

DFID Economic impacts of climate change: Kenya, Rwanda, Burundi	ICPAC, Kenya and SEI Oxford Office
Climate report Rwanda	October 2009

1 Rwanda

Rwanda is a landlocked country which lies within latitudes 1° -3° S and longitudes 28°-31°E and bordered by Uganda in the north and Tanzania in east while in the south and west are Burundi and the Democratic Republic of Congo, respectively. The country is characterized by complex topography that includes mountains, valleys and hills. Agriculture is the mainstay of the economy, contributing up to 80% of Gross Domestic Product (GDP). The majority of the population practice subsistence farming but some areas are under extensive farming.

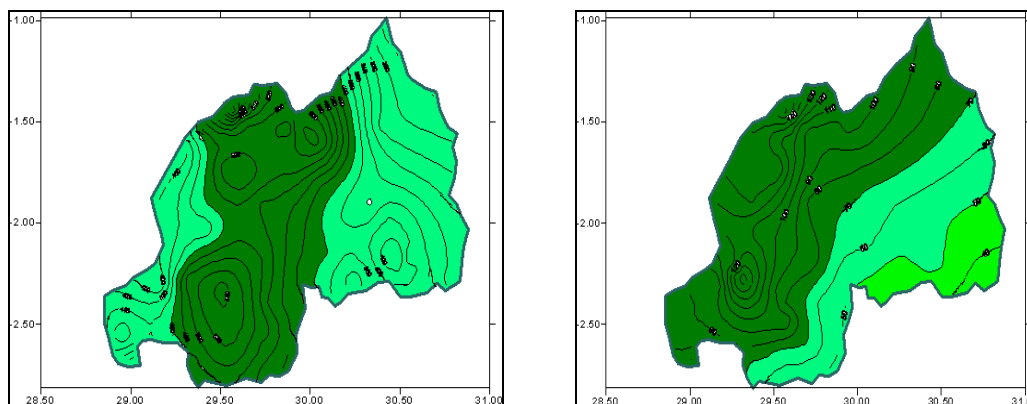
Although the country is located within the equatorial belt, its climate is strictly not of the equatorial rain forest type. It has a modified humid climate including rain forest and Savannah. The central and eastern part of the country is generally of semi-arid type owing to its position in the rainy shadow of the western highlands.

The climate is dominated by the ITCZ which passes over the country twice a year and determines two rainy periods: from mid-September to mid-December and from March to May. The ITCZ is in its turn controlled by the position and intensity of subtropical anticyclones. The equatorial climate is further modified by a widely varying altitude across the country (900 m in south-west, 1500 to 2000 m in the south and the centre of the country, 1800 to 3000 m in the highlands of the north and the west and 3000 to 4507 m in the regions of Congo-Nile Crest and the chain of volcanoes) and by the presence of large water bodies near the country.

The impact of floods and droughts associated with El Nino and La Nina events of recent years are thought to have been exacerbated by climate change and the poor environmental conditions suffered in the country identified in the NAPA (NAPA, 2005).

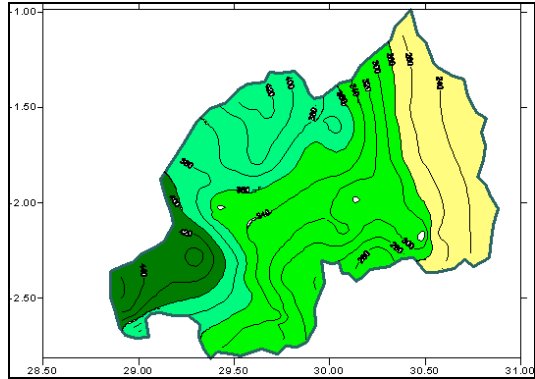
1.1 Spatial distribution of rainfall over Rwanda

Figure 1 shows the spatial distribution of the seasonal and annual rainfall in Rwanda. In general the rainfall increases from east to west of the country.

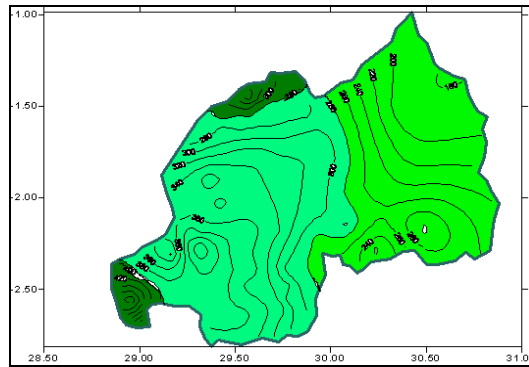


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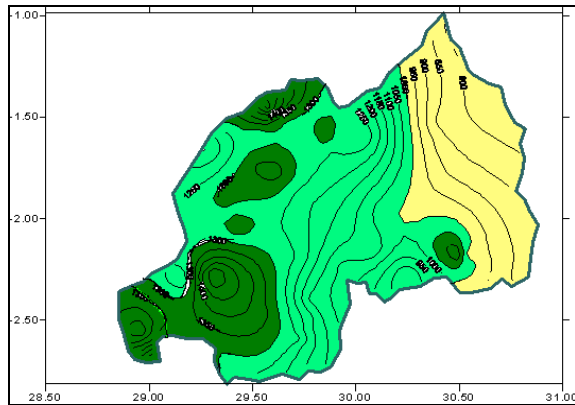
(a) March-May Seasonal rainfall



(b) Jun - Aug seasonal rainfall



(c) September-December season rainfall over Rwanda (d) December-February season rainfall over Rwanda



(e) Spatial distribution of annual rainfall over Rwanda

Figure 1 Spatial distribution of Seasonal rainfall over Rwanda

The discussions for the figures above are as follows:

For March – May, (Figure 1a) the rainfall amount ranges from 300mm to 600mm. The minimum is in the northeast (Gabirol, Kagitumba), while the maximum is located in the northwestern highland (Kinigi). There is the relative minimum of 360mm over Bugesera area (Karama). The relative maximum was also observed at Kibungo (Gahororo, 420mm), Nyungwe natural forest region (Wisumo, 540mm), Gishwati natural forest region (Muramba, 500mm), and Byumba province (Byumba, 520mm). The wide area of much rainfall (over the middle isohyets of 440mm) is extended from southwest sector (Mibirizi, Wisumo, Kibeho) all along Congo Nil Crest to northern highland (Rwankeri, Kinigi, Ruhengeri, Byumba), excluding the Lake Kivu coast.

Figure 1b, June – August: The rainfall distribution indicates a drastic decrease in rainfall amounts. The recorded rainfall indicates the minimum of 40mm over southeast (Rusumo) and the

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maxima of 160mm over Nyungwe natural forest (Wisumo) and over northwestern highland (Kinigi). The wide dry area (40-100mm) is located in the most of county including the eastern, central, southern and southwestern part.

Figure 1c, September – November: The rainfall amount range from 240mm - 440mm. This shows a slight decrease in rainfall compared to March – May rainfall. The minimum is located in the east (Umutara, National park and eastern Kibungo), while the maximum is in the southwest (Mibirizi). The relative minimum arise over Bugesera area (Karama, 260 mm) and the relative maximum was observed over northwestern highland (Kinigi, 420mm) and Byumba province (Byumba, 400mm). The wide area of much rainfall amount (over the middle isohyets of 360mm) was observed in the west and the north (Mibirizi, Wisumo, Mubuga, Kinigi, Byumba) with the hollow in the Col de Rugabano (Kaduha, Kirinda).

Figure 1d December-February: The figure recorded indicated that the rainfall was above 200mm over northeast (Gabirol, Kagitumba) but less than 480mm over southwest (Mibirizi). The relative minimum of 200mm was observe over Bugesera area (Karama) while the relative maxima was recorded at Kibungo (gahororo, 280mm), Nyungwe natural forest (Wisumo, 420mm) and at northwestern highland (Kinigi, 320mm). The wide area of much rainfall (over the middle isohyets of 300mm) is located in the most of western half of the country extending from Mibirizi to Kansi, from Mubuga to Byimana and from Murunda to Rulindo.

The annual rainfall distribution (Figure 1e) is very similar to the March-May distribution. The rainfall amount varies from 800mm over northeast (eastern Umutara) to 1500mm over Nyungwe natural forest (Wisumo) and northwestern highland (kinigi). The relative minima was observed over Bugesera area (Karama, 900mm) and over western Gisenyi province (Gisenyi, 1200mm). Three relative maxima was observed over Kibungo (Gahororo, 1100 mm), southwest (Mibirizi, 1450mm), Gishwati natural forest (Muramba, 1350mm). The wide area of much rainfall amount (over the middle isohyets of 1200mm) is located in the western half of the country extending from Byumba to Kibeho and from Kinigi to Mibirizi including the lake Kivu coast.

1.2 Climate trends

Figure 2 below gives the standardized rainfall anomalies over Kigali. The analysis of rainfall reported in the NAPA shows that the period between 1991 and 2000 has been the driest since 1961. In fact, Kigali station was marked by rainfall deficit during the years of 1992, 1993, 1996, 1999 and 2000 out of which two were very remarkable (1992 and 2000).

There were two years with notable excesses of rainfall (1998, 2001). Similar excess was observed in 1979.

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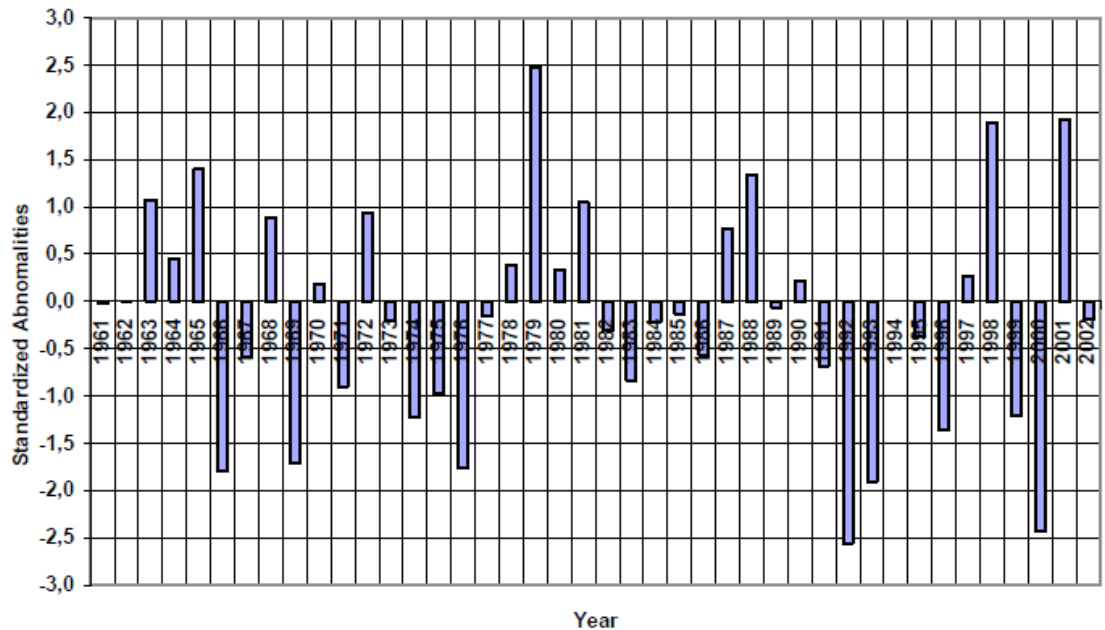


Figure 2 Standardised rainfall anomalies in Kigali, Rwanda

In the NAPA they noted the influence of El Nino/Southern Oscillation (ENSO) on seasonal rainfalls (IGAD, 2002) concluding that:

- El Nino years were characterized by a rainfall which tends to be excessive. However, some years of El Nino registered rainfall deficits. These years are also associated with a late start of rainy seasons and some years are characterized by increased frequency of dry spells
- During rainy seasons, the years, immediately following the El Nino phenomenon, registered lower rainfalls and were marked by a significant increase in frequency of short dry periods.

The analysis of number of days of rainy seasons (Figure 3) shows a progressive tendency of short rainy seasons from 1989 to 1994 but there was a recovery in more recent years.

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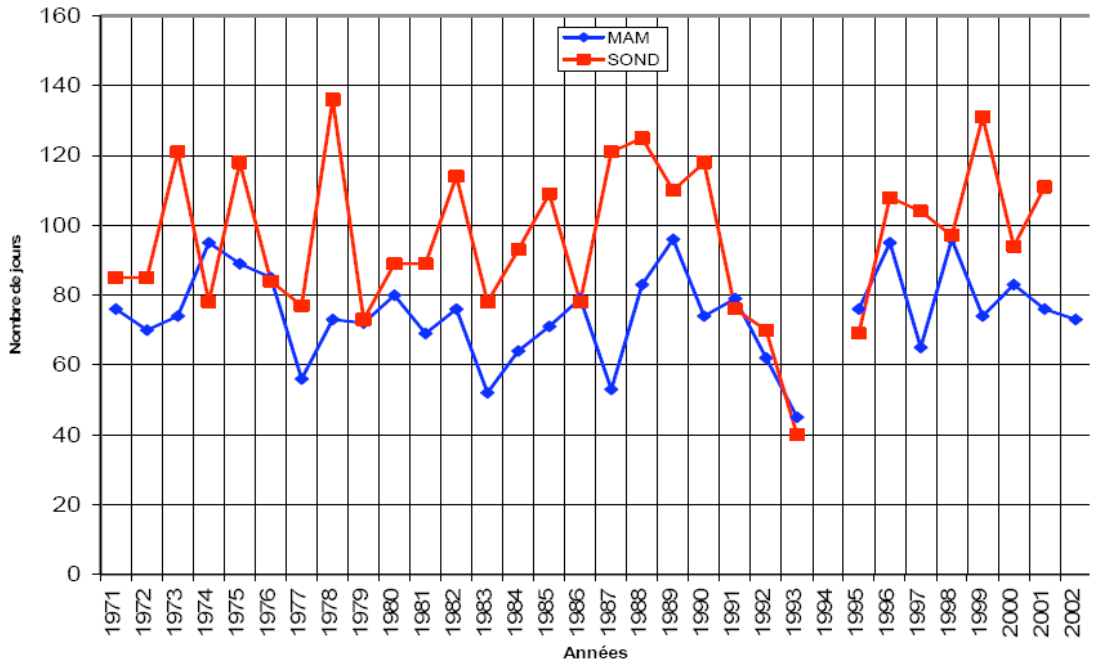


Figure 3 Length of rainy season in days at Kigali

Figure 4 shows the monthly time series of temperature for Kigali, note particularly the upward trend in minimum temperature since 2002

Figure 4 monthly temperature time series, Kigali

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1.3 Climate extremes

Floods, landslides, and drought episodes constitute the major repetitive natural disasters for Rwanda and are often linked with ENSO episodes. Rwanda suffered serious floods linked to the El Nino episode of 1997/98 which destroyed a large number of agricultural plantations and ecosystems occupying shallows and swamps of Nyabarongo and Akanyaru river basins. Prolonged drought of 1999 to 2000 seriously affected Bugesera, Umutara and Mayaga regions which was equivalent to the famous Ruzagayura famine during 1943 to 1945. Landslides are common in the North (Gakenke, Cyeru, Rulindo, Butaro, and Kinihira) and the West (Nyamasheke, Karongi and Ngororero) of the country and these occurred in 2001/2002.

Regions mostly exposed to rainfall deficits (**Figure 5**) have been determined from information on dates of beginning and ends of rainy seasons and from the analysis of short droughts (dry spells) data during March to May and September to December seasons. These regions are characterized by frequent droughts and they include: North-East (Umutara); East (Kibungo); South East (Bugesera and Mayaga regions).

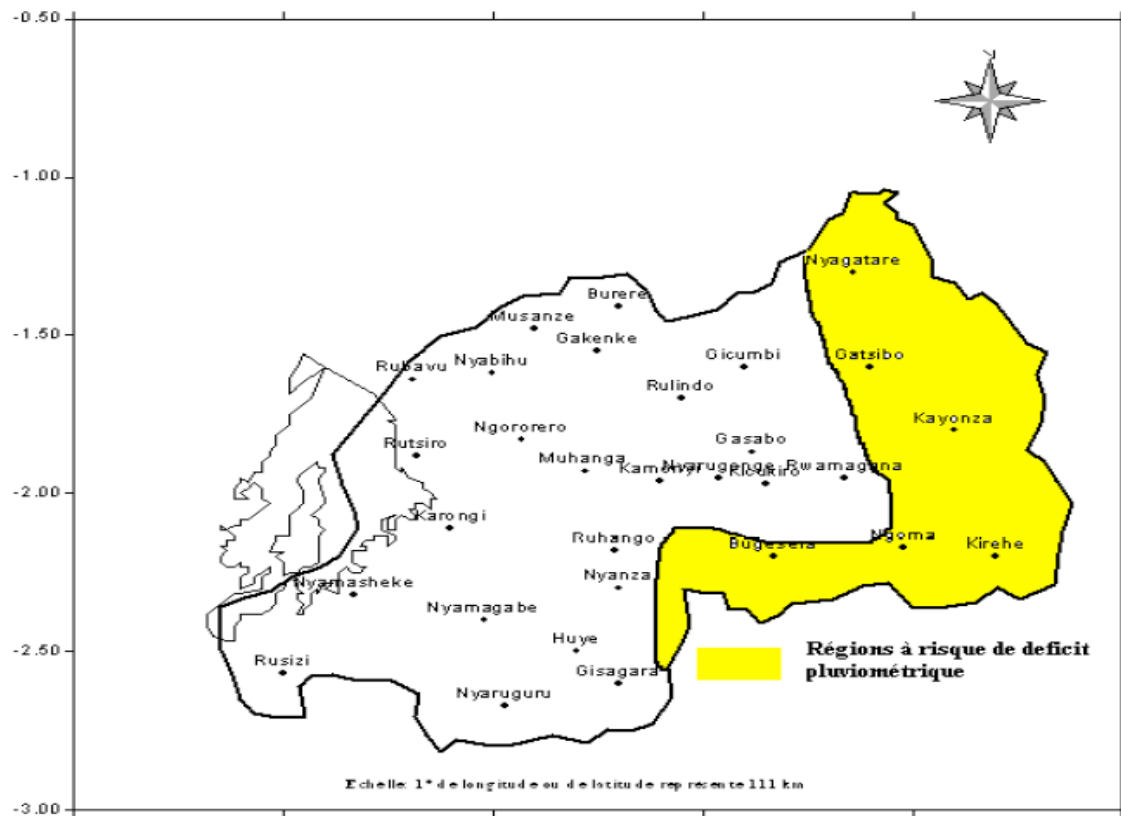


Figure 5: Drought Prone areas in Rwanda (Source, NAPA Report, 2006, Data from Meteorological service /MININFRA)

Regions most exposed to excessive rainfall were identified from the analysis of the frequency of precipitations above 50 mm per day (Figure 6). These regions are very vulnerable to negative effects caused by heavy rains. They are particularly exposed to destructive erosion, considerable soil

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degradation, landslides and landslips. Low altitude zones or least accidental are not spared. They include A big part of northern regions (Ex Provinces of Gisenyi, Ruhengeri and Byumba) and the Southwest region (Ex-Provinces of Gikongoro and Butare) and the western region (Ex- Provinces of Kibuye and Cyangugu); the north of Kigali and some parts of the center (Ndiza, Muhanga).

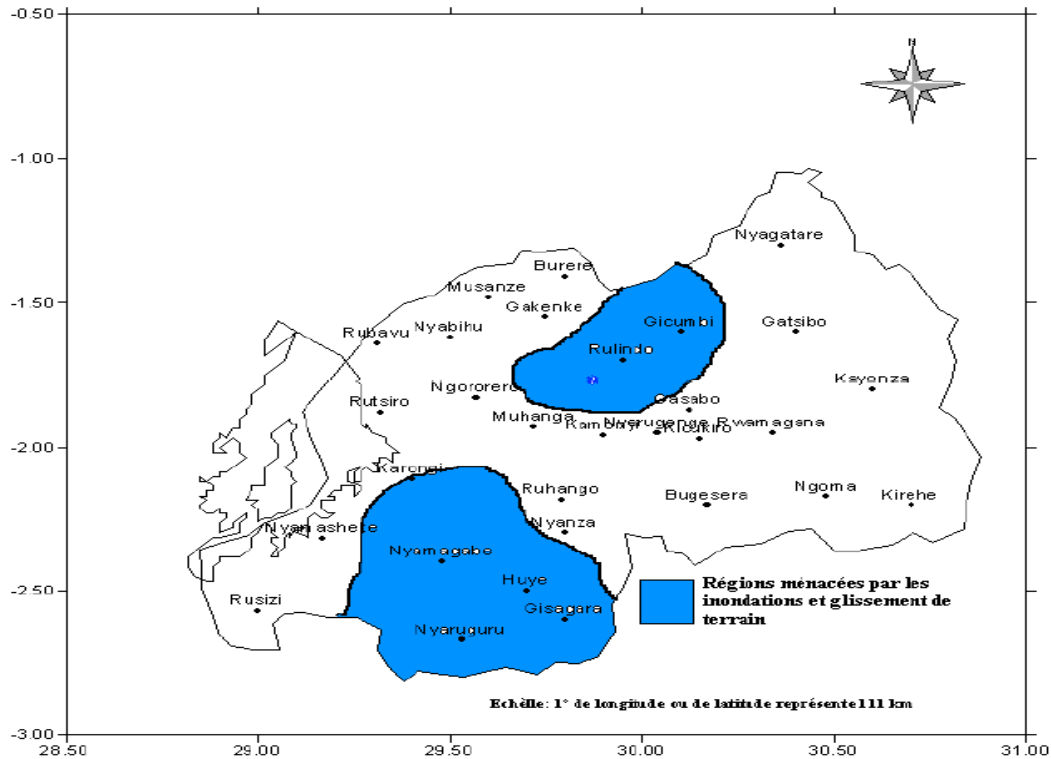


Figure 6 Flood and landslide prone areas in Rwanda (Source, NAPA Report, 2006, Data from Meteorological service /MININFRA)

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Since 1902, a series of severe famines, following prolonged droughts episodes has been recorded in Rwanda. In 1999/2000 East and South-eastern regions of the country were seriously affected by a low agricultural production associated with La Nina 1999/2000 episode. A similar event occurred again in 2005/2006. Also, an increase of frequent prolonged droughts has been experienced since the 1980's. Table 1 below gives the historical perspectives of the drought impacts in Rwanda since 1902 while Table 2 gives a summary of the implications and regions affected by climate hazards in Rwanda.

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Table 1 Historical perspectives of the drought impacts in Rwanda since 1902 (Source, NAPA Report, 2006)

El Nino/La Nina Episodes and Famines in Rwanda Period	El Nino /La Nina Episodes	Catastrophe	Consequence	Affected Region
1902/03	El Nino Episode		“Kimwaramwara” Famine	Butare
1916/1918	La Nina	-	“Rumanura” Famine	Generalized
1924/25	La Nina	-	Famine	Various regions
1943/44	La Nina	Drought	“Ruzagayura” Famine	Generalized
1963	El Nino Episode	Diluvian rain	“Rwagakoco” famine	Generalized
1982/83	El Nino Episode	Drought, high temperatures	Low agricultural production	Generalized
1986/87	Episode El Nino	high temperatures	-	-
1990	La Nina	-	Famine	Various regions
1991/92	El Nino Episode	Drought	-	East
1997/98	El Nino Episode	Drought, high temperatures	-	-
1999/2000	La Nina	Drought, high temperatures	Famine	East of country especially Bugesera
2005/2006	La Nina	High temperatures and prolonged drought	Famine; water sources drying; tendency of desertification	Generalized; East and South mostly affected

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Table 2 Climate impacts in Rwanda (Source, NAPA Report, 2006)

Climate hazards	Vulnerable regions	Consequences on most affected sectors
Increase of temperature, prolonged droughts and high evapotranspiration.	Swamp complexity of Akagera river. Akagera park, Rugezi swamp.	<p>Water resources</p> <p>Low river flows and disturbance of hydraulic cycle in general.</p> <p>Low water level of lakes and rivers;</p> <ul style="list-style-type: none"> ▪ Drying up of water sources. ▪ Loss of aquatic ecosystems (hippopotamus deaths due to drying of Gabiro-Akagera valley in the Akagera National Park during la Nina 1999-2000).
	Bioclimatic region of East and Southeast and some zones of the Central plateau (Umutara, Kibungo, Bugesera, Mayaga Gitarama)	<p>Land Ecosystem and Agriculture</p> <p>Decrease banana production.</p> <p>Cereal and leguminous production especially maize and beans growth becomes almost impossible.</p> <p>Favourable conditions to parasites (caterpillars on sweet potatoes and beans).</p> <p>Pastures without perpetual water or from irrigation become threatened and extinct.</p> <p>Food security</p> <p>Fluctuations in the production, risks of food insecurity and favourable conditions to famines.</p> <p>Hydroelectric and wood energy</p> <p>Reduction of hydroelectricity production.</p> <p>Limited forest resources and exposed to direct and indirect drought effects (bush fire).</p> <p>Low production of wood resources.</p>
	6 hydroelectric stations, Ntaruka, Mukungwa, Gihira and Gisenyi, RUSIZI I and RUSIZI II.	

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Table 4 continued Climate impacts in Rwanda Cont.. ((Source, NAPA Report, 2006)

Climate hazard	Most vulnerable regions	Consequences on most affected sectors
Heavy rains, floods, frequent landslides and landslips.	<p>Riverside regions of Akagera, Akanyaru and Nyabarongo rivers.</p> <p>High altitude regions of West, South-West, North, Centre and Congo Nile crater foothills (Budaha, Ndiza and Buberuka highlands).</p> <p>High mountainous regions, Congo Nile crater regions, valleys and shallows (peat bogs, altitude meadows); North (Cyeru, Nyamugali).</p> <p>6 hydroelectric stations (Ntaruka, Mukungwa, Gihira et Gisenyi, RUSIZI I and RUSIZI II).</p> <p>Protected zones, national parks, cultivated lands, Affluents and swamps: Nyabarongo, Rugezi, Akagera and Mukungwa rivers.</p>	<p>Health Proliferation of mosquitoes and diseases of water-borne origin (malaria, diarrhoea, etc). Loss of animal and human lives.</p> <p>Agriculture Erosion becomes an important factor for low agricultural production and food insecurity. Crops destruction risks and high silting-up particularly in swamps and shallows.</p> <p>Infrastructures Destruction of anti erosive systems, destruction of economic infrastructures (roads, bridges, schools, hospitals, houses, etc.).</p> <p>Economy Reduction of production, and GDP. Reduction of rural population revenues. Increase of foodstuff cost. Movements of the population in search of food.</p> <p>Hydroelectricity Low hydroelectric production.</p> <p>Ecosystems Problems related to water pollution and invasion of aquatic pollutant plants (toxic products, water hyacinth...); Loss of soil fertility by leaching of arable lands; Increase of sediments on arable land at the outlets of slopes; Local risks of landslides; Risks of irreversible land leaching Soil erosion and degradation; River, lake and reservoir sedimentation.</p>

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1.4 Climate change scenario projections

Results here are produced using CSAG's Climate Change Explorer tool – these are empirically downscaled scenarios produced through a statistical technique to produce station level projections of climate change from global climate models (Hewitson and Crane, 2006). The A2 emissions scenario is used for this projections. Unfortunately only the site of Kigali is available for Rwanda.

Average maximum monthly temperatures are expected to increase by 1.5-2.7C for 2046-2065, and greatest warming is likely from July-Sep. For monthly minimum temperatures may rise by between 1.7 and 3.1 °C for 2046-2065 from results from a set of 9 GCMS (Figure 7) with the most warming occurring in June to August.

Some of the model control runs significantly over-estimate dry season rainfall, and produce a rainfall peak too early; however, they capture the general temporal pattern of precipitation sufficiently. The models are remarkably consistent in projecting increases in precipitation for Kigali. Three out of nine models indicate possible decrease in precipitation in March and two in April, August and October (Figure 8). There is strong model agreement from September to December, indicating a strengthening of the second rains, and also in April and May which points to a stronger peak and end to the first rainy season. Confidence in the magnitude of the change is low, however, what we can say from the models is that it is unlikely to get dryer at Kigali. There is also an indication from looking at the monthly rain days with rainfall higher than the 90 percentile (Figure 9) that such extremes are more common in a lot of the scenarios with most consistency in December and January and May to July.

As high temperatures are clearly an issue in Rwanda, a graph (Figure 10) is presented showing the changes in the number of days above the 90th percentile against the increase in mean maximum temperature by month. This indicates that in some months there may be an increase of 2 more days per month with temperatures above the 90th percentile.

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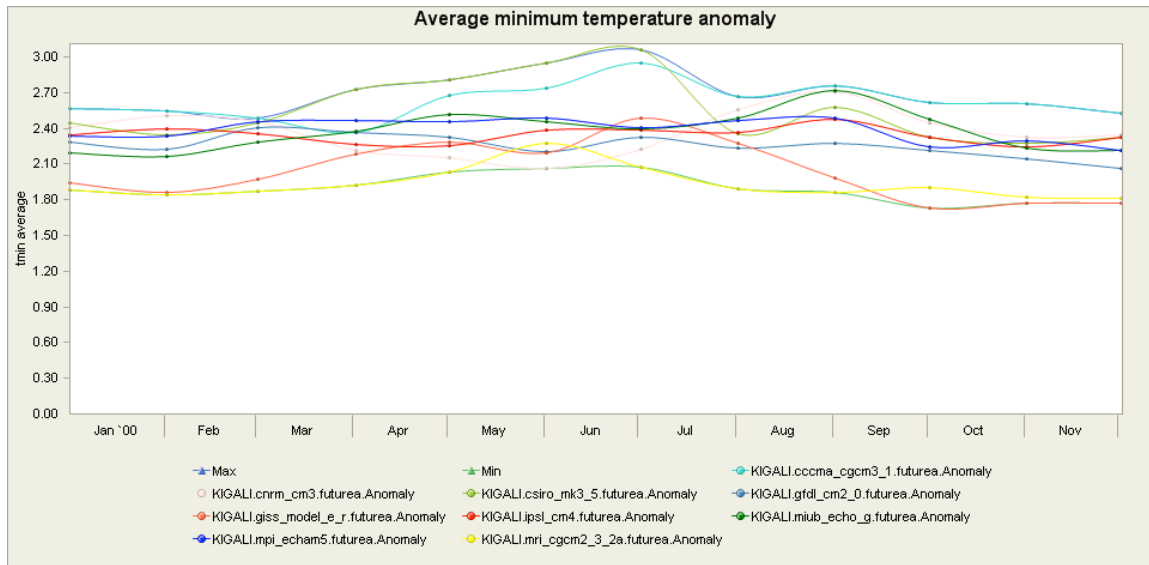


Figure 7 Average minimum temperature anomaly for Kigali, 2046-2065 timeslice

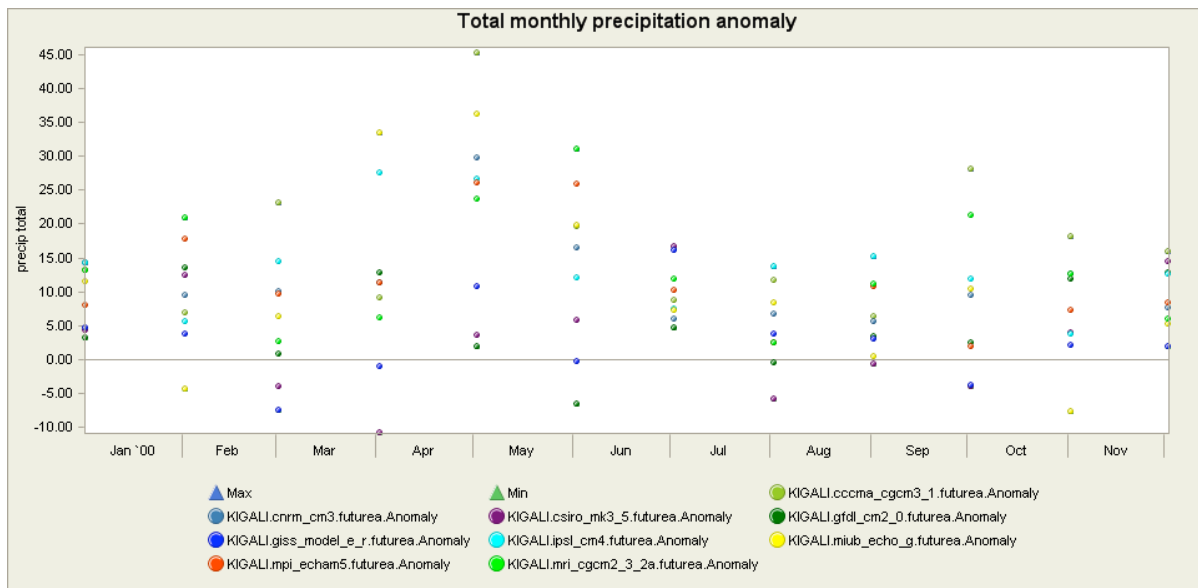


Figure 8 Total monthly precipitation anomaly for 2046-2065 for Kigali in mm

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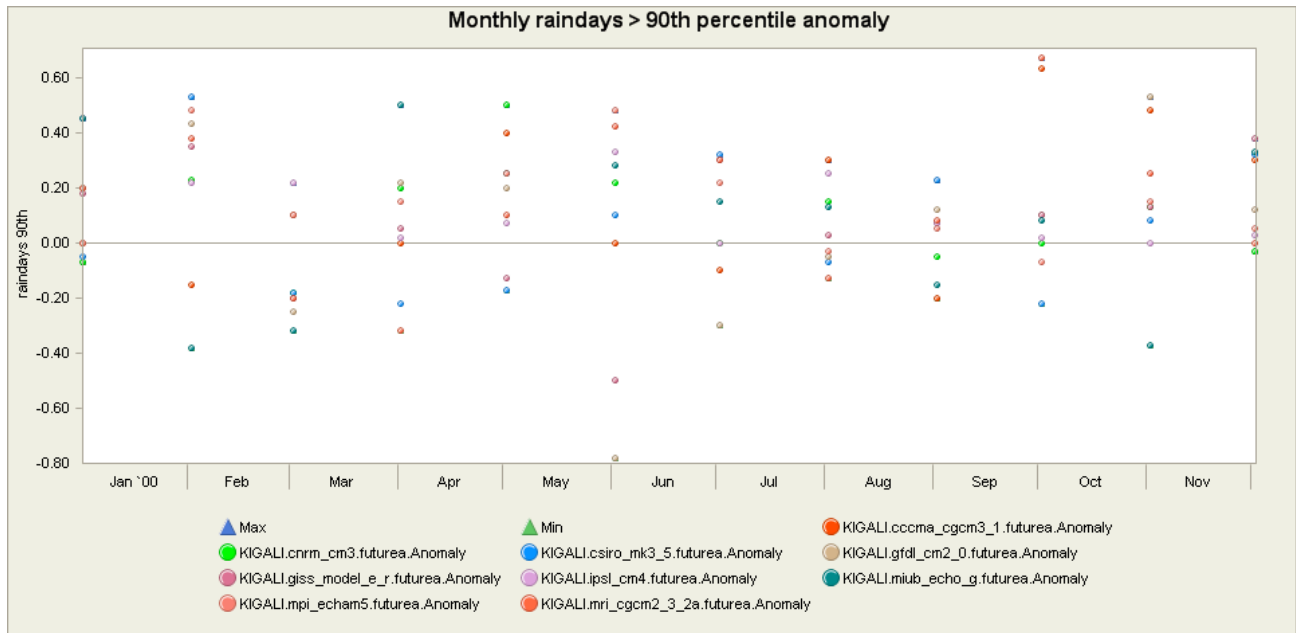


Figure 9 Monthly raindays > 90th percentile anomaly for 2046-2065, Kigali

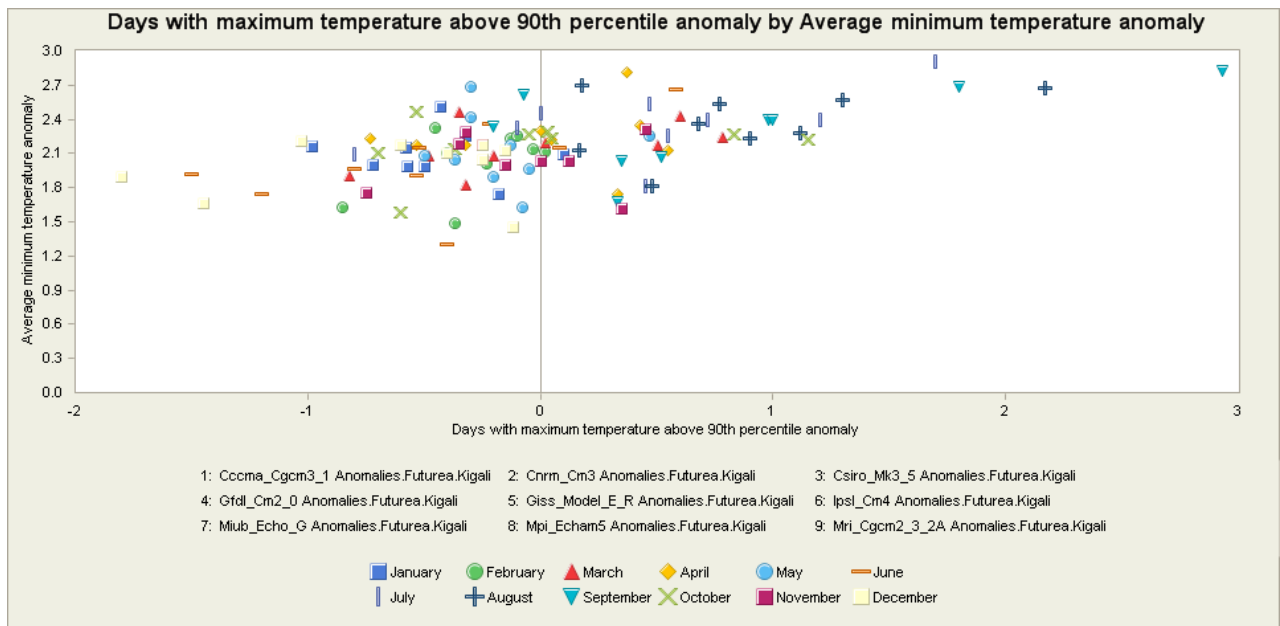


Figure 10 Scatter plot showing anomaly of average maximum temperature increase against anomaly of number of days per month with maximum temperature above the 90 percentile.

2 Summary

Climate analysis in Rwanda is limited because of the availability of climate data. The First National Communication reported that the meteorological service is functioning below optimum due to inadequate staffing and lack of data collection, capture and processing equipment. The main problem is the lack of comprehensive weather observation network

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as it existed before 1994. Since it resumed its activities after the war of 1994, the service has no climate yearbook and no agro-meteorological bulletin has ever been published so far.

No future projections using GCMs were shown in either the FNC or the NAPA although a good description of observations and impacts of the El Nino and La Nina years are presented in these documents.

Therefore the Kigali station scenario projections are the only projections available. These show a consistency in the warming of minimum and maximum temperatures by the middle of this century but with quite a wide range up to 3°C. For precipitation the balance across the models is for wetter conditions in all months, and also more very wet days may be expected particularly in July, August and September.

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