DOWNSCALED CLIMATE PROJECTIONS FOR NATIONAL ADAPTATION PLAN IN RWANDA

SUMMARY OF TECHNICAL REPORT

Rwanda Meteorology Agency
KN 96 St, Nyarugenge, Kigali
P.O. Box 898 Kigali,
Rwanda
website: www.meteorwanda.gov.rw
E-mail: ***info@meteorwanda.gov.rw***

Rwanda Environment Management Authority
P.O Box 7436 Kigali, Rwanda
website: www.rema.gov.rw
E-mail: info@rema.gov.rw

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1 Introduction

Climate change is a significant global environmental threat (IPCC, 2014, IPCC, 2021), mainly to the planet's human well-being and health. Over Africa, IPCC (2013) indicates that warming is likely more remarkable than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moisture tropics. Developing nations remain the most vulnerable to changing climate (Wanyama *et al.*, 2019), with the most considerable reductions in economic growth for an increase from 1.5°C to 2.0°C of global warming projected for low- and middle-income countries in Africa (IPCC, 2018).

Rwanda is a low-income country that remains highly vulnerable to the impacts of climate change, further complicating the path to reaching its ambitious target of becoming a high-income nation by 2050. Over the past decade, Rwanda has experienced strong economic growth across various sectors, including agriculture, energy, mining, industry, and services. By adhering to green economy principles during this growth, the country has positioned itself to become a world leader in green development (NLUDMP 2020). According to the World Bank's Rwanda Climate Risk Country Profile (2020), climate change impacts the country's efforts to achieve sustainable development. The pressures from a rapidly growing population on land, water, food, and energy resources are threatening the sustainability of its growth. Rwanda's Updated Nationally-Determined Contributions (NDC) also notes that the country is increasingly experiencing the impacts of climate change. Current and predicted effects of climate change are compounding these threats. The significant impacts of climate change in Rwanda are i) an increased frequency of extreme flood events, ii) an increased duration and frequency of droughts, and iii) increased average temperatures. These impacts are expected to become more severe over the coming decades, with intense adverse effects on agriculture, energy production, forestry and water supplies

Climate information constitutes a valuable resource for understanding the past and future space-time characteristics of all-weather parameters sensitive to socio-economic development. There is a growing international consensus that future climate change is inevitable even if stringent emission reduction measures are adopted (Osman *et al.*, 2021). Effective adaptation strategies for climate variability and change require reliable information at more acceptable spatial and temporal resolution. To address the various threats posed by climate change, Rwanda has decided to pursue a green growth approach to development. The availability of regional and local scale climate change scenarios is critical for assessing climate change impacts and vulnerability in various socio-economic sectors and developing appropriate adaptation strategies.

Therefore, there is a need for standardized climate projections for Rwanda specific to its different agro-ecological zones and biophysical conditions or for guidance on which external climate information sources to use and how to use them. This information needs to be accompanied by current knowledge and local expertise to ground and interpret the future scenarios in the context of climate-sensitive sectors, policies, and programmes. Therefore, this summary presents an analysis of downscaled information on historical and projected climate information to the country-level for the national adaptation plan in Rwanda.

2 Methodology

The primary source of observed rainfall and maximum and minimum temperature was Rwanda Meteorology Agency (Meteo Rwanda). The observed rain was based on merging bias-corrected Tropical Application of Meteorology using SATellite (TAMSAT) estimates with observed rainfall to generate a rainfall-gridded dataset covering the period of 1981 to 2019 following a methodology detailed in Siebert et al. (2019). Climate model output included Downscaled Coordinated Regional Downscaling Experiment (CORDEX) datasets based on Coupled Model Intercomparison Project Phase 5 (CMIP5). Table 4 presents the RCM models used for downscaling the GCM. These model properties are detailed in Nikulin et al. (2012). Dynamically downscaled climate model outputs were further downscaled based on statistical downscaling to station level. Validation of climate models was based on several statistical techniques, including correlation, coefficient of determination (R^2), bias and Root Mean Square Error.

Table 3-1: List of RCMs used and their driving GCMs models

Domain	RCM Model	Driving GCM Models
AFR-44	CCLM4-8-17	MOHC, MPI and ICHEC
AFR-44	RCA4	MOHC, MPI and ICHEC
AFR-44	REMO2009	MOHC, MPI and ICHEC

The study utilized scenarios based on two possible future trajectories to accommodate uncertainties around future GHG emissions and the success of mitigation measures. An RCP 4.5 w/m^2 represents the likely best-case scenario with a peak radiative forcing of 45 w/m^2 (~650 ppm CO_2 equivalent) at stabilization after 2100, while an RCP 8.5 w/m^2 represents a very high GHG emission scenario with a peak radiative forcing of 85 w/m^2 (~1,370 ppm CO_2 equivalent) and no expected stabilization in emissions. Three different periods were considered for the study and included 2021-2050 (Near Term), 2041-2070 (Medium-term) and 2071-2100 (Long term). Temporal analysis was based on the trend component of time series was based on Mann-Kendall (MK) trend test, Sen's Slope Estimator and Change magnitude as a percentage of mean and computed over the 30 years based on annual and seasonal time series. Computation of climate change indices was based on daily temperature and rainfall data using criteria set by the Expert Team on Climate Change Detection Monitoring Indices (ETCCDI). The spatial analysis involved plotting spatial maps to represent seasonal and annual variables (rainfall and temperature).

3 Observed and projected rainfall in Rwanda

3.1 Analysis of seasonal and annual precipitation

January to February (JF) season

The past JF season (1981-2010) indicates a considerable rainfall that ranged from 450 to -600mm over the southwestern areas near Nyungwe National Park and less than 50mm over most of the eastern part. Projected JF seasonal rainfall for 2021-2050 ranges from -16.72%/-0.9mm per year in Ruhengeri to -61.76%/-3.07mm per year in Gabiro under RCP 4.5 W/M^2 and ranges from +17.76%/2.19mm per year in Muganza to -23.56%/-1.83mm per year in Kibungo under RCP 8.5 W/M^2. For the period 2041-2070, non-significant projected JF seasonal rainfall ranging from +43.9%/+1.92mm per year in Gabiro to -4.18%/-0.36mm per year in Butare is expected under RCP 4.5 W/M^2 while a significant decreasing trend between -17.59%/1.59mm per year in Kamembe and -69.92%/-4.38mm per year in Bukora is likely under RCP 8.5 W/M^2. For 2071-2100, projected JF seasonal rainfall ranges from -30.76%/-4.92mm per year in Ntendezi to -82.76%/-3.12mm per year in Nyagatare under RCP 4.5 W/M^2 and between +42.16%/+1.29mm per year in Nyagatare to -33.88%/+1.66mm per year in Gisenyi under RCP8.5 W/M^2. JF precipitation remains highly variable under RCP 4.5 W/M^2 and RCP 8.5 W/M^2 during 2021-2050, 2041-2070 and 2071-2100 over Rwanda. The projected JF precipitation is expected to decrease from the Southwest (300-450mm) to the northeast (50-150mm). In contrast, the central areas toward the Northwestern parts maintain the rainfall ranging between 450 to 600mm, under both RCP 4.5 W/M^2 and RCP 8.5 W/M^2.

Spatial analysis of the JF season for 1981 to 2010 indicates a considerable rainfall ranging between 450-600mm over the southwestern areas near Nyungwe National Park and less than 50mm over most of the eastern part. Projected JF precipitation under both RCP 4.5 w/m^2 and RCP 8.5 w/m^2 indicates a decrease from the Southwest (Nyaruguru, Nyamagabe and Rusizi) to the northeast for the period 2021-2050, with the highest amounts between 300 and 600mm in Nyaruguru and Nyamasheke district and lowest quantities between 50 to 150mm around Nyagatare, Kayonza and Burera district. Similar projected precipitation distribution patterns are observed for 2041-2070 and 2071-2100 under both RCP 4.5 w/m^2 and RCP 8.5 w/m^2. The projected JF precipitation is expected to decrease from the Southwest (300-450mm) to the northeast (50-150mm). Under RCP 4.5 w/m^2 for 2021 to 2050, 2041 to 2070 and 2071 to 2100, most eastern parts are projected to have a negative change, especially Kayonza, Kirehe and regions Nyagatare and Gatsibo bordering Akagera National Park. In the RCP 8.5 w/m^2, an increase in the amount of precipitation is expected for 2021-2050 but later decreases to below its baseline by 2100.

March April May (MAM) season:

The observed (1981-2010) rainfall trend during the MAM season ranged from +63.42%/+8.91mm per year in Gabiro to -15.16%/-1.63mm per year in Bukora. In addition, most of the central parts, some parts of South-East (areas of southern Kirehe and Kayonza), Northern Bugesera extending to Kigali City, part of Northern Gicumbi, Rubavu, North-West and Congo Nile divide show a decreasing rainfall. For 2021-2050, the non-significant trend for MAM seasonal rainfall is projected to range between +2.1%/+0.28mm per year in Kamambe to -16.76%/-2.38mm/year in Gikongoro under RCP 4.5 W/M^2. Under RCP8.5, a significant trend between -51.16%/-2.33mm per year in Ruhengeri and -169.2%/-1.57mm per year in Nyamata is expected. At the same time, an increasing trend of between 0% (northern parts) and 2.0% (southern parts) is also expected. During 2041-2070, a non-significant trend ranging from -3.21%/-0.57mm per year in Busogo to -46.82%/-4.65mm per year in Bukora is expected under RCP 4.5 W/M^2 and from +10.51%/+1.29mm per year in Kamembe and -8.97%/-1.48mm per year in Gatumba under RCP 8.5 W/M^2. For the period 2071-2100 non-significant trend ranging from +25.41%/-+3.64mm per year in Gikongoro to +2.81%/+0.34mm per year in Rugobagoba is expected under RCP 4.5 W/M^2 and from +5.6%/+0.78mm per year in Byumba and -8.97%/-1.48mm per year in Gatumba is expected under RCP 8.5 W/M^2. MAM precipitation remains highly variable under RCP 4.5 w/m2 and RCP 8.5 w/m2 during 2021-2050, 2041-2070 and 2071-2100 over Rwanda. The reduction in rainfall is also expected in the central parts; the Congo Nile divide, the northern regions and the Amayaga areas in the annual rainfall.

Spatial analysis of the MAM season shows that the southwestern part bordering Nyungwe National Park received higher rainfall ranging between 700 and 800mm and reduced towards the southern, northern and western regions, which received amounts ranging between 450-600mm. The areas of Kigali extending to the eastern part received lower rainfall ranging between 300-450mm. Projected MAM precipitation for 2021-2050, 2041-2070 and 2071-2100 ranges between 300 and 700mm for both RCP 4.5 w/m^2 and RCP 8.5 w/m^2. However, the MAM seasonal totals are expected to decrease in most regions towards 2100, especially most parts of Eastern parts, Rubavu, Rusizi, Karongi and the southern region, where more reduction is expected in the areas of Kayonza, and Kirehe, both under RCP 4.5 w/m^2 and RCP 8.5 w/m^2. The central parts toward the Northwestern parts maintain the rainfall ranging between 450 to 600mm, under both RCP 4.5 w/m^2 and RCP 8.5 w/m^2. Projected precipitation changes under RCP 4.5 w/m^2 are expected to be positive over most parts of Rwanda for 2021-2050 and later decrease towards 2100 compared to 1981-2010. Projections under RCP 8.5 w/m^2 show positive changes in precipitation over parts of western and eastern provinces, which decreases decrease to 2100 compared to 1981-2010.

June July August (JJA) Season.

During the JJA Season, a reduction in rainfall for the period of 1981-2010 is observed over most parts of Southern (areas of Ruhango, Nyanza, Gisagara and Nyamagabe) and some parts of Northern parts (Nyabihu and Burera). The trend of observed (1981-2010) rainfall during JJA season ranges from +189.81%/+6.17mm per year in Masaka to -32.42%/-0.75mm per year in Save. Non-significant projected rainfall for the period 2021-2050 ranges from +19.24%/+0.65mm per year in Rutsiro to -31.7%/-0.59 mm per year in Nyagatare under RCP 4.5 W/M^2 while a significant projected trend ranges from -51.16%/-2.33mm per year in Ruhengeri to -169.2%/-1.57mm per year in Nyamata is expected under RCP 8.5 W/M^2. For 2041-2070, there was a non-significant trend ranging between +39.95%/1.7mm per year in Ntendezi to -22.19%/-0.18mm per year in Kibungo under RCP 4.5 W/M^2 and from +34.29%/+0.13mm per year in Butare to -28.03%/-0.23mm per year in Rubengera under RCP 8.5 W/M^2. During 2071-2100, there was a non-significant trend ranging from +106.95%/+0.75mm per year in Muganza to -14.17%/-0.26mm per year in Kamembe based on RCP 4.5 W/M^2 and ranged from -51.42%/-0.61mm per year in Gabiro to -117.82%/-0.61mm per year in Kibungo under RCP 8.5 W/M^2. Generally, the projected JJA precipitation indicates that under RCP 4.5 W/M^2, changes in rainfall will increase and become positive towards 2100, whereas, under RCP 8.5 W/M^2, positive changes in rainfall are expected in some parts of Rwanda for the period 2041-2070 while trend during the 2021-2050 and 2071-2100 expected to undergo negative change.

Spatial analysis of the JJA season indicates that the northwestern Kayonza, south-eastern Ngoma and Kirehe Districts received less than 50mm. Regions surrounding the Volcano National Park, eastern Nyamasheke, and southern

Karongi near Nyungwe National Park received between 300 and 450 mm rainfall. At the same time, the rest of the country experienced 50 and 150mm of rain. The JJA season precipitation is projected to decrease between <50mm and 150mm from northwest to southeast for 2021-2050, 2041-2070 and 2071-2100 under RCP 4.5 w/m^2 and RCP 8.5 w/m^2. Kigali city and the south-eastern provinces reported negative changes and will increase towards 2100 under all scenarios.

September October, November December (SOND) Season.

For the September to December season (SOND), a reduction in rainfall was observed over the central, northern, and southwestern parts of the areas of Rusizi. There is a significant trend ranging from +83.28%/+12.30mm per year in Gabiro to -51.69%/-6.0mm per year in Gitega. Non-significant projected SOND seasonal rainfall for the period 2021-2050 ranges from -2.1%/-3.9mm per year in Gisenyi to -25.11%/-3.52 mm per year in Kibungo under RCP 4.5 W/M^2 and significant trends ranging from -13.73%/-2.47mm per year in Butare to -35.98%/-9.01mm per year in Rutsiro under RCP 8.5 W/M^2. For 2041-2070, a non-significant trend ranged from +6.95%/+0.96mm per year in Byumba to -9.79%/-1.67mm per year in Rubengera based on RCP 4.5 W/M^2 and ranged from +0.93%/+0.12mm per year in Bukora to -18.08%/-3.32mm per year in Byimana under RCP 8.5 W/M^2. The period 2071-2100 ranged from +1.09%/+0.18mm per year in Rubengera to -36.92%/-4.73mm per year in Gabiro under RCP 4.5 W/M^2 and ranged from +31.59%/+4.12mm per year in Gabiro to +0.99%/+0.24mm per year in Kamembe under RCP 8.5 W/M^2. Projected SOND precipitation for 2021-2050, 2041-2070 and 2071-2100 ranged from 300mm to 1000mm for both RCP 4.5 W/M^2 and RCP 8.5 W/M^2. It decreased from the Southwest (around Nyungwe National park, Nyaruguru, Nyamagabe, Nyamasheke, Rusizi), extending to the northern highland and increasing towards the central plateau and the East, where most parts of the East are projected to have rainfall ranging from 300 to 600mm.

Spatial analysis of the SOND rainfall season indicates decreases from southwestern (800-900mm) to northern highland and central plateau (450-600mm) with less rainfall over the eastern regions (300-450 mm). Projected SOND precipitation shows most areas in eastern provinces expected to receive the rain of between 300mm and 450mm and increases towards the south of western province (>600mm). The SOND rainfall shows highly variable seasonal totals, with most areas expected to receive above the 1981-2010 baseline rainfall

Annual precipitation. Over the past period, a significant yearly increasing rainfall trend of +71.80%/+25.41mm per year was observed in Gabiro, while a non-significant decreasing trend of -7.65%/-3.41mm per year was observed in Mushubi. Projected non-significant decreasing annual rainfall for 2021-2050 ranges from -7.74%/-4.31mm per year in Busogo to -18.78%/-6.15mm per year in Nyagatare under RCP 4.5 W/M^2 and from -1.37%/-0.69mm per year in Muganza to -20.8%/-11.45mm per year in Rutsiro under RCP 8.5 W/M^2. For the period 2041-2070, a non-significant increasing trend of +5.7%/+2.22mm per year is expected over Ntaruka, while a decreasing trend of -12.98%/-4.05mm per year is expected over Bukora under RCP 4.5 W/M^2 while a significantly reduced trend of -19.43%/-8.22mm per year is expected over Byimana under RCP 8.5 W/M^2. For 2071-2100, a significant trend of -2.78%/-2.03mm per year is expected over Ntendezi under RCP 4.5 W/M^2 and a non-significant trend ranging from +13.55%/+3.74mm per year in Gabiro to –7.72%/-3.53mm per year in Ruhengeri under RCP 8.5 W/M^2. Overall rainfall distribution throughout the year is a decisive factor in scheduling cultivation practices and harvesting. For example, where the rainfall is unimodal, there will be two periods of blossoming and, consequently, two harvest periods – known as the 'early crop' and the 'late crop'. Coffee from the 'late crop' is of better quality.

On an annual basis, areas over southwestern, northern highland and around Volcano National Park received rainfall above 1400 mm and reduced towards the central plateau with amounts between 1200-1400mm. Amayaga, extending to the central-eastern regions, reported between 1000-1200mm of rainfall. The areas over the eastern part boarding Akagera National Park and the western of Nyagatare received amounts ranging between 800 and 900mm. Western parts of Rwanda received more rainfall during both seasonal and annual rainfall compared to the eastern regions. Projected annual precipitation for 2021-2050, 2041-2070 and 2071-2100 ranges from 700mm to >1400mm under RCP 4.5 w/m^2 and RCP 8.5 w/m^2 and is expected to decrease from the Southwest towards the east. For both RCP 4.5 w/m^2 and RCP 8.5 w/m^2, rainfall of more than 1400mm is projected mainly in mountain areas of southwest parts closer to

Nyungwe National Park, northern and Northwestern parts, including Rulindo and Gakenke. The western part is also expected to receive rainfall ranging between 1200 to 1400mm. A lower amount of rain is expected in the eastern areas of Gatsibo, Kayonza and Kirehe Districts. Changes in projected annual rainfall for 2021-2050 under RCP 4.5 w/m^2 and RCP 8.5 w/m^2 show that southwestern, North-western, and parts of South-eastern are expected to have positive change ranging from 30% to 90%, while parts of central and northeastern are expected to receive slightly negative change.

3.2 Analysis of extreme precipitation

Very-heavy precipitation days: Past extreme precipitation shows a significant trend in the very-heavy precipitation days, ranging from +125.86%/+0.92 days per year in Rwamagana to -69.41%/-0.33 days per year Kamembe, while very wet days range from +203%/+18.67days per year in Byumba to -93.14%/-8.10 days per year in Save. Projected very-heavy precipitation days for the period 2021-2050 indicate a significant trend of -36.22%/-0.14 days per year in Byimana under RCP 4.5 W/M^2 and a non-significant trend ranging from +26.97%/0.08mm per year in Gabiro to -18.01%/-0.14 mm per year in Ntendezi under RCP 8.5 W/M^2. For the period 2041-2070, a Projected non-significant trend in very-heavy precipitation days ranges from +28.85%/0.13 days per year in Byimana to -36.14%/-0.10 mm per year in Rubengera under RCP 4.5 W/M^2 and a significant decreasing trend of -45.87%/-0.17 mm per year in Rubengera under RCP 8.5 W/M^2. During 2071-2100, very heavy precipitation days are projected to decrease with a non-significant magnitude of -50.33%/--0.17 mm per year in Gabiro under RCP 4.5 W/M^2 and between +23.31%/+0.08 mm per year in Gisenyi to –9.17%/-0.06mm per year in Byimana under RCP 8.5 W/M^2.

Very wet days: The significant trend of observed (1981-2010) very wet days ranged from +203%/+18.67days per year in Byumba to -93.14%/-8.10 days per year in Save. The significant trend of very wet days for 2021-2050 is projected in Byimana with a magnitude of +71.02%/+6.76 days per year under RCP 4.5 W/M^2 and 80.6%/+5.47 days per year in Gikongoro under RCP 8.5 W/M^2. For 2041-2070, a significant trend of +14.33%/+1.04 days per year is expected over Byumba under RCP 4.5 W/M^2 and -53.56%/-6.49 days per year in Ntendezi under RCP 8.5 W/M^2. During 2071-2100, a significant trend in very wet days with a magnitude of +7.0%/+0.67 days per year is projected in Rubengera under RCP 4.5 W/M^2 and +78.25%/+7.53 days per year in Kawangire in Rubengera under RCP 8.5 W/M^2.

Consecutive dry days: The observed non-significant trend in Consecutive dry days ranges between +48.31%/+1.14 days per year in Kansi to -22.86%/-0.45 days per year in Ntendezi. The projected significant trend in consecutive dry days for 2021-2050 with a change magnitude of +36.55%/+0.57 days per year in Rutsiro under RCP 4.5 W/M^2 and 91.82%/+2.22 days per year in Kibungo under RCP 8.5 W/M^2. From 2041 to 2070, a significant decreasing trend in consecutive dry days with a magnitude of 37.9%/-0.71 days per year is expected in Ntendezi under RCP 4.5 W/M^2 and -28.8%/-0.52 days per year in Ruganda under RCP 8.5 W/M^2. Under the period 2071-2100, a projected significant trend in consecutive dry days is expected over Muganza with a magnitude of -41.5%/-1.13 days per year under RCP 4.5 W/M^2 and +87.98%/+1.27 days per year in Ntaruka under RCP 8.5 W/M^2.

Overall, the number of days per year with very heavy rainfall precipitation (R20mm) was higher over southwestern Nyungwe National Park, reducing toward the central plateau compared to eastern areas bordering Lake Kivu and northwestern parts of Rwanda. Similarly, annual total precipitation from days greater than 95th percentile mm was higher over southwestern parts, reducing toward the central and less rainfall over the eastern part of Rwanda. An increase in the frequency and intensity of heavy rain in Rwanda will result in enhanced natural disasters such as erosion, flooding and landslides, especially in the northern and western regions. Projections of extreme climate change indicate that these impacts are expected to intensify and become more frequent and thus severely impact the economy. On the contrary, areas to the East and South East of Rwanda are expected to remain vulnerable to prolonged drought. An increase in the number of dry spells during the rainy season is likely to result in poor performance of crops that may result in late-onset of rainfall and/or early rainfall cessation during the rainy season, which also affects the poor performance of agriculture productivity. In addition, floods and landslides are expected to reduce arable land use.

3.3 Impacts of observed and projected changes in precipitation

Overall, observed climate change in Rwanda over the past 30 years indicates a shift in the timing of rainfall seasons in certain regions. Notably, the length of seasons has changed and become invariably shorter and more intense, particularly in the Northern and Western provinces. According to the World Bank's Rwanda Climate Risk Country Profile (2020), rainfall has become increasingly intense, and the variability is predicted to increase by 5% to 10%. This change poses the risk of increased erosion in these mountainous areas. On the other hand, places where the frequency of below-normal rainfall has increased, such as eastern parts of the country, are expected to result in reductions in agricultural production. Higher rain in the country's northwest will likely lead to respiratory diseases and foot rot. Also, any water availability decrease will reduce agricultural productivity and food security. In addition, an increased incidence of floods and droughts will reduce water quality because of erosion and siltation.

In some cases, the average reduction in monthly rainfall, notably during September-October, may result in inadequate rainfall to support effective crop establishment during the period traditionally associated with the start of each growing season. Alternatively, the positive anomalies (i.e. predicted increases) in monthly rainfall in December – January may indicate an extension in the duration of the rainy season, thereby providing farmers with the option to extend or stagger the timing of crop establishment. Therefore, climate change may delay the onset of rainfall relative to the traditional agricultural calendar, resulting in changes to the timing of various agricultural activities such as field preparation and sowing of seeds. Drought will result in drier wetlands and will reduce river base flows, compromising the generating capacity of hydroelectric dams. Reduced base flows will affect downstream irrigation projects, and flood and drought events will likely damage water supply infrastructure**.** In addition, increased sediment load in rivers from soil erosion will further reduce base flows and result in i) the siltation of dams; and the ii) degradation of turbines and other hydroelectric infrastructure. The decrease in water availability in Rwanda's eastern and south-eastern regions is likely to lead to reduced tree cover. Similarly, flooding – the intensity and frequency of which is expected to rise under future climate change conditions –will also damage infrastructure. Consequently, floods and droughts will reduce the capacity for power generation, increasing the dependence of local communities on wood fuel. The increased usage of wood fuel will exacerbate the country's deforestation rate.

4 Observed and projected maximum/minimum temperature

4.1 Analysis of minimum temperature

January-February season

Baseline (1981-2010) JF mean minimum temperature shows no significant trend. The near Term projected mean JF minimum temperature exhibited a significant positive trend with a projected increase per year ranging from +0.03^{O}C in Gatumba (Ngororero) to +0.02^{O}C in Masaka under RCP 4.5 W/M^2. It ranged from +0.03^{O}C in Gatumba to +0.01^{O}C increase per year in Gisenyi under RCP 8.5 W/M^2. Medium Term, projected mean JF minimum temperature indicated a significant positive trend only under RCP 4.5 W/M^2 with a projected increase per year ranging from +0.03^{O}C in Gatumba to +0.01^{O}C in Masaka (Kicukiro). Future Term, projected mean JF minimum temperature exhibits a significant positive trend with a projected increase per year ranging from +0.05^{O}C in Gatumba to +0.03^{O}C in Kawangire (Kayonza) under RCP 4.5 W/M^2 and ranging from +0.04^{O}C in Gatumba to+0.04^{O}C in Gisenyi under RCP 8.5 W/M^2.

The highest projected JF minimum temperature is expected over eastern parts compared to western parts of Rwanda. In addition, projected minimum temperatures are expected to increase from 2021 to 2100, with more areas under RCP 8.5 W/M^2 to experience the highest minimum temperature towards 2100. Changes in minimum temperatures are expected to increase from approximately 0^{o}C over western and eastern (Bugesera, Bgoma and Rwamagana) provinces in 2021 to 2.5^{o}C over Kigali city and the northern, southern (Gisagara, Nyanza, Ruhango, Muhanga and kamonyi), and eastern (Kirehe, Kayonza, Gatsibo, Nyagatare, Gicumbi) provinces in 2100 under RCP 4.5 W/M^2. Similarly, changes in minimum temperatures are expected to increase from 1.0 ^{o}C over western, northern, southern and south of eastern provinces in 2021 to 6.0^{o}C over mostly north of eastern and East of the northern provinces in 2100 under RCP 8.5 W/M^2 during JF season.

March, April May (MAM) season

Temporal analysis shows no significant trend of the observed (1981-2010) mean MAM minimum temperature countrywide. The near-term projected MAM mean minimum temperature exhibit a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Bukora (Kirehe) to +0.01^{O}C in Rwankeri (Nyabihu) under RCP 4.5 W/M^2 and ranging from +0.03^{O}C increase in Cyinzuzi (Rulindo) to +0.01^{O}C in Rwamagana under RCP 8.5 W/M^2. Again, medium Term projected MAM mean minimum temperature exhibits a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Bukora (Kirehe) to +0.01^{O}C in Rwamagana under RCP 4.5 W/M^2 and ranging from +0.04^{O}C in Bukora to +0.03^{O}C in Rwamagana under RCP 8.5 W/M^2. The future Term projected MAM mean minimum temperature exhibits a significant positive trend only under RCP 8.5 W/M^{2,} with a projected increase per year ranging from +0.05^{O}C in Bukora to +0.03^{O}C in Kanombe. Overall, projected changes in MAM mean minimum temperature trend exhibits a significant positive trend in the near and medium Term under both RCPs. However, larger changes are noted for 2071-2100 under RCP 8.5 W/M^2 compared to 2021-2050, whereas a non-significant trend is expected between 2071-2010 under RCP 4.5 W/M^2.

Spatial analysis shows highest projected MAM minimum temperatures are expected over eastern parts compared to western parts of Rwanda. In addition, projected minimum temperatures are expected to increase from 2021 to 2100, with more areas under RCP 8.5 W/M^2 to experience the highest minimum temperature towards 2100. Overall, changes in minimum temperatures are expected to increase from approximately 1.0 ^{o}C over most parts of Rwanda in 2021 to 2.5 ^{o}C over Kigali city, Musanze, Burera and Rulindo in the northern province and Nyagatare, Gatsibo, Gichumbi and Kayonza districts in the eastern province in 2100 under RCP 4.5 W/M^2 and from 1.0 ^{o}C over western, northern, southern and most parts of eastern provinces in 2021 to 6.0 ^{o}C over most northern provinces, Gatsibo, Kirehe, Gichumbi and Nyagatare districts in the eastern province and Gisagara district in the southern province in 2100 under RCP 8.5 W/M^2 during MAM season.

June July August (JJA) season

There is no significant trend in the observed (1981-2010) mean JJA minimum temperature countrywide. The near Term projected mean JJA minimum temperature indicates no significant trend under RCP 4.5 W/M^2 and a significant positive trend with a projected increase per year ranging from +0.06^{O}C in Gatumba (Ngororero) to +0.03^{O}C increase per year in Masaka (Kicukiro) under RCP 8.5 W/M^2. Again, medium Term projected mean JJA minimum temperature indicated no significant trend under RCP 4.5 W/M^2 and a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Gatumba to +0.02^{O}C in Rubengera under RCP 8.5 W/M^2. Additionally, future Term projected mean JJA minimum temperature exhibited a significant positive trend with a projected increase per year over some locations like Nyagatare of +0.04^{O}C under RCP 4.5 W/M^2 and ranging from +0.05^{O}C in Gatumba to +0.03^{O}C in Masaka under RCP 8.5 W/M^2. Overall, projected JJA mean minimum temperatures exhibit no significant trend for the periods between 2021-2050 and 2041-2070 under RCP 4.5 W/M^2 and a significant positive trend under RCP 8.5 W/M^2 throughout all timescales.

The highest projected JJA minimum temperature is expected over eastern parts compared to western parts of Rwanda. In addition, projected minimum temperatures are expected to increase from 2021 to 2100, with more areas under RCP 8.5 W/M^2 to experience the highest minimum temperature towards 2100. Overall, changes in minimum temperatures are expected to increase from approximately 1.0 ^{o}C over most parts of Rwanda in 2021 to 3.0 ^{o}C over Nyagatare and Kayonza districts in the eastern province in 2100 under RCP 4.5 W/M^2 and from 1.0 ^{o}C over Rubavu Nyabihu, Rutsiro, Nyamasheke and Rusizi districts in western province, and Rwamagana, Bugesera and Ngoma districts in southern and provinces in 2021 to 6.0 ^{o}C over most parts of Rwanda in 2100 under RCP 8.5 W/M^2 during JJA season.

September October November December (SOND) season

Observed (1981-2010) mean SOND minimum temperature showed no significant trend countrywide. The near Term projected mean SOND minimum temperature exhibited a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Gatumba (Ngororero) to +0.01^{O}C in Nyamata (Bugesera) under RCP 4.5 W/M^2 and ranged

from +0.04^{O}C in Gatumba to +0.02^{O}C in Gisenyi under RCP 8.5 W/M^2. The medium Term projected mean SOND minimum temperature exhibits a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Nyagatare to +0.01^{O}C in Kamembe(Rusizi) under RCP 4.5 W/M^2 and ranging from +0.03^{O}C in Gatumba to +0.02^{O}C in Rubengera under RCP 8.5 W/M^2. The future Term projected mean SOND minimum temperature indicated no significant trend under RCP 4.5 W/M^2 and a significant positive trend with a projected increase per year ranging from +0.05^{o}C in Gatumba to +0.03^{o}C in Rubengera (Karongi) under RCP 8.5 W/M^2. Overall, the projected minimum temperature for the SOND season is expected to increase with the biggest anticipated changes under RCP 8.5 W/M^2 compared to RCP 4.5 W/M^2 over areas of Ngororero, Karongi, Rusizi, Rubavu and Nyagatare.

The highest projected SOND minimum temperature is expected over eastern parts compared to western parts of Rwanda. In addition, projected minimum temperatures are expected to increase from 2021 to 2100 with more areas under RCP 8.5 W/M^2 to experience the highest minimum temperature towards 2100. Overall, changes in minimum temperatures are expected to increase from approximately 1.0 ^{o}C over most parts of Rwanda in 2021 to 2.5 ^{o}C in 2100 under RCP 4.5 W/M^2 and from 1.0 ^{o}C over Kigali city, Northern, western, southern (Nyanza, Ruhango, Muhanga, and Kamonyi districts) and south of the eastern provinces in 2021 to 6.0 ^{o}C over southern, East of the northern provinces and north of the eastern province of Rwanda in 2100 under RCP 8.5 W/M^2 during SOND season.

Annual mean maximum temperature

There is a significant positive trend of observed (1981-2010) mean annual minimum temperature over some locations like Gabiro (Gatsibo) with an observed increase of +0.02^{o}C per year and a non-significant positive trend over other places like Mushubi (Ngamagabe) with an observed rise of +0.001^{o}C per year. Generally, the observed mean annual minimum temperature exhibits a positive trend. The near Term projected mean annual minimum temperature reveals a significant positive trend with a projected increase per year ranging from +0.02^{o}C in Gatumba to +0.01^{o}C in Nyamata under RCP 4.5 W/M^2 and ranging from +0.04^{o}C in Gatumba to +0.03^{o}C in Rubengera under RCP 8.5 W/M^2. Medium Term projected mean annual minimum temperature exhibits a significant positive trend with a projected increase per year ranging from +0.02^{O}C in Gatumba to +0.01^{O}C in Kamembe under RCP 4.5 W/M^2 and ranging from +0.04^{O}C in Gatumba to +0.02^{O}C in Rubengera under RCP 8.5 W/M^2. The future Term projected mean annual minimum temperature exhibited a significant positive trend with an annual projected increase ranging from +0.02^{O}C in Nyagatare to +0.01^{O}C in Rubengera under RCP 4.5 W/M^2. It ranged from +0.05^{O}C in Gatumba to +0.03^{O}C in Masaka under RCP 8.5 W/M^2. Overall, there is a significant positive trend in the projected annual mean minimum temperature under both RCP 4.5 W/M^2 and RCP 8.5 W/M^2.

Spatial analysis shows that the highest projected annual minimum temperature is expected over eastern parts compared to western parts of Rwanda. In addition, projected minimum temperatures are expected to increase from 2021 to 2100, with more areas under RCP 8.5 W/M^2 to experience the highest minimum temperature towards 2100. Overall, changes in minimum temperatures are expected to increase from approximately 1.0 ^{o}C over most parts of Rwanda in 2021 to 2.5 ^{o}C in 2100 under RCP 4.5 W/M^2 and from 1.0 ^{o}C over western, southern, northern (Musanze) and south of eastern provinces in 2021 to 6.0 ^{o}C over southern, northern, eastern (Kirehe, Kayonza, Gatsibo, Gichumbi and Nyagatare) and western (Karongi) provinces of Rwanda in 2100 under RCP 8.5 W/M^2

4.2 Analysis of maximum temperature

January-February season

The mean observed (1981-2010) maximum temperature showed a significant increase of +0.04^{o}C over Kamembe station in Rusizi district, while Gabiro in Nyagatare district showed a non-significant decreasing trend of -0.001^{o}C per year. The projected JF maximum temperature during the 2021-2050 period indicates an increasing trend with a larger increase under RCP 8.5 W/M^2 than RCP 4.5 W/M^2. Ruhengeri (Musanze) and Kamembe (Rusizi) show a significant increase of +0.04^{o}C and +0.02^{o}C per year under RCP 4.5 W/M^2 and RCP 8.5 W/M^2, respectively. Similarly, an increasing trend for 2041-2070 and 2071-2100 is expected under RCP 8.5 W/M^2 and increases higher than RCP 4.5 W/M^2.

Spatial analysis shows that the Eastern parts of Rwanda are expected to experience higher maximum temperature during the JF season of up to 30°C compared to western parts of Rwanda for the period 2021-2050 under both RCP 4.5 W/M^2 and RCP 8.5 W/M^2. In addition, RCP 4.5 W/M^2 is expected to have higher temperatures compared to RCP 8.5 W/M^2. Similar patterns of higher temperatures during the JF season over eastern parts of Rwanda compared to western parts of Rwanda are expected for the period 2041-2070 and for the period 2071-2100 under both RCP 4.5 and RCP 8.5 W/M^2. Overall, maximum temperatures are expected to increase from 1.5 °C in 2021 to 3.0 °C in 2100 under RCP 4.5 W/M^2. Similarly, maximum temperatures are expected to increase from 1.5°C in 2021 to 6.0°C in 2100 under RCP 8.5 W/M^2 during the JF season.

March, April May (MAM) season

Maximum temperatures have been increasing over southwestern parts compared to other parts and decreasing over northeastern parts of Rwanda. The projected MAM maximum temperature indicates an increasing trend for RCP 4.5 and RCP 8 5 for 2021-2050, with a significant increase of +0.05°C per year over Ruhengeri under RCP 4.5 W/M^2. However, a decreasing trend is expected from 2041 to 2070 under RCP 4.5 and an increasing trend under RCP 8.5 W/M^2. Similarly, the period 2071-2100 is characterized by a decreasing trend under RCP 4.5 compared to increasing trends under RCP 8.5 W/M^2 with a significant increase of +0.07°C at Rugobagoba (Kamonyi) under RCP 8.5 W/M^2.

Spatial analysis shows that the Eastern part of Rwanda is expected to experience higher maximum temperature during the MAM season compared to the western parts of Rwanda for the period 2021-2050 under both RCP 4.5 and RCP 8.5 W/M^2. In addition, RCP 4.5 is expected to have higher temperatures compared to RCP 8.5 W/M^2 Similar patterns of higher temperatures over Eastern parts of Rwanda compared to Western parts of Rwanda are expected for the period 2041-2070 and for the period 2071-2100 under both RCP 4.5, and RCP 8.5 W/M^2 Overall, changes in maximum temperatures are expected to increase from approximately 0 °C mostly in Nyabihu, Ngororero, Rutsiro, Rubavu, Nyamasheke and Rusizi in 2021 to 3.0 °C over most parts of Rwanda in 2100 under RCP 4.5 W/M^2 and from 1.0 °C mostly in Rusizi, Nyamasheke, Karongi, Rutsiro, Ngororero, Nyabihu, Rubavu, Musanze, Burera and Nyagatare in 2021 to 6.0 °C over most parts of Rwanda in 2100 under RCP 8.5 W/M^2 during MAM season.

June, July August (JJA) season

The observed (1981-2010) JJA season mean maximum temperature indicates a non-significant change over Rwanda. An increase of +0.02°C per year is observed over Gitega (Nyarugenge), while a decrease of -0.02°C is observed over Rwankeri (Nyabuhu). The Projected JJA season mean maximum temperature for 2021-2050, a significant increase of +0.06°C and +0.03°C is observed over Gatumba (Ngororero) and Kamembe (Rusizi), respectively, under RCP. In contrast, the increase of +0.03°C is marked over Ruhengeri (Musanze) and over Kamembe (+0.02°C) under RCP 8.5 W/M^2. Again, 2041-2070 showed an increase in maximum temperature of 0.04°C in Kamembe under RCP 8.5 W/M^2. For 2071-2100 a significant increase of 0.07°C and 0.05°C is reported at Gatumba (Ngororero) and Nyagatare, respectively, under RCP 8.5 W/M^2.

Spatial analysis shows that the Eastern part of Rwanda is expected to experience higher maximum temperature during the JJA season compared to western parts of Rwanda for the period 2021-2050 under both RCP 4.5 and RCP 8.5 W/M^2. In addition, RCP 4.5 is expected to have higher temperatures during the JJA season compared to RCP 8.5 W/M^2. Similar patterns of higher temperatures over eastern parts of Rwanda compared to western parts of Rwanda are expected for the period 2041-2070 and the period 2071-2100 under both RCP 4.5 and RCP 8.5 W/M^2 Overall, changes in maximum temperatures are expected to increase from approximately 1.5 °C over many parts of Rwanda in 2021 to 3.5 °C over northern, southern and south of western provinces of Rwanda in 2100 under RCP 4.5 W/M^2 and from 1.5 °C over eastern, north and south of western (Rusizi and Nyamasheke) provinces in 2021 to 6.0 °C over most parts of Rwanda in 2100 under RCP 8.5 W/M^2 during JJA season.

September October, November December (SOND) season

The observed (1981-2010) SOND season mean maximum temperature showed a non-significant increasing trend over Rwanda with a range of +0.01^{o}C to +0.03^{o}C per year in Rutsiro and Ruhango, respectively. The projected SOND season mean maximum temperature for 2021-2050 a significant increase of +0.04 in Gatumba (Ngororero) under RCP 4.5 W/M^2 and +0.03oC in Bukora (Kirehe) under RCP 8.5 W/M^2. For 2041-2070, a significant increase of +0.02^{o}c is expected in Ruhengeri under RCP 4.5 W/M^2 and from +0.07 (Gatumba) and +0.04 (Kamembe) under RCP 8.5 W/M^2. In addition, a significant increase in maximum temperature is also projected for 2071-2100 under RCP 8.5 W/M^2 at Gatumba and Kamembe (+0.006^{o}C and + 0.04^{o}C), respectively.

Spatial analysis shows that the Eastern part of Rwanda is expected to experience higher maximum temperature during the SOND season compared to the Western parts of Rwanda for the period 2021-2050 under both RCP 4.5 and RCP 8.5 W/M^2 In addition, RCP 4.5 is expected to have higher temperatures compared to RCP 8.5 W/M^2 Similar patterns of higher temperatures over Eastern parts of Rwanda during SOND season compared to western parts of Rwanda are expected for the period 2041-2070 and the period 2071-2100 under both RCP 4.5, and RCP 8.5 W/M^2 Overall, changes in maximum temperatures are expected to increase from approximately 1.5 ^{o}C over many parts of Rwanda in 2021 to 3.5 ^{o}C over most parts of Rwanda in 2100 under RCP 4.5 W/M^2 and from 1.5 ^{o}C over many parts of Rwanda in 2021 to 6.0 ^{o}C over most parts of Rwanda in 2100 under RCP 8.5 W/M^2 during SOND season.

Annual mean maximum temperature

There was a significant increasing trend in mean maximum temperature of +0.01^{o}C at Kamembe (Rusizi) and +0.01^{o}C at Bukora (Kirehe), while the rest of the country observed a non-significant increasing trend for the period 1981-2010. The projected annual maximum temperature trend shows an increase under both RCP 4.5 W/M^2 with a significant increase of + 0.04 and + 0.02 at Ruhengeri (Musanze) and Kamembe (Rusizi), respectively. Again, the same increase is projected for Kamembe and Ruhengeri stations under RCP 8.5 W/M^2 for 2021-2050. From 2041 to 2070, a significant increasing trend (+0.02) is expected in Gisenyi (Rubavu) under RCP 4.5 W/M^2 and over Gatumba and Kamembe with +0.06^{0}C and +0.04^{0}C respectively under RCP 8.5 W/M^2. From 2071-2100, a significant increasing trend is shown at Kamembe with 0.04^{0}C under RCP84, while Gatumba marks a significant increase for both RCP 4.5 W/M^2 and RCP 8.5 W/M^2.Again, Gatumba is projected to receive a non-significant decreasing trend of -0.01 under RCP 4.5 W/M^2.

Spatial analysis shows that areas expected to receive higher maximum seasonal and annual temperatures are the Bugarama valley and Kagitumba in Nyagatare district with temperatures ranging between 30-32^{o}C, Amayaga areas and Bugesera with temperatures ranging between 28-30^{o}C. Maximum temperature reduces from eastern toward the central plateau with a maximum temperature ranging between 26-28^{o}C. In contrast, lower maximum temperatures are observed over the western and northern highland areas, especially over Musanze and Nyabihu, with temperatures less than 14^{o}C. Over most parts of Rwanda, maximum temperatures are expected to increase from 1.5 ^{o}C in 2021 to 3.5 ^{o}C in 2100 under RCP 4.5 W/M^2 and from 1.5 ^{o}C in 2021 to 6.0 ^{o}C in 2100 under RCP 8.5 W/M^2.

4.3 Analysis of extreme temperature

Cold days (TX10p)

There was a non-significant increasing trend of observed (1981-2010) annual number of cold days countrywide, ranging from +0.12 days per year in Kibungo (Ngoma) to +0.001 days per year in Kamembe. Generally, the projected number of cold days shows a decrease during the period 2021-2050, with more areas expected to experience a greater number of cold days under RCP 8.5 W/M^2 compared to RCP 4.5 W/M^2. In addition, the period 2041-2070 shows the decreasing trend of the projected number of cold days with more decrease expected under RCP 8.5 W/M^2 compared to RCP 4.5 W/M^2. However, most parts of eastern Rwanda showed increasing trends in the number of cold days for 2071-2100. In contrast, regions over western Rwanda showed a decreasing trend in the number of cold days and thus a decreasing trend in the projected number of cold days with more decrease expected under RCP 8.5 W/M^2 compared to RCP 4.5 W/M^2.

Cold nights (TN10p)

There is a significant negative trend of observed (1981-2010) annual number of cold nights with an observed decrease in the number of cold nights per year of -0.31 days per year in Gabiro. The projected annual number of cold nights (2021-2050) exhibits a significant negative trend with a decrease in the number of cold nights per year ranging from -75.9%/-0.25 days per year in Byimana to -143.94%/-0.48 days per year in Gisenyi under RCP 4.5 W/M^2 and ranged from -75.7%/-0.25 days per year in Nyamata to -207.29%/-0.68 days per year in Nyagatare under RCP 8.5 W/M^2. Similarly, the projected annual number of cold nights (2041-2070) exhibits a significant negative trend with a projected decrease in the number of cold nights per year ranging from -78.45%/-0.2 in Kamembe to -128.94%/-0.2 in Butare under RCP 4.5 W/M^2 and ranged from -118.79%/-0.18 in Nyamata to -223.46%/-0.13 in Rugunga (Nyarugenge) under RCP 8.5 W/M^2. Additionally, the projected annual number of cold nights (2071-2100) exhibits a non-significant negative trend for a projected decrease in the number of cold nights under RCP 4.5 W/M^2. Overall, the number of cold nights is expected to decrease in Rwanda under both RCP 4.5 W/M^2 and RCP 8.5 W/M^2 from 2021 to 2100.

Warm days (TX90p)

The observed trend (1981-2010) for an annual number of warm days showed a non-significant increasing trend in Rwanda, ranging from +0.19 days per year in Save to +0.06 days per year in Kamembe. The projected number of warm days shows an increase during 2021-2050 under RCP 4.5 W/M^2 and with more areas expected to experience an increased number of warm days under RCP 8.5 W/M^2 compared to RCP 4.5 w/m^2. During 2041-2070, an increasing trend of the projected number of warm days during RCP 4.5 W/M^2 and RCP 8.5 W/M^2 with more increase expected under RCP 8.5 W/M^2 compared to RCP 4.5 W/M^2. During 2071-2100, RCP 4.5 W/M^2 and RCP 8.5 W/M^2 show a marked increase in the projected number of warm days. Western, northern, Bugesera district and northeastern areas are expected to receive a higher increase in warm days compared to the rest of the country for both scenarios. However, the Nyamagabe district is predicted to observe a non-significant decrease in warm days under RCP 4.5 W/M^2.

Warm nights (TN90p)

A non-significant positive trend was observed (1981-2010) for annual warm nights countrywide. The projected annual number of warm nights (2021-2050) exhibits a significant positive trend with a projected increase in the number of days per year ranging from +153.12%/+0.51 in Gisenyi to +95.21%/+0.32 in Butare under RCP 4.5 W/M^2 and ranged from +235.41%/+0.78 in Rutsiro to +110.0%/+0.36 in Nyamata under RCP 8.5 W/M^2. Similarly, the projected annual number of warm nights (2041-2070) exhibits a significant positive trend with a projected increase in the number of warm days ranging from +93.35%/+0.76 in Nyagatare to 60.98%/+0.46 in Gikongoro under RCP 4.5 W/M^2 and ranged from +153.1%/+1.98 in Kawangire to +67.65%/+0.51 in Nyamata under RCP 8.5 W/M^2. The projected annual number of warm nights (2071-2100) exhibits a significant positive trend, with the increase ranging from +90.11%/+1.11 in Gikongoro to +40.67%/+0.51 in Nyamata under RCP 4.5 W/M^2 and significant positive increase for some locations like Nyamata with a projected increase in the number of warm nights per year of +48.91%/+0.61 under RCP 8.5 W/M^2. The trend of the projected number of warm nights is expected to increase between 2021 and 2100 under RCP 4.5 W/M^2 and RCP 8.5 W/M^2. In contrast, under RCP 8.5 W/M^2, non-significant positive trends are expected in some locations towards 2100. The increase in the number of warm nights is an indicator of increased discomfort nights due to higher temperatures.

4.4 Impacts of observed and projected changes in temperature

Overall, Areas of higher maximum seasonal and annual temperatures are in the Bugarama valley and Kagitumba in Nyagatare district between 30 and 32^{o}C, Amayaga areas and Bugesera district between 28 and 30^{o}C. Maximum temperature reduces from eastern toward the central plateau with a maximum temperature ranging between 26-28^{o}C. In contrast, lower maximum temperatures are observed over the western and northern highland areas, especially Musanze and Nyabihu, with less than 14^{o}C. Maximum and minimum temperatures are expected to increase towards 2100**.** The increasing temperature could enhance solar energy production. While certain temperature projections

indicate a negative impact on the different sectors, others suggest that consequences will be modest or even benefit the sector. For example, banana production is likely to be unaffected as this crop grows well at higher temperatures.

Conversely, bean yields will decrease as the cooler temperatures required for optimal production are no longer consistent. Worth noting that Rwanda's main cash crops, coffee and tea, are expected to be negatively affected by climate change as both require specific temperatures for efficient production. For instance, temperatures higher than 25^{o}C cause reduced photosynthesis and prolonged exposure to temperatures above 30^{o}C incur so-called 'leaf chlorosis' and generates 'star flowers' (or blossom wilting), as well as defective fruit sets. High temperatures also develop plant diseases such as the 'coffee leaf rust (Hemileia vastatrix) and fruit blight (Cercospora cafeicola) and accelerate fruit maturation, whilst low temperatures facilitate coffee berry diseases. In addition, temperature increases will force farmers to plant these crops at higher altitudes, where the temperature is likely more suited to their production. However, the steeper gradients in these areas are prone to erosion, and conflicts may occur with small-scale farmer's areas that already occupy them. Rising temperatures also increase crop and livestock disease outbreaks, resulting in asset losses and further declines in crop yield, which in turn cause profit losses for farmers, rising food prices and an increase in household poverty and financial insecurity. For example, studies have found that climate change-induced temperature rises are expanding malaria zones into higher altitudes where the colder temperature previously created a natural barrier against the disease. The projected temperature increases are expected to increase the risk of contraction (up to 150% by the 2050s) in rural populations living in previously malaria-free areas, such as those at high altitudes. This increase in the country's disease burden is expected to be considerable. Additional effects of climate change include malnutrition because of decreased food security. Impacts of increasing temperatures will also include displacement of wet and dry seasons and, therefore displacement of livestock in the eastern region in search of pasture and water with drought expected to lead to dehydration, causing the fatigue of livestock and the occurrence of respiratory diseases.

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