Review of Climate Service Needs and Opportunities in Rwanda

Working Paper No. 180

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Rwanda's variable and changing climate is an increasingly serious challenge to the country's agricultural sector and farming population. Climate information services are emerging as a means to support farmers to manage risk and provide an opportunity to build the resilience of agriculture to climate at all time scales. Climate services include historical, monitored and forecast information, and value-added information products such pest and disease risk warnings, crop yield forecasts, or management advisories. The new Rwanda Climate Services for Agriculture project, funded by USAID, aims to benefit nearly one million farmers by 2019, and transform Rwanda's rural farming communities and national economy through climate services and improved climate risk management. This desk review was conducted to ensure that the project design is informed by and builds on existing needs, knowledge, services, capacities and initiatives. It synthesizes what is known about climate-related risks and their impacts on Rwanda's agriculture sector; the current status of climate information products and services; key institutions currently involved in the production, communication and use of climate-related information; and communication channels that can be used to deliver climate information services to relevant users including Rwanda's farming population.

The Rwanda Meteorological Agency (Meteo Rwanda), currently provides weather and climate information including: (a) historical and monitored observations (rainfall, temperature, humidity, wind speed and direction, sun shine hours); (b) analyses of weather and climate information (minimum, maximum and mean of variables, dry/wet spells, frequency of extreme events); (c) forecasts at daily, 5-day, 7-day, monthly and seasonal lead times; (d) agro-meteorological bulletins with information about monitored weather and current crop conditions, and agro-advisory information; (e) specialized products such as crop yield forecasts, flood monitoring, drought early warning, agricultural production and food security forecasting; and (f) weather data for weather index insurance. The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) prepares and publishes the National Risk Atlas showing advisories on drought, floods, windstorm and landslides. A few organizations such as Agriculture and Climate Risk Enterprise (ACRE) are partnering with government ministries to access weather data and build suitable weather index insurance

products. Several recent and current projects have objectives that are closely related to the Rwanda Climate Services for Agriculture project. Effective coordination with these complementary initiatives provides opportunity to leverage synergies and avoid duplication.

Innovative communication channels are available to communicate climate information. The Twigire Muhinzi national extension system, led by Rwanda Agricultural Board (RAB), is an extensive farmer-to-farmer system that is transforming Rwanda's agriculture sector. Information through this extension system can reach most farmers at the lowest administrative unit (the cell) through Farmer Field Schools (FFS), and Farmer Promoters. The trained FFS facilitators and Farmer Promoters use participatory processes that encourage experimentation and learning. Rwanda's farmers receive weather and seasonal climate forecasts and agro-advisory information through various media sources, with radio as the most popular. These media-based channels tend to be top-down, and are limited in their ability to respond to specific information needs or support farmer feedback.

This review suggested several opportunities to strengthen climate services that meet the needs of Rwanda's agricultural sector and farming population. First, because Rwanda's population is relatively young, packaging and communicating climate information products and services could be tailored to the interests of the youth, for example capitalizing on the popularity of social media (e.g., Facebook, Twitter). Second, tapping into the Twigire Muhinzi national extension system can take advantage of its extensive reach, and may increase the likelihood that farmers will adopt climate-related information and advisories. Third, participatory face-to-face communication of climate services can be scaled up through training Farmer Field School Facilitators and Farmer Promoters. Fourth, Rwanda's government policies are far ahead of most African countries on gender inclusiveness. If climate services are developed to address the needs of women, it can leverage the favorable policy environment and contribute towards gender inclusiveness. Fifth, the project is in a position to address a gap in information about who uses climate information, how they use it, and the benefits of climate services for farmers and for the nation's agricultural economy. Finally, there is a great need and opportunity to tailor climate-related information, advisories and tools to the specific needs of different users and different farming and livestock systems.

Keywords

Rwanda; Climate Services; Agriculture; Risk; Hazards; Communication approaches

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Contents

List of Tables

List of Figures

Acronyms

AMIS	Agricultural Market Pricing Information System
CICA	Agricultural Information and Communication Center
FAO	Food and Agriculture Organization of the United Nations
GoR	Government of Rwanda
IGAD	Inter-Governmental Authority on Development
ICPAC	IGAD Climate Prediction and Applications Centre
MASL	Meters Above Sea Level
MIDIMAR	Ministry Of Disaster Management And Refugee Affairs
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MINITERE	Ministry of Lands, Environment, Forestry, Water and Mines
NISR	National Institute of Statistic Rwanda
RAB	Rwanda Agriculture Board
RANET	Radio and Internet
REMA	Rwanda Environment Management Authority
RMA	Rwanda National Meteorology Agency
SEDOs	Socio Economic Development Officers
WMO	World Meteorology Organization

Introduction

Rwanda's variable and changing climate is an increasingly serious challenge to the country's agricultural sector and farming population. Climate information services are emerging as a means to support farmers to manage risk and an opportunity to build the resilience of agriculture to climate at all time scales. Climate services include historical, monitored and forecast information, and value-added information products such pest and disease risk warnings, crop yield forecasts, or management advisories.

The Rwanda Climate Services for Agriculture project, funded by the United States Agency for International Development (USAID), aims to benefit nearly one million farmers by 2019, and transform Rwanda's rural farming communities and national economy through climate services and improved climate risk management. The project will develop sustained capacity to achieve four outcomes: (a) climate services for farmers, (b) climate services for government planning, (c) improved climate information provision, and (d) sustained climate service governance. This desk review was conducted to ensure that the project design is informed by and builds on existing needs, knowledge, services, capacities and initiatives. It synthesizes what is known about climate-related risks and their impacts on Rwanda's agriculture sector; the current status of climate information products and services; key institutions currently involved in the production, communication and use of climate-related information; and communication channels that can be used to deliver climate information services to relevant users including Rwanda's farming population.

Overview of Rwandan Agriculture

Rwanda agriculture dominated by smallholder farmers, contributes a third of the country's domestic product (about 33% of the GDP $7.8 billion) (World Bank 2014). Climate plays a significant role in livelihoods of Rwanda's farming population. The influence of climate is also observed in agricultural related sectors such as transportation and energy. Limited adaptation strategies coupled with limited capacity to manage climate variability and change has made Rwanda extremely vulnerable to negative impacts of climate. This has prompted the

Government of Rwanda (GoR) to increase budgetary allocation to agriculture from 4.2% in 2008 to nearly 10% in 2011 in response to the target set up by Comprehensive Africa Agriculture Development Programme (CAADP) (IMF 2011; Bizimana 2015).

Agriculture employs more than 80% of Rwanda's population of 11.8 million (World Bank 2013, FAOSTAT 2014). The majority of Rwanda's farmers are women. The population is young, with over 41% under the age of 14 (NISR 2012a). Life expectancy is 63 years (World Bank 2013). A high proportion of female farmers are aged 55 years and above while for men, their ages range between 25-34 years (Table 1). This has implication on what type of climate information to disseminate and the communication approaches to use.

Table 1. Age distribution (percent within each age category) of the farmers in 2015

Age category (years)	Female	Male	Overall
14-24	6.3	5.0	5.4
25-34	16.6	27.7	24.2
35-44	18.2	24.3	22.4
45-54	22.2	20.8	21.2
55 and Above	36.7	22.2	26.8

Source: NISR 2015a

Rwanda is Africa's most densely populated country, with an average of 460 people per km^2, and more than 600 people per km^2 in northern districts such as Ruhengeri and Gisenyi (World Bank 2014). This has exerted enormous pressure on arable land (Diamond 2005, Boudreaux 2009), where farmers are engaged in diverse mixed crop-livestock farming .In the central highland, with elevations ranging from 1,500-2,500masl, farmers grow tea, maize and wheat. In the eastern lowlands close to Uganda, banana, maize, bush bean, sorghum, and cassava are the main crops cultivated. In the northern and western regions crops grown include potatoes, tea, maize, wheat, climbing beans, and pyrethrum. In the Southern region, farmers grow sweet potatoes, bush beans, tea, coffee, and wheat. Beans and bananas are the most popular crops that are grown on 18.1% and 17.3%, respectively of the total harvested land area (FAOSTAT 2014 and Table 2). In particular bananas are on over a third of the country's cultivated land and account for at least two-thirds of a small farmer's earnings (NISR 2015b). Other staple crops grown and the area under cultivation for each crop are maize (9.5%), cassava (9.2%), Irish potatoes (7.3%), sweet potato (5.9%), with coffee, tea and rice accounting for less than 4%.

Table 2. Land allocation to different crops in Season A and B

Rainy Season	Land allocation to different crops (%)					
	Roots and tubers	Banana	Cereals	Fruits	Vegetables	Pulses
Season A (September to February)	25	18	23	3	2	29
Season B (March to July)	54	27	6	6	4	3

Source: MINAGRI 2014

Table 3 shows the production of main crops in 2015 (NISR 2015b). About 90% of the food produced is consumed locally and only a few crops—tea and coffee—are exported, accounting for 70-90 percent of total export revenues (MINAGRI 2009).

Table 3. Production of main crops

Crops	Production (MT)	Percent of total production
Cereal (maize, paddy rice, sorghum, wheat)	369,966	10.5
Tubers and roots (cassava, sweet potatoes, irish potatoes, yams & taro)	1,319,108	37.4
Banana	983,215	27.9
Legumes and pulses (soya beans, groundnuts, climbing beans, bush beans and common beans)	275,498	7.8
Vegetables and fruits	165,144	4.7
Other crops	412,91	11.7

Source: NISR 2015b. The data were assessed for the following systems: Intensive agriculture land - Season A and B; marshland and rangeland.

Agriculture's contribution to greenhouse gases emissions

Agriculture contributes about 40% of Rwanda's total greenhouse gases emissions (GHG), mainly through rice cultivation, enteric fermentation, burning of savanna, manure management, agricultural soils, and field burning of agricultural residues (Byamukama et al. 2011). In 2005, GHG emissions from agricultural fields included methane (CH_4) 49 Gg, nitrous oxide (N_2O) 10 Gg and carbon dioxide (CO_2) 9 Gg (Mutabazi 2010). Due to the hilly landscape, soil erosion is a big problem with the country losing about 1.4 million tons of fertile soils per year (Byamukama et al. 2011).

Land tenure

Land is used mainly for six major activities. Arable land (land actually under agriculture) comprises 61%, wetlands (10%), forest (10%), water bodies (6%), protected areas (8%) and towns and highways (5%) (REMA 2009). The National Land Policy (NLP) of 2004 and the

Organic Land Law No. 08/2005 of 2005, provide a platform for a secure and stable form of land tenure for both men and women (Republic of Rwanda 2004). The policy permits anyone to secure land tenure through land registration and titling (land is held under an Emphyteutic Lease of 99 years). On the title deed, both names (husband and wife) are included and through this process, women who were previously not permitted to own and/or inherit land got an opportunity to secure their own land rights.

Average rural landholdings have decreased from 1.2 ha to 0.6 ha per household since the 1990s, due to the growing population and associated land fragmentation (NISR 2010, NISR 2011). As a result, 46% of households farm on less than 0.3 ha and 83% on land less than 0.9 ha (NISR 2012b). Mean rural household size is estimated at 4.8 (NISR 2011).

Livelihood strategies

In Rwanda, like the rest of Africa, farmers engage in diverse livelihood activities (Barrett and Reardon 2000). For the families that rely mostly on non-farm activity, agriculture still remains the secondary source of income (Table 4). Livelihood diversification ensures that income sources are diversified from a portfolio of assets (human, natural, physical, social) (Ellis and Freeman 2004). Sale of agricultural produce is the main source of household income, with over 70% of households selling beans, maize, potatoes and bananas (Ansoms and McKay 2010). Livestock are not commonly sold due to their cultural value as a status symbol, and the use of manure as fertilizer (Ansoms and McKay 2010). Small non-farming businesses are emerging as alternative sources of income in rural areas, and include transport of agricultural produce, agricultural wage labor (e.g., harvesting beans, sorghum and sweet potatoes), trade, services, construction, and processing of agricultural products. Remittances are a big source of income for most families. For example, on average, families regularly receive remittances[1] of about USD 200 on a quarterly basis through formal cash transfer (Rubyutsa 2012).

[1] Remittances have fluctuated from USD 166.2 million in 2011 to USD 175.2 million in 2012, to USD 152 million in November 2013.

Table 4. Livelihood activities and sources of income of the rural population

Livelihood activity[2]	Share of population (%)	Percent of revenue by source, for non-poor and poor households	
		Non-poor	Poor
Mostly agriculture	52.2	44.1	56.2
Mostly farm wage	3.6	4.6	14.4
Mostly non-farm wage	10.7	17.7	10.0
Mostly non-farm self-employment	16.2	25.0	11.7
Remittances	2.2	8.6	7.8

Source: NISR 2012b

Report by the NISR (2012b) suggests that rural residents who depend heavily on farm wages (employed to work on other people's farms) to generate their income have the highest levels of poverty[3]. These are followed by families that depend entirely on their farm to generate income and the less poor are those who seek non-farm self-employment and non-farm wage work. Between 2013-14, poverty rates in Rwanda were about 39.1% (UNDP 2015a), compared to 45.5% in Kenya, 24.5% in Uganda, 65.6% in Tanzania and 66.9% in Burundi (UNDP 2015b). Table 5 provides a breakdown of poverty rates by region, as of 2010-2011.

Table 5. Poverty rates by region in Rwanda[4]

Province	Poverty rate
Southern Province	56.5%
Western Province	48.4%
Northern Province	42.8%
Eastern Province	42.6%
Kigali City	16.8%
Urban/rural	
Urban	22.1%
Rural	48.7%

Source: NISR 2012b

[2] Agriculture refers to sales of small livestock and livestock products, sales of large and small crops plus food consumption of own production and income from processed products. Farm wage and non-farm wage includes cash and in kind received from wage activities. Non-farm self-employment includes cash and in-kind revenues for self –employed activities. Remittances include cash transfers and transfers of food and non-food received from within the boundary and foreign.

[3] The poverty line defines a level of household consumption per adult equivalent below which a household is deemed to be poor (NISR, 2012).

[4] This is based on household consumption per adult equivalent member, adjusted for differences in prices faced by households between regions, between months of the year

Due to small landholdings, livestock is reared on zero-grazing systems across all the regions (Table 6). A variety of livestock is reared with cattle being the most important as it is an economic asset, a symbol of social status and an indicator of wealth. Other livestock that are reared in the crop-livestock systems include sheep, goats, rabbits, pigs and chicken. About 47% of households own cattle (53% in western, 58% in Northern, 45% in eastern region). Annual animal production is estimated at 97,981 tonnes of milk, 39,126 tonnes of meat, 2,432 tonnes of eggs, 7,612 tonnes of fish and 1,499 tonnes of hides and skins (AfDB 2010). Low animal nutrition and limited access to water for livestock and quality forage is a challenge.

Table 6. Proportion of households owning livestock

Regions	Percent
All of Rwanda	68.2
Kigali city	34.5
Southern province	73.1
Western province	69.2
Northern province	76.1
Eastern province	70.1

Source: AfDB (2010)

Climate and its Impacts on Agriculture

Rwanda experiences a tropical temperate climate due to its high elevation, with annual temperatures ranging between 16 and 20°C (GoR 2011a). There are differences in annual rainfall and temperature among regions, due in part to differences in elevation (ranging from 900 and 4,500 masl) (Table 7). In some parts of the hilly northern region, temperatures can drop below Zero degrees Celsius especially at night (Twagiramungu 2006) leading to frost conditions that affect crop and livestock productivity.

Table 7: Rainfall ranges for different regions of Rwanda

Region	Average Altitude (masl)	Average annual rainfall (mm)	Changes in number of rainy days/year (+/-) for 30 years
Eastern lowlands	1000–1500	740–1000	-0.5–-2.5
Central plateau	1500–2000	1100–1300	-0.5–-2.5
Northern	2000–4500	1300–1550	+0.5–+2.5
Southern		1000–1250	
Western	1800–900	1200–1550	+0.5–+2.5

Sources: David et al. 2011, Ilunga et al. 2004, REMA 2009

Fluctuating precipitation and increasing temperature

Rainfall has a bimodal distribution. The long rainy season is from March to May and short rainy season is between October to December (World Bank 2016). There are two dry periods, between the months of December and February, and June to August. Annual rainfall varies across the country, with the highest amounts in northern and western region (average of >1200mm) and then diminishing towards eastern region (average of. <1000mm/year). The number of rainy days is declining for eastern and central regions and increasing for northern highlands (Muhire and Ahmed 2015a, GoR 2015). METEO-Rwanda analyses suggest that the rainy seasons are becoming shorter but more intense at the same time.

The smallholder agriculture is mainly rainfed. Land area under irrigation remains under 1% of the total cropland (IPAR 2009). This makes the agricultural sector highly dependent on climatic conditions and farming practices vulnerable to weather related shocks such as frequent, and prolonged dry spells that occur during critical periods in a cropping season. Rwanda is ranked as the 30th most vulnerable country to climate change and variability in the world, with a vulnerability index of 0.595 (ND-Gain 2014). Extreme weather events have resulted in droughts[5] in eastern and southern region and heavy rainfall with floods and landslides in northern and western regions (GoR 2011b). For example, the floods of April-May 2011 in Musanze, Nyabihu and Rubavu districts led to massive landslides (GoR 2011b).

Since 1950, historical observations show a rise in average temperatures of about 0.7-0.9°C per decade (Muhire et al. 2015b). This is a substantive temperature increase compared to the global average of +0.27°C per decade (IPCC 2014). The minimum temperatures have risen at an estimated 2°C in Rwanda over the last 30 years (Safari 2012) with 2005 being the hottest year in that time period (Table 8). Data from 5 stations (Kamembe, Gisenyi, Ruhengeri and Kigali Airport) show that between 1971-2010, mean temperature have significantly increased (from 19.8°C to 20.7°C) by almost half a degree per decade (0.35°C), with highest increase in January-February of 0.47°C per decade (McSweeney 2011). During the same period (1971-2010), relative humidity has reduced by about one and a half per cent per decade (1.58%) as temperature has increased (McSweeney 2011). The frequency of warm days (temperatures

[5] The drought of 2003 was the worst affecting over one million people. In 1999, 890,000 people and 420,000 in 1984. The eastern region is the most vulnerable, thus posing serious risk to its agriculture.

>30°C) have also increased from 5 to 80 days/year over the last 40 years, increasing the risk of new crop and livestock pests and diseases, and temperature-sensitive human diseases such as malaria (Mutabazi 2010). Climate models project continuing warming in response to increasing GHG (GoR 2014, CSC 2013), with the degree of warming dependent on future emissions.

Table 8. Temperature ranges by regions in Rwanda

Region	Average temperature (°C)
Eastern lowlands	25°C (it never falls below 18°C)
Northern	15°C (coldest month vary between -3°C and 18°C)
Southern	25°C (it never falls below 18°C)
Western	15°C (ranges from 13°C to 20°C)

Sources: David et al. 2011, REMA 2009

Climate-related hazards

In 2015, MIDIMAR released comprehensive disaster risk profiles for enhancing disaster management in Rwanda (MIDIMAR 2015). Titled "National Risk Atlas for Rwanda", the report provides an analysis of climate related risks and vulnerability, and potential economic cost that Rwanda could incur due to the risks. The following discussion is based largely on this report.

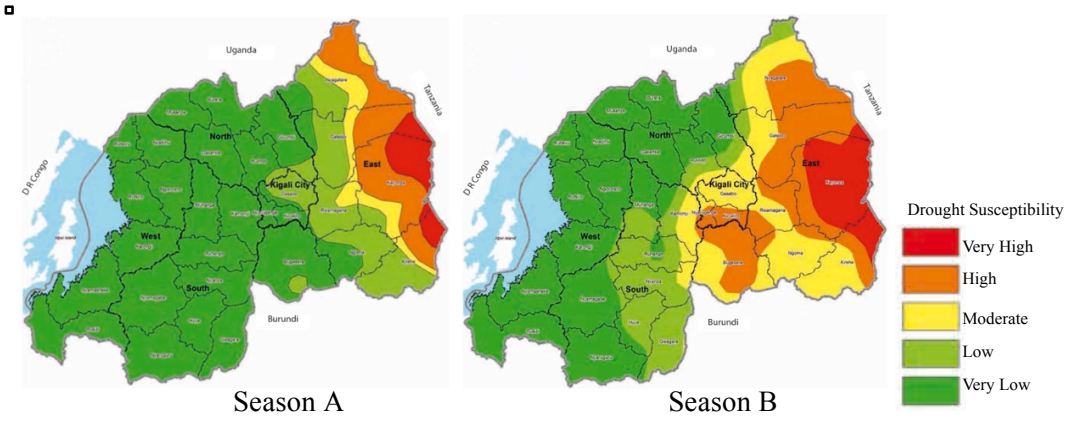
Drought

Rwanda faces agricultural drought, particularly in the eastern and southern districts[6] (MIDIMAR 2015). These districts experience high frequency of rainfall deficit, late rainfall onsets, early rainfall cessations, and a significant number of dry spells. Major droughts have occurred in 1910, 1976-77, 1984, 1989, 1996, 1999-2000, 2003, 2005, 2006 and 2014. These drought events have led to crop failure resulting in food shortages. Despite no death reported (except in 1989 where 237 deaths were reported), the number of people affected by drought has ranged from 60,000 to over a million (MDIMAR 2015). Drought risk also varies between the two rainy seasons (A and B), with land area during season B being more susceptible to drought than season A (Figure 1). During season A, the districts of Kayonza, Kirehe and Gatsibo (comprising of 11,900 hectares) are highly vulnerable to drought, affecting more than

[6] Eastern districts include Bugesera, Nyagatare, Gatsibo, Kayonza, Ngoma and Kirehe; while the southern districts include Gitarama, Butare, Gikongoro, Nyanza and Gisagara.

eight major crops —bananas, common beans, sorghum, maize, Irish potato, cassava, climbing beans and rice (MIDIMAR 2015). Cropland susceptible to drought doubles during season B compared to season A (about 21,400 hectares). This affects the volume of crop production, with banana, cassava and Irish potato being the most affected crops.

Figure 1. Drought risk map for Season A and Season B



Source: adapted from MIDIMAR (2015)

Torrential rains

Many districts in eastern region of Rwanda—Rwamagana, Kayonza, Gatsibo, Ngoma, and Kirehe— receive torrential rains. These torrential rains cause damage to crops (especially bananas, sorghum, maize and coffee) and homes. About 5,909 ha of cropland were affected by torrential rains in 2011, 261 ha in 2012 and 1,460 ha in 2013. The regions most affected were western and northern parts of Rwanda.

Landslides

Rwanda's terrain is very hilly, with steep slopes especially in northern and western regions and thus susceptible to landslides. Historical records indicate that landslides occurred in Rwanda in 1963, 1987, 2006, and 2010-2013 (MIDIMAR 2015). Landslides are caused by torrential rainfall, lack of land cover, soil type and soil stability, soil depth and degree of slope. Landslides can be triggered by high rainfall amounts, or by prolonged low-intensity rain (Bizimana and Sönmez 2015). Forty-two percent of Rwanda is classified as moderately to highly susceptible due to high rainfall and high degree of slope, primarily in the western highlands, while the eastern lowlands are less susceptible (MIDIMAR 2015). The Districts most vulnerable to landslides include Gakenke, Karongi, Muhanga, Ngororero, Nyabihu, Nyamagabe, Nyamasheke, Nyaruguru, Rusizi, Rubavu, and Rutsiro (MIDIMAR 2015,

Douglas et al. 2008). In the northern and western regions, slopes that face northwest and west are most prone to landslides (Bizimana and Sönmez 2015).

Floods

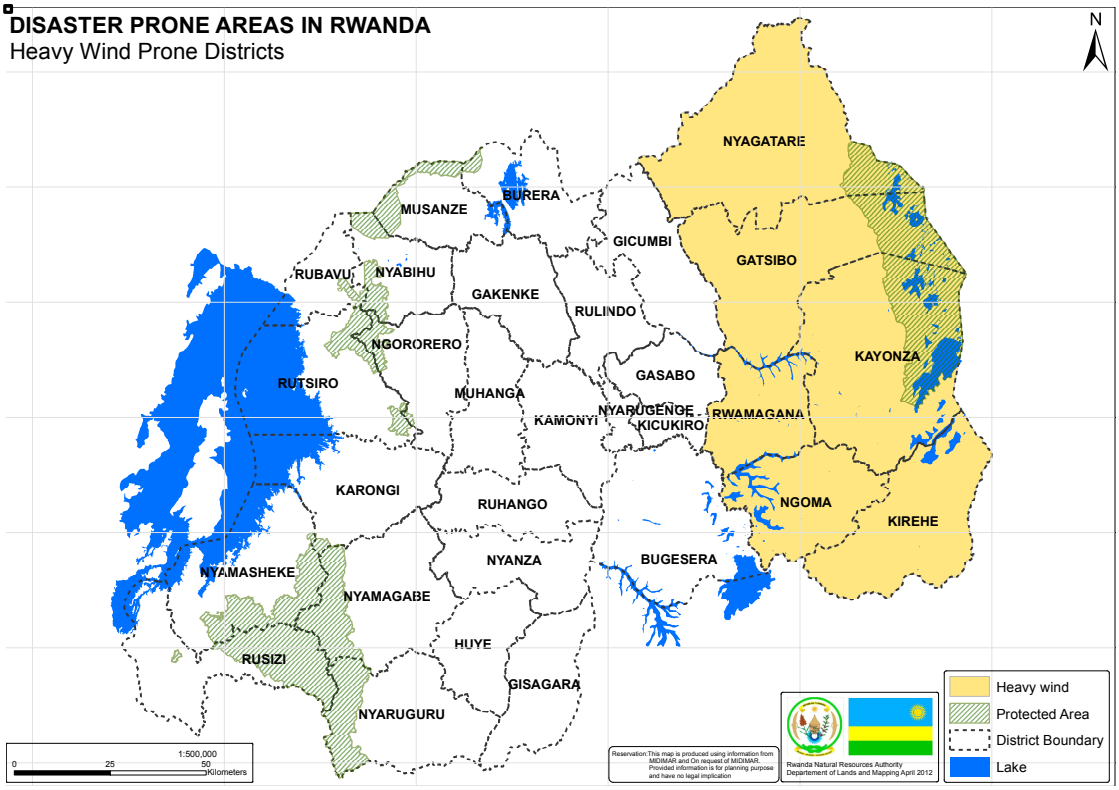
Rwanda experiences river and flash floods. River floods destroy farmland, crops and livestock, houses, roads and other infrastructure, including drowning of people. Flash floods occur in mountainous regions of Rwanda, often leading to massive landslides, soil erosion, destruction of infrastructure and settlements. Major flood incidents were reported in 1997, 2006, 2007, 2008 and 2009 (SEI 2009, REMA 2010) and led to loss and damage of agricultural crops, massive soil erosion, landslide, damage to infrastructure, loss of human life[7] and environmental degradation (MINAGRI 2010). The western and northern regions are most affected. Eastern and southern regions have also experience some floods, but the impact on infrastructure, crops and livestock, and human lives has been minimal compared to the western and northern regions. The floodplains of rivers Nyabarongo, Nyabisindu and Kagitumba experience flooding during most of rainy season A.

Windstorms

Windstorms are associated with torrential rain and mainly affect eastern and southern districts as shown in Figure 2—Rwamagana, Kayonza,Kirehe, Gatsibo, Bugesera, Nyagatare Ngoma and Gisagara. In September 2008, heavy rains and winds adversely affected agricultural production in Rubavu district in northern region (MIDIMAR 2013). Strong winds can damage banana, maize, beans and sorghum (Twagiramungu 2006).

[7] In 2013, 112 people died of landslides, floods and lightning. Floods and landslides triggered by heavy rains further demolished 3,934 houses. These disasters are likely to increase in frequency and intensity when rains become stronger and more erratic (Rwanda Ministry of Disaster Management and Refugee Affairs, 2013)

Figure 2. Windstorm-prone areas in Rwanda



Source: MIDIMAR (2012)

Climate impacts on agriculture and food security

Rwanda's changing and variable climate is causing yearly variability in crop production. Most households reported drought, irregular rains and dry spells as the most common shocks (Mutabazi (2011)). Major climate risks, associated impacts and consequences are presented in Table 9. In 2010, production of coffee and tea declined by 26% and 6%, respectively due to the unusually long dry season (MINAGRI 2011, Byamukama et al. 2011).

Table 9. Impacts of climate change and variability on agriculture and food security in Rwanda

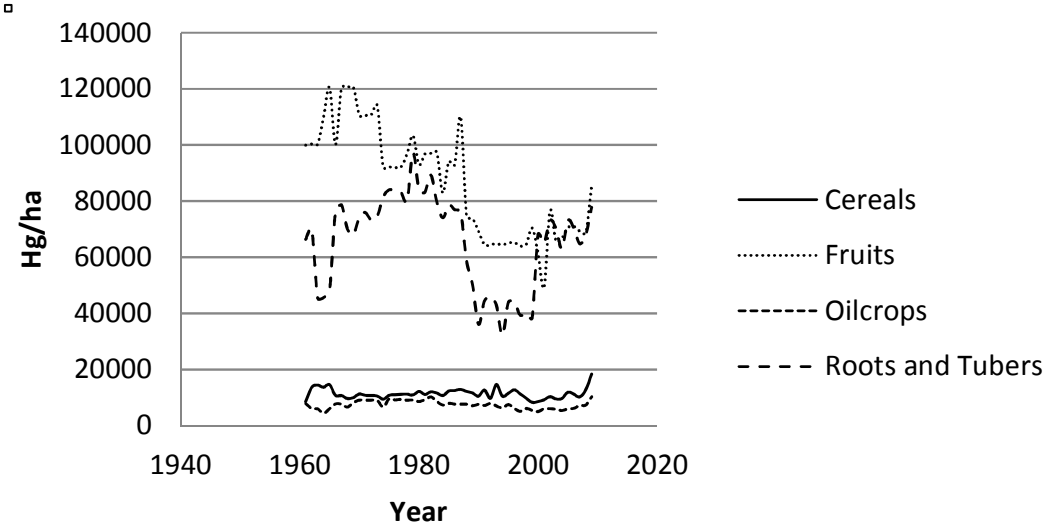
Climate factor	Most vulnerable regions	Impacts on agriculture	Consequences
Frequent and prolonged droughts (especially in eastern region), warmer temperatures and increased incidence of temperature extremes	East (Umutara, Kibungo). South East (Bugesera, Mayaga, Umutara, Kibungo, Gitarama)	Reduced production of maize and beans, livestock losses, and greater conditions conducive to famines. Increased stress on crops, which may in turn decrease yields of crops such as wheat, fruit, and groundnuts. Emergence of pests and diseases Drying out of seedlings when planting new crops or fruit trees. Delay in the flowering of crops e.g., coffee due to lengthened dry season June-August) Less rains especially in March, prolong the ripening process of the coffee cherries	Seasonal shortages of food supply Food insecurity Water shortages for agriculture Loss of income Increased malnutrition and hunger Incidences of diarrhea and infectious diseases. Reduced land available for production Reduced export earnings Crop and livestock pests and diseases proliferation. Displacement of livestock in search of pasture and water Lack of pastures and animal feeds Livestock dehydration causing the fatigue of livestock and the occurrence of respiratory diseases
Changes in rainfall timing and amount	North (Gisenyi, Ruhengeri and Byumba). Centre/West (Gitarama, Kibuye and Gikongoro). High altitude regions of West, South-West, North, Centre and Congo Nile crater foothills (Budaha, Ndiza and Buberuka highlands). High mountainous regions, Congo Nile crater regions, valleys and shallows (peat bogs, altitude meadows) North (Cyeru, Nyamugali).	Increased flooding and landslide frequency (especially in Western and Northern Provinces) that will lead to erosion Disappearance of the short dry season (mid-December - mid-February) with rains continuing until the first ten days of May.	Farmers get confused on planting dates and therefore cultivate late with the risk of an early onset of the dry season, before the harvest. Reduced agricultural production and destruction of crops Population displacement and death Damage to infrastructure Loss of arable land due to erosion and landslides Occurrence of animal respiratory diseases and foot rot due to increased rainfall Decrease in milk production leading to loss of income Increased sedimentation in lakes and rivers

Sources: Harding 2009, MINITERE 2006, Conway 2009, REMA 2015, GoR 2014

The suitability of maize—one of the Rwanda's staple crops—is projected to decrease due to increasing temperature and possible increase in dry spells and temperature changes

(MINIRENA 2011). Yields of cereals and oil crops show an increasing trend, while yields of fruits, root and tuber crops have shown declines and major fluctuations as shown in Figure 3(FAOSTAT 2015). Coffee, a key export crop, will be affected due to its sensitivity to temperature changes (MINIRENA 2011). Risk from invasion by new livestock and crop pests, parasites and diseases are higher with increasing temperatures (MINIRENA 2011). The IPCC WGII Fifth Assessment Report (2014) indicates that with warming temperatures, highland Arabica coffee- producing areas such as Rwanda are at risk to see an increase in the coffee berry borer (*Hypothenemus hampei*). In Rwanda, longer dry season (June-August, extended up to September) is reported to have led to delay in coffee flowering periods. Reduction in rainfall amount in the month of March causes delays in ripening period of coffee from March to April (Ngabitsinze et al. 2011). Low soil moisture adversely affected cassava production in 2009 (REMA 2009), but yields increased thereafter due to Rwanda's crop intensification program[8] that entailed use of clean cassava vines and fertilizers and an active extension system that provides agro advisory services (MINAGRI 2012a).

Figure 3. Crop yields in Rwanda, 1940-2020



Source: FAOSTAT (2012); Chauvin et al. (2012).

The impact of climate change and variability is also being felt along the agricultural value chain. Coffee, tea and fruit processing companies, for example, have experienced delivery shortages when landslides occur that block roads (Ngabitsinze et al. 2011). The disruption of

[8] CIP is a program started by MINAGRI in 2007 and targeted six crops namely maize, wheat, rice, Irish potato, beans and cassava. More information about CIP: http://www.minagri.gov.rw/index.php?id=618

electricity due to landslides and intensive storms can also raise costs of production at factories.

Farmers lack both traditional and scientific knowledge and skills that can enable them cope with climate change and variability. In particular, the unpredictable rainfall pattern is affecting farming decisions, since most farmers do not know the exact date to start land preparation and planting. The uncertainty of onset of rains makes farmers either plant early or late in the season, thus affecting yields. Emerging crop and livestock pests and diseases (occurrence and distribution) are greatly affecting agricultural production. This is leading to enormous yield losses, thus negatively affecting household food security and income. For example, with warmer temperatures, the banana *Xanthomonas* wilt that has led to decreased production in Rubavu district in the west and is now moving towards the Eastern Province. The rising temperature has led to increased damage by the coffee berry borer (*Hypothenemus hampei*) in Rwanda (AGRA 2014). The changing climate is also affecting maize production, with the maize lethal necrosis (MLN) disease, identified in Kenya in 2012 spreading to Rwanda and likely to cause enormous crop loss (AGRA 2014).

Climate risks and gender

At an annual growth of 2.7% (World Bank 2016), Rwanda's population is one of the fastest growing. Therefore, with a high population density, Rwanda's increasing population implies that more people will be exposed to the climate-related risks. A survey by the National Institute of Statistics shows that percentage of women and men are 51.8% and 48.2%, respectively, with a rural sex ratio of about 93 males per 100 females (NISR 2012a). This indicates that they are more women in rural agricultural landscapes than men and hence more women exposed to climate related risks. Furthermore, more women are involved in agriculture and yet lack access to essential resources to enable them cope with extreme weather events such as floods and droughts. Moreover, men can easily migrate to other regions or urban centers, such as Kigali. Women are expected to stay at home due to cultural restrictions and as the main caretakers of the home (GCCASP 2012). Both men and women perceive drought as the number one climate hazard due to its frequency of occurrence and its impact on crops and household welfare (GCCASP 2012). Women and girls are affected more by drought because there is shortage of water for domestic and livestock and it is the responsibility of the women and girls to collect water. Therefore, in most cases, during

drought girls have to drop out of school to help their mothers (GCCASP 2012). Women are also reported to have low level of literacy (NISR 2012b), limiting their opportunities for non-farm employment in urban areas compared to men. In addition, women lack access to quality agricultural inputs such as seeds and fertilizers (Randell and McCloskey 2014).

Current State of Climate Services

Climate services encompass production, translation and provision of climate information to end users to aid them in decision making in various sectors such as agriculture, health and energy (GFCS 2015, WMO 2014). Rwanda's highly climate dependent agricultural sector needs timely climate service and information to help communities and government to cope with the current climate variability and limit the economic and social damage caused by climate-related disasters such as floods and droughts.

Demand for and investment in climate and weather information services in Rwanda are increasing as depicted in the various climate change policy documents and development programs and initiatives (GoR 2007, GoR 2011a, GoR 2011b, GoR 2013, GoR 2014, Stone et al. 2011). Rwanda government and other development agencies are responding with various efforts to support farmers' adaptation to climate change and variability. These organizations range from financial institutions, insurance companies, seed companies and non-governmental organizations. With the increasing devastating impacts on agricultural production, farmers and other stakeholders need climate services that include high quality meteorological data, edaphic conditions, risks and vulnerability assessments, insurance products and agro-advisory information (Hewitt et al. 2012).

Due to the changing and variable climate in Rwanda, and the critical role that agriculture plays in the economy and livelihoods of farmers, access to climate information and services is becoming an essential input for effective climate risk management. Over the years, farmers have relied on indigenous knowledge that is passed on orally through generations to deal with climate change and variability. However, reports indicate that the coping strategies may not be effective due to the increasingly erratic climate variability and the rapid pace of other drivers of change. Therefore, effective climate services are needed to inform farmer decision-

making in the face of increasing uncertainty, improve management of climate-related agricultural risk, and help farmers adapt to change.

Available climate and weather information

Rwanda Meteorological Agency (Meteo-Rwanda) is entrusted with the task of provision and regulation of weather and climate services for various sectors in Rwanda. Meteo-Rwanda prepares forecasts based on observations and products from global centers, including European Centre for Medium-Range Weather Forecasts[9] (ECMWF), United Kingdom Meteorology Office[10] (UKMO), Global forecast System[11] (GFS) and the NOAA National Centers for Environmental Prediction (NCEP) (NOAA). These are available at the Regional Specialized Meteorological Centre in Nairobi, Kenya[12] hosted at the Kenya Meteorology Department.

Historical climate data analysis: variability and trends

Climate variability and trends for Rwanda have been extensively analyzed and used in several country documents such as the National Adaptation Plans of Actions (NAPAs) and Rwanda Vision 2020. An initiative on Enhancing National Climate Services (ENACTS[13]) that works with METEO-Rwanda has been implemented with the aim of improving the availability, access and use of climate information. Climate products developed by ENACTS include historical time series, routine monitoring and forecast and are available online in what is called Maprooms (http://iridl.ldeo.columbia.edu). These products are used for forecasting in agriculture, health and other sectors.

Biannual seasonal climate outlook

Under the frameworks of the World Meteorological Organization (WMO) and IGAD-ICPAC[14] GHACOF offers Rwanda and other Greater Horn of Africa countries (GHA)[15]

[9] http://www.ecmwf.int

[10] http://www.metoffice.gov.uk

[11] http://www.emc.ncep.noaa.gov/index.php?branch=GFS

[12] http://www.meteo.go.ke

[13] ENACTS is also implemented in Zambia, Rwanda, Ghana, Mali and The Gambia, Ethiopia, Madagascar and The Republic of Tanzania

[14] Challenges of EWI include; Coarse spatial resolution forecasts; Perceived low reliability in relation to the needs of individual user (e.g. farmer). Particularly for farmers, this has implications on; When will it rain? Where will it rain? For how long will it rain? How much? When will it not rain? Etc; Bad timing of disseminating

seasonal climate outlook three times a year. Meteo Rwanda and MINAGRI use this information to develop a biannual seasonal forecast issued in March and August prior to rainy season. At the national level, the seasonal outlook is further downscaled and interpreted for different economic sectors by METEO-Rwanda. Farmers use the seasonal outlook with accompanying agro-advisory messages to prepare their land and sow seeds that are recommended on time. The seasonal projections are produced in Nairobi, Kenya and two representatives (MINAGRI and the Rwanda Meteorological Service) go to collect.

Weather forecasts

METEO-Rwanda provides forecasts: daily forecasts, 5-day, 7-day, 10-day, monthly forecasts and decadal forecasts. These forecasts are available for different sectors including infrastructure, agriculture, water resource, aviation, health, energy, tourism, disaster management. Since agriculture is Rwanda's most important economic sector, prediction of future weather events or climatic conditions and their associated probabilities are extremely important for daily farming decisions (planting, spraying or fertilizing) and long-term planning decisions on the farm and in agribusiness (for private sector). The seasonal weather forecast (for each of the rainy season, long and short) provides rainfall information (whether it will be below normal, normal, above normal for each region), predicted onset, cessation and distribution of rainfall, potential impacts on agriculture and other sectors and an assessment of rainfall performance in the last season. Seasonal forecast is disseminated to RAB extension. Weather and climate data analysis are accessible at Meteo-Rwanda that provides data on Rainfall (1981-2014) and maximum and minimum temperature (1961-2014)[16].

Agro-advisories

In conjunction with the seasonal outlook, agro-advisory information is provided to farmers by extension officers and scientists. Agro-weather advisories include timing of land preparation, planting window, crop varieties, timing, type and rate of input application, herd management and feeding regimes, market information, insurance and financial arrangements. Agro-

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forecasts; Failure of dissemination channels to reach farmers, Forecasts not well interpreted to forms readily understood by users; Climate change messing up predictability;

[15] Djibouti, Burundi, Eritrea, Kenya, Ethiopia, Uganda, Sudan, Tanzania, Rwanda, Somalia, South Sudan

[16] http://maproom.meteorwanda.gov.rw/maproom/Climatology/Climate_Analysis/monthly.html.

advisory information is disseminated orally, printed and in video formats as well as practical learning techniques such as farmer field schools.

Early warning information

Meteo Rwanda in partnership with the Ministry of Disaster Management and Refugees Affairs (MIDIMAR), the Rwanda Environmental Authority (REMA) and the district administration has developed early warning information that issues rainfall planning forecasts on a regular basis to disaster managers and severe rainfall weather warnings to the general public to ensure they are better prepared. Early warning information is provided for onset and cessation of rainy seasons, and the amount of rainfall to expect with associated occurrence of severe impacts e.g. dry spells/drought, floods, severe thunderstorms, landslides, outbreaks of major crop pests and diseases including incidences and severity; and surface temperature (normal, too hot or too cold). Provision of early warning information is one of the priority actions outlined in Rwanda's NAPA (GoR 2006).

Agricultural production and food security forecasting

Historical and seasonal climate forecasts can be used to develop in-season crop yield forecasts. This product is important mostly to policy makers who can (a) monitor food availability, food demand and market access when assessing food shortage and planning for food redistribution; and (b) link weather condition as constraints to land productivity and food availability with meaningful early warnings to lower crop production risks and ensure public awareness and preparedness to act (Habyarimana 2014). The National University of Rwanda conducts agricultural monitoring through the following activities: crop monitoring, crop production quantification, yields forecasting, agricultural pest prediction and monitoring (Mutabazi, 2010). EARS also developed the Food Assessment by Satellite Technology (FAST) for crop yield forecasting at district and national level. FAO provides seasonal information on the food security situation for Rwanda for both seasons. In 2015, for example, FAO predicted that cereal production would be about 859,000 tonnes, 10% percent higher than the reduced output obtained in 2014 and equal to the last five-year average (FAO 2015). The forecast also reported that there will be minimal levels of food insecurity, except in some parts of southern and eastern Rwanda. World Food Program, through its Food Security Analysis Service, also provides a comprehensive Food Security and Vulnerability Assessment of Rwanda.

National Risk Atlas

MIDIMAR-Rwanda also produces national risk atlas that provides hazard assessment for drought, landslides, flood and windstorm. MINAGRI uses this information to inform food security policy and decision-making. In particular, MINAGRI uses the drought hazard map to design adaptation measures for drought-prone areas. These include irrigation infrastructure, agricultural insurance instruments, exposure profiling for crops to enable planning of what types of crops and timing for planting and harvesting and, emergency responses e.g. prepositioning of food stocks (MIDIMAR 2015). In addition, MIDIMAR produces the National Risk Atlas that show vulnerability risk assessment to climate hazards (drought, landslides and windstorm). The vulnerability assessment is further disaggregated by gender and age group.

Institutions involved in climate services

Rwanda Meteorological Agency

Rwanda Meteorological Agency (Meteo Rwanda), under the Ministry of Natural Resources MINIRENA, is mandated to provide weather and climate information and products for different sectors including agriculture. Meteo Rwanda's services are discussed in the preceding section.

Rwanda Agriculture Board

Rwanda Agriculture Board (RAB) is a technical agency within Ministry of Agriculture and Animal Resources (MINAGRI). Its mission is to develop agriculture and animal husbandry through use of modern methods in crop and animal production, research, agricultural extension, education and training of farmers in new technologies. It accomplishes this through research policy-related work, and through providing agricultural extension services to farmers.

Agricultural Information and Communication Centre

The Agricultural Information and Communication center (CICA, http://www.minagri.gov.rw/index.php?id=574) within MINAGRI, is an agricultural management information system that collects and disseminates information and knowledge. CICA produces different agricultural extension material targeting different users. These materials include booklets, brochures, leaflets, posters, training manuals, booklets and

billboards as well as weekly broadcasts from local radios, documentaries radio series and press and radio conferences, TV broadcast, and DVD distribution. These materials are available in Kinyarwanda, English and French, and are distributed at village level to enable farmers access information on various agricultural practices such as crop and animal production, pest and disease management and soil management.

IGAD Climate Prediction and Applications Centre

IGAD Climate Prediction and Applications Centre (ICPAC) provides climate information, prediction and timely early warning for applications in economic sectors for several African countries, including Rwanda. ICPAC has several objectives and projects but the most important is the Greater Horn of Africa Climate Outlook Forum (GHACOF 42) that provides regional seasonal climate outlooks for applications in climate sensitive socioeconomic sectors for decision support for resilience building and sustainable development. ICPAC also provides weather outlooks for a dekad (10-day), month and season in form of bulletins and a pre-season climate outlook forum for eastern Africa countries and other stakeholders.

Weather Index Insurance Providers

Agriculture and Climate Risk Enterprise (ACRE, formerly Kilimo Salama) provides insurance against drought, excess rain, and diseases and livestock insurance. Several products are generated including weather index, area yield index, and satellite-based index insurance. Crops targeted are maize, beans, wheat, sorghum, coffee, and potatoes.

Working in partnerships with International Finance Corporation's Global Index Insurance Facility program, MicroEnsure (a subsidiary of Opportunity International) provides affordable, flexible and responsive weather index insurance to farmers. MicroEnsure is involved in designing new and affordable index based insurance products, developing an effective distribution network to reach more farmers across Rwanda and scaling up agricultural index insurance into a commercially viable and sustainable product.

Remote sensing company EARS Earth Environment Monitoring[17] also developed and initiated a drought and excessive rainfall insurance system for maize and rice in Rwanda.

[17] EARS Earth Environment Monitoring Ltd, is a remote sensing and climate services provider based in Delft, the Netherlands.

Under its FESA Micro-Insurance and using the broker MicroEnsure[18], 1725 maize farmers in 6 communities and 4483 rice farmers in 11 communities received drought insurance in 2012. MicroEnsure works in partnership with Meteo Rwanda.

Weather and climate-related information projects

Strengthening Meteo Rwanda's Weather and Climate Services

Strengthening Meteo Rwanda's Weather and Climate Services project[19] aims to achieve a transformational change in the delivery, understanding and use of weather and climate information in decision-making across scales. The project runs from July 2014-June 2018 with the objectives to: (a) enhance engagement between Meteo Rwanda and key stakeholders; (b) build capacity of Meteo Rwanda staff on climate information (c) improve access to weather and climate information to farmers; and (d) enhance awareness and integration of weather and climate issues into national plans, policies and budgets.

Climate Resilient Post-Harvest and Agribusiness Support project

The Climate Resilient Post-Harvest and Agribusiness Support Project (PASP)[20] aims to alleviate poverty, increase rural income and contribute to the overall economic development of Rwanda, through pro-poor and climate-resilient post-harvest interventions for crop and dairy businesses in the context of the country's Crop Intensification Program (CIP). The project has employed an agrometeorologist to work with Meteo Rwanda to produce and disseminate meteorological bulletins to project staff, MINAGRI staff, district and sector agronomists and environmentalists, and cooperative committees. It coordinates the integration and maintenance of the weather stations developed by the REMA – Early Warning project; and has collaborated with the FONERWA project on climate information needs assessment of PASP stakeholders so that specific climate information products are developed that meet the needs of the different end-users. It also channels climate finance to smallholder farmers so they can access the information tools and technologies that help build their resilience to

[18] MicroEnsure, in partnership with the Rwanda national Meteorological Service has installed several automatic weather stations.

[19] http://www.fonerwa.org/sites/default/files/Meteo%20Rwanda-PD.pdf

[20] http://operations.ifad.org/web/ifad/operations/country/project/tags/rwanda/1497/project_overview)

climate change. The five year project (2014-2018) is implemented by MINAGRI, and supported by IFAD's Adaptation for Smallholder Agriculture programme (IFAD 2015).

Increasing Climate-resilience in Rwanda through EWS, Disaster Preparedness and Integrated Watershed Management

The Increasing Climate-resilience in Rwanda through EWS, Disaster Preparedness and Integrated Watershed Management project aims to strengthen national and district capacities to deliver a functional early warning and disaster preparedness system that would allow for early warning of vulnerable populations in four districts covering Gishwati forest area in western Rwanda (see http://www.adaptation-undp.org/projects/ldcf-reducing-vulnerability-rwanda). The component of the project that is related to climate services involves strengthening national and district capacities to deliver a functional early warning and disaster preparedness system that would allow for early warning of vulnerable populations in the Gishwati ecosystem particularly, but not only, in terms of flooding, and also to deliver support to develop agricultural planning at the household level. The project was implemented from July 2010 to June 2014, by REMA, UNSP and UNEP; and supported by the Least Developed Country Fund (LDCF).

Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL)

The HyCRISTAL project aims to increase the resilience of communities in East Africa through developing climate science and helping water users assess their vulnerabilities; through the development and application of new tools for water resource management in a changing climate (see http://www.futureclimateafrica.org/project/hycristal). The project included a pilot study focused on mainstreaming near-term (10 years+) climate change information into Rwanda's coffee and tea sector development plans[21]. HyCRISTAL is supported by the Future Climate for Africa (FCFA) program.

Enhancing National Climate Services (ENACTS)

Enhancing National Climate Services (ENACTS) is a multi-stakeholder initiative led by the International Research Institute for Climate and Society (IRI), that aims to build the capacity of African meteorological services to reconstruct complete, high quality historical data at high

[21] http://www.futureclimateafrica.org/wp-content/uploads/2015/02/Rwanda-technical-report.pdf

spatial resolution, and provide a range of derived products available through online "maprooms" (see http://iri.columbia.edu/resources/enacts). Meteo Rwanda implemented the basic version of ENACTS through a 2013-2015 project funded by the UNECA's African Climate Policy Center (ACPC). The high-resolution gridded time series data and online maprooms (http://maproom.meteorwanda.gov.rw/maproom/) provide a promising foundation for developing additional climate information products for Rwanda's agriculture sector.

Rwanda Early Warning Service Case Study

The UK Met Office partnered with Meteo Rwanda, MIDIMAR, REMA and district administration to support the development of a pilot Early Warning System (EWS) that would provide better weather information services to disaster managers and the public in areas prone to extreme impacts of weather and climate. Project activities included development of a scoping report; and training of Meteo Rwanda forecasters on numerical weather prediction, seasonal forecasting, climate change modeling, and the delivery of severe weather products[22]. The project ended and was implemented by REMA and the UK Met Office.

Communication Channels for Climate Services

Rwanda farmers operate in a complex agricultural landscape where several factors including climate, culture, farming practices, natural resources and information intersect. How climate-related information is delivered to the farmers and other users is important. The complexities of the agricultural sector and diversity of needs and communication channels has implications for coordination, training on how to package the information, and timeliness of information delivery. Above all, the climate information must reach the end user (e.g. farmers) in good time, and in appropriate forms for the user to understand the information and use it appropriately for decision-making on-farm. For each end user, the channel of communication must be accessible and have user-friendly attributes such as timeliness, accuracy, reliability, ease of use, depth of content, and language.

[22] http://rema.gov.rw/climateportal/IMG/pdf/-31.pdf

MINAGRI is the main custodian of agricultural information (Table 10). MINAGRI employs a range of mechanisms to communicate this information. Communication with farmers is primarily through the *Twigire Muhinzi* national agricultural extension system.

Table 10. Information, education and communication materials, and their location and uses

Materials	Location	Uses
Intellectual agricultural resources	MINAGRI-HQ, CICA, RAB, NAEB, Task forces	Develops and store Scientific knowledge
Website (AMIS Rwanda)	MINAGRI/CICA	Agricultural information
SMS and web system (e-Soko)	MINAGRI/CICA	Agricultural products price information sharing
Library (databases and documents)	MINAGRI/CICA	Documentation and sharing agricultural information
Audio-visual (documentaries, interview and advertisements through TV, radios)	MINAGRI/CICA	Agricultural information
E- newsletter (weekly flash news)	MINAGRI/CICA	Weekly activities in agricultural sector
Agricultural shows (exhibitions)	MINAGRI/RAB	Sharing agricultural innovation & best practices
GIS and mapping (electronic, software and documents for maps and reports)	MINAGRI/CICA	Sharing spatial information on agriculture
Booklets and documents (Hinga Worora magazine, printing materials)	MINAGRI/CICA	Sharing and disseminating information in agriculture
Voucher system (Database)	MINAGRI/Post harvest Unit	Information on agricultural inputs

Twigire Muhinzi national agricultural extension system

Rwanda has the second largest extension system in east Africa with 1,244 extension agents (Swanson and Davies 2014). The national extension is under two ministries: MINAGRI, which sets policies and guidelines and MINALOC (Ministry of Local Government), which implements the policies.

The *Twigire Muhinzi* national extension system, implemented by RAB (through MINAGRI and MINALOC) provides decentralized, face-to-face extension services through Farmer Field Schools (FFS) and Farmer Promoters (FP). The system involves a range of stakeholders, including farmer organizations, agro-dealers, and NGOs (including CARITAs, World Vision, Catholic Relief Services), who ensure that smallholder farmers have access to agricultural technologies and knowledge. *Twigire Muhinzi* encourages farmer groups and agricultural committees to empower farmers and ensure that services are demand driven. Farmers

involved in the FFS and FP also get access to delivery services through a helpdesk with a toll free number.

The RAB extension agents integrate both individual and group approach at the village level. The extension system is structured from the village level (Cell) where the FP and FFS facilitators operate. These are assisted by Socio Economic Development Officers (SEDOs). The sector level is next and its headed by a Sector agronomist and the officer in charge of livestock. District level is next where the District agronomist and the officer in charge of livestock operate. At the province are the RAB directors. Women and the youth are represented at various levels of the *Twigire Muhinzi* structure. This is at the Agricultural Extension Committee, Sector Agricultural Platform and District Agricultural Platform. Farmers are trained as frontline extension agents (FEA). By 2015, there were 14,837 Farmer Promoters and 3,800 FFS Facilitators (Munyaneza et al. 2014). The FEA disseminate crop and livestock materials and knowledge through several methods as summarized below.

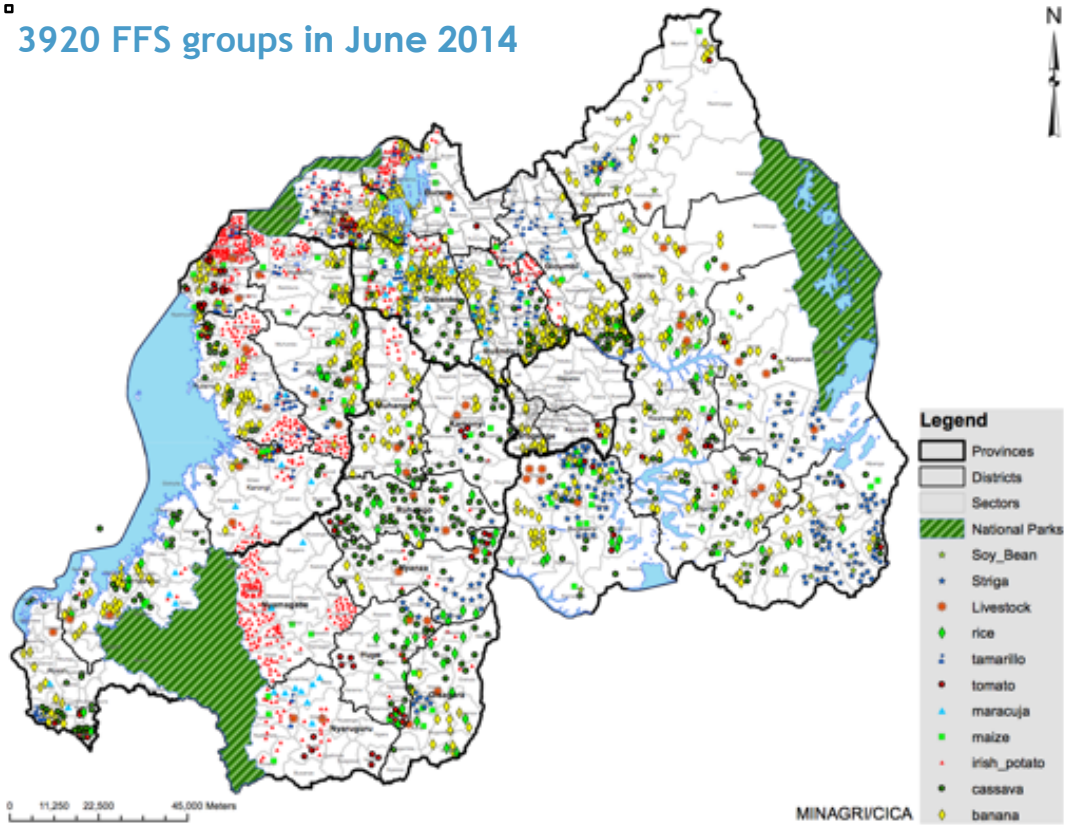
Farmer Fields Schools (FFS)

RAB[23] uses FFS to engage farmers in experimentation with different farming practices and provide advisory services for crop and livestock under a community facilitator. By 2009, 80,000 farmers in 30 districts participated in a FFS where they experimented at least 12 different crops (Figure 4). Farmer Field Schools are networked with input dealers for quality seeds, fertilizers and agro-chemicals, markets, finances institutions and have access to seasonal weather information and other climate products from METEO-Rwanda.

The success of FFS created community mobilization campaigns that scaled up successful farming practices from the field schools to wider community. These are spinoffs from the farmer field schools that target a specific problem e.g., eradication of striga weed from farms. Several stakeholders are mobilized for the campaigns including the farmers, facilitators, Governors, Mayors and local leaders.

[23] RAB partners with Belgian Development Agency to promote FFS

Figure 4. Distribution of FFS for specific crops



Source: Farmer Field School Handbook (2014)

Farmer Promoters

This is an initiative of RAB in partnership with One Acre Fund, whereby one farmer is trained in each village as an agricultural expert. The farmer promoter is expected be a conduit of agricultural information to other farmers. Currently there are 14,000 farmer promoters spread out across the country[24]

Public meetings, field days, and field exchange visits

These are used by RAB extension agents who through local leaders arrange meetings. The local leaders include village elders, religious leaders and leaders of farmer groups and community organizations. Field days, organized by FFS Facilitators, Farmer Promoters or Extension Agents, are effective for the rapid spread of new agricultural technologies and weather information. Farmers are involved in field exchange visits usually organized by MINAGRI/RAB. The farmers visit district extension officials, FFS, and model women

[24] https://www.oneacrefund.org/blogs/tag/partnership/139

farmers to learn and exchange information. ICT4Ag also organizes field trips for farmers to learn about ICTs use in agriculture.

Agricultural Market Pricing Information System (AMIS)

MINAGRI is providing farmers and other stakeholders with access to digital agricultural markets. Implemented by Rwanda Information Technology Authority (RITA), E-soko provides farmers, produce traders and input dealers with market price information (see http://www.esoko.gov.rw/esoko/). E-Soko helps farmers to market their agricultural produce and get premium prices via short message service (SMS). Development of this system costed less than $200,000 (RDB 2012). Currently about 7,100 farmers, traders and consumers are using the e-soko systems (RDB 2012). Prices of more than 60 agricultural commodities from 41 markets across the country are included in the SMS database and farmers get information through the local language – Kinyarwanda. The SEDOs are equipped with smart phones to collect and enter the pricing information in the databases into any of the 30 TeleCentres or Business Development Centres (BDCs) set up in each district. Farmers send an SMS to the short code – 7656 and they get commodity prices.

Media

In addition to the face-to-face communication channels that *Twigire Muhinzi* supports, the various media channels provide additional options for providing climate-related information to farmers. Outside of Kigali, the capital city, radio and mobile phone have the greatest reach (Table 11).

Table 11. Proportion of households owning different communication tools by region

Region	Percent of households owning at least one			
	Radio	Television	Mobile phone	Computer
Southern	57.9	4.9	54.0	1.3
Western	52.0	5.9	58.2	1.1
Northern	61.9	4.1	60.8	1.2
Eastern	63.9	6.1	67.0	1.0
Kigali City	66.9	44.1	90.0	12.8
Urban/Rural				
Urban	67.5	41.4	87.9	12.2
Rural	58.2	3.4	58.6	0.5
National	59.8	9.9	63.6	2.5

Source: NISR 2015a

Radio

Radio is the most popular channel for accessing information for most rural people of East Africa, including Rwanda, Kenya, Tanzania, Uganda, Burundi and Ethiopia. An impact assessment by African Farm Radio Research Initiative that worked with 25 radio stations in five countries—Tanzania, Malawi, Uganda, Mali and Ghana—reported that over 20 million farmers learned about agricultural technologies, with 10 million of them adopting some of the practices (Farm Radio International 2011). In the same report, farmers reported that information shared through radio was still not useful enough and did not meet their needs. About 60% of households in Rwanda own a radio (Table 11) (NISR 2015b). Rural households own more radios (61%) compared to urban dwellers (58%). Rwanda has a dense network of radio stations that air weather forecast provided by RMA. Other radio stations source from internet. A project by Radio and Internet[25] (RANET) has been successful in disseminating climate and weather information to rural areas via the RANET radio network. Another initiative by the African Farm Radio Research Initiative and Farm Radio International is geared towards development and production of education dramas for agricultural information. The radio drama use storytelling techniques to convey agricultural messages. MINAGRI also uses radio spots and discussion, weekly broadcasts through local radios, documentary radio series and press and radio conferences to disseminate weather and agro-advisory information.

Mobile Phones

Mobile phones are used for phone calls, short messaging services (SMS) and mobile money and insurance premium transfers and various advisory applications (apps). About 63% of households own a phone in Rwanda (NISR 2015b). Farmers are using mobile phones to call Hotline numbers at call centers for agricultural information. Through the eSoko system, for example, farmers without mobile phones can use the village phones to access information especially for market prices. ACRE is using mobile phones to offer insurance of which they use for transactions (paying premiums and payouts). This eliminates paper work and reduces time.

[25] Partners involved in this project include: Australian Government, the Australian Bureau of Meteorology and the African Center of Meteorological Applications for Development (ACMAD). Support has been provided by the USAID Office of Foreign Disaster Assistance, the NOAA Office of Global Programs, and FVI.

An app (The WeatherSafe Coffee Farmer Edition app[26]) specifically for coffee farmers (and other stakeholders including processors, exporters and MINAGRI and RAB staff) is being developed by WeatherSafe to provide highly local weather forecasts and recommendations, coffee pests and diseases risk, outbreaks and contamination (WeatherSafe 2016).

Television

Only 9.9% of Rwandese own a television (NISR 2015b). However, this is skewed towards urban dwellers who own more TVs than rural people. This is due to limited electricity connectivity (14% of the Rwandan population have access to electricity and mainly in Kigali) and low income levels in rural areas (NISR 2015b). Meteo Rwanda has a TV weather studio where weather bulletins are recorded and sent via FTP to TV stations for airing.

Internet

Most farmers cannot access internet and yet many organization continue to publish information on their websites. Probably to reach out to the youth who are emerging as internet users. Despite this, MINAGRI produces news articles on its website and the weekly flash news. The website is in both English and Kinyarwanda languages. Another website dedicated to farmers is the Noza Ubuhinzi n'Ubworozi (see http://nozubu.minagri.gov.rw).

Rwanda Telecentres

Telecenters are located in all the 30 districts. In addition to collecting and disseminating market prices, the centers also offer various services including farmer training on new crop production methods and high-yielding varieties. World Vision has established a Community Knowledge Centre in the southern region where community members including students and teachers can access internet and information.

Magazines

MINAGRI publishes magazines that are distributed to farmers. For example, the *Hinga Worora* magazine (http://www.minagri.gov.rw/index.php?id=715), written in Kinyarwanda, distributes 5,000 copies countrywide.

[26] This app will be available on Apple iOS, Android and BlackBerry device

Conclusions

Rwanda's variable and changing climate is an increasingly serious challenge to the country's agricultural sector and farming population. Climate information services are emerging as a means to support farmers to manage risk and an opportunity to build the resilience of agriculture to climate at all time scales. The new Rwanda Climate Services for Agriculture project, funded by USAID, aims to benefit nearly one million farmers by 2019, and transform Rwanda's rural farming communities and national economy through climate services and improved climate risk management.

The development of climate services can take advantage of Rwanda's innovative *Twigire Muhinzi* national extension system, in combination with communication through media channels such as radio and mobile phones. Several recent and current projects have objectives that are closely related to the Rwanda Climate Services for Agriculture project. Effective coordination with these complementary initiatives provides opportunity to leverage synergies and avoid duplication.

This review suggested several opportunities to strengthen climate services that meet the needs of Rwanda's agricultural sector and farming population. First, because Rwanda's population is relatively young, packaging and communicating climate information products and services could be tailored to the interests of the youth, for example capitalizing on the popularity of social media (e.g., Facebook, Twitter). Second, tapping into the *Twigire Muhinzi* national extension system can take advantage of its extensive reach, and may increase the likelihood that farmers will adopt climate-related information and advisories. Third, participatory, face-to-face communication of climate services can be scaled up through training Farmer Field School Facilitators and Farmer Promoters. Fourth, Rwanda's government policies are far ahead of most African countries on gender inclusiveness. If climate services are developed to address the needs of women, it can leverage the favorable policy environment and contribute towards gender inclusiveness. Fifth, the project is in a position to address a gap in information about who uses climate information, how they use it, and the benefits of climate services for farmers and for the nation's agricultural economy. Finally, there is a great need and opportunity to tailor climate-related information, advisories and tools to the specific needs of different users and different farming and livestock systems.

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