Planning and costing adaptation of perennial crop systems to climate change: Coffee and banana in Rwanda

Case study report

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Acronyms and abbreviations

CBOs	Community-based organisations
CGIS-NUR	Centre for GIS and Remote Sensing of the National University of Rwanda
CIP	Crop Intensification Program
ClimDev	Climate for Development (in Africa)
CoE	Cup of Excellence®
CWS	Coffee washing station
EDPRS	*Economic Development and Poverty Reduction Strategy, 2008-2012* (2007)
ENSO	El Nino/Southern Oscillation
EUMESAT	European Organisation for the Exploitation of Meteorological Satellites
EWS	Early warning system
EWS-C	Early Warning System for Coffee
FEWSNET	Famine Early Warning System and Network
GCAP	Global Call to Action Against Poverty
GIS	Geographic information system
GoR	Government of the Republic of Rwanda
IIED	International Institute for Environment and Development, UK
ISAR	Institut des Sciences Agronomiques du Rwanda
ITCZ	Inter-Tropical Convergence Zone
IWRM	Integrated water resource management
MDG	Millennium Development Goal
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MINELA	Ministry of Environment and Lands
MINITERE	Ministry of Lands, Environment, Forests, Water and Mines
MTEF	Medium Term Expenditure Framework
NAEB	National Agriculture Export Board
NAPA Rwanda	*National Adaptation Programmes of Action to Climate Change NAPA Rwanda* Report (2006)
NGO	Non-governmental organisation
NISR	National Institute of Statistics Rwanda
NPK	Nitrogen-phosphorus-potassium fertilizer
NUR	National University of Rwanda
OCIR	Office Nationale des Cultures Industrielles
OCIR-Café	Rwanda Café Authority
PSTA II	Second *Strategic Plan for the Transformation of Agriculture* (2004)
PUMA	Preparation for the Use of MSG in Africa

RAB	Rwanda Agricultural Board
RADA	Rwanda Agriculture Development Authority
REMA	Rwanda Environment Management Authority
RH	Relative humidity
RWF	Rwanda franc
SEI	Stockholm Environment Institute
SNV	Netherlands Development Organisation
SPOT	Système Probatoire d'Observation de la Terre: a high-resolution, optical imaging satellite system
SPOT-VGT4Africa	System of distributing vegetation data for Africa from the SPOT satellite through EUMETCast
SST	Surface sea temperature
US$	United States dollar
USAID	United States Agency for International Development
VUP	Vision 2020 Umurenge Programme
WFP	World Food Programme

Executive summary

The Rwandan economy is mainly based on agriculture, which accounts for 43 per cent of GDP and sustains almost 90 per cent of the population. Agricultural production in Rwanda can be grouped into two main categories: staple crops (leguminous, cereals, roots, tubers and banana) and cash crops (coffee, tea, and pyrethrum). Since agricultural production in Rwanda depends almost exclusively on the quality of the rainy season and specific temperature ranges, it makes the country particularly vulnerable to climate variability and change. Moreover, the changing patterns of precipitation and the extreme events of storms and droughts lead not only to a decline in land productivity but also to an increase of plant disease incidences in the study area.

The study objective of evaluating and costing the most suitable climate change adaptation measures for this geographic context responds to the Rwandan *Economic Development and Poverty Reduction Strategy, 2008-2012* (EDPRS) (MINECOFIN 2007), in which climate change and its adverse impacts were recently identified as a high priority. For instance, the EDPRS highlights the establishment of criteria for secure settlements in the areas that are exposed to meteorological hazards, as well as the development and implementation of early warning systems to improve drought and food security.

This study has particularly focused on coffee and banana farming systems and aimed at analysing shocks due to climate change from farmer to policymaker perspectives. The study found that in the last 30 years, Rwanda has experienced a series of climate fluctuations in terms of frequency, intensity, and persistence of existing extremes. Heavy rains, storms, heatwaves and droughts are the observed manifestations of climate change in specific areas of Rwanda. Changing weather patterns have an adverse impact on the country's agricultural production and thus on the country's GDP. The following in particular were identified:

1. Lack of research and reliable climate data.
2. Limited knowledge about mitigation and adaptation strategies.
3. Poor farming, storage and processing practices.
4. Limited access to technologies; inadequate financial mechanisms.
5. Insufficient communication.

The adaptation options were then formulated accordingly, including the following efficiency-enhancing agricultural interventions:

1. Adaption of crop calendars to new climate patterns (more effective distribution of inputs such as fertilizers and pesticides).
2. Investments in farming equipment.
3. Improvement of extension services and research.
4. Restructuring of the institutional frameworks and development plans.

However, integrated water resources management (IWRM); setting up information systems for early warning systems and rapid intervention mechanisms; intense agri-pastoral activities; and research on climate-resilient varieties were identified as primary requirements for agricultural adaption to climate change. In addition, developing alternative energy sources (e.g., substituting firewood) and the promotion of non-agricultural income-generating activities were identified as the main climate change adaptation strategies not directly related to the agricultural sector.

Strategies for implementation have also been discussed in this study. It was found that coordinated, consolidated, and streamlined community-based monitoring systems are crucial to build a 'bottom-up' structure that strengthens the existing meteorological service in Rwanda. In addition, the inclusion of 'climate proofing' to the Vision 2020 Umurenge Programme (VUP) was found to be necessary for implementing the early warning (EWS) and rapid response systems, while other institutions could be included by focusing on aspects that are beyond VUP's mandate.

1. Introduction

1.1 Country background

As pointed out in the *National Adaptation Programmes of Action to Climate Change NAPA Rwanda* Report (MINITERE 2006), the Rwandan economy is mainly agricultural. The agriculture sector accounts for 43 per cent of GDP and sustains almost 90 per cent of the population. Since agricultural production depends almost exclusively on the quality of the rainy season, it makes the country particularly vulnerable to climate variability and change. The increased frequency and duration of droughts, floods, landslides and erosion currently observed considerably decrease the country's food availability.

Another significant issue is the high density population zones, which are currently characterised by overexploitation of lands and a severely altered vegetal cover. The overall situation explains the present migratory dynamics of people from the most densely populated cities in the north (Musanze, Rubavu and Gicumbi) and the south (Huye and Muhanga) towards the least populated areas, especially in the east (Nyagatare and Ngoma) and south east (Bugesera), in search for new land for agriculture and livestock (National Census Service 2003). These migrating populations are already suffering from economic vulnerability that is increased further by the high risk of drought and desertification in susceptible zones.

The NAPA Rwanda Report refers to the *National Disaster Management Policy* initiated by the Office of the Prime Minister in January 2003, following the natural catastrophes and recent extreme events of prolonged floods and droughts and their effects on initiating famines, loss of human and animal lives, and reduction of food production. The overall aim of the national policy on disaster management is to put in place systems, structures, programmes, necessary resources and capacities that reduce the risks of catastrophes and therefore find solutions to these threats in Rwanda for protecting human lives, the economy and environment while also limiting the loss of property, to ensure sustainable development.

1.2 Objectives of the country study

The main objectives of this study are almost the same as the main objectives of the Rwanda *Economic Development and Poverty Reduction Strategy, 2008-2012* (EDPRS) (MINECOFIN 2007). Among the priorities considered in relation to climate change, we emphasise:

1. Establishment of criteria for secure settlements in the areas exposed to meteorological hazards.

2. Development and implementation of a programme of early warning systems for drought and food security in order to protect the affected population by maintaining their food supply and the capacity of the population to acquire food.

In addition to those main objectives regarding agriculture, the IIED formulates the following main objectives of this study:

1. Bridging the gap between the climate change debate and the agricultural policy debate by analysing the synergies and trade-offs between the two at the global, national and local (district and community) levels regarding policies, institutions, implementation and funding.

2. Highlighting the specific nature of agriculture in a developing country by analysing the adaptation pathways in specific agricultural systems. These pathways are shaped by immediate, medium- and long-term local livelihood pursuits and official plans and programmes. This goes beyond the question of 'adapting to what?' but includes adaptation targets.

3. Costing the adaptation pathways to reflect the roles and functions of players at the different levels of adaptation 'signatures', thereby aligning costing of adaptation under imperfect future climate knowledge and agricultural development.

The Rwandan country study has focused on coffee and banana agricultural systems and aims at analysing shocks from climate change. It also presents some suggestions on how the population can adapt and thus limit the aforementioned adverse impacts. However, it has been revealed that the population requires extensive support from many stakeholders (for instance government, NGOs, private sector, civil society, international organisations). Indeed a detailed planning of the costs related to climate change adaptation in agriculture is needed for the government to include respective measures in future development plans. In this study we will elaborate on how the costs should be computed and implemented in relation to needs.

1.3 The contribution of Rwanda's agriculture to socioeconomic and environmental development

Agriculture is an engine of development by indirectly facilitating the development of other sectors like industry and services (and therefore the whole economy). Agriculture is an important sector to Rwanda, and will continue to remain so for the foreseeable future. It contributes more than 36.7 per cent to GDP (2010), employs more than 80 per cent of the workforce, and supplies 90 per cent of the nation's food and nutritional needs (Rwirahira 2010).

Figure 1: Contribution of coffee to GDP and rural income (data source: MINECOFIN 2007).

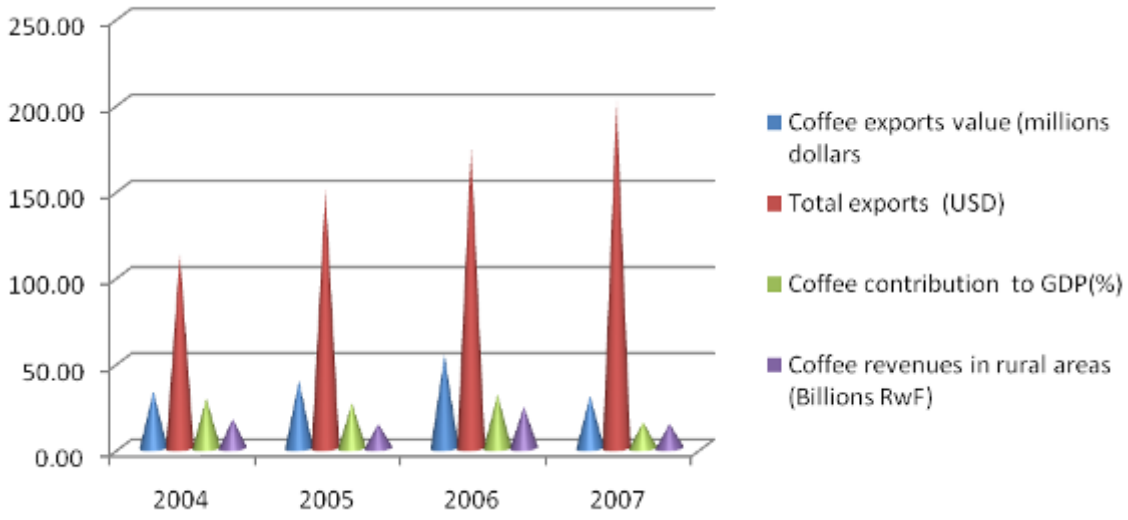


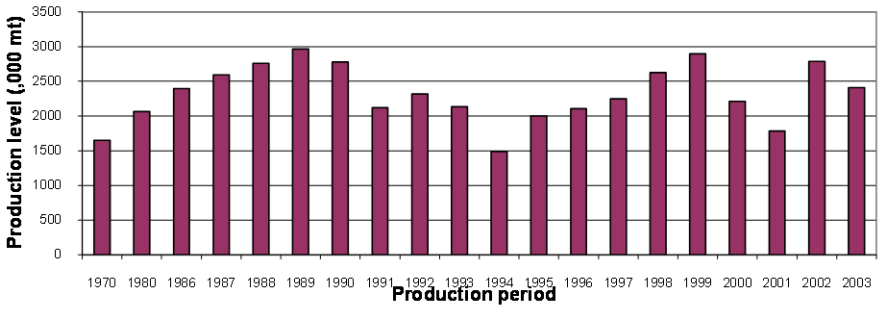
Table 1: Gross domestic product by activity, 1990-2006, (in billions of RWF) (Source: NISR 2006).

	1990	*1995*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Gross domestic product	**632.7**	**411.2**	**683.8**	**741.8**	**823**	**825.4**	**868.8**	**930.4**	**981.1**
Agriculture	**255**	**163**	**254.5**	**276.9**	**318.3**	**3035**	**303.8**	**318.5**	**322**
Food crops	207.4	136.7	218.2	237.6	277.8	263.8	259.2	275.7	275.7
Export crops	15.3	7.1	7.5	8.5	8.7	7.1	11.2	8.5	11
Livestock	26.1	12.4	16.5	17.6	18.1	18.6	19.1	19.6	20.1
Forestry	4.9	6.2	9.6	10.4	10.7	11	11.2	11.5	11.8
Fisheries	1.4	0.7	2.6	2.9	2.9	3	3.1	3.2	3.2
Industry	133.9	65.5	93.1	105	110	113.7	127.8	136.6	147.8
Mining and quarrying	3.5	0.8	2.1	5.6	4.3	3.4	5	6.6	5.6
Manufacturing	73.2	38.8	46.6	51.3	56.3	56.4	60	62.1	70.3
Electricity, gas, and water	6.1	2.5	3.7	3.3	3.8	4.2	3.5	4.1	4.7
Construction	51	23.4	40.7	44.8	46	49.8	59.3	63.9	67.2
Services	238	173.4	297.3	317.4	345.2	360.9	389.3	424.6	459
Wholesale and retail trade	79.6	66.4	69.2	73.6	80.1	78.1	84.3	91.8	97
Hotels and restaurants	5.3	2.2	6.6	6.9	6.8	7.8	7.9	9	9.5
Transport, storage, communication	28.9	18.4	37.8	43.1	47.5	47.5	53.1	58.7	63.1
Finance, insurance	16.1	9.5	21.1	22	23	29.9	35	38.7	46.5
Real estate, business services	28.4	41.3	70	72.3	75.9	80.1	82.5	89.4	94.3
Public administration, education	79.4	35.4	86.9	93.3	105.1	109.7	118.3	126.9	137.1
Other personal services	0.2	0.2	5.8	6.1	6.8	7.9	8.3	10.1	11.5
Adjustments	5.7	9.3	39	42.5	49.1	47.1	47.3	47.9	50.7
Less: imputed bank services	-7.6	-9.6	-11.7	-12.5	-12	-13.9	-16.5	-18.3	-22
Plus: VAT and other taxes on product	13.3	18.8	50.7	55	61	61.2	64.4	69	74.4

In Rwanda, the coffee industry plays an important role in the country's economic development. For many years coffee used to be Rwanda's top export product and thus main source of foreign exchange income (Tobias and Boudreaux 2009). It provides a livelihood for almost 500,000 Rwandan families (corresponding to approximately 2 million people and 25 per cent of the total population) who belong to cooperatives and grow coffee in small plots (NAEB 2005).

Banana is also a reliable crop that contributes significantly to household income, food security, and regional trading. The Rwandan banana industry produces three different banana products: brewing bananas (60 per cent), cooking bananas (30 per cent) and dessert bananas (10 per cent) (RADA 2010). About 80 per cent of Rwandan households practice banana production, mainly for household food security and income generation. A typical household's agricultural enterprise regime comprises 50 per cent tubers, 30 per cent bananas and 20 per cent legumes, cereals and vegetables (RADA 2007). It is the second major food crop in Rwanda after green beans. It is used both as food and cash crop (MINECOFIN 2001; Kiiza *et al*. 2004) and it is grown all over the country by small-scale farmers, but principally in the Eastern Province as well as in the Western Province.

Figure 2: Banana production in Rwanda over a 30-year period (1970-2003) (Source: NISR 2006).



The agriculture sector generally is pressured by climate change in the way that periodic floods and droughts (extreme events) already cause major socioeconomic impacts and reduce economic growth in the country. After the 1994 genocide, major flood events occurred in 1997/98, 2006, 2007, 2008, and 2009, where rainfall resulted in infrastructure damage, fatalities and injuries, landslides, loss and damage to agricultural crops, soil erosion and environmental degradation. In some regions of the country there have also been periodic droughts, for example in 1999/2000 and 2005/6.

According to Byamukama *et al.* (2011), seasonal yield losses can be directly attributed to climatic variances, e.g., coffee production dropped from 35,000 tons in 1986 to 28,495 tons in 1993. According to the Speciality Coffee Association of America (SCAA) auction standards and requirements for coffee, the quality of Rwandan coffee also fell from 48 per cent of standard coffee in 1986 to 0.32 per cent in 1992. After the 1994 war and genocide, the situation became worse and production fell to 55 per cent of the 1993 situation, reaching a production of only 14,268 tons in 1998 (MINAGRI 2008a). The situation improved from 2002 (29 per cent standard coffee, STD, and 59 per cent ordinary coffee, ORD) up to 2006 (31 per cent STD and 51 per cent ORD) with the highest observed quality in 2005 (50 per cent STP and 36 per cent ORD). The quality dropped again in 2007 (seven per cent fully washed coffee, FW, 18 per cent STD and 59 per cent ORD) (NAEB 2007) corresponding to a severe event of heavy rains, storms and floods in some parts of Rwanda.

Estimated costs of this event range from 4 to 22 million US$ (equivalent to around 0.1 to 0.6 per cent of GDP) for Musanze and Rubavu districts, accounting for costs of household damage, agricultural losses and fatalities. However, wider economic costs are associated with damage to infrastructure, water articulation and contamination and soil erosion, as well as the direct and indirect impacts to individuals and the labour force. The range of potential effects and its critical importance to the economy and livelihoods mean that the agricultural sector has to be a governmental priority for future development considerations, for instance through further research and timely actions.

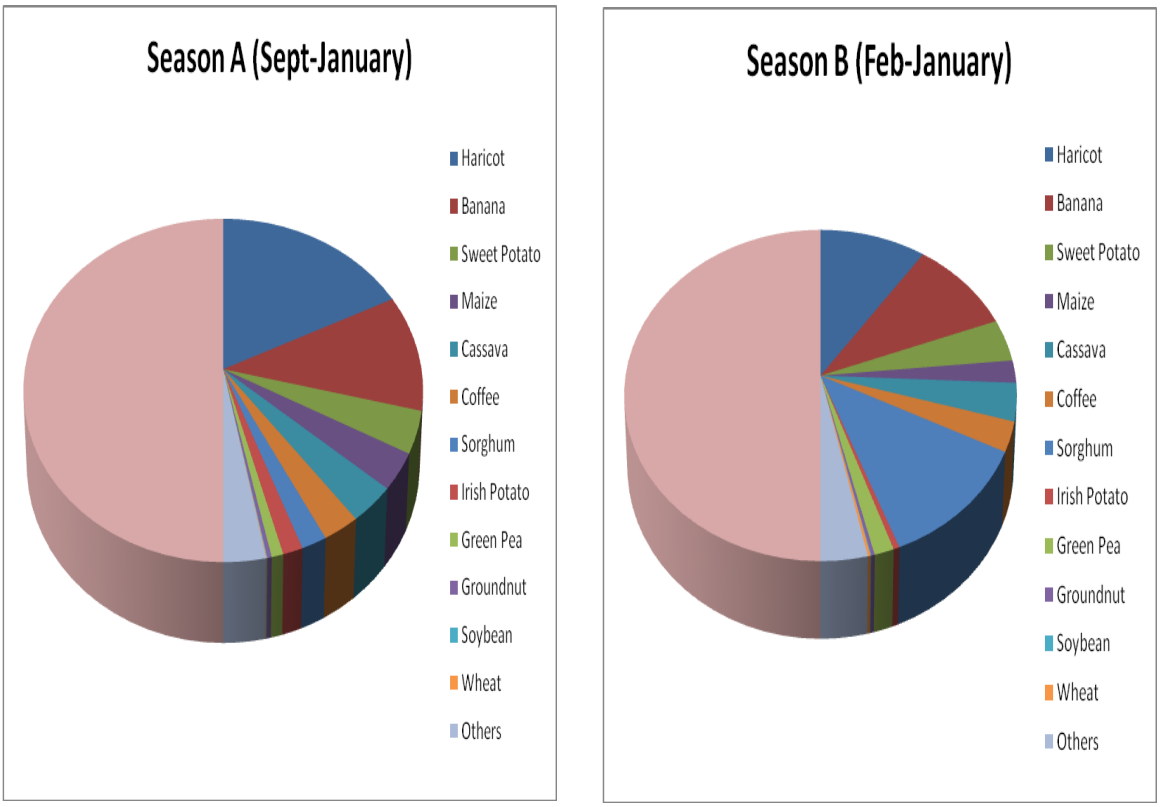
2. The agricultural system in Rwanda

2.1 Overview

Rwanda has four main types of land: cultivated lands, marshlands, forests, and wetlands. Cultivated land represents 1.12 million hectares, around 46 per cent of the country, distributed between 870,000ha for annual crops and 250,000ha for permanent crops. But the Ministry of Finance and Economic Planning (MINECOFIN 2006) indicates that around 420,000 to 560,000ha more could be cultivated. Forested areas represent around eight per cent of the country and are mainly located in natural protected areas.

The spatial pattern of the agricultural regions and their respective crop growth is determined by the physical environment in Rwanda. The country is characterised by dramatic contrasts in temperature and rainfall as the elevation changes from the lowland savannah areas of the east to the mountain chains of the west. The Rwandan agricultural economy depends on its climatic conditions to a high degree and is thus vulnerable to any changes of weather patterns.

Figure 3: Rwanda's main crops by season (authors' computation from MINAGRI 2008b data).



The country is susceptible to environmental degradation, for example erosion and deforestation caused by heavy rainfall. Because of the reduction of biodiversity and ecosystems, some species of mammals, birds and vegetation have already disappeared; plant species have often lost resistance, which adversely affects their yielding status.

Agricultural production in Rwanda can be grouped into three categories: food crops (leguminous, cereals, roots and tubers, banana), the traditional cash crops (coffee, tea, pyrethrum), and the new cash crops or export crops (fruits, vegetables, flowers, spices). Food crops occupy 92 per cent of the total cultivated land while coffee and tea occupy respectively 6.3 per cent and 1.6 per cent of the total cultivated land (MINAGRI 2010a).

The dominant farming type is smallholder, which is also influenced by the extraordinarily young population and the need for parents to divide their land into small parcels in order to distribute it equally among their children. In addition, general population pressure on available resources causes this kind of land sharing among community members.

Photograph 1 (by the authors, 2011): shows Rwandan farming systems and agricultural pressure on steep slopes.

The rural economy of Rwanda is based on traditional agriculture that is characterised by semi-intensive and subsistence-based production, with a growing tendency towards more intensified cropping systems. Agricultural intensification is difficult for Rwandans to practice due to the country's topography, soil structure, producers' skills and mindset, population growth status, labour force in the sector, and available financial means.

2.2 An overview of the coffee sector in Rwanda

2.2.1 The coffee sector in Rwanda: historical background and supply chain description

Coffee in Rwanda can be dated back from its introduction in 1904 and its first export in 1917. Upon its introduction, coffee became a major source of income and benefited from strong political support from the colonial authorities. It was imposed by the colonialists on agriculturists in 1927 and its cultivation was made obligatory in 1933. Legislation passed by the Government of Rwanda at Independence in 1963 prohibits the uprooting of coffee trees (Chemonics International Inc. for USAID 2006).

The Ministry of Agriculture established a regulating agency in 1964, OCIR (Office Nationale des Cultures Industrielles), and in 1974, the ministry established a parastatal agency, OCIR-Café, with monopolistic powers. It was tasked with organising smallholders; purchasing their crops in the form of 'café parche'; contracting private factories to process the *parche* into green coffee ('café marchand'); and selling the final product on the international market. At that time (and up to 1988) two companies – Rwandex and Etiru – had marketing monopolies. Rwandex sold only to Drucafé in London and Etiru only to Sobelder in Belgium; Rwandex had the greater share of exports by far.

Market research was commenced in 1991 with a view to introducing liberalisation. This started after the 1994 genocide with the licensing of several private coffee exporters and the installation of several private parchment mills (by companies such as Rwandex, Rwacof, Coffex, Caferwa, etc.). Thus the coffee marketing chain has now changed from a central monopoly to a free market. With that liberalisation policy (introduced in the early 1990s but actually implemented only after the war), the mandate of OCIR-Café has changed. OCIR-Café is now a promotion, regulation and monitoring agency in the sub-sector. Private traders are now allowed to purchase parchment coffee from the smallholder growers, and to sell it to the hulling companies. Exports are increasingly carried out by private enterprises, acting as agents or paying a fee to OCIR-Café.

In the late 1980s, Rwanda experienced a decade-long quantitative and qualitative drop in production and exports due to an international market crisis (Boudreaux and Ahluwalia 2009). Moreover, due to falling income and hunger, farmers uprooted as many as 300,000 coffee trees and planted food crops (Boudreaux and Ahluwalia 2009) and other attractive cash crops (Verwimp 2003). The production of commercial green coffee has dropped from 40,000 tons (1985 - 1992) to 15,000 - 20,000 tons (1996). The coffee export earnings amounted to only 20 million US$ in 2001 against 60 million US$ in 1990.

A diagnostic analysis of the Rwandan coffee supply chain carried out by a coffee expert for SNV, the Netherlands development organisation, mentioned three main reasons for that decrease, comparing it against the decreasing of world coffee prices generally:

1. The old age of the coffee trees (a large number of trees exceed 20 – 25 years in age, the limiting age for economically optimal exploitation).

2. The low remunerative price of green coffee, which encouraged the growers to divert towards the cultivation of food crops.

3. The abandonment of good cultivation methods (cut backs, pruning, mulching, etc.).

In response to the steady decline in coffee production, quality, and export earnings, and in view of the recognized potential contribution that the sector could make to increased economic growth, the Government of the Republic of Rwanda (GoR) adopted the *Rwanda National Coffee Strategy 2008-2012* (MINAGRI/MINICOM 2008), which was later extended to 2010. Key points of this strategy included:

- Increasing production through the dissemination of improved varieties, the adoption of better crop husbandry practices, appropriate and timely use of inputs, and by supporting grower associations to assume progressively greater responsibility for production activities.
- Improving coffee quality through producer education, improved infrastructure, investment in washing stations, and strengthened cooperative and association management.
- Promoting greater equity in value distribution through producer participation in coffee marketing.

In 2004, a coffee strategy update study, carried out by the American consultancy firm On The Frontier (OTF), assisted the GoR in redefining the policies and strategies of the previous plan and led to its extension up to 2010 (as discussed in the paragraph above). This new action plan had the following quantitative objectives:

1. Production of 44,160 tons commercial coffee, including 28,000 tons of fully washed coffee.[1]
2. 107 operational washing stations.
3. An average yield of 1,500kg/ha.

2.2.2 Liberalisation of the coffee supply chain

As mentioned above, the GoR launched major coffee trade liberalisation policies in 1995. The liberalisation consisted of complete withdrawal of OCIR-Café from commercial activities, market determination of producer prices and other internal prices, public announcement of free entrance of exporting firms into the export business, and privatization of the government-owned washing stations and warehouses. Before that time, all the prices and marketing costs were fixed by the government, including producer prices in all the regions and marketing margins of the internal traders and exporters. Under this system, the producer price was fixed at a certain nominal level for a number of years. It was changed only when economic variables affecting producer prices, such as world coffee prices or exchange rates, changed drastically.

The system had merit in providing coffee growers with stable prices but often resulted in high implicit taxes on coffee. This system, which has been common in French-speaking sub-Saharan Africa, was supported by a Stabilisation Fund. The Fund acted as buffer to maintain fixed producer prices when world prices fluctuated. In January 1995, the GoR decided to discontinue the Stabilisation Fund. Between January and April 1998, a progressive export tax system was in force, with the objective of keeping nominal producer prices stable. The GoR attempted to keep producer prices at 300 RWF/kg by changing the tax rate depending on world coffee prices. This effectively taxed the difference between the border price and the sum of the producer price and the marketing cost. This tax and producer pricing system was functional as long as the border prices were high enough to support (effectively fixed) producer prices, which was the case for this particular period of the system being operational.

The progressive export tax system came to an end in April 1998. Creating informal exports of about 30 per cent of the exports, it was the main reason for the low producer prices and was a disincentive to investment in coffee. The GoR changed the coffee export tax policy from progressive to a fixed ad-valorem tax system of 16 per cent. Although there was no explicit government policy of keeping out coffee exporting firms other than Rwandex before 1994, there was a perception that the government favoured Rwandex and attempted to keep away other firms. To actively encourage other firms to enter the coffee exporting business, the GoR publicly announced its policy of free entry in January 1995. By 1998 there were three coffee exporters operating in Rwanda- Rwandex, Rwacof and Coffex; by 2002 five main exporters were operating.

[1] Prior to 2001, Rwanda was unknown on the specialty coffee market meaning that at that time fully washed coffee production was zero.

3. Climate change and the agriculture systems of Rwanda

3.1 Overview and adverse impacts of climate change

In Rwanda, the equatorial climate is deeply modified by the land relief at varied altitudes (900m in the south west, 1500 to 2000m in the south and the centre of the country, 1800 to 3000m in the highlands in the north and the west, and 3000 to 4507m in the Congo-Nile divide and volcanoes' regions).

Taking an example of the average rainfall of the period 1961-1990 (from the operational rainfall stations), both rainfall and temperature were moderate, indicating the existence of controlling factors. The principal factor for influencing the rainfall seasons in Rwanda is the Inter-Tropical Convergence Zone (ITCZ) due to the low pressure and high humidity, together with the convergence of winds, that are its typical characteristics. The ITCZ crosses Rwanda twice a year and creates two rainy seasons: a short rainy season ranging from mid-September to mid-December, and the long rainy season from March to May. It is also controlled by the altitude and subtropical anticyclones such as the Mascareignes, Saint Helen, Acores, and Arabian Dorsal. Moreover, further impacting weather patterns exist: subtropical anticyclones, tropical cyclones, monsoons, and episodes linked to El Nino/the Southern Oscillation (ENSO) (MINITERE 2006).

During the short rainy season, the dominating winds are from the northeast and humidity comes from air masses humidified by the Indian Ocean and Lake Victoria. The dry season that follows (from mid-December to the end February) is characterised by the penetration in East Africa of masses of dry and cold airs from the Arabian Dorsal. However, the moderating effect of Lake Victoria and the diversity of the Rwandan land relief maintain some rainfall in our country. During the long rainy season, Rwandan weather is strongly influenced by a front of dry winds moving from the southeast and southwest, which carry humidity from the South Atlantic through the Congo Basin. During the dry season (from June to Mid-September), the air masses of winds from the southeast arrive in Rwanda dried from the continental air crossing Tanzania and present a divergence that is unfavourable to precipitation formation (MINITERE 2006).

In the last 30 years, Rwanda has experienced a series of climate fluctuations in terms of frequency, intensity, and persistence of existing extremes such as heavy rains, heatwaves, drought, and climatologic parameters. Occurrences of rainfall deficit have reached 16 per cent (MINITERE 2005). Frequencies of rainfall deficits and excess have also significantly increased. The period between 1991 and 2000 has been the driest period since 1961. For example, at Kigali meteorological station (central plateau), a pluviometric deficit was marked during five years (1992, 1993, 1996, 1999, and 2000), and two pluviometric excesses occurred during 1998 and 2001. A similar excess was observed by the same station in 1979 and during the years 1981, 1988, 1998 and 2001 as well as 1976, 1992, 1993 and 2000 (MINITERE 2006).

A quick analysis of rainfall behaviour using 22 selected stations across the country has revealed a decrease of rains in the period from 1931 to 1958, and an increase from 1959 to 1988, remaining stable from 1989 to 2009. The highest precipitations were recorded in 1937, in the north west at Murunda Station (2088mm); in 1968, in the north east at Byumba Station (1977mm); and in the north central region at Ruhengeli Station in 1975 (1894 mm). The lower precipitations were recorded in Eastern Province: at Kibungo Station in 1945 (671mm) and Rwamagana Station in 1952 (570mm).

A recent study conducted by the Stockholm Environment Institute, *Economics of Climate Change in Rwanda* (SEI 2009), has summarised key extreme events such as the periodic floods and droughts that have already caused major socioeconomic impacts and reduced economic growth in Rwanda. Major flood events occurred in the years 1997, 2006, 2007, 2008, and 2009, where heavy rainfall resulted in infrastructure damage, fatalities, injuries, landslides, loss and damage of agricultural crops, soil erosion, and environmental degradation. In some regions of the country there have also been periodic droughts, for example in 1999/2000 and 2005/6.

3.2 Requirements of coffee-growing systems

Coffee is not exempt from the adverse effects of climate change; in fact coffee is a highly climate-sensitive plant requiring specific weather patterns (rainfall, temperature, sunshine, wind behaviour) during different growing periods. For example, temperature values and their fluctuations have significant impacts on the behaviour of the coffee tree. The optimum mean temperature for coffee Arabica is given as 18^{o}C during the night and 22^{o}C during the day (the optimal average annual temperatures are between 22 ^{o}C and 28^{o}C). Tolerated extremes extend to 15^{o}C during the night and 25-30^{o}C during the day. Temperatures higher than 25^{o}C cause reduced photosynthesis and prolonged exposure to temperatures above 30^{o}C incur so-called 'leaf chlorosis' and generate 'star flowers' (or blossom wilting), as well as defective fruit sets. High temperatures also initiate the development of plant diseases such as the 'coffee leaf rust' (*Hemileia vastatrix*) and fruit blight (*Cercospora cafeicola*) and accelerate fruit maturation, whilst low temperatures facilitate coffee berry diseases (e.g., *Colletotricum coffeanum*) (Wintgens 2009).

Rainfall patterns matter in the way that a few months with little or no rain are necessary to induce, for instance, the flowering period. Generally speaking, a total annual rainfall between 1400 and 2000mm is favourable for Arabica growing, whereas Robusta needs about 2000-2500 mm. Rates below 800-1000 mm for Arabica and 1200 mm for Robusta, even if they are well distributed, can be hazardous to the productivity of the coffee plantation. The average annual water requirement for coffee was studied over 12 years and was found to be 951 mm during normal dry seasons (Wintgens 2009). Therefore, overall rainfall distribution throughout the year is a decisive factor for scheduling cultivation practices and harvesting. For example, where the rainfall is unimodal, there will be two periods of blossoming and, consequently, two harvest periods – known as the 'early crop' and the 'late crop'. Coffee from the 'late crop' is of better quality.

So-called atmospheric or relative humidity (RH) of the air also has a marked influence on the behaviour of the coffee plant, particularly in the case of Robusta. The best RH for Arabica should be around 60 per cent and for Robusta, 70-75 per cent. A high level of atmospheric humidity will reduce the water loss by plants, whereas a low level will increase transpiration. Persistent levels above 85 per cent will adversely affect the quality of the coffee.

Flowering, and thus productivity, is significantly stimulated by direct sunlight and shading as much as by adequate fertilization (through nitrogen in particular). In Rwanda, few coffee plantations are farmed in a forest environment; most of them are grown in the direct sun. Some study observations have revealed that the peripheral forage of trees has the effect of auto-shading, which makes further shading redundant, particularly in cloudy areas (Wintgens 2009).

However, further studies indicated that shading improves the quality of coffee because it diminishes the risk of erosion, restricts weed growth, and generates mulch – which protects and improves soil structure and enriches the soil with organic matter (Guhl 2009; Payan *et al*. 2009; Siles *et al*. 2010). The effect of shading on the intensity of the photosynthesis process in coffee trees has been abundantly researched; however only a few study results have produced conclusive evidence to establish basic guidelines for producers (Wintgens

2009). Similarly, elsewhere it has been ascertained that a lack of luminosity can diminish productivity. In the Great Lakes Region, for instance, in Mayumbe (Democratic Republic of Congo) in 2009, surveys (Wintgens 2009) have concluded that Robusta coffee trees are practically unproductive because they lack sufficient luminosity, even though the average soil fertility is perfectly adequate. In this area, exposure to sunshine is only 1330h/year.

For the best results, coffee requires an average of 2200-2400 hours of sunlight per year (Wintgens 2009); exposure to sunlight should reach approximately 60 per cent of potential during the rainy season and 60-75 per cent during the dry season. This is the case at Rubona in Rwanda, where the average annual exposure to sunlight between 7 a.m. and 5 p.m. is 58 per cent during the rainy season and 75 per cent in the dry season.

In Rwandan sub-regions, optimal environmental conditions for coffee Arabica have been registered on the shore of Lake Kivu, in Impala, and in the central plateau agricultural regions. The Mayaga and peripheral Bugesera areas are characterised by a constraining climate, with relatively low rainfall limiting growth of coffee. A further decrease in rainfall towards the east gives a further reduction in suitability, with the eastern plateau being moderately to marginally suitable, whereas the climate is marginal or too dry for coffee in the eastern savannah and central Bugesera District. Unsuitable climate conditions are recorded in the cool high altitude of the northwest of Rwanda (Verdoodt and Van Ranst 2003).

3.3 Evolution of coffee production and reported climate influence

Little is known with regard to the impact of climate on coffee production. A low yield was reported in 2007 and climate variability was quoted among the causes (MINAGRI 2008b). Insufficient rainfall in the last three months of 2006 (the period of coffee flowering) proceeding the short dry season in the first two months of 2007 was recorded. The reduced rainfall was also poorly distributed across coffee growing regions in Rwanda. However, in 2008 the situation improved since the production of 2008 was increased by about 40 per cent due to sufficient rainfall in the period of September/November 2007 and in March 2008. 2 shows the evolution of coffee production from 1986 to 2008.

Table 2: Rwandan coffee production over time (Source: MINAGRI 2005. No data are available in the literature for 2009 – 2010 yet).

Year	**1986**	**1987**	**1988**	**1989**	**1990**	**1992**	**1993**	**1995**	**1996**	**1998**
Production (tons)	35,424	43,026	43,026	39,091	39,575	38,970	28,495	21,829	15,239	14,268
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2007**	**2008**	**2009**	**2010**
Production (tons)	16,098	18,267	19,796	14,175	29,000	17,000	14,700	21,000	No data	No data

3.4 Need for climate change planning and monitoring for Rwanda's food security and development

According to recent study (SEI 2009), Rwanda has a current adaptation deficit, i.e., it is not adequately adapted to existing climate risks. Four major sectors were identified as priorities for action: health, water, infrastructure and agricultural sectors.

However, in terms of coffee cultivation planning, no clear and mutually agreed suggestions for mitigating/adapting practices to combat climate change effects on coffee production exist. Since many pest and diseases are stimulated by a change in temperature and humidity, certain pest and disease control measures are proposed for implementation on an annual basis.

4. Planning and costing adaptations to climate change in a perennial crop farming system: coffee in Rwanda

4.1 Description of the study area

The selection of the study area was based on the variability in climate conditions (i.e. rainfall, temperature, and dry periods). Features of the physical environment – topography and soil for example – were also considered to be important since they reflect cause and effect of changes in climate conditions. More importantly, the disparity in households' ability to engage in cash crops depends on agro-ecological conditions.

The maps of the sites (Figures 4-6, a and b) show that the decrease in rainfall and increase in temperature follow a west - east direction, translating into 'high' down to 'marginal' productivity systems for coffee and banana. This climate set-up is highly characteristic of the topography of Rwanda. Moreover, the high geomorphologic and climatic variability made the selected sites ideally suited to assess the impact of climate variability on small-scale cash cropping systems in Rwanda. The main climatic and edaphic characteristics of the selected study sites are summarised in Table 3.

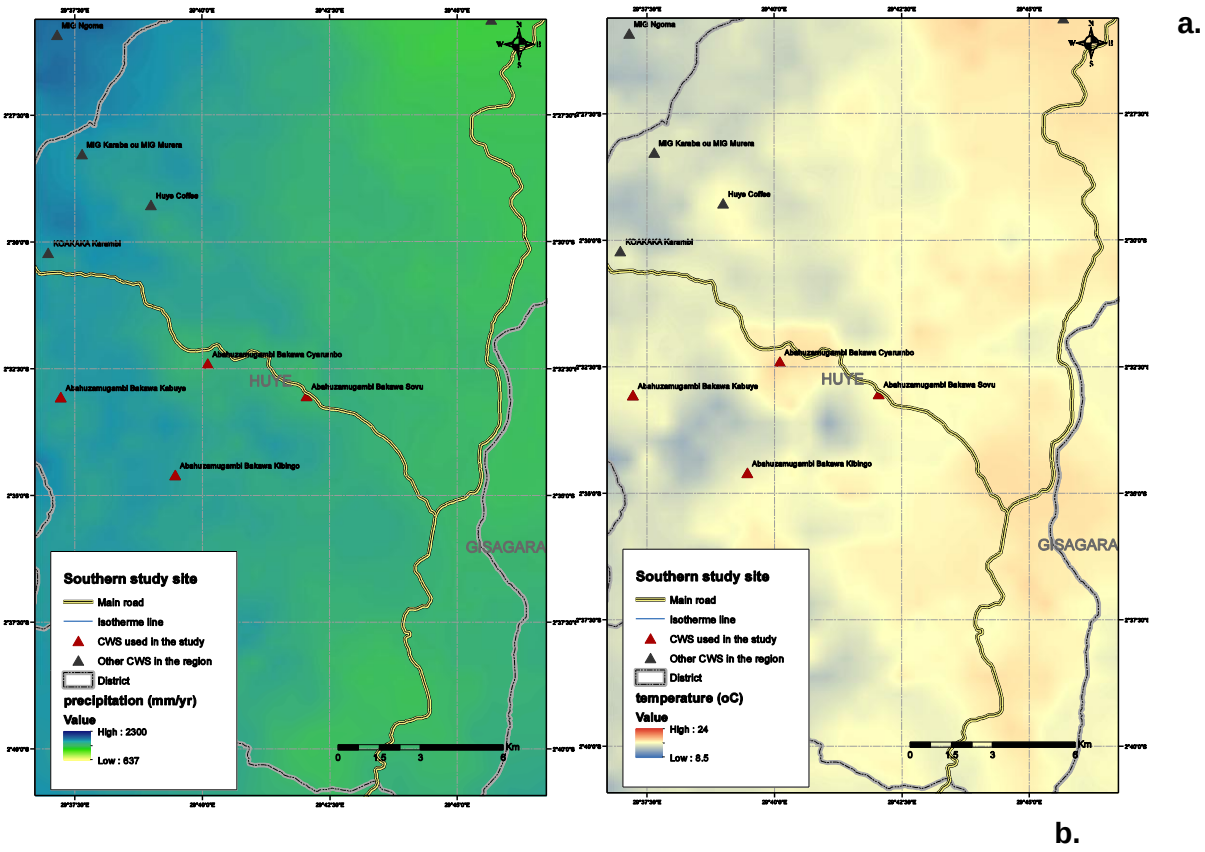
Table 3: Physical characteristics of the study sites.

Selected site	Coffee washing station (CWS) cooperative	Altitude min-max (m)	Rainfall min-max (mm. year)	Temp. min-max (^{o}C)	Average dry period (months)	Soil type
Southern site	Abazahuzamigambi Ba Kawa	1400-2100	1000 - 2000	17 - 22	2	Humiferous
Western site	Abaryoshyakwa	1460-1900	1100 - 2400	18-21	2	Shallow, clay, loam
South-eastern site	Dutezimberekawa	1350-1500	900- 1300	20 - 24	3+	Clayey- schist

4.1.1 Abahuzamugambi Ba Kawa Cooperative (southern study site)

Abahuzamugambi Ba Kawa Cooperative was founded by 300 smallholders after the 1994 war and genocide that had devastated the Rwandan coffee industry. It is located in Maraba (Southern Province), one of the poorest areas in Rwanda. The members are subsistence farmers who rely on the sale of their high-quality coffee for 70 per cent of their cash income and therefore for paying for their basic necessities. However, this rapidly growing cooperative is working to make coffee farming a viable occupation by accessing the specialty coffee market and developing strong relationships with coffee roasters. It has one main coffee washing station (CWS) (Cyarumbo) and three other mini-stations (Sovu, Kabuye and Kibingo), as shown on the maps below.

Figure 4: (a and b): Rainfall and temperature distribution in the coffee zone of Abahuzamugambi Ba Kawa Cooperative (southern study site).



Abahuzamugambi Ba Kawa Cooperative was created in 1999, with about 300 members initially. Since the cooperative has been supported by the National University of Rwanda and SPREAD (Sustaining Partnerships to enhance Rural Enterprise and Agribusiness Development – a USAID-funded non-profit organisation formed to assist in Rwandan agribusiness value-chain management), the cooperative has produced a coffee of premium quality that successfully penetrated the international market.

The cooperative was Fair Trade certified by Fairtrade Labelling Organizations International (FLO) in 2002. More than 50 per cent of its members are women (predominantly widows). The identified target group was the members of cooperative whose main activity is to grow the coffee known as Maraba Bourbon coffee (Maraba was a former district of Butare Province). Its fully washed coffee received the name in 2001 after it was proven to have a distinguished quality (facilitated by the PEARL project, a USAID-funded project in partnership with the National University of Rwanda).

Today the cooperative offers scholarships to members' children, so that they are able to complete their basic education. The cooperative also initiated a health care programme that covers medical insurance fees for members and their families. The cooperative provides community health and sanitation trainings targeting women by addressing general household hygiene.

With regards to rainfall and temperature variation, coffees grown further east will suffer in insufficient rains (i.e.,<1400 mm, while the range of favorable rain is between 1400 and 2000 mm). Abahuzamugambi Ba Kawa Cooperative Huye mountain coffees (Sovu and Kabuye coffees) therefore enjoy favourable rainfall because they receive at least 1460 mm of

precipitation per year. High yields and good quality are also registered in the Huye mountain chain, which has been proven by successes in the Golden Cup in 2007 and the Cup of Excellence® (CoE) in 2008.[2]

Huye mountain coffees have a temperature tolerance range of between 15°C and 25°C. The average temperature in the mountain chain is estimated at around 16°C, whereas in the east of Maraba, the temperature goes up to 22°C. However, the effect of temperature on production is less notable than that of changes in rainfall.

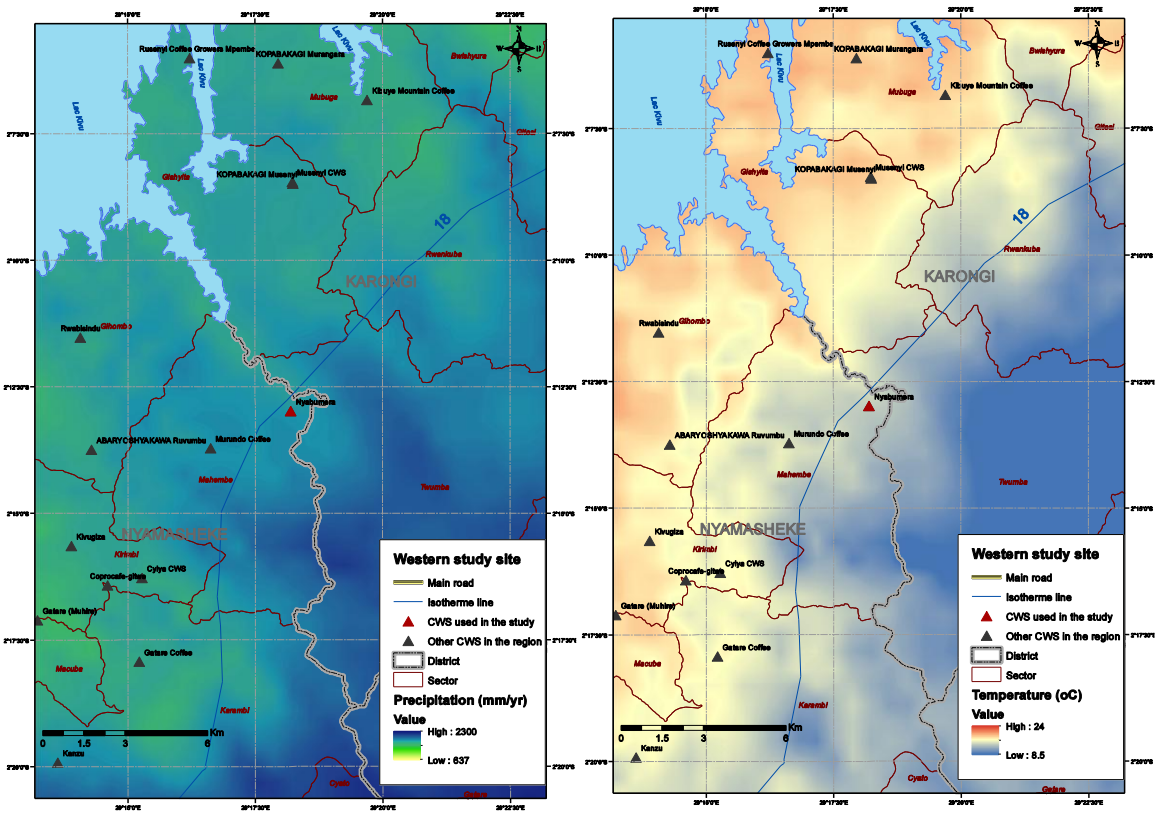
4.1.2 Abaryoshyakawa Cooperative (western study site)

These cooperative members work together with the Nyabumera CWS located in Nyamasheke District of the Western Province of Rwanda. This washing station was founded in February 2005 and is located on the shore of Lake Kivu, where coffee is extensively grown. Nyabumera CWS is one of four mini-stations that belonged to Abaryoshyakawa Cooperative at one time. Due to issues of mismanagement of the cooperative, the decision to split the mini-CWSs into two groups based on geography was made. Nyabumera and Ruvumbu mini-CWSs are now owned (after being put out to tender) by a different private investor from the other two and are working hard to recover from the setback

Rainfall and temperature variation in the coffee zone of Abaryoshyakawa Cooperative are within favorable ranges (1400 and 2400 mm of annual rainfall and above 16° C for monthly temperature). High yields and good quality were awarded with a CoE in 2010. This zone is typical of areas of high coffee productivity and quality due to the microclimate of the Lake Kivu shore zone throughout the coffee season (February to June).

[2] The Golden Cup is Rwanda's national coffee contest; the Cup of Excellence® is an international coffee competition with winners selected by an international jury. See: http://www.cupofexcellence.org/WhatisCOE/Introduction/tabid/147/Default.aspx

Figure 5: (a and b): Rainfall and temperature distribution in the coffee zone of Abaryoshyakawa Cooperative (western study site).



a. b.

4.1.3 Dutezimberekawa Cooperative (south-eastern study site)

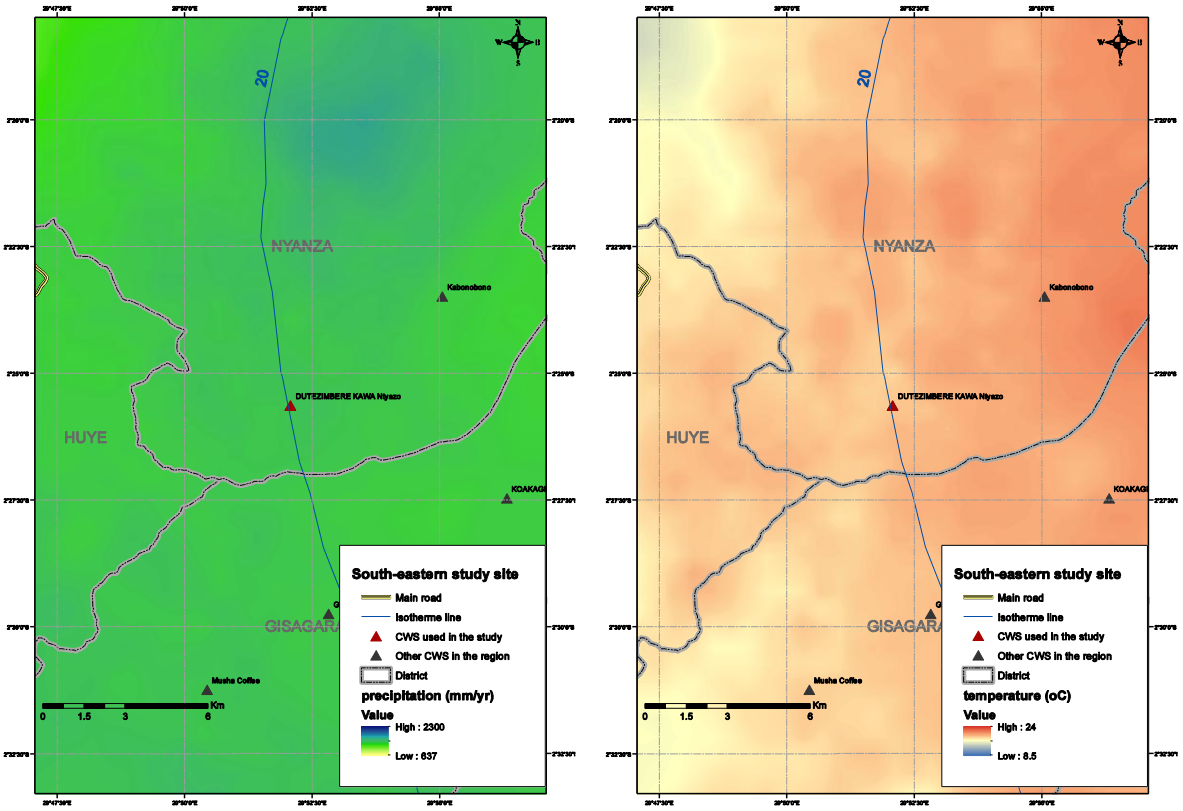
Dutezimberekawa Cooperative is located in Bugali Cell, Ntyazo Sector, Nyanza District, Southern Province. It was founded in March 1999. In this district more than 90 per cent of the population is engaged in agricultural activities. The main crops are coffee, maize, rice, beans and cassava. Land is generally fertile but productivity has declined due to excessive exploitation and irregular rainfall. The district has some dynamic markets (Ntyazo, Nyanza, Busoro and Rurangazi) but most of the rural trading centres lack dynamism and basic infrastructure, such as water and electricity. Nyanza District is among the poorest districts of the country. To date, Dutezimberekawa has not had the opportunity to be represented in CoE competitions.

As targeted for 2012, agricultural modernisation in the area includes improvements in food security, and productivity and quality of coffee, as well as the development of the coffee industry in general. Currently the district has 4,990,000 coffee trees with a present production of 2,345 tons of coffee, whereas the washing stations are still in the trial phase. Each year one million new coffee trees will be planted and old ones replaced. By 2012, four million additional coffee trees will have been planted, of which two million will be productive.

Farmers do not use chemical fertilizers and use of organic fertilizers is not developed either. To increase agricultural production, application of industrial inputs and fertilizers should have reached the following levels: 55 per cent of farming households using organic fertilizers; 10 per cent of farming households using chemical fertilizers; 35 per cent of farming households using pesticides.

As compared to western and southern coffees, eastern coffees of Rwanda will suffer much in insufficient rains (i.e., <1200 mm, while the range of favorable rain is between 1400 and 2000 mm). Dutezimberekawa Cooperative has not yet been successful in the Cup of Excellence® competition because of the natural constraint of high evapotranspiration of the coffee plantation induced by the high temperatures (above 20°C) of the south-eastern (Mayaga) part of the country. Although the area has high quality soil, mulching is very important (especially from May onwards) in order to retain soil moisture, at least until the coffee 'cherries' have reached maturity.

Figure 6 (a and b): Rainfall and temperature distribution in the coffee zone of Dutezimberekawa Cooperative (south-eastern study site).



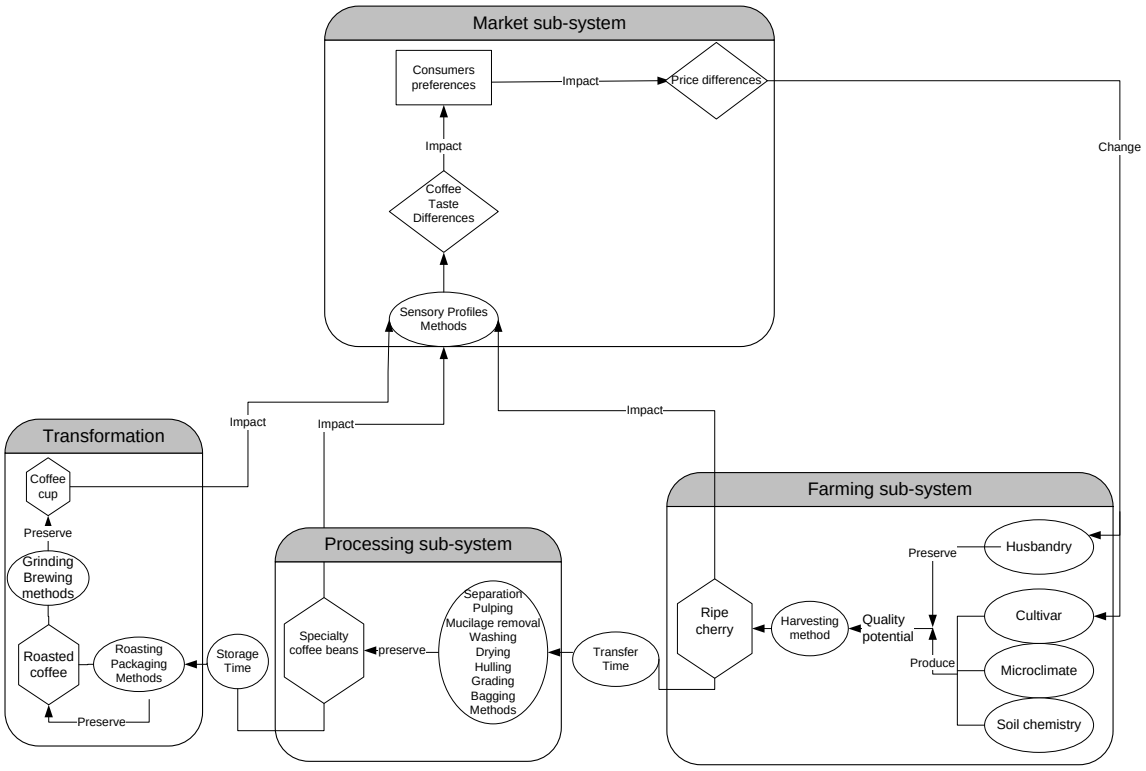
a. b.

4.2 Household and CWS surveys: results and discussions

4.2.1 Supply chain information

The following diagram shows the supply chain activities from the farm gate to the consumer market. Price changes are strongly determined by coffee quality, which in turn depends on the amount of effort expended by the farmer and miller along the supply chain in order to preserve the coffee's inherent quality characteristics. On some occasions, however, the local price is set by a global production boom (e.g., in the 1980s).

Figure 7: Conceptual diagram showing the main components of coffee supply and demand.



This study focused on the supply chain (farming and processing) most affected by climate change. The transformation and market components are outside the scope of the study since the coffee beans are exported. The whole cycle is presented to illustrate how price plays an important role in the investment made by the coffee farmer.

The analysis of the coffee supply chain in Rwanda is based on interviews at various levels of the supply chain, and a representative coffee growers' survey. The supply growers (103 coffee and banana growers) survey was organised during February 2011.

At the processing and marketing level, several interviews were held with managers and technicians at the three study sites (see sites descriptions) regarding their operational capacity, employment, investment, production input and output, quality of input and output, contract details downstream (with farmers), price policy towards farmers, contract details upstream (with purchasing firms for fully washed coffee), financial viability of the washing stations, and the quality of testing and roasting within the washing station. In addition, we asked about climate change impacts on their businesses. It would appear, *inter alia*, that both millers and farmers prioritise coffee quality over coffee quantity, due to the higher purchase prices that can be demanded.

4.2.2 Characteristics of small coffee and banana farming systems

The survey conducted with 103 coffee and banana growers revealed that the number of coffee and banana trees is around 9,000 per household. According to the data from OCIR-Café, the average number of coffee trees per hectare is almost 2,500, therefore identifying individual farmers with more than 2,000 trees is difficult since the average land holding per household is about 0.5ha. However, a cooperative can comprise more than 1ha since it consists of the consolidated land of a group of farmers. We underline that our sample is based on cooperative members, many of whom can have a higher number of trees compared to non-cooperative members. For instance, for the three study cooperatives we found that the maximum number of banana trees is 600 and the minimum is 420 per household. However, an estimation of banana trees in Rwanda based on the farmer survey is difficult since banana is intercropped with other food crops (e.g., with beans) and varies throughout the country.

In Rwanda, 0.5 ha per household is the average land holding size; in the survey the maximum land holding was 2.5ha. This explains the calculated number of 9,000 trees per household (see Annex 1).

4.2.3 Coffee processing at CWSs

As soon as the coffee ‘cherries’ are ripe, farmers usually harvest them by hand, which they do every few days since they only pick the red (ripe) fruit. To extract the bean, the fruit hull has to be removed in a rigidly-defined multi-step process. Firstly, growers bring their cherries to a CWS to get them weighed and de-pulped. The cherries are then pre-sorted by floating them on water, which separates the heavier cherries from the lighter ones (which is at the same time a classification of quality). Next, the cherries are run through pulping machines that remove much of the fruit from the bean. The beans are then fermented in holding tanks, as fermentation makes it easier to remove the remaining mucilage. After the fermentation process is accomplished, the beans are washed up to four or five times. The beans are sorted again and left to float for 24 hours. After this period, the beans are laid out on sorting tables, and workers pick out damaged or irregularly-shaped beans.

After that, the beans are dried in the sun until they reach the desired moisture level of about 12 per cent, which requires between ten days to two weeks depending on the weather and sunshine intensity. This ‘parchment’ coffee is then packed in burlap bags and stored for shipment by an exporter. Deparchment of coffee to green coffee beans is sometimes done by the miller but not all beans are deparched in Rwanda. Depending on the buyer’s preferences some are shipped with their parchment skin intact.

According to our findings during the washing stations survey, the number of farmers who delivered coffee cherries to the stations during the last five years increased from 10,000 in 2005 to 120,000 in 2010. The main challenge faced by washing station holders is the fluctuation of productivity – washing stations can only operate at full capacity for certain

periods of the year and even full capacity may not be sufficient measured against the high amounts of beans that require processing (see Annex 2).

4.3 Case study findings, summary

The case study baseline showed the following **key changes in climate variability and induced vulnerabilities**:

1. A longer dry season (June-August, extended up to September) leading to delayed flowering periods.
2. The heavy rains of March are reducing; this delays the ripening period so that it starts in April instead of March.
3. A non-systematic shift of climate variables, facilitating migration of pest and disease (rotation/cyclical pest and diseases incidences) is making spraying requirements longer, or even permanent in some places.

Beside the issues of climate variability, some **weaknesses in sector planning** were raised by farmers:

1. Poor planning of coffee management activities heavily reduced the crop performance, especially regarding the scheduling of fertiliser and pesticides application.
2. Delayed access to cash in rural areas: low access to credit and opportunities for wealth creation, as well as difficulties for farmers to fulfil social payments (school fees, health insurance, housing in rural areas).

Existing coping strategies by farmers included:

1. Intercropping where possible.
2. Coffee farming conversion to seasonal food crops (mainly beans, banana, etc.) and other crops that have a higher resilience to climate variation and do not require extensive investments.
3. Reducing inputs to coffee farming.
4. Reduced reliance on bank loans and input credits for agricultural activities.

Consequently, the sector faces:

1. Unexpected low production in potentially high productive regions.
2. Declining coffee quality, which inevitably induces a move from speciality processed coffee (fully washed) to traditional processed coffee (individual traders in low grade coffee).
3. Failure to satisfy the demand from the high revenue-generating specialty coffee market.

4.4 Mapping climate hazards onto the coffee calendar

4.4.1 The existing coffee calendar

In the nursery, sowing takes place in October and November. Coffee planting also takes place in October and November and replanting is then conducted in March. The organic fertiliser needs to be applied prior to the planting as well as at the beginning of each rainy season (March and September). Other coffee cultivation practices in the various growing stages are also necessary to retain soil fertility and productivity. Weeding takes place in October-November. Pruning is also carried out directly after the harvest months (August-September);

4.4.2 Diseases and pests

In coffee farming, various diseases and pests occur in different parts of the seasons; the presence of many pest and diseases is affected by heavy rain or the absence of rain. Therefore a brief review of diseases and pests is presented in this study:

1. 'Coffee bug' is caused by an insect called *Antestiopsis lineaticolis.* This insect inflicts considerable damage to the coffee tree, which tremendously decreases productivity and negatively affects the quality of the coffee by introducing a well-known 'potato taste' in the cup. It hides well between branches of coffee trees and within cherries. The insect perforates coffee beans and sucks juice from them. Coffee beans then cannot develop any more, nor ripen. Not only do drupes deteriorate, but bugs also attack new leaves, branch ends and flowers. This hinders the growth of coffee trees, flowers become scarce on branches, and young drupes are eaten up by the insects – which reduces production in general. As a control measure, insecticides such as Chloropyriphas ethyl are used in October and November after flowering. The spray is applied once to the whole coffee field.

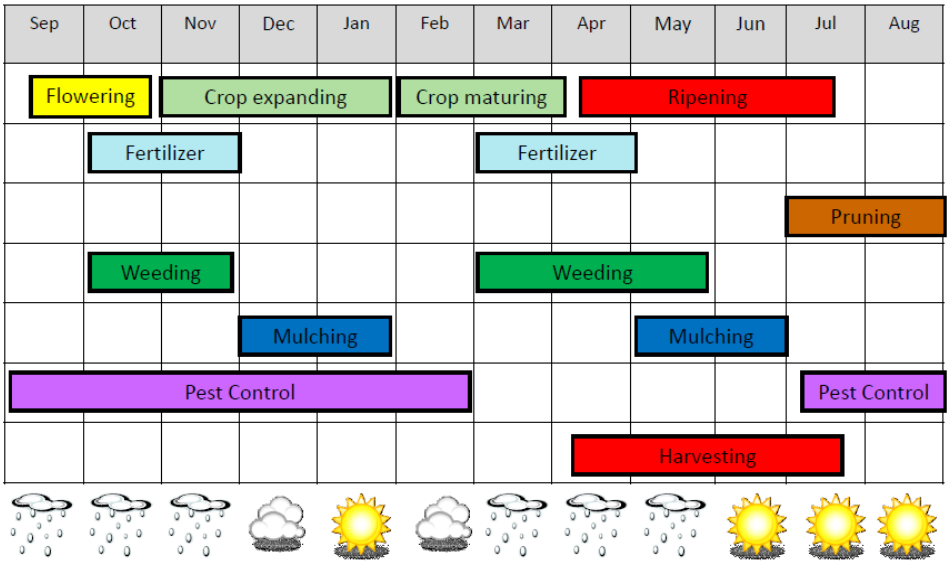
2. For other diseases like the 'coffee berry disease', transmitted by a tiny insect called *Colletotricum coffeanum,* the farmer uses fertilization and pruning as prevention measures. Copper oxychloride may also be applied as a chemical treatment. The treatment is conducted in September, October, November, December, and February.

3. The 'coffee leaf rust' has also been seen to occur more frequently recently and is transmitted by an insect called *Hemileia vastatrix.* The disease is common in hot weather, especially towards the end of rainy seasons and at the beginning of dry seasons. For prevention purposes, farmers grow resistant varieties disseminated by ISAR and again apply adequate management practices for coffee plantation (mulching, fertilization and pruning). Copper oxychloride can also be applied once a month in the same periods as the treatment against 'coffee berry disease'.

4. Another disease is called 'die back', which is a physiological disease characterised by physical degeneration. It generally attacks weak coffee trees that are planted on poor soil, and those that are healthy but not well fertilised. As an avoidance measure, farmers try to plant coffee trees in rich soils and manage them carefully with regular fertilization, abundant mulching, and regular pruning.

5. 'Cercosporiosis' is another frequently-occurring disease in the coffee plantation. This disease is transmitted by a kind of fungus called *Cercospora cafeicola.* The disease is particularly severe on weak coffee trees and it is common on soil which is poor in nitrogen. Smallholders therefore apply more fertilizer to fight its occurrence.

Figure 8: Actual schedule of the cultivation practices and harvesting of coffee recommended for farmers (Source: TechnoServe 2011).



4.4.3 Scheduling regional coffee cultivation practices into the seasonal calendar

Coffee cultivation is composed of a set of management practices from the nursery to the harvest, via preparation of the area to be planted, fertilisation, weeding, pruning, regular pest and diseases management, as well as harvesting – leading to a farm gate product known as 'coffee cherries'. All these management practices are described in the *National Annual Agricultural Agenda* produced by the Ministry of Agriculture and Animal Resources (MINAGRI 2009) and in the coffee management schedule that is produced by the Rwanda Coffee Authority OCIR-Café and distributed to agricultural technicians located at the sector level, which is the closest administrative unit to farmers.

- Fertilisation: coffee farmers and processors stressed the issue of the delay in fertilizer application during the yearly calendar. It was the general view of the western site (Dutezimberekawa Cooperative) farmers that the November application should move back to September or October, whereas March is too late to apply the NPK because not only do heavy rains wash it out (so that it contributes less to production) but its application implies high costs that add to its eventual price.

- Pesticides use: farmers stressed the lack of equipment for spraying. The treatment here is also not done in the right time, even though chemicals are subsidised by OCIR. It was noted that the rotation of equipment among farms delays the activity and facilitates the migration of insects around neighbouring farms. We discussed with farmers how the future spray calendar should look; the results are shown in Table 4.

Table 4: Proposed modifications to regional coffee calendars.

a. Proposed coffee calendar for western coffees of the Lake Kivu shore.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Crop expanding			Crop maturing			Cherries ripening					Flowering
Fertilizer					Fertilizer						
Pruning											Pruning
	Weeding					Weeding					
	Mulching					Mulching					
Pest Control								Pest Control			
								Harvesting			

b. Proposed coffee calendar for western and southern Rwanda.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Crop expanding			Crop maturing			Cherries ripening					Flowering
Fertilizer					Fertilizer						
Pruning											Pruning
	Weeding					Weeding					
	Mulching					Mulching					
Pest Control								Pest Control			
								Harvesting			

c. Proposed coffee calendar for south-eastern Rwanda.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Crop expanding			Crop maturing			Cherries ripening					Flowering
Fertilizer					Fertilizer						
Pruning										Pruning	
	Weeding					Weeding					
	Mulching							Mulching			
			Pest Control					Pest Control			
							Harvesting				

For the future it was also recommended that regional planning should be explored further, as opposed to national planning. One of the possibilities is to use the district administration office or CWS as a service provider to ensure that local plans adjust to the climate shifts that are difficult to predict.

4.5 Priority adaptations actions and their justifications, as suggested by GoR institutions

4.5.1 Agriculture food crops

The GoR envisages taking certain actions according to its second *Strategic Plan for the Transformation of Agriculture* (PSTA II, MINAGRI 2004), the Millennium Development Goals (MDGs), the *Economic Development and Poverty Reduction Strategy 2008 – 2012* (EDPRS, MINECOFIN 2007), and *Rwanda's Vision 2020* (MINECOFIN 2000).

In the public financial budgetary cycle for 2011-2012, the GoR recognizes that agriculture is the sector most pressured and vulnerable to climatic change and that causal impacts are related to variances in Rwanda's diverse climatic sub-regions, moderate bi-annual wet-dry seasons, uneven rainfall, and increasing episodes of extreme droughts and floods. Currently, the GoR invests in ensuring growth for exports and incomes, developing human resources, improving living conditions, as well as ensuring good governance and public accountability. From a more quantitative perspective, the *Agriculture Investment Strategy 2010-2015* (MINAGRI 2010b) calls for emphasising the following targets:

1. Sustainable management of natural resources, water and soil husbandry – 852,000ha of additional land protected against soil erosion, using radical and progressive terracing as well as the construction of 70 new valley dams and reservoirs.
2. Agricultural intensification promotion of both crop and livestock – whereby the proportion of households with livestock should rise from 71 per cent to 85 per cent, and improvements towards eradication of epidemic animal diseases should be conducted under the 'One Cow Per Poor Family' programme.[3] Inorganic fertilizer inputs are intended to increase from 11 per cent to 40 per cent, and improved seed use should rise from 24 per cent to 37 per cent.
3. Marshland reclamation – reclaimed area should increase from 11,105ha to 30,000ha in 2012.
4. Irrigation development – the area under irrigation is planned to be extended from 15,000 to 24,000ha in 2012, with irrigated hillside area increased to 1,100ha (from 130ha), with legal provisions set for water user associations and riparian rights.
5. Supply and use of agricultural inputs – increase fertilizer usage nationally to 56,000MT by 2012 (from 14 MT); production of 14,000MT of founded seeds (increase from 3,000 MT); Crop Intensification Program (CIP) expanded.
6. Food and nutrition security and vulnerability management – average availability per day should increase from 1,734kcal to 2,150kcal; 49g to 55g of protein and 8.8g to 23g of lipids. Additional measures include expanding the food and nutrition security monitoring system, and establishing 1,000 hermetic storage facilities to an operational level.

Priority actions and target indicators are also included in the *Rwanda 2020 Vision* for the agriculture and agribusiness sector, and are summarised in Table 5.

[3] In August 2006, the Government of Rwanda instituted the 'One Cow Per Poor Family' programme, which aims to give the poorest households in the country support to produce milk for home consumption.

Table 5: *Vision 2020* indicators for the agriculture sector (Source: MINECOFIN 2007).

***Vision 2020* indicator**	**Situation in 2000**	**Target in 2020**
Population of Rwanda	7,700,000	13,000,000
Urban population (per cent)	10	30
Agricultural population (per cent)	90	50
Poverty per cent less than 1 US$/day	64	30
GDP per capita in US$	220	900
Growth rate of agriculture sector	9	6
Modernised agricultural lands (per cent)	3	50
Use of fertilizers kg/ha/yr	0.5	15
Financial credits for agriculture sector (per cent)	1	20
Access to clean water (per cent)	52	100
Ag. production kcal/day/person per cent of needs	1612	2200
Availability of proteins/person/day (per cent of needs)	35	65
Road network km/km^2	0.54	0.60
Access to electricity (per cent)	2	35
Protected lands from erosion (per cent)	20	90
Non-agricultural jobs	200,000	1,400,000

4.5.2 Coffee

1. Put in place a system for improving input distribution and management, and monitoring that distribution (including seedlings, plantings, application of inputs, and studies to evaluate fertilisation strategies). Poor soil fertility is a major constraint for increasing volumes of high quality coffee. Chemical fertilisers are certainly necessary but government distribution programmes have not been very effective in the past, which has also been confirmed by the farmers. This needs to be re-examined in terms of alternative private models that may work better (PSTA II, MINAGRI 2004). In addition, organic fertilizers also need to be part of the scheme. This is especially true since Rwandan soil nutrients are highly leached and chemical fertilisers alone will not produce the positive results required to sustain the soils in the long term. As part of better farm management for coffee, the implementation of a national programme for shading coffee is recommended. Although some fragmented attempts at shading have been attempted using indigenous tree species, there is a need to implement this approach on a systematic basis.

2. Regarding fertilisation: interviews conducted by the authors found that: a.) no studies have been done under field conditions to see whether the current fertilizer regime is effectively absorbed into coffee trees; and b.) experiments are being designed without an adequate control group so it will be difficult to draw robust conclusions. At present, it seems that farmers do not find the formulas and rates for fertilisers an issue, but the schedule for distribution of fertilizers to farmers is problematic.

3. Improve pesticides use. There is a need to protect coffee against 'coffee bug' caused by the *Antestiopsis lineaticolis* insect, which introduces a 'potato taste' in the coffee cup. This defect constitutes a major constraint for getting better prices for Rwandan coffees. For example, nearly 25 per cent of all Rwandan specialty coffees in 2008 revealed significant levels of this defect. This percentage is higher than 2009 and last

year. The specialty coffee industry realizes now that Rwandan coffees will continue to be infected with this defect unless remedial actions are taken. As confirmed by farmers, the delay in pesticide distribution, coupled with insufficient equipment for spraying, causes the insect to migrate from one farm to the neighbouring one until the spray tour is finish (i.e., the tour will have less effect). As a remedial action, farmers propose that OCIR-Café makes available sufficient sets of spray equipment in the region so that at least the spraying for insects like *Antestiopsis* can be done simultaneously, to prevent its migration to the neigbouring farms.

4. Implement a control programme for 'coffee leaf rust' and other diseases that affect the coffee crop. Since this is the main threat to coffee cultivation it therefore needs to be attacked decisively. Also, carry out continuing adaptive research on coffee varieties, including those from Ethiopia. Utilise the competitive funding mechanism to support this research. The Ethiopian variety Panama now produces the highest-valued speciality coffee in the world (MINAGRI/MINICOM 2008).

5. Implement a turnaround programme for washing stations to improve their productivity and profitability, including wider application of the post-sale premium payment schemes that are already operational in some coffee cooperatives. This activity will also include upgrading their infrastructure and capacity building, since many of the washing stations still operate inefficiently and with weak management.

6. Carry out a programme for improved international marketing of coffee to gain higher prices for a wider number of producers. This will include: a.) support the operationalisation of the Coffee Marketing Alliance (including systems of quality control) and the Cup of Excellence® Program; and b.) create additional value-added activities including toll (or contract) roasting and partnerships with major buyers abroad.[4] This is another principal route to increasing the value of Rwandan coffee and to bring higher return to farmers.

7. Continue the programme of rehabilitating and replacing old coffee plantations with plantings of new varieties that are of better quality and are more disease-resistant, and developing multiplication centres for new seedlings.

8. Strengthening the research unit of OCIR and supporting the Institut des Sciences Agronomiques du Rwanda (ISAR) to conduct the identified research is among the priority lines in PSTA II and in annual plans of OCIR.

9. Mapping the current distribution of coffee and identification of potential areas of expansion is assigned to the Center of GIS and Remote Sensing of the National University of Rwanda (CGIS-NUR).

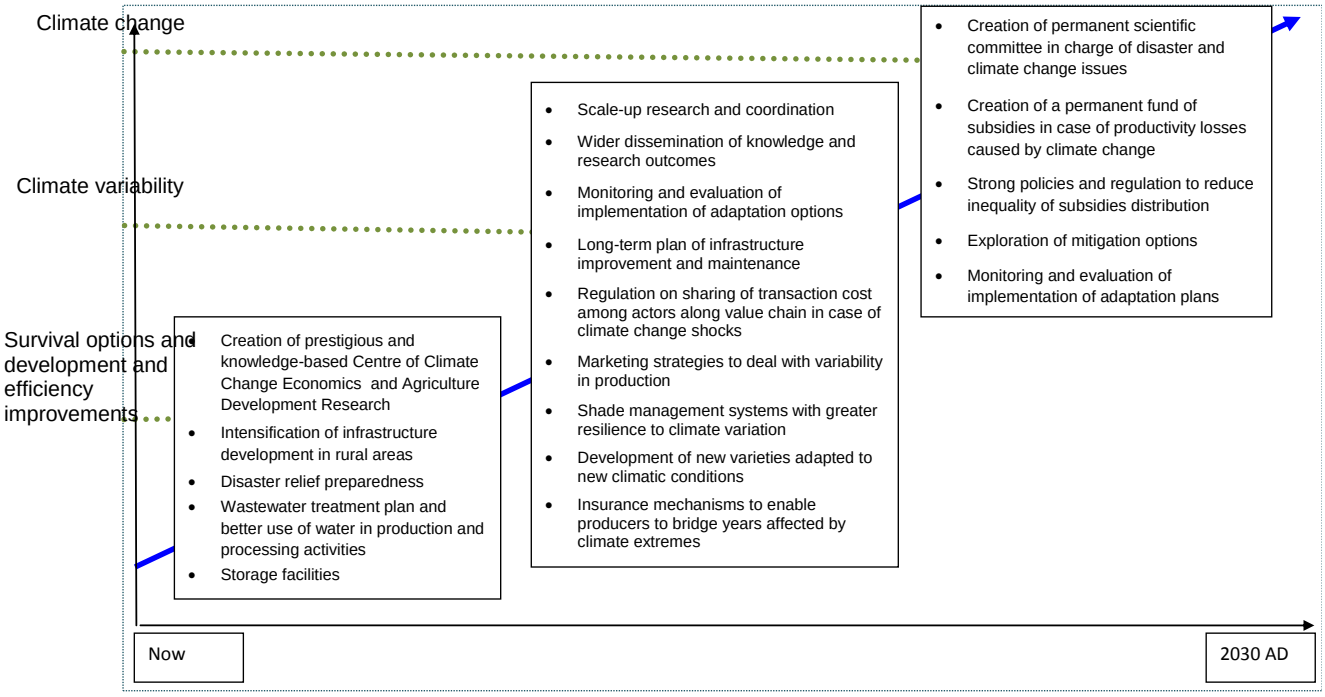
4.5.3 Banana

1. Support organic dessert banana production with technical assistance for cultivation, post-harvest handling and marketing. The technical assistance needs to cover all relevant topics, from maintenance of soil fertility with minimal use of inorganic fertilisers and organic means of pest control, to certification and marketing strategies for organic products.

2. Develop and implement the programme for controlling the banana wilt disease.

[4] MINAGRI/MINICOM 2008, *Rwanda National Coffee Strategy 2008-2012*

Figure 9: Adaptation signatures in agriculture.



4.6 Other priority adaptations actions and their justifications, as suggested by authors (subject to discussion with stakeholders).

Table 6: Priority actions, investments, and adaptation strategies from national to community level for the agriculture sector and coffee in particular.

Priority Actions NAPA	**MDGs and *Vision 2020* targets**	EDPRS & PSTAII & *Agriculture Investment Strategy 2010-2015*	**Coffee OCIR-Café (targets)**	**Staple crops and banana RADA targets**	**Macro-level adaptation actions**	**Adaptation actions, community level**
1. Integrated water resources management (IWRM)	100 per cent of arable land protected against soil erosion 100 per cent of the population have access to safe/clear water 30 per cent of land area covered by forest (refer to marginal/degraded lands)	852,000ha protected against soil erosion using radical and progressive terracing 70 dams and reservoirs constructed Valleys under irrigation increased in 2012 from 15,000 to 24,000ha Hillside area irrigated expanded from 130ha to 1,100ha	-	-	Wastewater treatment plan and watershed management	Put in place an integrated farming system to provide enough mulch and preserve quantity of production and quality
2.Set up information systems of hydro agrometeorologic early warning system and rapid intervention	-	Invest in weather stations (new and rehabilitated) and collection of weather data – to enable its application to a larger number of crops in a larger number of areas.	-	-	Creation of prestigious and knowledge-based Centre of Climate Change Economics and Agriculture Development Disaster relief preparedness	Need for an early warning system

Priority Actions NAPA	**MDGs and *Vision 2020* targets**	EDPRS & PSTAII & *Agriculture Investment Strategy 2010-2015*	**Coffee OCIR-Café (targets)**	**Staple crops and banana RADA targets**	**Macro-level adaptation actions**	**Adaptation actions, community level**
3.Promotion of income-generating activities in rural area	Road network (0.6 km/km^2) Land tenure security: 60 per cent of land parcels with land titles Non-agricultural jobs created in rural areas (1,400,000)	Off-farm employment increased to 30 per cent Creation of approximately 600,000 new non-farm jobs Enlarge the programme of agricultural loan guarantees (AGF) for private lending to agriculture, agro-processing, and agricultural export activities	Implement turnaround programme for CWSs to improve their productivity and profitability, including wider application of the post-sale premium payment schemes Support the operationalisation of the Coffee Marketing Alliance, including systems of quality control, and the Cup of Excellence® Program Create additional value-added activities, e.g., toll roasting and partnerships and relationships with major buyers abroad	-	Intensification of infrastructure development in rural areas	-

Priority Actions NAPA	**MDGs and *Vision 2020* targets**	EDPRS & PSTAII & *Agriculture Investment Strategy 2010-2015*	**Coffee OCIR-Café (targets)**	**Staple crops and banana RADA targets**	**Macro-level adaptation actions**	**Adaptation actions, community level**
4.Promotion of intensive agriculture and animal husbandry	Use of fertilisers (15 kg/hectare/ year) Use of chemical or organic fertilisers (50 % of households); Modernised agricultural lands (50 % of total land) Financial credits to the agricultural sector increased (20 %) Agricultural production increased (2,200 kcal/person/day)	Proportion of households with livestock should rise from 71 % to 85 % Inorganic fertilizer inputs increase from 11 % to 40 % Improved seed use to rise from 24 % to 37 % Reclaimed wetland area to increase from 11,105ha to 30,000ha by 2012 Fertilizer usage increased from 14MT to 56MT in 2012. Increased production from 3,000MT to 14,000MT Average availability per day increased in 2012 from 1,734kcal to 2150Kkcal: 49g to 55g of protein, 8.8g to 23g of lipids 1,000 hermetic storage facilities established	Put in place a system to improve input distribution, management and monitoring in coffee (fertilizer, seedlings, plantings etc.) Implement a national programme for shading coffee Improve pesticides use. Protect coffee against ‘coffee bug’ Implement a programme of control of ‘coffee leaf rust’ and other diseases that affect coffee crop	Extend such progress to food security crops such as sweet potatoes, beans, banana and cassava, through improved usage of agricultural inputs Support organic dessert banana production with technical assistance for cultivation, post-harvest handling, and marketing	Storage facilities	Improving farmers’ saving schemes

Priority Actions NAPA	**MDGs and *Vision 2020* targets**	EDPRS & PSTAII & *Agriculture Investment Strategy 2010-2015*	**Coffee OCIR-Café (targets)**	**Staple crops and banana RADA targets**	**Macro-level adaptation actions**	**Adaptation actions, community level**
5.Introduction of varieties resistant to environmental conditions	Agricultural production (2,200 kcal/person/day)	-	Carry out adaptive research on coffee varieties (e.g. Panama from Ethiopia) Replacing old coffee plantations with plantings of new varieties that are of better quality and are more disease-resistant Develop multiplication centres for new seedlings	Develop and implement a programme for control of banana wilt disease	Research, development and distribution of new varieties adapted to new climatic conditions	-
6.Development of alternative energy sources to firewood	Energy derived from wood (50 %) Access to electric energy (% of population)	-	-	-	-	-

Data compiled by the authors from different sources: GoR documents, interviews with different stakeholders, and farmer's responses.

Table 7: Adaptation costs for now and 2030 in US$.

Action	Actor(s)	Cost/$ now	Cost/$ 2030
1. Creation of prestigious and knowledge-based Centre of Climate Change Economics and Agriculture Development	1. Government (Ministry of Finance and Economic Planning) 2. Donors and civil society organisations: the GoR should plan strategically in interesting and mobilising these partners to allocate money in the establishment of the Centre	**5,700,000**	**20,000,000**
2. Research, development and distribution of new varieties adapted to new climatic conditions	1. ISAR 2. Donors, civil society organisations	**1,000,000**	**15,000,000**
3. Intensification of infrastructure development in rural areas	1. Ministry of Agriculture and Animal Resources; Ministry of Infrastructure 2. Donors, civil society organisations	**4,000,000**	**40,000,000**
4. Disaster relief preparedness	1. Ministry of Disaster Management and Refugee Affairs 2. Donors, civil society organisations	**2,000,000**	**40,000,000**
5. Wastewater treatment plan and watershed management	1. Ministry of Environment, Ministry of Agriculture and Animal Resources, and Ministry of Infrastructure 2. Donors, civil society organisations	**1,500,000**	**15,000,000**
	Total	**14,200,000**	**130,000,000**

Table 8: Adaptation costs for now and 2030 in US$ (coffee).

Action	Actor(s)	Cost/$ now	Cost/$ 2030
1. Implement turnaround programme for CWSs to improve their productivity and profitability, including wider application of the post-sale premium payment schemes	1. OCIR-Café 2. CWS owners	**500,000**	**2,500,000**
2. Support the operationalisation of the Coffee Marketing Alliance, including systems of quality control, and the Cup of Excellence® Program. Create additional value-added activities, e.g., toll roasting, and partnerships and relationships with major buyers abroad	OCIR-Café	**500,000**	**2,500,000**
3. Toll roasting and partnerships and relationships with major buyers abroad	OCIR-Café	**500,000**	**2,000,000**
4. Carry out adaptive research on coffee varieties (e.g., Panama from Ethiopia)	ISAR	**300,000**	**1,500,000**
5. Replace old coffee plantations with plantings of new varieties that are of better quality and are more disease-resistant, and develop multiplication centres for new seedlings	1. OCIR-Café 2. ISAR	**700,000**	**4,000,000**
	Total	**2,400,000**	**12,500,000**

Table 9: Adaptation measures, efforts, and allocation of funds for given priorities.

Activities	2011 - 2015	2016 - 2020
Training and agricultural research	50%	40%
Extension and awareness	10%	25%
Monitoring and evaluation	10%	20%
Infrastructure and data development (meteorological stations, etc.)	20%	5%
Climate change research	5%	5%
Policy, institutional strengthening, production, efficiency, marketing, etc.	5%	5%

5. Institutional, policy, and funding contexts for agricultural adaptation in the country

'Ensuring the sector's resilience against existing and future climatic change is a national concern for long-term development' (EDPRS, MINECOFIN 2007), the GoR's goal in respect of the MDGs Goal 1 is to ensure improved and sustainable production methods, crop selection, modernisation, land consolidation and protection, post-harvest storage, agroforestry, climate-sensitive extension, land and animal husbandry, and collaborative management.

5.1 Current institutional set-up and agriculture planning initiatives

To achieve the above GoR goal, it has been established that the lead agencies of MINAGRI should implementing the second *Strategic Plan for the Transformation of Agriculture* (PSTA II). As implementation units, the Rwandan Agricultural Development Authority (RADA), the Rwanda Animal Resources Development Authority (RARDA), and the Institut des Sciences Agronomiques du Rwanda (ISAR) constitute the Rwanda Agricultural Board (RAB), and OCIR-Café, OCIR-Thé and Rwandan Horticulture Development Authority (RHODA) are organised under the National Agriculture Export Board (NAEB).

The creation of the agriculture sector-wide working group has been instrumental in harmonizing activities and contributing to a shared vision with the effective collaboration of implementing agencies, donors, support agencies and key stakeholders.

Today, rapid progress and success has been achieved under the programmes of the PSTA II initiative. The high sectoral growth rate of 7.7 per cent in 2009/2010 is accredited to the Crop Intensification Program (CIP), which has seen a rise in the use of fertilizers, improved quality of seed, and, through land consolidation, improved planting techniques with the assistance of implementing agencies such as RADA.

Strong progress has been achieved in areas of soil erosion, land terracing, and marshland development with projects such as the Land Husbandry, Water Harvesting and Hillside Irrigation (LWH) Project. Notably, production exceeded estimates in 2009/2010 and also over the previous three growing seasons (2006-2008), though this can partially be attributed to favourable rainfall. Production increased by 9.5 per cent over the previous year. The leading agricultural development initiatives and priority areas are:

- Crop intensification.
- Land and animal husbandry.
- Water storage and harvesting.
- Irrigation and community-based watershed management.
- Agricultural transformation, modernisation and extension; and land consolidation.
- Post-harvest storage and transport.
- Agricultural finance, crop-based credit, and agricultural insurance.

5.2 Climate change knowledge management and gaps in the agricultural sector

There are still barriers and constraints that hamper the smooth implementation of the agriculture adaptations. The coffee sector is especially affected.

Table 10: Institutional barriers, constraints and opportunities.

Institutional barriers and constraints	Institutional opportunities
Lack of measurement tools and skills, and insufficient infrastructure for collecting climate data and other related data	Local research and education institutions and present partnerships with regional and international institutions expert in climate fields Funding alignment system, information and data sharing (data infrastructure sharing through RDB)
A lack of technical capacity in climate forecasting from national to local level	Use service providers or community-based organisations (CBOs) to participate in extension services and knowledge transfer in the form of community training in agriculture adaptation
Gaps between problems and research set-up/design	Public-private partnerships; existing community involvement in governance. Need to explore such channels in agriculture adaptation research
A lack of coordination between ministries' plans and donors concerning similar objectives/directions	Ongoing initiatives around climate and adaptations
Lack of knowledge and data on agriculture shocks and adaptation measures	Local research and education institutions and present partnerships with regional and international institutions expert in climate and agriculture
Cumbersome funding mechanisms resulting in the very slow implementation of solutions	Good governance structure +NGOs and CBOs, and service providers
Weak mechanisms for the distribution of funds and poor prioritisation	Good governance structure +NGOs and CBOs, and service providers

A. **Lack of a national climate observatory**: although Rwanda has had a National Meteorological Service since the 1990s, there is still a general lack of climate data for Rwanda – which prevents the development of reliable climate models and hence significant climate projections. But these are essential if Rwanda intends to incorporate changes in climate into its economic and social planning. It was proposed by Byamukama *et al*. (2011) that the Smith School works with the Hadley Centre in Rwanda to establish a Climate Observatory in Rwanda. This will also include training of local researchers and technicians in data capture and analysis.

B. **Lack of knowledge on climate change; lack of mitigation and adaptation strategy**: this should be addressed by incorporating the following information into the current strategic plans:

1. A roadmap for future climate resilience and adaptations for economic growth in Rwanda.
2. Existing climate change initiatives and opportunities that are currently being undertaken in relative isolation in Rwanda.
3. A framework about which detailed sectoral studies and implementation plans can be built.

C. **Lack of geo-information data for the agriculture sector that could lead to more generalised adaptation measures**: in fact, the lack of clear and stable agriculture land-use planning and crop zoning in Rwanda has restricted the ability of district authorities to plan for sustainable land consolidation, which protects environmental, social and economic needs and adaptation at the local level. National spatial planning is now being addressed by the introduction of the *National Land Use and Development Master Plan* (MINELA 2010). The master plan requires implementation by land-related authorities and subsequent preparation of detailed district plans that will link together the national master plan.

Explanatory notes on the *National Land Use and Development Master Plan (*by Swedesurvey in 2009) call for an increased development of the detailed planning process within local authorities, capacity development of planning officers, and greater use and exploitation of GIS in the planning process.

Agricultural data for the districts is also inadequate. Agriculture is a primary economic driver in Rwanda and has an important influence on the rural areas of the districts. However, the analysis of agricultural capabilities of each district is not well developed. Specific data on existing agricultural production and agro-ecological/economic potential should be included in the analysis of land-use planning and expenditures. In coffee-based farming systems especially, the data on major crop staples at the regional (district level) should be included in the analysis of coffee farming, as a move towards an integrated coffee farming approach as one of the best adaptation practices. Examples for exploring the possibility of an integrated banana – beans - coffee farming system in the area (wherever feasible) could be one of the solutions to minimise the impacts of climate change on livelihoods.

6. Policy implications

6.1 Priority areas for investment in agriculture in Rwanda

This research analysed climate change and its impact on agricultural systems in Rwanda. The main priority areas for investment are grouped into six options:

1. Integrated water resources management (IWRM).
2. Setting up information systems for a hydro-agro-meteorological early warning system and rapid intervention mechanism.
3. Promotion of non-agricultural income-generating activities.
4. Promotion of intense agri-pastoral activities.
5. Introduction of new varieties adapted to these environmental conditions.
6. Development of alternative energy sources to firewood.

Those main investment areas aim at reducing the vulnerability of ecosystems, populations and sectors due to the quantitative and qualitative shortage of water resources and the damage caused by runoff due to climate change. By improving the information and hydro-agro-meteorological early warning systems, as well as intervention measures, the exposure of populations and sectors to the adverse impacts of climate change is reduced. The promotion of income-generating non-agricultural activities, the setting up of agro-sylvo-pastoral systems, the promotion of appropriate cultivation techniques, and the introduction of varieties resistant to environmental conditions, will increase the capacity of farmers and pastoralists to adapt to climate change through the promotion of alternative sources of energy, thus reducing the pressure on the remaining national forest stocks.

6.2 Priority areas for investment in coffee

The main priority area for investments in the coffee sector is to put in place a system for improving the distribution, management, and monitoring of inputs – especially regarding pesticides use. Coffee washing stations should employ their own agronomists to spread best practices among farmers, as part of a wider CWS development programme. Further initiatives should include building the capacity of exporters, extending necessary infrastructure, and generally enhancing research and development in the coffee sector.

6.3 Priority areas for investment in banana

The banana sector, according to our findings, doesn't have a strong long-term agenda (as opposed to the coffee sector). Existing policies aim at developing a banana programme, reinforcing banana cooperatives and associations, as well as developing research and development systems in order to support future adaptation options and their implementation.

6.4 Other investments for adaptive agriculture

Other enabling factors that have significant potential for promoting adaptation, especially in terms of irrigation and intensive livestock production systems, are households' access to electricity and ownership of farm capital (i.e., machinery). Facilitating access to technology such as electricity and machines increases farmers' capabilities for taking up adaptation measures. Better access to markets – through improved infrastructure and thus reduced transport and other market-related transaction costs – would also contribute to more effective adaptation strategies at the farm level. Simultaneously, farmers would be enabled to buy new crop varieties and invest in new irrigation technologies and other important inputs they may need if they are to change their practices to cope with the predicted changes of climate in the future.

In many other countries, it has already been found that utilising positive experiences drawn from the farming community promotes effective adaptation. Experienced farmers usually have sound knowledge and information on climate change and agronomic practices that they can then apply to cope with changes in climate and other socioeconomic conditions. This suggests that education to improve their awareness of the potential benefits of adaptation is an important policy measure for stimulating farm-level climate adaptation.

Institutional support for the entire process is crucial, and requires the mainstreaming of climate change at each level of the supply chain. Therefore careful communication among all actors is required. Climate risks should neither be oversimplified nor overstated, but be well understood and explained. Local options to confront climate risks should be emphasised and strengthened.

7. Conclusions and stakeholder recommendations

The Rwandan study findings have revealed that the current situation of climate variability and change has had an adverse impact on the country's agricultural systems and therefore the overall economy. The changing patterns of precipitation and temperature, as well as the more frequent appearances of extreme events like floods and droughts, lead to a decline in soil fertility and productivity, as well as an increase in incidences of plant diseases.

Since Rwanda is not equipped to cope with these climate risks, urgent action by implementing climate change adaptation measures is needed to sustainably protect livelihoods and ecosystems. The specific areas for adaptation were determined based on the following identified shortcomings: lack of research and reliable climate data; limited knowledge about mitigation and adaptation strategies in general; poor farming and processing practices; restricted access to technologies; inadequate financial resources; and insufficient communication. The adaptation options accordingly formulated for implementation include: more effective distribution of inputs such as fertiliser and pesticides; investments in farming equipment; improvement of extension services and research; as well as restructuring of the institutional frameworks and development plans.

The importance of climate change adaptation can be especially emphasised by taking the coffee sector as an example. The Rwandan coffee industry has undergone a remarkably successful transformation by positioning its coffee as and appreciated and recognized brand in the international premium coffee market, which has created a high value for Rwanda's economy. In view of the fact that coffee is a very climate-sensitive plant in terms of productivity and quality, appropriate identified adaptation measures need to be implemented soon in order to preserve this value and optimise further economic opportunities.

7.1 Stakeholders' recommendations in respect to technology

During the validation workshop, the stakeholders and the Rwandan researchers agreed on the following main suggestions for action on adaptation to climate change in agriculture:

The creation of a centre to monitor climate change and production patterns, which will also coordinate projects and support the downscaling of activities for increasing the efficiency of data gathering. For example, coffee yield monitoring needs to be coupled with agro-meteorological data in the future as part of the Early Warning System for Coffee (EWS-C) to improve sector planning.

Weather forecasting technologies across the continent have been greatly enhanced in recent years by initiatives of PUMA, and provide timely climate and crop data through EUMESAT and SPOT-VGT4Africa – e.g., the MSG ground receiving station, available at the GIS centre at the National University of Rwanda (CGIS-NUR). The current lack of these systems and skilled human resources have been confirmed in the 'Social Protection and Climate mission', organised by AFTSP/WB (also called the 'scoping mission') undertaken between the 5th and 25th June, 2010.

There is a need for coordinated, consolidated, and streamlined community-based monitoring systems to build a 'bottom-up' structure that is intended to compliment and strengthen the new FEWSNET and meteorological service weather and hydrology forecasts that are 'top-down' oriented.

It was suggested that a comprehensive review of the draft meteorological service strategy should be carried out and follow-up discussions conducted with FAO, UNDP and ClimDev about possible points of actions for weather stations and capacity building.

The additional inclusion of ‘climate proofing’ to the Vision 2020 Umurenge Programme (VUP) is also necessary through the incorporation of early warning system (EWS) and rapid response systems. VUP could coordinate some of the implementation activities of the EWS itself, while other institutions should be included as well by focusing on aspects that might be beyond VUP’s control and mandate.

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Annexure 1: Descriptive statistics of coffee production 2005 – 2010 (all figures are per household).

	Number of coffee and banana growers surveyed	Minimum	Maximum	Mean	Std. deviation
Total number of coffee trees in 2010	103	40	5,000	697.26	761.049
Total number of coffee trees in 2009	103	30	5,000	621.07	679.241
Total number of coffee trees in 2008	103	30	5,000	592.67	666.361
Total number of coffee trees in 2007	103	25	9,000	656.94	1058.399
Total number of coffee trees in 2006	103	25	8,000	631.72	983,.550
Total number of coffee trees in 2005	103	25	7,000	600.16	904.587
Total number of coffee trees in production in 2010	103	20	5,000	579.91	682.112
Total number of coffee trees in production in 2009	103	20	4,000	530.76	579.435
Total number of coffee trees in production in 2008	103	15	3,900	534.69	563.750
Total number of coffee trees in production in 2007	103	0	3,800	511.17	544.405
Total number of coffee trees in production in 2006	103	0	3,500	488.83	532.101
Total number of coffee trees in production in 2005	103	0	2,250	431.32	424.645
Total number of banana trees in 2010	103	0	600	158.00	104.539
Total number of banana trees in 2009	103	0	600	145.59	97.919
Total number of banana trees in 2008	103	0	600	140.81	91.940
Total number of banana trees in 2007	103	0	600	136.59	91.148
Total number of banana trees in 2006	103	0	600	115.84	81.826
Total number of banana trees in 2005	103	0	600	119.10	81.135
Total number of banana trees in production in 2010	103	0	500	119.94	76.292
Total number of banana trees in production in 2009	103	0	500	106.23	70.553
Total number of banana trees in production in 2008	103	0	420	100.14	62.314
Total number of banana trees in production in 2007	103	0	430	87.90	57.627
Total number of banana trees in production in 2006	103	0	420	88.21	57.430
Total number of banana trees in production in 2005	103	0	460	89.38	59.925

Annexure 2: Descriptive statistics of labour use in CWSs

	N(CWS)	Minimum	Maximum	Std. deviation
Number of farmers who delivered coffee cherries to the station in 2005	3	100.00	500.00	282.84271
Number of farmers who delivered coffee cherries to the station in 2006	3	150.00	700.00	388.90873
Number of farmers who delivered coffee cherries to the station in 2007	3	150.00	950.00	426.03443
Number of farmers who delivered coffee cherries to the station in 2008	3	200.00	1,200.00	532.04793
Number of farmers who delivered coffee cherries to the station in 2009	3	200.00	1,200.00	519.46639
Number of farmers who delivered coffee cherries to the station in 2010	3	400.00	1,200.00	400.22036
Quantity (kg) of coffee washed daily when the washing station is operating at full capacity	3	3,000.00	8,000.00	2817.35692
Number of managers at washing station in the peak season	3	1.00	2.00	0.57735
Number of technicians at washing station in the peak season	3	2.00	3.00	0.57735
Number of labourers at washing station in the peak season	3	38.00	90.00	26.22975
Number of managers at washing station in the low season	3	1.00	1.00	0.00000
Number of technicians at washing station in the low season	3	0	2.00	1.15470
Number of labourers at washing station in the low season	3	1.00	8.00	4.04145
Number of technicians employed on an average day in the peak season in 2010	3	2.00	2.00	0.00000
Number of technicians employed on an average day in the peak season in 2009	3	2.00	2.00	0.00000
Number of technicians employed on an average day in the peak season in 2008	3	2.00	3.00	0.57735
Number of technicians employed on an average day in the peak season in 2007	3	2.00	2.00	0.00000
Number of technicians employed on an average day in the peak season in 2006	3	0	2.00	1.15470
Number of technicians employed on an average day in the peak season in 2005	3	0	2.00	1.15470
Number of labourers employed on an average day in the peak season in 2010	3	38.00	400.00	191.62811
Number of labourers employed on an average day in the peak season in 2009	3	26.00	100.00	37.36308
Number of labourers employed on an average day in the peak season in 2008	3	32.00	100.00	34.17601
Number of labourers employed on an average day in the peak season in 2007	3	20.00	70.00	26.45751
Number of labourers employed on an average day in the peak season in 2006	3	0	70.00	36.05551
Number of labourers employed on an average day in the peak season in 2005	3	0	70.00	35.11885