FUTURE TEMPERATURE PROJECTIONS FOR RWANDA USING STATISTICAL DOWNSCALING

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Declaration

I declare that this dissertation contains my own work except where specifically acknowledged

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Abstract

Climate change is considered to be one of the greatest environmental threats to the world, and the changes in climate extremes are estimated to have greater negative impacts on human society and the natural environment than the changes in mean climate. Under This study presents the projections of future temperature over Rwanda .SDSM downscaling method was used as a tool for downscaling weather data statistically in Rwanda. Four Global Climate Models (GCMs), CNRM-CERFACS-CNRM-CM5, ICHEC-EC-Earth, MOHC-HadGEM2-ES, MPI-M-MPI-ESM-LR have been used to project future temperature.

The predictor variables are extracted from: Coordinated Regional Climate Downscaling Experiment (CORDEX) under RCP scenarios RCP 8.5 have been presented for future periods: 2021-2050 Different methods were used for verifying the performance of the simulation .After analysis (Maximum temperature increases in future for almost all the scenarios for both GCMs.). After analysis, the model MPI-M-MPI-ESM-LR became more useful compared to others.

Key words: Climate change, Temperature, Downscaling, Rwanda

LIST OF ACRONYMS AND ABBREVIATIONS

CORDEX	Coordinated Regional Climate Downscaling Experiment
GCM	General Circulation Model
RCM	Regional Climate Model
IPCC	Intergovernmental Panel on Climate Change
RCP	Representative Concentration Pathways
SDSM	Statistical downscaling model
IIASA	Integrated Assessment Framework by the International Institute for Applied Systems Analysis
JGCRI	Joint Global Change Research Institution
RMSE	root mean square error
MAE	mean absolute error

GLOSSARY

Climatology: Long-term average of a given variable, often over time periods of 20 to 30 years. For example, a monthly climatology consists of a mean value for each month computed over 30 years, and a daily climatology consists of a mean value for each day.

Downscaling: Derivation of local to regional-scale (10-100 kilometers) information from larger scale modeled or observed data. There are two main approaches: dynamical downscaling and statistical downscaling.

Emissions Scenario: Estimates of future greenhouse gas emissions released into the atmosphere. Such estimates are based on possible projections of economic and population growth and technological development, as well as physical processes within the climate system.

General Circulation Model (GCM): A global, three-dimensional computer model of the climate system that can be used to simulate human-induced climate change. GCMs represent the effects of such factors as reflective and absorptive properties of atmospheric water vapor, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures, and ice boundaries

Spatial downscaling: Refers to the methods used to derive climate information at finer spatial resolution from coarser spatial resolution GCM output. The fundamental basis of spatial downscaling is the assumption that significant relationships exist between local and large-scale climate.

Temporal downscaling: Refers to the derivation of fine scale temporal data from coarser-scale temporal information (e.g., daily data from monthly or seasonal information). Its main application is in impact studies when impact models require daily or even more frequent information.

Predictor: A variable that can be used to predict the value of another variable. In downscaling, the predictor is the large-scale climate variable

Predictand: The variable that is to be predicted. In downscaling, the predictand is the local climate variable of interest

Regional Climate Model (RCM): High-resolution (typically 50 kilometers) computer model that represents local features. It is constructed for limited areas, run for periods of ~20 years, and driven by large-scale data

Systematic bias: The difference between the observed data and modeled results that occurs due model imperfections.

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Chapter one

I.1 INTRODUCTION

Temperature variations influence agriculture, architecture, power generation and use, including electrical power for heating and cooling; melting of snow and the effects of freezing and icing on transportation systems; flowering and harvesting dates. For growing of almost all plants, it is necessary to keep them in a certain sustainable temperature. The temperature plays a key role in the development and growth of plants as a source of heat energy[1] The main reason for this temperature increase is carbon dioxide and other heat-trapping “greenhouse” gases that human activities produce. The biggest source of added carbon dioxide is from people burning coal and other fossil fuel[2] According to climate scientists, our world is highly likely to continue to warm over this century and beyond. This conclusion is based on scientists’ understanding of how the climate system works and on computer models designed to simulate Earth’s climate. Results from a wide range of climate model simulations suggest that our planet’s average temperature could be between 2 and 9.7°F (1.1 to 5.4°C) warmer in 2100 than it is today.

Many studies have investigated surface air temperature change because variations in this parameter are thought to be indicative of climatic fluctuations and change.

I.2 Problem Statement

In the 21st century, climate change is considered to be one of the greatest environmental threats to the world, and the changes in climate extremes are estimated to have greater negative impacts on human society and the natural environment than the changes in mean climate[3] Although Rwanda is a low-carbon economy; it is among those most vulnerable to climate change. Rwanda has been faced with unusual irregularities in climate patterns including extreme temperatures. Severe weather events, particularly droughts, have historically imposed heavy costs in Rwanda.

Droughts associated with extreme temperatures have been reported ever more in Eastern part of Rwanda. Droughts and extreme Temperatures are known to affect the Eastern part. In Bugesera District of the Eastern Province was affected by the drought in 1999 and 2000, and until 2007 no great change has been observed and the whole area would dry for almost six months every year. The droughts resulted into serious hunger and food shortage and forced tens of thousands of people to leave their homes.

I.3 Objectives

- Investigating past/present temperature and temperature projection in Rwanda
    - to assess future variation of temperature in Rwanda
    - to testify the capability of SDSM in downscaling extreme events in temperature to project their future patterns for Rwanda.

1.4 Hypothesis of the Study

Temperature over Rwanda has undergone strong variability, resulting in properties damage. That variability is likely to continue even in the future.

1.5 Justification of the problem

The main economic activity in Rwanda is agriculture, contributing about 80% of GDP. Temperature extremes affect crop production resulting in food insecurity. Infrastructures are damaged and even there is death of people during extreme temperature events. This study will help decision makers being aware of extreme temperature variability and plan accordingly. It will also bridge the gap in climate research in Rwanda as there are no sufficient works previously done on this matter.

I.6 Study area

Rwanda is a small mountainous, landlocked country in the Great Lakes region of Africa. Bordered by the Democratic Republic of the Congo (DRC), Burundi, Tanzania and Uganda, it is located at 02˚00 Latitude South and 30˚00 Longitude East. Total land area is about 24,950 km2, and inland lakes cover about 1390 km^2. Because of
the high altitude of the country, Rwanda has a pleasing moderate and tropical climate.

I.6.1 Topography

The Rwandan relief is hilly and mountainous with an altitude varying between 900 m and 4507 m. The components of that relief are: Congo Nil Ridge overlaying Lake Kivu with an altitude between 2500 m and 3000 m. It is dominated in the North West by the volcanic ranges consisting of five volcanic massifs of which the highest is Karisimbi itch 4507 m. The central plateau presents a relief of hills with an altitude ranging between 1500 m and 2000 m. The lowlands of the East are dominated by a depression characterized by hills with a more or less round top and 1000 to 1500 m in altitude. The lowlands of the South-West in Bugarama plain with an altitude of 900 m are part of the tectonic depression of the African Rift Valley.

I.6.2 Temperature climatology of Rwanda.

Rwanda has a tropical temperate climate due to its high altitude. The average annual temperature ranges between 16°C and 20°C, without significant variations. Rainfall is abundant although it has some irregularities. Winds are generally around 1-3 m/s. In the high regions of the Congo-Nile ridge, average temperatures ranges between 15 and 17°C and the rainfall is abundant. The volcanic region has much lower temperatures that can go below 0°C in some places. In areas with intermediary altitude, average temperatures vary between 19 and 21°C and the average rainfall is around 1000 mm /year. Rainfall is less irregular, and sometimes causes periods of drought. In the lowlands (East and Southeast), temperatures are higher and the extreme can go beyond 30°C in February and July-August. The absolute temperature of 32.8°C was recorded in the Southeast by Karama-Plateau . Temperature in Rwanda varies throughout the year with two maxima and two minima. The low maximum temperature occurs in February while the high maximum temperature occurs in August. The two minima occur respectively in June and in November. The average temperature for Rwanda is around 20˚C and varies with the topography. The warmest annual average temperatures are found in the eastern plateau (20˚C - 21˚C) and south-eastern valley of Rusizi (23˚C - 24˚C), and cooler temperatures are found in higher elevations of the central plateau (17.5˚C - 19˚C) and highlands (<17˚C). Observations from the National Meteorological Service have indicated that during the last 30 years minimum temperature has risen up to two degrees. The year 2005 was the hottest year for many years in Rwanda. Minimum temperature climbed to 20.4˚C in August and maximum temperature climbed to 35˚C in the Capital City, Kigali

Chapter two

2.0 LITTERATURE REVIEW

2. 1 Temperature Variability

Changes in temperature-related excess mortality are also highly dependent on the extent of warming expected under alternative emission scenarios. The strongest effects are projected under RCP8.5, a scenario characterized by unabated greenhouse gas emissions and an associated steep increase in temperature[4].

Global atmospheric temperature is predicted to rise by approximately 4 ˚C by 2080, consistent with a doubling of atmospheric CO2 concentration. As temperature rises, the efficiency of photosynthesis increases to a maximum and then falls, while the rate of respiration continues to increase more or less up to the point that a plant dies In response to global warming, the hydrological cycle is expected to accelerate as rising temperatures increase the rate of evaporation from land and sea. In Rwanda, Temperature predictions suggest that the country's temperature will increase another 1-2.5℃ between 2000 and 2050, and 1-6℃ by 2100. The increase is expected to be consistent across the country and across seasons – although the increase in the long dry season may be slightly higher than in other seasons. Besides influencing on crop yields , this will make previously malaria-free highlands more susceptible or even highly suitable for malaria in several decades12, with populations a risk increasing by 150% by 2050 [5].

2.2 Regional climatic variability of Temperature Greenhouse Forcing and Land Use Changes.

Human activity is supposed to affect the earth's climate mainly via two processes: the emission of greenhouse gases and aerosols and the alteration of land cover. While the former process is well established in state-of-the-art climate model simulations, less attention has been paid to the latter. However, the low latitudes appear to be particularly sensitive to land use changes, especially in tropical Africa where frequent drought episodes were observed during recent decades. Here several ensembles of long-term transient climate change experiments are presented with a Global climate model to estimate the future pathway of Rwanda climate under fairly realistic forcing conditions. Therefore, the simulations are forced with increasing greenhouse gas concentrations as well as land use changes until 2100. Three different scenarios are prescribed in order to assess the range of options inferred from global political, social, and economical development. The authors find a prominent surface heating and a weakening of the hydrological cycle over most of tropical Africa, resulting in enhanced heat stress and extended dry spells. In contrast, the large-scale atmospheric circulation in upper levels is less affected, pointing to a primarily local effect of land degradation on near-surface climate. In the model study, it turns out that land use changes are primarily responsible for the simulated climate response. In general, simulated climate changes are not concealed by internal variability. Thus, the effect of land use changes has to be accounted for when developing more realistic scenarios for future Rwanda climate[6]

2.3 Impact of climate change

Climate changes can directly affect human health by varying exposure to non-optimal outdoor temperature. However, evidence on this direct impact at a global scale is limited, mainly due to issues in modeling and projecting complex and highly heterogeneous epidemiological relationships across deferent populations and climates [4].

Observed changes in climate, especially warmer regional temperatures, have already affected biological systems in many parts of the world (IPCC 2001b, Chapters 5, 10, 13; IPCC 2002; CBD 2003, Chapter 2). There have been changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks, especially in forested systems. Many coral reefs have undergone major, although often partially reversible, bleaching episodes, when sea surface temperatures have increased by 1 Celsius during a single season (IPCC 2001b, Chapters 6, 17), with extensive mortality occurring with observed increases in temperature of 3 Celsius[7]

2.4 GENERAL CIRCULATION MODELS

General Circulation Model (GCM) is a tool that numerically simulates changes in climate as a result of slow changes in some boundary conditions like solar constant or physical parameters like greenhouse gases concentration (Greets & Linacre, 1998). These models represent physical processes in the atmosphere, ocean, cryosphere and land surface

General or global circulation models (GCMs) simulate the Earth's climate via mathematical equations that describe atmospheric, oceanic, and biotic processes, interactions, and feedbacks. They are the primary tools that provide reasonably accurate global-, hemispheric-, and continental-scale climate information and are used to understand present climate and future climate scenarios under increased greenhouse gas concentrations [8]

General circulation models are the most used models in depicting the changes of climate. The GCMs are the most comprehensive and exhaustive models. It is basically a mathematical model based on the general circulation of the earth's atmosphere and ocean. Many complex equations of fluid dynamics like Navier-Stokes equation, thermodynamic principles, Coriolis force and many more complex phenomena are employed[9]

Global Climate Models (GCMs) used for climate studies and climate projections are run on large scale and cannot be used to simulate sub grid scale feature. In order to get climate information on small scale, there is need to change from coarse to higher resolution, thus the need to downscale[10]

A GCM is composed of many grid cells that represent horizontal and vertical areas on the

Earth's surface as shown in figure 1

2. 4 Downscaling

Downscaling is a process of taking a known information at large scale to make predictions on a small scale. Downscaling can be applied spatially and temporally. Oftentimes, several downscaling methods are combined to obtain climate change information at desired spatial and temporal scales[8]. It is subdivided into dynamical and statistical downscaling. Both the methods have their advantages and disadvantages.

In the present study statistical downscaling method is used. Statistical downscaling can capture the predictive signal evident in the global hindcasts and in general shows a similar performance, although losing a bit the predictive skill at grid-box scale[11]

Also GCMs used are from AR5 in this project. In AR5 more comprehensive RCP is being used. RCP is the representative concentration pathways. RCP is better approach as it employs parallel approach[9]. Visual representation of the concept of downscaling is shown in figure 2.

2. 4.1 Statistical downscaling

Statistical downscaling involves the establishment of empirical relationships between historical large-scale atmospheric and

local climate characteristics. Once a relationship has been determined and validated, future large-scale atmospheric conditions projected by GCMs are used to predict future local climate characteristics. In other words, large-scale GCM outputs are used as predictors to obtain local variables or predictands. Statistical downscaling encompasses a heterogeneous group of methods that vary in sophistication and applicability. Statistical downscaling methods are computationally inexpensive in comparison to RCMs that require complex modeling of physical processes. Thus, they are a viable and sometimes advantageous alternative for institutions that do not have the computational capacity and technical expertise required for dynamical downscaling. Unlike RCMs, which produce downscaled projections at a spatial scale of 20–50 kilometers, statistical methods can provide station-scale climate information[12].

In contrast to the dynamical method, the statistical methods are easy to implement and interpret. They require minimal computing resources but rely heavily on historical climate observations and the assumption that currently observed relationships will carry into the future. However, high quality historical records often are not available in developing countries[8]

2.4.2 Main function of SDSM

A. Quality control and data transformation

There can be few meteorological stations have 100% complete or fully accurate data sets. Handling of missing and imperfect data is necessary for most practical situations. The 'Quality Control' identifies gross data errors, specification of missing data codes and outliers prior to model calibration. Transformation function will apply selected transformations for selected data files.

B. Screening of downscaling predictor variables

Identifying empirical relationships between gridded predictors (such as mean sea level pressure) and single site predictant (such as minimum temperatures) is vital to all statistical downscaling methods. The main purpose of the screen variables operation is assisting to decide and select appropriate downscaling predictor variables.

C .Model Calibration

This operation takes user-specified predictand along with a set of predictor variables, and estimates the parameters of multiple regression equations via an optimization algorithm by either dual simplex or ordinary least squares methods.

It is needed to specify the model structure: whether monthly, seasonal or annual sub-models are required; whether the process is unconditional or conditional. In unconditional models a direct link is assumed between the predictors and predictant. In conditional models, there is an intermediate process between regional forcing and local weather.

D. weather Generator

This operation generates ensembles of synthetic daily weather series given observed (or NCEP reanalysis) atmospheric predictor variables. This procedure enables the verification of calibrated models (using independent data) and synthesis of artificial time series for present climate conditions. Also, specification of the period of record to be synthesized and the desired number of ensembles are needed.

E. Data Analysis

This provides means of interrogating both downscaled scenarios and observed climate data with summary statistics and frequency analysis. This will allow use r to specify the sub-period, output file name and chosen statistics. For model output, ensemble member or mean must also be specified.

F. Graphical Analysis

This provides the options to analyze frequency analysis, compare results and time series analysis

2.4.3. Scenarios of AR5

Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth assessment report (AR5) .They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of Radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2, respectively).

In this study we considered RCP **8.5 .** The **RCP 8.5** was developed using the MESSAGE model and the IIASA Integrated Assessment Framework by the International Institute for Applied Systems Analysis (IIASA), Austria. This RCP is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels.

Chapter three

3.0 DATA AND METHODOLOGY

3.1 Data

3.1.1 Station data

Observed long term meteorological data, thirty years of maximum and minimum temperature baseline data for the period 1981-2010 was collected from Rwanda Meteorological Agency (meteo Rwanda)

Monthly mean values of temperature are computed from their corresponding daily values calculated from the maximum and minimum temperatures over the each month,

3.1.2 GCM Data

The historical and projected model output were collected on the Coordinated Regional Climate Downscaling Experiment CORDEX Africa portal (http://wcrpcordex.ipsl.jussieu.fr/) which is an international coordinated effort under the auspices of the World Climate Research Programmer’s Working Group on Regional Climate to provide homogeneously designed regional climate model output to users[14]. The models selected are highly applicable for African climate studies[15].

3. 2 METHODOLOGY

Statistical measures were used to assess the performance of each model to simulate the temperature over Rwanda. The method used under this study consist of Pearson correlation, , mean absolute error and the index of agreement.

3.2.1 Pearson correlation

Pearson correlation was used to assess the relationship between the observed data and CORDEX data

$$r = \frac{\frac{1}{n}\sum_{t=1}^{n}(Oi-o)(Pi-p)}{\sqrt{\frac{1}{n}\left[\sum_{t=1}^{n}(Oi-o)^2\right]\left[\sum_{t=1}^{n}(Pi-p)^2\right]}}$$

3.2.2 Mean absolute error (MAE)

The mean absolute error (MAE) which is the arithmetic average of absolute differences between the observed (Oi) and predicted (Pi) values[16] [17][18] It is expressed as:

$$MAE = \frac{1}{n}\left[\sum_{i=1}^{n} |Pi - Oi|\right]$$

Where n is the number of observations, Pi is the predicted value, and Oi is the observed value. For perfect prediction, the MAE ranges between zero and large positive values but a perfect MAE is zero[19][20][21]

Where n is the number of observations, Pi is the predicted value, and Oi is the observed value.

3. 2.3 The index of agreement (d)

The index of agreement (d) was calculated as follows

$$\mathrm{d} = 1 - \left[\frac{\sum_{\mathrm{i}=1}^{\mathrm{n}}(\mathrm{Pi} - \mathrm{Oi})^2}{\sum_{\mathrm{i}=1}^{\mathrm{n}}(|\mathrm{Pi} - \mathrm{p}| + |\mathrm{Oi} - \mathrm{o}|)^2}\right]$$

Where n is the total number of observations, Pi is the predicted value, Oi is the observed value, and p and o are the means of the predicted and observed values, respectively. The relative accuracy measure‘d’ accounts for the differences between means and variances of Pi and Oi. It ranges between 0.0 and 1.0. Values close to 1.0 indicates better agreement between the Oi and Pi

In order to downscale our results, a simple linear regression were developed which estimates the intercept and slope of a linear model which predicts the value of a single dependent variable (y) against a single independent variable (x) in the form[20]

$y = a + b x$

Where a is the intercept of the straight line (the value of y when it crosses the Y-axis) while b is its slope

Annual mean temperature of observed data and predicted data

Chapter four

4.0 RESULT AND DISCUSSION

This chapter summarize the results obtained using various methods. The results include annual mean temperature of predicted and observed, projected future temperature under RCP 8.5.

Several statistical measures were performed in assessing the performance of CORDEX models in simulating the present climate Rwanda such as correlation coefficient, mean absolute error and index of agreement.

Annual mean temperature for six stations was assessed and the results are presented.

4.1 correlation coefficient, mean absolute error and index of agreement

Correlation coefficient, mean absolute error and index of agreement were used to assed capacity of model to simulate climate of Rwanda. After analyzing, it has been observed that all models do not present a good correlation with the observation; however the results in the (table 4,5,6,7,8,9)Indicate that the MPI- CLMCOM RCM has reasonable positive correlation compared to other models we have adopted using MPI-CL for future temperature projection over all station.

4.2 Projected average mean temperature

The difference between projected temperature and observed temperature data indicate how model is under or over estimate the observed temperature.

In (table 10) indicate over estimation for may and November in Kamembe station, in Nyamagabe station model will be under estimated for May, August and September, in Kigali station model indicate under estimation in November and December.

In Ngoma station model is under estimation for May, July, August and September

For Kayonza station model is under estimation for May and June. This means that in some months we will get increase in temperature at some location or decrease in temperature in some period.

4.2 Trend of annual mean temperature

Trend analysis was used to testify if there is trend between observed and predicted annual mean temperature.

As shown in (figure6, 7, 8, 9) there is a trend between observed and predicted mean temperature over Musanze , ngoma, Kayonza and Kigali stations.

4.3 Projection of future Temperature under RCP (8.5)

The projected January mean temperature reveals a decreasing variability over Kigali, musanze, Ngoma, Nyamagabe and Kayonza while an increasing variability was observed over Kamembe station respectively as shown in (figure 10) while The projected February mean temperature (Figure 11) variability reveals a decreasing variability over Kigali, musanze, Ngoma, Nyamagabe, Kayonza while an increasing variability was observed Kamembe station respectively. For march The results obtained from the projected mean temperature variability (Figure12) indicate an increasing variability over all stations used in this study while The results obtained from the projected April,May,july october,November and december mean temperature variability (Figure13, 14,15,18,19 and 20) indicate an increasing variability of temperature at all.

The results obtained from the projected August mean temperature variability (Figure16) indicate an increasing variability over Kigali, Kamembe and Ngoma while a decreasing variability was observed over Musanze, Kayonza and nyamagabe stations respectively.

The results obtained from the projected September mean temperature variability (Figure 17) indicate a decreasing variability over Kigali, Nyamagabe and Kayonza while an increasing variability was observed over Kamembe, Musanze and Ngoma stations respectively.

Chapter 5

CONCLUSION AND RECOMMENDATION

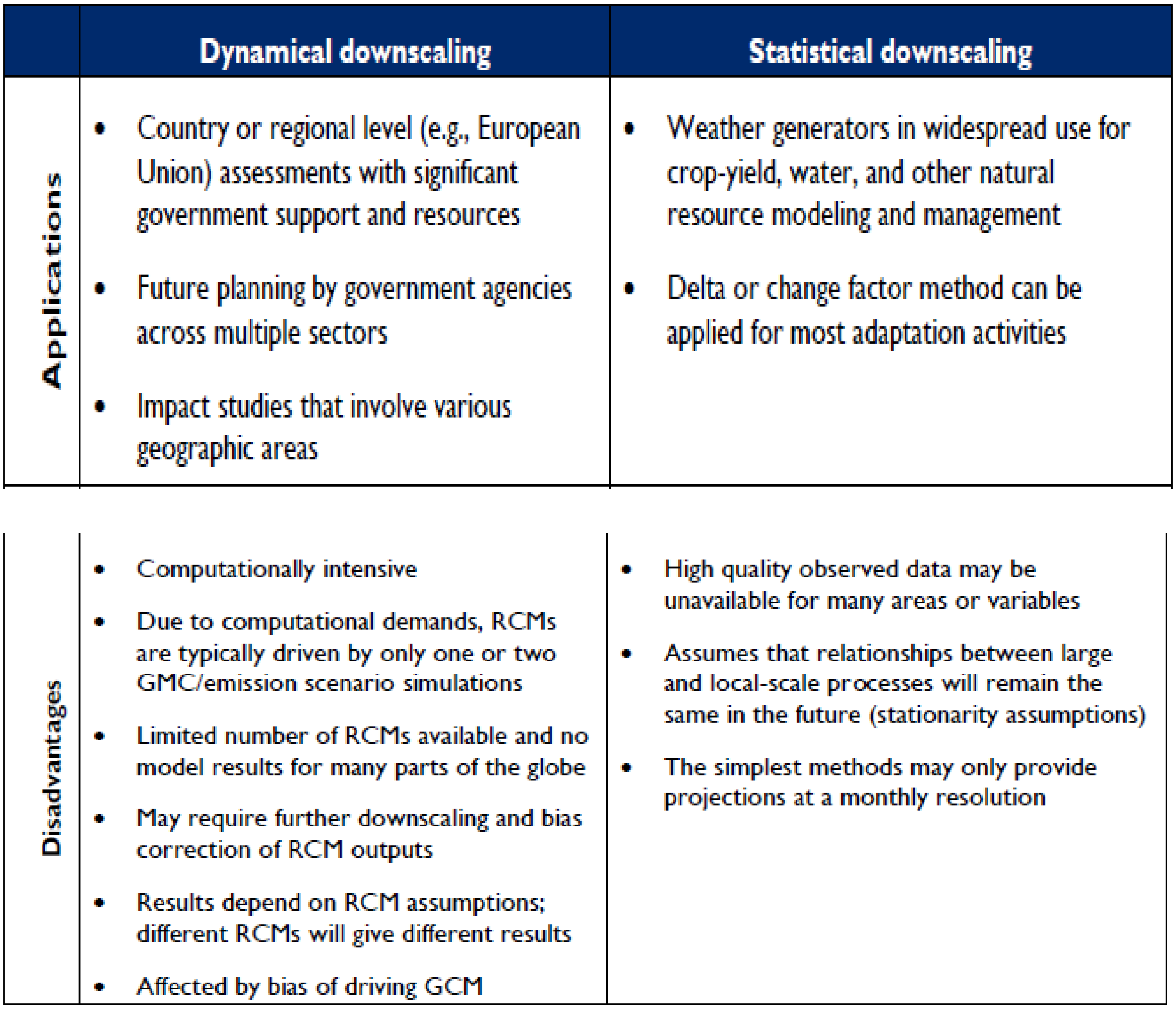
The previously cited conclusion and recommendations are made related one scenario, So it helpful to use other scenario to give more conclusions recommendation.

On the other hand ,I used one Regional Climate Model(RCM) driven by difference General circulation Model(GCM),other RCM may be also be evaluated to give more conclusions' and recommendations.

Due to complex, natural of Rwanda topography, it is highly recommended to use Regional Climate Model (RCM) designated to Rwanda

ADDENDUM 1: LIST OF TABLES

Table 1: Comparison of the main strengths and weakness of statistical and dynamical downscaling



	Dynamical downscaling	Statistical downscaling
Applications	• Country or regional level (e.g., European Union) assessments with significant government support and resources • Future planning by government agencies across multiple sectors • Impact studies that involve various geographic areas	• Weather generators in widespread use for crop-yield, water, and other natural resource modeling and management • Delta or change factor method can be applied for most adaptation activities
Disadvantages	• Computationally intensive • Due to computational demands, RCMs are typically driven by only one or two GMC/emission scenario simulations • Limited number of RCMs available and no model results for many parts of the globe • May require further downscaling and bias correction of RCM outputs • Results depend on RCM assumptions; different RCMs will give different results • Affected by bias of driving GCM	• High quality observed data may be unavailable for many areas or variables • Assumes that relationships between large and local-scale processes will remain the same in the future (stationarity assumptions) • The simplest methods may only provide projections at a monthly resolution

Table 2: Stations used

Stations	Longitude	Latitude
Musanze	29.63222	-1.49944
Kigali	30.13278	-1.965
Ngoma	30.5	-2.16
Kayonza	30.44778	-1.82417
Nyamagabe	29.57	-2.48
Kamembe	28.92	-2.47

Table 3: models used in this study

GCM	**RCM**
MPI	CLMCOM
CRNM	CLMCOM
ICHEC	CLMCOM
MHOC	CLMCOM

Table 4: Nyamagabe correlation coefficient, mean absolute error and index of agreemet

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM- CLMCOM	r	0.30	0.16	0.35	0.30	0.43	0.05	-0.05	0.16	0.04	0.16	0.38	0.32
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.03	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.03	0.02	0.02	0.02
MPI- CLMCOM	r	0.14	0.05	0.12	0.38	0.52	0.07	0.23	0.16	0.39	0.71	0.62	0.60
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.06	0.07	0.04	0.01	0.01
MOHC-CLMCOM	r	0.21	0.26	0.26	0.01	0.23	0.21	0.37	0.45	0.16	0.35	0.53	0.51
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.03	0.03	0.02	0.03	0.04	0.05	0.05	0.05	0.03	0.02	0.01	0.02
ICHEC-RCA4	r	0.44	0.01	0.18	0.37	0.25	0.37	0.08	0.07	0.05	0.29	0.40	0.26
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.03	0.02	0.02	0.03	0.04	0.05	0.05	0.05	0.03	0.02	0.01	0.02

Table 5: Kamembe correlation coefficient, mean absolute error and index of agreement

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM- CLMCOM	r	0.48	0.31	0.36	0.15	0.34	0.14	0.19	0.16	0.26	0.22	0.39	0.44
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.02	0.02
MPI- CLMCOM	r	0.48	0.28	0.05	0.48	0.35	0.07	0.03	0.02	0.21	0.64	0.67	0.51
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.04	0.03	0.05	0.04	0.03	0.02	0.05	0.08	0.06	0.02	0.02
MOHC- CLMCOM	r	0.24	0.19	0.25	0.24	0.19	0.12	0.19	0.22	0.14	0.52	0.50	0.29
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.04	0.04	0.03	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.01	0.02
ICHEC- CLMCOM	r	0.33	0.16	0.22	0.15	0.31	0.28	0.14	0.47	0.31	0.45	0.49	0.29
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.04	0.03	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.02	0.02

Table 6: Kayonza correlation coefficient, mean absolute error and index of agreement

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM- CLMCOM	r	0.5	0.1	0.3	0.4	0.4	0.4	0.1	0.1	0.2	0.1	0.4	0.5
	d	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	MAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MPI- CLMCOM	r	0.2	0.1	0.2	0.4	0.5	0.2	0.1	0.0	0.3	0.6	0.6	0.5
	d	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	MAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MOHC- CLMCOM	r	-0.1	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.3	0.6	0.6	0.6
	d	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	MAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ICHEC- CLMCOM	r	0.1	0.0	0.0	0.4	0.0	0.2	-0.1	0.1	0.1	0.5	0.5	0.3
	d	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	MAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7: Kigali correlation coefficient, mean absolute error and index of agreement

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM-CLMcom	r	0.35	0.18	0.08	0.15	0.47	0.15	0.21	0.15	0.09	0.21	0.41	0.49
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.04	0.04	0.03	0.04	0.05	0.05	0.05	0.06	0.05	0.04	0.03	0.03
MPI-CLMcom	r	0.08	0.19	0.20	0.20	0.33	0.07	0.03	-0.08	-0.02	0.55	0.70	0.11
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.02	0.03	0.04	0.03	0.04	0.03	0.04	0.07	0.07	0.05	0.01	0.02
MOHC-CLMcom	r	0.35	0.30	0.43	0.15	0.55	0.36	0.50	0.38	0.40	0.61	0.41	0.63
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.03	0.04	0.03	0.04	0.05	0.04	0.05	0.05	0.04	0.04	0.02	0.03
ICHEC-CLMcom	r	0.32	0.34	0.26	0.37	-0.04	-0.01	0.16	0.09	0.17	0.58	0.40	0.34
	d	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.05	0.04	0.03	0.03

Table 8: Musanze correlation coefficient, mean absolute error and index of agreement

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM-CLMcom	r	0.53	0.32	0.14	0.28	0.32	0.36	0.04	-0.05	0.20	0.23	0.47	0.53
	d	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.07	0.07	0.05	0.03	0.04	0.05	0.05	0.04	0.03	0.04	0.04
MPI-CLMcom	r	0.08	0.32	0.13	0.52	0.55	0.02	0.15	-0.14	0.24	0.57	0.71	0.54
	d	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.06	0.06	0.04	0.03	0.06	0.07	0.06	0.04	0.04	0.05	0.05
MOHC-CLMcom	r	0.16	0.15	0.36	0.09	0.45	0.23	0.45	0.23	0.20	0.53	0.57	0.48
	d	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.08	0.05	0.03	0.04	0.05	0.06	0.05	0.06	0.05	0.03	0.04	0.04
ICHEC-CLMcom	r	0.22	0.26	0.37	0.34	0.11	0.27	0.11	0.28	0.20	0.57	0.51	0.26
	d	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	MAE	0.05	0.08	0.07	0.05	0.03	0.04	0.04	0.06	0.04	0.03	0.04	0.04

Table 9: Ngoma correlation coefficient, mean absolute error and index of agreement

MODEL	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CNRM- CLMcom	r	0.6	0.2	0.33	0.36	0.32	0.25	0.32	0.28	0.29	0.2	0.41	0.48
	d	1	1	1	1	1	1	1	1	1	1	1	1
	MAE	0.01	0.01	0.02	0.02	0	0.03	0.03	0.01	0	0.01	0.02	0.01
MPI- CLMcom	r	0.11	0.1	0.16	0.44	0.47	0.13	0.1	0.15	0.41	0.61	0.65	0.53
	d	1	1	1	1	1	1	1	1	1	1	1	1
	MAE	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.03	0	0.03	0.03
MOHC- CLMcom	r	0.24	0.3	0.25	0.16	0.27	0.23	0.36	0.24	0.24	0.5	0.57	0.57
	d	1	1	1	1	1	1	1	1	1	1	1	1
	MAE	0.02	0.01	0.02	0.02	0	0.02	0.03	0	0.01	0.01	0.02	0.02
ICHEC- CLMcom	r	0.32	0.03	-0.06	0.29	-0.09	0.23	-0.11	-0.04	0.13	0.49	0.46	0.27
	d	1	1	1	1	1	1	1	1	1	1	1	1
	MAE	0.02	0.02	0.02	0.01	0	0.02	0.03	0.01	0	0.01	0.02	0.01

Table 10: Projected average mean temperature change

Months	Kamembe	Nyamagabe	Kigali	Ngoma	Kayonza	Musanze
January	-1.36099	0.052124	-0.64914	0.912793	-0.46315	1.28979
February	-1.23357	0.233729	-0.97893	0.701616	-0.36414	1.104478
March	-1.01512	0.019048	-0.97452	0.895841	-0.01298	1.101355
April	-1.12237	0.249951	-0.01687	1.228119	0.754299	1.262622
May	0.107259	-0.2309	-0.95765	-0.33228	-0.76728	-0.16127
June	-0.89194	0.112269	-0.81978	0.539542	-1.63218	-1.03573
July	-0.44966	0.196057	-0.7479	-0.22979	-0.43707	0.591609
August	-1.04223	-0.25489	-1.01824	-0.59043	-0.36843	0.948294
september	-2.0623	-0.45531	-2.20023	-0.62819	-1.52627	0.064843
October	-1.04283	0.86067	-0.83789	1.015002	-0.10508	0.059063
november	0.503687	0.704376	0.924776	0.815503	0.944306	0.860007
december	-0.10496	0.203114	0.010329	0.643167	-0.12657	0.738494

Table 11: Observed monthly climatological average temperature from 1981-2010

Months	obsmusanze	obskamembe	obskigali	obskayonza	obsngoma	obsnyamagabe
1	16.01667	20.425	21.28833	20.55333	20.86667	20.72167
2	15.64667	20.59667	21.6	20.63667	21.325	20.87667
3	15.74	20.37167	21.38	20.335	21.00667	20.68
4	16.14333	20.745	21.16833	20.02667	20.71333	20.40667
5	16.56167	20.46833	21.30833	20.27333	20.97333	20.525
6	15.895	20.15333	21.215	20.42167	21.73833	20.62667
7	15.53	19.96167	21.35333	20.485	22.03	20.69833
8	15.80167	20.57667	22.34667	21.03833	22.06	21.565
9	16.20833	21.365	22.22167	21.14167	21.98333	21.535
10	16.27833	20.73333	21.49667	20.605	21.31833	20.70667
11	16.16167	19.83167	20.90167	20.19667	20.76667	20.27167
12	16.02	19.77167	21.01167	20.33167	20.855	20.405

Table 12: Predicted monthly climatological average temperature from 1981-2010 for CNRM baseline

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	19.07061	19.73754	20.19031	21.25419	19.80257	17.30441
2	19.34971	19.99701	20.5022	21.57644	20.22807	17.84193
3	19.33037	19.93191	20.44873	21.55937	20.17849	17.8243
4	19.1447	19.60542	20.09093	21.21969	19.81174	17.58489
5	19.03745	19.39847	19.92625	21.07699	19.61959	17.40192
6	18.57611	19.11116	19.79871	20.94167	19.38222	16.99488
7	18.51784	19.30778	20.02268	21.22242	19.60352	16.93661
8	19.20701	20.06348	20.67339	21.86453	20.30146	17.41757
9	19.6733	20.58464	20.82897	22.02583	20.2836	17.37316
10	19.35735	19.96866	20.30653	21.48146	19.89663	17.27972
11	19.33804	19.74509	20.10028	21.28166	19.7862	17.24171
12	19.17911	19.68546	20.09782	21.12777	19.71743	17.15953

Table 13: Predicted monthly climatological average temperature from 1981-2010 ICHEC baseline

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	18.95856	19.68139	20.16604	21.20461	19.79055	17.23363
2	19.40337	20.06442	20.56273	21.67516	20.27481	17.84523
3	19.34555	19.95561	20.48476	21.5757	20.20623	17.89337
4	19.14784	19.51949	19.98882	21.12156	19.71908	17.54592
5	19.00356	19.43701	19.97381	21.1038	19.64202	17.40845
6	18.65673	19.15754	19.8328	20.97762	19.42372	17.03171
7	18.47003	19.23009	19.96181	21.16656	19.54709	16.87386
8	19.20951	20.09462	20.67687	21.88282	20.28461	17.42981
9	19.68962	20.55418	20.84879	22.04213	20.36546	17.46997
10	19.3592	20.03886	20.3152	21.48569	19.84308	17.18326
11	19.34436	19.79657	20.13942	21.27844	19.82068	17.30663
12	19.19155	19.64623	20.03773	21.14723	19.69898	17.16611

Table 14: Predicted monthly climatological average temperature from 1981-2010 MOHC baseline

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	19.32086	19.96913	20.45328	21.60444	20.02118	17.38126
2	19.35941	20.21	20.61567	21.78452	20.16347	17.38059
3	19.35649	19.98037	20.33497	21.48016	19.95291	17.27749
4	19.19521	19.82576	20.1776	21.32742	19.7831	17.25053
5	19.17387	19.69206	20.13004	21.26585	19.82674	17.39303
6	19.1551	19.72031	20.2426	21.40363	19.96238	17.50302
7	19.17608	19.69216	20.1518	21.24627	19.83804	17.4927
8	19.02155	19.60495	20.15794	21.22552	19.86449	17.47456
9	19.01447	19.46786	20.0466	21.17358	19.72812	17.40454
10	18.89011	19.48454	20.06715	21.19667	19.73085	17.32692
11	19.13218	19.79979	20.38436	21.54953	20.00528	17.45614
12	19.10771	19.82273	20.33467	21.5418	19.90238	17.29165

Table 15: Predicted monthly climatological average temperature from 1981-2010 for MPI baseline

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	19.32086	19.96913	20.45328	21.60444	20.02118	17.38126
2	19.35941	20.21	20.61567	21.78452	20.16347	17.38059
3	19.35649	19.98037	20.33497	21.48016	19.95291	17.27749
4	19.19521	19.82576	20.1776	21.32742	19.7831	17.25053
5	19.17387	19.69206	20.13004	21.26585	19.82674	17.39303
6	19.1551	19.72031	20.2426	21.40363	19.96238	17.50302
7	19.17608	19.69216	20.1518	21.24627	19.83804	17.4927
8	19.02155	19.60495	20.15794	21.22552	19.86449	17.47456
9	19.01447	19.46786	20.0466	21.17358	19.72812	17.40454
10	18.89011	19.48454	20.06715	21.19667	19.73085	17.32692
11	19.13218	19.79979	20.38436	21.54953	20.00528	17.45614
12	19.10771	19.82273	20.33467	21.5418	19.90238	17.29165

Table 16: Projected monthly climatological average temperature from 2021-2050 for CNRM model under RCP 4.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.38469	21.34011	22.19862	23.07427	21.76649	19.39619
2	20.64515	21.8153	22.3542	23.34591	22.19684	19.71096
3	20.43765	21.28563	21.89983	23.14662	21.73294	19.3083
4	20.29314	20.67366	21.21219	22.56714	21.02733	18.86131
5	20.03865	20.32737	20.9044	22.19739	20.71217	18.54468
6	19.46531	19.96592	20.77497	21.89766	20.40804	17.91152
7	19.44324	20.32304	21.10333	22.17559	20.75908	17.96874
8	20.22863	21.42323	22.21558	23.21266	21.85887	18.79208
9	20.95053	22.44237	22.85747	23.81063	22.30746	19.57301
10	20.80183	21.9361	22.4327	23.45609	21.72369	19.56045
11	20.48824	21.74761	21.92074	23.53649	21.61507	18.87586
12	20.18923	21.30248	21.53643	23.09145	21.295	19.00053

Table 17: Projected monthly climatological average temperature from 2021-2050 model under RCP 8.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.6896	21.75648	22.76249	23.56612	22.32395	19.77973
2	20.7484	22.11478	22.63418	23.69217	22.59681	20.043
3	20.62427	21.57018	22.11833	23.43429	21.87156	19.74497
4	20.55834	20.88893	21.51761	22.89588	21.25923	19.29563
5	20.41984	20.58698	21.25089	22.67644	21.10728	18.82233
6	19.7842	20.29617	21.18447	22.22217	20.81981	18.26207
7	19.41395	20.36345	21.20235	22.30624	20.91701	17.91987
8	20.22589	21.46367	22.37005	23.31425	21.96438	18.76994
9	21.02219	22.43007	22.91993	23.86907	22.38794	19.58833
10	20.56831	21.63433	22.2163	23.40727	21.71948	19.40116
11	20.83216	22.17729	21.91209	23.52131	21.64568	19.42911
12	20.75946	22.06297	21.91484	23.50992	21.68515	19.51326

Table 18: Projected monthly climatological average temperature from 2021-2050 for MPI model under RCP 4.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.6279	21.59343	22.40977	23.19009	21.9839	19.53555
2	20.56587	21.64816	22.5542	23.51153	22.23211	19.76255
3	20.74517	21.06881	21.68271	22.8067	21.40831	19.35657
4	20.40251	20.64363	21.24037	22.43561	21.12743	19.14898
5	20.06708	20.32235	20.95722	22.34987	20.87768	18.57461
6	19.65096	20.01569	20.8213	21.94646	20.53724	18.12864
7	19.60062	20.29696	21.01506	22.25071	20.78204	18.03161
8	20.34882	21.3856	22.10622	23.20909	21.79816	18.74247
9	20.24954	21.73327	22.16386	23.38154	21.62357	18.7593
10	20.19622	21.41598	21.7229	23.2844	21.22549	18.73782
11	20.7135	21.55638	22.02934	23.27936	21.43102	19.2354
12	20.68404	21.5873	21.84495	23.27416	21.42382	19.21363

Table 19: Projected monthly climatological average temperage from 2021-2050 for MPI model under RCP8.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.70704	22.06572	22.94895	23.91376	22.93382	20.0722
2	20.85276	22.0714	23.10928	24.04796	23.11077	20.50784
3	21.29447	21.80688	22.48273	23.70469	22.49343	20.60833
4	20.81867	21.09866	21.61023	22.95946	21.66078	19.87962
5	20.46224	20.9168	21.61855	22.91496	21.90811	19.18714
6	20.06051	20.41324	21.28029	22.28123	21.29383	18.82104
7	19.98913	20.70726	21.49812	22.54341	21.46737	18.61005
8	20.73614	21.92809	22.82288	23.63726	22.74334	19.39744
9	20.84417	22.43332	23.17066	24.16517	22.90917	19.8422
10	20.82942	22.05994	22.57235	24.01073	22.33618	19.65134
11	21.42789	22.10982	22.40596	24.01118	22.15689	19.94994
12	20.88786	21.87423	22.22357	24.06397	22.14986	19.65306

Table 20: Projected monthly climatological average temperature from 2021-2050 for MOHC model under RCP 4.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.61014	21.07085	21.69141	22.95037	21.34668	19.22246
2	20.17116	20.63642	21.26675	22.59053	20.96442	18.74363
3	20.18684	20.73998	21.37552	22.71906	21.08681	18.67163
4	20.15733	20.90597	21.47786	22.84666	21.19012	18.59394
5	20.1499	21.03408	21.59899	23.02533	21.23474	18.58696
6	20.58153	21.43912	21.94143	23.25868	21.51043	19.0194
7	20.76513	21.68587	22.13082	23.3933	21.61723	19.33688
8	20.80611	21.72133	22.17117	23.38459	21.58512	19.49274
9	21.09713	21.804	22.37241	23.62341	21.8601	19.89463
10	20.91083	21.46519	22.11254	23.32623	21.66555	19.82054
11	20.94884	21.50214	22.19114	23.39356	21.7972	19.80177
12	20.72828	21.2632	21.88282	23.16752	21.53668	19.41226

Table 21: Projected monthly climatological average temperature from 2021-2050 for MOHC model under RCP 8.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.83269	21.38771	21.9879	23.51311	21.59367	19.26287
2	20.60704	21.05962	21.68585	23.16984	21.39922	18.99762
3	20.37496	21.0064	21.65435	23.11475	21.38055	18.74737
4	20.45941	21.25068	21.8376	23.32173	21.50327	18.79523
5	20.46513	21.39957	21.96518	23.47733	21.60084	18.85648
6	20.72282	21.56918	22.1574	23.54792	21.69911	19.23742
7	21.20505	21.89719	22.51389	23.77271	21.92527	19.90655
8	21.41017	22.1146	22.65773	24.00455	21.96737	20.13254
9	21.44757	22.08466	22.68567	24.04028	21.96031	20.22002
10	21.37486	21.83398	22.43706	23.76396	21.75316	19.94837
11	21.12877	21.61692	22.2153	23.61427	21.58711	19.76357
12	21.06375	21.49311	22.02951	23.56194	21.50037	19.46529

Table 22: Projected monthly climatological average temperature from 2021-2050 for ICHEC model under RCP 4.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	20.43872	21.25922	22.47926	23.52281	22.01745	19.58442
2	20.72998	21.9475	22.77793	23.69782	22.68819	19.96421
3	20.75635	21.72627	22.42472	23.54029	22.80972	20.49041
4	20.32321	20.69656	21.32717	22.49314	21.30981	19.55309
5	20.16732	20.51904	21.25305	22.22029	21.04891	18.73628
6	19.50286	19.90319	20.72607	21.88194	20.65552	18.10494
7	19.28238	19.90657	20.69201	21.73737	20.46026	17.76614
8	20.22768	21.39478	22.10844	23.09397	21.95383	18.75719
9	20.59666	22.22733	22.57481	23.62218	22.26818	19.34806
10	20.60786	21.31868	21.73647	23.02846	21.47394	19.13432
11	20.55362	21.28289	21.59278	23.00593	21.46969	19.11323
12	20.36925	21.41906	22.01788	23.0538	21.5982	19.07906

Table 23: Projected monthly climatological average temperature from 2021-2050 for ICHEC model under RCP 8.5

Months	Kamembe	Gikongoro	Kigali	Ngoma	Kayonza	Musanze
1	21.00696	21.98412	22.96437	23.974	22.69495	20.01735
2	21.12038	22.47955	23.29351	24.1634	23.31412	20.24649
3	21.1426	21.84356	22.52465	23.42851	22.79237	20.65835
4	20.3792	20.96279	21.61947	22.8277	21.59761	19.80866
5	20.24446	20.69108	21.44199	22.62102	21.37106	19.11784
6	19.89141	20.0903	20.90908	21.99934	20.89013	18.46299
7	19.67362	20.49183	21.30898	22.36468	21.09583	18.23991
8	20.32827	21.80525	22.5252	23.47956	22.35352	18.99148
9	20.66336	22.62731	23.09492	24.08119	22.80282	19.71976
10	20.64883	21.63524	22.20758	23.3482	21.93033	19.72876
11	21.11566	21.74891	22.07364	23.4068	21.92813	19.80506
12	20.84942	22.11602	22.5204	23.85451	22.42468	19.80373

ADDENDUM 2: LIST OF FIGURE

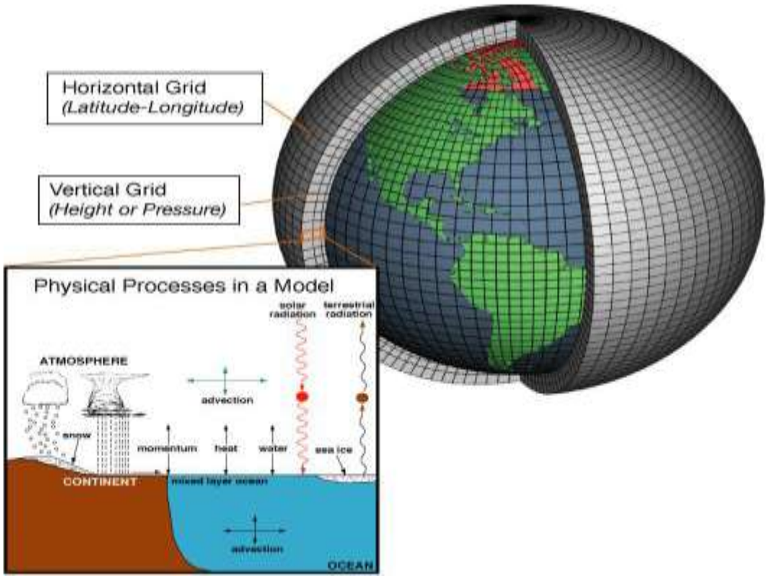


Figure 1: The process in a GCM

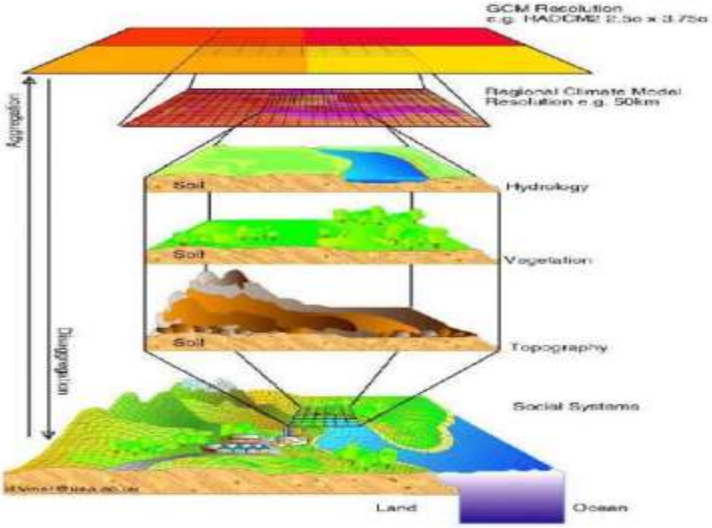


Figure 2: Representation of the concept of downscaling

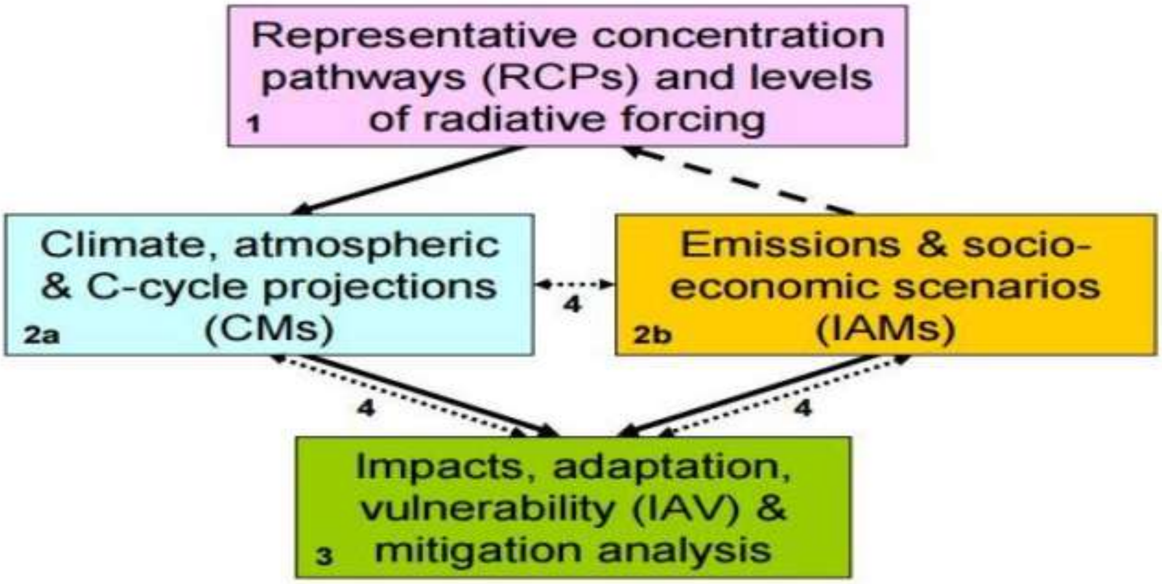


Figure 3 parallel approach of RCP

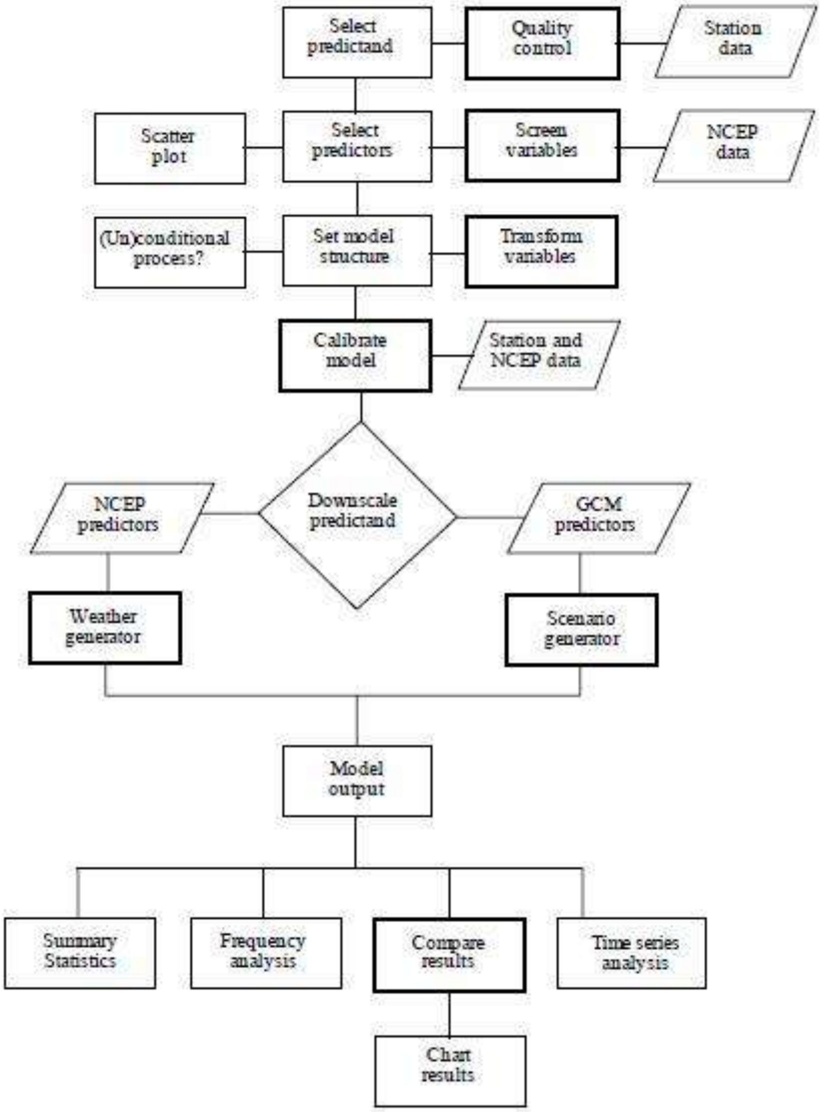


Figure 4 : SDSM diagram

SDSM follows this schematic diagram proposed by [13]

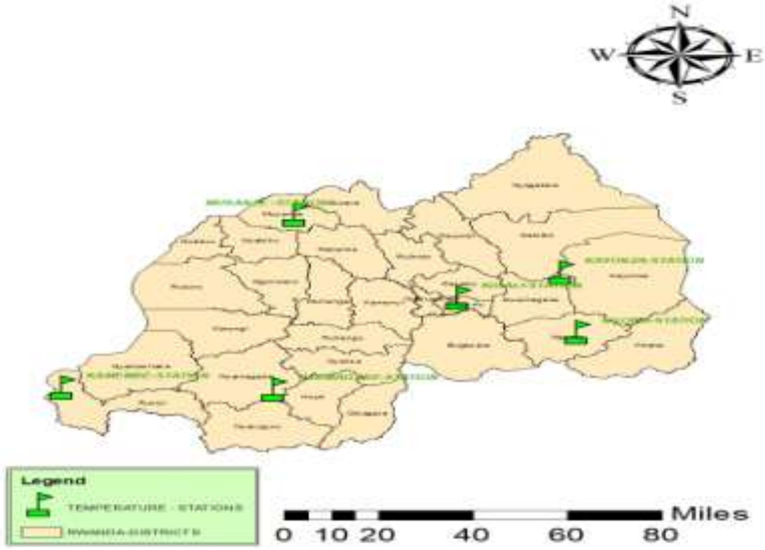


Figure 5: Location of the six stations used in this study

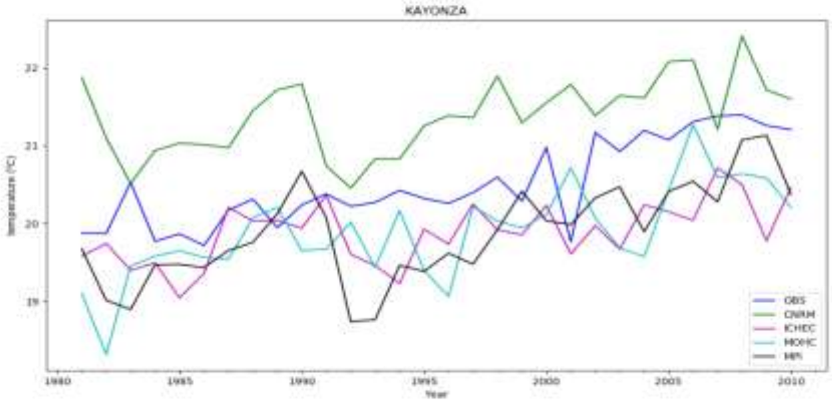


Figure 6: Trend of annual mean temperature of observed and predicted under Kayonza station

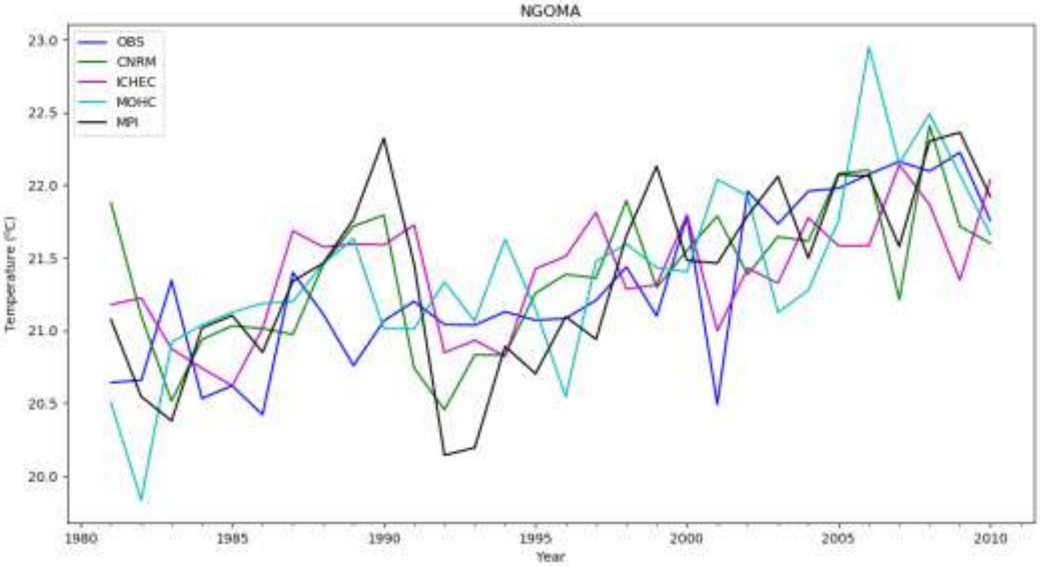


Figure 7: Annual mean temperature of observed and predicted data

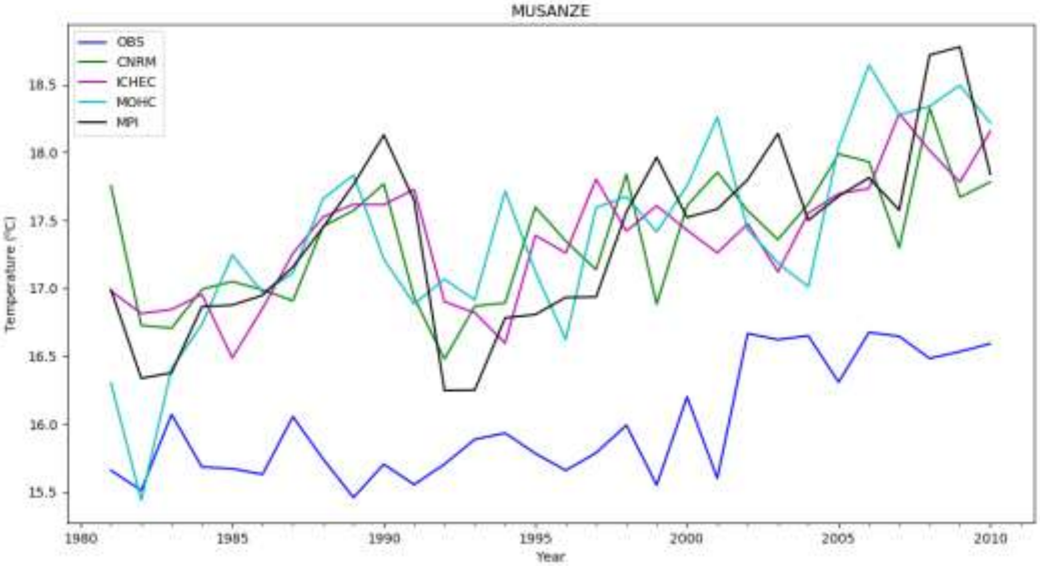


Figure 8: Annual mean temperature of predicted and observed over Musanze station

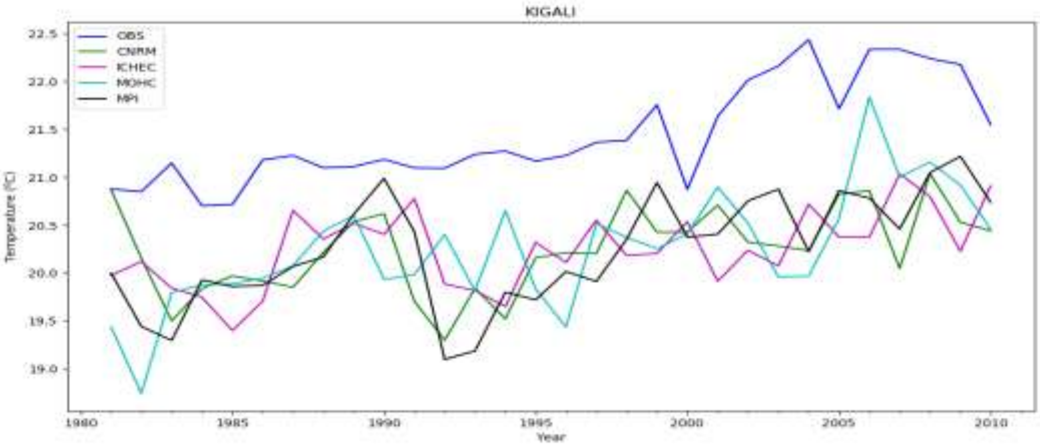


Figure9: Annual mean temperature of predicted and observed in Kigali

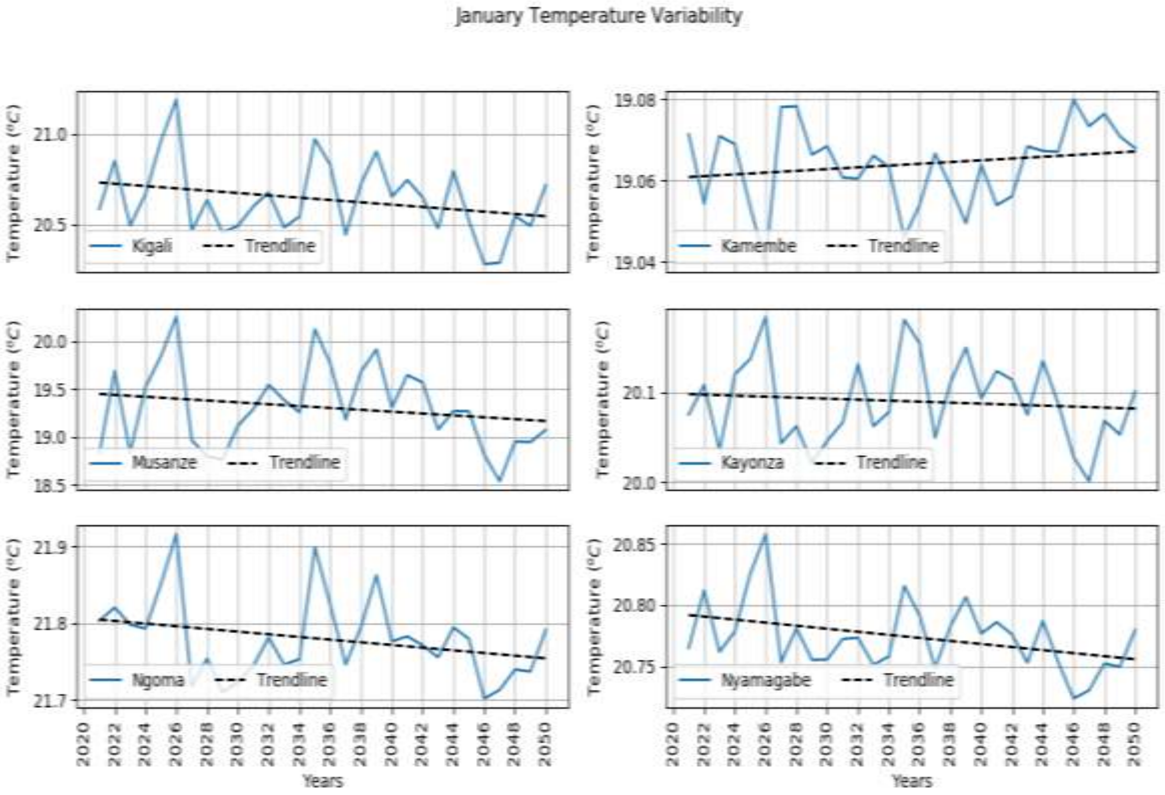


Figure 10: January temperature variability

Projected January mean temperature under RCP 8.5

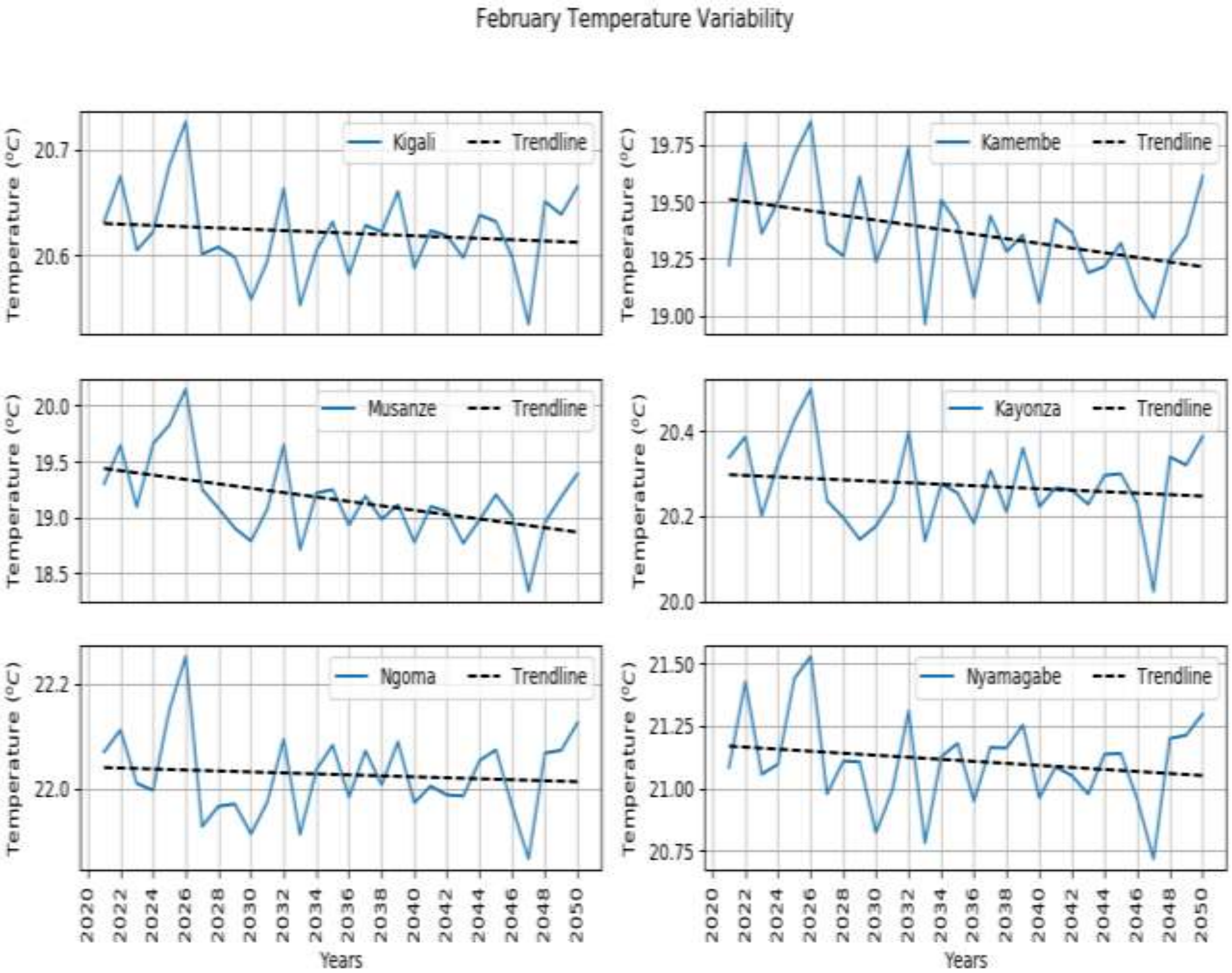


Figure 11: February Temperature Variability

The projected February mean temperature

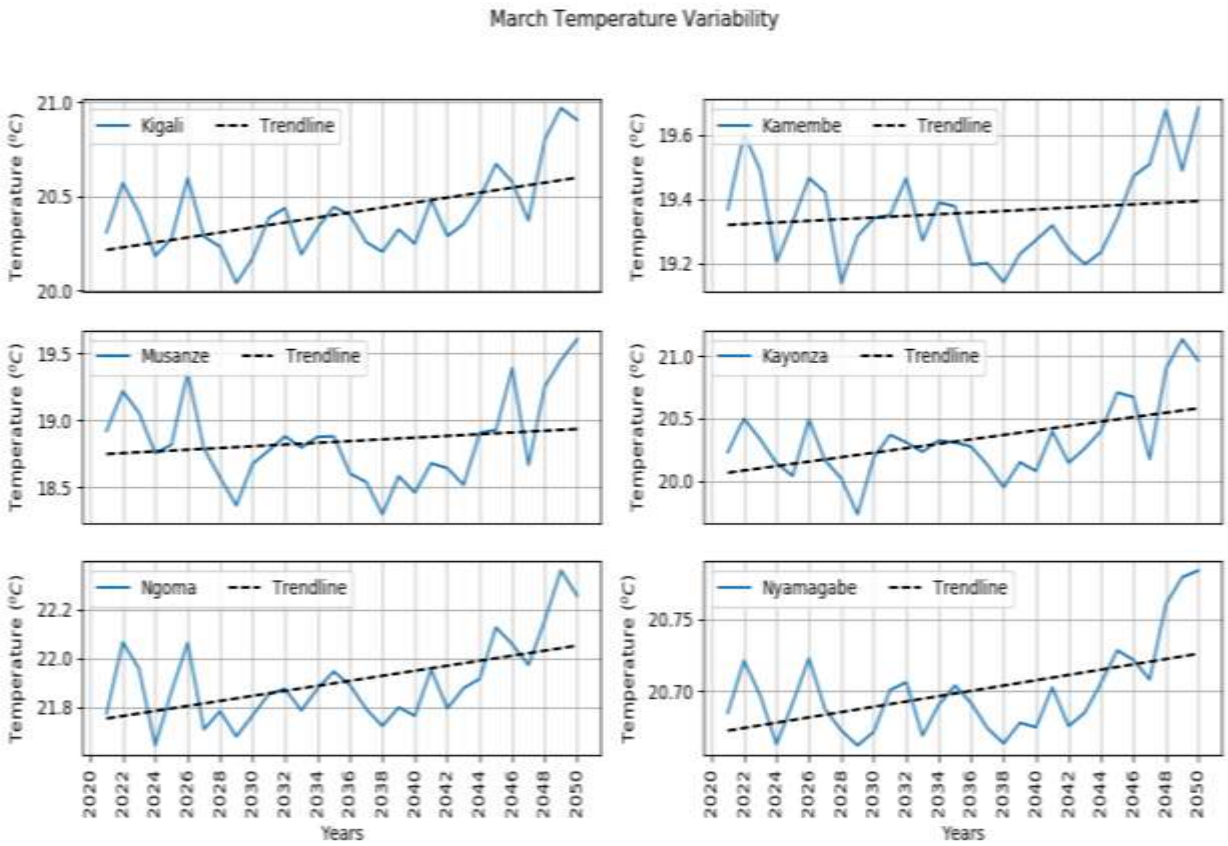


Figure 12: March Temperature Variability

The projected March mean temperature

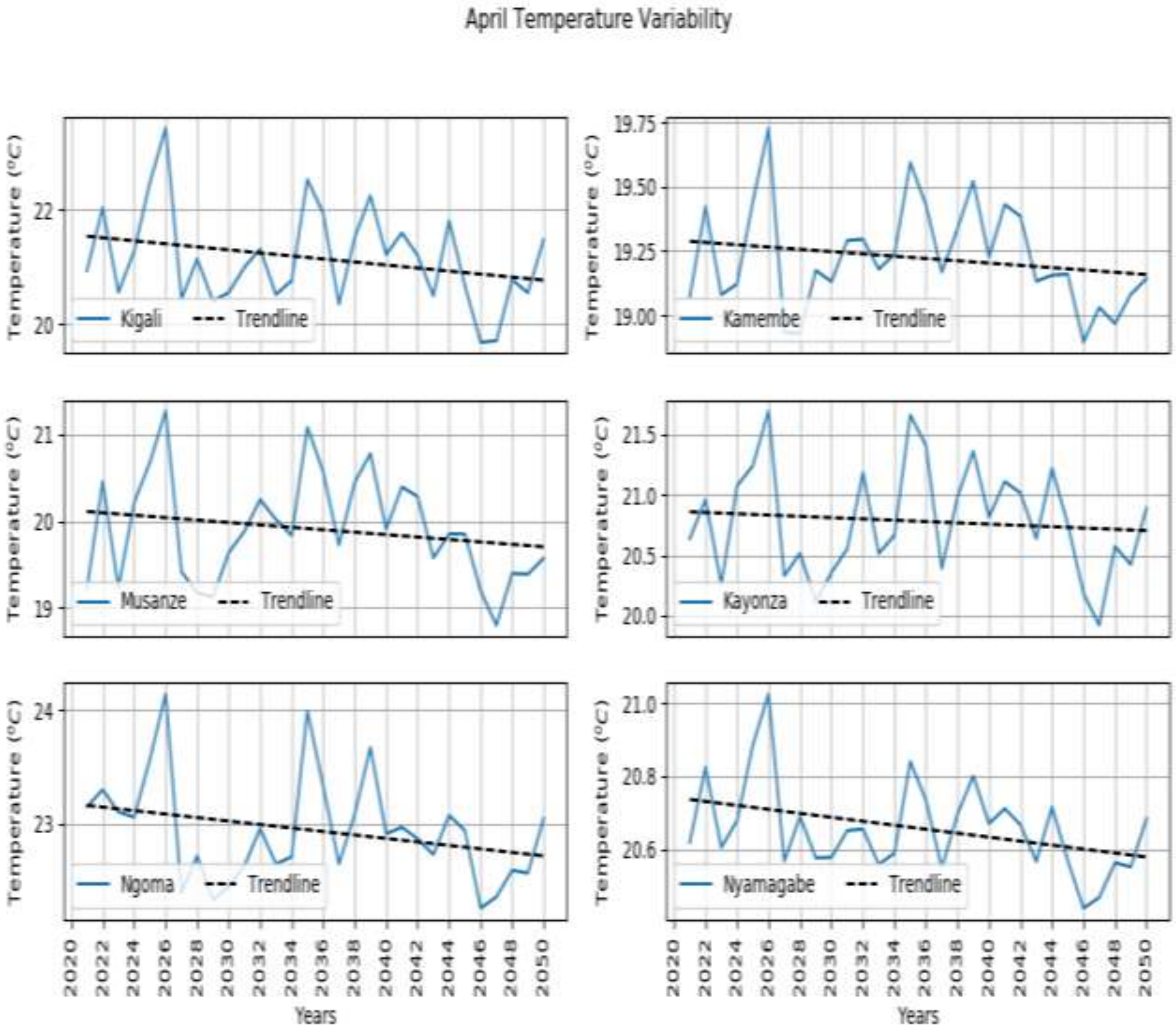


Figure13: April Temperature Variability

The projected April mean temperature

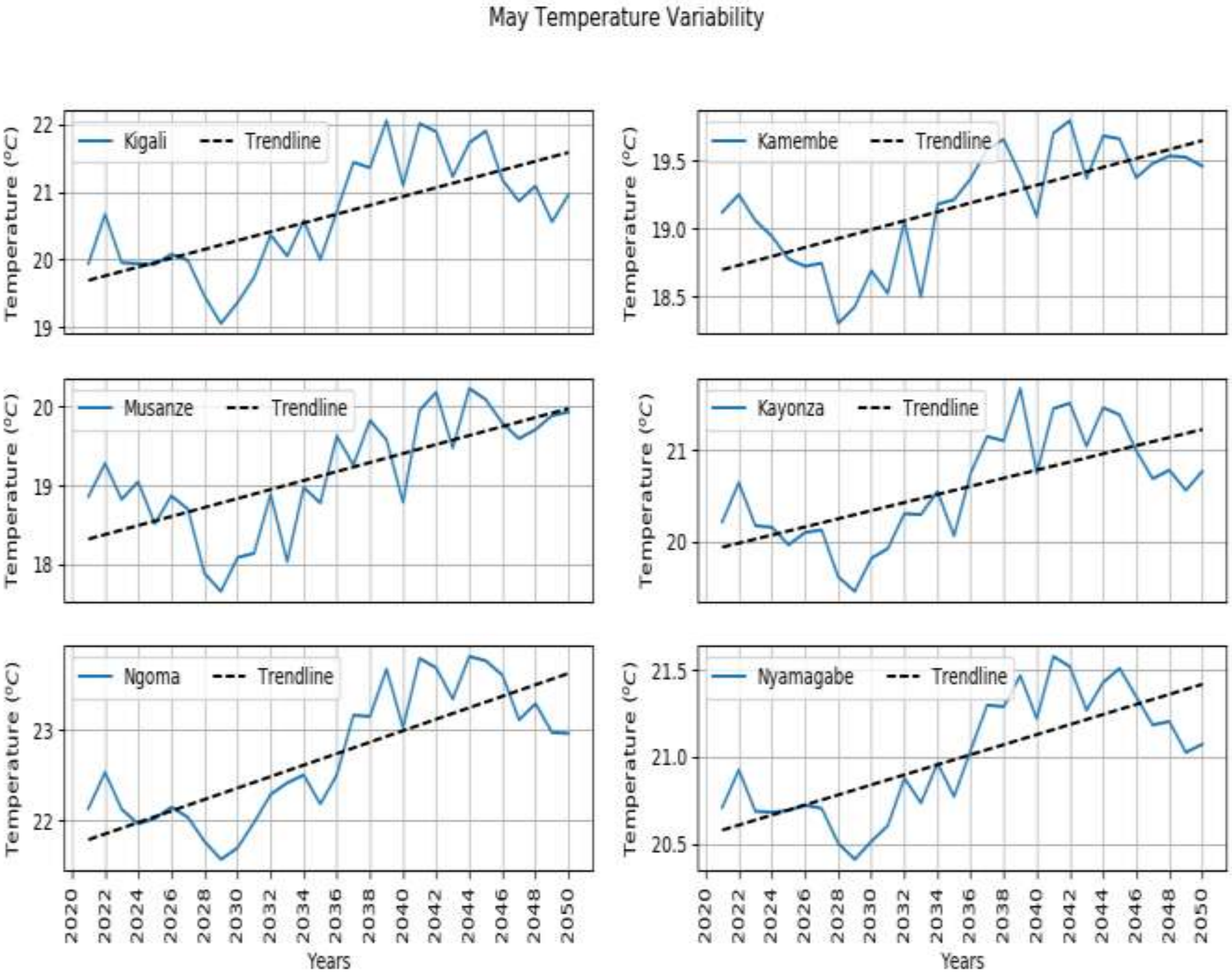


Figure 14: May Temperature Variability

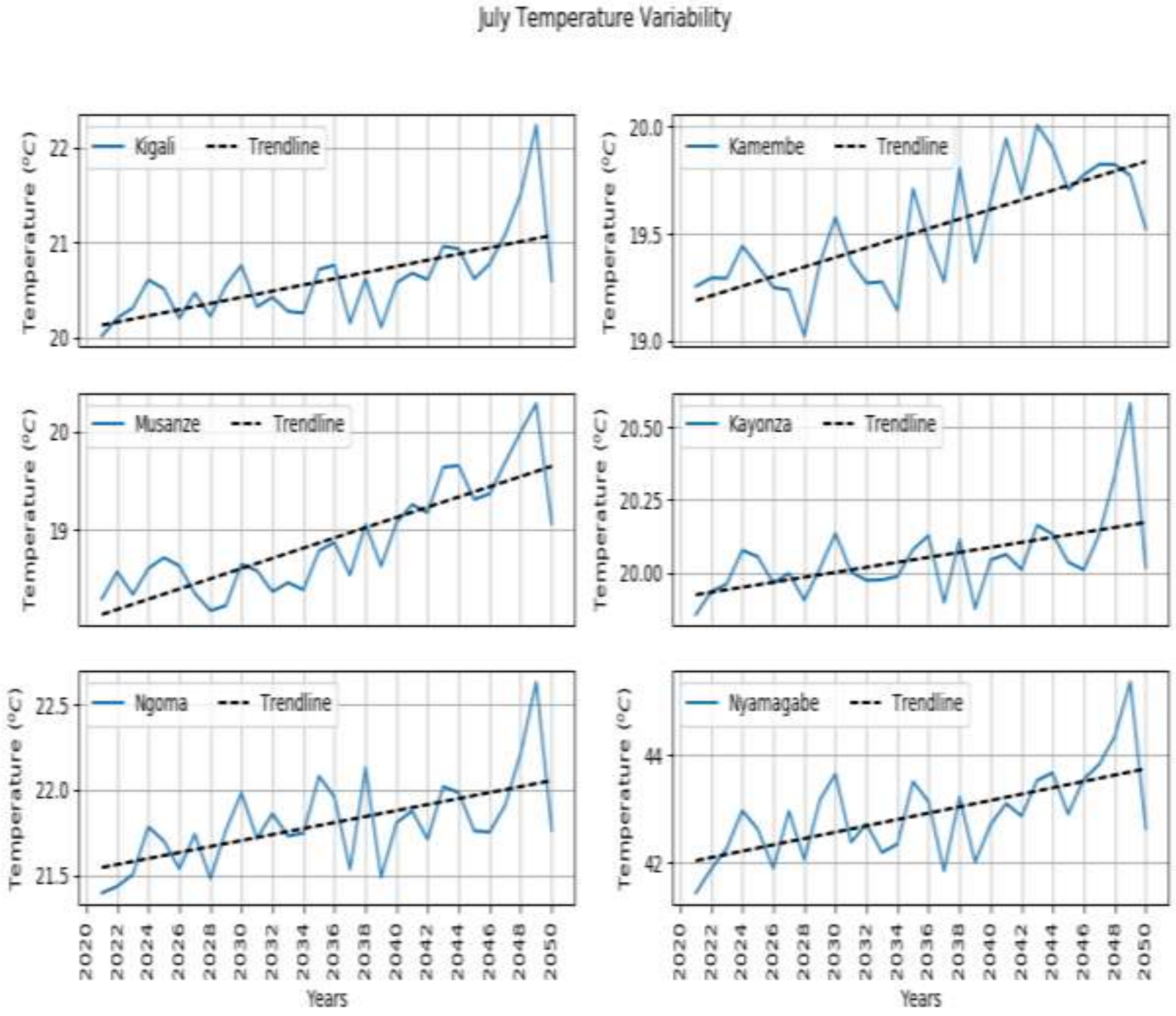


Figure 15: July Temperature Variability

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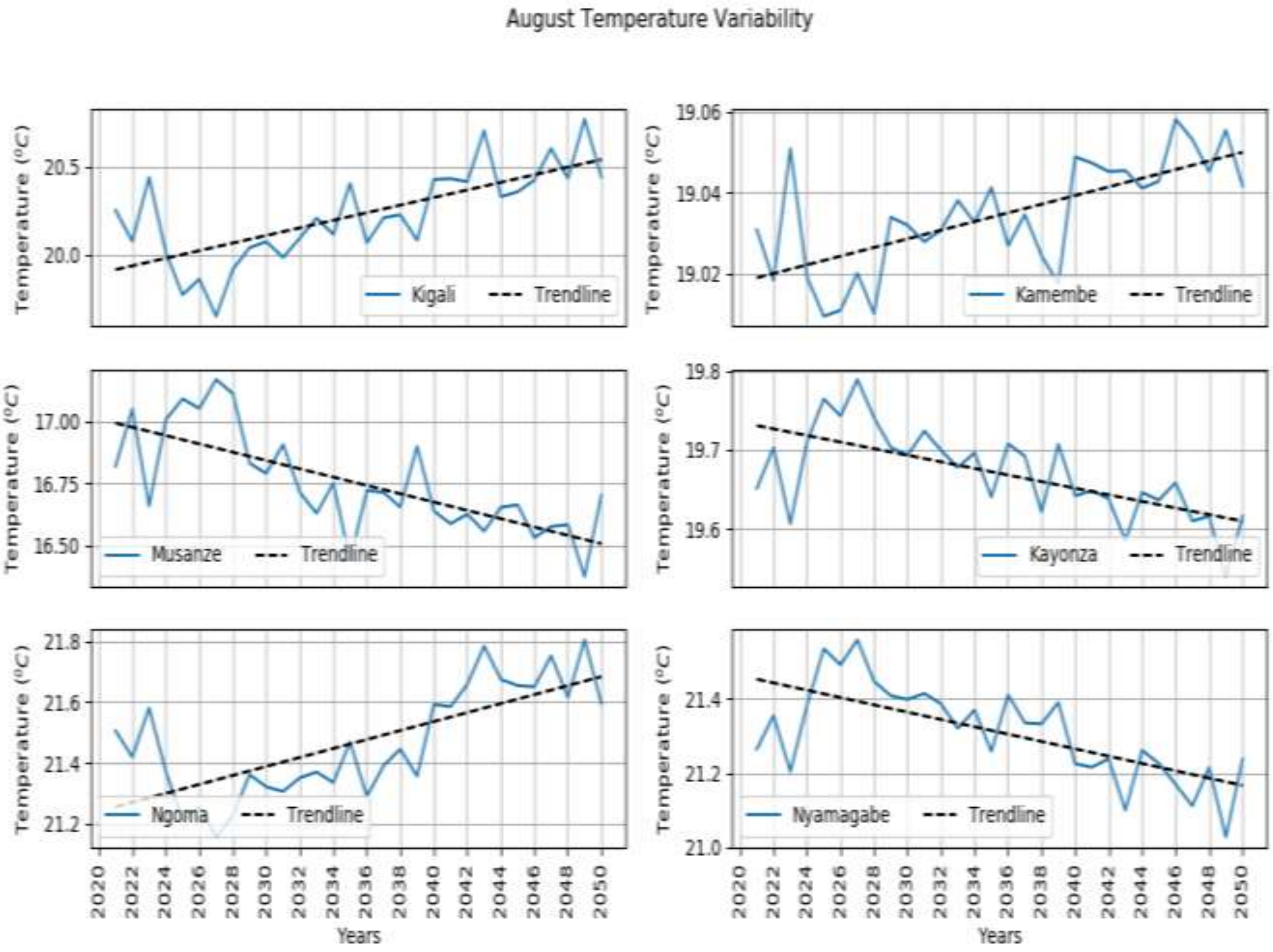

Figure16: August Temperature Variability

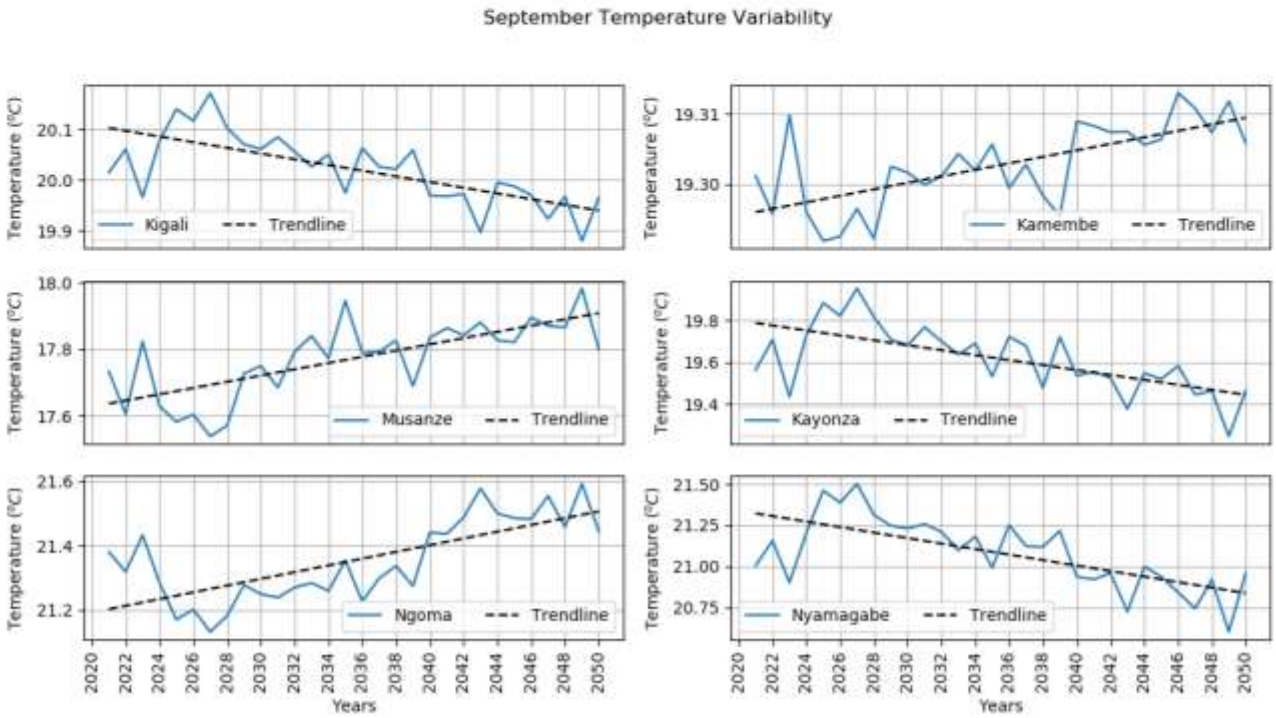

Figure17: September Temperature Variability

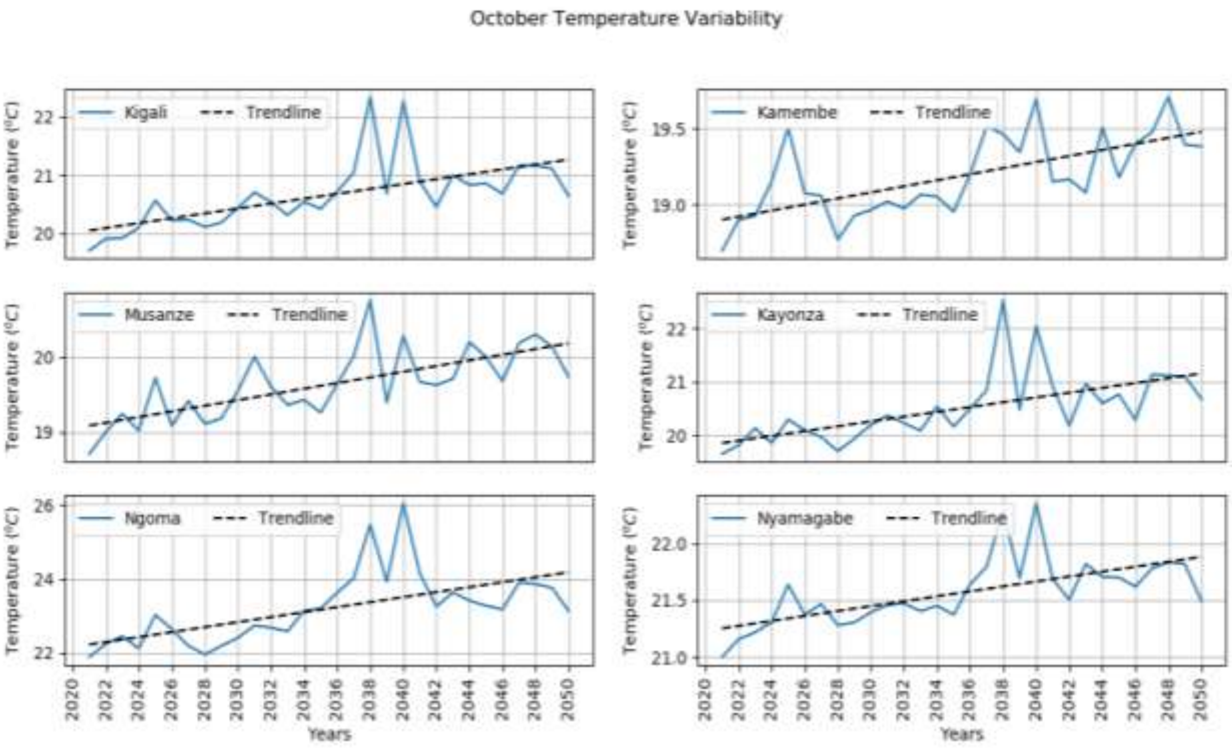

Figure18: October Temperature Variability

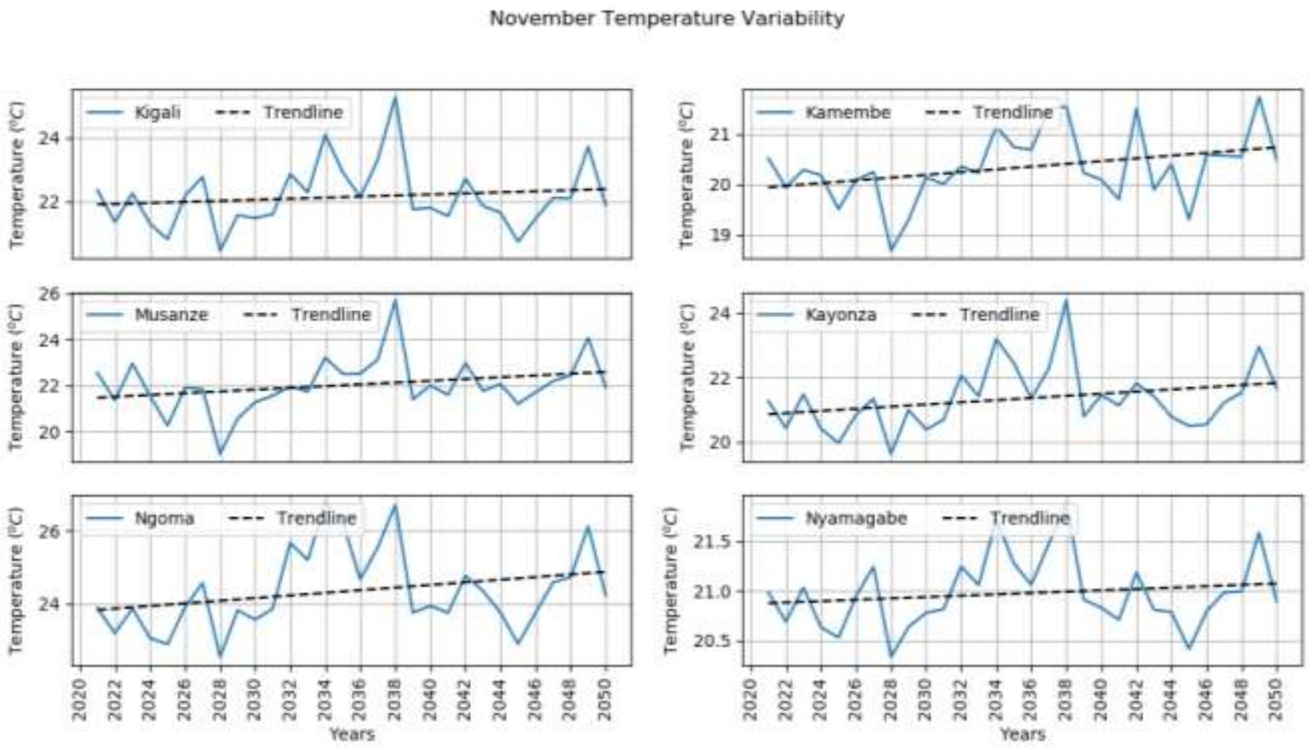

Figure19: November Temperature Variability

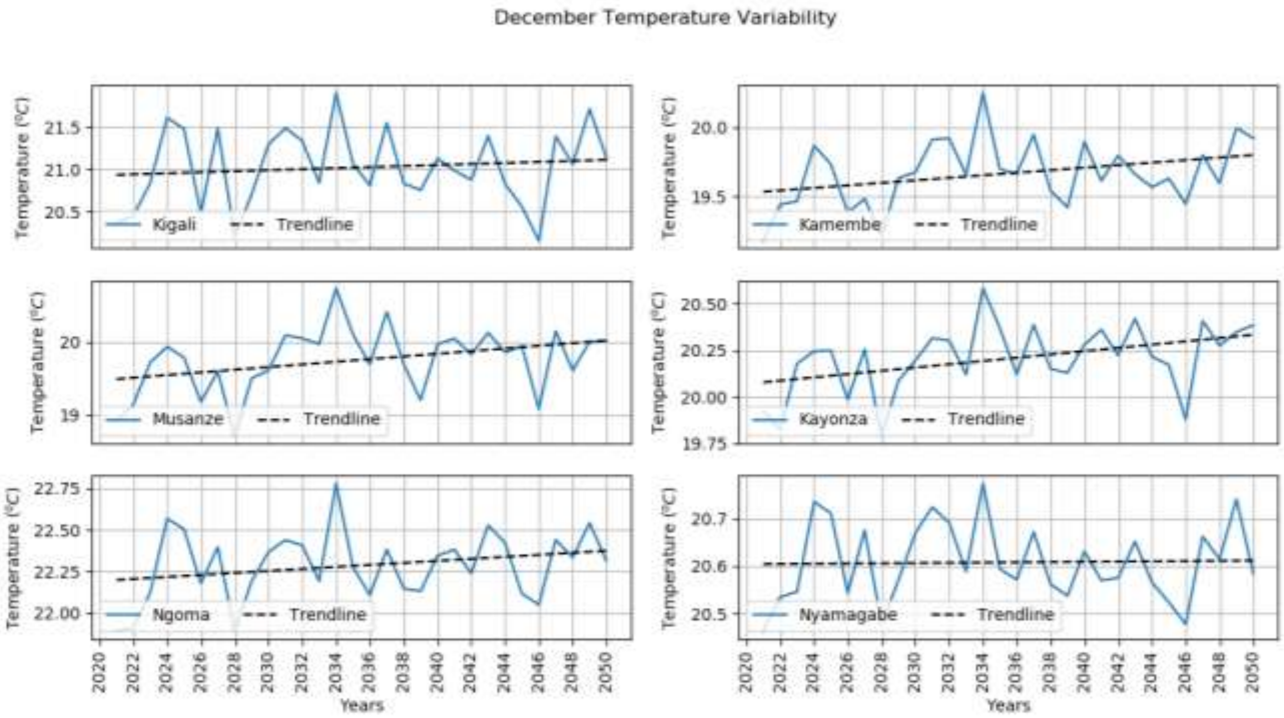

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Figure20: December Temperature Variability

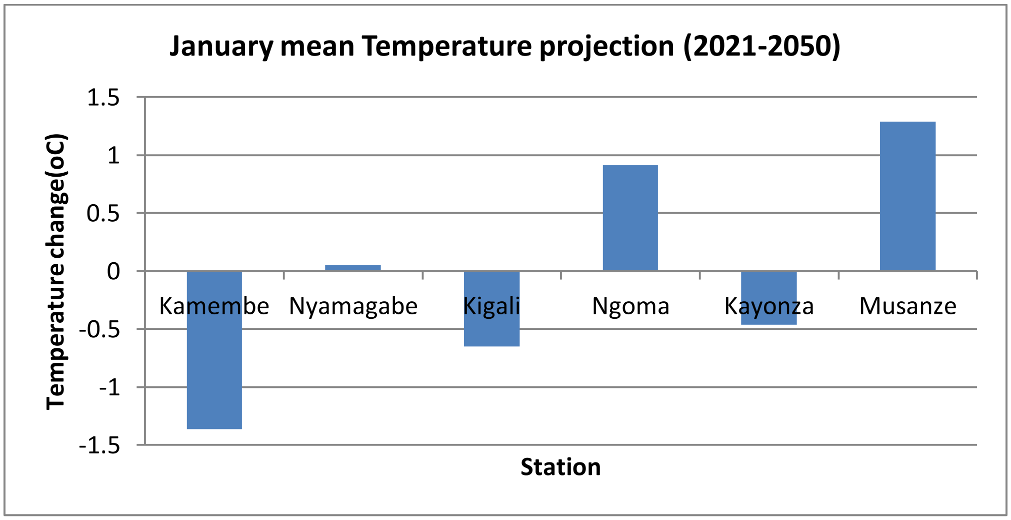

Figure22: Projection of January mean temperature over all stations

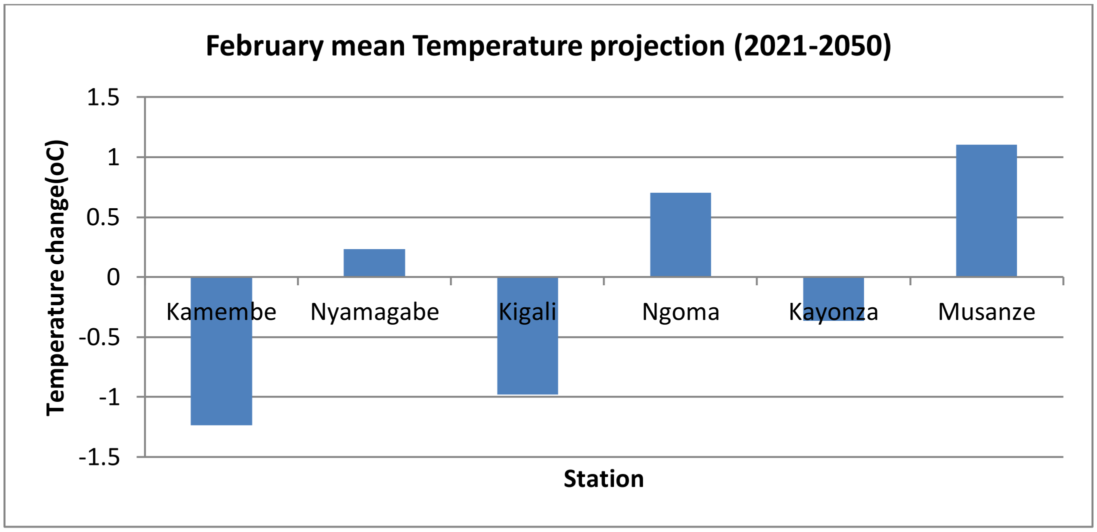

Figure 23: Projection of February mean temperature

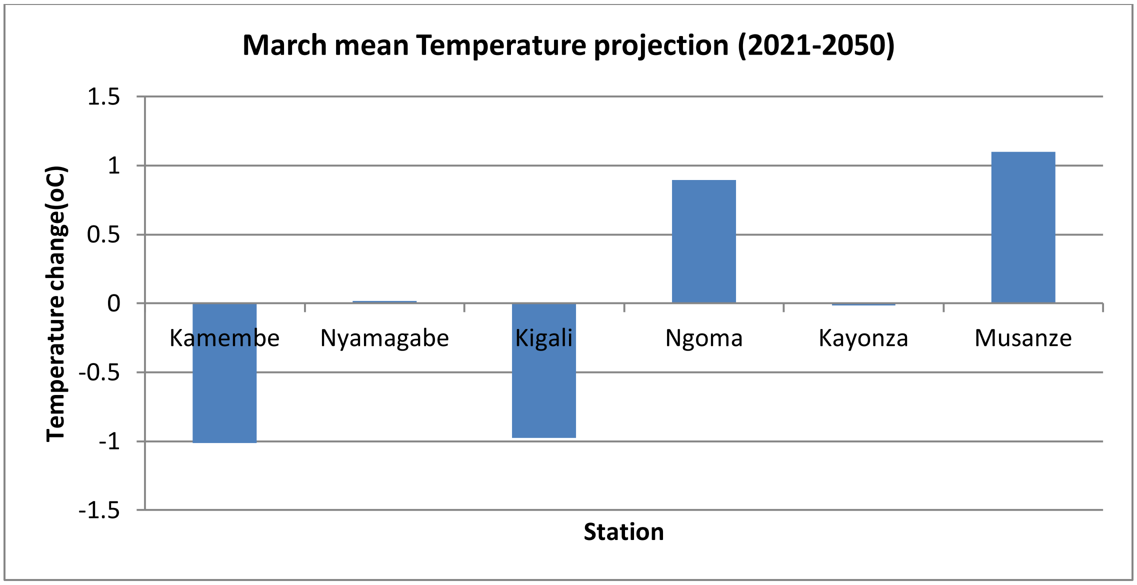

Figure 24: Projection of march mean temperature

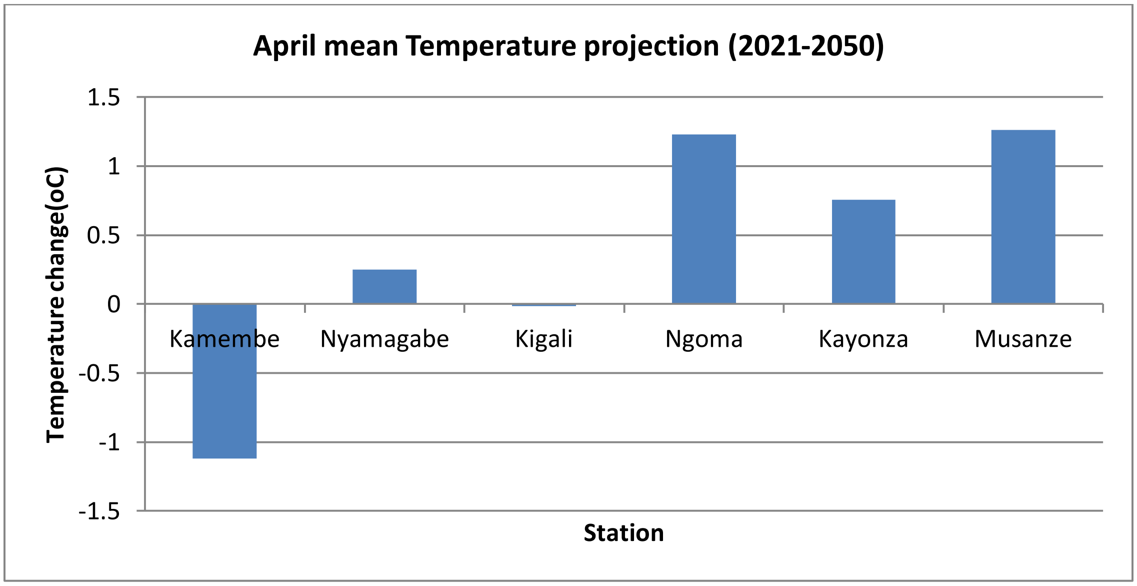

Figure 26: Projection of April mean temperature

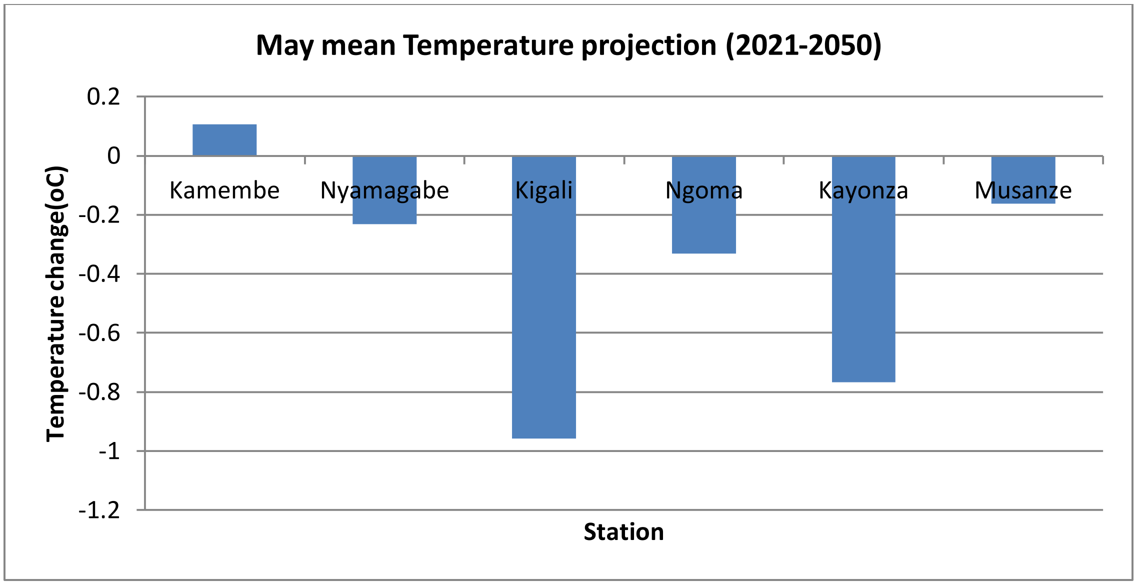

Figure 27: Projection of May mean temperature

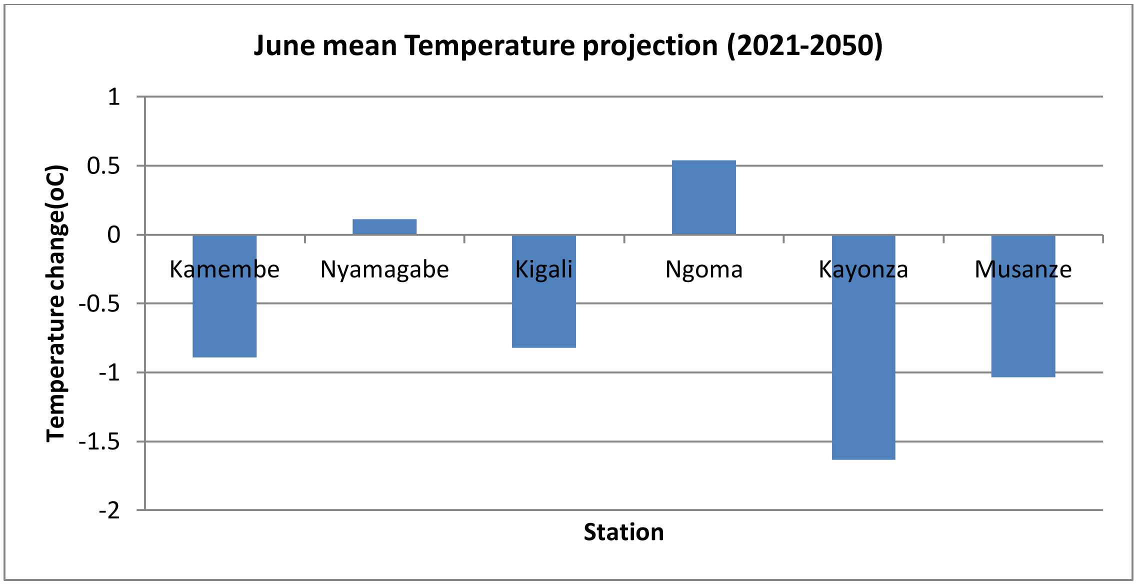

Figure28: Projection of June mean temperature

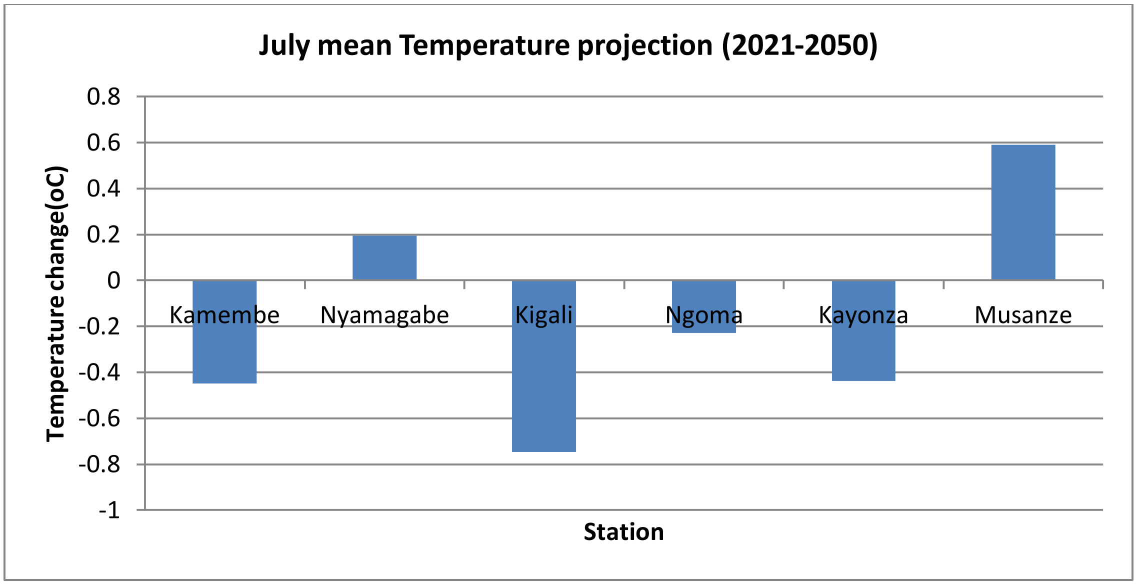

Figure29: Projection of July mean temperature

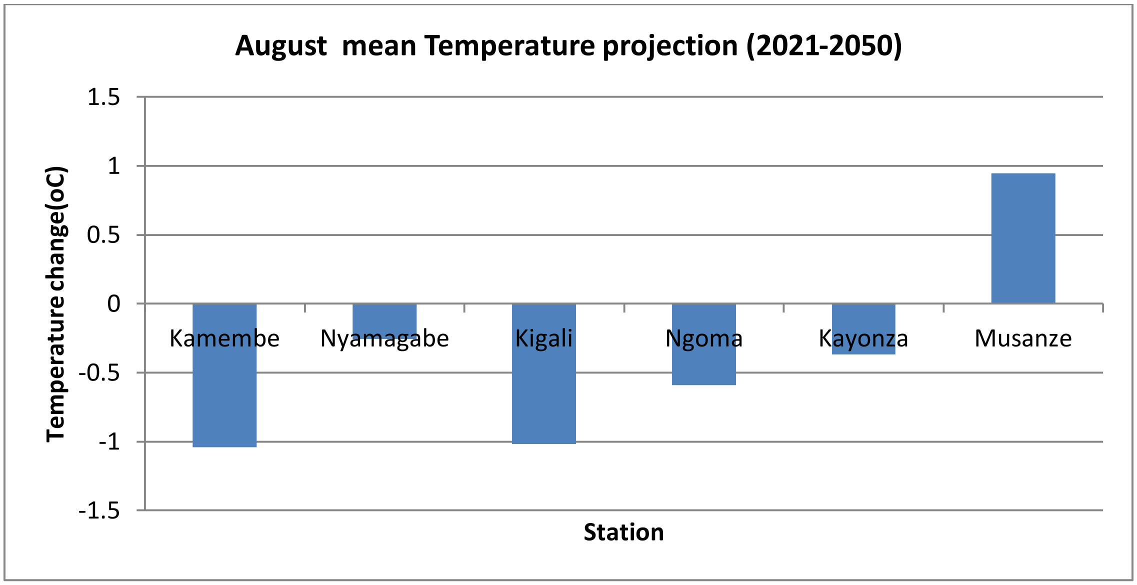

Figure30: Projection of August mean temperature

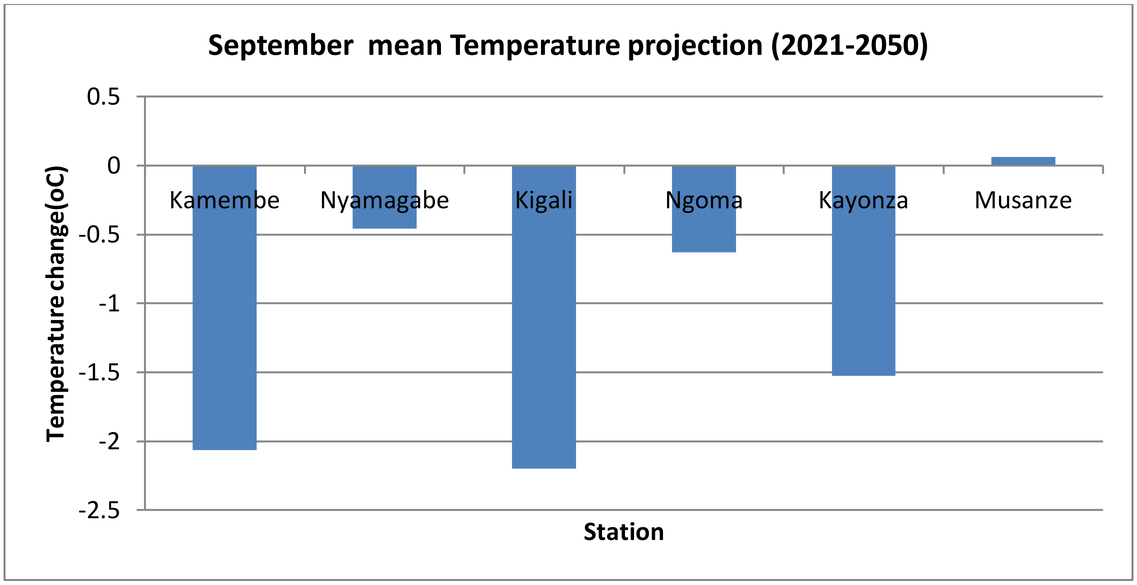

Figure 31: Projection of September mean temperature

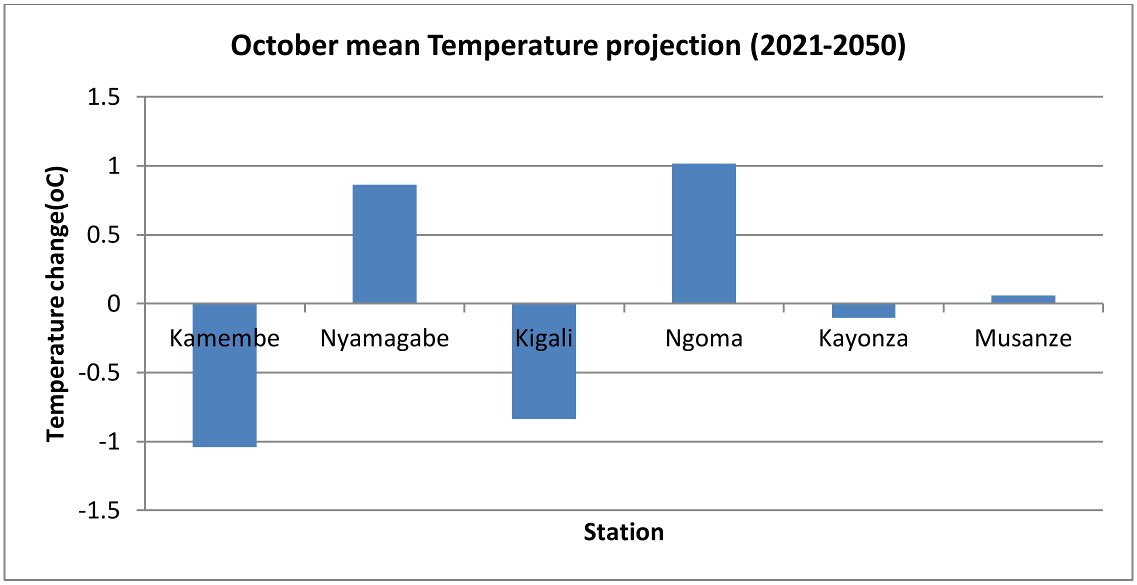

Figure 32: Projection of October mean temperature

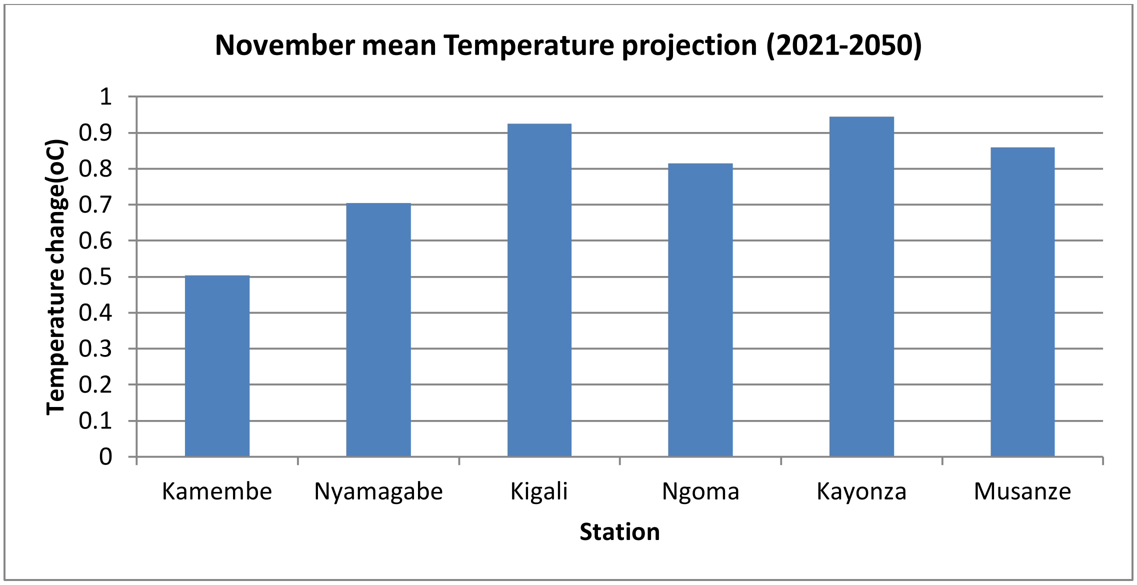

Figure 33: Projection of November mean temperature

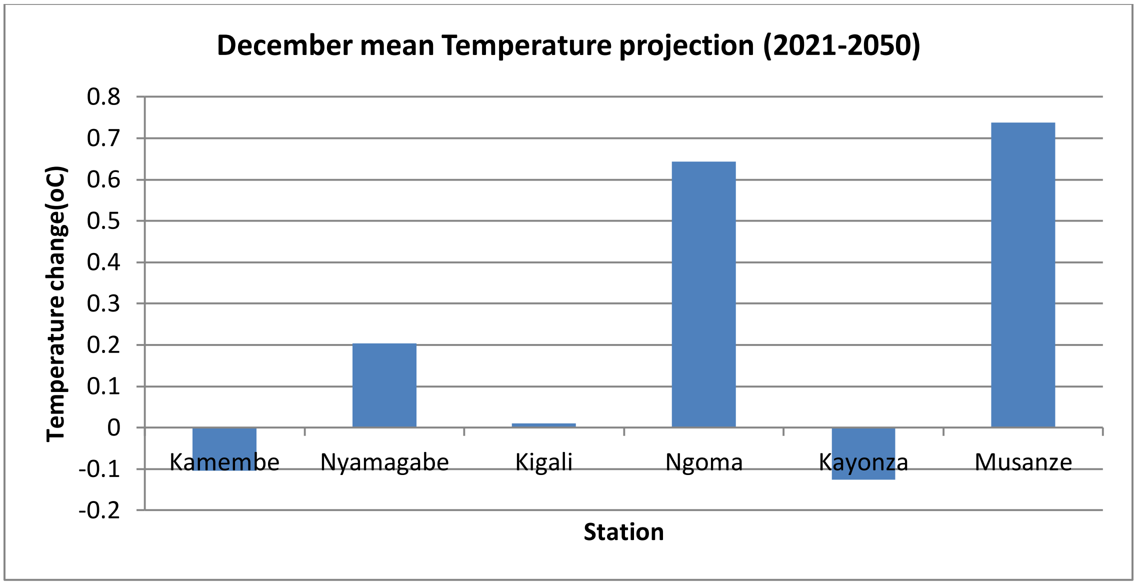

Figure 34: Projection of December mean temperature

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