AGRICULTURAL AREA AND AREA PER HOUSEHOLD (HA), BY PROVINCE, 2010

Province	Area, Ag. Holdings (ha)	Average Area per Household (ha)
Northern	211,576	0.65
Southern	237,047	0.71
Eastern	439,204	1.10
Western	269,964	0.62
City of Kigali	32,959	0.65

Source: NISR 2010.

TABLE 2.4. AGRICULTURAL HOLDINGS BY SIZE (%)

Area held (ha)	Share (%)	Cumulative (%)
Less than 0.20	26.3	26.3
0.20–0.49	30.5	56.8
0.50–0.99	23.2	80.0
1.00–1.99	14.0	94.0
2.00–2.99	3.6	97.6
3.00–3.99	1.2	98.8
4.00–4.99	0.6	99.4
Greater than 4.99	0.6	100.0

Source: NISR 2010.

Farm size in Rwanda is extremely small and farms are fragmented. The average area per agricultural household is 0.76 ha (NISR 2010). As shown in table 2.4, 80 percent of agricultural land holdings are less than 1 ha and the land is highly fragmented; on average, each household has four land plots. Under these circumstances it is very difficult for farmers to take advantage of economies of scale by adopting modern agricultural equipment. The government's Land Consolidation Program and Crop Intensification Program (CIP) are designed to address this problem by organizing farmers into cooperatives (box 2.1).

Because of Rwanda's hilly topography, 70 percent of the land is either on hillsides or on the top of hills. Only 30 percent of farms in Rwanda are located on flatland or at the bottom of hills, which contributes to a series of challenges

[11] These include CNRM-CM3, ECHAM, and MIROC 3.2. See Tenge, Aphonse, and Thomas 2012, 264.
[12] Ibid.

BOX 2.1. RWANDA'S CROP INTENSIFICATION PROGRAM

The Crop Intensification Program is a flagship project for the Ministry of Agriculture and Animal Resources. Launched in 2007 and with a current budget of RF 9,092 million, it focuses on maize, wheat, rice, Irish potatoes, beans, and cassava. Its overall objective is to increase agricultural productivity in high-potential food crops and ensure food security and self-sufficiency. Its main activities include land consolidation, proximity extension services, service providers for extension, demonstration plots, seed distribution, and improved seeds and fertilizer use.

Distribution of improved inputs—in a move to raise productivity levels through improved inputs, the government decided to initially supply inputs and encourage farmers to use them.

Improved seeds—improved seed from neighboring countries such as Kenya and Tanzania, along with improved planting materials (cuttings) of cassava and potatoes, are distributed.

Distribution of fertilizers—vouchers are distributed to farmers through service providers for subsidized fertilizer.

Consolidation of land use—because of high demographic pressure in Rwanda that has led to highly fragmented agricultural landholdings, this involves successfully rearranging land parcels to consolidate the use of farm holdings. Under the policy, farmers are required to grow a specific food crop together with the aim of improving productivity and environmental sustainability. Consolidated land area was measured at 503,000 ha in 2011.

Source: MINAGRI 2011a.

and risks (table 2.5). Hilly land is subject to drought, soil erosion, and landslides, whereas marshland is subject to floods during heavy rains. The hilly topography makes it very difficult to use modern farm equipment or irrigation. This not only reduces agricultural productivity but also adds to agricultural risks in the event of unfavorable weather conditions.

Traditional agricultural practices persist around the country. According to a NISR survey, 98 percent of agricultural land is rain fed and only 0.6 percent is under irrigation. Irrigation is one solution to address drought. However, in Rwanda it will be very difficult and expensive to bring more area under irrigation. Furthermore, only about 0.2 percent of the land uses animal traction or mechanical equipment, whereas 99.8 percent uses traditional hand hoe manual cultivation. Similarly, the number of farmers who use modern agricultural inputs is small (table 2.6).

TABLE 2.5. TOPOGRAPHIC POSITION OF FARMS IN RWANDA, 2010

Topography	Share (%)
Top of the hill	24.3
Side of the hill	45.8
Bottom of the hill	12.0
Plain	15.8
Marsh	2.2
Total	100.0

Source: NISR 2010.

TABLE 2.6. AGRICULTURAL HOUSEHOLDS' USE OF AGRICULTURAL INPUTS

Inputs	Season A (%)	Season B (%)
Improved seeds	13.3	7.1
Pesticides/ fungicides	15.7	14.2
Manure	39.5	29.8
Compost	38.3	23.4
Fertilizer	17.7	13.7

Source: NISR 2010.

CHAPTER THREE
AGRICULTURE SECTOR RISKS

The identification, analysis, and prioritization of agricultural risks cover three separate categories of agricultural commodities grown in Rwanda: (1) food crops, (2) export crops, and (3) livestock. As discussed in chapter 1, the assessment looks at the largest commodities that jointly account for 80 percent of Rwanda's agricultural production value as well as the two largest agricultural export commodities. The selected commodities are:

Food crops: cassava, maize, Irish potatoes, sweet potatoes, plantains, beans, and rice
Export/cash crops: tea and coffee
Livestock: cattle—meat and dairy

This chapter looks at production risks, market risks, and enabling environment risks for the commodities in these three categories.

FOOD CROPS

Food crops for domestic consumption dominate primary agriculture and are therefore the main focus of Rwanda's Crop Intensification Program. Cassava, Irish potatoes, sweet potatoes, maize, and bananas are the largest commodities in terms of production value and account for 56 percent of total production value (2009–11 average). Bean production accounts for just over 5 percent of total production but is important because of its wide application across Rwanda, as 92 percent of rural households cultivate various varieties of beans (NISR 2012a). Beans are also an important source of protein.

Largely a result of targeted agricultural policies and expansion of production areas, maize, cassava, potato, and plantain production increased rapidly in the early to mid-2000s. As explained earlier (box 2.1), the CIP supports maize, cassava, rice, Irish potato, bean, and wheat producers with improved inputs; finances research for improved seeds for these crops; and encourages production on consolidated land through cooperative structures. The support for rice, maize, and wheat production is largely in anticipation of expected dietary shifts toward more rice and wheat intake, following expected rises in incomes over the next decade.

Food crops are mainly subject to production-related risks, but the risks prevalent in the sector are likely to alter as the sector transforms. Pests and diseases pose a risk to Rwanda's food crop producers, particularly because food crop producers have less organized supply chains and less access to preventive inputs than do export crop producers. Weather-related risks are less of a concern for food crop producers; the main impacts on production are from moisture stress caused by erratic rainfall. Marketing risks are limited, with prices responding predictably to seasonal supply and demand, and domestic prices are not affected by global prices. However, as Rwanda's agriculture sector transforms, the risk landscape is likely to alter. Importantly, land consolidation and monocropping facilitate the spread of pests and diseases. Similarly, Rwandan farmers' current practice of mixing local varieties for crops, which mitigates certain risks, is likely to be replaced with single-variety cultivation as output markets become more sophisticated. There are also signs of storage-related risks that are currently limited because of the limited storing in Rwanda, but these are expected to expand in scope as storage of commodities increases. Conversely, as productivity increases, farmers are likely to have better access to inputs and the knowledge to mitigate these risks. Marketing and enabling environment risks may emerge as the sector transforms, but this will largely depend on the role the government plays in the future.

PRODUCTION RISKS

Unpredictable Weather Patterns

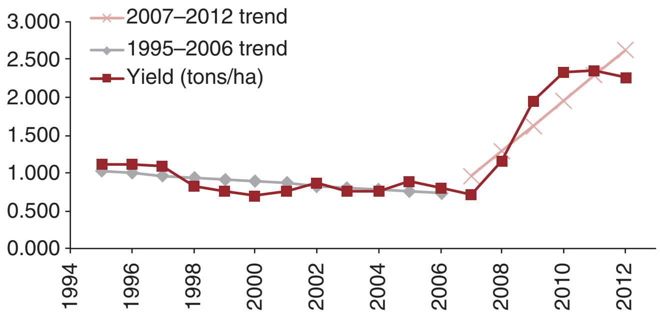
Unpredictable weather patterns can pose a risk to producers but there are no clear patterns of systemic weather risks on food crop production in Rwanda. The frequency of substantial rainfall deficit in a given season is low (less than 10 percent), but the probability of erratic rainfall and short-term moisture stress is high. A certain degree of yield loss from moisture stress is almost inevitable, contributing to the risks faced by individual farmers.

In Rwanda, maize and rice are arguably the least moisture stress-tolerant crops. Maize requires constant moisture for optimal growth and yield is reduced if the maize crop is allowed to wilt consistently for more than 48 hours. Growth is particularly sensitive: (1) when the crop is 50 cm high and dry conditions can restrict the development of the reproductive organs (15 percent); (2) during tasseling, silking, and the completion of pollen germination, when dry conditions can reduce the number of grains that will develop in each cob (50 percent); and (3) during early grain development, when dry conditions can result in shriveled or aborted grains (30 percent). During the latter two growth stages, the maize plant is more developed with a greater leaf area, transpiration from which may require as much as one liter of water per day. If soils are deep and well structured, crops at these growth stages may be able to extract more water from greater soil volumes by virtue of their greater depth of rooting, but if soils are shallow or of low water-holding capacity, then the demands of evapotranspiration will exceed the supply capacity of the soil and wilting will occur.

Exactly how much is lost on an annual basis throughout the country is not clear, but a variation of 20 percent in seasonal rainfall could reduce yields by as much as 50 percent if the dry spell occurred during the critical tasseling and silking stage of growth. Anecdotal evidence from Rwanda supports this: in 2008, erratic rainfall caused yield losses for 37 percent and 26 percent of smallholders in the Eastern and Southern Provinces, respectively, compared with 19 percent and 14 percent in the Northern and Western Provinces, respectively.[13] However, at a national level, systemic losses are not visible. Maize yields shifted slightly downward in the late 1990s, and a decade later increased significantly from 2007 to 2010, arguably in response to the CIP, introduced in 2007. Because of the large shift in the long-term trend, it makes more sense to divide the trend into two periods: 1995–2006 and 2007–12. Figure 3.1 depicts these two trends and shows that in fact, systemic losses to maize at the national level are limited.

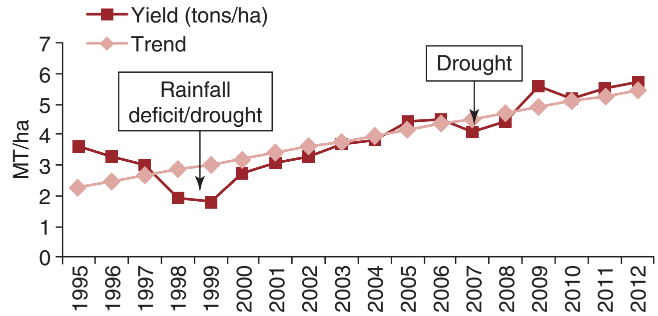
[13] Comprehensive Food Security and Vulnerability data.

FIGURE 3.1. MAIZE YIELDS (MT/HA), 1995–2012



Source: FAOSTAT 2013.
Note: MT/ha = metric tons per hectare

FIGURE 3.2. PADDY RICE YIELDS (MT/HA), 1995–2012



Source: FAOSTAT 2013.

During the preparation of this report, rice farmers expressed concerns about water availability; however, yield data do not indicate nationwide systemic rice losses from droughts in Rwanda (figure 3.2). Research (Akram, Sattar, Rehman, and Bibi 2013) demonstrates that withholding irrigation water from a rice crop for a 14-day period reduced paddy yield by 10–40 percent, depending upon the time at which moisture stress was imposed. Drought stress at panicle initiation had the greatest impact on yield, whereas stress at anthesis and grain filling led to reduced impacts. In Rwanda, rice is produced under marshland conditions, which is not the same as irrigated conditions (although some irrigation systems do exist) but depends more upon controlled drainage to ensure adequate levels of moisture are available at key growing periods. Such systems are vulnerable to water shortage, especially at the beginning of the season if delayed rains have precluded the accumulation of adequate moisture for initial germination and growth.

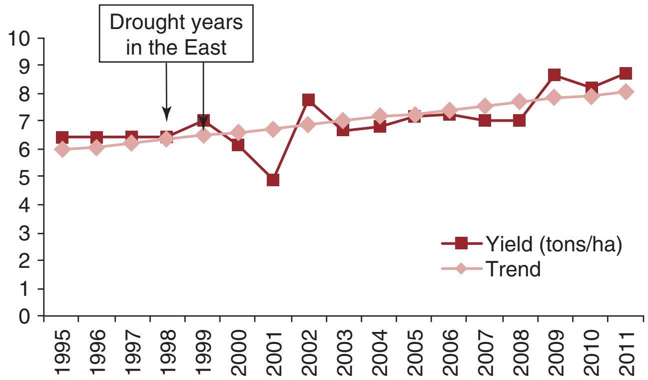
Despite this, no exact figures exist for annual rice losses caused by moisture stress in Rwanda. At a national level, most of the drought/rainfall deficits go unnoticed, even for the big drought in 2003. One explanation may be because rice is grown in marshlands across the country and regional droughts are masked by good yields in other parts of the country. Another potential explanation is that marshlands retain water better than does agricultural land on hillsides, and therefore rice manages better during dry periods. Finally, the timing of the dry periods may affect the impacts on rice production.

For other food crops, moisture stress is not a major a concern in terms of systemic risks. In general, weather-related shocks on production result in short-lasting dips below the general yield trend, and although there are declines in production for several crops that correlate with drought or flood years, these events have either been regional or did not result in multi-year declines in production. For example, banana yields saw a decline in 2000–01, which correlates with a severe drought in the Eastern Province in 2000 related to La Niña (figure 3.3). This would indeed affect production because bananas are sensitive to drought. However, looking at the subnational level, the decline in yield clearly occurred throughout the country; therefore, the drought in the Eastern Province does not fully explain the decline in banana yields in 2000–01.

Although beans are sensitive to temperature, weather does not have any significant impact on Rwanda's production of bush and climbing beans (figure 3.4). This is largely because Rwandan bean producers minimize weather-related risks by growing a mix of local and improved varieties and applying different varieties across the country. Applying a mix of varieties, rather than solely improved varieties, results in lower yields to a certain extent, particularly because improved varieties can yield twice as much as traditional varieties. However, the reduced risk of adverse effects from unpredictable weather events justifies this practice.[14]

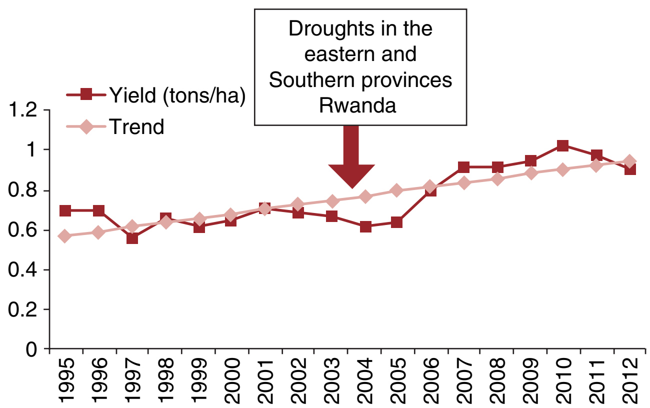
[14] Rwanda has relatively competitive bean yields internationally.

FIGURE 3.3. BANANA YIELDS (MT/HA), 1995–2012



Source: FAOSTAT 2013.

FIGURE 3.4. BEANS YIELDS (MT/HA), 1995–2012

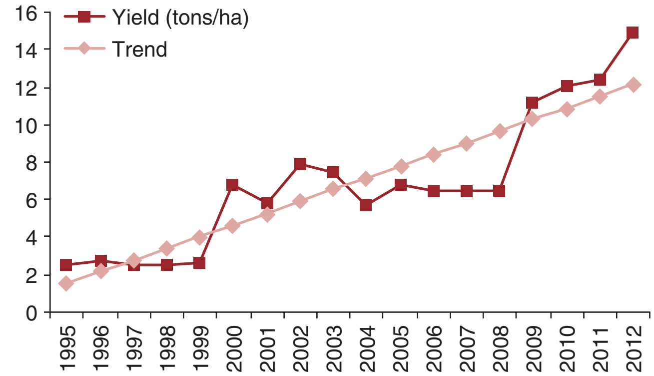


Source: FAOSTAT 2013.

Cassava is the most moisture stress-tolerant crop of those studied in this assessment, because of its ability to respond quickly to decreased moisture in the environment (see appendix E). Production is not affected by moisture stress more than 1 in 10 years under Rwanda's current rainfall patterns. At a national level, cassava yield trends do not indicate systemic impacts from weather-related shocks (figure 3.5).

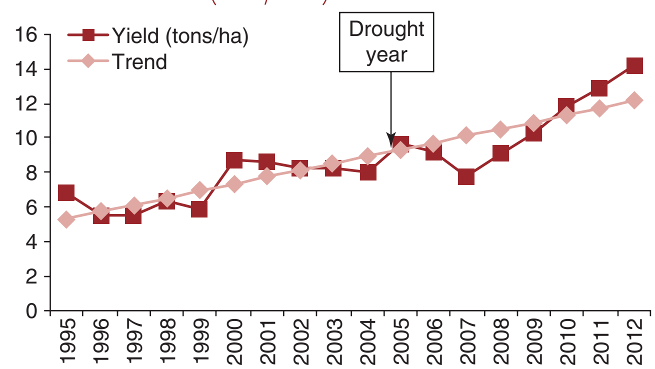
Similarly, Irish and sweet potato yields show few large dips (figures 3.6 and 3.7). The exception is for Irish potato yield in 2007, which coincides with a drought in the Eastern Province. Sweet potatoes, conversely, show no particular dips, but rather shifts in yield every half decade that affect the longer-term trend line. Nevertheless, there are no significant yield drops that can be explained by shock events.

FIGURE 3.5. CASSAVA YIELDS (MT/HA), 1995–2012



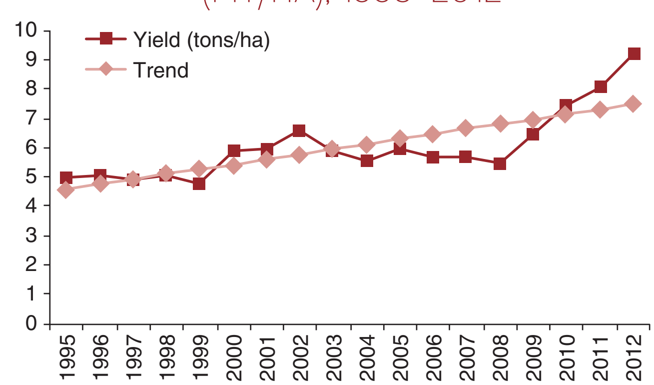
Source: FAOSTAT 2013.

FIGURE 3.6. IRISH POTATO YIELDS (MT/HA), 1995–2012



Source: FAOSTAT 2013.

FIGURE 3.7. SWEET POTATO YIELDS (MT/HA), 1995–2012



Source: FAOSTAT 2013.

Other weather-related risks are less of a concern for food crop producers in Rwanda on a systemic basis. Floods, winds, and hailstorms are reportedly a problem and can have devastating impacts for individual farmers, wiping out up to 100 percent of the harvest. However, these events tend to be highly localized and do not affect production at the national or even provincial level.

Pests and Diseases

For most food crops, the bulk of production losses are seemingly from pests and diseases. Although no data exist on aggregate annual crop losses from pest and diseases, information on the impact from individual pests and diseases indicates that losses are significant. However, the existing literature and the reporting of pests and diseases in Rwanda indicate that pests and diseases are endemic and that outbreaks are relatively localized. Thus it is not possible to see the impact of pests and diseases as shocks affecting the yield data at the national or even provincial level. Some diseases, such as cassava mosaic virus (CMV), come in cycles and do not affect all farmers simultaneously but seem to be ever present in Rwanda and likely contribute to existing yield gaps. Others, such as banana bacterial wilt (BBW) and maize chlorotic mottle virus (MCMV), were introduced rather recently and are on the rise but have yet to make a significant mark on national yield levels. Some, such as the maize stalk borer, may spread more rapidly and affect larger areas as the structure of the sector changes into larger single-crop land areas with more homogenous varieties. Finally, climate change models project a more favorable environment within which certain pests and diseases will flourish.

Unmanaged, pests and diseases cause high losses for producers in Rwanda. The main bean pests in Rwanda, the beanfly[15] and the bean *Bruchid*,[16] have been estimated to reduce bean yields nationally by as much as 25 percent and 30 percent, respectively (Trutmann and Graf 1993; Jones 1999).[17] Similarly, banana production is highly affected by diseases, particularly black sigatoka, banana bunchy top disease (BBTD), and banana bacterial wilt (or banana xanthomonas wilt [BXW]).[18,19] Depending on the disease and when the plant is infected, an individual grower may easily experience 100 percent yield loss.

For cassava, the most damaging pest is the green spider mite (*Mononychellus tanajoa*), which is widespread. In 2007, it was found to infest approximately 40 percent of all cassava plants, causing 45 percent damage on average where infestation occurred (Night et al. 2011). The cassava mosaic virus and cassava brown streak virus (CBSV) can reduce yields by as much as 95 percent. Currently CMV is more prevalent; a 2007 assessment found the disease at 94 percent of plots visited, with 32 percent of plants infected and the impact on the yield of infected plants estimated at 60 percent (Night et al. 2011). However, the disease situation in Rwanda has historically been quite fluid, with new virus diseases arising every 10–15 years (FAO 2010), and it is possible that a new form of CBSV is spreading rapidly (Bigirimana, Barumbanze, Ndayihanzamaso, Shirima, and Legg 2011). Both CMV and CBSV are spread by the white fly, *Bemisia tabaci,* and by the distribution of infected plant material.

Insect pests of rice are limited to the rice fly (*Diopsis thoracica*), the larvae of which eat out the center of young tillers, causing blind shoots. Yield losses of 5–20 percent are commonly recorded (Akinsola and Agyen-Sampong 1984), depending on the severity and timing of infestation. The impact of early infestation, if controlled by insecticides, can be mitigated by compensatory growth.

The occurrence of pests and diseases seems to be on the rise and to spread more rapidly now than in the past. For example, the potential frequency of occurrence of BBW is increasing and the disease is spreading rapidly: BBW was first found in Rwanda in 2005; by 2012, it

[15] Bean stem maggot, *Ophiomyia* spp.

[16] That is, a number of *Bruchid* species.

[17] 180–225 kg/ha; *Bruchid* species infest bean pods in the field and can then become important pests of stored beans.

[18] Two main banana pests in Rwanda (nematodes and the banana weevil) limit yield when stands of bananas are not rotated or when cultural practices are inadequate. Nevertheless, under most conditions, the risk to banana production posed by pests is minimal.

[19] A fourth banana plant disease, the Panama disease, exists in Rwanda but its risk is limited. It only affects modern banana varieties and is of no risk to the East African Highland clone sets, which are resistant to the disease and constitute the bulk of production in Rwanda.

had spread to 23 of the country's 30 districts. Similarly, levels of maize pests and diseases are currently low; until 2013, only leaf blight and maize streak virus were recorded as significant diseases of the growing crop (MINAGRI 2008). However, in June 2013, MCMV was identified in the Western and Northern Provinces. This virus is a component of maize lethal necrosis disease (MLND), a disease complex that has spread rapidly in Kenya since 2012 and can cause up to 100 percent loss of yield. This disease poses a significant threat to future maize production.

Stored crop can also be vulnerable to pests. Unless addressed, pests will continue to be a problem as grain is stored in larger volumes and for longer periods in the future. *Bruchid* species infest bean pods already in the field and can then become important pests of stored beans causing, losses of up to 30 percent (Jones 1999). The pest can also be sustained within stores under poor storage conditions. Although a minimal level of infestation is inevitable, good storage practices will constrain such infestations. This includes making use of resistant varieties, anaerobic storage, and fumigants and coating seeds with edible oil (which will kill *Bruchid* eggs). Insect damage from common pests of stored maize and rice (weevils such as *Sitophilus zeamais* and *Sitophilus oryzae*) (Dunkel, Sriharan, Niziyimana, and Serugendo 1990) is not unusual, but because grain is stored only for a short period, levels of loss have generally been low; hence, this is not a significant risk for growers or millers. However, unless addressed, this problem may increase in the future as postharvest infrastructure expands.

To a certain extent, the occurrence and losses from certain pests and diseases are predictable and attributable to suboptimal agro-environmental conditions or agricultural practices. For example, the cassava pest is ubiquitous and current control options, including breeding for resistance and biological control, have yet to demonstrate substantial success. Chemical control of the pest, although effective, is impracticable under current conditions, as the patchwork nature of smallholders' plots allows rapid reinfestation from neighboring land.[20] In the Eastern Province, infestation of the striga weed can cause high levels of maize crop loss, but as the weed's incidence is predictable, it is less of a risk and more of a constraint to production. For Irish potato growers, blight (*Phytophtera infestans*) poses a significant risk but is in part exacerbated by poor agricultural practices. The cool, wet conditions under which most potatoes are grown in Rwanda contribute to the spread of this disease, which can result in up to 100 percent loss of yield and can render inedible any tubers that might survive. Even mild infections can result in significant loss of yield. Considerable emphasis is placed on regular application of fungicides to control the disease and in some areas, growers delay planting so that the crop matures under drier conditions, although this increases the risk of yield loss caused by insufficient moisture. But the disease also flourishes in part because of poor crop hygiene, including: reduced rotation periods (the period between potato crops in the same soil should ideally be at least four years); the ubiquity of volunteer or backyard potato plants grown by noncommercial growers that can act as a reservoir for disease; and the use of infected seed (as a result of the limited supplies of clean planting material).

Because rice is grown in large areas across valley bottoms, the crop is vulnerable to the rapid spread of pests and diseases. Rice blast (*Magnaporthe oryzae*) and bacterial disease complexes (leaf and panicle blight caused by *Xanthomonas* spp. and sheath rot associated with *Pseudomonas* infection) are the major diseases causing yield loss in rice, and can affect all known varieties. Control is currently based mainly upon crop and varietal rotation, but discussions with specialists reveal that for these diseases pathogen evolution is so fast that within 3 to 4 growing seasons most grown varieties become susceptible to the extent of causing total crop failure. Lower levels of yield loss are more common, but can regularly be as much as 20 percent. Other diseases such as rice yellow mosaic virus and smuts also occur but with little impact on yield.

The changing agricultural landscape is giving rise to new risks related to pests and diseases. As noted earlier, maize losses caused by insect pests in fields are rarely significant. Maize stalk borer (*Busseola fusca*) is the only pest reported

[20] Unless blanket treatment of a large area could be carried out, but this would be prohibitively expensive.

TABLE 3.1. MAIN PESTS AND DISEASES OF SELECTED FOOD CROPS IN RWANDA

Crop	Pest	Disease
Banana	• Banana weevil (*Cosmopolites sordidus*) • Nematodes	• Panama diseases (only affect modern varieties) • Black sigatoka (*Mycosphaerella*) • Banana bunchy top disease • Banana bacterial wilt
Beans	• Beanfly (bean stem maggot, *Ophiomya* spp.) • Bean *Bruchid*	• Angular leaf spot • Anthracnose • Common bacterial blight • Halo blight • *Ascochyta* blight • Rust • Bean common mosaic virus • Root rot
Cassava	• Green spider mite (*Mononychellus tanajoa*) • Cassava mealy bug (*Phenacoccus manihoti*) • White fly (*Bemisia tabaci*)	• Cassava mosaic virus • Cassava brown streak virus
Maize	• Maize stalk borer (*Busseola fusca*) • The greater weevil (*Sitophilus zeamais*, for in-store grain) • Striga weed	• Leaf blight • Maize streak virus • Maize chlorotic mottle virus (component of maize lethal necrosis disease)
Potatoes	• Blight (*Phytophthera infestans*) • Potato viruses • Bacterial wilts (caused by *Pseudomonas solanacearum* and by *Erwinia* complexes)	• Sucking pests
Rice		• Rice blast (*Magnaporthe oryzae*) • Leaf and panicle blight (caused by *Xanthomonas* spp.) • Sheath rot (associated with *Pseudomonas* infection) • Rice yellow mosaic virus • Smuts

to have caused significant losses.[21] However, prior to 2007, maize areas in Rwanda were considerably smaller and more dispersed than they are now and the increased consolidation and importance of the maize crop that has occurred in the last five years will undoubtedly increase the probability of losses caused by pests and diseases. Again, increasing periods of storage and larger stored volumes will contribute to increases in related risks, as will global climate change, because projected temperature increases will provide a more favorable environment for pests and diseases.

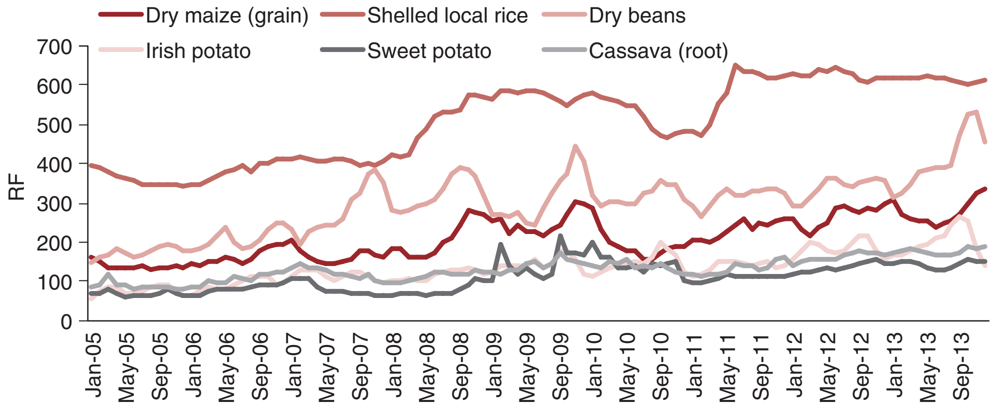
Table 3.1 gives an overview of the main pests and diseases in Rwanda. A more detailed description of the impacts from production risks on each crop is given in appendix E.

[21] Ibid.

MARKET RISKS

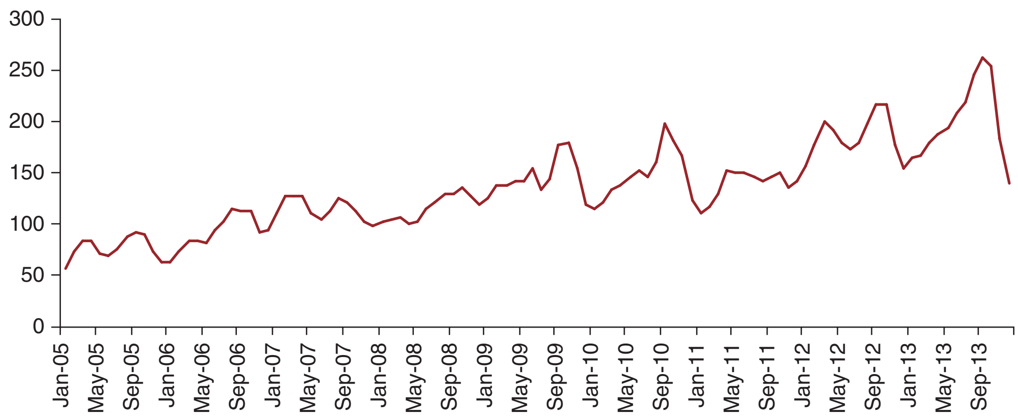
In general, market risks are limited for Rwanda's food crop producers. Because most markets are local, prices fluctuate seasonally and in direct response to supply and demand (figure 3.8). As such, price fluctuations do not constitute a risk but are rather caused by constraints. Domestic markets for commodities such as beans seem to be well integrated, with limited disparities in terms of fluctuations. Nevertheless, prices in Rwanda are to a certain degree influenced by the availability of postharvest infrastructure. The lack thereof, such as for potatoes, can cause volatilities whereas there is evidence that a developed processing industry, such as for cassava and beer bananas, tends to provide more stable producer prices for the studied commodities.

FIGURE 3.8. RWANDA FOOD CROP PRICES (RF), JANUARY 2005–SEPTEMBER 2013



Source: Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.

FIGURE 3.9. RWANDAN PRICES OF IRISH POTATOES (RF/KG), JANUARY 2005–SEPTEMBER 2013



Source: Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.

Prices in neighboring countries affect domestic prices because of trade but global price fluctuations have little influence over Rwandan prices. This is largely because high transportation costs effectively insulate Rwanda from global price fluctuations, especially for perishable commodities such as bananas. Neighboring markets have more impact, but do not show significant volatility between seasons. For certain products, such as cassava, foreign markets also help smooth price fluctuations in times of overproduction. For products such as maize, imports stabilize seasonal fluctuations. Rwanda's membership in the East African Community (EAC) and its adherence to open trade policies support this. Nevertheless, potato, rice, and banana producers (of other than beer banana) face certain marketing risks.

Potato farmers regard domestic price volatility as an inherent production risk. Potato price fluctuations are largely the result of the limited storage and processing facilities for potatoes in Rwanda; a potato shortage occurs immediately before harvest and a glut immediately after (figure 3.9). To avoid the impact of each glut, growers tend to harvest as early as possible, generally before the tubers are fully mature, which tends to reduce shelf life considerably. Price volatility is offset to some extent by three factors: (1) the fact that potatoes can be grown in two seasons in Rwanda; (2) the staggering of planting across different provinces; and (3) the import of early- or late-harvested potatoes from Uganda. Although both Rwanda and Uganda export to the Democratic Republic of Congo (DRC) and Burundi, Rwandan prices are determined almost entirely by production within Rwanda and neighboring parts of Uganda. International price volatility does not contribute to the risks involved in the production of potatoes and there is no evidence of any global market impact (for example, of potatoes from Egypt or China).

Banana growers face inherently different market risks because of the perishability and fragility of bananas. Dessert bananas are mainly grown for home consumption in Rwanda and supply chains are therefore not well developed. As a result, prices for dessert bananas can be variable and considerable risk exists in commercial production for the dessert banana market. Cooking banana prices are more stable because the fruit is harvested when it is more resistant to damage and can therefore be transported to a wider market. Nevertheless, prices still fluctuate, and in some cases, unpredictably. Growers of beer bananas report that prices offered by processors are more stable. Stable prices are also quoted as a reason for growing beer bananas in preference to the other two types, even though the beer banana yields are generally lower than those of cooking or dessert bananas. Rwanda also imports bananas and prices fluctuate in parity with markets in Uganda and, to a lesser extent, Kenya, the DRC, and Burundi. Because of reasons discussed earlier, global prices have little impact on Rwandan banana prices.

Because of the structure of the rice sector, rice producers are faced with certain income risks. Rice prices in Rwanda are determined by government policy, which sets a minimum price paid to rice mills by licensed traders. Smallholders, as members of cooperatives, receive inputs and produce rice that is purchased by mills at a price determined before the crop is sown. Traders are not allowed to buy directly from smallholders, so large mills are the only source of rice for traders. As a result of this system, neither growers nor mills face any risk from domestic price volatility; prices and potential margins are known before any investment in inputs is made. Nevertheless, such prices are not always favorable to growers; for example, in December 2013, farmers in Muhanga district complained that the price they received (RF 250/kg) was inadequate to cover the costs of production at the yield they had achieved (3.5 MT/ha). They suggested that RF 300/kg would have been appropriate to cover their costs. The cooperative's response was that prices were set before sowing and would not be increased and that farmers should seek to improve the fertility of their land for the next crop. The risk for farmers thus lies with obtaining a high enough yield to cover costs and income needs given set prices. Growing alternative crops is not an option for rice farmers, as by law, lands developed for irrigated rice production can be used only for that purpose. The stability of domestic prices, coupled with the significant costs of transport to Rwanda from seaports, create a stable domestic rice market, even though imports from Tanzania, Thailand, and Pakistan may make up 50 percent of the market volume (figure 3.9).

EXPORT CROPS

Export crops play an important role in Rwanda's economy through their contribution to export earnings even though their share in agriculture GDP is very small (about 2 percent in 2013). Tea and coffee exports account for 81 percent of agricultural exports[22] and about 20 percent of Rwanda's goods exports (WDI 2013). The value of tea and coffee exports almost tripled over the 14-year period from 2000 to 2013. With government plans to expand areas under tea and coffee, these will remain an important source of export earnings.

As export crop subsectors' structures differ from those of food crops, export crop producers face different risks. As the term "export crops" indicates, a large share of production is exported and because Rwanda is landlocked, export ports are located in neighboring countries (Mombasa in Kenya and Dar es Salaam in Tanzania). The subsectors are thus exposed to exogenous risks, including international price volatilities, exchange rate fluctuations, and other countries' trade policies.

PRODUCTION RISKS

Tea

All tea produced in Rwanda is rain fed and as such is subject to weather-related risks (see box 3.1). Figure 3.10 shows tea yields over time. The annual fluctuation in the area under tea and the total production of Made tea (conversion rate from green leaves is 4.5) over time is shown in

[22] 2008–10 figures (FAOSTAT 2014).

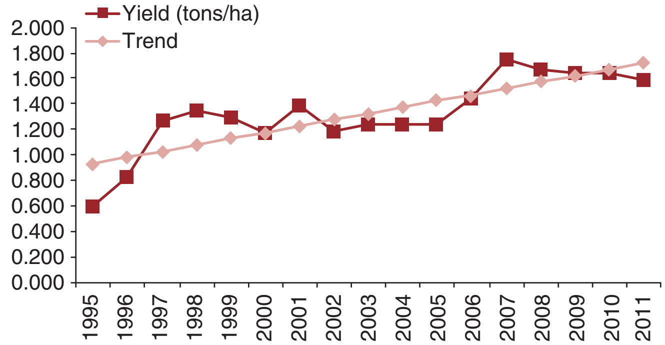
BOX 3.1. TWO ACTORS IN THE TEA SUPPLY CHAIN

Sorwathe Tea Factory was one of the first and is the largest private tea factory in Rwanda. Construction of the factory started in 1975 and tea production began in 1978. At present, the factory employs about 2,500 employees and partners with about 4,500 tea farmers who are members of the Assopthe Tea Cooperative. Sorwathe Tea Factory accounts for about 15 percent of Rwanda's tea production. The factory produces several types of tea products, including black, green, and white tea. Its total annual production is about 3 million kilograms (3,000 MT) of final product (Made tea). The total area under tea surrounding this factory is about 1,275 ha, of which 1,000 ha are under the cooperative and 275 ha are under the tea factory. A large share of the tea is produced on marshlands that are subject to floods during the two rainy seasons. The cooperative must maintain the drainage system on a regular basis and rehabilitate the drainage system, when needed, to keep it operational. The Assopthe Tea Cooperative accounts for about 75 percent of green leaf tea production in the production zone of the factory (the rest is produced by the factory itself). The factory has plans to expand its capacity as well as the variety of tea products offered in the future.

Pfunda Tea Cooperative is another key actor in Rwandan tea production. This tea plantation began in 1972, and tea farmers were later organized into Pfunda Tea Cooperative, which presently has 1,988 members. The cooperative sells its green tea leaf production to the Pfunda Tea Factory. Green leaf tea production increased from 4,554.5 MT in 2005 to 7,457.2 MT in 2013, an almost 64 percent increase in eight years. About 776 ha are under tea production. A large share of the tea is produced on marshlands that are subject to floods during the two rainy seasons. As with the Assopthe Tea Cooperative, Pfunda Tea Cooperative has to maintain the drainage infrastructure on a regular basis and rehabilitate it when necessary to maintain green tea leaf yields. In 2013, tea on about 12 ha was destroyed by floods.

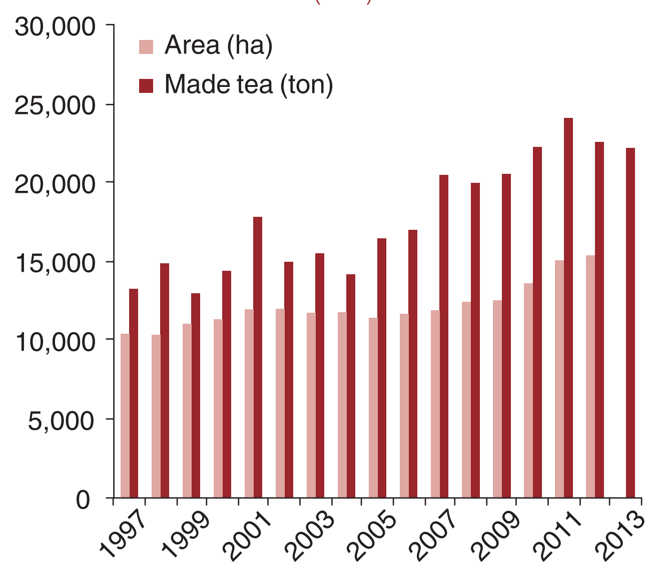
Source: World Bank interviews with cooperatives.

FIGURE 3.10. TEA YIELDS IN RWANDA (MT/HA), 1995–2011



Source: FAOSTAT 2014.
Note: Yield figures are derived from production and area figures.

FIGURE 3.11. TEA PRODUCTION (MT) AND AREA (HA), 1997–2013



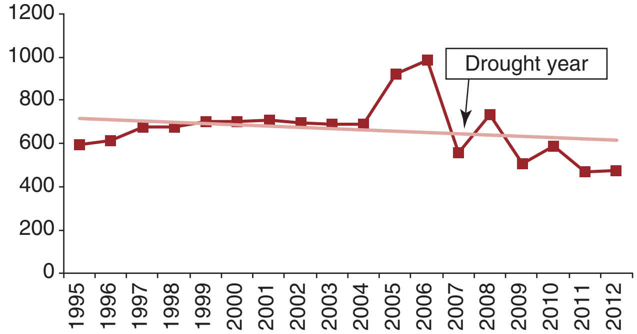
Sources: NISR 2013; NAEB 2014.
Note: NAEB = National Agricultural Export Board.

figure 3.11. In 1999, 2002, 2004, 2008, 2011, and 2012, tea yields were the result of unpredictable weather events, that is, erratic rains, drought, and floods in marshlands. Although pests and diseases have limited impact on tea production, diseases carried by insects are correlated with weather incidents as dry weather makes tea bushes more susceptible to these diseases.

Tea planted on marshlands is subject to floods caused by heavy rains. This is particularly the case in the Northern and Western Provinces. One tea cooperative recently lost 12 ha (out of 776 ha) of tea because of floods, which now need to be replaced. Another reported about 20 ha (out of 575 ha) lost in 2012, damaging some 260,000 trees. Drainage needs to be regularly maintained to avoid flooding.

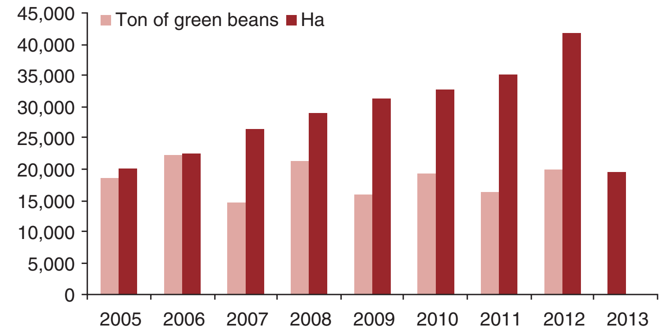
Hailstorms damage tea leaves and prevent plucking for up to three months in affected areas. One cooperative with a tea plantation in a marshland reported that hailstorms used to

FIGURE 3.12. COFFEE (GREEN BEANS) YIELDS (KG/HA), 1995–2012



Sources: FAO for 1995–2004; NAEB for 2005–12.
Note: NAEB data are inconsistent with FAO data for some years and thus NAEB data were used when available.

FIGURE 3.13. COFFEE PRODUCTION (MT) AND AREA (HA), 2005–13



Source: NAEB 2014.

affect about 2–3 ha, but that in 2013, 113 ha were damaged because of hailstorms, affecting about a fifth of the cooperative's productive land. Nevertheless, it is difficult to assess the impacts that these types of risks have at the national level.

Coffee

Drought, pests, and diseases are all major production risks to coffee in Rwanda. Coffee yields have been somewhat turbulent since the mid-2000s, with important drops in coffee production in 2007, 2009, and 2011, but the overall trend is downward sloping (figure 3.12). This decline in coffee yields was the result of: (1) bad weather, including erratic rains, floods, and drought; and (2) outbreaks of coffee pests and diseases, including intestia, coffee berry disease (CBD), and coffee leaf rust (CLR). Coffee is very sensitive to drought conditions during the flowering and bean formation period from October to March, and there is a clear relationship between coffee yield and drought, as seen in 2007 (EARS 2008). The 2010 drought also reportedly had an impact on coffee yields in the affected provinces (Eastern and Southern) but this is not reflected at the national level.

Farmers reported other weather-related risks that affect coffee, including hailstorms (which affect the quality and weight of the coffee cherry) and mudslides caused by heavy rains. However, these risks are highly localized and do not have systemic impacts on Rwanda's aggregate or even provincial coffee production.

Although the drop in yields is masked in the aggregate to some degree by an increase in area planted, weather-related risks still affect overall production levels. Figure 3.13 shows coffee production in Rwanda and the total area planted; yield changes clearly affected total production, with production drops in 2007, 2009, and 2011. Although coffee production in 2012 and 2013 was somewhat similar to that in 2005, it would have dropped significantly if the area planted had not doubled between 2005 and 2012.

Pests and/or Diseases Risk

Unlike tea, coffee is seriously affected by insects and diseases. The most common disease is CLR, caused by *Hemileia vastatrix*. Coffee yields in Rwanda are generally low and coffee plants are not in good health; plants are therefore more susceptible to insect and disease attacks than they would be otherwise. Research demonstrates that CLR exists across Rwanda, but in the Eastern Province, almost 100 percent of the plants surveyed were affected. Losses range from 30–90 percent, depending on environmental conditions and varieties. Higher altitudes are less affected (previous research found a negative correlation between altitude and CLR of –0.71). Further, the varieties most commonly grown in Rwanda are especially susceptible to the disease. Other pests such as coffee leaf miner, stem borer, and antestia bugs are also a problem. In the Northern Province, as much as 35 percent of all coffee plants are estimated to be infested with coffee leaf miner, and antestia can reportedly destroy over 35 percent of coffee yields (Bigirimana, Barumbanze, Ndayihanzamaso, Shirima, and Legg 2012). CBD is currently a minor disease in Rwanda but as with CLR, the coffee varieties grown in Rwanda are susceptible to CBD and the agro-climatic conditions are advantageous for the disease.

CBD epidemics are therefore deemed to be a potential risk to Rwanda's coffee growers (Bigirimana, Barumbanze, Ndayihanzamaso, Shirima, and Legg 2012). REMA has developed a national Integrated Pest Management (IPM) framework in the context of the Lake Victoria Basin in Rwanda. This IPM framework should be relevant for controlling coffee pests and diseases as well as pests and diseases for other export and food crops.

Potato Taste Risk: So-called "potato taste" in coffee is a big problem in Rwanda. No consensus exists as to what causes potato taste, but most experts believe it is caused by the antestia bug. This insect enters coffee cherries on plants that are not very healthy. According to some ad hoc estimates, almost 60 percent of coffee in Rwanda is affected by potato taste. One coffee exporter in Kigali reported that 9 out of 16 containers (56 percent) were rejected by Starbucks because of potato taste. In the Rwanda Cup of Excellence competition, 60–65 percent of samples were found to have potato taste. The direct impact of potato taste is a drop in coffee price by 15 percent or more, which results in almost US$5 million in annual losses of export earnings.

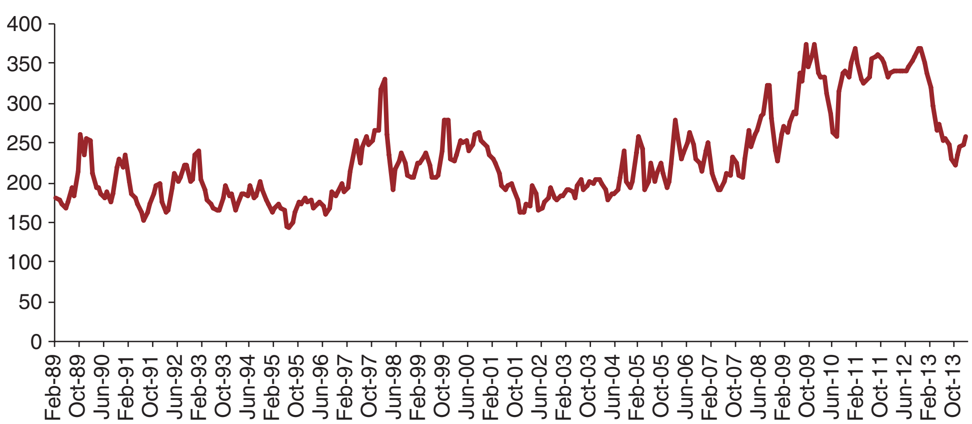
MARKET RISKS

Price Risks for Tea

Tea production prices in Rwanda are fixed by the National Agricultural Export Board (NAEB) every four months based on a range of factors, including international auction prices and the exchange rate. Figure 3.14 shows the fluctuations in tea prices at the Mombasa auction (where all Rwandan tea is sold) over the past 15 years. These fluctuations are reflected in the farm gate prices for leaf tea, which increased by 31 percent in 2013 and declined by almost 18 percent in 2014. Effective as of 2012, NAEB switched from a cost-based price model to the international price-based model to fix the floor price. However, most of the fall in prices is absorbed by farmers, and the farmers interviewed complained that prices are currently insufficient to cover input costs. As a result, farmers may reduce input use, reduce investment in the rehabilitation of drainage, or delay replacement of old tea plants (for example, 30 percent of tea plants need to be replaced at one cooperative visited). All of this will affect green leaf tea yield, Made tea production, and farmers' profitability over time.

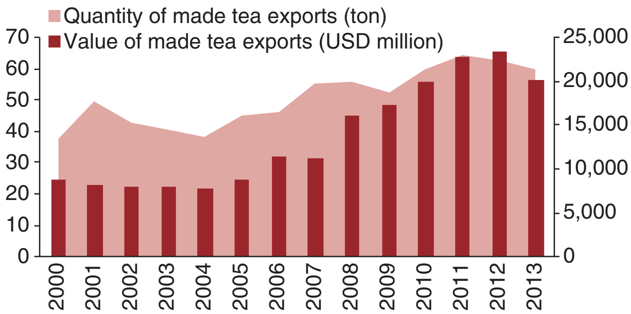
Fluctuations in tea production and prices also affect Rwanda's export earnings. The value of Rwanda's tea exports tripled between 2000 and 2013, but growth has not been consistent because both the quantity exported and international tea prices have also fluctuated. Figure 3.15 shows the quantity and value of tea exports from 2000 to 2013. It is evident that declining prices played an important role in the value of tea exported, especially in 2001, 2005, 2007, and 2013.

FIGURE 3.14. MONTHLY PRICES OF RWANDAN TEA AT THE MOMBASA AUCTION (U.S. CENTS/KG), FEBRUARY 1989–OCTOBER 2013



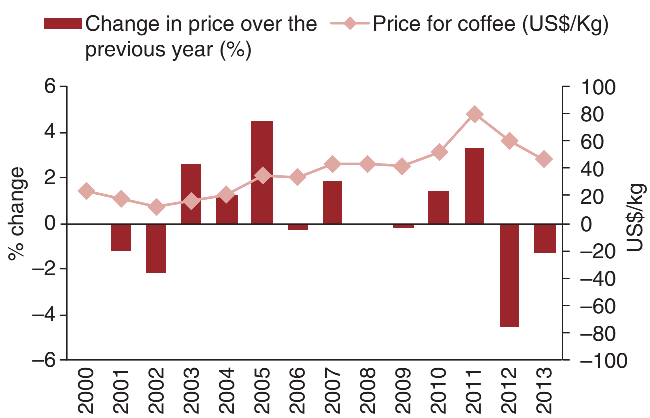
Source: NAEB 2014.

FIGURE 3.15. VOLUME (MT) AND VALUE (US$ MILLION) OF RWANDAN TEA EXPORTS, 2000–13



Sources: MINECOFIN 2013a; NAEB 2014.
Note: Percentage share is calculated by the authors.

FIGURE 3.16. COFFEE PRICES IN RWANDA (US$/KG), 2000–03

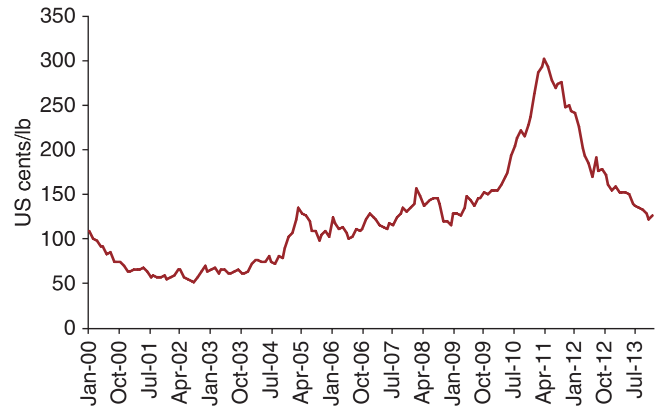


Source: MINECOFIN 2013a.

Price Risks for Coffee

Because coffee is sold in the international market, Rwanda's coffee prices follow international prices (figures 3.16 and 3.17). Coffee prices have no consistent predictable pattern, but they do depend on the international markets. Coffee prices experienced a significant decline during 2001 and 2002 as well as during 2012 and 2013; they increased linearly between 2003 and 2011; and in 2006, 2008, and 2009, coffee prices declined slightly or remained stable. Processors and exporters tend to hedge against price volatility risk through forward contracts or other such mechanisms,

FIGURE 3.17. MONTHLY INTERNATIONAL COFFEE PRICE (U.S. CENTS/LB), JANUARY 2000–JULY 2013



Sources: International Coffee Organization: New York ex-dock cash price for other mild Arabica coffee.

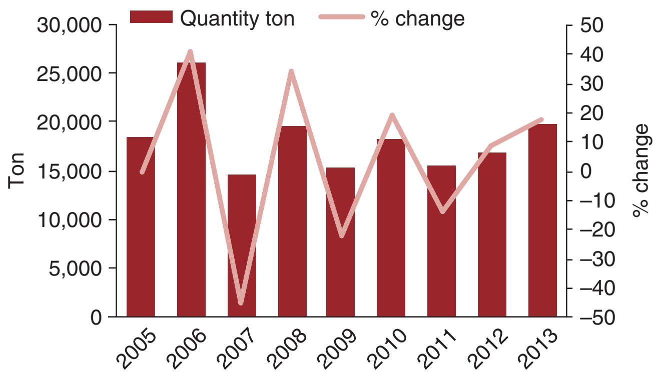
but farmers and washing stations are more exposed to these price changes. The farmers with whom the World Bank team met confirmed that prices are unpredictable; one farmer reported that in 2013, prices varied from RF 130 to 350/kg for coffee of the same quality. According to this farmer, coffee price fluctuations are his main concern as they make it difficult for him to plan his production activities.

Annual coffee price volatility has a major effect on Rwanda's national export earnings (figure 3.18). The value of coffee exports declined over the previous year in 2001, 2002, 2007, 2009, 2012, and 2013, primarily because of two factors: a decline in coffee production and a decline in the international price of coffee. In 2011, the quantity exported declined but export earnings increased because of an increase in coffee prices in the international market. In 2012 and 2013, the value of coffee exports declined because of a decline in international coffee prices, even though the quantity exported increased (figure 3.19).

Exchange Rate Fluctuations Risk

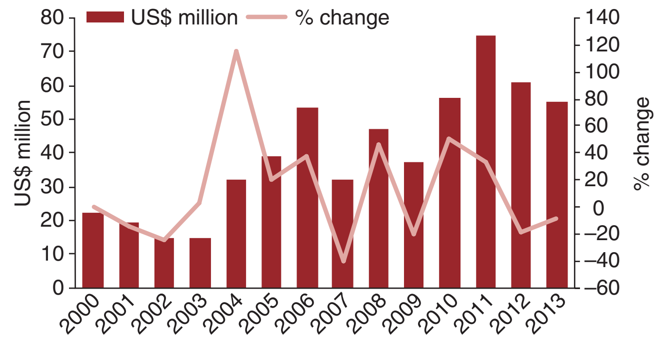
Because both tea and coffee are exported in USD but the farmer is paid in RF, farmers are subject to exchange rate fluctuations. The final impact on farmers, however, depends on which currency appreciates or depreciates.

FIGURE 3.18. FLUCTUATIONS IN THE VOLUME OF COFFEE EXPORTS FROM RWANDA (MT), 2005–13



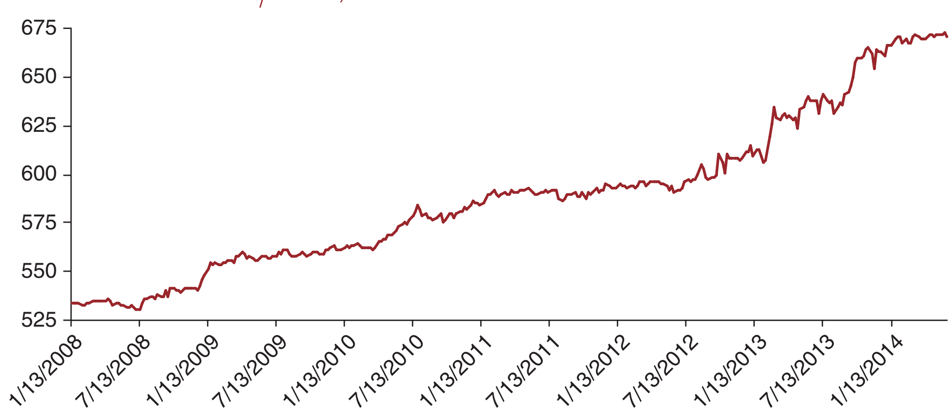
Source: NAEB 2014 from 2005 onward.

FIGURE 3.19. FLUCTUATIONS IN THE VALUE OF COFFEE EXPORTS FROM RWANDA (US$ MILLION), 2000–13



Sources: MINECOFIN 2013a for 2000–04; NAEB 2014 for 2005–13.

FIGURE 3.20. AVERAGE WEEKLY EXCHANGE RATE OF RF/USD, JANUARY 2008–JANUARY 2014



Source: Oanda, www.oanda.com/currency/historical-rates/.

Similarly, fertilizer prices in USD are converted into farm gate prices in RF by using the prevailing exchange rate. Although exchange rate fluctuations can favor farmers, they can also work against them, as farmers have no protection against them. However, exchange rates have not been overly volatile in past years. Instead, the value of the RF has steadily depreciated, which favors Rwanda's producers and processors, depending on who captures the gains. Conversely, any imported inputs, like fertilizers, will be more expensive. Regardless, exchange rate fluctuations cannot be considered a significant risk to Rwanda's agricultural export (figure 3.20).

ENABLING ENVIRONMENT RISKS

Contract Enforcement (Counter Party Risk): Coffee processors and exporters have contracts with farmers and/or washing stations to deliver cherries and/or parchment at a certain time and price. Depending upon the market price and other prevailing conditions, the terms and conditions of the contract are not always fulfilled. Although Rwanda has made substantial progress in improving contract enforcement, there is still scope to make more improvements, as noted by coffee stakeholders in Rwanda.

Logistics Risk: Rwanda is a landlocked country, known to be made up of a thousand hills. Landslides are common, particularly in the Northern and Western Provinces. Landslides damage roads and bridges and pose domestic transportation risks. Reportedly lengthy border crossings and insecurities in other countries add further logistical risks. Nevertheless, although many transportation- and logistics-related problems exist, these are mainly predictable constraints rather than risks.

LIVESTOCK (DAIRY AND MEAT)

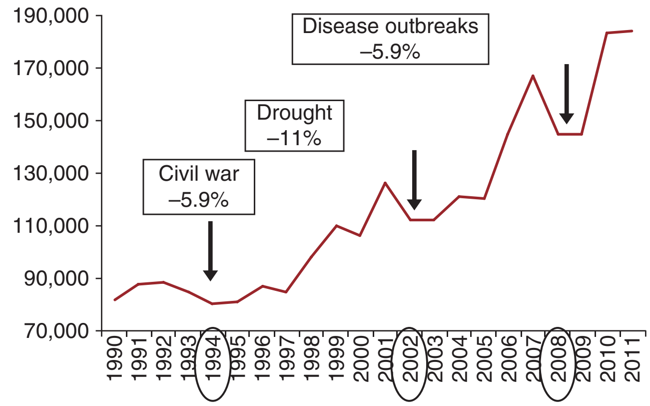
Livestock are important to households in terms of income and food security and for the organic manure produced, which is applied in the fields. According to NISR, half of all households own a goat, cow, and/or chicken. Of livestock units, 68 percent are cattle. The key risks for the milk value chain occur first at the production level, then at the marketing level (that is, bulking/collecting and transporting), and finally at the retailing stage. For meat production, the main risks are related to production and prices. Enabling environment risks are limited for both milk and meat.[23]

PRODUCTION RISKS

Milk production has increased exponentially since the mid-1990s, but shocks to production have been incurred on the way. Overall, three years had systemic shocks to milk production at the national level: in 1994, a 6 percent loss in milk production was experienced because of the war; in 2002/03, a major drought (affecting 1 million people) led to an 11 percent loss in milk production; and in 2008, multiple disease outbreaks of anthrax, lumpy skin disease and foot and mouth disease caused a 13 percent loss in milk production compared with the previous year's production (figure 3.21).

[23] The national production data series covered about 12 years; therefore, the team relied on FAOSTAT data, which are available from 1961. The disease data were based on OIE data, which were available from 1997, but with a gap between 1998 and 2002. With regard to price data, the team relied on FAOSTAT data, which were only available from 1995. Therefore, the analysis concentrates on the period between 1990–2011, depending on data availability.

FIGURE 3.21. SYSTEMIC LOSSES TO MILK PRODUCTION (WHOLE, FRESH, COW) (MT), 1990–2011



Source: FAOSTAT 2014.

Drought: A drought affects livestock production in a number of ways. Primarily, animals' water intake is reduced, which affects their production. Therefore, supply of water is critical for livestock well-being and production. Second, the water available for production is reduced, which affects activities such as cleaning of animal sheds and milk hygiene and handling. This tends to increase the incidence of disease among cattle and affects the quality of cattle products. Last, the availability of feed is affected. This is especially true in Rwanda, where access to commercial feeds is limited, and thus farmers rely on rain-fed pastures and open water sources.[24] Milk production can decrease by as much 60 percent during a drought (Olsson 2012). As table 3.2 shows, the 2002/03 and 2007/08 droughts had the highest impact on milk production and milk yield over the last decade. In both cases, despite an increase in the number of milking animals, milk production fell because of lower water availability, which resulted in less milk produced per cow (that is, lower milk yield). In contrast, national milk production and milk yield significantly increased in 2010, despite a drought in the Eastern Province. Arguably, good rains and improved breeds increased production in

[24] http://amor.cms.hu-berlin.de/~h1981d0z/pdf/2006-02-kenia/kabete-lect.pdf (accessed February 2014); and TechnoServe Rwanda 2008.

TABLE 3.2. IMPACT OF DROUGHT AND DRY SPELLS ON MILK PRODUCTION, SELECT YEARS

	2002/03	2005	2007/08	2010
Change in milk production (%)	−11	−1.2	−13.0	26.7
Change in heads of milking animals (%)	8.9	−0.4	9.9	0.9
Change in milk yield (%)	−18.3	−0.8	−20.8	25.5

Source: FAOSTAT, 2014.

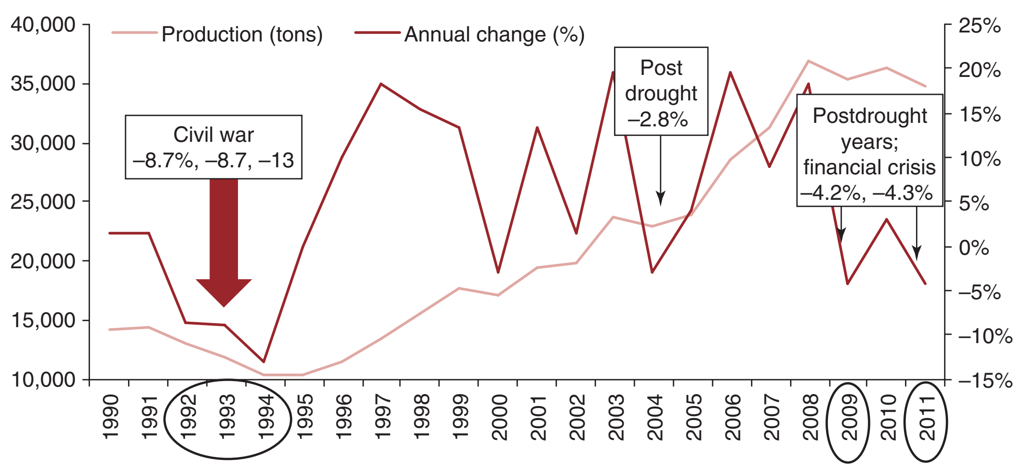
other parts of the country, so the provincial drought did not affect national milk production.

Drought has less impact on meat production than on milk in Rwanda, although this is likely to change in the future. The dry spells and droughts of 2002/03, 2007/08, and 2010 seem to have had a lagging effect, in that the decrease in production is visible a year after the event, rather than during the drought year (figure 3.22). Nevertheless, the impacts are limited. For example, the 2005 drought did not register on meat production at all. The 2009 drop in production was likely to have been exacerbated by the global financial crisis, which had an impact on both production and prices.

Both the amount of meat produced and prices increased, whereas the proportion of slaughtered animals did not go above the average in the 2000s except in 2008. However, the government developed a strategic plan to increase meat production to 165,000 MT, of which beef will contribute about 60,000 MT. This will require improved beef and other meat breeds, which will increase the water requirements for animal production as well as food requirements. Currently, the livestock sector relies on rain-fed fodder and pastures to feed the national herd, a situation that will not be feasible in the future if targeted production is to be achieved. Thus, as meat production increases, it is anticipated that drought risk will become more important to the meat industry.

Past decades' droughts have led to the displacement of livestock in the affected areas, which has negatively affected the sector. Droughts often force pastoralists to move their herds in search of feed and water, sometimes to neighboring countries or into national park areas. The cattle do not cope well during these long moves and yield less milk as a consequence, or even die in extreme cases. These moves also result in herds being mixed, and livestock being in contact with wild animals, both of which increase the spread of diseases. FMD is a particular problem, as wild animals are carriers of the disease. The movement of animals between countries increases the risk of transferring diseases across borders.

FIGURE 3.22. SYSTEMIC LOSSES TO BEEF PRODUCTION, 1990–2011



Source: FAOSTAT 2014.

TABLE 3.3. TOTAL NUMBER OF LIVESTOCK-RELATED DISEASE OUTBREAKS, 2002–12 (AVERAGE)

Disease	New Outbreaks	Susceptible	Cases	Deaths	Destroyed	Slaughtered
FMD	48	266,429	758	93	262	68
CBPP	12	351,219	1,706	97	27	-
LSD	123	730,195	2,434	81	91	-
Anthrax	160	929,906	2,097	362	122	106
Total	343	2,277,749	6,995	633	502	174

Source: OIE 2014.

Diseases: Livestock diseases can have a significant impact on the sector. Among the most common disease outbreaks are FMD, contagious bovine pleuropneumonia (CBPP), anthrax, black quarter, and LSD (table 3.3). The increase in incidence is attributed to the movement of cattle across the borders with Uganda, Tanzania, and the DRC. In the event of an outbreak, RAB quarantines the affected area(s),[25] such that all livestock and livestock products cannot be sold or transported out of the affected area until the ban is lifted, causing a disruption in trade as well as the possibility of discounted prices. In addition, depending on the nature of the outbreak, the government might slaughter and destroy[26] animals and animal products within the affected area. The losses incurred depend on the size of the affected area, the number of farms and animals within the area, and the outbreak's duration.[27]

Underlying the aggregate numbers in table 3.3 is significant variability, with years when no outbreaks occurred and years when there were several. Additionally, there is variability in the number of susceptible animals and the number of cases, deaths, animals destroyed, and animals slaughtered in any given outbreak. Therefore, each outbreak is unique, creating uncertainty for the government as it plans and prepares for livestock epidemics, a situation complicated by the government's limited resources.

Both 2008 and 2012 were devastating years for Rwanda's livestock sector caused by the high number of disease outbreaks (table 3.4). These two years accounted for half of all new outbreaks, the number of susceptible animals, and the cases seen in the 2000s. Furthermore, a third of deaths and animals destroyed occurred in these two years. FMD, anthrax, and LSD epidemics struck in both years; however, besides LSD, the dominant disease outbreak in 2008 was FMD, whereas in 2012 it was anthrax.

Although the impact of transboundary diseases is thought to have been quite high in 2012, data were not available and it was therefore not possible to determine the impact on milk production. Milk production decreased by 13 percent in 2008 from 2007, primarily because of the disease outbreaks mentioned above. This translates into an estimated US$10 million[28] loss in milk-related income to farmers and US$163,000[29] in the value of destroyed, slaughtered, and dead cattle. These figures do not include the direct costs of disease control measures.

Aflatoxins: Aflatoxins are toxins produced by mycotic organisms that grow in poorly stored animal feed. In countries with developed animal feed industries, aflatoxins have been known to cause poisoning that could lead to death depending on the level of contamination.

[25] Interviews with MINAGRI staff.

[26] "Destroyed" refers to animals having to be killed and disposed of and so they cannot be used for commercial purposes because of disease, as opposed to "slaughtered," which means that some of the animal's value may be retained through sales.

[27] http://www.oie.int/doc/ged/D9251.PDF. Accessed February 25, 2014.

[28] Based on FAOSTAT milk production and prices. Estimated as the difference in milk production between 2007 and 2008 multiplied by the average milk price in 2008.

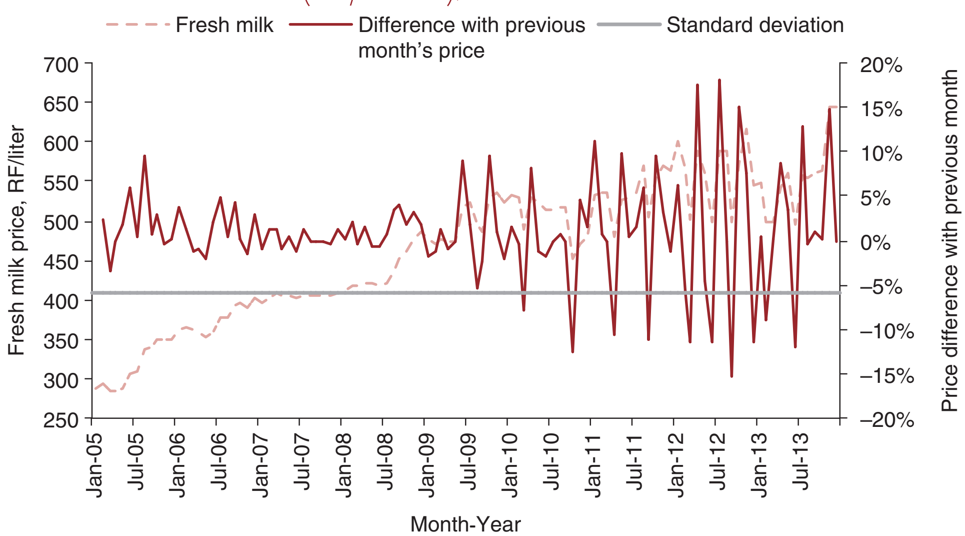
[29] Based on OIE data, the "Dairy Value Chain in Rwanda" report, and the NISR *Statistical Yearbook 2012*. The report estimates the value of an exotic bull to be RF 500,000, which is also assumed to be the average value of a milking cow. The total number of destroyed, slaughtered, and dead cattle were multiplied by the estimated value in RF and then converted to USD.

TABLE 3.4. AVERAGE NUMBER OF DISEASE OUTBREAKS ANNUALLY IN 2002–11 VERSUS 2008 AND 2012

Period	New Outbreaks	Susceptible	Cases	Deaths	Destroyed	Slaughtered
Average 2002–11	21	106,837	370	45	39	19
Actual 2008	41	470,860	191	58	120	-
Actual 2012	117	845,358	3,472	168	27	-
Total 2002–12	343	2,277,749	6,995	633	502	174
2008 % of total	12%	21%	3%	9%	24%	0%
2012 % of total	34%	37%	50%	27%	5%	0%

Source: OIE 2014.

FIGURE 3.23. MONTHLY RETAIL PRICE VARIABILITY OF FRESH MILK (RF/LITER), JANUARY 2005–DECEMBER 2013



Source: NISR.

MINAGRI is promoting intensification of dairy farming, which will require commercial feed production and distribution. To this end, the Ministry is supporting the construction of animal feed factories, two of which are now under construction. Aflatoxin is a challenge that could destroy the industry unless its regulation and enforcement are introduced in the nascent stages of the industry's development.

Maize Production Shortages: As the animal feed industry grows, it will require a consistent and reliable supply of maize, the main ingredient, comprising about 60 percent of the feed. Therefore, should a shock affect maize production, the animal feed industry would suffer, and the cost would be passed onto farmers. There are few signs that this has affected production in the past, however.

MARKET RISKS

Domestic Milk Price Volatility: Annual milk production increased exponentially from 55,577 liters in 1999 to 503,130 liters in 2012,[30] resulting in a decrease in imports. Today, the proportion of imported milk is less than 1 percent of all milk consumed in Rwanda, shielding the domestic market from international price volatility.

As the gap between domestic milk supply and demand has narrowed, domestic price volatility has increased. As figure 3.23 shows, the price of milk steadily rose as consumer demand increased. However, as milk supply approached milk demand, prices became increasingly more volatile, with several dips below the standard

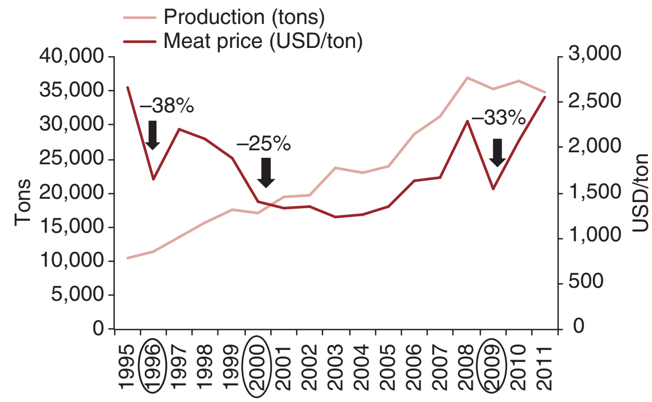
[30] Livestock data from MINAGRI.

deviation beginning in January 2010. With the availability of water in the wet season, a price drop is expected; however, the monthly price difference is widening. A 15 percent drop in the milk price (as seen in September 2012) would lead to significant losses in household income for dairy farming households. The reason for this volatility is not clear. In general, this kind of price volatility can occur when daily milk consumption is fairly constant (that is, demand is relatively stable), as even small shifts away from equilibrium supply levels will lead to high price volatility. Similarly, high demand price elasticity for milk may magnify volatility at smaller changes in supply, as consumers will be quick to respond to price changes. Differences between supply and demand, upward price pressure from processors, and a quality-related price premium on milk are some of the explanations given by actors in the sector. At the consultative stakeholder meeting, questions were raised regarding the quality of the price data. A deeper analysis is needed to understand if and why the price volatility reflected in the data exists, but this is beyond the scope of this analysis.

Meat Price Risks: Meat prices have seen both multi-annual decreases and increases over the past decades, with several deviations from longer-term trends (figure 3.24). The fact that animals are slaughtered on order or based on a contract partly mitigates this. Because meat is sold fresh, butchers and retailers order based on their experience of what their customers will be able to buy. However, price drops definitely have implications for farmers, who assume most of this risk. Using a drop of ≥25 percent as a threshold, the frequency of price shocks is one in five years. Anecdotal evidence suggests that prices were quite high immediately following the war because of low availability of meat on the market. As production increased, prices gradually reduced to a low of US$1,238/MT in 2003 except for sharp falls in 1996 and 2000 (of 38 percent and 25 percent, respectively). After 2003, prices consistently increased until another sharp drop of 33 percent in 2009.

The causes of the shocks in 1996 and 2000 are not clear, but prior to both events there were three or more high-production years before the fall in prices. In 2000, meat production dropped slightly in parallel with the price

FIGURE 3.24. MEAT PRICES (US$/MT) AND MEAT PRODUCTION (MT), 1996–2011



Source: FAOSTAT 2014.

drops (by 2.9 percent). The level of imports and exports were on average below 1 percent of production over the period analyzed and are therefore thought to have had a minimal effect on prices. The 2009 event was driven by the impact of the global financial crisis on the Rwandan economy, which slowed down in 2009. The 2009 real GDP growth rate was 6.2 percent and real GDP per capita was 3.2 percent, compared with an average of 8.2 percent and 5.1 percent, respectively, between 2008 and 2012 (Ministry of Finance and Economic Planning [MINECOFIN 2013b]).

Potential for Milk Contamination: Only about 20 percent of the milk in Rwanda is processed; the rest is either marketed directly in the community or through traders and retailers. For milk not sold directly in the community, milk aggregators are the key to bringing economies of scale to milk processors and traders, as Rwanda's herd sizes are too small to supply individually. Monitoring of standards is limited at milk collection centers (MCCs) and farmers have differing milk handling standards and levels of hygiene. Further, hygiene standards differ widely between MCCs. Because the majority of marketed milk is not pasteurized, this creates a risk for contamination, particularly with *Salmonella* spp., *Escherichia coli*, and *Brucella* spp. Traders and consumers generally boil milk before it is sold or consumed, respectively, thus mitigating the risk of contamination. However, this practice is not strictly enforced, so there is a risk of milk spoiling and/or infecting consumers with a virulent strain of bacteria. Depending on the size of the batch, this can have large consequences for consumers and suppliers. Because of interruptions in electricity supply, the cold chain is not necessarily kept cold and the current conditions are conducive to the evolution of a heat-resistant and highly virulent bacterial strain.

The risk of contaminated milk lies both with consumers and producers. Consumers are at risk of being infected by contaminated milk; producers, traders, and retailers risk losing markets if they deliver contaminated milk. For traders and retailers, the main concern is shelf life. Because contaminated milk spoils more quickly and has a shorter shelf life, traders and retailers risk returns on milk stocks if they do not last as long as expected. As milk consumption is still relatively at a low level, this is currently not a significant problem. Nevertheless, if past years' increases in milk continue, the risk of contaminated milk is likely to have broader impacts in the future.

Potential for Meat Contamination: MINAGRI's Strategic and Investment Plan to Strengthen the Meat Industry in Rwanda highlights the constraints related to the sanitary conditions in which meat is slaughtered, transported, and sold. Given the low level of meat consumption in Rwanda, sanitary conditions are considered future risks that will have to be addressed as the meat industry grows, but are of limited risk at present.

ENABLING ENVIRONMENT

Drug and Livestock Inputs' Contamination and Adulteration Risk: Similar to the risks mentioned above, contamination and adulteration are risks that the livestock sector could face in the future. The regulation of the veterinary drug industry is the responsibility of RAB under MINAGRI. However, its capacity to monitor and regulate veterinary pharmacies is limited, and it currently does not have the resources (financial and human) or facilities to test the drugs on the market. As this report has shown, diseases pose a real threat to the sector, so it is important that the main method of solving and mitigating disease risk does not become a threat itself.

REGULATORY CHANGES IN THE AGRICULTURE SECTOR

During the work on this report, many stakeholders in the private sector (particularly processors) pointed out risks to the regulatory environment in frequent policy changes that make investments unpredictable. However, an overview of government policy over the past decade does not reveal erratic agricultural policy changes (table 3.5). Importantly, no subsector has been specifically targeted or favored through specific tax and/or trade regulations. The exception seems to be to encourage the domestic processing industry through regulation of raw material (leather) and tax breaks (processed coffee). Also, Rwanda adheres to the East Africa Common Market Protocol, which was introduced in 2010 and should enhance the predictability of trade policy.

TABLE 3.5. SUMMARY OF REGULATORY CHANGES IN RWANDA'S AGRICULTURE SECTOR, 2001–13

Date	Reform/Change	Note
2001	GoR lifts the ban on milk imports from Uganda	Ban imposed in March 1999.
2005	Income Tax Act (profit and income tax rules and rates) or Law 16/2005	Exemptions related to agriculture sector: • Farm enterprises are exempt from tax with turnover up to RF 12 million/year. • Agricultural and livestock products except for those processes (locally processed milk is exempt) as well as agricultural inputs and equipment
2005	Ban on importation of poultry products by GoR	Outbreak of avian flu.
Sept 2005	Ban on export of raw hides and skins	The official position of GoR was that of developing the leather industry.
Sept 2005	The ban on export of raw hides and skins is temporarily recalled	The first decision was implemented without notice—leaving large stocks with no market. This decision was meant to allow those involved to resume for three more months. At the end of this period, companies were expected to have made progress toward setting up tanneries to produce the material locally.
2008	Import tariff decreased on food products	
2008	GoR lifts ban on the importation of poultry products	
2009	GoR temporarily lifts ban on export of raw hides and skins	Prices of raw/unprocessed hides and skins went down in the meantime (2005: RF 1,500/kg; 2008: RF 500/kg)
2010	GoR removes export tax on owners of coffee processing facilities	
2010	The East Africa Common Market Protocol comes into effect, allowing free movement of goods, services, capital, and labor among Members	
2012	Law passed governing agrochemicals (fertilizers, pesticides), placing them under regulated imports and introducing requirements for imports	
2012	New guidelines on milling and trade of rice	
2012	Rwandan Cabinet approves a tea pricing mechanism that provides market-based pricing and rewards quality standards (the previous mechanism was cost-based)	This mechanism means that farmers who produce high-quality green leaf tea will earn more. In turn, the quality and price of tea made by factories will increase.
Sept 2013	18 percent VAT charge introduced on processed staple foods, including rice	

CHAPTER FOUR
ADVERSE IMPACTS OF AGRICULTURAL RISK

The existence of agricultural risk has negative consequences for the productivity and production of agricultural commodities as well as the level of profits and investments in agribusiness for various supply chains. This can be measured in the form of losses resulting from the prevalence of various agricultural risks. The purpose of this chapter is to quantify the production losses for individual food and export crops in different provinces of the country, as well as the aggregate losses. This is important to understand how frequently risks occur, the volume and monetary value lost in each risk event or for each crop, and the geographic distribution of these losses. Ultimately, this will help in identifying and targeting risk management interventions in a way that has the greatest ability to minimize risk-related losses.

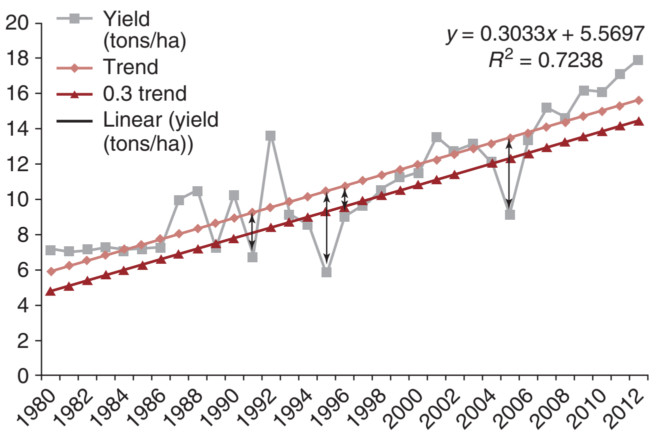
THE METHODOLOGY USED TO ESTIMATE PRODUCTION LOSSES

Losses that occur because of agricultural risks refer primarily to production losses caused by weather-related events such as droughts, floods, erratic rains, landslides, hailstorms, and diseases and/or pest outbreaks. The following method was applied to calculate production losses in a particular year: (1) a historical linear trend line for the yield of each crop was constructed; (2) a second linear trend line was drawn, representing one-third of the standard deviation of the crop yields; (3) loss years were identified as those in which actual yields were lower than the linear trend line; (4) production losses were calculated using the difference between the predicted value (the original trend line) and actual yield; and (5) losses were totaled and divided by the total number of years examined to determine the average annual loss rate for a particular crop; (6) the annual quantity lost was converted into value terms by using the producer price for each crop; and (7) because producer prices are in local currency, the value was converted to U.S. dollars using the average exchange rate. Figure 4.1 shows the outcome of steps (1)–(5) for a hypothetical crop.

Information about the production loss for a particular crop and in a particular year can also be used to (1) calculate the loss as a share of agricultural GDP for that crop in a particular year; (2) add production losses for different crops to estimate aggregate production losses for all crops; and (3) add the production losses of all crops over a number of years to estimate the indicative production losses in a particular period.

Most of the data used in the loss analysis were obtained from the FAO Corporate Statistical Database (FAOSTAT). Generally, MINAGRI supplies data to the Food and Agriculture Organization (of the UN) (FAO). FAO in turn sanitizes the data and makes them consistent with data from other countries using their own methodology.

FIGURE 4.1. EXAMPLE OF CROP PRODUCTION LOSS CALCULATION



This analysis covers the selected food and export crops in Rwanda. Valuation was done by using an average of each crop's annual producer prices from 2009, 2010, and 2011 from FAOSTAT. Each crop's production value was calculated by taking the 2009, 2010, and 2011 average.

INDICATIVE CROP PRODUCTION LOSSES

Using the methodology outlined above, indicative production losses caused by various production risks for individual crops were estimated for the selected food and export crops (summarized in table 4.1). The results indicate the following:

1. Average annual production losses are US$65 million for the selected crops;
2. These production losses are 2.2 percent of the total value of crop production;
3. Cassava and bananas account for almost 60 percent of all the estimated production losses;
4. Total production losses over a period of 18 years (1995 to 2012) are estimated at US$1.16 billion.

These losses are too large and affect the government's growth objectives.

The correlation between losses in the sector and growth in agricultural GDP is not exact (figure 4.2). However,

TABLE 4.1. SUMMARY OF INDICATIVE PRODUCTION LOSSES FOR RWANDA'S FOOD AND EXPORT CROPS, 1995–2012

Crop	Average Annual Losses (MT)	Average Annual Losses (US$)	Annual % Loss of Crop Production Value*	Total Losses (MT, 1995–2012)	Total Losses (US$, 1995–2012)
Cassava	82,326	24,656,594	0.81	1,481,865	443,818,687
Maize	9,658	3,538,799	0.12	173,849	63,698,384
Potatoes	34,507	7,919,246	0.26	621,117	142,546,426
Bananas	89,458	17,957,199	0.59	1,520,785	305,272,377
Beans, dry	7,586	3,733,660	0.12	136,541	67,205,881
Rice, paddy	665	297,948	0.01	11,971	5,354,960
Sweet potatoes	38,027	6,202,261	0.20	684,492	111,640,698
Coffee, green	969	1,347,368	0.04	16,476	22,905,262
Tea	637	97,371	0.00	10,826	1,655,305
Total	**263,833**	**65,749,995**	**2.17**	**4,657,925**	**1,164,097,981**

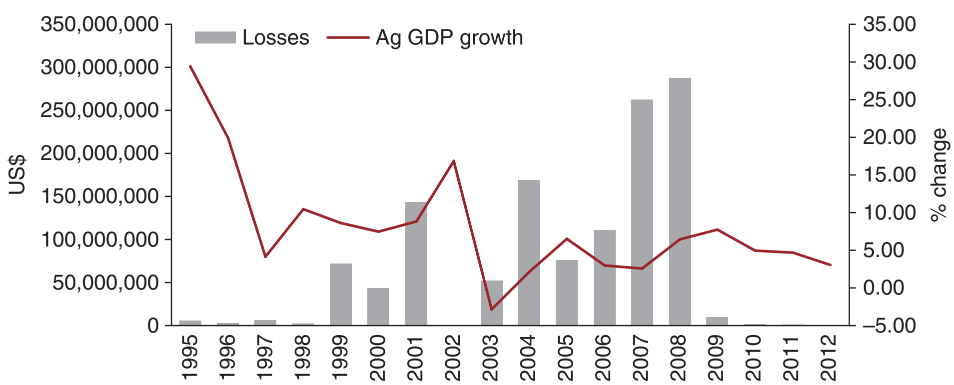
Sources: FAOSTAT 2013; Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.
*Of 2009–11 average agricultural production value.

TABLE 4.2. COST OF MAJOR ADVERSE EVENTS FOR CROP PRODUCTION, 1995–2012

	Indicative Loss Value		
Year	**US$ (in millions)**	**% Ag. Production Value (current, average 2009–11)**	**Causes/Risk Events**
2001	138,241,657	−4.57	Excessive rainfalls in the Northern and Western Provinces
2004	150,078,184	−4.96	Heavy rains in high altitude areas and a drought in Eastern and Southern Provinces
2006	87,062,028	−2.88	Drought/high heat in Eastern and Southern Provinces
2007	238,236,805	−7.87	Drought in Eastern Province
2008	269,030,202	−8.89	Drought in Eastern Province

Sources: FAOSTAT; Authors' calculations.
Note: Plantain, tea, and coffee were calculated 1995–2011. Cassava, paddy rice, sweet potatoes, maize, dry beans, and Irish potatoes were calculated 1995–2012.

FIGURE 4.2. LOSSES AND GROWTH IN AGRICULTURAL VALUE ADDED, 1995–2012

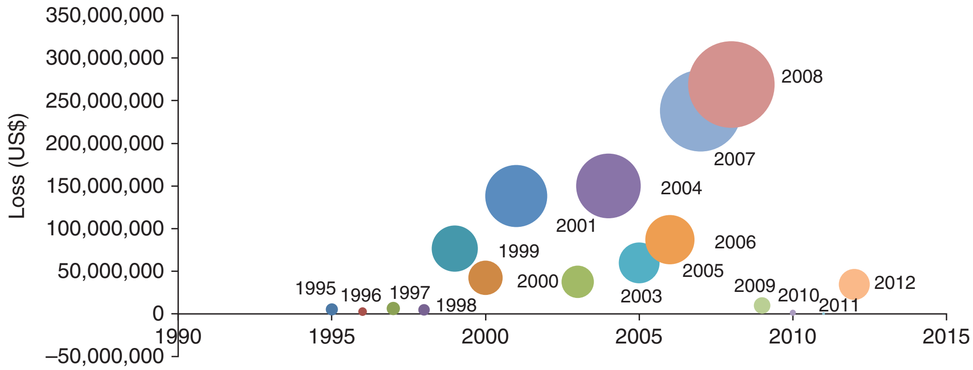


Source: Authors' calculation based on FAOSTAT 2014 and WDI 2014.

between 1995 and 2012, the biggest monetary losses occurred in 2001, 2004, 2006, 2007, and 2008 (table 4.2), amounting to up to 8.9 percent of total agricultural production value in 2008. It is clear that in terms of both monetary value and as a share of agricultural production value, losses became significantly greater in the 2000s (figure 4.3).

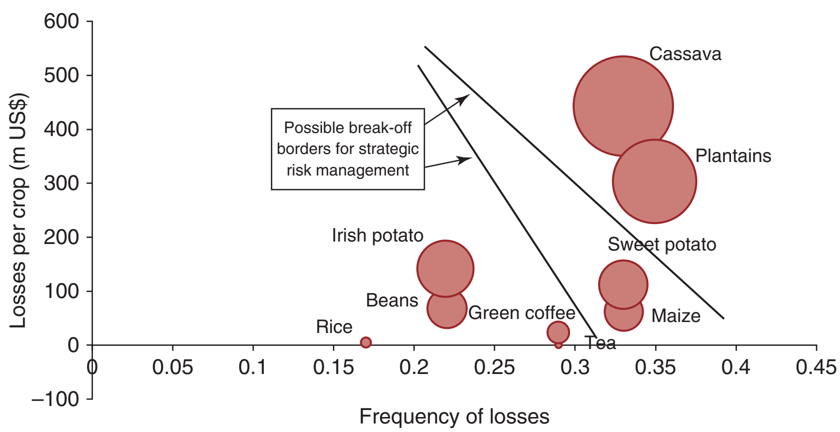
There are important differences in losses between individual crops. Cassava and plantain experienced the biggest losses in the period 1995–2012, followed by fairly evenly distributed losses between Irish potatoes and sweet potatoes. Maize has relatively frequent losses but the losses are not as large as for the first four crops. The scope of the losses are clearly in line with the importance of the crop in the total sector, as cassava, plantains, potatoes, and maize dominate agricultural production in terms of value. In an environment of scarce resources, this may have implications for risk management policy decisions when deciding on which crops to allocate resources for risk mitigation (figure 4.4).

FIGURE 4.3. AGRICULTURAL PRODUCTION LOSSES AND SHARE OF TOTAL PRODUCTION VALUE IN SPECIFIC YEARS



Source: Authors' calculations based on FAOSTAT 2014.
Note: The size of the bubbles signifies the scope of the loss in terms of its share of total production value in that particular year.

FIGURE 4.4. FREQUENCY AND SCOPE OF LOSSES PER CROP, 1995–2012



Sources: FAOSTAT; Authors' calculations.

INDICATIVE PRODUCTION LOSSES BY PROVINCES

Although risks are generally assessed in terms of the national impact in this report, there is value in disaggregating losses and considering them at the provincial level. This will help optimal targeting of interventions geographically. Indicative crop production losses were calculated for the five provinces in the country: Northern, Western, Eastern, Southern, and the City of Kigali (see figure 4.5). The relative volatility among different provinces was measured using the coefficient of variation (CV) of yields.[31] Losses were estimated for four crops: maize, bananas, cassava, and Irish potatoes using the 2000–12 disaggregated data from MINAGRI.

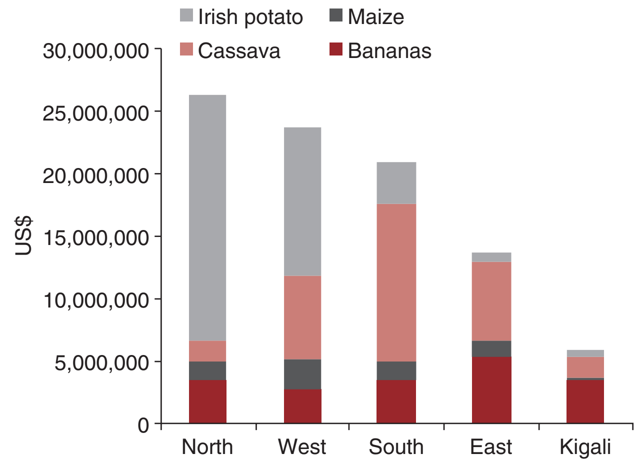
Overall, the results indicate that losses are the greatest in absolute terms in the Northern Province and smallest in the City of Kigali (which also produces a lot less than the other provinces). Figure 4.6 provides an overview of the value of annual losses by province for Irish potatoes, cassava, maize, and bananas. The bulk of the losses associated with Irish potatoes is in the Northern Province but a large amount also occurs in the Western Province. Most of the losses of cassava take place in the Southern Province, followed by the Western and the Eastern Province. Banana losses are more evenly distributed between provinces, but the Eastern Province has slightly higher losses than the other provinces and the Western Province the lowest. Maize production has the

[31] This is calculated as the standard deviation by the series' arithmetic median. It shows the extent of variability in relation to the population mean; that is, the higher the CV, the worse the risk.

FIGURE 4.5. RWANDA'S FIVE PROVINCES

Source: Central Intelligence Agency 2010.

FIGURE 4.6. ANNUAL LOSSES BY PROVINCE (US$, SUM OF SEASON A AND SEASON B)



Sources: Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.
Note: See appendix D for detailed tables with exact values.

TABLE 4.3. PRODUCTION VOLATILITIES BY PROVINCE (CVs OF YIELDS, %)

	Bananas	Maize (1998–2006)	Maize (2007–12)	Cassava	Irish Potatoes
Season A (1998–2012)					
Eastern	26.8	31.1	33.6	31.9	46.1
City of Kigali	25.3	32.1	50.4	34.8	46.6
Northern	19.0	9.7	45.6	34.2	78.8
Southern	15.0%	21.1	51.4	46.0	43.0
Western	14.4	12.9	40.8	40.8	61.1
National	**18.2**	**6.8**	**38.2**	**35.5**	**27.6**
Season B (2000–12)					
Eastern	17.5	23.9	55.6	47.8	15.2
City of Kigali	10.2	13.6	38.7	47.1	12.4
Northern	13.1	15.6	42.5	44.2	26.5
Southern	10.3	43.6	37.8	46.3	12.8
Western	11.3	22.9	38.9	39.5%	21.6
National	**12**	**21.9**	**41.9**	**44.5**	**16.9**

Sources: Authors' calculations, based on NISR's 2014 Seasonal Agricultural Survey.

lowest losses in absolute terms relative to the other crops, with slightly higher losses in the Western Province than in the other provinces, followed by the Northern, Southern, and Eastern Provinces and the City of Kigali. Although the Northern Province has the highest aggregate losses in absolute amounts, it is clear that the geographic target area for any risk management intervention will depend on the crop. Detailed loss estimates for each respective province are presented in appendix D.

Volatility in the provinces is also high for most crops. For cassava, volatility is relatively high across seasons, whereas for Irish potatoes, Season A production is a lot more volatile than that of Season B (table 4.3).

The results indicate that banana production volatility is highest in the Eastern Province in both seasons, and this area also has the most production. Whereas production volatility is relatively even across provinces, from a low of 14.4 percent in the Western Province to 25.3 percent in the City of Kigali (Season A), and a low of 10.2 percent in the City of Kigali to 13.1 percent in the Northern Province (Season B), volatility is markedly higher in the Eastern Province, at 26.8 percent (Season A) and 17.5 percent (Season B). This means that the area most subject to production volatility of bananas also produces the most and so will feel the effect of risks most strongly. The FAO considers bananas as highly sensitive to moisture stress (Brouwer, Pins, and Heibloem 1989) and the Eastern Province is widely accepted as a dry, hot, lowland zone. Other losses for bananas are generally incurred on an individual level, such as localized flooding and wind. Pests and diseases are also a problem, but it is hard to disaggregate these at the provincial level. As Rwanda is a small country, market risks (that is, domestic and international price volatility) do not differ much across provinces.

There is large volatility in maize, particularly in the Southern Province, with a CV of 78.4 percent in Season A and 70.8 percent in Season B. Seventy-five percent of all households grow maize, three-quarters of which is grown in Season A. Research indicates that given the differing soil types and depths in the country, it is difficult to attribute all volatility to one factor, such as erratic rainfall. However, the Eastern and Southern Provinces received less rain compared with the Western and Northern Provinces and do show more volatility (CVs of 57.7 percent and 78.4 percent compared with 48 percent and 50 percent, respectively, in Season A). Flooding similarly varies greatly with location, and does not exhibit a specific trend, although much of the maize in the Eastern Province is grown in the lowlands of the Akanyeru River basin, where additional moisture even under dry conditions is above average, but there is an increased risk of losses from flooding. Pests and diseases show provincial tendencies, with MCMV identified in the Western and Northern Provinces. Striga weed has infested maize production in the Eastern Province, but is generally predictable so more of a constraint than a risk.

Volatility in cassava production is high in all provinces and across seasons. The highest volatility occurs in the Southern Province, where 40 percent of cassava is planted. During Season A, the Southern Province demonstrates the highest CV of yields (46 percent), although the CVs range from a low of 31.9 percent in the Eastern Province to a high of 40.8 percent in the Western Province. During Season B, the Eastern Province is most volatile, with a CV of 47.8 percent, whereas the Southern Province is third, with a CV of 46.3 percent. Cassava is generally unaffected by weather, but suffers from losses linked to pests and diseases at a national level.

Irish potatoes are mostly grown commercially in the Northern and Western Provinces, the two provinces with the highest CVs of yields in both seasons. In Season A, the Northern and Western Provinces are significantly more volatile, with CVs of 78.8 percent and 61.1 percent, respectively. Potato production is very dependent on soil moisture and calculations show that yields are substantially reduced when soil moisture is low, although this only occurs 1 year in 10.

Although disaggregate losses were not estimated, other crops of note have provincial risk dynamics: beans and rice. Beans are considered by FAO to have medium-high sensitivity to moisture stress (Brouwer, Pins, and Heibloem 1989), so the probability of yield loss of arguably the most important crop in Rwanda in terms of national consumption is particularly high in the Eastern and Southern Provinces. Calculations indicate that erratic rainfall/moisture stress contributes to approximately 50 percent reductions in the potential output of beans in the Eastern Province. The impact is less in the other three provinces, particularly the Western and Northern Provinces, but is still significant. Provincial climatic differences also play a role in the impact of some pests and diseases, including anthracnose and ashocyta blight. Both of these diseases thrive in cool and wet conditions and are therefore more prevalent in the Northern and Western Provinces.

Rice is grown almost exclusively in the bottom of the lower valleys where temperatures are high enough to sustain growth, and marshy conditions provide adequate water in the Western, Southern, and Eastern Provinces.

Less data were collected on export crops; however, a few conclusions can be drawn on provincial risk disaggregation. Tea and coffee, the main export crops, are grown across the entire country although more farmers in the Southern and Eastern Provinces grow coffee, and in the Northern and Western Provinces, tea. It can generally be said that coffee farmers are more susceptible to drought given the agroclimatic realities in the Southern and Eastern Provinces. The Northern and Western Provinces, in comparison, are hilly and receive more rainfall, which means that tea production is more at risk from soil erosion and landslides in the hilly areas and from floods in the marshlands.

Livestock holdings are largest in the Eastern Province, which is dry and flat and therefore has the most optimal conditions for pastoralism, but this is also where most risks are found when disaggregating provincially. This may be partially explained by Rwanda's geographic location and shared borders with Tanzania and Uganda in the east, which increases the cases of transboundary pest and disease outbreaks, but also because of the relatively higher proportion of cattle in this province and the area's pastoralist movement (transhumance) history. During years of dry spells, pastoralists moved to Uganda, Tanzania, or within Rwanda depending on where there was water and pasture. But the GoR has more recently encouraged pastoralists to settle, limited their movements, and distributed land for farms to them. However, FMD and CBPP outbreaks have only occurred in the Eastern Province, whereas anthrax and LSD outbreaks have been found in almost all provinces, but mostly in the Eastern and Western Provinces.

PARTICULARLY VULNERABLE GROUPS

Over the past decade, Rwanda has made significant progress in reducing poverty, from 57 percent in 2005/06 to 45 percent in 2010/11. Extreme poverty decreased from 36 percent to 24 percent in the same period. The increase in agricultural productivity is partly attributable to this achievement. Nevertheless, many groups remain vulnerable, not the least in rural areas, where 49 percent of the population lives below the poverty line compared with 22 percent in urban areas. Poverty is higher for those mainly engaged in agriculture and overall 40 percent of households in Rwanda can be classified as "low-income" agriculturalists. Further, poverty is higher in female- and widow-headed households compared with the national average (table 4.4).

FOOD SECURITY

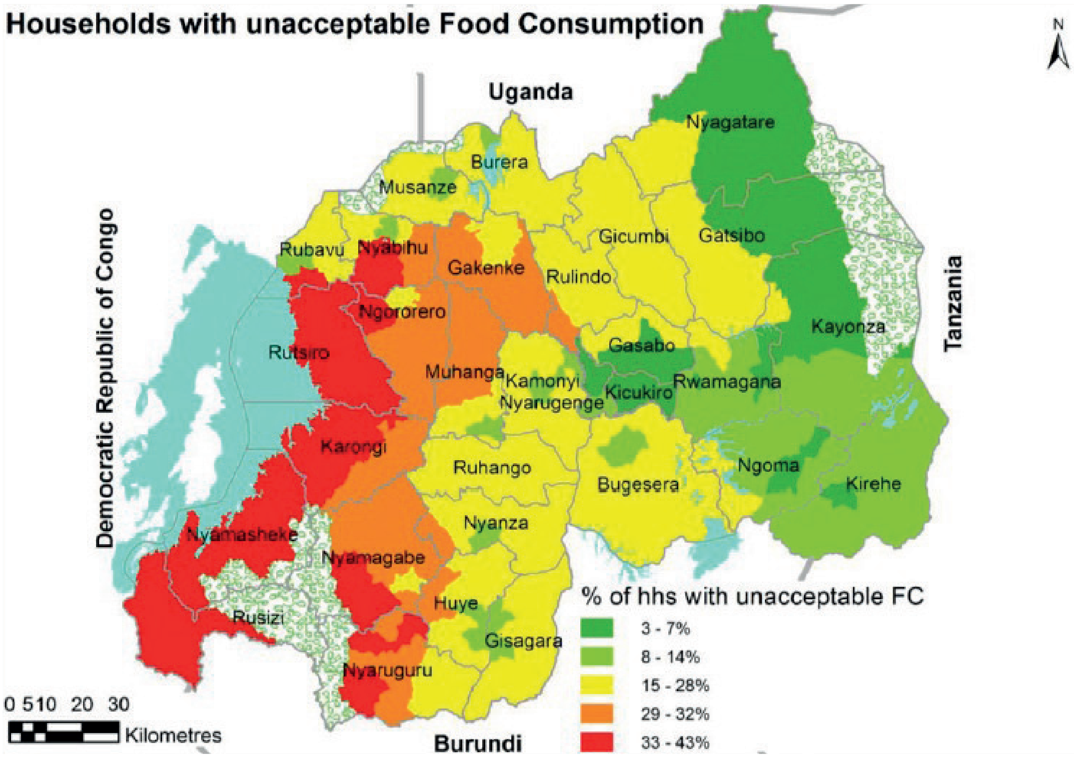
Food insecurity is closely linked to the agriculture sector. The World Food Programme's (WFP's) survey reports that 36 percent of rural households had unacceptable food consumption in September 2011 and could be considered food insecure, compared with 3 percent in Kigali City. Households with less diversified incomes are more food insecure, and of those households with only one activity (43 percent of Rwandan households), most are engaged in agriculture. Further, in the WFP Food Security and Vulnerability Assessment, agriculture (size of land cultivated in Season A, crop diversity, ownership of livestock,

TABLE 4.4. POVERTY IN DIFFERENT GROUPS OF HOUSEHOLDS, 2000/01 VERSUS 2010/11

	2000/01		2010/11	
Type of Household	**Population Share (%)**	**Poverty Incidence (%)**	**Population Share (%)**	**Poverty Incidence (%)**
All households	100	60.4	100	45
Urban			18	22
Rural			82	49
Female headed	27.6	66.3	23.8	60.2
Widow headed	22.0	67.7	18.7	59.9
Child headed	1.3	60.1	0.7	56.9

Sources: MINAGRI 2010; NISR 2012b; World Development Indicator Database, accessed in 2011; WFP 2012.

FIGURE 4.7. HOUSEHOLDS WITH UNACCEPTABLE LEVELS OF FOOD CONSUMPTION



Source: WFP 2012.

cultivating a kitchen garden, whether the household still had food in stock from the last harvest in April) was one of four variables found to be statistically significant in explaining household food consumption. It can be noted that food insecurity is highest in the Western Province, although this province has less volatility and lower production losses in absolute terms than do the Northern and Southern Provinces (tables 4.2–4.5). Instead, food insecurity in this province is structural and due to geographic and agro-ecological conditions, such as relatively infertile soils compared with other provinces, the prevalence of land located on steep slopes, and long distances to markets. However, the Northern and Southern Provinces have higher food insecurity than the Eastern Province, and 15–28 percent have unacceptable levels of food consumption in these two provinces (figure 4.7).

The food security status in Rwanda is mixed and about 20 percent of those who are food insecure report seasonal food insecurity. Over half of those who are food insecure are chronically or acutely food insecure. After Seasons A and B, 60 percent of households should have acceptable food stocks. Seasonal food access problems occur in the lean seasons just before the two main harvests (from March to May and from September to November) because food stocks run out. The households most exposed to seasonal food insecurity were the poorest and those relying most on seasonal work. Thus, food crop losses caused by risk events have a direct impact on seasonal food security.

Rural households consume a significant share of their produce within the household. On average and for all crops produced, households sold 23 percent of their production and consumed 71 percent. The rest was reported as either given away (2 percent) or spoiled/lost after harvest (3 percent). The main consumed cereals, roots, and tubers as well as beans and cooking bananas are mostly kept for home consumption. In contrast, households sold more than half of their production of cash crops (tea, coffee, pineapples, and sugar cane—all over 85 percent sold) and fruits and vegetables (tomatoes—80 percent sold, passion fruit—60 percent, cabbage—58 percent) in addition to sorghum (54 percent) and rice (63 percent), meaning that these are more important sources of income (table 4.5).

TABLE 4.5. PERCENTAGE OF HOUSEHOLDS THAT GROW SPECIFIC CROPS AND SHARE OF PRODUCTION SOLD ON MARKETS, 2012

	Households Growing Crop (%)	Crop Sold in Market (%)
Beans	90	12
Sweet potatoes	45	11
Maize	42	22
Plantains	28	30
Irish potatoes	15	32
Cassava	40	23

Source: WFP 2012.

TABLE 4.6. SOURCES OF FOOD AND FOOD VERSUS NONFOOD EXPENDITURES, 2012

	Share of Total Consumption (%)	Change Since 2005/06 (%)
Food purchases	26.6	+ 24
Consumption of own food	15.8	− 6
Total food consumption	42.4	+ 11
Nonfood expenditure	57.8	+ 38
Total	100	+ 24

Source: WFP 2012.

Markets provide little over 60 percent of the household food basket, whereas own production contributes about 37 percent (table 4.6). The market is the main source for rice (81 percent), groundnuts (67 percent), fish and meat (90 percent—except poultry: 50 percent), and milk (55 percent), meaning that prices affect access to these food products.

In conclusion, losses caused by agricultural risks have ripple impacts on income, poverty, and food insecurity, and especially seasonal vulnerability among farmers. In general, impacts on food security will depend on how much is grown for consumption versus sales (for example, whether the farmer is a net producer or net consumer of agricultural products) and if the risk is a production risk or a market risk. Because cereals, tubers, roots, beans, and bananas are mainly grown for home consumption, losses of these products have a direct impact on household food security, especially for households with limited resources to buy these food items to compensate for insufficient production. In turn, prices of rice and animal products affect food access because the majority of households purchase these products.

GENDER AND VULNERABILITY IN AGRICULTURE

The agriculture sector is worked largely by women, but much of their labor input goes uncompensated or is not visible in official statistics. Women are primarily restricted to subsistence agriculture, receive low prices for their products, are underrepresented in agribusiness, and are employed in low-paid positions in secondary agriculture. Female-headed households constitute about 30 percent of Rwanda's households and these households are very poor, which has consequences for their access to productive inputs and assets. High poverty levels in these households also make them vulnerable to shocks, as they don't have assets to cushion the impacts. As discussed above, livestock has important impacts on food consumption and income, but because of gender structures, larger livestock (such as cattle and goat) are generally a man's domain, which restricts women from profiting from these assets. Thus, livestock risks should have more impact on men's incomes than on women's.

A clear gender divide exists in the types of crops cultivated. Because land is traditionally controlled by men, crops produced by men are allocated more land. The types of crops dominated by men versus women are not consistent across the country, but depend on the potential income from each crop in that particular area. The production of crops with higher income potential tends to be controlled by men. Few women are involved in coffee and tea production activities and their value chains are highly gender divided, whereby men seem to benefit more from labor inputs and control proceeds from sales.

Although not comprehensive for Rwanda as a whole, and allowance should be given to differences between families and individuals, based on table 4.7 and the loss analysis

TABLE 4.7. GENDER DIVISION OF CROP CULTIVATION FOR DIFFERENT DISTRICTS

District	Crops Cultivated by Women	Crops Cultivated by Men	Crops Cultivated by Both Men and Women
Bulera (North)	Beans	Irish potatoes	Maize, wheat
Gasabo (Kigali)	Beans, sweet potatoes, cassava, maize, amaranth (*Amaranthus*)	Plantains, coffee, exotic vegetables (tomatoes, eggplants, cabbage, green peppers)	Fruits
Kirehe (East)	Maize, beans, flowers	Plantains, coffee, pineapples	Sorghum
Nyabihu (West)	Maize, beans, sorghum	Irish potatoes, cabbage, carrots	
Highlands	Beans		Tea (but supply chain is gender divided), Irish potato, wheat, and maize
Middle veld	Beans, sorghum, sweet potatoes, cassava	Coffee	
Ruhango (Kigali)	Beans, sweet potatoes, vegetables	Cassava, coffee, rice	Maize

Source: MINAGRI 2010.

previously discussed, it is possible to draw some conclusions about the different impacts of risks on men and women producers:

- » Beans are mainly grown by women; therefore, any risks related to beans will be borne by women.
- » Maize is grown either by women or by both men and women depending on location. The highest volatility in maize production occurs in the Southern Province, whereas the biggest losses are in the Western Province. No gender-disaggregated production information is available for the Southern Province, but the large losses in the Western Province have a disproportionately high impact on women.
- » Bananas are mainly grown by men, so any risks related to bananas will be borne by them.
- » Of all provinces, the Northern and Western Provinces experience by far the highest production losses and volatility for Irish potatoes, where it is grown predominately by men, who consequently bear most of these losses.

This type of analysis is important to secure a complete overview of risk impacts because it can aid the design of risk management interventions. Similarly, important lessons on gender access and participation can be drawn from ongoing agricultural programs to strengthen potential risk management interventions. For example, women reportedly have less access to technologies promoted under the CIP. Partly, this has to do with their more limited access to financial capital and assets, as the improved varieties, fertilizers, and chemicals promoted under the program are expensive. In particular, female-headed households seem restricted from optimal participation in the activities under the program. However, the technologies being promoted are also very labor intensive, which reportedly restricts women from participating on equal terms. Similarly, the "One Cow per Poor Family" program planned for 30 percent of the beneficiaries to be women, but given the financial costs involved (owing to the necessity of developing zero-grazing infrastructure), women and especially female-headed households are largely excluded from this program. It is thus important that any risk management activity is designed to keep in mind gender differences in access to programs and to incorporate the needs of both male and female actors in the sector to minimize agricultural risks.

Appendix C gives a more detailed overview of particularly vulnerable groups and gender differences in Rwanda's agriculture sector.

CHAPTER FIVE

RISK PRIORITIZATION AND MANAGEMENT

A variety of risks exist across Rwanda's agriculture sector. Previous chapters described the major risks affecting Rwanda's agriculture sector and specific commodity groups (food crops, export crops, and livestock), attempted to quantify losses associated with these major risks, and assessed their impacts on actors in the agriculture sector. Special attention was given to impacts on Rwanda's most vulnerable groups and how those impacts affect men and women differently.

The analysis undertaken during the risk assessment allows for prioritization of risks in relation to the probability of events and their degree of impact, followed by the relevant measures to manage these risks. In Rwanda, many programs and activities funded by government and donors are already in place to make the agriculture sector more resilient. Furthermore, businesses, individual farmers, and consumers may adopt other measures, such as managing higher prices and limited availability of certain commodities by substituting for others. This leads to questions about the effectiveness of existing activities and the sufficiency of their coverage. Options for better management, taking into account the capacity to implement and fund them in Rwanda, should also be considered.

This chapter prioritizes existing risks and provides recommendations for how Rwanda can more effectively manage risks, based on a consultative stakeholder exercise. It identifies priority areas for risk management interventions that will be explored in depth in the Phase II Solutions Assessment.

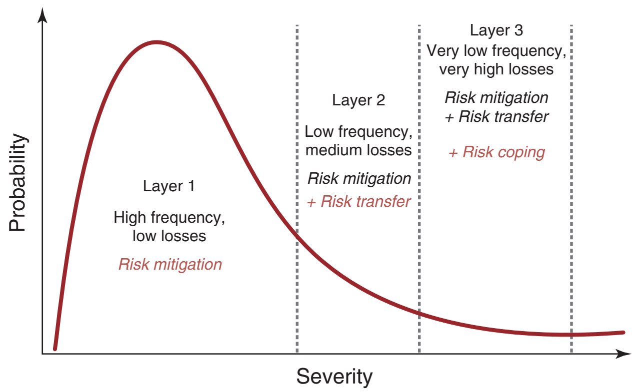
RISK PRIORITIZATION

Identifying and prioritizing risks is an important first step in designing a set of comprehensive and effective measures to manage risks. With scarce budgetary resources, it is crucial that some sort of prioritization takes place to understand the key risks in terms of frequency of occurrence and degree of impact. Given the data constraints, it is important to note that this list is not exhaustive and the ranking of risks is based on the World Bank team's evaluation from both data analysis and on-the-ground research. The differing significance of these risks to different stakeholders in society can be found in the previous chapter; vulnerability is discussed in the vulnerability assessment.

To get an overview of the frequency and the severity of the key risks to food crops, export crops, and livestock, and to prioritize them, a national risk prioritization matrix was developed (table 5.1). Importantly, the matrix ranks the risks to individual crops and livestock *relative to risks to other crops and livestock*; that is, the risks are not ranked according to their importance for a particular crop, but according to their importance to the sector. As such, the main risks to Rwanda's agriculture sector are:

1. Pests and diseases for crops and livestock;
2. Weather-related risks for crops and livestock; and
3. Price volatility for export crops and dairy producers.

FIGURE 5.1. STRATEGIC RISK INSTRUMENTS ACCORDING TO RISK LAYERS



Source: World Bank ARMT.

RISK MANAGEMENT

CATEGORIES OF RISK MANAGEMENT MEASURES

Risk management measures can be classified into three types:

» **Risk mitigation (ex ante):** Actions designed to reduce the likelihood of risk or to reduce the severity of losses (for example, soil and water conservation measures, changes in cropping patterns, adoption of improved practices that improve performance and reduce risks such as conservation farming, using short duration and tolerant varieties, irrigation and flood control infrastructure).

» **Risk transfer (ex ante):** Actions that transfer the risk to a willing third party. These mechanisms will usually trigger compensation in the case of a risk-generated loss (for example, purchasing insurance, reinsurance, financial hedging tools).

TABLE 5.1. NATIONAL RISK PRIORITIZATION MATRIX

Impact/Probability of Event	Low	Moderate	High
Highly probable [1 year in 3]	• Potato taste (coffee) • Landslide (all crops) • Floods—local and large scale (all crops) • Milk contamination (dairy) • Milk collection center power cuts (dairy) • Counterparty risk (coffee) • Price fluctuations (food crops and milk) • Exchange rate fluctuations (export crops)	• Price volatility (export crops) • Livestock disease outbreaks	• Pests and diseases (all crops) • Drought and erratic rains (all crops and livestock)
Probable [1 year in 5]	• Hail (all crops)		
Occasional [1 year in 10]	• Glut (dairy) • Frost (tea) • Losses in transit (tea) • Aflatoxins in feed (livestock) • Maize shortage (dairy)		

» **Risk coping (ex post):** Actions that help the affected population and the government cope with the loss. They usually take the form of compensation (cash or in-kind), social protection programs, and livelihood recovery programs (for example, government assistance to farmers, debt restricting, contingent financing).

How instruments are applied for a given risk will likely depend on the probability of the risk and the severity of its impacts (figure 5.1). Strategic choices of risk management instrument will likely include a combination of the three types of risk management instruments.

The report highlights some of the indicative interventions that could be undertaken to manage selected risks in Rwanda (table 5.2). Although agricultural risk management measures are discussed individually and/or sequentially, many of these would in fact be implemented jointly and have positive, complementary impacts while addressing multiple risks and would contribute to improved risk management in the short, medium, and long terms.

POTENTIAL INTERVENTIONS FOR AGRICULTURAL RISK MANAGEMENT IN RWANDA

Existing interventions in risk management and national policies are already in place to begin addressing some of these key issues. The potential interventions identified by the report cover all three groups and, in conjunction with

TABLE 5.2. POTENTIAL INTERVENTIONS FOR RISK MANAGEMENT IN RWANDAN AGRICULTURE

Risk	Mitigation	Transfer	Coping
Pests and diseases	• Integrated pest management • Pest and disease-tolerant varieties • Good agricultural practices (GAPs)/ extension services • Information systems/Increased border surveillance (livestock) • Vaccination (livestock)	• Insurance (livestock)	• Rapid disease response system • Vaccination
Drought/ erratic rain	• Soil and water conservation • Training in improved agronomic practices • Drought-tolerant varieties • Irrigation	• Insurance	• Social safety net programs and emergency relief • Grain aggregation • Storage network • Savings groups
Floods	• Soil and water conservation • Drainage • Flood-tolerant varieties • GAPs/extension services • Infrastructure	• Insurance	• Social safety net programs and emergency relief • Grain aggregation • Storage network • Savings groups
Domestic price volatility	• Improved market information systems • Training on milk handling and hygiene	• Hedging	• Social safety net programs and emergency relief • Grain aggregation • Storage network (crops and cold chain storage and transportation for milk) • Savings groups
International price volatility	• Improved market information systems • Regional trading system • Shorten farm-to-export time • Training on milk handling and hygiene	• Futures contracts • Hedging • Options to buy/ sell on international exchanges	• Social safety net programs and emergency relief • Grain aggregation • Storage network • Savings groups

the risk prioritization matrix, will form the basis for the solutions areas to be focused on during the next phase of the agriculture sector assessment.

Soil and water conservation measures can yield significant productivity gains and help mitigate the effects of climate change. These measures (including sand dams, afforestation/reforestation, conservation agricultural practices, and terracing) are all effective and efficient mechanisms for mitigating the risks of drought, floods, and/or landslides. They are generally undertaken on individual farmland or at the community level, whereas those involving a broader watershed or landscape approach require coordinated measures across a number of communities.

One of Rwanda's well-known constraints with regard to soil and water conservation is topography. Several projects, both government- and donor-funded, focus on or have elements that focus on soil and/or water conservation in some way. The World Bank–GoR fund a large project—the Land Husbandry, Water Harvesting and Hillside Irrigation Project (LWH)—at US$43 million. LWH's goal is to increase the productivity and commercialization of hillside agriculture in target areas, achieved by strengthening human and organizational capacity for hillside intensification and transformation and development of the required physical infrastructure. Specific interventions exist for livestock in the form of the Livestock Infrastructure Support Project (LISP), which is setting up livestock watering facilities for farmers. Currently, it is working only in Nyagatare district and is focused on dairy farmers, but it is anticipated that in the future the program will be spread to other districts, especially in the Eastern Province, which experiences more rainfall variability, dry spells, and droughts than the rest of the country.

Widespread availability of **tolerant and short-maturing** seed varieties will help in ensuring crop production during drought and flood occurrences in addition to reducing losses from pest and disease outbreaks. Short-maturing varieties will aid in avoiding the effects of drought at either end of the growing season when the frequency of rains tends to be more unpredictable. Tolerant varieties, on the other hand, are better able to survive periods of moisture stress or excess water and build resilience to specific pests and diseases. A seed baseline study (Nkuliyimana 2010) funded by the EU and the Common Market for Eastern and Southern Africa (COMESA) was carried out under a regional agreement signed between Burundi, Ethiopia, Malawi, Rwanda, Swaziland, Uganda, Zambia, and Zimbabwe. One of this agreement's objectives was to improve smallholder farmers' access to high-quality seed. This built on the 2007 National Seed Policy, which oversees four types of seeds: foundation, basic, certified, and quality declared. The government promotes the use of seeds and other agricultural inputs through the National Agricultural Extension System (NAES), better information on seeds, and better geographic seed distribution. The National Seed Council in Rwanda oversees everything related to monitoring and implementation of the policy, which supports the formal seed production sector spearheaded by the private sector.

Risk transfer solutions such as agricultural insurance and commodity price hedging (using forward contracts and futures) could be useful risk management instruments. Successful functioning of farmer-level agricultural insurance requires a number of preconditions such as: affordability (ability and willingness to pay premiums); relatively low frequency of events; robust crop and weather data infrastructure; and farmers' access to financial products and services. At present, two major companies provide agricultural insurance (Kilimo Salama and MicroInsure). These companies have been in operation for about four years. Overall, the experience has been positive. However, to sustain these insurance programs in the long term, ways must be found to reduce insurance premiums, increase the size of the insurance portfolio, and aggressively promote the likely benefits of insurance programs to transfer agricultural risks. Weather data infrastructure in the public sector must be further strengthened and incentives provided to private companies to invest in such infrastructure.

In terms of livestock, Kilimo Salama (Syngenta Foundation for Sustainable Agriculture) plans to develop a livestock insurance product. The product is expected to cover accidental death. Kilimo Salama hopes to establish a network of veterinarians that would carry out post mortems in the case of death to determine the cause. In addition, clients would be trained on disease management, animal nutrition, and hygiene, and monitored to ensure that they follow the recommended livestock management techniques. Such a product once available should help transfer the risk of animal mortality from diseases. However, decreased production caused by diseases would not be covered, so the emphasis for such diseases should be on vaccination, epidemiological surveillance, and rapid response systems.

Pest and disease information systems/increased border surveillance for livestock farmers, providing ready access to timely, accurate, and localized information about impending events that could affect livestock, are a prerequisite to allow stakeholders to reduce exposure and loss. Given the land issue constraints in Rwanda, pest management plays an important role. Poor management in the past has contributed to some of the low quality of soils now experienced. This means that many of the larger projects had a specific IPM component. Under the second phase of the Lake Victoria Environmental Management Project, REMA has a national IPM framework. With the introduction of high-yielding varieties and increased use of fertilizer and pesticides for crop intensification, development and adoption of a participatory IPM system for all major food and cash crops is required. This is a regional approach to reduce reliance on pesticides in Kenya, Uganda, Tanzania, Burundi, and Rwanda. The LWH project has a requirement for a pest management plan to help farmers reduce crop losses, and it encourages appropriate and timely pest management actions.

With regard to crops, Rwanda's use of pesticides is currently very low, mainly used for coffee, potatoes, and tomatoes. However, with the increased focus on and promotion of horticultural crops, IPM may become increasingly important. In terms of livestock, the porous border between the livestock community in Rwanda and the communities in Tanzania, Uganda, and the DRC has been a source of a number of disease outbreaks in Rwanda. Currently eight border posts are manned by veterinarians, but several other informal crossing points exist through which livestock cross in and out of Rwanda. In 2013, the government initiated a Community Animal Health Workers (CAHW) program whereby 1,000 volunteers in the Eastern Province were trained by RAB to monitor livestock movements as well as to act as a first point of contact for farmers regarding disease management. Although the program is in its early stages, RAB has received positive feedback from farmers; therefore, it is proposed that a plan be developed to gradually expand the program, initially focusing on border districts and then the rest of the country. In addition, traceability systems, such as a national identification system, should be developed to augment existing disease surveillance systems.

Irrigation has the potential to aid in controlling erratic rain, but the performance of this type of intervention is mixed. The Rwanda Irrigation Policy and Action Plan was released in August 2013 after the Irrigation Master Plan in 2010, the overall objective of which was to provide Rwanda with a planning tool to use its soil and water resources. Development of the tool took into consideration identification of the most favorable areas to establish irrigation water infrastructure; prioritization of distribution of irrigation water; identification of means of transporting water to selected sites; and establishment of irrigated agriculture in small-, medium-, and large-scale projects on hillsides, marshlands, and other suitable areas. The current area under irrigation is just over 25,590 ha, according to government sources.[32]

Flood control and drainage infrastructure investments such as dams, dykes, draining systems, and other flood control infrastructure can effectively mitigate the impact of floods. Issues of drainage and flood control are also included in the Rwanda Irrigation Policy and Action Plan 2013 (described in more detail above because of the focus on the policy and action plan on irrigation).

Improved **access to extension services** would allow producers to be better informed and to access advice, technology, and inputs to alter their agronomic practices in view of the prevailing and emerging risk profile of the sector. After 1994 and a nationally disjointed approach to extension services generally driven by nongovernmental organization (NGOs) working in isolation, Rwanda restructured MINAGRI and created RAB and NAEB. Most recently, the decision was made to decentralize agricultural extension activities to be overseen by the Ministry

[32] "Rwanda Irrigation Policy and Action Plan," August 2013, p. 6, and "Strategic Plan for the Transformation of Agriculture in Rwanda, Phase III," July 2013, section SP 1.2.

of Local Government (MINALOC) to increase efficiency and address the specific issues of farm households within each district. In 2011, International Food Policy Research Institute (IFPRI), FAO, and the Inter-American Institute for Cooperation on Agriculture undertook a Worldwide Extension study that indicated that Rwanda had 1,244 extension staff.[33] Existing weak linkages and connections between research, extension, and farmers need to be addressed, however. Extension staff at many of the existing institutions in charge of agricultural development also lack proper training.

Social safety net programs are limited mechanisms but can help affected populations cope with high-frequency and high-impact covariate shocks. Emergency food aid and disaster relief from donors and government can partially help but are not sufficient to help with recovery from income and asset loss. The best-known program in Rwanda for social safety nets is the Vision 2020 Umurenge program. The poorest people in each district (*umurenge*) are identified and then offered labor-intensive work, credit for small businesses, and cash transfers and assets to those who cannot work. According to the Ministry of Finance, poverty fell from 57 percent to 45 percent in 5 years, lifting more than 1 million people out of poverty and decreasing extreme poverty from 36 percent to 24 percent (NISR 2012b). This program was not the only one to reduce poverty, but it contributed to the poverty reduction process.

An improved **market information system** can provide accurate, timely, and transparent information about production and stocks, trade flows, and prices in different markets to aid in the management of price volatility in domestic, regional, and international markets. MINAGRI, through a World Bank–funded "ICT for Development" project implemented by the Rwanda Information Technology Authority (RITA) has developed e-SOKO, which seeks to empower farmers and make them more informed about market pricing, thus making them more successful. Some challenges with the system have arisen, not only because it requires farmers to be trained on the use and maintenance of the system, but also because it relies on MINAGRI field staff to collect the necessary information and upload it into the databases.

Vaccination is used in disease management both as an ex ante and ex post solution to disease outbreaks. RAB has been vaccinating consistently since 2002.[34] In spite of these vaccination campaigns, several outbreaks occur every year. On average, vaccination coverage was 30 percent for FMD, 14 percent for LSD, 23 percent for anthrax, and 26 percent for CBPP. Part of the solution may lie in increasing the coverage, if possible to 100 percent, particularly for anthrax and LSD, which have a higher incidence, as the surveillance mechanisms are further strengthened. Increasing vaccination coverage should be complemented by a Performance of Veterinary Service evaluation and gap analysis with the help of OIE. This study should analyze the rapid disease response system and give recommendations.

As the meat industry grows, **meat handling and hygiene** will require attention because the risk of contamination will increase. Therefore, it is recommended that the government: (1) support where possible investments in transportation, modern abattoirs in every major town, inspection both antemortem as well as postmortem, and food safety laboratories; and (2) increase the capacity of Rwanda Bureau of Standards (RBS) to monitor and certify meat products and processing facilities. These investments should be complemented by training in meat handling and hygiene for traders, transporters, and staff in abattoir and processing facilities as well as the inspectors.

A summary of existing interventions for the three groupings by the GoR can be found in appendix D.

DECISION FILTERS FOR SOLUTION PRIORITIZATION

Using decision filters to evaluate and prioritize the list of solutions can aid in making rational resource allocation decisions in place of a detailed cost-benefit analysis. Rwanda, like most countries, is resource constrained and decision makers are compelled to find the quickest, cheapest, and most effective measures among the options presented. A detailed cost-benefit analysis can help in selecting the most appropriate intervention. However, this

[33] See http://www.worldwide-extension.org/africa/rwanda/s-rwanda

[34] Vaccination data were not available for 2004 and 2005.

exercise was too costly and time consuming to conduct under this risk assessment.[35] Furthermore, many elements involved in making these decisions are not easily quantifiable and not easy to factor in.

A number of complex analytic screening tools can be used to assess the various decision filters; this report does not claim methodological rigor in its assessment of filters. Filters were applied to provide a rapid assessment to obtain some form of prioritization of risk solutions based on feedback from key stakeholders. The following criteria were presented by the World Bank team for this purpose:

- » ***Applicability:*** Whether the proposed intervention fits into the current policy/programming or business objectives of a government department or private sector firm.
- » ***Feasibility:*** Whether it is or would be easy for a government/firm to implement this intervention in the short/medium term.
- » ***Affordability:*** Whether or not an intervention is affordable, with regard to current and future budgets.
- » ***Scalability***: Whether or not a pilot/small-scale project can be rolled out to a wider group of beneficiaries.
- » ***Sustainability***: Whether an intervention will be sustainable in the long run or once government funding runs out or resources are directed elsewhere.

Some major projects and interventions are already taking place in the sector and it is important that proposed interventions are in line with government priorities. The World Bank team enumerated the existing priorities and interventions in the sector. This ensures increased buy-in from the government and attempts to aid in efficient use of limited resources. MINAGRI's latest annual report (*Annual Report FY 2011–2012*) had several overall strategy priorities that are consistent with some of the proposed interventions:

- » Development of quality irrigation and mechanization systems (using public and private resources);
- » Comprehensive approach to land husbandry (soil fertility, soil conservation, water harvesting and management, livestock feed);
- » Increased use of agricultural inputs (fertilizer, quality seeds, and extension services);
- » Animal resources mobilization; and
- » Development of agricultural postharvest handling storage systems and farmer capacity.

Finally, nine interventions were drawn out from the consultation exercise and analysis carried out by the World Bank team in the field. Overall, stakeholders advocated more training in improved agricultural practices, IPM, and handling and hygiene practices for livestock products, as well as better access to livestock vaccination and improved planting material. Investments rated highly in the consultation were in market information systems and cold chain storage and transportation. Further information on the possible interventions proposed in the consultation exercise and how they were ranked can be found in appendix A.

The priority interventions align with existing government policy and interventions already in place, although at a much smaller scale, with effects at a much more localized level. Greater emphasis should be placed on whether or not these could be scaled up to the national level by both the government and nongovernmental stakeholders in the sector, many of whom are already involved, to more meaningfully affect Rwanda's agriculture sector.

PROPOSED SOLUTIONS FOR FURTHER ASSESSMENT

Given the prioritized risks, the feedback from stakeholders, and the ongoing interventions, seven possible solutions areas emerge as the most relevant for further assessment.

1. Water management in the crop sector, particularly to improve practices in preparation for dry periods and scattered rainfall, but also to better manage rainfall in valleys to minimize flooding. Solutions areas may include:
    - » Expansion of on-farm water harvesting systems
    - » Viable mechanisms for financing small-scale irrigation
    - » Expansion and rehabilitation of drainage infrastructures in valleys
    - » Agricultural practices to improve soil moisture and reduce flooding, including minimum tillage agriculture

[35] Any feasibility study for investments would include a cost-benefit analysis. Such analysis could potentially also be part of a solutions assessment.

2. Weather-risk management in the livestock sector, particularly as it relates to water and feed access. Solutions may include:
   - Improved rural water infrastructure
   - Development of existing feed supply chains to temporarily substitute for the lack of pastures in provinces where grazing is allowed
   - Training of farmers in livestock management in water scarce situations, and in good hygiene practices with special focus on practices in dry periods

3. Pest and disease management, particularly as it relates to potential future risks as a result of land consolidation and increased monocropping. Similarly, potential changes in pest and disease risks as a result of climate change should be integrated in such assessment. Solutions may include:
   - Improving agricultural practices and pest management, including further developing integrated pest management
   - Strengthening the crop research system on pest and disease management and resilient crops
   - Strengthening access to inputs, including developing network of input dealers
   - Developing information system on pests and diseases

4. Developing livestock disease management infrastructure to mitigate and manage disease outbreaks with the purpose of decreasing the economic impact on the sector. Solutions may include:
   - Developing livestock information systems, including animal registers and disease warning systems
   - Developing veterinary services and vaccination programs
   - Strengthening animal reference laboratory capacity
   - Strengthening regional cooperation in livestock disease management

5. Sanitary institutions and practices in the livestock sector, throughout the supply chain and involving both public and private actors. As incomes increase, this sector is likely to grow, so the necessary institutional infrastructure must be in place to mitigate risks and minimize losses. Solutions may include:
   - Strengthened animal disease management in relevant institutions
   - Farm-level livestock management
   - Increased capacity of food safety institutions
   - Improved hygiene practices throughout the supply chain
   - Mitigation of aflatoxin contamination in the feed supply chain

6. Assessment of possible price management mechanisms for actors in the export crop supply chain. Given the exposure to international prices for actors in the coffee and tea supply chains, scope exists to strengthen price management mechanisms in the sector. By analyzing the physical and financial flows on current transaction arrangements for exports, a set of options on how to reduce exposure to risk can be identified. Potential solutions areas may include:
   - Strengthening existing price information systems that allow for transparent price setting throughout the supply chain, and training actors throughout the chain to optimize given available information
   - Providing price risk management training to actors in the supply chain, for example in forwarding Price To Be Fixed contracting
   - Assessing available policy mechanisms for supporting actors in the sector against price risks
   - Assessing possible production and marketing investments for producers and processors that can lessen relevant actors' exposure to risk

7. Analysis of milk price volatility to better understand the reasons behind the fluctuations in milk prices. This would include proposing appropriate price risk management mechanisms depending on the identified causes behind existing price volatilities.

It is important to recognize that the GoR is already doing a lot in all of these areas. However, given the risks identified in this analysis and especially given the strategic path Rwanda has outlined for the sector, there is room for strengthening these risk management areas. The proposed solutions assessment could thus support Rwanda in preparing the sector for effective risk management in the next decades.

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APPENDIX A
STAKEHOLDER FEEDBACK

DECISION FILTERS

Rwanda, like most countries, is resource constrained and so decision makers are compelled to find the quickest, cheapest, and most effective measures among the options presented. A detailed cost-benefit analysis can help in selecting the most appropriate intervention; however, this exercise itself would be costly and time consuming. Furthermore, many elements in making these decisions are not easily quantifiable and not easy to factor in. Using decision filters to evaluate and prioritize the list could aid in making rational resource allocation decisions in place of a detailed cost-benefit analysis.

The following criteria were presented by the World Bank team for this purpose. A number of complex analytic screening tools are available to assess the various different filters and this report does not claim methodological rigor in assessing the filters. These filters were applied to provide a rapid assessment to obtain some form of prioritization based on feedback from key stakeholders.

> ***Applicability:*** Whether a government department or a private sector firm, there are current policy/programming or business objectives. In an aim to make the interventions enter seamlessly into existing practices/plans, it is important that the applicability of specific interventions is taken into account.
> ***Feasibility:*** Whether it would be/is easy for a government/firm to implement this intervention in the short/medium term is an important factor to take into consideration; often "quick-wins" will come across as more attractive and implementable.
> ***Affordability:*** One of the most important considerations for anyone getting involved in implementing an intervention is whether or not that intervention is affordable with regard to current and future budgets.
> ***Scalability:*** Whereas an intervention may have positive results in a small pilot, it is important for actors to take into consideration whether or not they will be able to roll out the intervention to a wider group of affected people.

Sustainability: Whereas some interventions, such as coping mechanisms, quickly provide resources for affected people, for larger and more expensive interventions it is important to think about how sustainable the intervention will be in the long run or once government funding runs out or resources are directed elsewhere.

For Rwanda, three matrixes were drawn up, one each for food crops, export crops, and livestock (figures A.1–A.3). The results after the application of these decision filters are shown next, but it should be remembered that they are indicative and imperfect. However, they do provide a first step toward development of a more comprehensive and strategic approach for managing risks in Rwanda's agriculture sector.

FIGURE A.1. PRIORITIZATION OF POSSIBLE INTERVENTIONS: FOOD CROPS

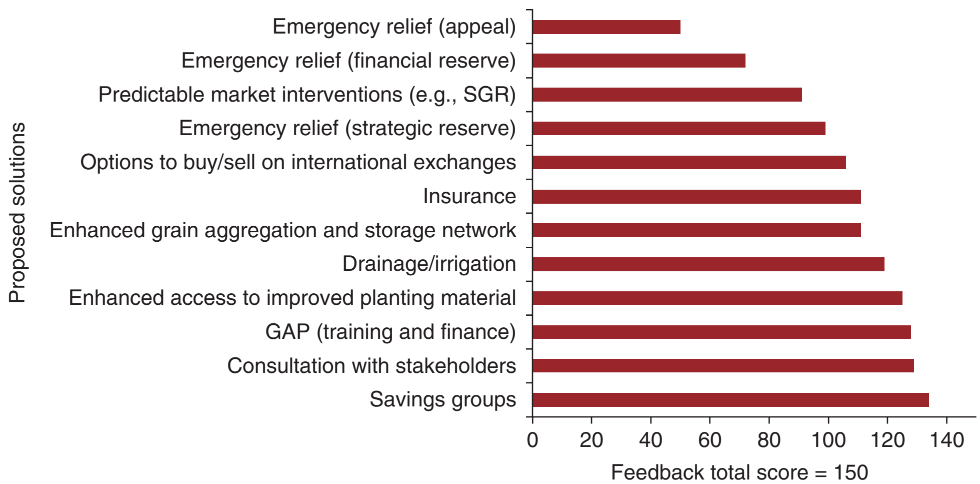


FIGURE A.2. PRIORITIZATION OF POSSIBLE INTERVENTIONS: EXPORT CROPS

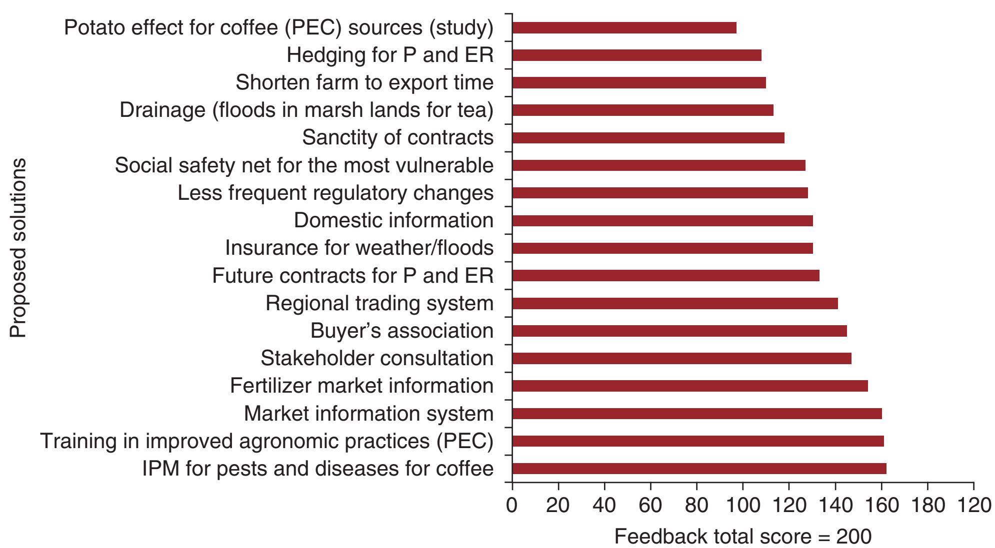
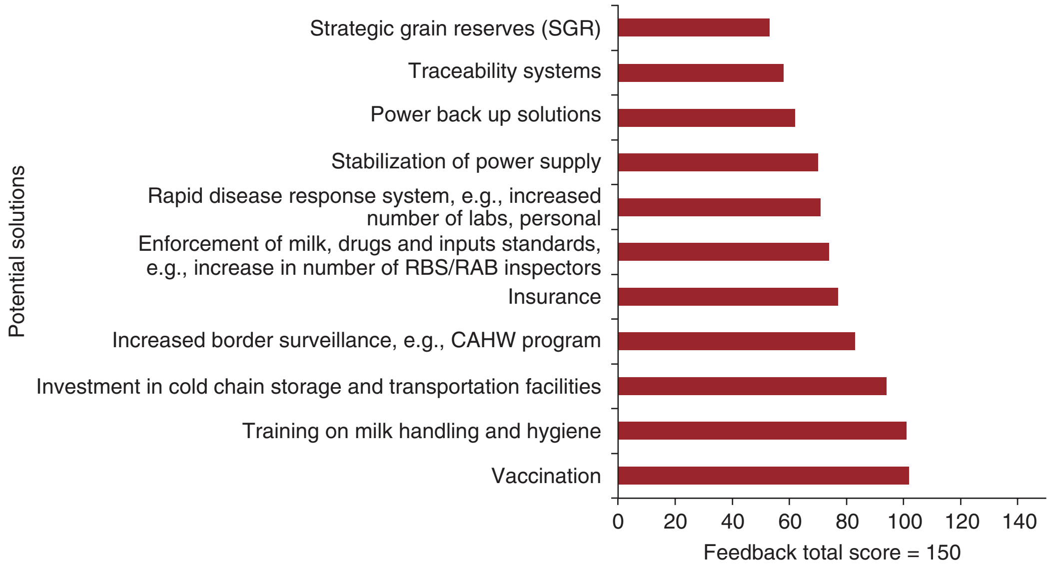


FIGURE A.3. PRIORITIZATION OF POSSIBLE INTERVENTIONS: LIVESTOCK



In summary, the following areas ranked the highest in the three commodity categories:

Food crops

1. Savings groups
2. Training and finance for good agricultural practices (GAPs)
3. Enhanced access to improved planting material

Export crops

1. Integrated pest management (IPM) for coffee
2. Training in improved agronomic practices
3. Market information system

Livestock

1. Vaccination
2. Training on milk handling and hygiene
3. Investment in cold chain storage and transportation

APPENDIX B
CLIMATE CHANGE IN RWANDA

CURRENT CONDITIONS

Situated on mountainous terrain in the East African Rift Valley, Rwanda has a tropical temperate climate (REMA 2009, 97). The hilly terrain produces a diverse range of agro-ecological conditions in the country, allowing for a wide variety of crops to be grown but also adding to climate forecasting challenges.

Temperatures in the country vary with altitude, but average annual temperatures hover between 16°C and 20°C (REMA 2009, 97.).

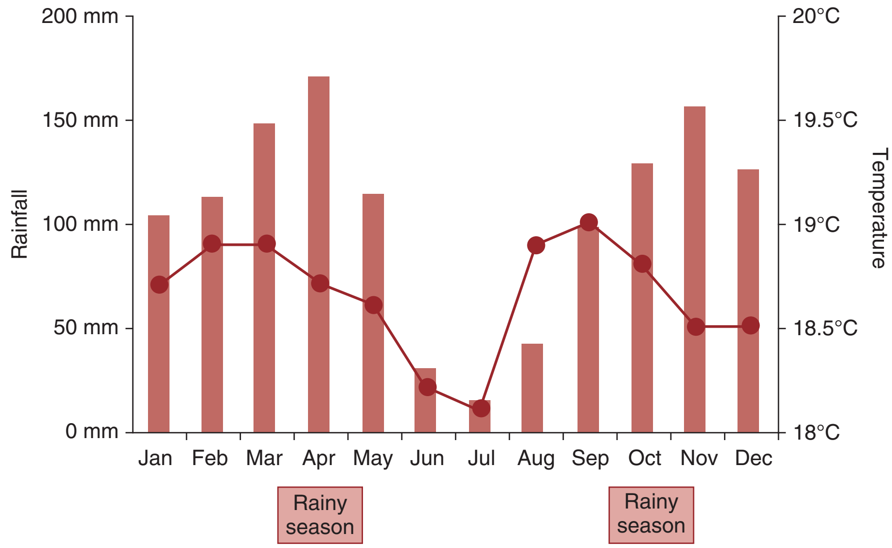
Rainfall in the country is also shaped by multiple factors. On average, the country receives 1,250 mm of rainfall annually (Stockholm Environment Institute 2009, 4). Primary influence of rainfall patterns falls on the Inter Tropical Convergence Zone where the weather systems of the Northern and Southern Hemispheres meet. The progression of the ITCZ results in two types of seasons: dry and rainy.

El Niño and La Niña, opposite phases of the El Niño-Southern Oscillation[36] (ENSO), also affect Rwanda, creating heavy rainfall and severe dry conditions, respectively, when they occur every three to five years (Smith School of Enterprise and the Environment 2011a, 4). Furthermore, the Congo air mass, a moist air appendage of the ITCZ, as well as the Mascarene, Azores, St. Helena, and Arabian high-pressure systems, and subtropical anticyclones also influence rainfall (Smith School of Enterprise and the Environment 2011a, 4).

Four seasons divide a calendar year in Rwanda: two rainy seasons, from September to November and from March to May (figure B.1); and two dry seasons, from December to February and June to August.

[36] The El Nino–Southern Oscillation makes up the cyclical temperature fluctuations between the ocean and atmosphere in the East-Central Equatorial Pacific, which occur every 3–5 years. For more information, see NOAA, http://oceanservice.noaa.gov/facts/ninonina.html.

FIGURE B.1. AVERAGE MONTHLY RAINFALL AND TEMPERATURES IN RWANDA, 1960–90



Source: World Bank Climate Change Portal.

In addition to altitude levels, regions also see varying climate patterns. Because of the topography of the country and the existence of large bodies of water, the eastern and southeastern portions of the country experience more frequent and prolonged droughts, whereas the northern and western regions receive more rainfall (REMA 2009, 97).

CROPS IN CURRENT CONDITIONS

Bananas and plantains have traditionally grown well in Rwanda's tropical temperatures and rainfall conditions (table B.1). These crops are usually cultivated by small-scale farmers for food security and income-generation purposes (Tenge, Aphonse, and Thomas 2012, 260). Beans are another critical food source that has thrived in Rwanda's higher altitudes because they require cooler temperatures. Coffee, a key export crop for Rwanda, has very particular temperature and rainfall requirements, alterations of which significantly affect quality and thereby export price.

TABLE B.1. IDEAL GROWING CONDITIONS FOR SELECTED CROPS IN RWANDA

Crop	Temperature Requirements in Rwanda	Other
Bananas*	15°C–30°C	Deep soils, typically require 1,000–2,000 mm of rainfall
Beans*	14°C–18°C	Typically grow in higher altitudes in Rwanda because of cooler temperature requirements
Coffee**	Below 25°C. Ideal for Arabica is 18°C at night and 22°C during the day	For Arabica varieties, 800–1,000 mm of rainfall and 1,200 mm for Robusta is required

Sources: IFPRI 2012; Tenge, Aphonse, and Thomas 2012, 18.
*Tenge, Aphonse, and Thomas 2012, 260. **Ngabitisinze, Chrysostome, Mukashema, Ikirezi, and Niyitanga 2011, 18.

GLOBAL CLIMATE CHANGE IMPACTS ON RWANDA

The International Panel on Climate Change (IPCC) concluded that there is evidence in Africa of warming over land. This warming is expected to continue and by 2100 to exceed a 2°C increase above the mean annual temperature of the late 20th century. The report found that African ecosystems are already being affected by global climate change and future impacts are expected to be substantial (IPCC 2014, Chapter 22: Africa, 3).

Current global climate change models, however, can offer only a crude picture of future climate change impacts on Rwanda, as gathering accurate data on current climate conditions still proves difficult. Although the number of rainfall gauges has improved in recent years, the country still has few accurate gauges situated around the country.[37]

Gathering historical data is even more challenging. Most of the monitoring network was destroyed during the 1990–94 civil war, limiting data gathering in subsequent years. Because of this destruction, the only complete records from 1994–2009 are from one station at the Kigali airport.[38] Information prior to the war, when over 100 meteorological stations were operating,[39] was collected, including data from the early 20th century, but it is difficult to obtain (REMA 2009, 97) and has yet to be fully digitized.[40]

No specific climate modeling has been completed for Rwanda; instead, projections from global climate change models have been downscaled to information from a single Rwandan weather station, making them a very crude measure (Smith School of Enterprise and the Environment 2011a, 3).

Regionally, there is little more to offer, as nearly all of Rwanda's East and Central African neighbors suffer from similar data issues. Furthermore, global climate change models are currently not well tuned to model the magnitude or even direction of regional rainfall changes in Africa, because they omit or underweight conditions that are important for determining regional rainfall in Africa, such as dynamic land cover–atmosphere interactions and climate variability drivers such as ENSO (van de Steeg et al. 2009, 23–24).

[37] Today, to record weather the country has 72 rainfall stations, 72 climatological stations, 39 automatic weather stations, and 13 agro-synoptic across the country. See Rwanda Meteorology Agency, "Observation Stations," http://www.meteorwanda.gov.rw/index.php?id=10, accessed June 2014. This is a marked improvement. A mere three years earlier, the country had only 26 rainfall stations, 13 agro-synoptic stations, and 5 automatic weather stations. See Smith School of Enterprise and the Environment 2011a, 4.

[38] See Rwanda Meteorology Agency, "Observation Stations," http://www.meteorwanda.gov.rw/index.php?id=10.

[39] See Smith School of Enterprise and the Environment 2011a, 4.

[40] For instance, gathering colonial data requires liaising with the Belgian government. See Smith School of Enterprise and the Environment 2011a, 4.

OBSERVED CHANGES

From the available information, changes in both rainfall and temperature patterns are already apparent. An analysis conducted of these variables over the past 30 years shows that the rainy season is becoming shorter with higher intensity, leading to both more droughts and floods simultaneously (REMA 2009, 97). Parts of the country are experiencing these events differently. The Northern and Western Provinces are seeing heavier rains and floods, whereas the Eastern Province is seeing more rainfall deficits (REMA 2009, 98).

Furthermore, increased mean, maximum, and minimum temperatures have been observed from 1971 to 2010 in all four seasons, with all of these temperatures rising roughly one-half of a degree per decade (Smith School of Enterprise and the Environment 2011b, 11–13). This is greater than the global trend of 0.19°C and 0.32°C for mean temperature per decade, and 0.29°C for maximum and minimum temperatures (Smith School of Enterprise and the Environment 2011b, 11). Humidity, meanwhile, has decreased over the same time period, at a rate of 1.58 percent every decade (Smith School of Enterprise and the Environment 2011b, 14).

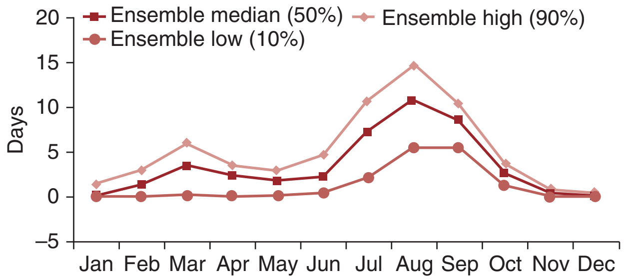
FORECASTED CHANGES

Despite these observed patterns, many climate models are in disagreement over rainfall changes in Rwanda over the next 30 years. For East Africa as a whole, high rainfall extremes (events typically occurring once in every 10 years) are expected to increase in frequency (van de Steeg et al. 2009, 27). Torrential rainfalls present an added problem in Rwanda as they create landslides that can wipe away the numerous farms that reside on the sides and bottoms of the hills that spot the country.

There is more agreement between the climate models regarding temperature increases. Three different climate change models[41] forecast a 1°C–2.5°C increase in maximum temperatures. Studies of the effect of this on key crops are lacking, but such temperature increases are thought to affect crop productivity particularly by increasing the prev-

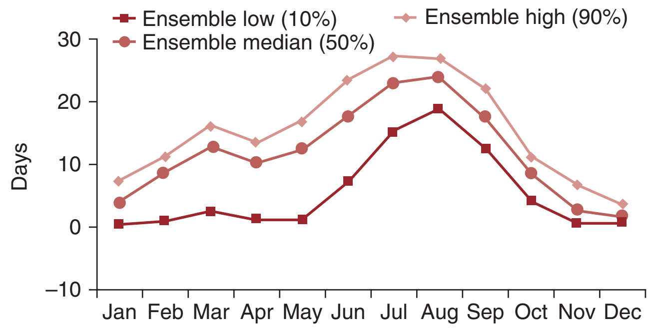
[41] These include CNRM-CM3, ECHAM, and MIROC 3.2. See Tenge, Aphonse, and Thomas 2012, 264.

FIGURE B.2. HOT DAYS, RWANDA, 1961–2000



Source: World Bank Climate Change Portal.

FIGURE B.3. HOT DAYS, RWANDA, PROJECTED FOR 2046–65



Source: World Bank Climate Change Portal.

alence of pests and diseases. For crops that also require cooler temperatures to grow, such as beans, such temperature increases are likely to produce declining yields (Tenge, Aphonse, and Thomas 2012, 264).[42]

Figures B.2 and B.3 show the number of hot days (days that fall in the 90th percentile of high temperatures) projected in Rwanda based on an assembly of 15 climate change models. At its peak during the dry season, the models predict an increase of 10–15 more hot days per year.

CROPS AND CLIMATE CHANGE

In-depth climate change studies and the subsequent impacts on crops in Rwanda have not been completed, as is the case in other SSA countries.[43] Therefore, the full effects of climate change on crops are not yet understood. For some crops, such as maize, in the near term, Rwanda is expected to have yield increases[44] as a result of rising temperatures;[45] however, other crops will likely require significant alterations in planting or new varieties to succeed.

Throughout the country, the length of the growing season is expected to decline. Under two different growth scenarios and two different climate models, the land area that currently has 210 or more growing days is expected to shrink from today's 92 percent to roughly 78 percent by 2030, and then further to about 60 percent by 2050 (van de Steeg et. al. 2009, 50). This indicator is by no means a direct measurement of agricultural productivity, as climate variability may in fact reduce yields in areas with longer growing periods (Thornton et al. 2011, 122). Nonetheless, a smaller growing window may put more pressure on farmers to produce their crops. The following summarizes the available studies on climate change's impacts on existing crop varieties.

One study notes that coffee is vulnerable to high temperature increases. Temperatures above 25°C affect the plant's photosynthesis process and spur the development of diseases such as coffee leaf rust (CLR) and fruit blight. Low temperatures, below 15°C, spur coffee berry diseases (Ngabitsinze et al. 2011, 18). Coffee must also have rainfall above 800–1,000 mm for Arabica varieties and 1,200 mm for Robusta (Ngabitsinze et al. 2011, 18). Therefore, should temperatures in Rwanda continue to increase as expected, coffee will be at risk of declining yield. The study found that there are already delayed flowering periods for coffee as a result of longer dry seasons and delayed ripening periods as a result of a reduction in heavy rains in March. It also found that pests and diseases are migrating more easily, increasing the need for and length of chemical spraying (Ngabitsinze et al. 2011, 27). Furthermore, increasing temperatures may push perennial crops, such as coffee, to higher altitudes and thereby likely reduce the potential land area on which they can be grown (IPCC 2014, Chapter 22: Africa, 20).

[42] See also IPCC 2104, Chapter 22: Africa, 20.

[43] For instance, there is a comprehensive report by USAID on climate change impacts on crops in Malawi.

[44] See IPCC 2014, Chapter 22: Africa, 20.

[45] This is for the near term. For the long term, at least one study found that maize yields are expected to decline by 19 percent in East Africa in 2090. See Thornton et al. 2011, 122.

Climate change impacts on maize production have also been studied. One study (Jones and Thornton 2003) applied a global climate change model to calculate expected impacts on four generic maize varieties in Latin America and Africa in 2055. For Rwanda, the authors found an approximately 7 percent reduction in kg/ha yield from a baseline of 1990 climate conditions (Jones and Thornton 2003). However, because of the diversity of Rwanda's climate, this broad application of global scenarios is only a crude measurement of potential impacts.

For this reason, the same authors conducted a follow-up observing the effects of climate change in East Africa only.[46] The authors found that maize in the region may see improved yields in high altitudes, because of temperature increases, but decreased yields in lower altitudes for the same reason (Thornton et al. 2009). Maize yields will also depend on water balances, and many places in the region are expected to see water stress for the crop (Thornton et al. 2009). The authors also evaluated the impact on secondary-season beans (beans planted after maize harvesting) and found that yield reductions will likely occur in areas below 1,000 m in altitude, and in many areas under 1,500 m. However, higher elevations may see yield increases as long as average temperatures do not go above 20°C–22°C, the temperature threshold for bean yields in the region (Thornton et al. 2009). For East Africa as a whole, the authors found that the region could expect 1–3 percent reductions in production levels (kg) by 2050 in low-emission scenarios for maize and beans, and 11–15 percent reductions in production levels (kg) in high-emission scenarios for the same crops (Thornton et al. 2009).

Finally, cassava and bananas may see increased yields in East Africa by 2030 because of increased temperatures (IPCC 2014, Chapter 22: Africa, 20).

Whereas the exact impacts of global climate change on crops in Rwanda remain unknown, it is clear that the climate is altering, with increased potential for extreme events. Because of the high population density of the country, where plot sizes are very small, adaptation measures will need to be taken to dampen shocks from these changes.

[46] In this study, they found that crop yield responses to climate change are heterogeneous, and vary by crop type, location, temperature, and time.

APPENDIX C

VULNERABILITY ASSESSMENT

Over the past decade, Rwanda has made significant progress in reducing poverty, from 57 percent in 2005/06 to 45 percent in 2010/11. Extreme poverty decreased from 36 percent to 24 percent in the same period. The increase in agricultural productivity is partly attributable to this achievement. Nevertheless, many groups remain vulnerable, not the least in rural areas, where 49 percent of the population lives below the poverty line compared with 22 percent in urban areas. Overall, 40 percent of households in Rwanda can be classified as "low-income" agriculturalists; 14 percent of households rely on both agriculture and unskilled daily labor; and 13 percent rely solely on agriculture. Further, poverty is higher in female- and widow-headed households compared with the national average (see table C.1).

TABLE C.1. POVERTY IN DIFFERENT GROUPS OF HOUSEHOLDS, 2000/01 AND 2005/06

	2000/01		2010/11	
Type of Household	**Population Share (%)**	**Poverty Incidence (%)**	**Population Share (%)**	**Poverty Incidence (%)**
All households	100	60.4	100	45
Urban			18	22
Rural			82	49
Female headed	27.6	66.3	23.8	60.2
Widow headed	22.0	67.7	18.7	59.9
Child headed	1.3	60.1	0.7	56.9

Sources: MINAGRI 2010; NISR 2012b; World Development Indicator Database, accessed in 2011; WFP 2012.

FOOD SECURITY

Food consumption is closely linked to the agricultural context. Households with less diversified incomes are more food insecure, and of those households with only one activity (43 percent of Rwandan households), most are engaged in agriculture. Further, in the WFP Food Security and Vulnerability Assessment (WFP 2012b), agriculture (size of land cultivated in Season A, crop diversity, ownership of livestock, cultivating a kitchen garden, whether the household still had food in stock from the last harvest in April) was one of four variables found to be statistically significant in explaining household food consumption.

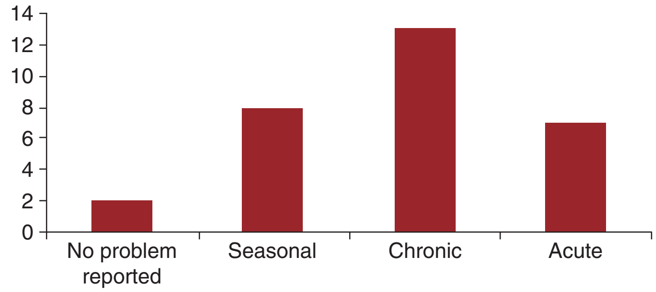
Similarly, food insecurity remains an issue and WFP's survey reports that 36 percent of rural households had unacceptable levels of food consumption in September 2011 and could be considered food insecure, compared with 3 percent in Kigali City. However, the food security status in Rwanda is mixed and about 20 percent of those households that are food insecure report seasonal food insecurity. Over half of those who are food insecure are chronically or acutely food insecure (figure C.1).

After Season A and B, 60 percent of households should have acceptable food stocks. Seasonal food access problems occur in the lean seasons just before the two main harvests (from March to May and from September to November) because food stocks run out. The households most exposed to seasonal food insecurity are the poorest and those relying most on seasonal work.

In Rwanda, 85 percent of all working adults cultivate their own farm and the WFP Food Security and Vulnerability Assessment shows that the more crops a household cultivated in Season A, the more likely it was to have better food consumption. Households reporting acceptable food consumption cultivated an average of three crops, whereas those with poor food consumption cultivated two. Having a vegetable garden was also correlated with better food consumption. Finally, livestock ownership was associated with higher levels of food security (figures C.2 and C.3).

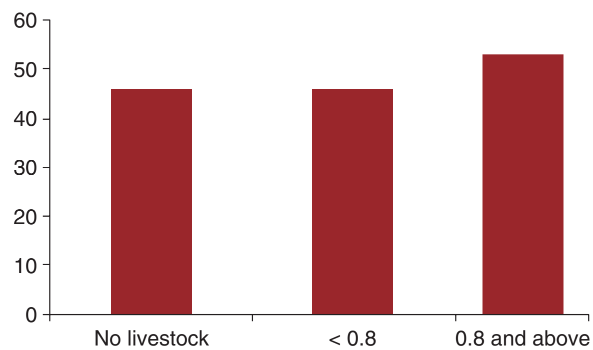
On average and for all crops produced, households sold 23 percent of their production and consumed 71 percent. The rest was reported as either given away (2 percent) or spoiled/lost after harvest (3 percent). The main consumed cereals, roots, and tubers as well as beans and cooking bananas were mostly kept for home consumption. In contrast, households sold more than half of their production of

FIGURE C.1. DISTRIBUTION OF FOOD INSECURITY IN RWANDA, 2012



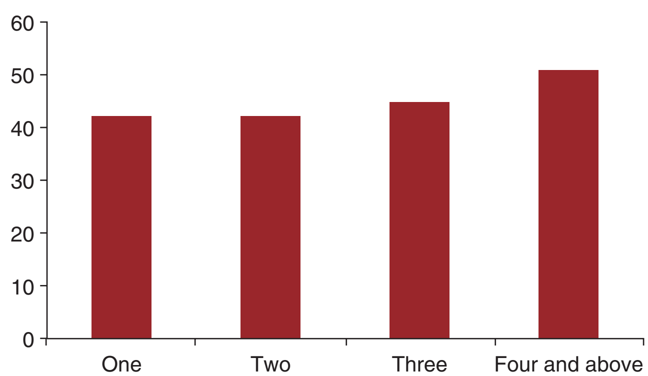
Source: WFP 2012.

FIGURE C.2. FOOD SECURITY AND LIVESTOCK UNITS IN RWANDA, 2012



Source: WFP 2012.

FIGURE C.3. FOOD SECURITY AND NUMBER OF CROPS CULTIVATED IN RWANDA, 2012



Source: WFP 2012.

TABLE C.2. PERCENTAGE OF HOUSEHOLDS THAT GROW SPECIFIC CROPS AND SHARE OF PRODUCTION SOLD IN MARKETS

	Households Growing Crop (%)	Crops Sold in Markets (%)
Beans	90	12
Sweet potatoes	45	11
Maize	42	22
Plantains	28	30
Irish potatoes	15	32
Cassava	40	23

Source: WFP 2012.

TABLE C.3. SOURCES OF FOOD AND FOOD VERSUS NONFOOD EXPENDITURES, 2012

	Share of Total Consumption (%)	Change Since 2005/06 (%)
Food purchases	26.6	+ 24
Consumption of own food	15.8	− 6
Total food consumption	42.4	+ 11
Nonfood expenditure	57.8	+ 38
Total	100	+ 24

Source: WFP 2012.

cash crops (tea, coffee, pineapples, and sugar cane—all over 85 percent sold) and fruits and vegetables (tomatoes—80 percent sold; passion fruit—60 percent; cabbage—58 percent) in addition to sorghum (54 percent) and rice (63 percent), meaning that these are more important sources of income (table C.2).

Markets provide little over 60 percent of the household food basket, whereas own production contributes about 37 percent (table C.3). The market is the main source for rice (81 percent), groundnuts (67 percent), fish and meat (90 percent; except poultry—50 percent), and milk (55 percent), meaning that prices affect access to these food products.

GENDER AND VULNERABILITY IN AGRICULTURE

The agriculture sector is largely worked by women, but much of their labor input goes unrewarded or is not visible in official statistics. Women are primarily restricted to subsistence agriculture, receive low prices for their products, are underrepresented in agribusiness, and are employed in low-paid positions in secondary agriculture. Also, female-headed households constitute about 30 percent of Rwanda's households and these households are very poor, which has consequences for their access to productive inputs and assets. High poverty levels in these households also make them vulnerable to shocks as they do not have assets to cushion the impacts. Livestock have important impacts on food consumption and income, but because of gender structures, larger livestock (such as cattle and goat) are generally a man's domain, restricting women from profiting from these assets.

A clear gender divide exists in the type of crops cultivated (table C.4). Because land is traditionally controlled by men, crops produced by men are allocated more land. The types of crops dominated by men versus women are not consistent across the country, but depend on the potential income from each crop in that particular area. The production of crops with higher income potential tends to be controlled by men.

Few women are involved in coffee and tea production activities. Women tend to have fewer trees than men because they have smaller land lots, but also because they tend to prioritize food crops over export crops. Further, men have better access to agricultural extension services than women, which affects their choice of crop. Tea and coffee value chains are gender divided in terms of the type of work conducted. For example, in the tea value chain, men plant and sell the tea, but women maintain the plants and pick the leaves. Although women spend more time than men on tea production activities, men are paid better in both value chains and also control the benefits from coffee and tea production.

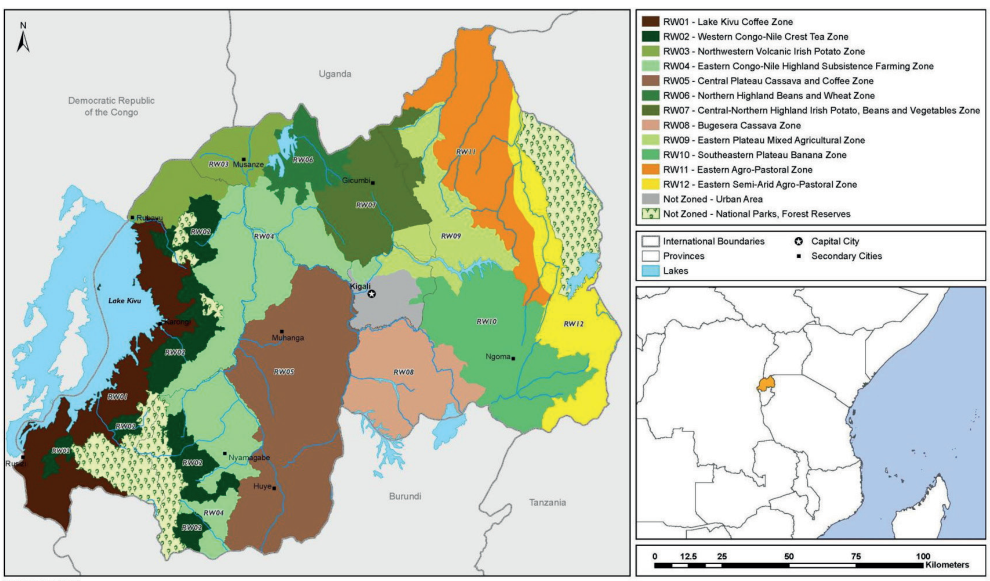
Importantly, women reportedly have less access to technologies promoted under the Crop Intensification Program. This has partly to do with their more limited access to financial capital and assets, because the improved

TABLE C.4. GENDER DIVISION OF CROPS CULTIVATION FOR DIFFERENT DISTRICTS

District	Crops Cultivated by Women	Crops Cultivated by Men	Crops Cultivated by Both MEN and women
Bulera	Beans	Irish potatoes	Maize, wheat
Gasabo	Beans, sweet potatoes, cassava, maize, amaranth (*Amaranthus*)	Plantains, coffee, exotic vegetables (tomatoes, eggplants, cabbage, green peppers)	Fruits
Kirehe	Maize, beans, flowers	Plantains, coffee, pineapples	Sorghum
Nyabihu	Maize, beans, sorghum	Irish potatoes, cabbage, carrots	
Highlands	Beans		Tea (but supply chain is gender divided), Irish potato, wheat, and maize
Middle veld	Beans, sorghum, sweet potatoes, cassava	Coffee	
Ruhango	Beans, sweet potatoes, vegetables	Cassava, coffee, rice	Maize

Source: MINAGRI 2010.

FIGURE C.4. LIVELIHOOD ZONE MAPPING IN RWANDA



Source: FEWS NET 2011.

varieties, fertilizers, and chemicals promoted under the program are expensive. Female-headed households seem especially precluded from optimal participation in the activities under the program. However, the technologies being promoted are also very labor intensive, which reportedly restricts women from participating on equal terms. Similarly, the "One Cow per Poor Family" program planned for 30 percent of the beneficiaries to be women, but given the financial costs involved (because of the necessity of developing zero-grazing infrastructure), women, and especially female-headed households, are largely restricted from benefiting under this program.

LIVELIHOOD AND VULNERABILITY ACROSS REGIONS

To better understand the impact of livelihoods on vulnerability in different regions (and especially as they relate to agriculture), Famine Early Warning System Network (FEWS NET) conducted a "Livelihood Zoning" exercise in Rwanda (see figure C.4). FEWS NET drew the following conclusions from this exercise:

- Most livelihoods in Rwanda are considered relatively food self-sufficient.

- Bugesera Cassava Zone is the only food-deficit production zone in the country, which happens only in bad years. This zone is drought-prone area.
- Eastern Semi-Arid, Eastern Agro-Pastoral, and parts of the East Congo-Nile Highland Farming Zones are at risk of acute food insecurity during bad production years.
- The three Eastern livelihood zones (Bugesera Cassava, Eastern Agro-Pastoral, and Eastern Semi-Arid Agro-Pastoral Zones) are drought-prone areas.
- Poor households living in the Eastern Agro-Pastoral, Eastern Semi-Arid Agro-Pastoral, and Eastern Plateau Agriculture Zones purchase significant portions of their annual food needs.

APPENDIX D

DETAILED CALCULATIONS OF PROVINCIAL LOSSES

TABLE D.1. BANANA PRODUCTION BY PROVINCE, 1998–2012 (SEASON A) AND 2000–12 (SEASON B)

	Average Annual Losses (MT)	Average Annual Losses (US$)	Annual Loss of Ag. Production Value in US$ (2009–11) (%)	Coefficient of Variation of Yields (%)	Average Yield (MT/ha)
Season A					
Eastern	17,947	3,602,524	–0.12	26.8	9.2595
City of Kigali	15,087	3,028,396	–0.10	25.3	7.2099
Northern	9,579	1,922,860	–0.06	19.0	7.5191
Southern	8,701	1,746,671	–0.06	15.0	4.9795
Western	9,053	1,817,292	–0.06	14.4	7.4352
National*	**48,007**	**9,636,548**	**–0.32**	**18.2**	**7.3199**
Season B					
Eastern	8,888	1,784,071	–0.06	17.5	9.7224
City of Kigali	2,309	463,473	–0.02	10.2	7.0310
Northern	7,385	1,482,412	–0.05	13.1	7.1201
Southern	8,783	1,762,963	–0.06	10.3	5.7059
Western	4,945	992,644	–0.03	11.3	7.5112
National*	**23,276**	**4,672,171**	**–0.15**	**12**	**7.6081**

*Totals are calculated based on the government's national-level data and are not the sum of the provincial data.

TABLE D.2. MAIZE PRODUCTION BY PROVINCE, 1998–2012 (SEASON A) AND 2000–12 (SEASON B)

	Average Annual Losses (MT)	Average Annual Losses (US$)	Annual Loss of Ag. Production Value in US$ (2009–11) (%)	Coefficient of Variation of Yields 1998(A)/ 2000(B)–2006 (%)	Average Yield 2007–12 (MT/ha)
Season A					
Eastern	2,547	933,275	–0.03	31.1	2.0533
City of Kigali	330	120,926	0.00	32.1	1.5901
Northern	768	281,406	–0.01	9.7	1.9678
Southern	1,314	481,443	–0.02	21.1	1.6966
Western	2,482	909,381	–0.03	12.9	1.8705
National*	**7,060**	**2,586,749**	**–0.09**	**6.8**	**1.9013**
Season B					
Eastern	883	323,560	–0.01	23.9	1.4417
City of Kigali	86	31,312	0.00	13.6	1.2986
Northern	555	203,351	–0.01	15.6	1.5465
Southern	687	251,664	–0.01	43.6	1.3811
Western	1485	543,925	–0.02	22.9	1.6222
National*	**3,406**	**1,247,758**	**–0.04**	**21.9**	**1.5280**

*Totals are calculated based on the government's national-level data and are not the sum of the provincial data.

TABLE D.3. CASSAVA PRODUCTION BY PROVINCE, 1998–2012 (SEASON A) AND 2000–12 (SEASON B)

	Average Annual Losses (MT)	Average Annual Losses (US$)	Annual Loss of Ag. Production Value in US$ (2009–11) (%)	Coefficient of Variation of Yields (%)	Average Yield (MT/ha)
Season A					
Eastern	7,096	2,125,186	–0.07	31.9	7.7885
City of Kigali	4,203	1,258,855	–0.04	34.8	8.5125
Northern	1,991	596,274	–0.02	34.2	7.1621
Southern	13,041	3,905,920	–0.13	46.0	7.6621
Western	9,317	2,790,422	–0.09	40.8	7.1294
National*	**25,776**	**7,719,773**	**–0.26**	**35.5**	**7.7704**
Season B					
Eastern	13,867.	4,153,319	–0.14	47.8	9.9042
City of Kigali	1,382	414,013	–0.01	47.1	8.5548
Northern	3,050	913,498	–0.03	44.2	7.9180
Southern	29,224	8,752,597	–0.29	46.3	9.6543
Western	13,164	3,942,641	–0.13	39.5	7.8525
National*	**62,625**	**18,756,143**	**–0.62%**	**44.5%**	**9.1216**

*Totals are calculated based on the government's national-level data and are not the sum of the provincial data.

TABLE D.4. IRISH POTATO PRODUCTION BY PROVINCE, 1998–2012 (SEASON A) AND 2000–12 (SEASON B)

	Average Annual Losses (MT)	Average Annual Losses (US$)	Annual Loss of Ag. Production Value in US$ (2009–11) (%)	Coefficient of Variation of Yields (%)	Average Yield (MT/ha)
Season A					
Eastern	2,339	536,730	–0.02	46.1	2.9022
City of Kigali	2,123	487,280	–0.02	46.6	4.2955
Northern	70,908	16,273,446	–0.54	78.8	22.9434
Southern	10,550	2,421,261	–0.08	43.0	4.2931
Western	40,247	9,236,643	–0.31	61.1	14.5475
National*	**45,214**	**10,376,654**	**–0.34**	**27.6**	**9.2085**
Season B					
Eastern	1,089	250,021	–.01	15.2	4.8118
City of Kigali	159	36,408	0.00	12.4	5.6629
Northern	15,041	3,451,808	–0.11	26.5	11.4993
Southern	3,567	818,701	–0.03	12.8	6.6173
Western	11,235	2,578,447	–0.09	21.6	10.5824
National*	**23,706**	**5,440,585**	**–0.18**	**16.9**	**9.6239**

*Totals are calculated based on the government's national-level data and are not the sum of the provincial data.

APPENDIX E

FOOD CROP SUPPLY CHAIN ANALYSIS

INTRODUCTION

The environment for staple crop production benefits from relatively consistent rainfall, occurring in two clear seasons, Season A (November to January) and Season B (April to June), although rainfall may also occur between these periods. Rainfall statistics indicate that within the rainy seasons, few periods of severe drought have occurred in the last 30 years, although seasonal variations may be as large as +/−15 percent, occurring approximately every 10–15 years. At the same time, Rwanda's elevation at 1,500–4,500 meters above sea level promotes a cooler climate that permits the production of a wider range of crops than elsewhere in Sub-Saharan Africa. Potatoes in particular grow well under the cooler conditions prevailing at higher altitudes; conversely, at lower altitudes crops such as bananas and rice grow well. Nevertheless, overall the temperature range is generally below the harsher high temperatures that can curtail crop growth.

The moist conditions that prevail during the rainy seasons promote the spread of fungal diseases, whereas the consistent temperatures favor the development of insect pests. High levels of rainfall contribute to the leaching of soil nutrients and acidification of the soil. Moreover, the steep slopes that dominate much of the country render soils liable to erosion, especially once cultivated. Rwanda's meteorological conditions are thus a two-edged sword that favors the growth of crops and their pests and diseases whereas also promoting soil degradation.

Almost all staple crops (with the exception of rice) are grown by a large proportion of smallholders, many of whom produce only on a subsistence basis. The average farm size in 2006 was 0.72 ha. This is insufficient to provide sustainable food security and in rural areas, agricultural income (including the value of home consumption) averages RF 120,697 (US$180) and represents only approximately 52 percent of average household income of RF 235,000 (US$350). Of this amount, home consumption amounts to approximately 87 percent (NISR 2012b). Given the emphasis on subsistence production, markets have developed based on the commercial surplus that is sporadically generated and that can vary from season to season. In most cases, prices also fluctuate bimodally within the seasonal framework, albeit in a relatively predictable manner. Nevertheless, such markets are generally poorly developed so that local surpluses and shortages can arise as a result of traders' limited capacity to take advantage of opportunities for spatial arbitrage. (Temporal arbitrage opportunities are limited by the fact that most crops are produced twice in each year, so that price variations are short term in nature, as well as by limited storage capacities among traders and processors.)

The financial investment by most smallholders in crop production has been low in the past. Growers have tended to apply livestock manure and compost to nourish crops as opposed to inorganic fertilizer. Fungicides and insecticides have been rarely applied, and traditional varieties have predominated over new improved seeds and planting material. Much of this is now changing as a result of the government's Crop Intensification Program, which has promoted the use of inorganic fertilizers and the dissemination of improved seeds and planting materials. This has resulted in a substantial increase in the production of all the crops falling under this program, although the level of fertilizer usage remains low (only 34,200 MT of inorganic fertilizer were imported into Rwanda in 2010/11, equivalent to less than 38 kg/ha over the entire seasonal crop area per annum and less than 20 kg/ha per crop. This is higher than many SSA countries, but still considerably less than the economic optimum. At the same time, most smallholders grow crops in mixture (in some cases mixing not only crops but varieties of crops as well). Beans are often grown in mixture with maize, whereas bananas act as a shade crop for other lower-growing plants. This strategy allows optimal use of whatever plant nutrients are available, and may reduce the spread of pests and diseases, but also results in less than optimal yields of all the crops that are sown.

Under conditions of good rainfall and equable temperatures, coupled with low input/output farming systems, it is not surprising that the following analysis of risk for six food crops grown in Rwanda shows little impact of most hazards upon the generally increasing production trends at a national level. Nevertheless, it is also evident that production levels are still substantially below those that could be achieved given adequate investment in crop inputs. This suggests that at the individual household level, risk may play a larger part in restricting investment and reducing production. This aspect of risk and its impact upon production is assessed in the following analyses of the six food crops in turn and the different aspects of the risk inherent in the production of each.

BANANAS

Bananas are the most important crop in Rwanda in terms of volume and are grown throughout the country. Three types of bananas are recognized: Integrated Household Living Conditions Survey 3 (EICV3) data indicate that in 2010/11, 59.3 percent of rural households grow cooking bananas, 47.9 percent grow beer bananas, and 38.8 percent grow dessert bananas.[47] The crop is produced throughout the year, with marginally higher levels of offtake occurring during Season A.

The value chain for dessert bananas is poorly developed, and the extent of damage between production and consumption can be substantial, so most dessert bananas are consumed at home. Cooking bananas are more resilient and are both consumed at home and widely marketed domestically and in neighboring countries. Beer bananas are both used at home and sold into the domestic market, which consists mainly of small beer and wine producers, although some larger processing plants also exist (for example, the COVIBAR factory, with a capacity of over 2 million liters per annum).

In Rwanda, bananas are grown under three systems: (1) backyard cultivation (1–10 plants); (2) on small plots where bananas are planted as a second-story shade crop in mixture with either perennial or annual crops; or (3) in monoculture. The bulk of Rwanda's bananas are produced from small mixed plots where the bananas receive little direct fertilizer but benefit from the fertilizer applied to other crops or generated by them through nitrogen fixation.

[47] Almost all bananas grown in Rwanda are part of the East African Highland Bananas subgroup. These are largely derived from *Musa acuminata* and are genetically distinct from plantains. The subgroup contains five clone sets; one consists exclusively of beer bananas, whereas the other four clone sets include both cooking and dessert bananas.

PRODUCTION RISKS

Moisture Stress

The FAO defines bananas as being highly sensitive to moisture stress (Brouwer and Heibloem 1989). Yield reductions from lack of moisture can occur at any stage of growth, although it might be expected that the greatest impacts would occur during fruit development. Nevertheless, the period from flowering through to the development of ripe fruit is long (105–155 days depending upon variety), allowing opportunities for compensatory growth so that given the relatively consistent rainfall regimes in both Season A and Season B, substantial loss of yield is unlikely. It is only during extreme seasons (which occur with less than 10 percent frequency) that significant loss because of moisture stress occurs. This does not imply that rain-fed bananas in Rwanda can be expected to produce the yields observed under irrigation.

Flood and Wind

Bananas are susceptible to flooding and short periods of submergence can lead to the death of plants. Nevertheless, the occurrence of flooding is generally localized and to some extent predictable so that flooding is not considered a significant risk to banana production.

Localized intense storms and high winds occur frequently in Rwanda. Winds in excess of 70 km/hr can cause fruiting banana plants to topple. Plants that are completely uprooted can be replanted but will lose any fruit that has been developed. Partially toppled plants may continue to bear fruit, but the resulting bananas are small and yields are significantly reduced. Losses caused by wind are unpredictable and can be substantial for individual farmers, although some damage can be prevented by propping plants as the bunches begin to develop. Reports suggest that losses caused by wind although potentially severe at an individual level, are restricted to no more than 100–200 hectares each year, and are hence of minimal significance to national production. Neither is the frequency or extent wind damage sufficient to affect the investments made by growers in banana production.

Pests and Disease

The two main pests of bananas are nematodes and the banana weevil (*Cosmopolites sordidus*). Both pests are widespread and lead to chronic losses. Nematodes of a number of different species feed on the roots of bananas, causing lesions that can promote bacterial infection as well as restricted root growth that can lead to a higher frequency of toppling. The most common nematode infesting bananas (*Pratylenchus goodeyi*) is found predominantly above 1,400 m, where it is present in most soils. Nematode populations increase over time in dense stands of bananas, and may eventually cause significant loss of yield, but their impact can be reduced by cultural practices, including crop rotation and intercropping. Where these are practiced, yield losses are small.

Banana weevils feed upon exposed corms of bananas and are most prevalent below 1,200 m and in monoculture plots. The damage caused by banana weevils is generally limited, although in extreme cases, individual plants can die and yield loss will be 100 percent. Nevertheless, as with nematodes, the impact of banana weevils can be reduced by good cultural practices, including minimizing the exposure of corms above the surface of the soil.

The two main banana pests thus constitute constraints to production, limiting yield when stands of bananas are not rotated or when cultural practices are inadequate. Under most conditions, the risk to banana production posed by either pest is minimal.

Four diseases affect banana production in Rwanda. The first, Panama disease, caused by *Fusarium oxysporum,* only affects modern varieties of bananas and is of no risk to the East African Highland clone sets which are resistant to the disease and constitute the bulk of production in Rwanda. The risk caused by Panama disease is thus limited. The second, black sigatoka (*Mycosphaerella fijiensis*), is capable of infecting all known varieties of bananas and of causing substantial loss of yield. The disease caused serious loss of yield in Rwanda in 2004 (National Bank of Rwanda, 2005 Annual Report) and has been present throughout much of Rwanda since that time. Under ideal warm and wet conditions, transmission of black sigatoka can be rapid. It is spread by wind-borne ascomycetes, by raindrop splash, and by poor crop hygiene. Cultural control is of limited use and a preventive fungicidal regime of up to 10 applications annually is required if substantial loss of yield is to be avoided. This is beyond the capacity of many growers, so the risk posed by black sigatoka to banana production is considerable.

Banana bunchy top disease is caused by a virus spread by sucking insects and poor crop hygiene. It causes the deformation of emerging leaves leading to eventual death of the plant. Early infection causes 100 percent loss of yield, whereas late infection results in small and deformed fruit. The disease is relatively easily transmitted, causes severe yield loss and most importantly, is rarely detected until the characteristic "bunchy top" appears, by which time infection is extensive and the plant will already be acting as a source of infection to new plants. It is not surprising that BBTD is considered the most devastating viral disease affecting bananas (ProMusa 2014).

Banana bacterial wilt (BBW—also referred to as banana Xanthomonas wilt—BXW), was first identified in Rwanda in 2005. The disease is caused by *Xanthomonas campestris* pv. *musacearum;* bacteria multiply within the plant, producing a gummy exudate that blocks vascular tissues (causing wilting) and rots fruit. Infected plants die, with 100 percent loss of yield. The disease is spread by insects that carry the bacterial exudates from plant to plant and by poor crop hygiene. It can remain in the soil for up to five months. As of 2012, BBW had spread to 23 of Rwanda's 30 districts. All varieties of banana are susceptible and no chemical treatment exists. Control is by uprooting and destroying diseased plants and rotating with other crops for at least six months. BBW/BXW ranks with BBTD in its severity of impact.

Overall, the risks posed to banana growers by disease are considerable. An individual grower may easily experience 100 percent loss of yield, the potential frequency of occurrence of any of the three diseases (black sigatoka, BBTD, and BBW) is increasing, and the remedies available to growers are few. At a national level, the risk to the banana subsector posed by these diseases is also substantial. Although not quantifiable using a historical methodology, the potential impact to the industry is severe enough to warrant substantial investment in research and extension to control all three diseases.

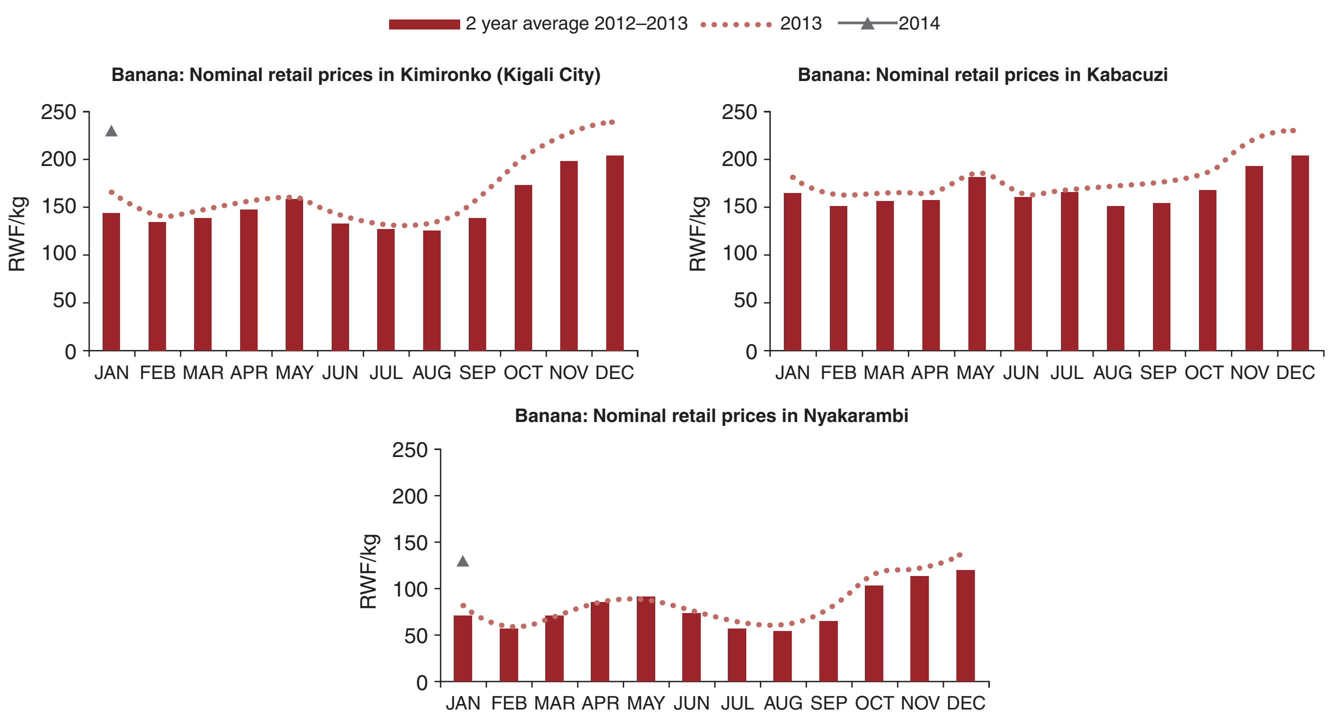
MARKET RISKS

Domestic Price Volatility

The domestic market for bananas fluctuates, with lowest prices obtained at the end of each season as the bulk of the fruit matures and comes to market (figure E.1)

Markets also vary according to type. Dessert bananas are grown on a subsistence basis by most households. The

FIGURE E.1. RETAIL PRICE VARIATION IN DOMESTIC MARKETS FOR BANANAS



Source: FEWS NET 2013b.

value chain is not well developed and the risk of damage to fruit is high. As a result, prices for dessert bananas can be variable and there is considerable risk in engaging in commercial production for the dessert market. Cooking banana prices are more stable because the fruit is harvested when it is more resistant to damage and can therefore be transported to a wider market. Nevertheless, prices still fluctuate, in some cases unpredictably. By contrast, growers of beer bananas report that the offtake and market for their product is more stable; this is cited as a reason for growing beer bananas in preference to the other two types, even though the yields of beer bananas are generally lower than those of cooking or dessert bananas.

Nevertheless, Rwanda currently consumes more bananas than it produces, with the deficit imported mainly from Uganda, so that prices remain close to import parity for much of the year. From this perspective, the probability of a significant fall in prices to unprofitable levels is minimal.

International Price Volatility

Given the consistent domestic deficit in bananas, it is inevitable that the Rwandan market will be affected by international prices. Nevertheless, the international prices in question are those of markets in Uganda and to a lesser extent Kenya, the DRC, and Burundi. Global banana prices, which normally peak in March and are at their lowest in October–December, have little impact on the international market that surrounds Rwanda, which is effectively insulated against global market price fluctuations by the high cost of transport of bananas into the area. As a result, international price volatility is of a similar order to the domestic price volatility and is not a major factor affecting the risk involved in banana production.

Summary

Rwandan banana producers operate mainly with an extensive mixed cropping system that provides few inputs to bananas and relies upon cultural practices to achieve adequate levels of pest and disease control. The intensity of production could be substantially increased and yields could be increased by 120 percent if a package of inputs more in keeping with international standards could be accessed by growers and applied. Nevertheless, such a level of investment is currently very much at risk from the impact of at least three potentially severe diseases (black sigatoka, BBTD, and BBW) for which no effective treatment exists and which can therefore cause dramatic loss of yield. From this perspective, a low-level system of production that requires minimal investment appears to be entirely justified. Only if it is clearly evident that these three diseases can be effectively controlled can smallholders be expected to increase the intensity of their production systems. Viewed in this way, the risks inherent in banana production are currently restricting national production to no more than 40 percent of potential output.

BEANS

Beans are arguably the most important crop in Rwanda in terms of national consumption. They are grown throughout the country by 92 percent of rural households. Almost all beans grown in Rwanda are of the *Phaseolus* type,[48] which can be divided into bush beans, and the more recently introduced climbing beans. A wide number of different local and improved varieties exist for both types. They are adapted to different purposes and conditions, with different lengths of growing period, degrees of determinacy, and components of yield. Different varieties are grown in different parts of the country as mixtures of varieties, in mixture with other crops, or in monoculture. Beans are produced in both Season A and Season B.

PRODUCTION RISKS

Moisture Stress

The FAO defines beans as being of medium-high sensitivity to moisture stress (Brouwer, Prins, and Heibloem 1989). Sensitivity is particularly high during the periods of flowering and pod initiation, when moisture stress can result in the abortion of pods, and during pod filling, when moisture stress can cause reduced bean size. The probability of yield loss through moisture stress is clearly greater in the drier climate in the eastern and southern parts of Rwanda, but can be reduced through the use of varieties that have a shorter growing period, albeit with a reduced yield. Bush beans have a shorter growing period than climbing beans and are therefore more suited for production in the Eastern and Southern Provinces.

[48] Other types of bean including *Vicia faba* and *Vigna* types are also grown, but the quantities produced are very small.

Significantly, in Season A 2012, climbing beans in the Eastern Province yielded 1.45 MT/ha, whereas bush beans yielded only 0.78 MT/ha (approximately half). This suggest that a lack of moisture is not a constant constraint to the production of beans in the Eastern Province—rather that growers have adopted a risk mitigation strategy based upon bush bean production because given the variability of rainfall amounts in the Eastern Province, it is more certain that bush beans will produce a crop than will climbing beans. From this perspective alone, it would appear that erratic rainfall/moisture stress contributes to the risks involved in bean production that result in an approximately 50 percent reduction in the potential output of beans from the Eastern Province.

The impact of moisture stress in terms of varieties selected and consequent production is less in the other three provinces, especially in the Western and Northern Province of the country, but it is nevertheless clear that moisture stress is a significant component of risk affecting bean growers' cultural practices throughout the country.

High and Low Temperatures

Beans are sensitive to temperature, growing optimally at day temperatures of 20°C to 26°C. Temperatures of 30°C or above during flowering can lead to the abscission of flowers and low pod set, whereas temperatures below 20˚C will delay maturity, thereby increasing exposure to moisture stress. The many different varieties of bean in Rwanda exhibit different degrees of sensitivity to temperature and it is possible that the common practice of planting different varieties in mixture mitigates the impact of extreme temperatures by ensuring production from at least some proportion of the mixed crop. This risk reduction strategy will inevitably reduce yields below those that could be achieved using single improved varieties (many of which yield at least twice as much as the traditional landraces), but the risk of yield loss through extreme temperature is enough to justify accepting a lower level of production to guard against the more severe losses that would occur if a single modern variety were to be planted.

Pests and Disease

There are two main pests of beans grown in Rwanda: the beanfly (bean stem maggot, *Ophiomyia* spp.) and the bean *Bruchid* (that is, a number of *Bruchid* species). The beanfly is widespread throughout Rwanda. Loss of yield is caused by the beanfly larvae, which emerges from eggs laid within young leaves and mines its way through the plant to the base of the stem where it completes its development. Damage can be extensive depending upon the severity and timing of infestation, but has been estimated to reduce bean yields nationally by 180–225 kg/ha (that is, as much as 25 percent of yield) (Trutmann and Graf 1993). At an individual farm level, the extent of damage is also affected by the vigor of the crop. Adequate soil moisture and nutrients are associated with vigorous crop growth and limited damage from beanfly, whereas stressed or stunted crops tend to exhibit higher levels of damage. Beanfly can be controlled through integrated pest management, including the use of resistant varieties, and by chemical spray, including neem, but it represents a constant threat to growers. It is almost inevitable that some damage will occur, but there is a lower probability that such damage will result in severe yield loss. Nevertheless, beanfly damage represents more than a constraint to production and must be considered as contributing toward the risk faced by bean growers.

Bruchid species infest bean pods in the field and can then become important pests of stored beans, causing losses of up to 30 percent (Jones 1999). The pest can also be sustained within stores under conditions of poor storage management. Control can be achieved through the use of resistant varieties, by coating seeds with edible oil (which will kill *Bruchid* eggs), through anaerobic storage, and through the use of fumigants. The two *Bruchid* species that infest beans are widespread in Rwanda and a minimal level of infestation is inevitable. Good storage practices will constrain such infestations. Poor practices will result in higher levels of damage. As a result, the impact of *Bruchids* is less of a risk inherent in bean production and more of a constraint that obliges growers to invest in the basic requirements for good storage.

Beans are susceptible to a wide range of diseases, in Rwanda, at least seven important diseases of beans exist: angular leaf spot, anthracnose, bacterial blight, aschocyta blight, rust, bean common mosaic virus (BCMV), and root rot.

Angular leaf spot is the most important cause of loss of yield in Rwanda (Mukeshimana and Kelly 2001). It is caused by the fungus *Phaeoisariopsis griseola*, which infects the leaves, causing cell necrosis and consequent loss of yield. The disease can occur at a range of temperatures, and is favored by humid conditions; water is essential to infection. Angular leaf spot is spread between crops on infected plant debris, and within crops by raindrop splash and by air currents that can distribute spores over a wide area. Control can be improved through improved crop hygiene, but the risk of airborne infection remains. Damage to infected crops can be reduced through the use of fungicides.

New varieties of bean are available that show resistance to angular leaf spot. Nevertheless, resistance tends to be more to specific local isolates of *P. griseola,* so that some risk of breakdown of resistance remains. As such, angular leaf spot poses a significant risk to bean producers in that its incidence is unpredictable and its impact can be substantial.

Anthracnose is the second most important cause of yield loss in Rwanda, and can reduce production by 35–95 percent according to the extent and timing of infection. The disease, caused by the fungus *Colletotrichum lindemuthianum*, is spread between crops on infected material, and in infected seed. Within crops, the disease spreads by raindrop splash. Anthracnose development is favored by cool, wet conditions and is thus more prevalent In the Northern and Western Provinces. Control can be achieved through crop rotation combined with the use of disease-free seed. Some varieties of beans show different degrees of resistance to anthracnose so selection and planting of resistant varieties can also provide effective control. Chemical control is also possible, but must be provided on a preventive basis to be effective. This is generally too expensive for most smallholders.

Although anthracnose can cause severe loss of yield, it is an avoidable disease if clean seed of resistant varieties is planted in fresh ground. From that perspective, the disease is less of a risk and more of a constraint to production in those situations where control has not been adequate, in which case some level of infection is almost inevitable.

Bacterial blight of beans includes two diseases, common bacterial blight (CBB) is caused by *Xanthomonas campestris* pv. *phaseoli,* and halo blight (HB) by *Pseudomonas syringae* pv. *phaseolicola.* These are the two most important bacterial diseases of beans in East Africa. The incidence of blight in Rwanda can vary both locally and from season to season. Both diseases are favored by high levels of humidity and the continuous growing of beans in the same area, and can cause substantial loss of yield if crops are infected early. Control measures include increasing the length of time between crops of beans in a plot and the use of modern varieties that are effectively resistant to both CBB and HB.

Aschocyta blight is a disease of cool humid climates and as such is more prevalent in the Northern and Western Provinces. The disease is caused by a number of *Aschocyta* species and although many bush varieties of beans are susceptible, most of the modern climbing cultivars are resistant to aschocyta blight. As a result, it is expected that although the disease has been a significant constraint to production in the past, with the spread of improved seeds into the Northern and Western Provinces, its significance will diminish.

Bean rust is caused by the fungus *Uromyces appendiculatus*. This pathogen infects leaf material and disrupts cell metabolism, leading to the production of new fungal spores at the expense of plant growth, causing severe loss of yield in the process. The disease is favored by moist, warm conditions, which promote both the growth and multiplication of the pathogen. *U. appendiculatus* can persist between crops as tough teliospores, but multiplies rapidly within crops through the formation of uredospores, which are spread on wind currents to infect new plants. Bean rust exists as a wide range of races of varying virulence, with new races continually arising. Conversely, the many different varieties of beans in Rwanda possess different degrees of resistance to the different races of rust. Consequently, the development of a new and virulent races of rust can result in the rapid development of an epidemic if it can overcome the resistance of existing varieties. This occurs irregularly every 10–20 years. Chemical control of rust is possible, but the disease multiplies so rapidly that fungicides must be applied on a preventive basis to be effective and this is too expensive for most smallholders. Thus, although bean rust can be partially controlled by breeding for disease resistance, there is a continual risk of the development of an epidemic, and consequent high levels of loss caused by bean rust.

The bean common mosaic virus is a disease of beans in Rwanda that can cause yield losses of 35–98 percent (Schwartz and Galvez 1980). It infects the entire plant, causing root necrosis and leaf chlorosis and die back. It is spread by sucking insects, especially the black aphid. Control can be achieved by good crop hygiene, particularly the use of clean seed, and by varietal resistance. Many of the newly introduced climbing varieties are resistant to BCMV, but as with some other diseases, resistance is specific to specific varieties of the virus and can break down if new varieties of BCMV arise. In common with many other diseases of beans, the spread of infection can be reduced by planting beans in mixture with other crops or as mixtures of varieties. BCMV is thus unpredictable in its incidence and infection, and once begun cannot be controlled. From this perspective, it poses a risk to bean producers.

Root rots caused by a range of fungal agents (mainly *Fusarium, Rhizoctonia, Pythium,* and *Sclerotium* spp), either alone or in complexes, can cause loss of yield varying in severity with the timing of infection and the condition of the plant. Weak plants growing in waterlogged soils can be killed if infected at the seedling stage, whereas older plants in drier soils may appear unaffected. A number of local and improved varieties, especially climbing varieties, have been found to be resistant to one or more of the various fungal agents (Nzungize, Chrysostome, Mukashema, Ikirezi, and Nivitange 2011), suggesting that the genetic diversity of Rwanda's bean subsector has evolved as an effective mechanism to cope with various risks, including in this case, root rots. Control therefore consists of good cultural practices (especially crop rotation) and the use of resistant improved or traditional varieties. If these are available, the probability of root rot infection is low and the risk posed by the disease is similarly minimal.

Overall, it is evident that a wide range of diseases pose a significant threat to bean production in Rwanda. In some cases, diseases exist as constant constraints to production (for example, anthracnose, aschocyta, and root rots), causing relatively predictable levels of loss under certain conditions. Other diseases can cause higher levels of loss with much less predictability and little effective control other than improved cultural practice and the use of resistant varieties. Such diseases, including angular leaf spot, rust, BCMV, and blights, require the constant development of new resistant varieties to combat the development of new varieties of the pathogens. As such there will always be a risk of resistance breaking down and of epidemic infections caused by the development of new and virulent varieties of these diseases.

From this perspective it is clear that a limited number of specific diseases constitute a significant risk to bean growers. Intensive investment in the production of beans will be inhibited until such time as either new varieties with strong "horizontal" resistance that is not easily broken down can be bred and disseminated, or until growers can afford the cost of preventive fungicides to combat these "high-risk" diseases.

MARKET RISKS

It is estimated that up to 30 percent of the bean crop is marketed. Most production is sold domestically, but the value chain is not well developed and it is hard to acquire commercial volumes of beans for trading purposes. Nevertheless, the domestic market appears to be well integrated, with prices moving in parallel in different markets (figure E.2).

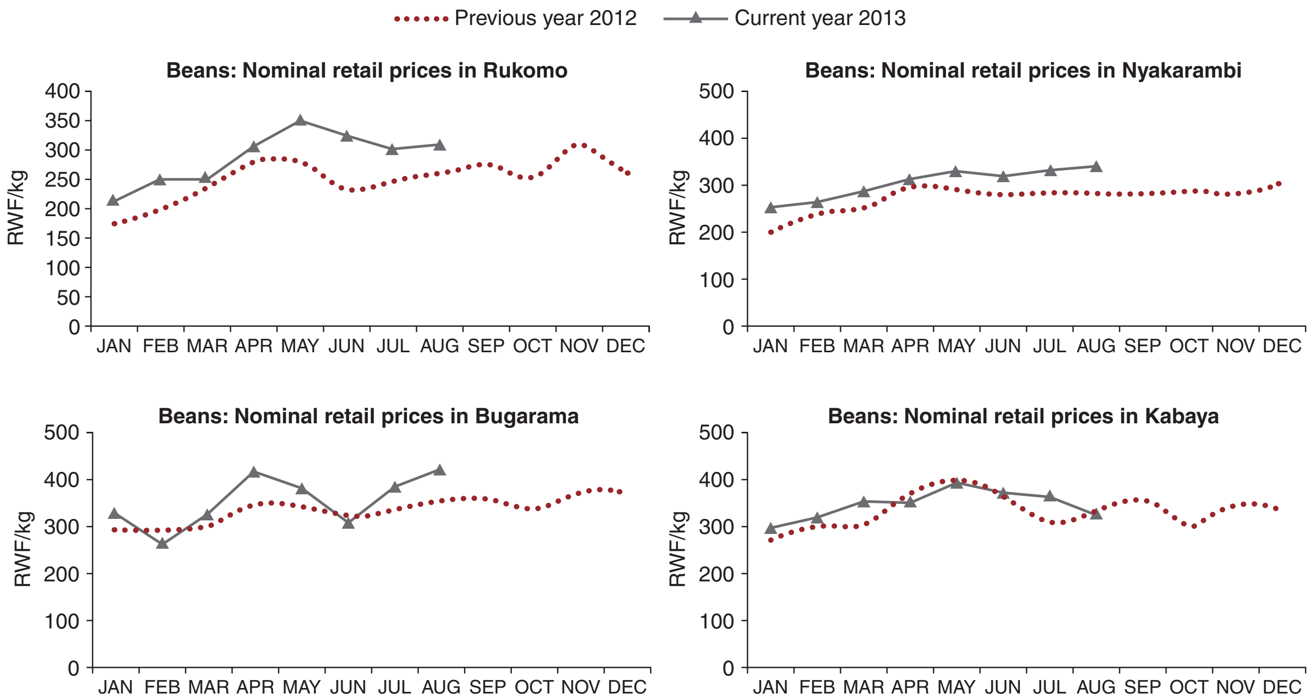
Price data show small seasonal fluctuations, but overall domestic price volatility is limited and the element of risk because of poor market prices in any given season is not great.

A very small amount of Rwanda's bean production is exported, mainly to Burundi and the DRC (and some beans are occasionally imported from Uganda depending upon local price fluctuations), but the market is isolated by transport costs from the global trade and overall the impact of international price fluctuations is negligible.

Summary

Rwandan bean growers produce yields that are higher than that of most of the rest of Africa, but lower than the commercial optimum and substantially less than the potential of new varieties. The element of risk is clearly a factor in the reduced investment that leads to the lower level of production. That risk includes the impact of irregular rainfall and moisture stress, high and/or low temperatures, and especially the impact of specific diseases.

FIGURE E.2. PRICE MOVEMENTS IN DOMESTIC MARKETS FOR BEANS



Source: FEWS NET 2013b.

The mixed crop cultivation methods used by most Rwandan growers are appropriate for the level of risk inherent in bean production. They provide an optimal strategy in the face of diverse risks of uncertain frequency and potentially substantial impact. If growers have access to disease-resistant varieties, a significant element of risk is removed and higher levels of investment are appropriate (and are indeed used—the level of fertilizer application on the more disease-resistant climbing beans is twice that used on local varieties). This clearly demonstrates the significant impact of risk upon bean production and suggests that if such varieties could be more widely disseminated, yields might be increased by 50 percent overall.

Thus the longer-term yield trends for beans are largely dependent upon the dissemination of disease-resistant cultivars which remove a substantial element of the risk facing growers and thereby permit more intensive cultivation.

CASSAVA

The area and production of cassava in Rwanda are slightly less than those of Irish potatoes. As such, it is the third most important perennial crop (after bananas and Irish potatoes) and fifth crop overall (when the grain crops maize and beans are included). The crop is grown throughout the country by 52.3 percent of rural households and is produced throughout the year.

In Rwanda, cassava is often interplanted with beans or other low-growing crops. Cassava thus benefits from whatever fertilizer is applied to the other crop, or in the case of beans, indirectly from nitrogen fixation. The crop is consumed both as a subsistence crop and marketed in raw and processed forms. Raw tubers can be found in local markets, but the crop must be processed if it is to be stored and a substantial proportion of Rwandan cassava is sold as dry chips or flour. Processing is generally a cottage industry; chips are often produced by individual smallholders and flour by micro millers (although a large cassava processing plant was opened at Kinazi in 2013). Cassava is the fifth most widely consumed commodity in Rwanda, making up 3.4 percent of national consumption.

Global data suggest that under rain-fed conditions, cassava yields of over 25 MT/ha/year can be regularly achieved through the use of improved modern varieties and the application of approximately 100 kg/ha N, 50 kg/ha P_2O_5, and 100 kg/ha K_2O as inorganic fertilizer.

Current national yields of 12.1 MT/ha/year are markedly below this level. This may be the result of a number of factors, including the continued use of less productive varieties, poor cultural practices, high levels of disease, and reduced levels of soil fertility. The following analysis attempts to quantify these effects.

PRODUCTION RISKS

Moisture Stress

Cassava is widely considered to be a drought-tolerant crop, although the soil moisture levels at which cassava demonstrates symptoms of stress are actually higher than those for maize and beans. However, it is this characteristic of cassava (the capacity to respond rapidly to moisture stress by closing stomata and limiting cell metabolism) that allows it to endure periods of low moisture and equally rapidly regain production once adequate soil moisture is restored (Lebot 2009). Nevertheless, cassava is sensitive to moisture stress during the period of root growth (30–150 days) and prolonged drought can reduce yields by 30–60 percent. Under the rainfall conditions that prevail in Rwanda, cassava production will be substantially affected by reduced rainfall approximately 1 year in 10 at most. It is therefore unlikely that moisture stress contributes significantly to the risks inherent in cassava production in either season in Rwanda.

Pests and Disease

Pests of cassava include the green spider mite (*Mononychellus tanajoa*), cassava mealy bug (*Phenacoccus manihoti*), white fly (*Bemisia tabaci*), and nematodes. Of these, the green spider mite is widely distributed and in 2007 was found to infest approximately 40 percent of all cassava plants, causing 45 percent damage on average where infestation occurred (Night et al. 2011). The predatory mite *Typhlodromalus aripo* has been introduced into Rwanda as a biological control agent of green spider mite, but appears to be only moderately successful in controlling levels of infestation. White fly is present in all areas, and although the direct impacts of this pest are minimal, it is significant as a primary means of transmission of viral diseases. The incidence of cassava mealy bug has been reduced by the introduction 30 years ago of the parasitoid wasp *Apoanagyrus lopezi* as a biological control agent, which effectively controls more than 90 percent of infestations (Norgaard 1988). As a result, although the cassava mealy bug can be found throughout Rwanda, its impact on yield is relatively low and it can be considered more as a constraint to the achievement of maximum yields than a risk. The impacts of nematodes are similarly a constraint to yield rather than an unpredictable cause of significant yield loss.

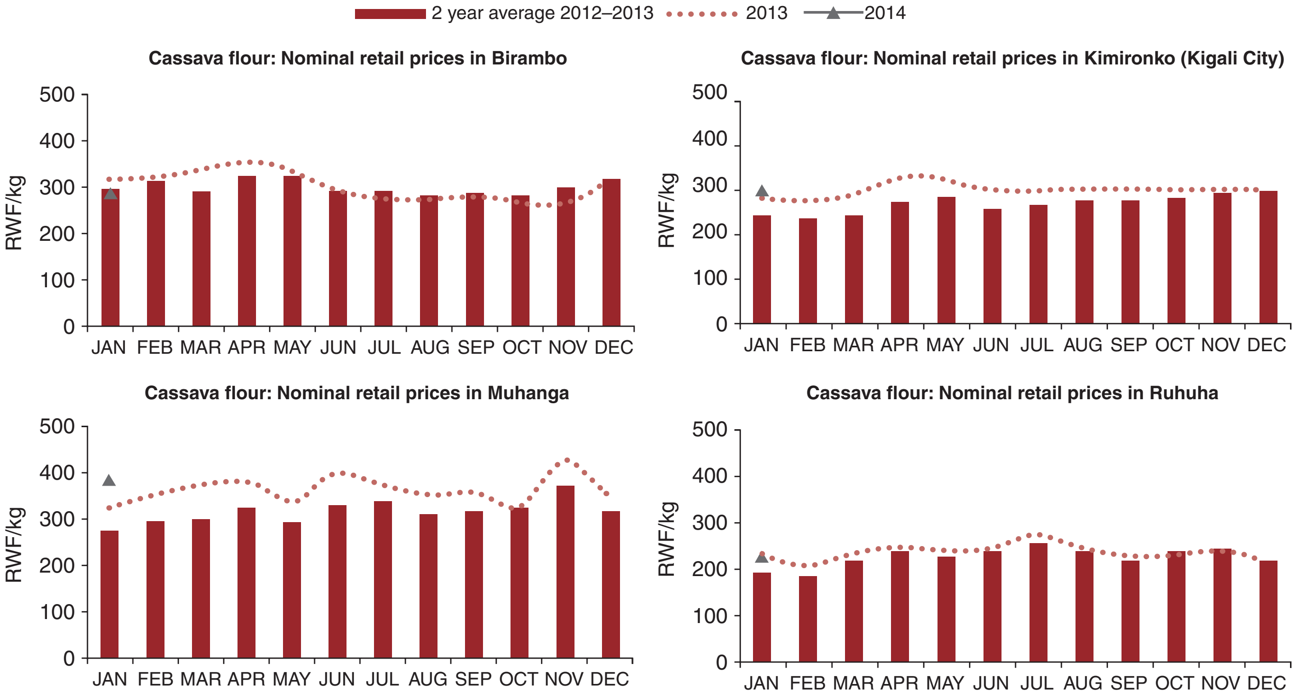
The impact of the green spider mite on yield can be considerable, but the pest is sufficiently ubiquitous that it might currently be considered more of a constraint to production than a risk. Current control options, including breeding for resistance and biological control, have yet to demonstrate substantial success and chemical control of the pest, although effective, is impracticable under current conditions.

Two main diseases currently affect cassava production in Rwanda, caused by the cassava mosaic virus and the cassava brown streak virus. Both viruses are spread by the white fly *B. tabaci* and by the distribution of infected plant material. Both viruses can reduce yields by as much as 95 percent. Currently CMV is more prevalent, but the disease situation in Rwanda has historically been quite fluid, with new virus diseases arising every 10–15 years (FAO 2010) and it is possible that a new form of CBSV is spreading rapidly (Bigirimana, Barumbanze, Ndayihanzamaso, Shirima, and Legg 2011). In 2007, an assessment of CMV found the disease at 94 percent of plots visited, with 32 percent of plants infected and an impact on the yield of infected plants estimated at 60 percent (Night et al. 2011).

Control of viral diseases in cassava relies upon good crop hygiene to limit the spread of infection and upon the introduction of new disease-resistant planting materials. New cultivars with good resistance to CMV are available, but given the relatively slow rate at which cassava can be multiplied through conventional processes (one plant generally yields about 10 cuttings for planting) and the bulk of the planting material required, the diffusion of new varieties through the country will take several years.

Nevertheless, planting material resistant to CMV has been introduced to many growers, and yields of cassava have increased substantially since 2007. For those growers who continue to use older susceptible varieties, CMV and CBSV must be considered constraints to production,

FIGURE E.3. MONTHLY RETAIL PRICES OF CASSAVA FLOUR, 2012 AND 2013



Source: FEWS NET 2013b.

limiting yields and thereby constraining levels of investment in the crop. By contrast, for those growers who have planted disease-resistant varieties, the reoccurrence of disease is now a much-reduced risk, allowing them to apply more inputs and greater attention to the cassava crop in the knowledge that they are likely to achieve substantially greater yields.

MARKET RISKS

Price Volatility

In Rwanda, cassava is marketed as a raw tuber, as flour, or as chips. The multiplicity of markets and the opportunities for processing help smooth market prices over the course of the year and domestic price volatility is low (figure E.3).

Cassava is exported from Rwanda to Burundi and the DRC as flour and to Burundi as raw tubers. This generally occurs when cassava production in either of these two countries is reduced but has little impact upon domestic prices in Rwanda other than to support the market in times of surplus. Global cassava prices do not affect markets in Rwanda and there is little price risk as a result of either domestic or international price volatility.

Summary

Overall, there are few risks inherent in the production of cassava. This is surprising, because although the crop is relatively unaffected by weather, it is significantly affected by pests and diseases. Moreover, national yields are significantly below the levels that could be achieved under optimal investment. The reason for this appears to lie in the frequency with which pests and disease impacts occur; that is, among those growers using traditional varieties, the impacts of pests and diseases are sufficiently consistent for these hazards to be considered constraints to yield. Nevertheless, among growers using disease-resistant varieties, whereas green spider mite infestation may still be a constraint, disease is not, and hence cassava production can be undertaken with a much higher degree of certainty that potential yields will be achieved. For these growers, there remains the uncertainty of yield loss from green spider mite and this may still be a factor affecting investment decisions. Nevertheless, with the exception of this one pest, the production of disease-resistant varieties of cassava exposes smallholders to few risks. This may account for the consistent increase in production observed since 2007.

MAIZE

Maize is widely grown in Rwanda: 75 percent of all households grow maize, making it the fourth most frequently grown crop after dry beans, sweet potatoes, and *Amaranthus* (pigweed). Almost three-quarters (72 percent) of the maize grown in Rwanda is grown in Season A.

Maize is the most rapidly expanding crop in Rwanda. As one of the CIP crops, its production has benefited from subsidized inputs of seed and fertilizer (which are also provided as loans). In 2012, it was the second largest grain crop after beans in terms of volume produced (over 500,000 MT). Nevertheless, according to the EICV3 consumption survey conducted in 2010/11, only 11 percent of the crop is actually sold; a substantial proportion of the crop is consumed as green maize, before the grains ripen; maize grain (or flour) itself accounts for only 2.6 percent by value of the national diet (NISR 2012b).

PRODUCTION RISKS

Moisture Stress

Maize requires constant moisture for optimal growth and yield is reduced if the maize crop is allowed to wilt consistently for more than 48 hours. Growth is particularly sensitive to moisture stress during three periods: (1) when the crop is 50 cm high and dry conditions can restrict the development of the reproductive organs (15 percent); (2) during tasseling, silking, and the completion of pollen germination, when dry conditions can reduce the number of grains that will develop in each cob (50 percent); and (3) during early grain development, when dry conditions can result in shriveled or aborted grains (30 percent). During the latter two growth stages, the maize plant is more developed, with a greater leaf area, transpiration from which may require as much as one liter of water per day. If soils are deep and well structured, crops at these growth stages may be able to extract more water from greater soil volumes by virtue of their greater depth of rooting, but if soils are shallow or of low water-holding capacity, then the demands of evapotranspiration will exceed the supply capacity of the soil and wilting will occur.

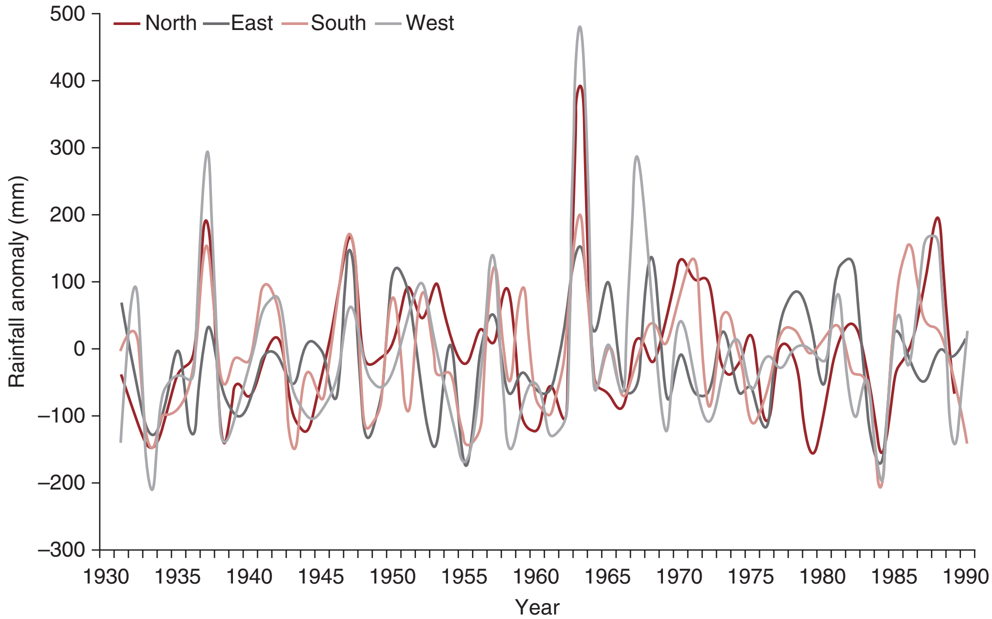
Given the multiplicity of soil types and depths across the country, it is effectively impossible to quantify the impact of erratic rainfall upon maize yields in different parts of Rwanda on the basis of an analysis from first principles. Nevertheless, the issue can be addressed from two perspectives. From a meteorological perspective, the data show a general trend across the country, according to which lower rainfall amounts are received in the Eastern and Southern Provinces (<900 mm per year) compared with the Western and Northern Provinces (1,200 mm per year). This reducing trend might be expected to be associated with a higher degree of variability but in fact, statistical analysis of rainfall data has shown no significant trend in the variability of rainfall amounts across the country (indeed the Western Province appears to be marginally more variable) and no significant difference in variability between the two main rainy seasons (McSweeney, Semafara, Cole, and Washington 2011). At the same time, rainfall records do indicate a degree of interannual variation, especially when data are disaggregated across different parts of the country. Variations equivalent to +/−20 percent of the seasonal total are relatively common, with negative anomalies occurring at least once every 10 years (figure E.4).

Although meteorological data indicate few distinct trends, this may be more a reflection of the very limited number of weather observations available for analysis than of a real lack of difference in variation, because from the perspective of smallholders, erratic rainfall in 2008 caused a loss of yield among 37 percent and 26 percent of smallholders in the Eastern and Southern Provinces, respectively, as opposed to 19 percent and 14 percent in the Northern and Western Provinces.[49] These figures, recorded in a year of above average rainfall nationally, show that uncertain rainfall is perceived to have a significant impact upon yield and might therefore be considered a significant risk faced by smallholders. Indeed, a variation of 20 percent in seasonal rainfall could reduce yields by as much as 50 percent if the dry spell occurred during the critical tasseling and silking stage of growth.

Smallholders can respond to this perceived risk in a number of ways. By reducing plant density, more soil water will be available per plant so that a reduced sowing rate is a common adaptation in drier areas. The use of maize varieties that, although they may yield less, complete their growth cycle in a shorter time (90 days as opposed to the

[49] Comprehensive Food Security and Vulnerability data.

FIGURE E.4. RAINFALL ANOMALIES FOR THE MARCH-APRIL-MAY PERIOD (SEASON B), BY PROVINCE



Source: McSweeney, Semafara, Cole, and Washington 2011.

traditional 120–150 days) also reduces exposure to the risk of erratic rainfall, especially the late onset or early cessation of rains. Good soil management can make a substantial difference, although the application of organic matter, often promoted as a way of increasing the water-holding capacity of soil, has little impact, whereas improving rooting depth through the removal of hoe- or plough-induced soil pans has been shown to have a much greater impact (Conservation Farming Unit 2007).

Overall, however, a limited number of options are open to farmers who wish to grow maize and it must be accepted that at least 1 year in 10, individual crop yields may be substantially reduced.

Floods

Flooding is an occasional hazard reported by smallholders in Rwanda. Young maize plants are very sensitive to flooding and can survive for only two to four days under water.[50] But this sensitivity decreases over time and once maize has reached the stage of grain formation, shallow depths of flooding will not cause any noticeable damage.[51]

[50] http://www.ag.ndsu.edu/procrop/env/fldwhb07.htm

[51] Ibid.

The significance of flooding as a risk varies greatly with location. In valley bottoms, the probability of flooding is much higher than on the hillsides. A significant proportion of the maize currently produced in the Eastern Province is grown in the lowlands of the Akanyeru River basin, where the additional moisture under otherwise dry conditions results in above-average yields, albeit with an increased risk of losses caused by flooding. In these areas, improved drainage infrastructure is the most appropriate measure to mitigate this risk. Nevertheless, for the majority of smallholders growing maize, flooding is not a major risk and is unlikely to affect yield. This is reflected in national data, which suggest that the impact of flooding on maize production is negligible.

Pests and Disease

Prior to 2007, maize areas in Rwanda were considerably smaller and more dispersed than they are now, and the increased consolidation and importance of maize that has occurred in the last five years will undoubtedly increase the probability of losses caused by pests and diseases. Currently, however, pests and diseases levels remain low; until 2013, only leaf blight and maize streak virus were recorded as significant diseases of the growing crop. In June 2013, however, maize chlorotic mottle virus was identified in the Western and Northern Provinces. This virus (together with sugar cane mosaic virus—SCMV) is a component of maize lethal necrosis disease, a disease complex that has spread rapidly in Kenya since 2012 and can cause up to 100 percent loss of yield. This disease poses a significant threat to future maize production. It can be controlled through the introduction of resistant varieties and through stringent crop hygiene measures. These include improved scouting to detect early outbreaks and immediate disposal by uprooting and burning all diseased plants.

Similarly, losses caused by insect pests in the growing crop have rarely been significant. Maize stalk borer (*Busseola fusca*) is the only pest reported to have caused significant losses.[52] In stored grain, insect damage from common pests of stored grain (such as *Sitophilus zeamais,* the greater grain weevil) is not unusual, but because the grain is stored only for a short period, levels of loss have generally been low. The larger grain borer (*Prostephanus truncatus*) is not yet a threat in Rwanda.

One other threat to maize production in the Eastern Province is infestation of the striga weed, which can cause high levels of crop loss. Nevertheless, because the presence of this weed is generally predictable, this is less of a risk and more of a constraint to production.

Overall, the risk to smallholders growing maize from pests and diseases has been historically low, but is expected to increase as plots of maize are consolidated and as grain is stored for longer periods. Viral diseases in particular are a potential threat and warrant an intensive extension program to help smallholders learn how to identify and dispose of diseased plants.

MARKET RISKS

Domestic Price Volatility

Maize prices in Rwanda are determined primarily by local supply and demand. The relatively consistent production that occurs twice a year results in limited and predictable fluctuations in price, with the lowest prices occurring immediately after harvest in February/March and to a lesser extent in August/September. Because the country is a net importer of maize, seasonal variations in price occur against a backdrop of import parity pricing, with prices falling below import parity during periods of immediate surplus and rising to import parity levels over the remainder of the year (figure E.5).

Historically, maize prices show few unexpected variations and appear to be at least as consistent as those in global maize markets. Domestic price volatility cannot therefore be considered a significant risk for maize producers.

International Price Volatility

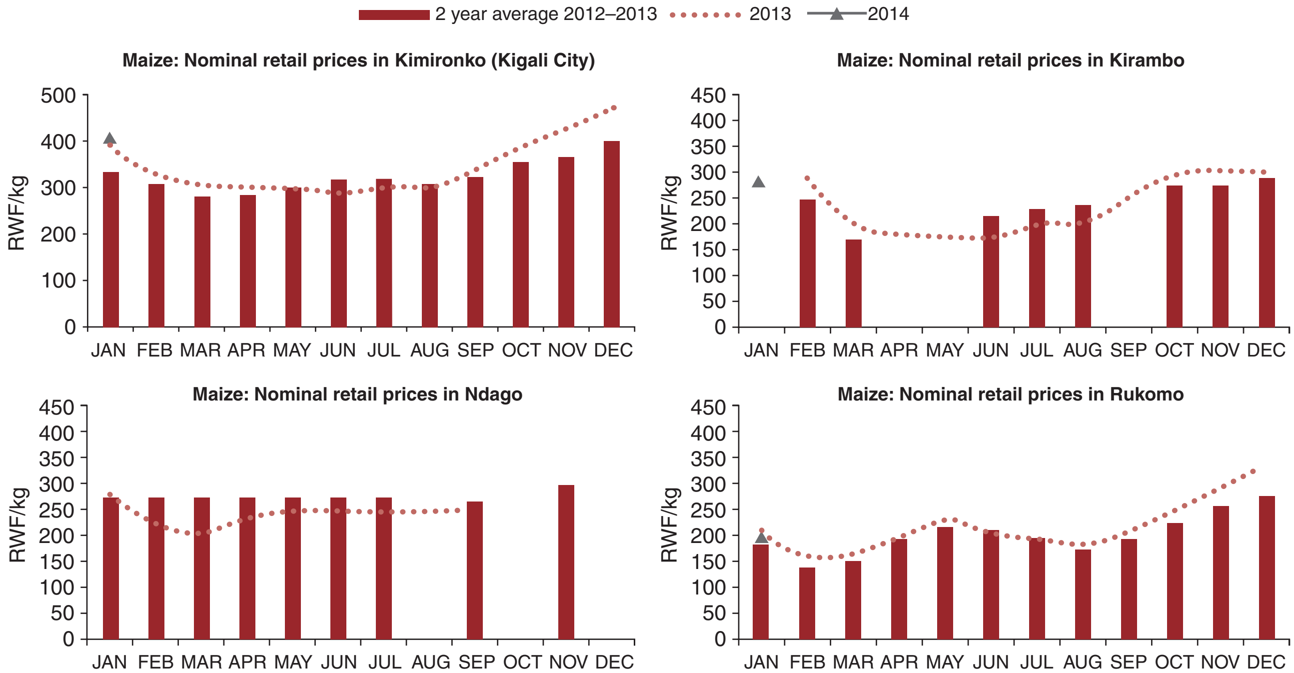
Because Rwanda is situated at a considerable distance from any seaport, costs of inland transport reduce the relative importance of short-term fluctuations in global markets; thus Rwanda is more dependent upon the prices prevailing in neighboring countries. Recently these prices have been at or above average, with the exception of the Zambian market, which can be accessed via Lake Tanganyika and which in 2011/12 was oversupplied with grain. Nevertheless, even though free on board (FOB) grain prices in Zambia were only 50 percent of domestic prices, supplies were limited and did not significantly affect the Rwandan market. Overall, a comparison of national and global price indexes suggests that Rwandan maize markets have not been greatly affected by international price volatility and this has not posed a significant risk to growers.

Risk inherent in maize production appears to be primarily associated with the availability of adequate moisture and this factor more than any other can be expected to constrain the investment decisions of growers. A potential risk may exist as a result of increased disease pressure, particularly the threat of MLN disease, but that has not yet been widely experienced and as a result is unlikely to be factored into smallholders' investment decisions at present.

Nevertheless, it is not yet possible to determine how much of the substantial gap between the current levels of maize production and those that could potentially be achieved can be ascribed to smallholders' perception of risk and how much is attributable to the limited availability of inputs, especially inorganic fertilizers. Under the CIP program, fertilizer inputs have been made available for maize both on credit and at a 50 percent subsidy. The volume of fertilizer purchased in 2011 for the production of maize

[52] Ibid.

FIGURE E.5. SEASONAL VARIATION IN RETAIL PRICES OF MAIZE IN DIFFERENT MARKETS



Source: FEWS NET 2013b.

and wheat was 8,000 MT of urea and 10,000 MT of DAP. This was theoretically applied to 223,000 ha of maize and 43,000 ha of wheat, giving an average nitrogen application rate of only 20 kg/ha. That is an amount that would be removed by 1.2 MT of maize grain per ha, suggesting that the current levels of fertilizer availability are inadequate to sustain yields above those currently achieved.

Thus, whereas the impact of agricultural risk, especially the risk of yield loss caused by erratic rainfall, on the production of maize might be significant, it is currently masked by the limited availability of inputs. The risk to growers of crop loss caused by disease might be of greater significance in the short term if MLN disease becomes more widespread.

IRISH POTATOES

In 2012, Irish potatoes were the second largest vegetable crop after bananas in terms of volume produced (over 2.1 million MT). EICV3 data for 2010/11 indicate that it was grown by 52.9 percent of all households. Irish potatoes are the second most important staple in Rwanda. EICV3 data indicate that they constitute 7.6 percent of all food purchases and 8.3 percent of all food consumption. Much of the crop is consumed locally; only a small volume is exported, although Rwanda is a net exporter of Irish potatoes.

National yields of potatoes in Season A have tended to be higher than those in Season B and areas sown in Season A have been consistently higher, so 60 percent of the national crop is now produced from Season A and 40 percent from Season B.

Potential Potato Yields

Irish potato yields have been recorded at up to 35 MT/ha (Durr 1983); field trials of the Kinigi and Gahinga varieties (both still widely grown in Rwanda) when they were first released in 1982 by the National Potato Program (PNAP) achieved yields of 25.8 MT/ha (Monares 1984). This would suggest that an economic optimal yield would be between 20 and 30 MT/ha.

Internationally, a yield of 25 MT/ha is often considered the commercial optimum under ideal commercial conditions. In practice, countries such as the United States, Canada, and the United Kingdom achieve average yields of 20 MT/ha, 31 MT/ha, and 45 MT/ha, respectively, whereas in Africa, Ugandan and Kenyan growers produce approximately 7 MT/ha. Part of the wide disparity is due to climate, which is certainly more variable in Kenya than it is in the United Kingdom. A major difference, however, lies in the higher level of inputs applied than the more stable climate justifies. In the United Kingdom, the average rates of N, P_2O_5, and K_2O application recommended for optimal yield are N: 150–210 kg/ha, P_2O_5: 250 kg/ha, and K_20: 360 kg/ha. By contrast, potatoes in Rwanda receive on average only 12 kg/ha of each plant nutrient as inorganic fertilizer. It can be argued that additional plant nutrients are applied as manure and compost, but the volumes necessary to achieve the rates of nutrient application required to produce optimal yields are massively greater than the amounts of organic manure available and applied in practice.

Yields of potatoes in Rwanda are thus currently constrained by the amounts of plant nutrients available to growers. This is unfortunate given that the use of other inputs of potato production—especially fungicides for disease control—is quite widespread, but has not resulted in the potential yield benefits that could be achieved through the application of adequate nutrients. It is possible that growers have limited their use of inputs to those they consider most appropriate given the perceived risks. The following analysis considers whether or not those decisions are justified.

Distribution

The production of Irish potatoes requires low temperatures to restrict pests and diseases and high soil moisture availability. Consequently, Irish potatoes are grown on a commercial basis almost exclusively in the Northern and Western Provinces. In fact, data for Season A in 2012 indicate that 60 percent of potato production was concentrated in just three districts: Niyabihu (19 percent) and Rubavu (23 percent) in the Western Province and Musanze (20 percent) in the Northern Province. Nevertheless, the crop is an important staple and although the volumes recorded from the Southern and Eastern Provinces are small, the proportion of households producing the crop remains substantial (table E.1).

PRODUCTION RISKS

Moisture Stress

The production of potatoes is very dependent upon the availability of adequate soil moisture. The FAO classifies the potato crop as highly sensitive to soil moisture (FAO 1989) throughout the period from stolonization through to tuber initiation to early ripening. Moisture stress during this period can result in the development of fewer tubers, whereas moisture stress during tuber growth causes misshapen potatoes. Stress at either time will reduce yields. Although the variability of rainfall during both Season A and Season B is not large compared with that of rainfall in other SSA countries, it is nevertheless possible that yields may be substantially reduced by limited moisture availability at least 1 year in 10 and that lesser yield reductions may occur more frequently. The risk of crop losses as a result of moisture stress is to some extent offset by the impact of drier conditions upon disease (see below) and by the high returns that potato production can generate when demand exceeds supply. As a result of these factors, growers that can absorb the risk of drought-induced loss normally adopt an intensive approach to potato cultivation. This is not the case in Rwanda, suggesting either that growers:

1. Perceive the risks of drought to be substantial;
2. Lack the capacity to absorb crop losses when they do occur; or

TABLE E.1. YIELDS AND TOTAL PRODUCTION OF IRISH POTATOES BY PROVINCE IN SEASON A, 2012

Province	Southern	Western	Northern	Eastern	City of Kigali
Yield (MT/ha)	5.26	17.07	18.04	5.17	3.52
Production (MT)	81,419	712,394	502,547	38,172	1,446
Production (%)	6	53	38	3	<1
Households (%)	58.3	46.5	58.1	57.3	20.9

Source: Agricultural Marketing Information System 2012; NISR 2012b.

3. Are unable to source the inputs necessary to adopt a more intensive approach to potato production.

Pests and Disease

All conventional varieties of potatoes are susceptible to blight (*Phytophthera infestans*) to some degree. This disease more than any other reduces potato yields in Rwanda (and indeed elsewhere in the world). Other important diseases include a range of potato viruses that are most commonly spread by sucking insects and which can cause leaf yellowing or other deformities, and bacterial wilts caused by *Pseudomonas solanacearum* and by *Erwinia* complexes (also causing soft rots), which are spread by latently infected tubers and by volunteer plants. All of the above diseases are exacerbated by poor crop hygiene, including reduced rotation periods (the period between potato crops in the same soil should ideally be at least four years), the ubiquity of volunteers or backyard potato plants grown by noncommercial growers that can act as a reservoir for disease, and by the use of infected seed (as a result of the limited supplies of clean planting material).

Nevertheless, the occurrence of blight is the greatest risk faced by potato growers, because the spread of this disease is favored by the cool, wet conditions under which most potatoes are grown in Rwanda. Indeed, the overall impact of blight may well be mitigated by the fact that the conditions that favor its spread are also those that lead to the highest yields of potatoes. The impact of blight can be devastating, resulting in up to 100 percent loss of yield and rendering such tubers as might be produced inedible. Even mild infections can result in significant loss of yield and it is not surprising that considerable emphasis is placed upon the regular application of fungicides to control the disease, whereas in some areas growers delay planting so that the crop matures under drier conditions. This reduces the incidence of blight, but increases the risk of yield loss through insufficient moisture.

The probability that a potato crop in Rwanda will be infected by blight is inherently high. The risk that such an infection might lead to devastating loss of yield might be somewhat higher than in other countries, but can definitely be reduced through timely application of a fungicidal regime using a chemical (Dithane) that has been widely available for 40 years. It might therefore be argued that blight need not be so much a risk to potato growers, but a predictable constraint to profitability measured simply in terms of the cost of the chemicals required and their application, as a necessary and inevitable input to the production process. This does in fact appear to be the general trend among growers, who are increasingly aware of the necessity for the preventive use of fungicides and are investing accordingly. Nevertheless, to be fully effective, this trend should be accompanied by government regulations to control the spread of diseases on noncommercial plots, including the destruction of volunteers and diseased plants.

Insect pests do infest potatoes, but are of less significance themselves than as carriers of disease, especially a number of different viruses that infect *Solanaceae*. Nevertheless, the presence of sucking pests is a constant constraint to the production of new planting material, which must be kept as free of insects as possible if it is not to contain viruses when sold to farmers.

MARKET RISKS

Domestic Price Volatility

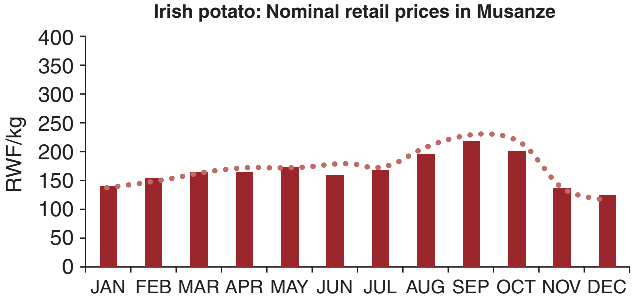
Neither storage nor processing facilities exist for potatoes in Rwanda, hence domestic price volatility is considerable (figure E.6). There is no government intervention in the market for potatoes, which faces shortages immediately before harvest and gluts immediately afterward.

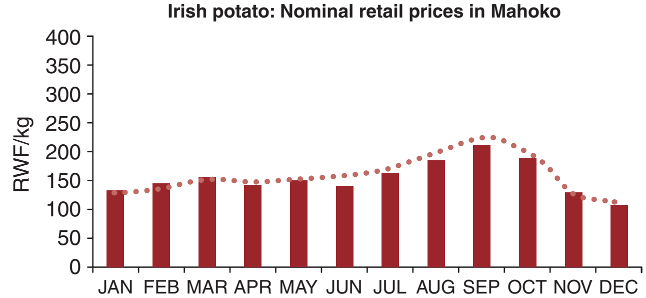
To avoid the impact of each glut, growers tend to harvest as early as possible, generally before the tubers are fully mature, which tends to reduce their shelf life considerably. Price volatility is offset to some extent by three factors: (1) the fact that potatoes can be grown in two, if not three, seasons in Rwanda; (2) the staggering of planting across different provinces; and (3) the import of early- or late-harvested potatoes from Uganda. Nevertheless, farmers regard domestic price volatility as a significant risk inherent in the production of potatoes. Investment in storage and/or processing facilities might help to offset this risk.

International Price Volatility

There is a market for potatoes produced either in Rwanda or Uganda in both the DRC and Burundi, and potatoes from either source can be found in both destinations. To

FIGURE E.6. VARIATION IN DOMESTIC MARKET PRICES OF IRISH POTATOES





Source: FEWS NET 2013b.

that extent, it could be expected that the domestic market would be closely linked with the international market and that prices in both markets would follow similar trends. This is broadly true, but neither domestic nor international markets for potatoes are well developed. The number of large traders active in these markets is small (reportedly less than 10) and clear opportunities for spatial arbitrage frequently exist (USAID 2012). It is evident though that the prices available to producers and traders are determined almost entirely by production within Rwanda and neighboring parts of Uganda, and there is no evidence of any impact of global markets (for example, of potatoes from Egypt or China). International price volatility does not contribute to the risks involved in the production of potatoes.

Summary

Potato producers appear to be at risk as a result of erratic rainfall, disease (mainly blight), and fluctuations in market price. The responses of growers to these risks include changes in sowing and harvesting dates as well as the use of fungicides and pesticides. Overall, cultural practices achieve yields of no more than 50 percent of what has been shown to be commercially achievable under rain-fed conditions in Rwanda. Much of the difference between actual yields and the economic optimal yield (in the main potato-producing districts) can be ascribed to inadequate crop nutrition. What is unclear at present is whether or not inadequate nutrition is a result of the limited availability of fertilizer within Rwanda, or of a reluctance on the part of growers to invest in the application of additional nutrients because of the perceived risk that the returns may not justify the additional investment.

Given that additional investment in plant nutrients can result in substantial additional yield, it might appear that the primary constraint to potato production is indeed the lack of available fertilizer. Nevertheless, the volatility of prices and especially the marked declines in price associated with overproduction (even if only in the short term) can offset the beneficial impact of an increase in yield. Evidence for the counterargument (that the primary constraint to investment is perceived risk) comes from Uganda, where average yields of 7.0 MT/ha are lower than those in Rwanda, even though conditions are similar and the same technologies are available in both countries.

If it is indeed perceived risk that constrains growers' investment in and production of potatoes, then measures such as the increased availability of multi-seasonal finance, crop insurance, and subsidized inputs may all serve to offset that risk and should lead to increased productivity. Further investigation is required before this can be determined with certainty.

RICE

Rice is a CIP crop that benefits from subsidized inputs of seed and NPK fertilizer. In 2012, it was the third largest grain crop (after beans and maize) in terms of volume produced (over 80,000 MT). It is planned to expand the area sown to rice substantially, but this will require significant development of drainage and irrigation infrastructure, and areas sown are currently static. Domestic rice consumption exceeds that of maize flour. Local rice constituted 3.7 percent of all food purchases in 2010/11 and imported rice, 3.1 percent (NISR 2012b). Local supply meets approximately 50 percent of demand at present.

The production of rice in Rwanda is subject to two major constraints: temperature and moisture. As a result, it is grown almost exclusively in the lower valley bottoms, where temperatures are high enough to sustain growth and the marshy conditions provide adequate water. This restricts the area under production; only 4.5 percent of all households grow rice in Rwanda. The crop is produced mainly in three provinces (Western, Southern, and Eastern); lower temperatures preclude its production in the Northern Province, and it is most common in the Eastern Province, which is both warmer and contains the valley areas necessary for optimal production. Approximately 40 percent of the rice grown in Rwanda is grown in Season A and the balance in Season B.

PRODUCTION RISKS

Moisture Stress

Rice in Rwanda is produced under marshland conditions, which are not the same as irrigated conditions (although some irrigation systems do exist), but depend more upon controlled drainage to ensure adequate levels of moisture are available at key growing periods. Such systems are vulnerable to water shortage, especially at the beginning of the season if delayed rains have not allowed the accumulation of adequate moisture for initial germination and growth. Thereafter, a prolonged dry spell may reduce growth and ultimately yield, as may excessive flooding, although varieties capable of withstanding both dry and wet conditions are increasingly available.

Research (Akram et al. 2013) has demonstrated that withholding irrigation water from a rice crop for a 14-day period reduces paddy yield by between 10 and 40 percent, depending upon the time at which moisture stress was imposed. Drought stress at panicle initiation had the greatest impact on yield, whereas stress at anthesis and grain filling led to reduced impacts. In all cases, however, yield reductions exceeded 10 percent.

It is not surprising that when interviewed, rice farmers' key concern appeared to be the availability of water, both from adequate rainfall and from its equitable distribution through communal drainage systems. Farmers considered it essential that available water be effectively distributed both through improved drainage and irrigation channels and through proper management of those channels once in place.

Pests and Disease

Given that rice is grown in large areas across valley bottoms, the crop is vulnerable to the rapid spread of pests and diseases. From a research perspective, these appear to be the main risks now inherent in rice production. Rice blast (*Magnaporthe oryzae*) and bacterial disease complexes (leaf and panicle blight caused by *Xanthomonas* spp. and sheath rot associated with *Pseudomonas* infection) are the major diseases causing yield loss in rice and can affect all known varieties. Control is currently based mainly upon crop and varietal rotation, but RAB noted that for these diseases, "pathogen evolution is so fast that within 3 to 4 growing seasons most grown varieties become susceptible to the extent of causing total crop failure." Lower levels of yield loss are more common, but can regularly be as much as 20 percent. Other diseases such as rice yellow mosaic virus and smuts also occur but with little impact on yield.

The few chemical treatments available to constrain the spread of these diseases appear to have little effectiveness in Rwanda. Some experts noted that this may be because the disease is often recognized and pesticides are generally applied only after the disease has become well established and affected yields.

Insect pests of rice are limited to the rice fly (*Diopsis thoracica*), the larvae of which eat out the center of young tillers, causing blind shoots. Yield loss depends upon the severity and timing of infestation because the impact of early infestations, once controlled by insecticides, can be mitigated by compensatory growth. Nevertheless, yield losses of 5–20 percent are commonly recorded (Akinsola and Agyen-Sampong 1984).

Insect pests of stored rice have been reported, especially the rice weevil (*Sitophilus oryzae*) (Dunkel, Sriharan, Niziyimana, and Serugendo 1990), but these do not appear to be a significant risk for growers or millers given the limited time for which the crop is stored.

MARKET RISKS

Domestic Price Volatility

Rice prices in Rwanda are affected by a government policy that determines a minimum price paid to rice mills by licensed traders. Extensive restructuring of the rice-milling subsector has resulted in the closure of small private mills, which have been replaced by new and more efficient large mills owned by rice cooperatives. Smallholders as members of the cooperatives receive inputs and produce rice that is purchased by the mills at a price determined before the crop is sown. Traders are not allowed to buy directly from smallholders and the large mills are the only source of rice for traders. As a result of this system, neither growers nor mills face any risk from domestic price volatility, in that prices and potential margins are known before any investment in inputs is made.

Nevertheless, such prices are not always favorable to growers; for example, in December 2013, farmers in Muhanga district complained that the price they received (RF 250/kg) was inadequate to cover the costs of production at the yield that they had achieved (3.5 MT/ha). They suggested that RF 300/kg would have been appropriate to cover their costs. The cooperative's response was that prices were set before sowing and would not be increased and that farmers should seek to improve the fertility of their land for the next crop.

International Price Volatility

The stability of domestic prices, coupled with the significant costs of transport to Rwanda from seaports, have created a stable domestic rice market, even though imports from Tanzania, Thailand, and Pakistan may make up 50 percent of the market volume. International price volatility is not a significant risk to either growers or processors in the Rwandan rice value chain.

Summary

Although there is only limited market risk for growers and processors of rice, growers in particular are vulnerable to the impacts of erratic rainfall and disease. It is therefore unexpected to see such high levels of investment and consequent high yields achieved across much of the rice-producing areas by smallholder producers, who have limited capacity to absorb the downside impact of the risk incurred through such investment. Actual yields are consistently more than half of the potential maximum that could be economically achieved, suggesting that growers are either confident that they can mitigate the impacts of moisture stress and disease or that they can absorb those impacts, although in practice neither of these situations are realistic. The high levels of production that have been observed can be viewed from another perspective: an individual marshland smallholder is obliged to invest as much as he/she can to achieve an economic return from rice because he/she is effectively tied into a communal drainage/irrigation system that offers no alternative sources of income, and no market other than the local cooperative, and which charges a membership fee, irrigation fee, and management fee, as well as rent for the land (which the cooperative leases from the state and allocates to growers). Under such circumstances, a low-risk strategy is futile, because overheads will inevitably be incurred and the most effective strategy will be to maximize returns through intensive investment.

Provided the local cooperative provides a rice grower with the support necessary to absorb the downside impact of risk (for example, through insurance, deferred loan repayments, or subsidized inputs), then high levels of risk can be incurred and a high input/high output system of production can be sustainable. If that support is not available, then growers facing losses will be unable to participate in rice production on an ongoing basis.

Current observations suggest that the degree of risk inherent in rice production will increase as areas sown to rice expand and disease pressures increase. If growers can be assisted to develop the capacity to absorb the increasing risk, then levels of production can be sustained. If not, they may not increase beyond current levels unless risk itself can be reduced—primarily through the development of disease-resistant varieties and improved disease scouting to assist in the identification and control of disease outbreaks.

CONCLUSION

The above risk analysis for selected staple crops in Rwanda suggests that even though Rwanda has a fairly consistent climate and stable markets, growers still face considerable risk and adjust their level of investment and production accordingly. All growers face risks associated with climate. Although the frequency of significantly low rainfall amounts in a given season is not high (less than 10 percent), the probability of erratic rainfall and short-term moisture stress is much higher, so that some element of yield loss from moisture stress is almost inevitable. This factor contributes to the risks faced by growers of most crops, especially maize, beans, bananas, and, to a lesser extent, rice and potatoes. Only cassava is not much affected.

A significant component of risk is related to the unpredictable impact of disease, especially in beans and bananas, and to a lesser extent in rice and maize. In Irish potatoes, disease can be expected to occur with a high frequency and thus constitutes more of a constraint than a risk.

Market risks appear to be of limited significance to the production of most staple crops, at least insofar as variations in retail prices indicate little unpredictable volatility in domestic markets and only limited linkage with international markets. This may be a result of the limited level of production by growers who have tailored their output to match normal domestic demand. From this perspective, poorly developed markets might be considered as constraints to production, but there is little evidence that they make a significant contribution to the risk faced by growers.

One significant exception to the response to risk observed for most crops is found in the production of rice, for which growers apply significantly higher levels of inputs and achieve yields closer to those of commercial producers. This assumption of risk appears to be due on one hand to the commercial nature of the crop and on the other to the particular circumstances under which the crop is grown, according to which growers are faced with significant overheads regardless of the level of production they achieve. As a result, they are obliged to assume a higher level of risk to achieve profitability.

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