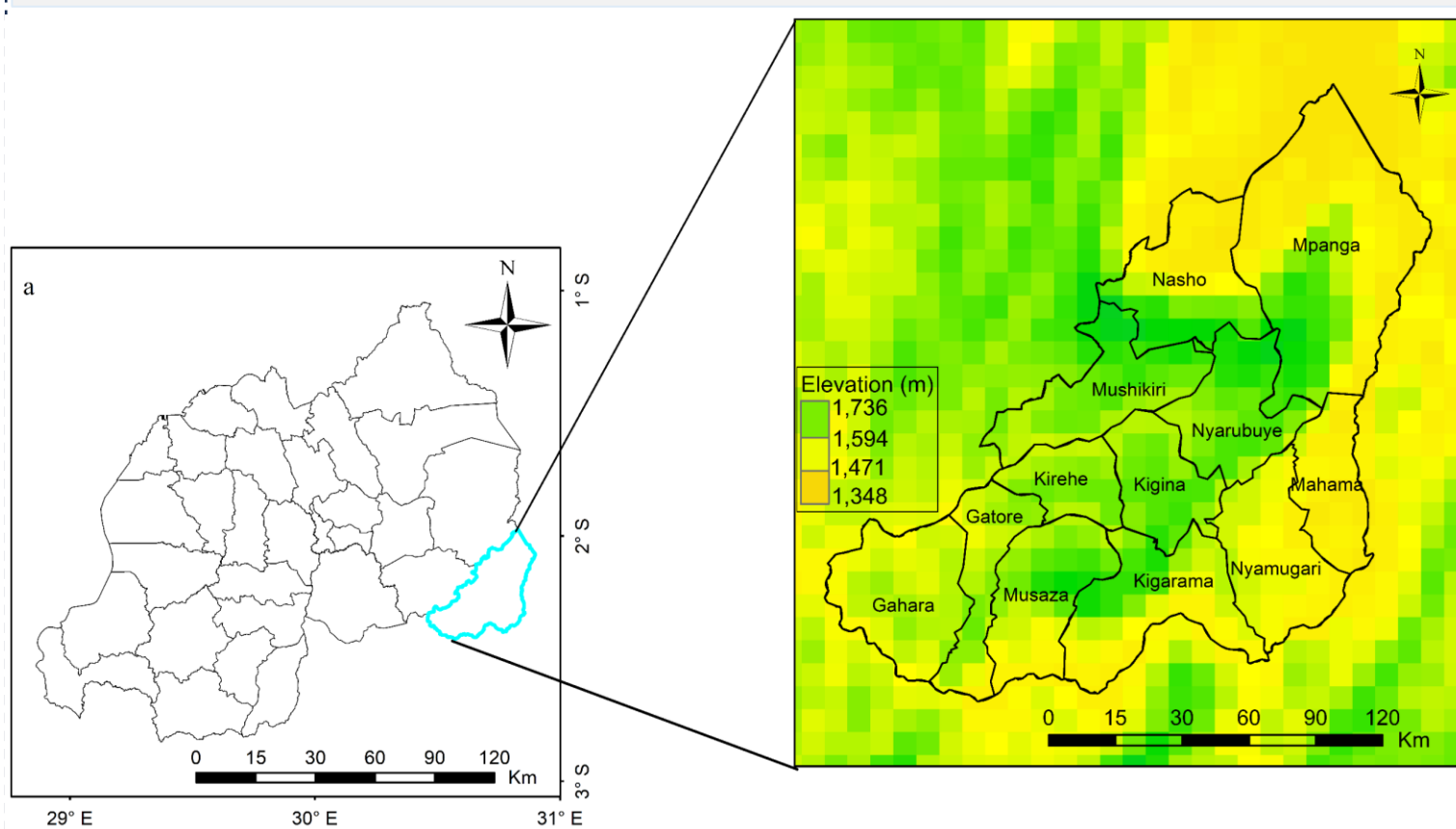


Title: Observed Variability and Trends of Rainfall and Climate Extreme Indices in Kirehe District, Eastern Rwanda: Implications for Climate-Sensitive Planning

Author(s): Alexis Nizeyimana & Ndakize Joseph Sebaziga

Affiliation: Rwanda Environment Management Authority (REMA)

Kirehe District is located in the southeastern part of Rwanda, within the Eastern Province, in the eastern lowland climate zone. The district experiences a bimodal rainfall pattern, with the main rainy seasons occurring from March to May (MAM) and September to December (JF) and dry seasons extending from January to February (JF) and June to August (JJA). The district's topography is characterized by hills and valleys, influencing rainfall distribution and runoff. Predominantly an agricultural region, Kirehe's livelihoods are heavily reliant on rainfed farming, making it particularly vulnerable to rainfall variability and extreme weather events. Understanding rainfall patterns and extreme indices is therefore critical for informing climate-resilient agricultural practices, water resource management, and disaster preparedness in this drought-prone district.



Geographical location of Kirehe district in Rwanda (a) and administrative with elevation map of Kirehe district (b)

Objective: Spatial analysis of variability and trends for seasonal and annual rainfall and their related extreme rainfall indices in Kirehe district.

Data: Gridded rainfall at 4kmx4km resolution from 1983 to 2021 obtained from the Rwanda Meteorology Agency.

Method:
 i) Variability: Coefficient of variation (CV)
 ii) Trends: Mann-Kendall test and Sen's slope.
 iii) extreme rainfall indices: Computed following the methodology of the Expert Team on Climate Change Detection and Indices (ETCCDI).

Rainfall extreme indices	Units
Consecutive dry days (CDD)	Days
Consecutive wet days (CWD)	Days
Total annual precipitation (PRCPTOT)	mm
Heavy precipitation days (R10mm)	Days
Very heavy precipitation days (R20mm)	Days
Precipitation from very wet days (R95pTOT),	mm
Maximum 1-day precipitation (RX1day)	mm
Maximum 5-day precipitation (RX5day)	mm
Simple daily intensity index (SDII)	mm/day

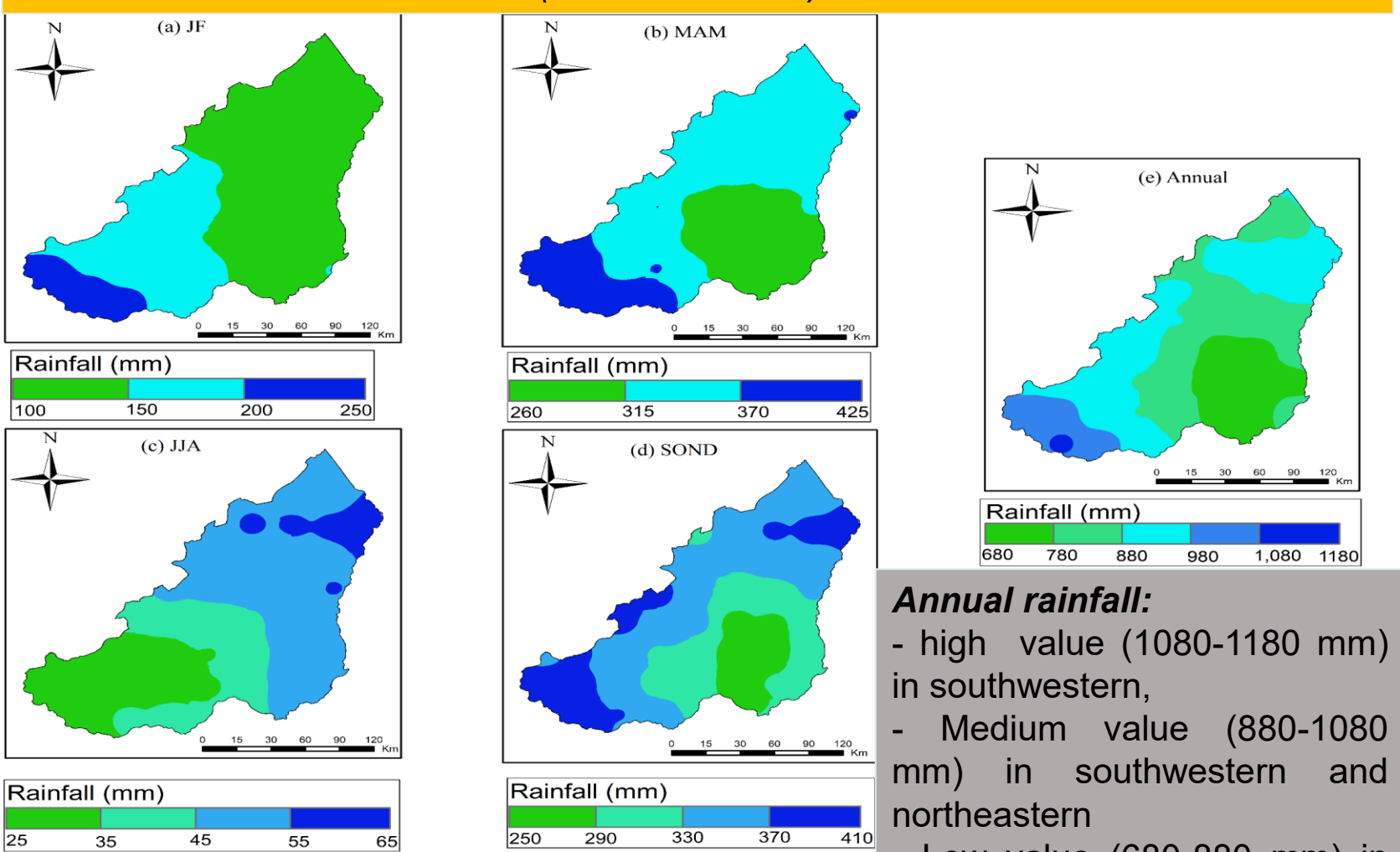
Spatial distribution of Seasonal and annual rainfall

JF: high values (200-425 mm) in southwestern, medium values (150-200 mm) in southern and low values (100-150 mm) in central, southeastern

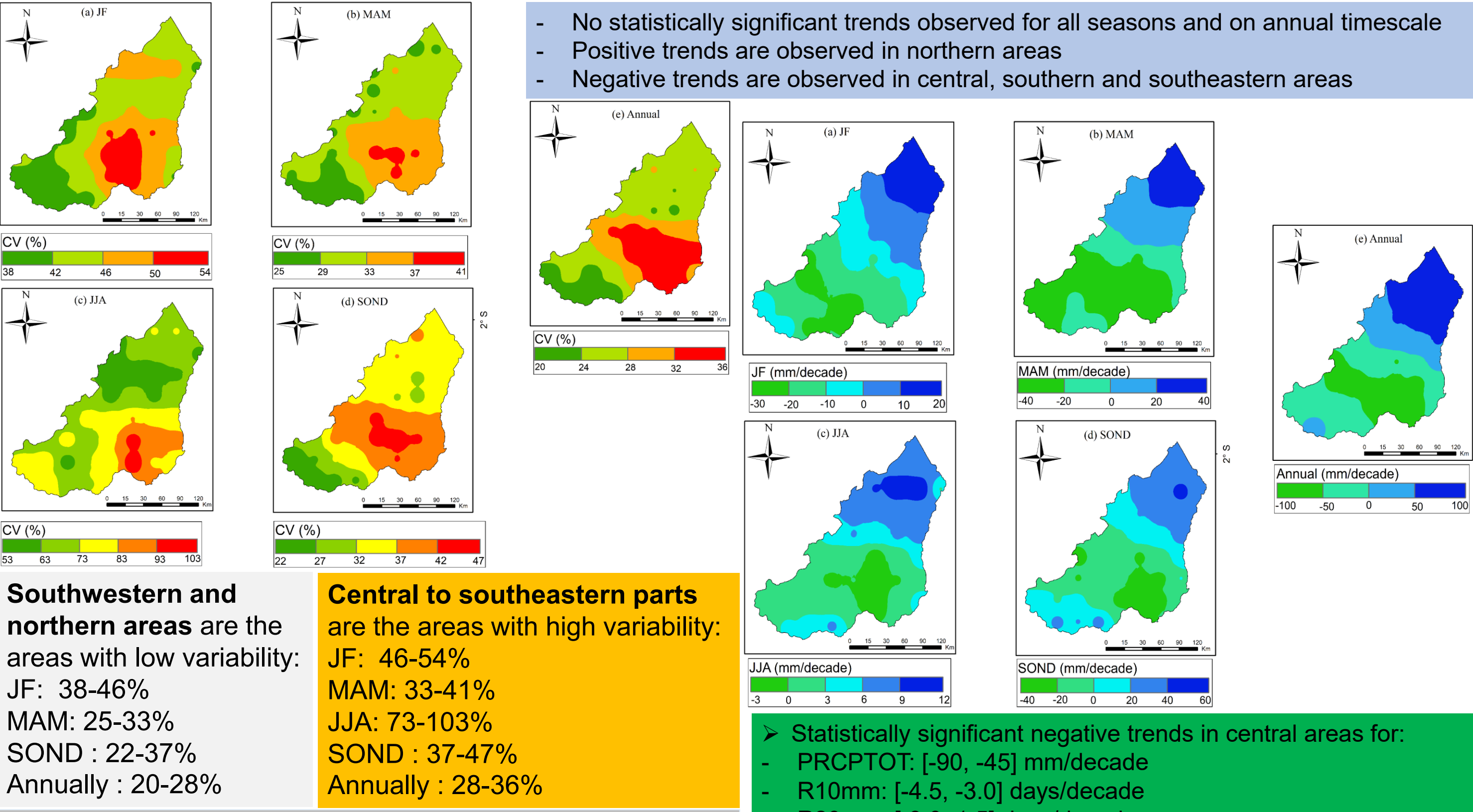
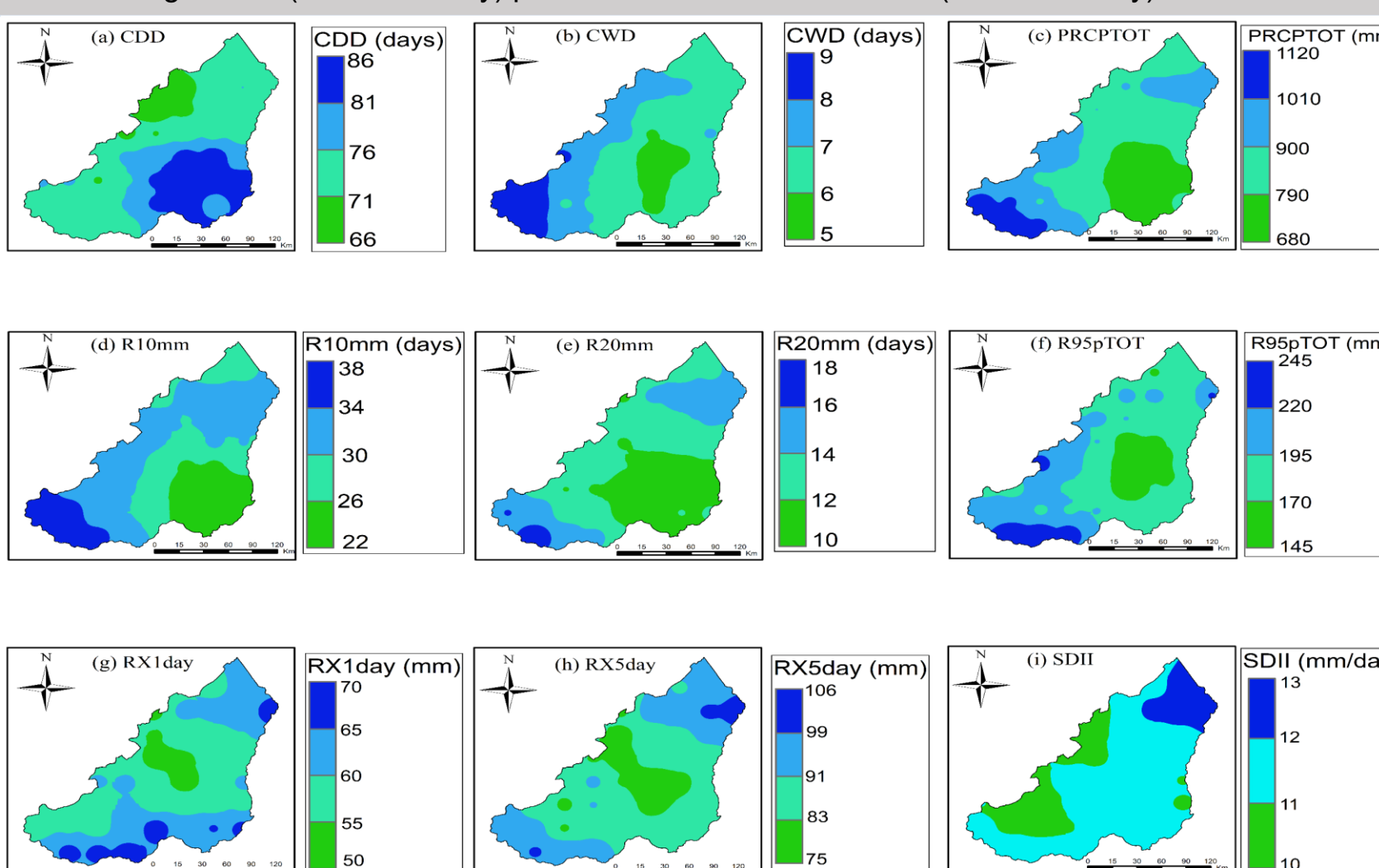
MAM: high values (370-250 mm) in southwestern, medium values (315-370 mm) in central to northern and low values (260-315 mm) in

JJA: high values (55-65mm) in eastern, central and northern and low values (25-45 mm) in central to southern

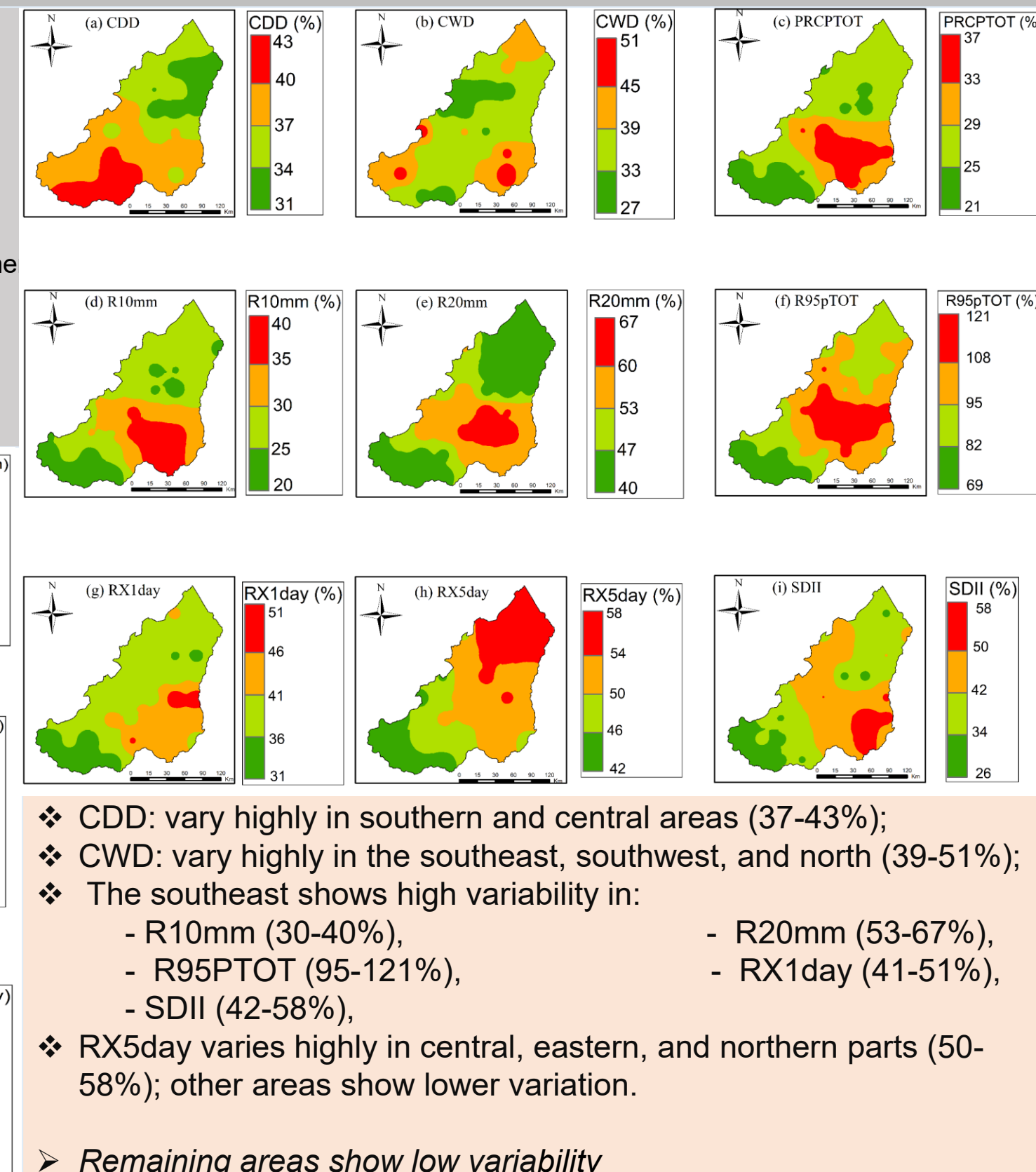
SOND: high value (330-410 mm) in southern, western and very high in northern and low value (250-330 mm) in central and eastern



- CDD: shows high value (76-86 days) in southeastern and low (66-76 days) in other areas
- CWD: high values (7-9 days) in southern and western and low (5-7 days) in other areas
- PRCPTOT: high values (900-1120 mm), in southern, western and northeastern and low values (680-900 mm) in other areas
- R10mm: high values (30-38 days) in southern, western and northeastern and low values (22-30 days) in other areas
- R20mm: high values (14-18 days) in southern and northeastern and low values (10-14 days) in other areas
- R95pTOT: high values (195-245 mm) in southern and western and low value (145-195 mm) in other areas
- RX1day: high values (60-70 mm) in southern and northeastern and low value (50-60 mm) in other areas
- RX5day: high value (91-106 mm) in southern and northern and low value (75-91 mm) other areas
- SDII: high value (12-13 mm/day) in northeastern and low value (10-12 mm/day) in other areas



Areas with low variability present reliable rainfall while areas with high variability present more erratic rainfall.



- Statistically significant negative trends in central areas for:
 - PRCPTOT: [-90, -45] mm/decade
 - R10mm: [-4.5, -3.0] days/decade
 - R20mm: [-3.0, 1.5] days/decade
 - R95pTOT: [-60, -20] mm/decade
 - RX1day: [-12, -6] mm/decade
 - RX5day: [-10.0, -5.0] mm/decade
- Statistically significant Negative trends in northern for:
 - CDD: [-10, -5.0] days/decade

- Statistically significant positive trends in northern areas for:
 - CWD: [0.5, 1.0] days/decade
 - PRCPTOT: [45, 90] mm/decade
 - R10mm: [1.5, 4.5] days/decade

Spatial disparities in rainfall variability and extreme indices expose Kirehe District to uneven risks for agriculture, water security, and disaster preparedness. Targeted adaptation such as climate-resilient crops, irrigation, water conservation, infrastructure reinforcement are urgently needed.

Title: Spatial and Temporal Analysis of Rainfall Variability and trends over Amayaga region, Rwanda

Author(s): Euphrosine Muyizere

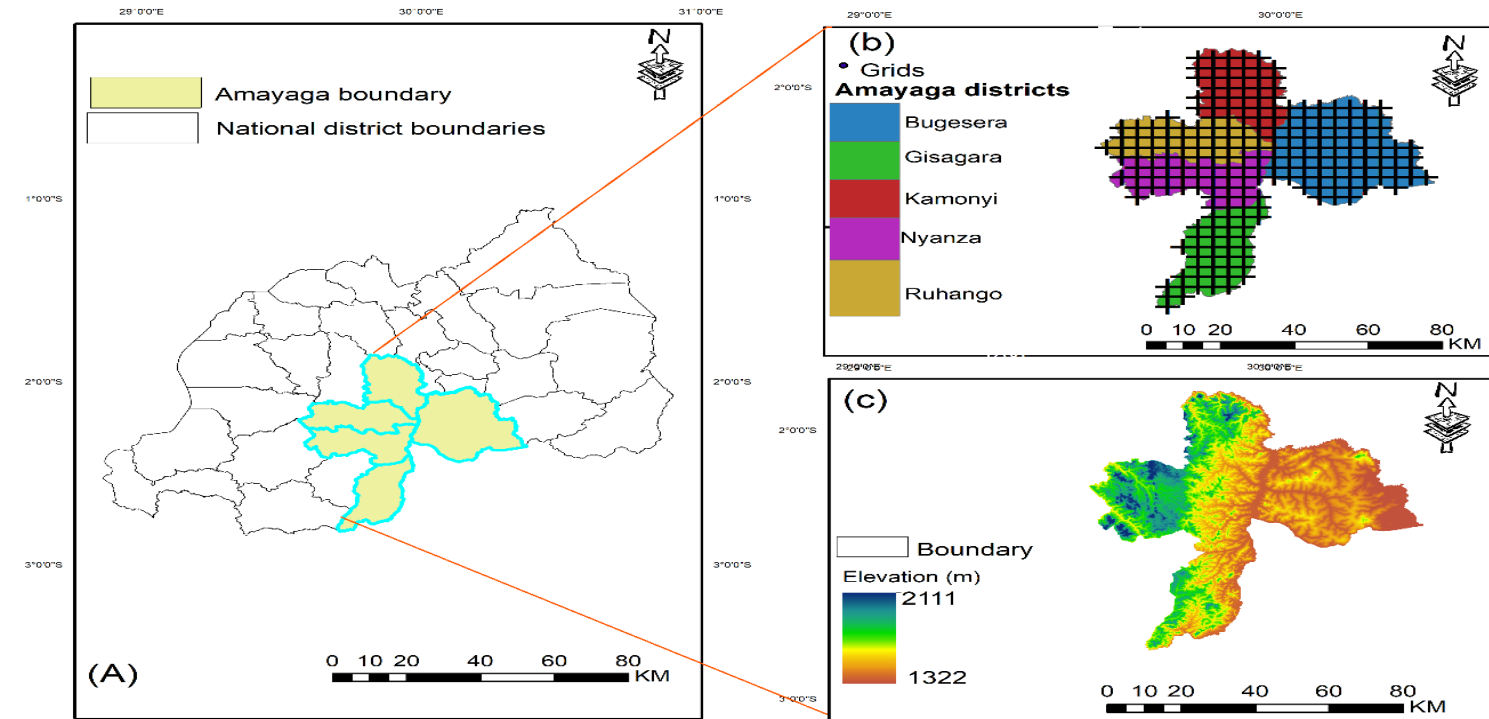
Affiliation: University of Lay Adventists of Kigali (UNILAK)

Introduction

Rainfall variability poses serious challenges to Rwanda's Amayaga region, threatening rain-fed agriculture and water resources. Understanding rainfall patterns is crucial for developing climate-resilient practices and improving disaster preparedness.

Study area

- The Amayaga region includes five districts: Kamonyi, Ruhango, Nyanza, Gisagara, and Bugesera, with elevations from 1,322 to 2,111 m.
- It spans about 3,921.8 km² and has a population of 2,114,842, with slightly more females than males.
- The area is drained by rivers and lakes such as Akanyaru, Nyabarongo, Migina, Rukarara, Cyohoha, and Ihema.
- Amayaga experiences four seasons: short dry (JF), long dry (JJA), long rains (MAM), and short rains (SOND).
- Its economy relies mainly on rain-fed farming, growing crops like cassava, maize, pineapple, rice, coffee, beans, and sorghum, along with livestock.



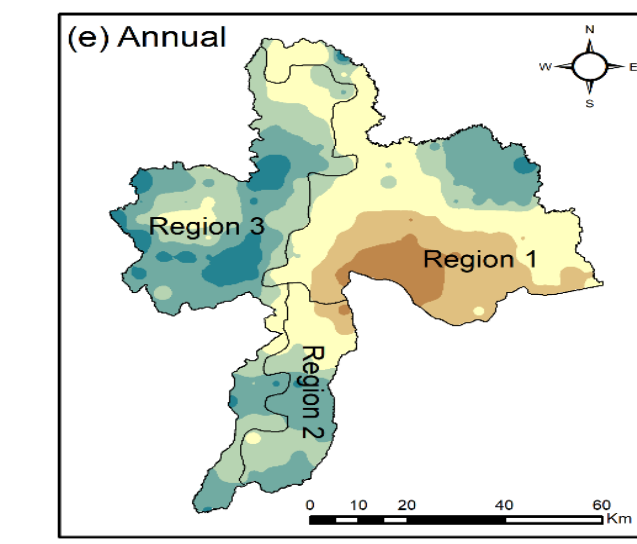
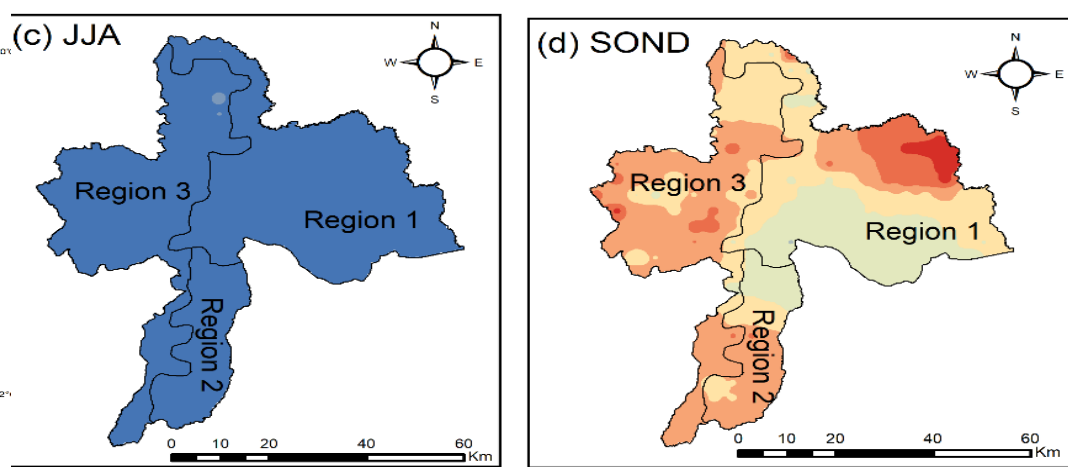
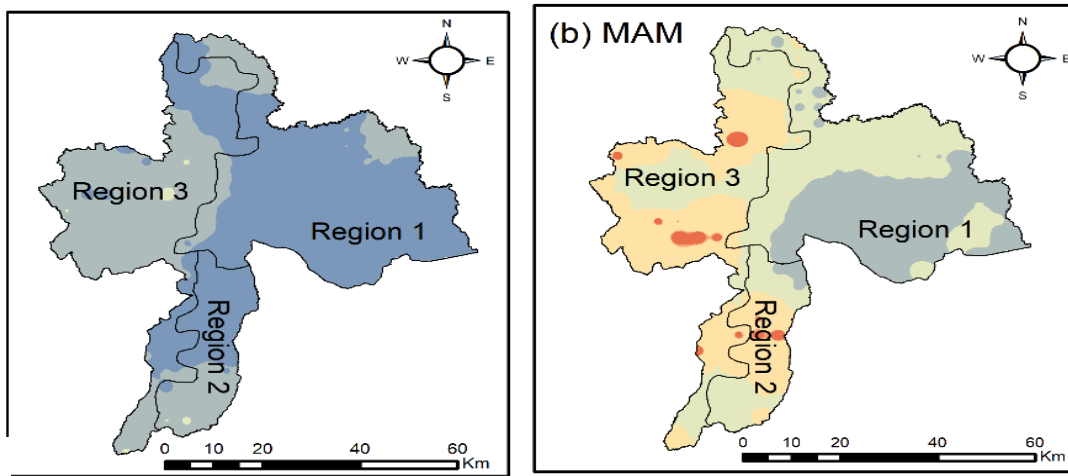
Spatial distribution of Seasonal and annual rainfall

JF: high values (195-275 mm) in southern part of R2 and central part of R3, and low values are observed in central part of R2 and northeastern part of R3 (115-195 mm).

MAM: high values (355-435mm) in central part of R2, north and southern part of R3 (315-370 mm) and low values (195-275 mm) in central part of R3

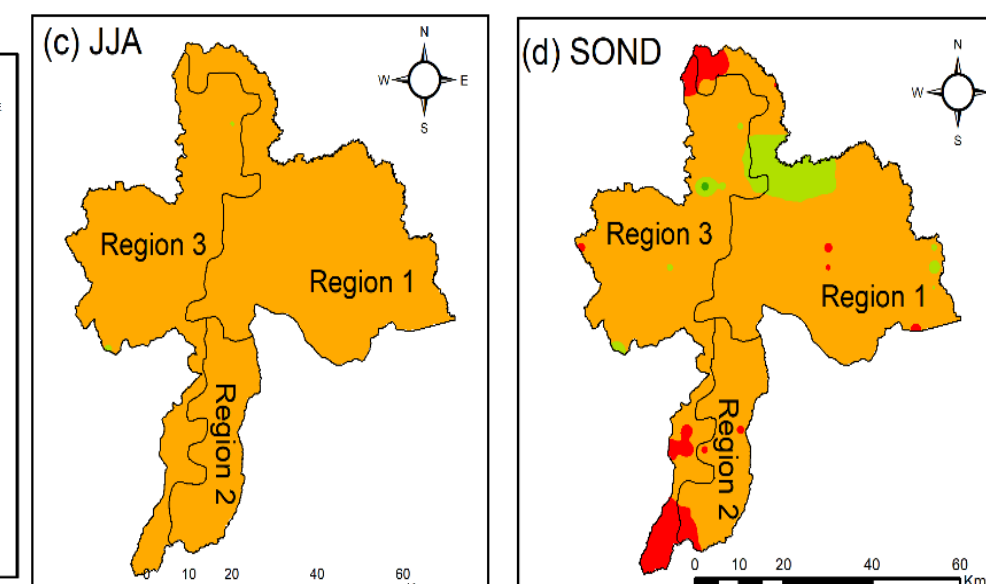
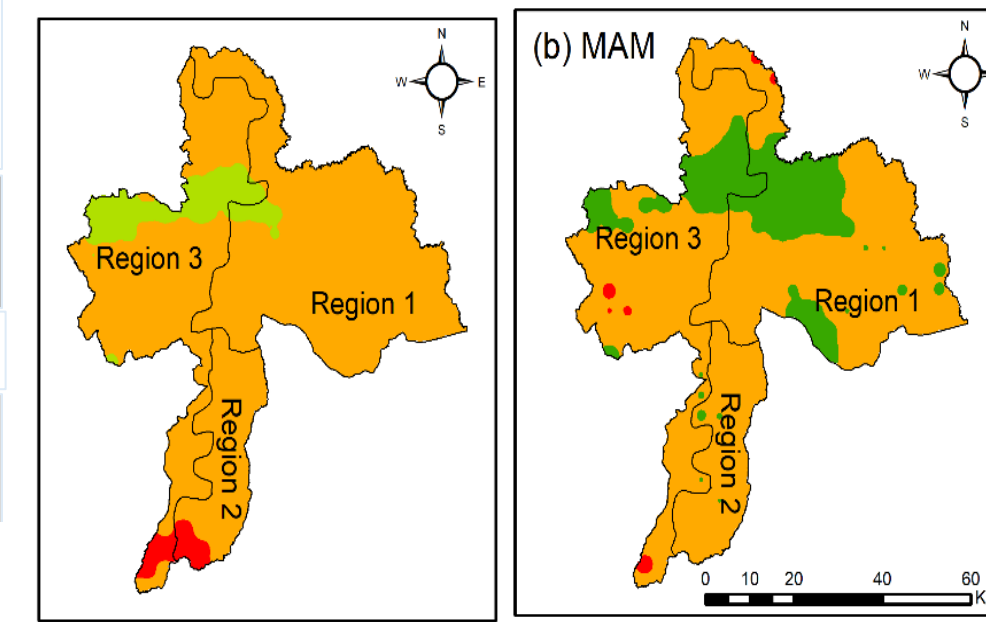
JJA: All regions indicated lower mean rainfall (35-115mm)

SOND: high value (435-515 mm) in northern part of R1, R2 and R3 and low value (275-355 mm) in northern part of R1, R2 and R3



Annual, R1 south indicated lower mean rainfall (700-800mm) and R2 south, R3 and northeastern part of R1 have indicated higher mean annual rainfall (1200-1300mm).

Seasonal and annual rainfall trends



No statistically significant trends in rainfall were detected at either seasonal or annual timescales in any of the three regions

Regional variability

Regionally, JF shows high variation (33%) in R1 and low variation (29.8%) in R2 while MAM shows low variation (20.0%) in R1 and high variation (22.5%) in R3. JJA shows high variation (96.5%) in R2 and low variation (86.9%) in R3. SOND shows low variation (20.2%) in R1 and high variation (25.3%) in R2. Annually, R3 shows high variation (19.8%) while R1 shows low variability (15.7%)

Season	Regions	μ (mm)	σ (mm)	CV (%)	Slope (mm/decade)
JF	R1	158.7	53.2	33.5	0.4
	R2	195.0	58.1	29.8	2.4
	R3	221.2	68.3	30.9	-6.5
MAM	R1	354.1	70.9	20.0	-18.5
	R2	437.6	93.9	21.5	-13.9
	R3	451.0	101.7	22.5	-6.9
JJA	R1	62.5	59.2	94.7	-6.5
	R2	66.3	64.0	96.5	-5.1
	R3	82.4	71.6	86.9	-4.9
SOND	R1	398.8	80.6	20.2	3.4
	R2	407.9	103.2	25.3	5.8
	R3	460.8	109.1	23.7	7.9
Annual	R1	978.5	154.1	15.7	-10.4
	R2	1112.1	199.1	17.9	5.5
	R3	1220.2	242.1	19.8	-3.2

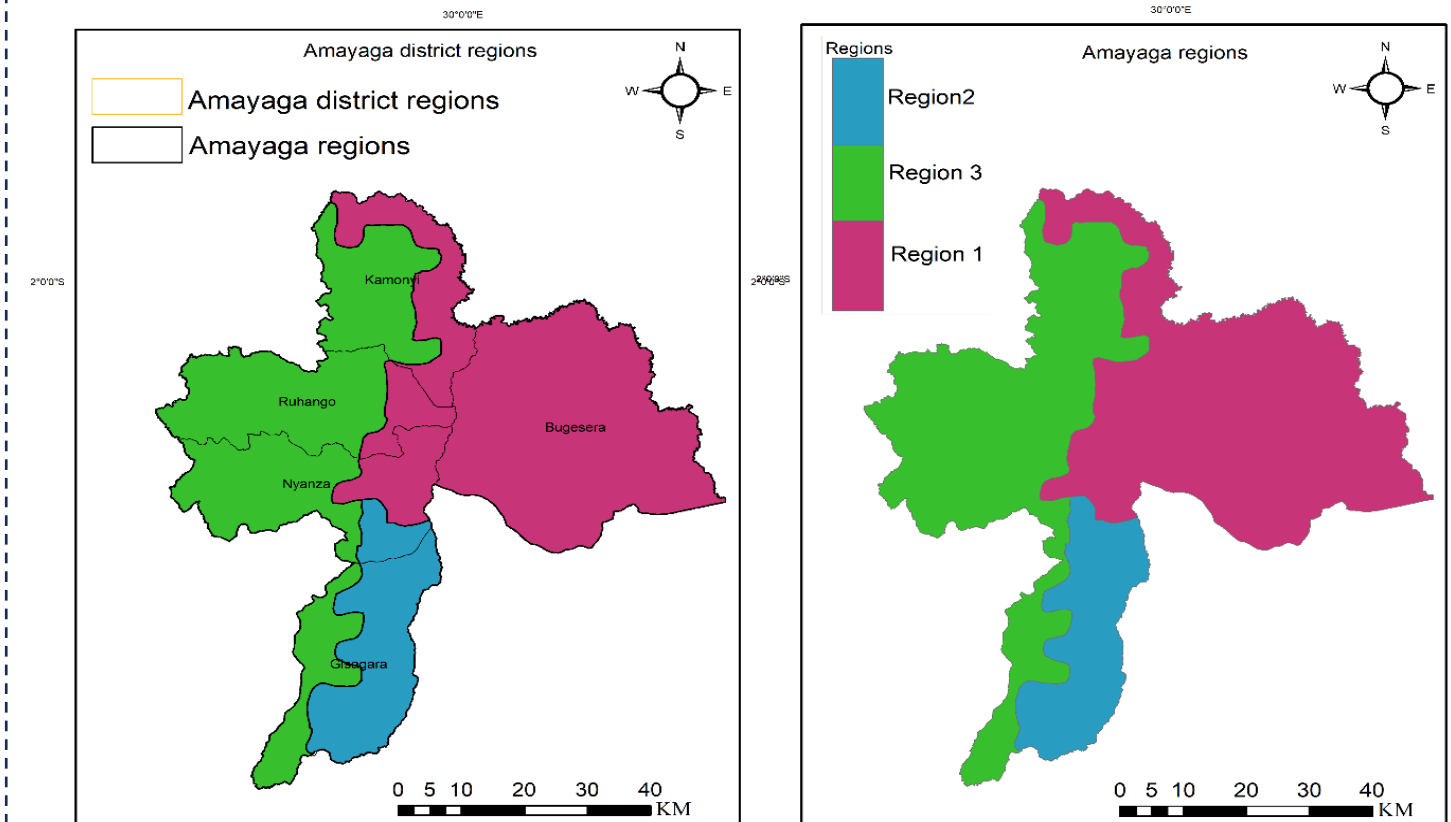
Objective: Assessing Spatial and Temporal Analysis of Rainfall Variability and trends over Amayaga region, Rwanda

Data: Gridded rainfall data (4Kmx4Km) obtained from the Rwanda Meteorology Agency for the period 1983-2021.

Method:

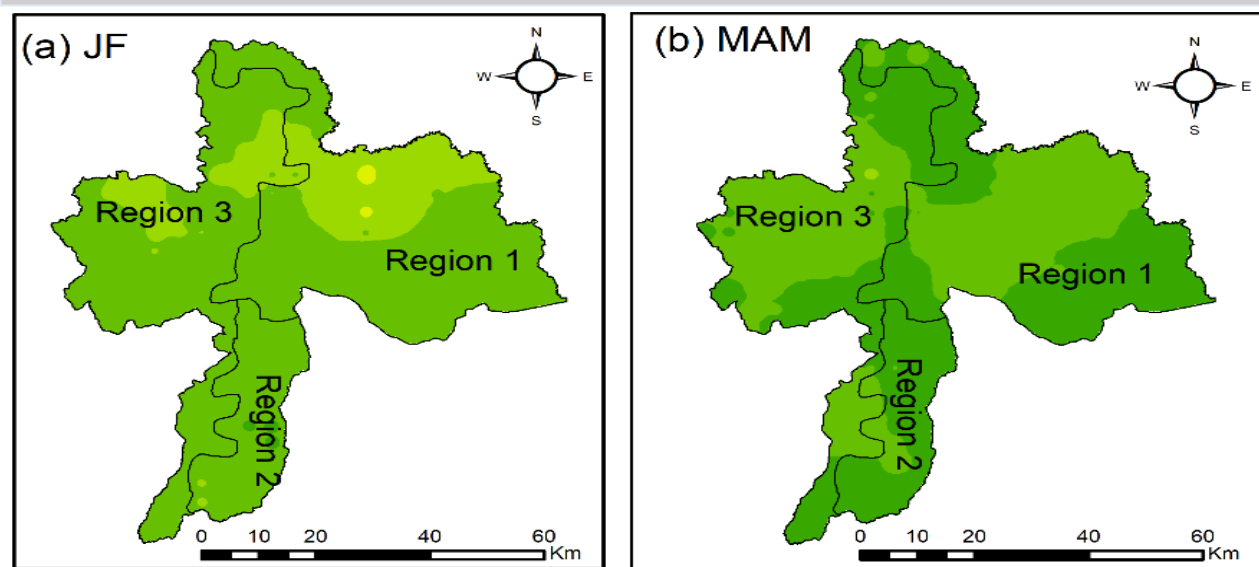
- Zoning: K-Mean clustering
- Variability: Coefficient of variation (CV)
- Trends: Mann-Kendall test and Sen's slope.

Climate zones (regions)

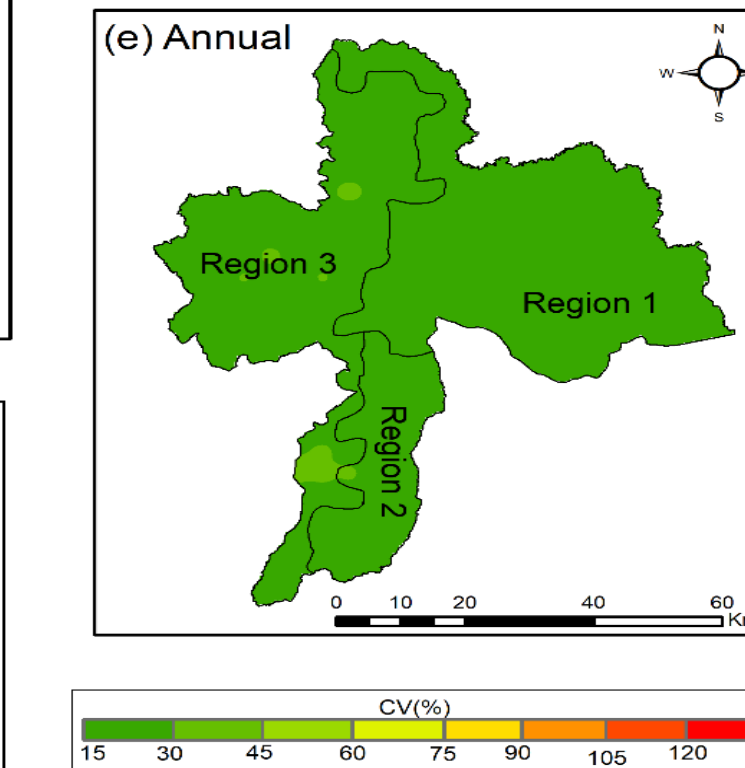
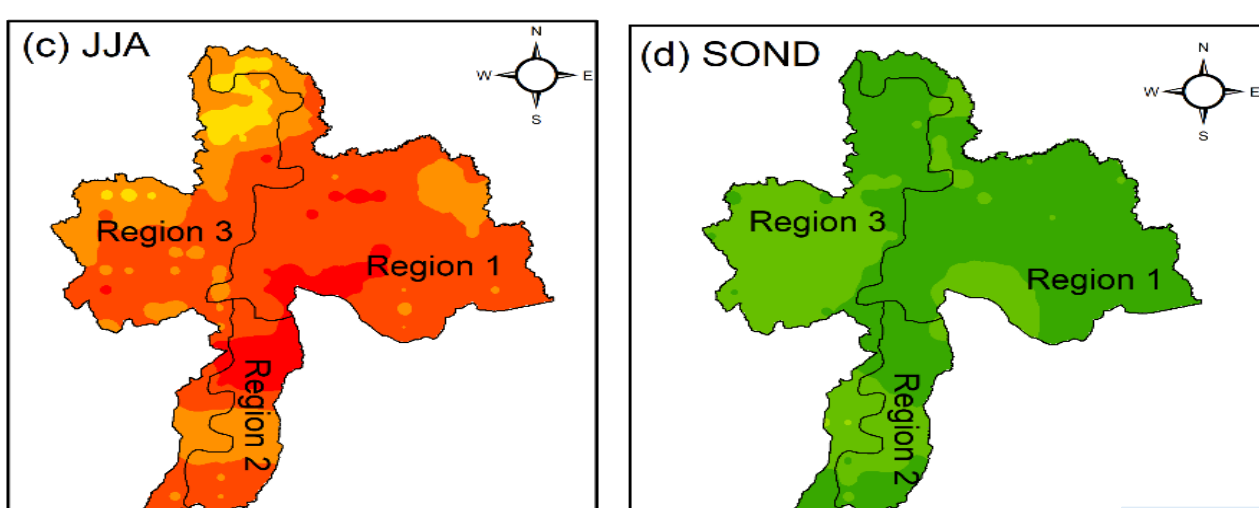


Three climatological zones were identified.
 Region 1 (R1): central-eastern and northeastern of Amayaga region
 Region 2 (R2): the southeastern parts of Amayaga region
 Region 3 (R3): western part of Amayaga region

Seasonal and annual rainfall variability



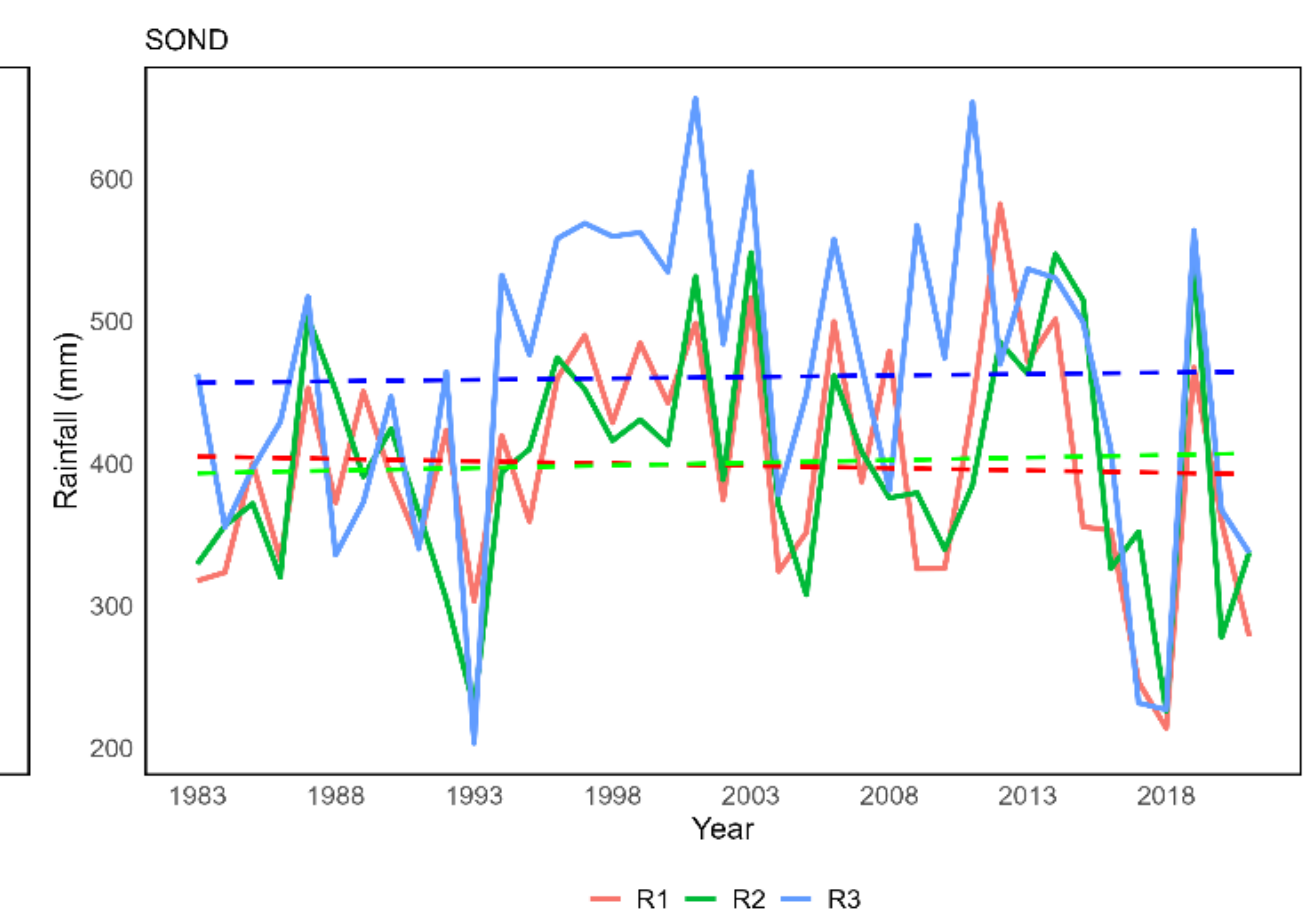
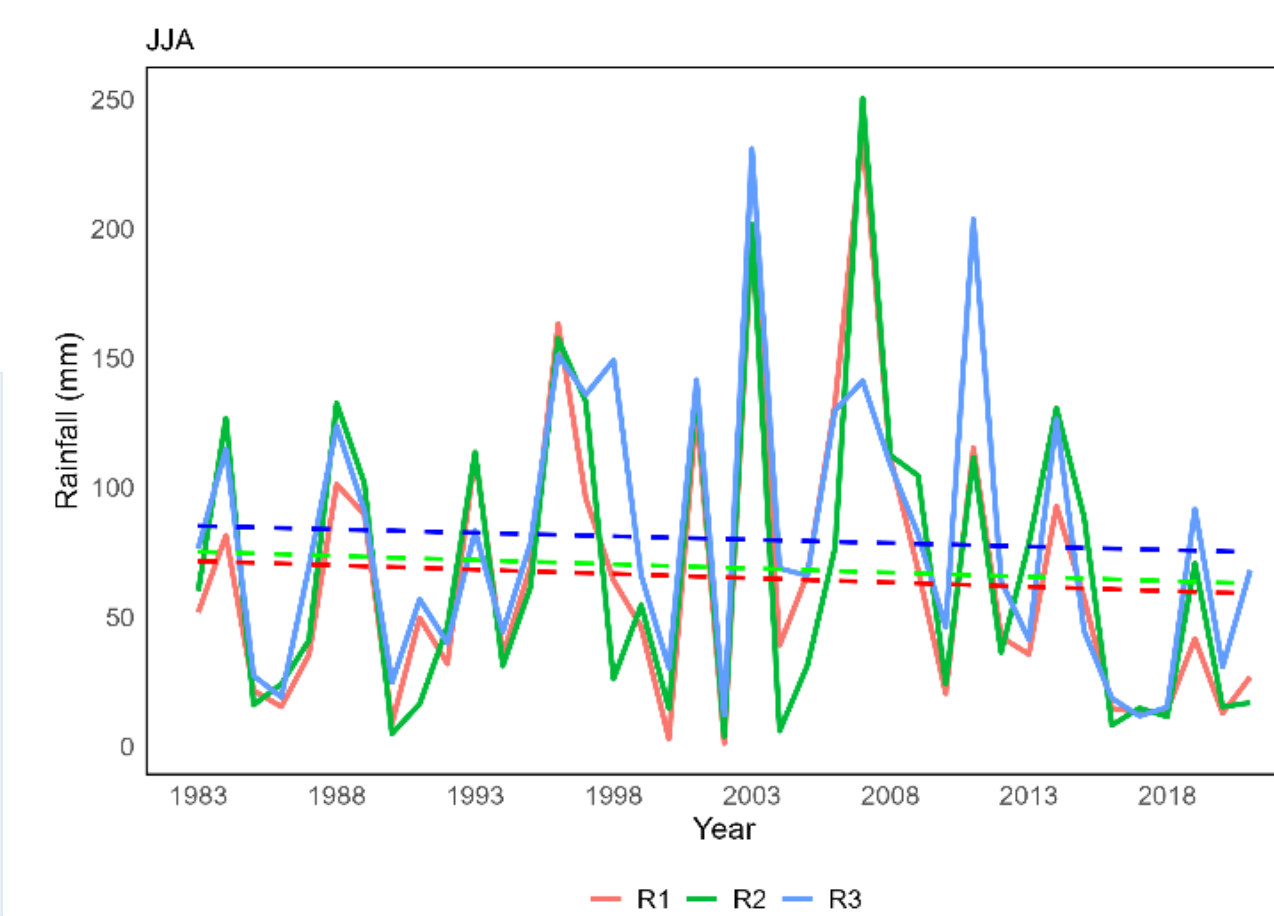
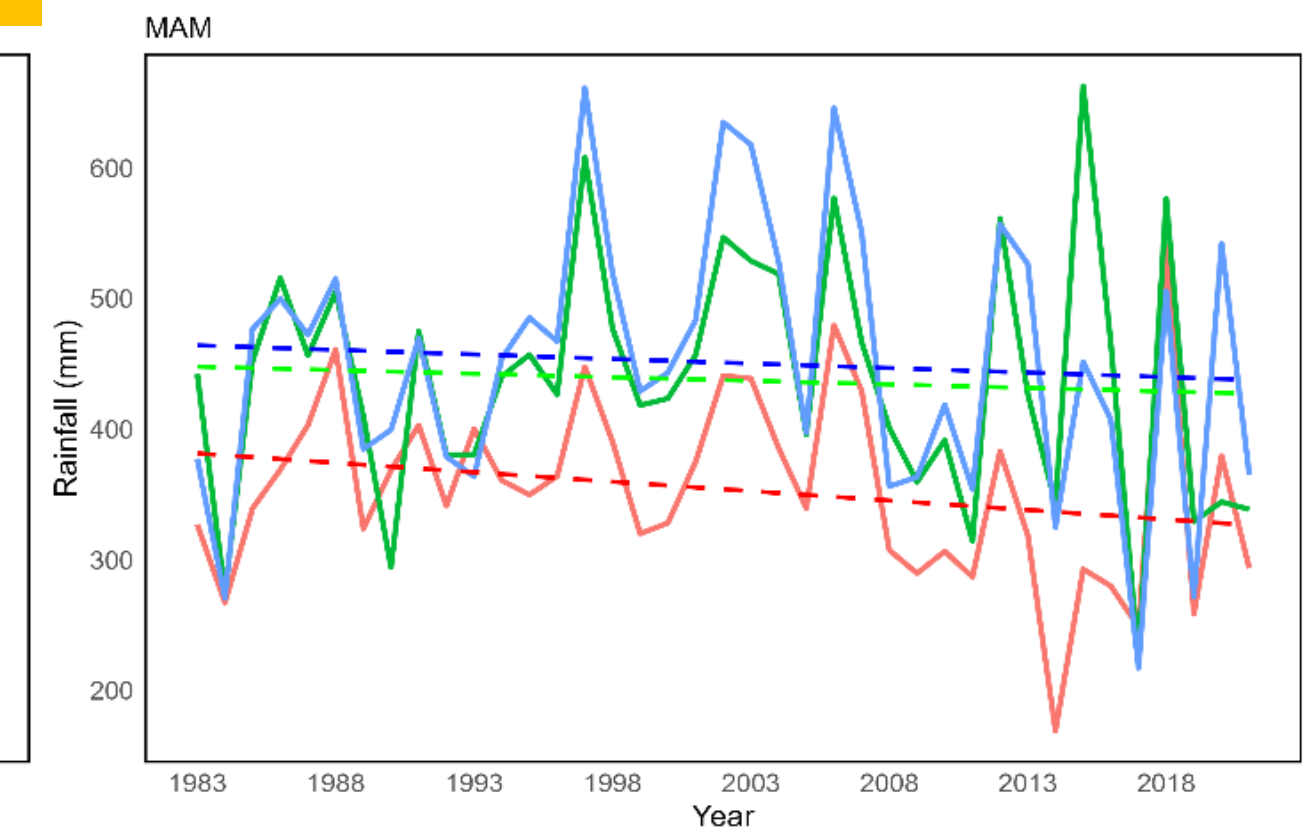
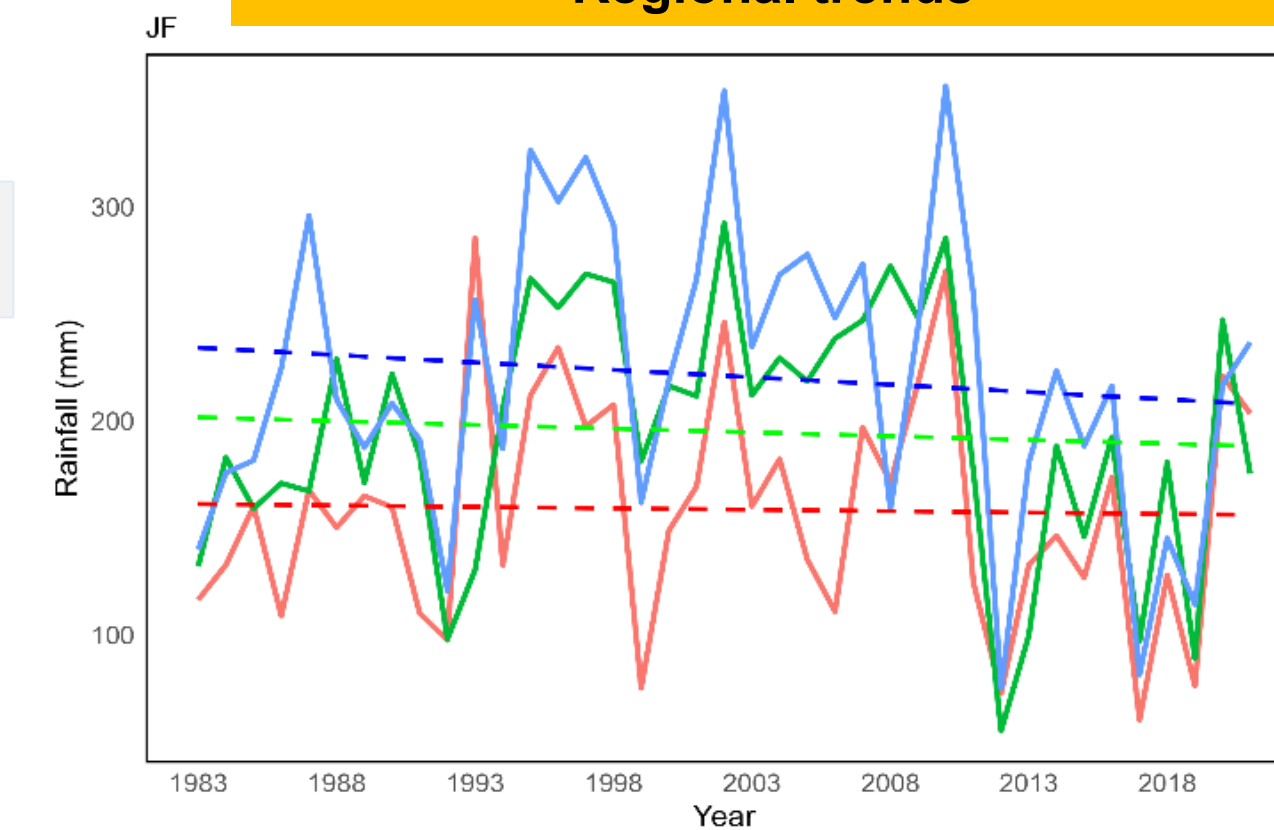
Annual
 Low variation (15-30%) → all regions



Dry seasons:
 ✓ **January-February (JF)**
 High values (45-60%) → northern R1 extending to north-central R3
 Low values (30-45%) → remaining areas
 ✓ **June-August (JJA)**
 High variability (75-105%) → central R2, western R3
 Very high values (105-120%) → remaining parts across all regions

Wet seasons:
 ✓ **March-May (MAM)**
 High variation (30-45%) → central R1, central R3, western R2
 ✓ **September-December (SOND)**
 High variation (30-45%) → central to western R2, central to western R3, southern R1
 ❖ Low variation for MAM and SOND (15-30%) → remaining areas

Regional trends



Title: Assessment of Maize Suitability Under Climate Change for Sustainable Agriculture: Evidence from Sub-Saharan African Countries

Author(s): John Nshimyumukiza

Affiliation: UNILAK, ESRI Rwanda

Introduction

Climate variability significantly affects agricultural productivity in Sub-Saharan Africa, where maize is a major staple crop. Understanding and predicting the impacts of climate change on maize suitability is crucial for achieving sustainable agriculture and food security.

Maize is a staple crop for millions in the countries of Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia, Zimbabwe, Rwanda, Burundi, Eswatini, and Lesotho, supporting livelihoods, nutrition, and local economies (Santpoort, 2020). However, the region's reliance on rain-fed maize farming makes it highly vulnerable to climate variability, with projected increases in temperature and shifts in rainfall patterns posing serious risks to yield and food security (Kent et al., 2017; Omotoso et al., 2023; Santpoort, 2020).

This study assess climate driven maize suitability using Environmental Information Systems and Maxent modeling for sustainable agriculture. It focused on Assessing the variability in climatic and maize production, Validating the performance of Maxent model to predict maize suitability, Assessing future maize suitability under climate change scenarios.

Study area

The study focused on a selected region in Sub-Saharan Africa, comprising eleven key maize-producing countries: Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia, Zimbabwe, Rwanda, Burundi, Eswatini, and Lesotho. These countries were selected based on their dependence on maize as a staple food crop and their vulnerability to climate variability and change (Kent et al., 2017; Omotoso et al., 2023; Santpoort, 2020).

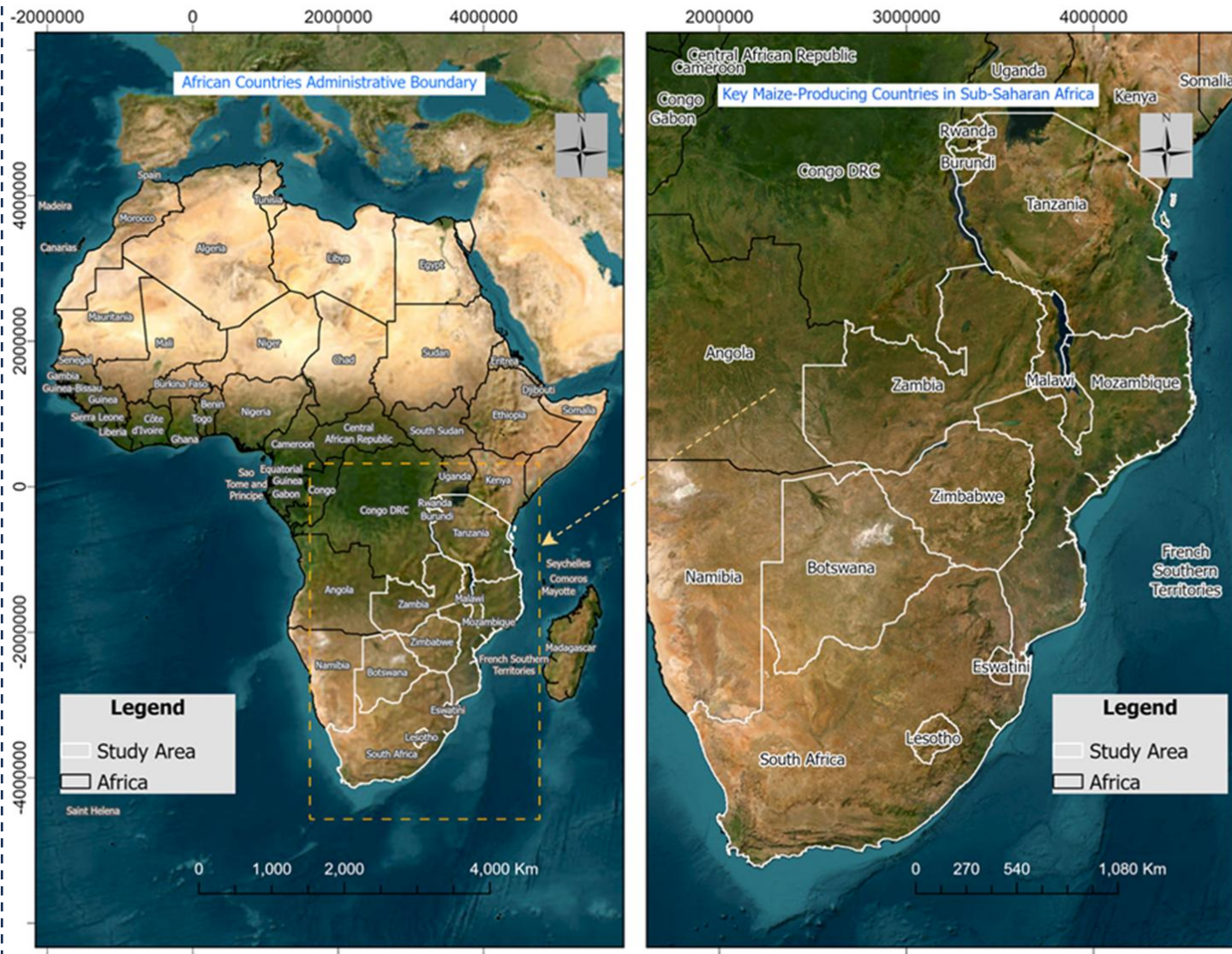
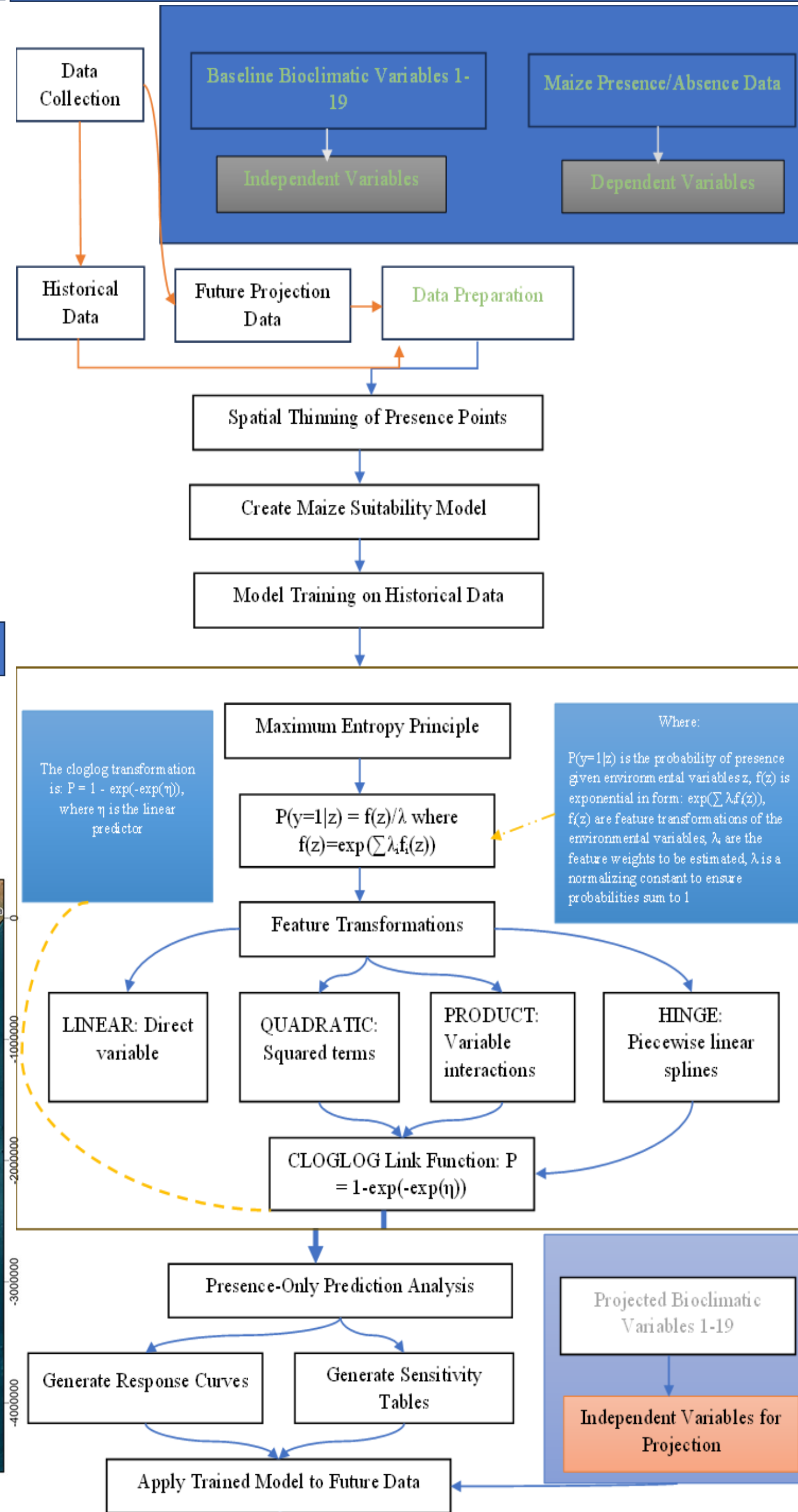


Figure 1: Key maize producing countries in Sub-Saharan Africa

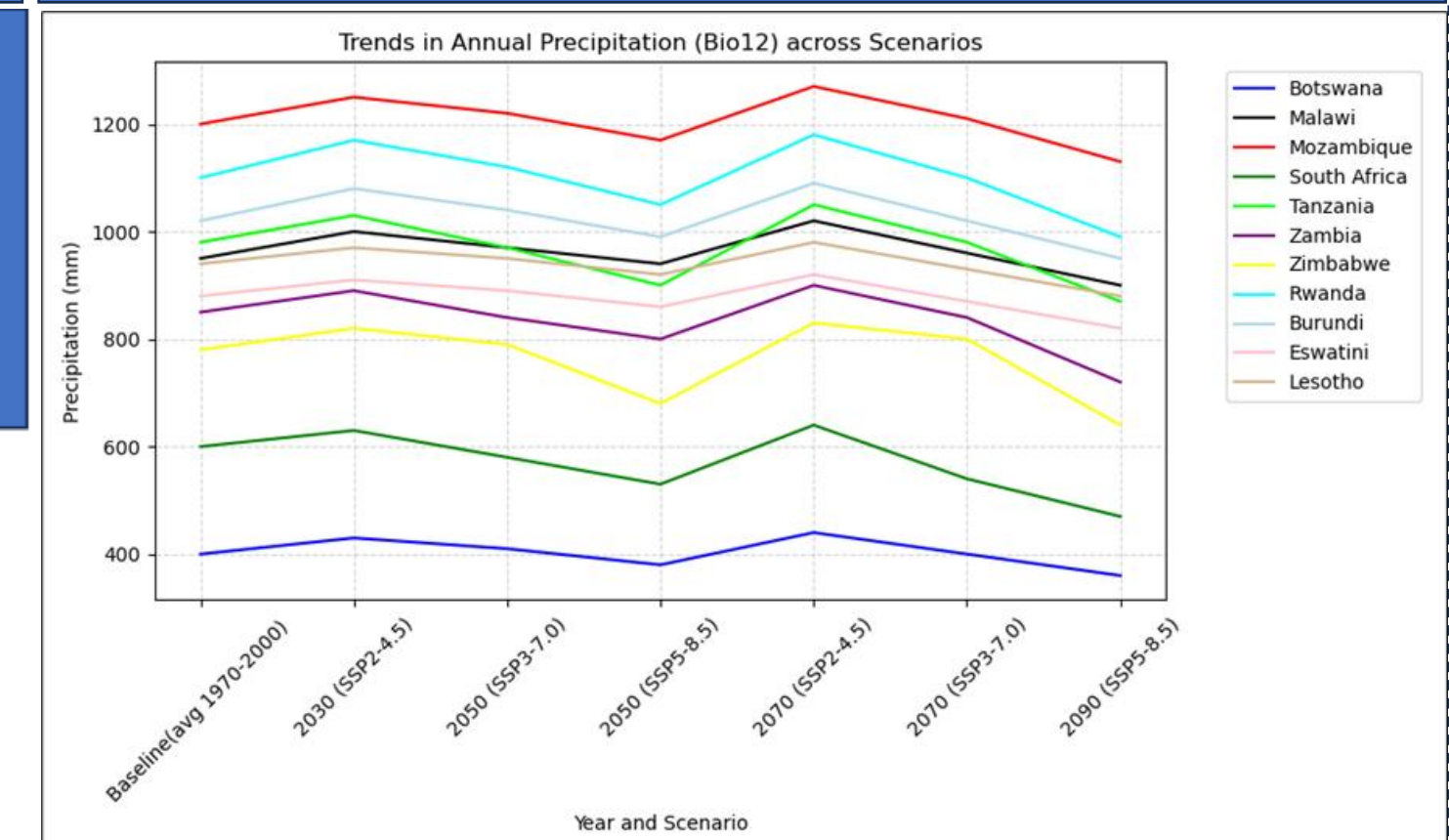
Data

Data Type	Source	Resolution	Time Period	Description
World Climate Data	WorldClim v2.1 (via Esri Living Atlas)	4 km	1970–2000	Dataset comprises 19 bioclimatic variables, including temperature and precipitation, which offer a comprehensive insight into the historical climate conditions of the research area.
Future Climate Projections	WorldClim v2.1 (via Esri Living Atlas)	4 km	2030, 2050, 2070, 2090	Dataset presents prospective climate scenarios derived from various shared socio-economic pathways (SSPs), specifically SSP2 4.5, SSP3 7.0, and SSP5 8.5.
Dominant Crop Data	Global Food-and-Water Security-support Analysis Data (GFSA D)	1 km	Latest available data	Raster dataset delineates the predominant crop kinds in each region essential for examining spatial patterns and temporal changes in land use.
Maize Harvested Area	Spatial Production Allocation Model (SPAM)	1 km	1999–2001	Dataset delineates the regions where maize is cultivated within the research area.
Elevation Data	GIS Databases (Esri)	10m	Latest available data	Essential for terrain modeling and comprehending the impact of altitude on climatic conditions and agricultural yield.

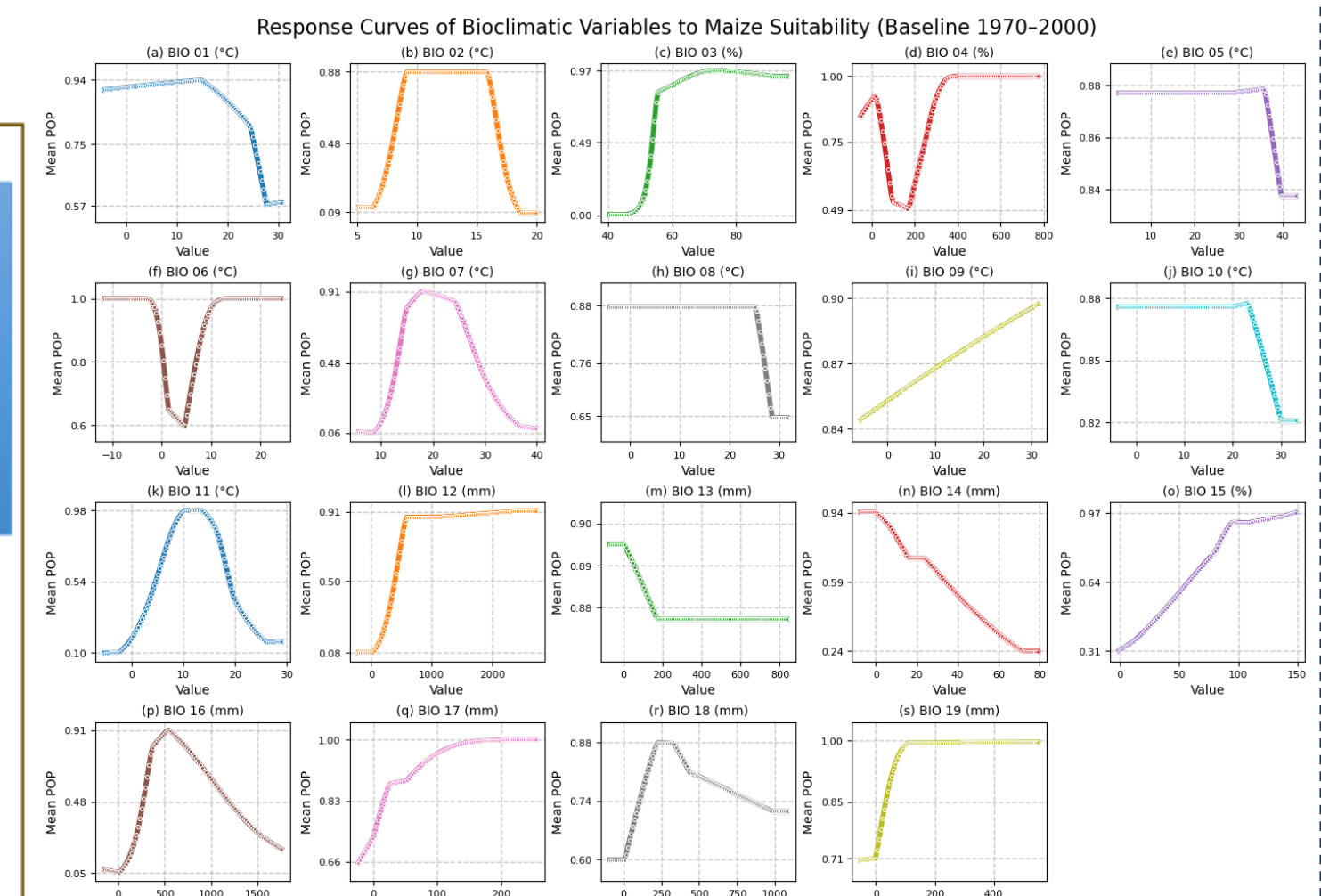
Methods & Model



Annual Precipitation across SSPs



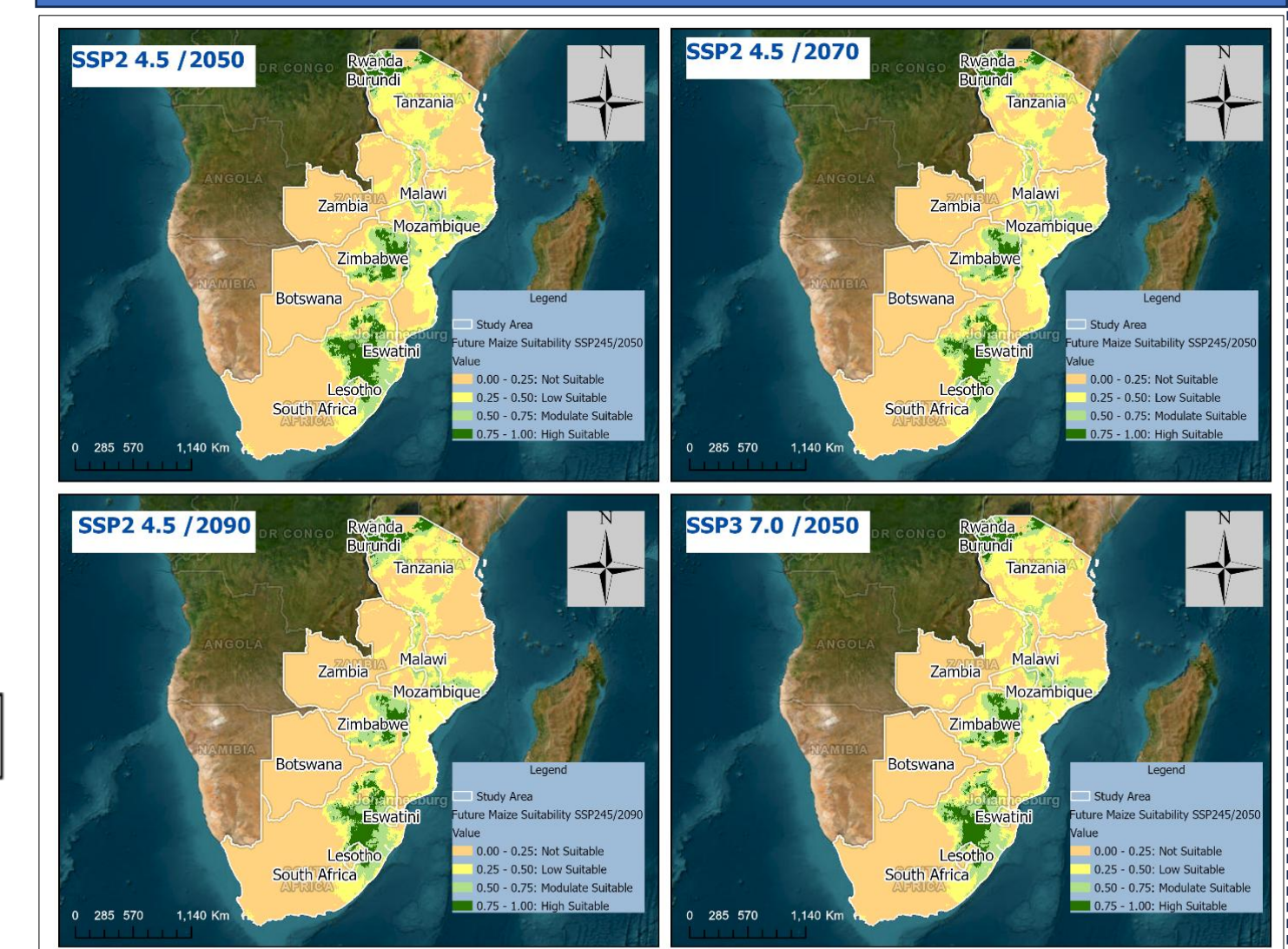
Influence of individual variables on the model



Performance of Maxent Model

Metric	Value
AUC	0.8506
Omission Rate	0.2683
Presence Points Used in Model	90,469
Classified Presence	11,314
Background Points Used in Model	909,524
Classified Presence	126,519
Classified Presence	26,816

Projected Suitability under SSP Scenarios



Conclusion

This study concludes that climate change will have a significant and spatially variable impact on maize production in Sub-Saharan Africa. While some countries such as Rwanda, Burundi, and Tanzania may benefit from shifts in agroecological zones and enhanced rainfall patterns under moderate climate scenarios, others especially Botswana, Mozambique, and South Africa are likely to face intensified stress from rising temperatures and water shortages. The research confirms that suitable maize-growing zones are projected to shrink in arid and semi-arid countries under extreme scenarios like SSP5 8.5, posing serious risks to food security and rural livelihoods.

Contact Information

UNILAK & ESRI Rwanda

Contact Information

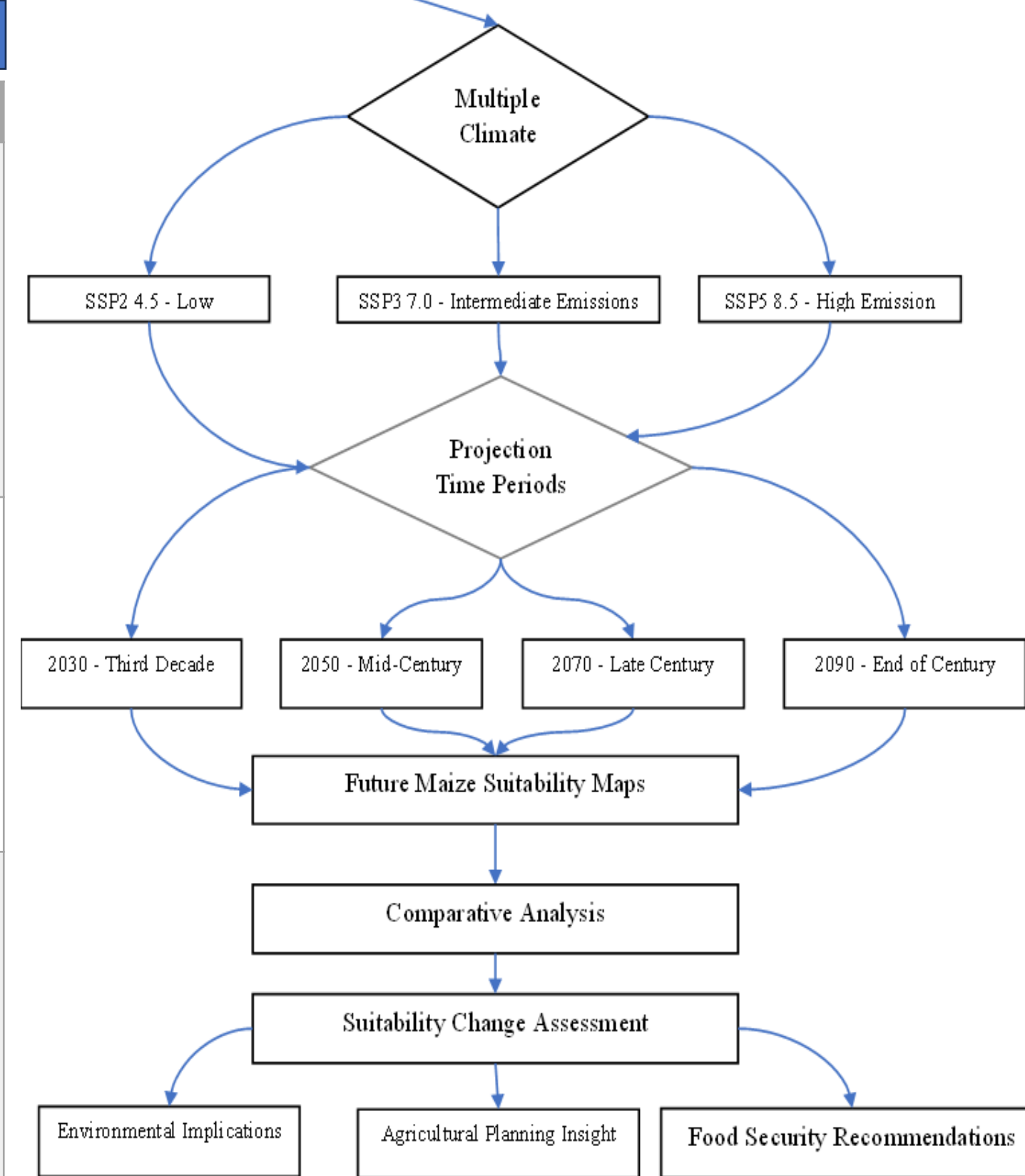
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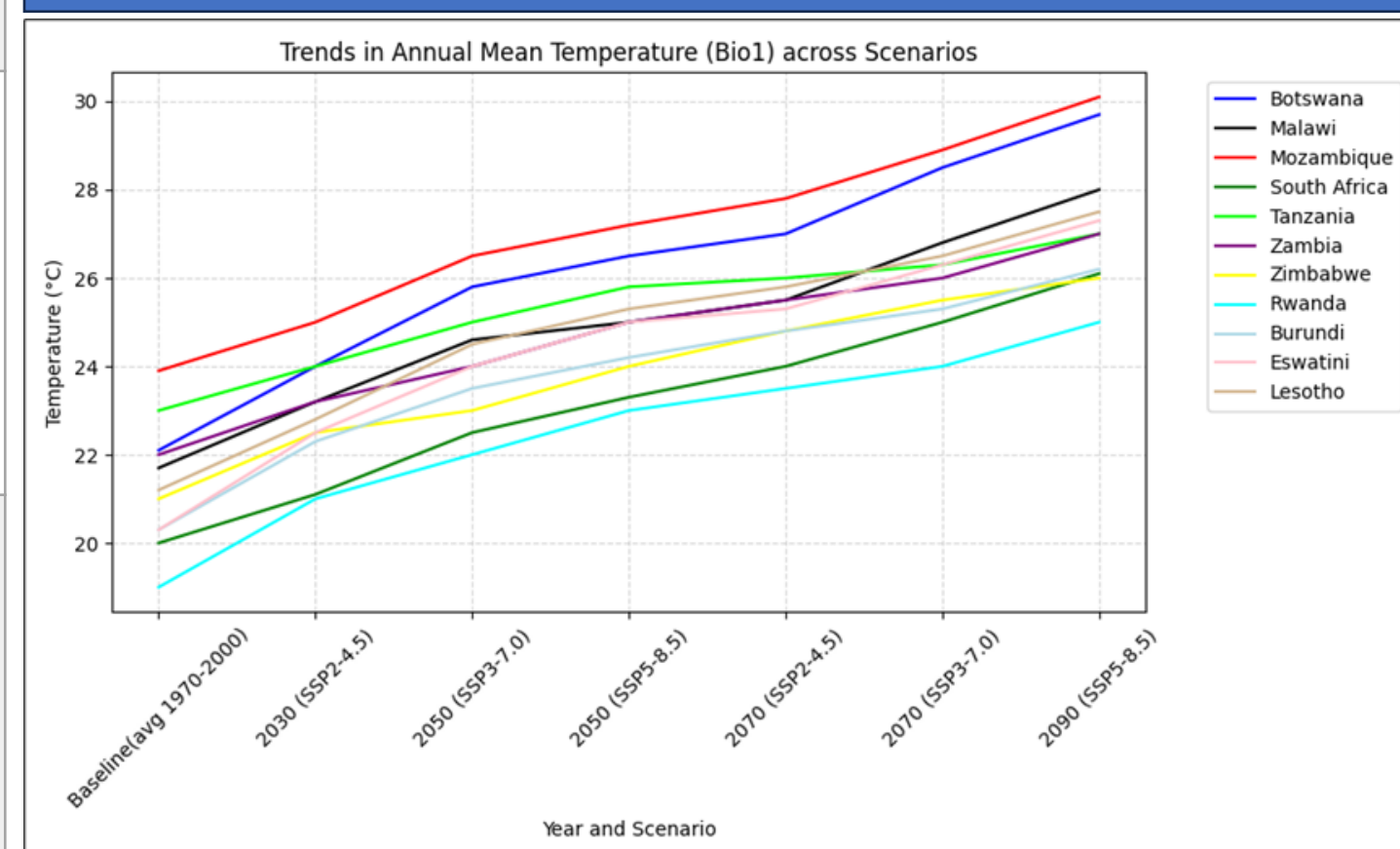
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Annual Mean Temperature across SSPs



Effects of growth temperature and drought on net photosynthesis and stomatal conductance in Rwanda native tree species

Brigitte Uwajeneza, Prof. Donat Nsabimana, Prof. Johan Uddling and Dr. Myriam Mujawamariya
University of Rwanda/Rwanda TREE Project

Introduction

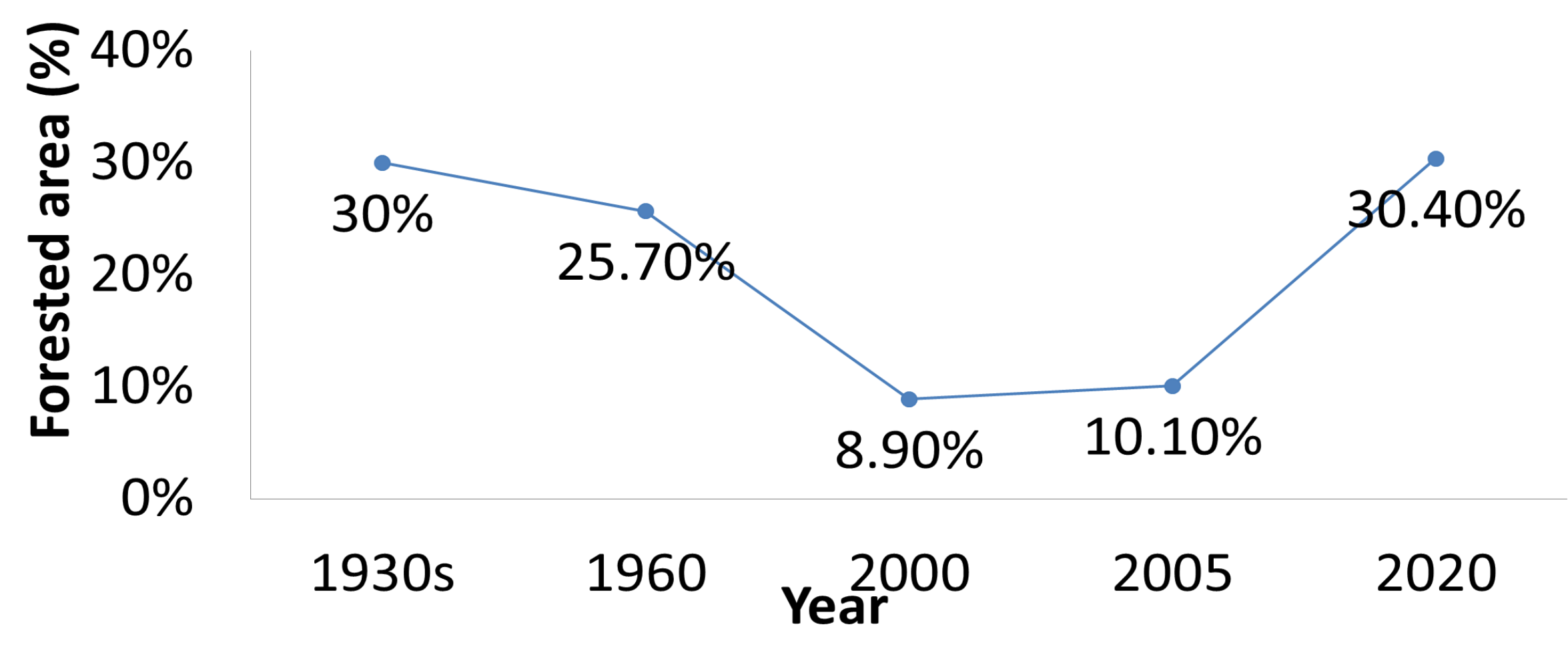


Figure 1: Decline of forested area in Rwanda from 1930s to 2020

- The dominance of exotic monoculture specifically *Eucalyptus spp* (89%) enhance soil erosion, allelopathic effects, pests and diseases attraction and depleting soil nutrients
- Rwanda new Forest Policy (2018) focus on native tree species to increase tree diversity in forest restoration. However, there is a lack of information about the adaptation of native tree species in different agro-ecological zones in Rwanda
- This study aimed to assess the impact of growth temperature and drought on net photosynthesis in native tree species along an elevation gradient in Rwanda
- We hypothesized that (1) Species exhibit the lowest net photosynthesis at low elevation (warmer) site, (2) early successional (ES) species have higher net photosynthesis than late successional (LS) species at all sites and (3) the net photosynthesis declines under drought conditions at all sites

Methodology

- This study was conducted within the Rwanda Tropical Elevation Experiment (Rwanda-TREE) having multispecies forest plantations with 20 native species (grouped into LS and ES species) along an elevation gradient

High elevation
Sigira/Nyamagabe
2400 m. a. s. l.
17.5/23.8 °C, 2100

Mid elevation
Rubona/Huye
1600 m. a. s. l.
22.5/28.6 °C, 1600 mm

Low elevation Ibanda
Makera/Kirehe
1300 m. a. s. l.
23.8/31.4 °C, 1050 mm

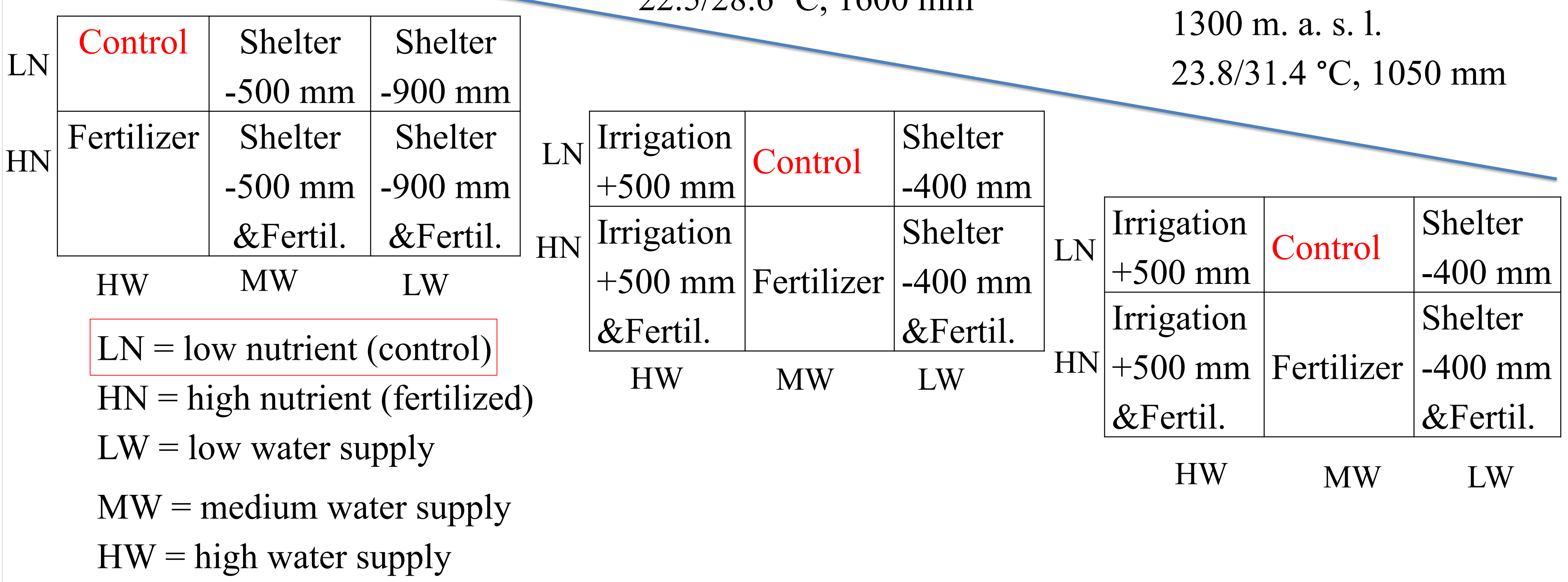


Figure 2: Rwanda TREE experimental Design

- Leaf gas exchange measurements were made using LI-COR (LI-6400XT) to assess the effect of temperature change and drought on stomata conductance (g_s) and net photosynthesis (A_n) of trees under study

Results

- The net photosynthesis and stomatal conductance are lower in LS than ES and the difference got smaller under drought (Figure 3a,b)
- The net photosynthesis and stomatal conductance declined at LE (warmer) site were lower at warmer site and the strong decline is observed LS species (Figure 3a,b)
- The net photosynthesis and stomatal conductance declined under drought conditions (low water treatment) (Figure 3c,d)

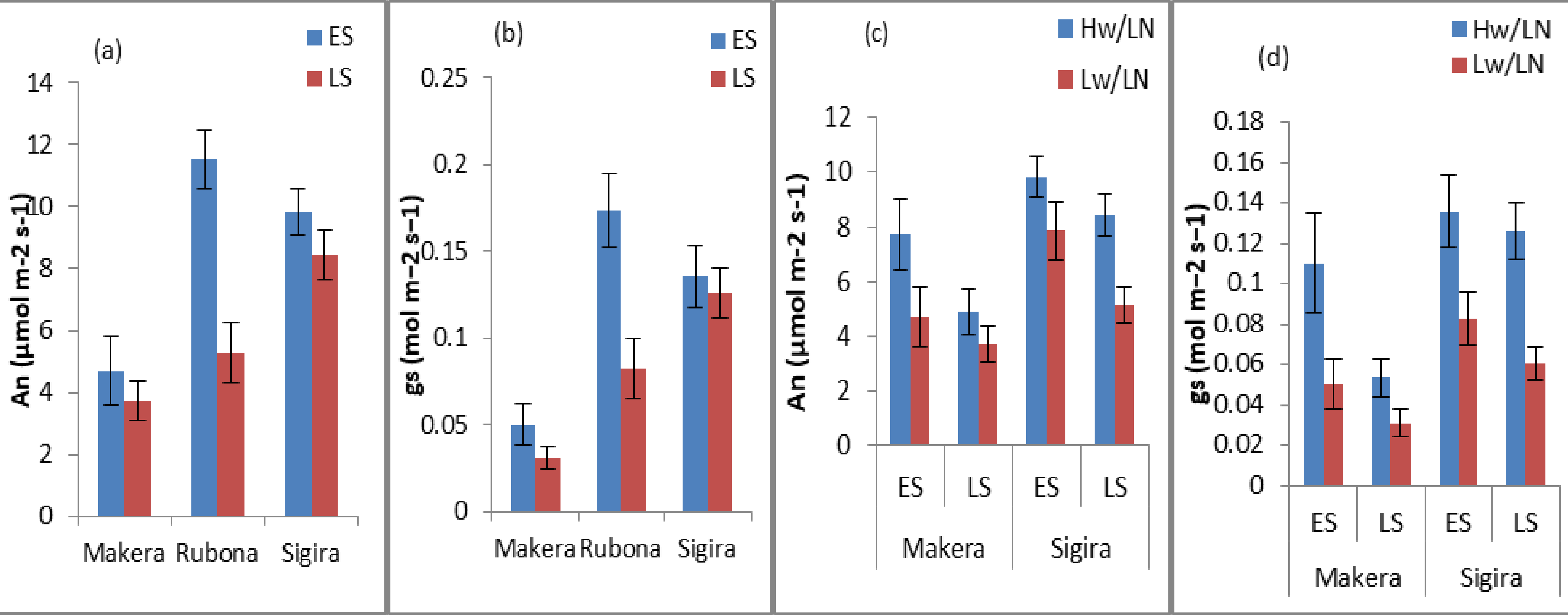


Figure 3: Growth temperature effect on net photosynthesis, A_n (a); stomatal conductance, g_s (b). Drought effect on A_n (c) and g_s (d) at high and low elevation sites

Discussion

- The decline of A_n at LE site is a result of the reduction in the availability of CO_2 due to the decline in g_s observed at this site. As temperature increase leaf stomata closes partially to reduce water loss
- The high A_n and stomatal conductance observed in ES is proposed to be the result of their higher metabolism and ability to acquire resources and lower photo-inhibition than do shade-adapted (LS) species
- Drought negatively affects A_n at both sites due to stomatal limitation which increase as soil water content declines. Negative water potential also increase the vulnerability of vessels to embolism

Conclusion

- The response of photosynthesis to high temperature and drought will affect the growth of trees suggesting a higher risk to some species, particularly LS and montane tree species in a changing climate
- Recommendation:** Further research on other growth factors' effects to those species to confirm their adaptability to different climatic conditions

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Title: Impact of climate variability on agricultural productivity: Case study of Bugesera district, Rwanda

Author(s): Angele Uwimana

Affiliation: MINEDUC

Introduction

Agriculture is highly sensitive to climate, especially in rain-fed systems like those in Bugesera District, Rwanda. Despite national strategies, limited irrigation and low adoption of climate-smart practices leave the region vulnerable to droughts and erratic rainfall. This study analyzes rainfall and temperature variability from 1981 to 2021 and incorporates farmers' experiences to inform practical, locally grounded solutions.

Study area

Bugesera District, in Rwanda's Eastern Province, features rolling hills, arid valleys, wetlands, and lakes like Rweru and Cyohoha. With elevations between 1,100 and 1,780 meters, it has a mild climate shaped by its varied topography. The average temperature in Bugesera district, Rwanda, typically ranges between 20°C to 26°C.

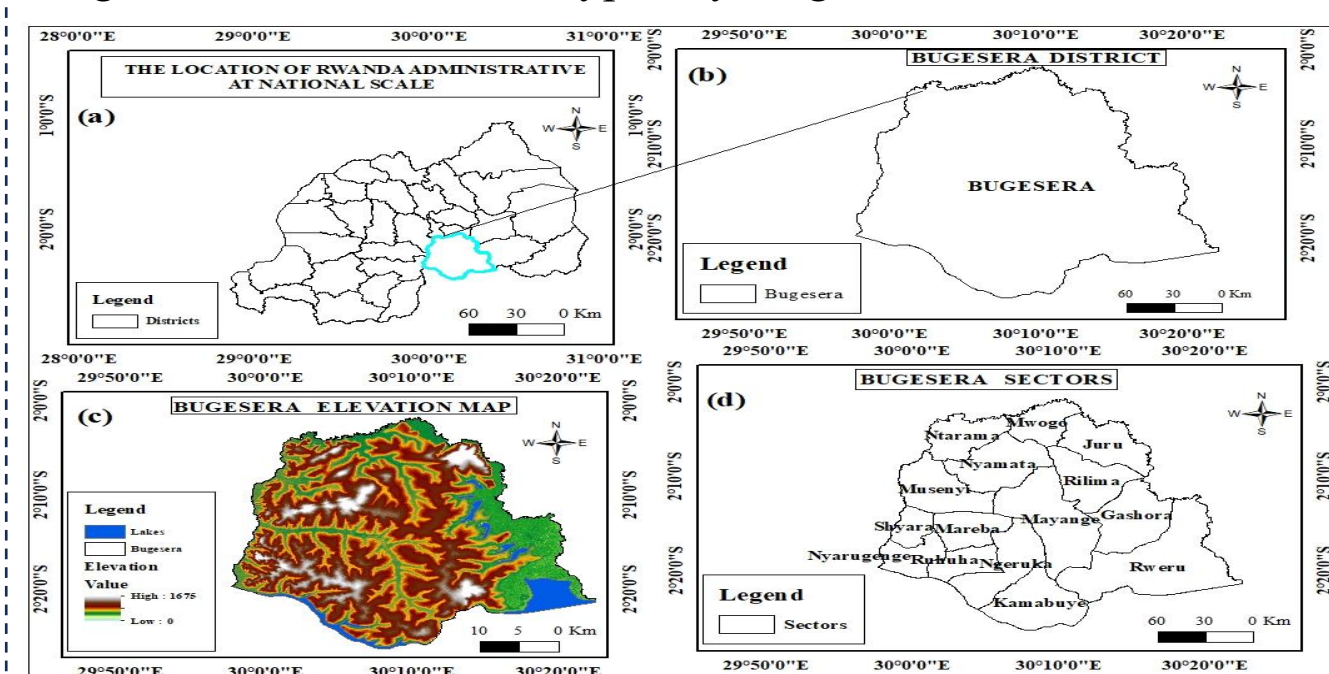


Figure 1: Geographical location of Bugesera District in Rwanda (a), the Bugesera district administrative map (b), elevation and lakes in Bugesera district (c) and Bugesera district sector administrative map (d).

Data:

The study used both primary and secondary data: surveys from 400 Bugesera farmers to assess climate impacts and adaptation, and historical temperature and rainfall data (1983–2021) from Rwanda Meteorology Agency, analyzed at seasonal, and annual scales.

Methods:

The variability in rainfall and temperature were assessed using coefficient of variation (CV), trends were assessed using Modified Mann-Kendall test and trends magnitude were assessed using Sen's Slope Estimator.

Results:

Rainfall in Bugesera shows a consistent north-to-south gradient across all seasons, with the northern areas receiving the highest rainfall ([1100,1200] mm), central areas moderate ([900,1000] mm), and southern areas the least ([700,800] mm). Rainfall variability in Bugesera is highest in the north and decreases southward annually, though seasonal patterns vary, with SON showing peak variability in the south. Bugesera's rainfall trends vary by season, with increases in southwest and central areas, and declines in the north and southeast. Maximum temperature variability in Bugesera is highest in the south and southeast, especially during JJA and SON, while central and northern areas remain more stable year round. Maximum temperature trends in Bugesera peak in the central and eastern areas, especially in MAM and SON, while the west and southwest remain consistently cooler throughout the year. Minimum temperature variability in Bugesera (1983-2021) ranges from 3°C to 8°C, with SON showing the highest variability. Minimum temperature trends in Bugesera (1983-2021) show warming in all seasons, with the highest increases in JF and SON, and lower increases in JJA and annually. Bugesera shows moderate to high temperature variability ([5,8]°C) in the southeast, with the northwest and east experiencing the fastest warming ([0.29,0.44]°C/decade). Though 86% of farmers access climate info, 57% say adaptation hasn't improved food security. While 97% report better productivity, key needs include financial aid and infrastructure. The study highlights rising temperatures, no rainfall trends, and calls for climate-smart agriculture, irrigation, and policy support.

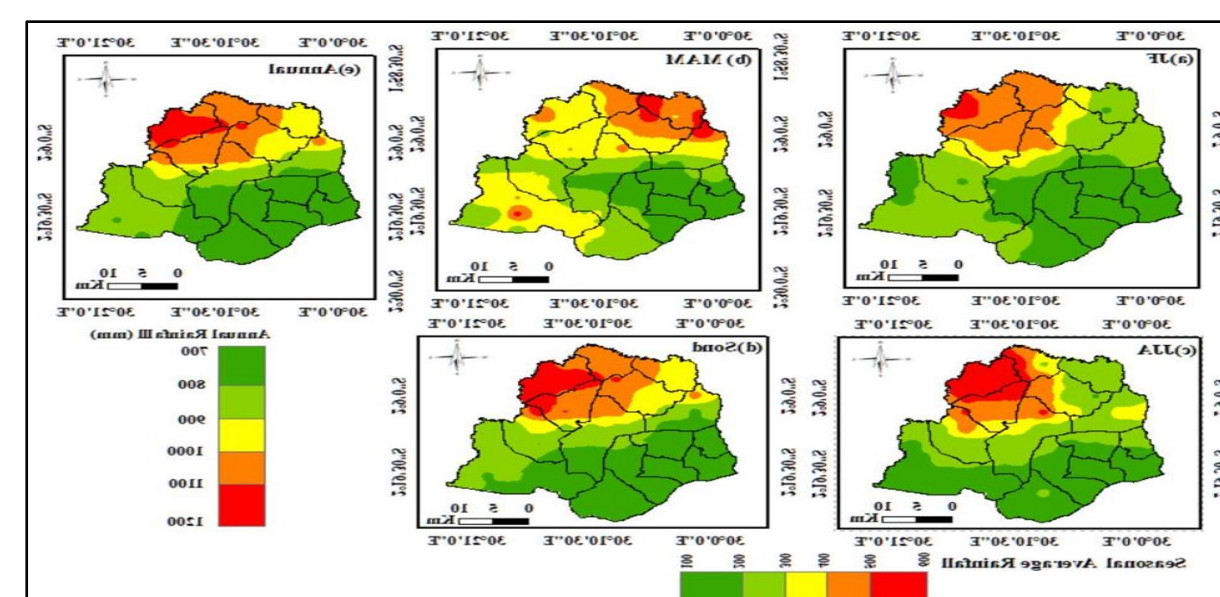
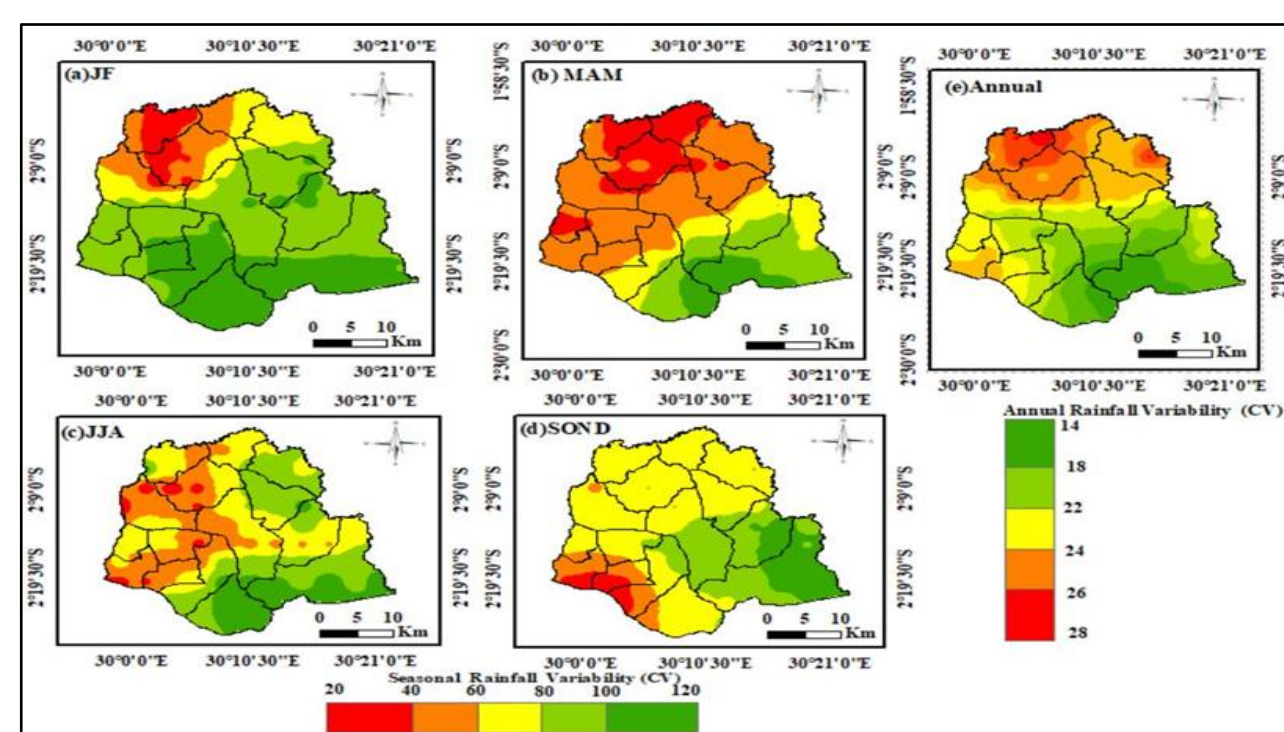
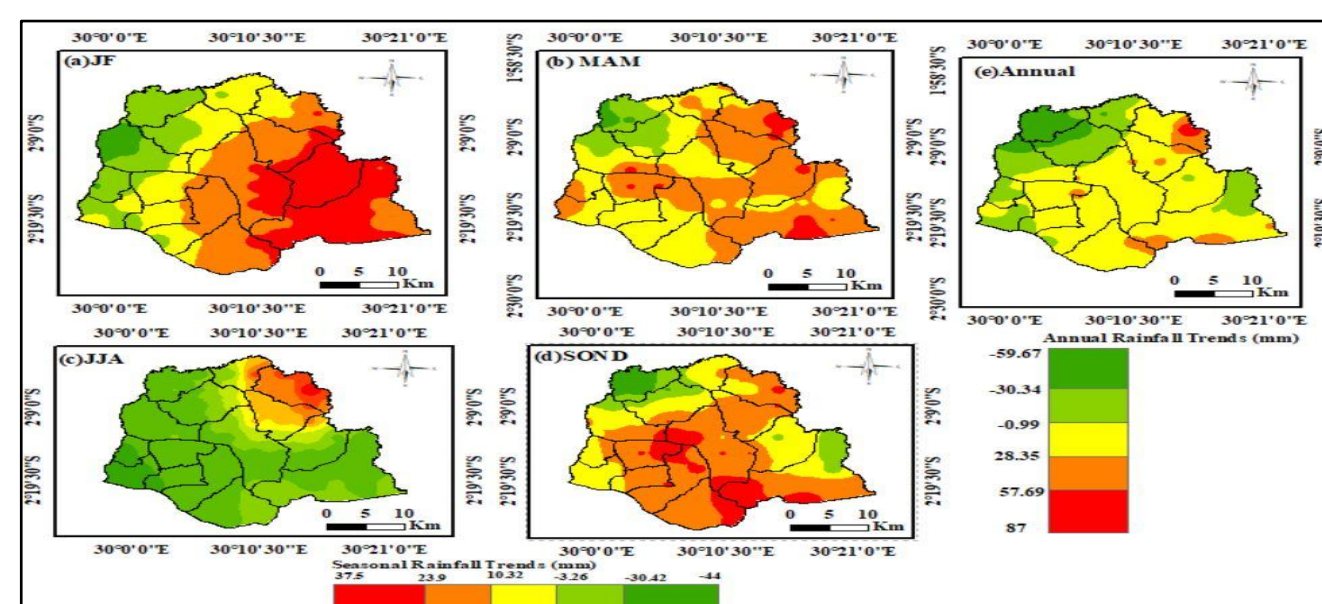


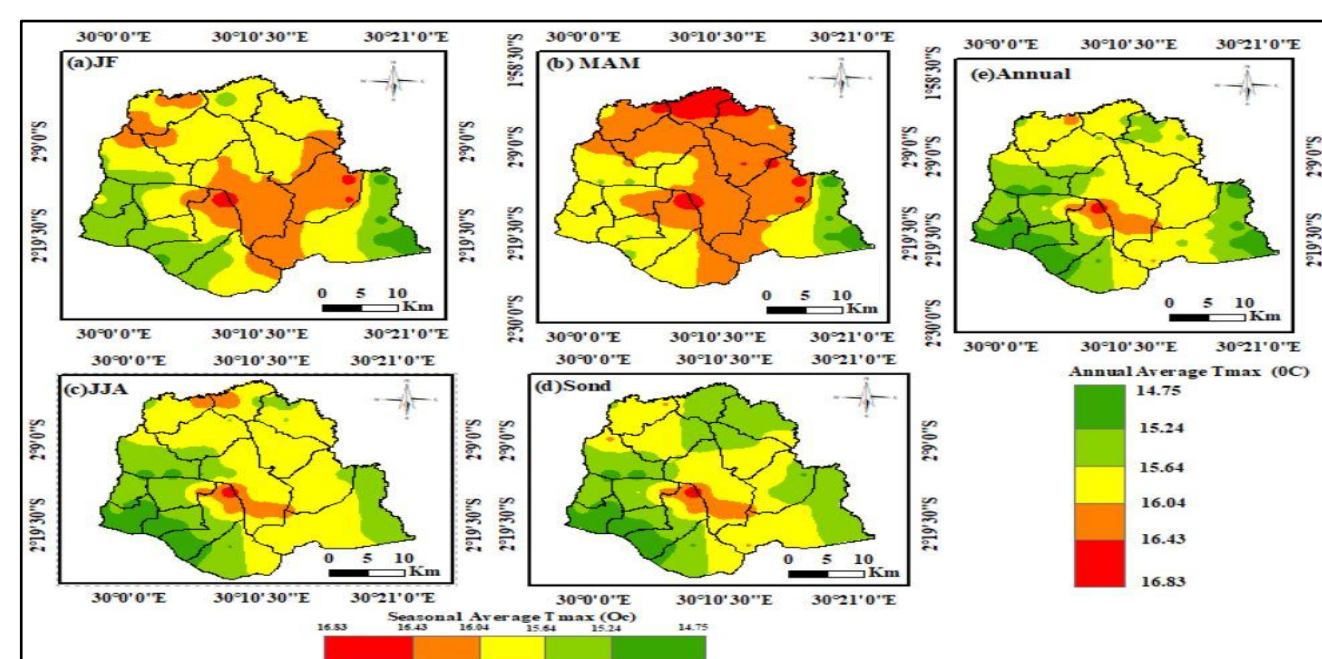
Figure 2: Average rainfall distribution during JF, MAM, JJA, SON, and Annual over the Bugesera district from 1983-2021.



The figure 3: Spatial Variability of seasonal and annual rainfall during JF, MAM, SON, and Annual time series from 1983 to 2021



The figure 4: Rainfall trends during JF, MAM, JJA, SON, and ANNUAL time series throughout 1983-2021



The figure 5: Spatial distribution of seasonal and annual maximum temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021

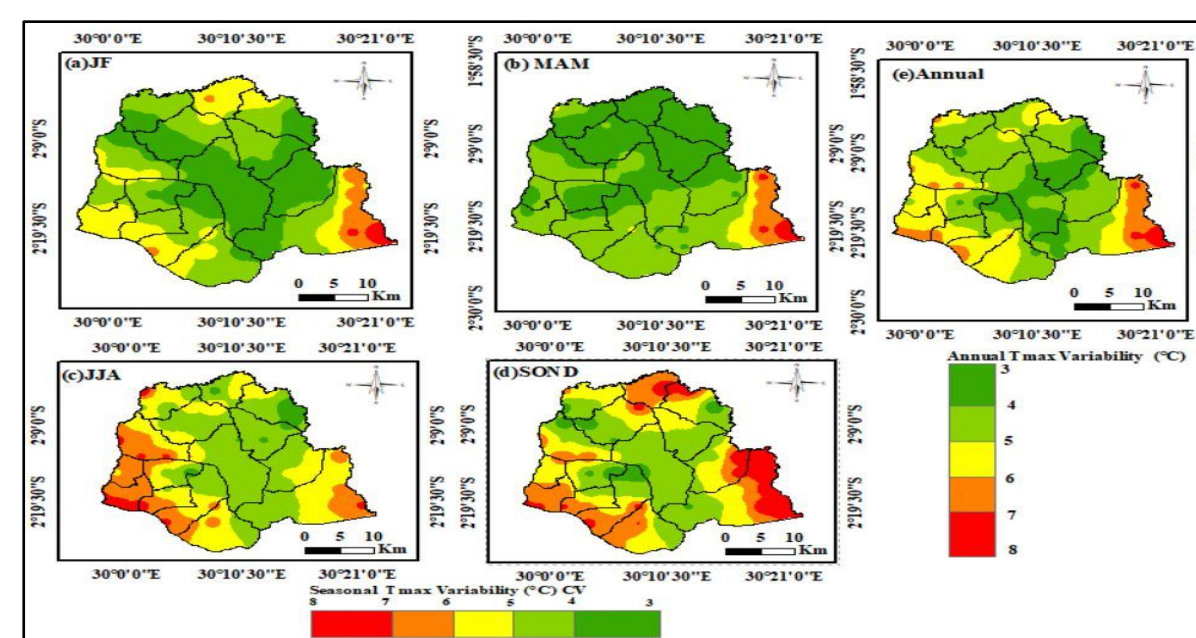


Figure 6: Seasonal and annual maximum temperature (Tmax) from 1983-2021 in Bugesera district

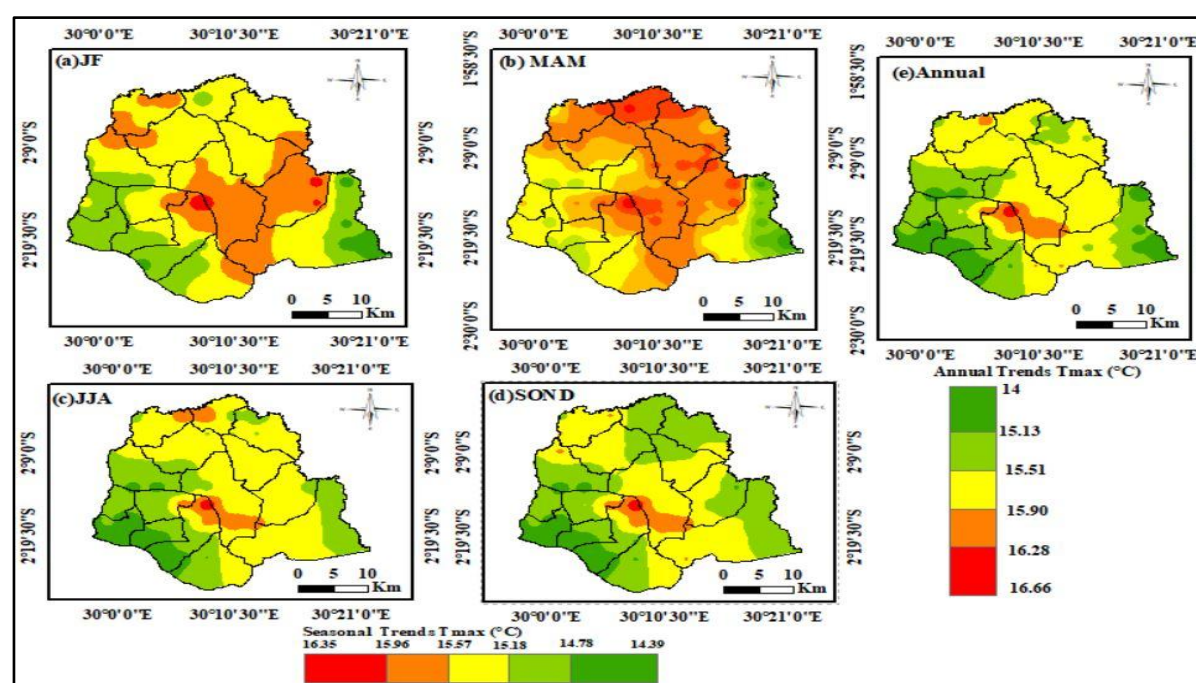


Figure 7: Spatial trends of seasonal and annual maximum temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021

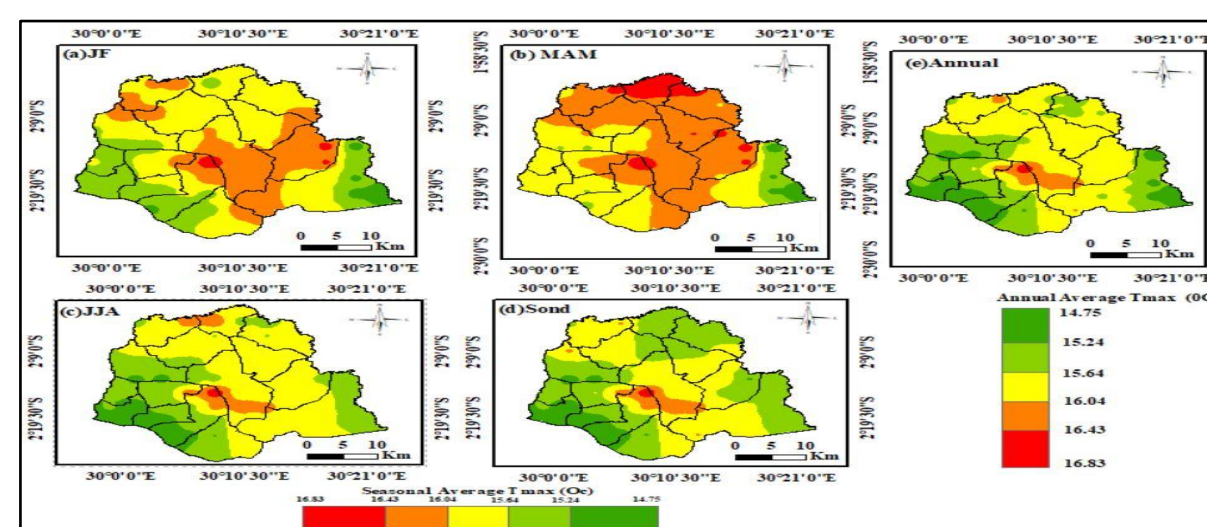


Figure 8: Spatial distribution of seasonal and annual minimum temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021

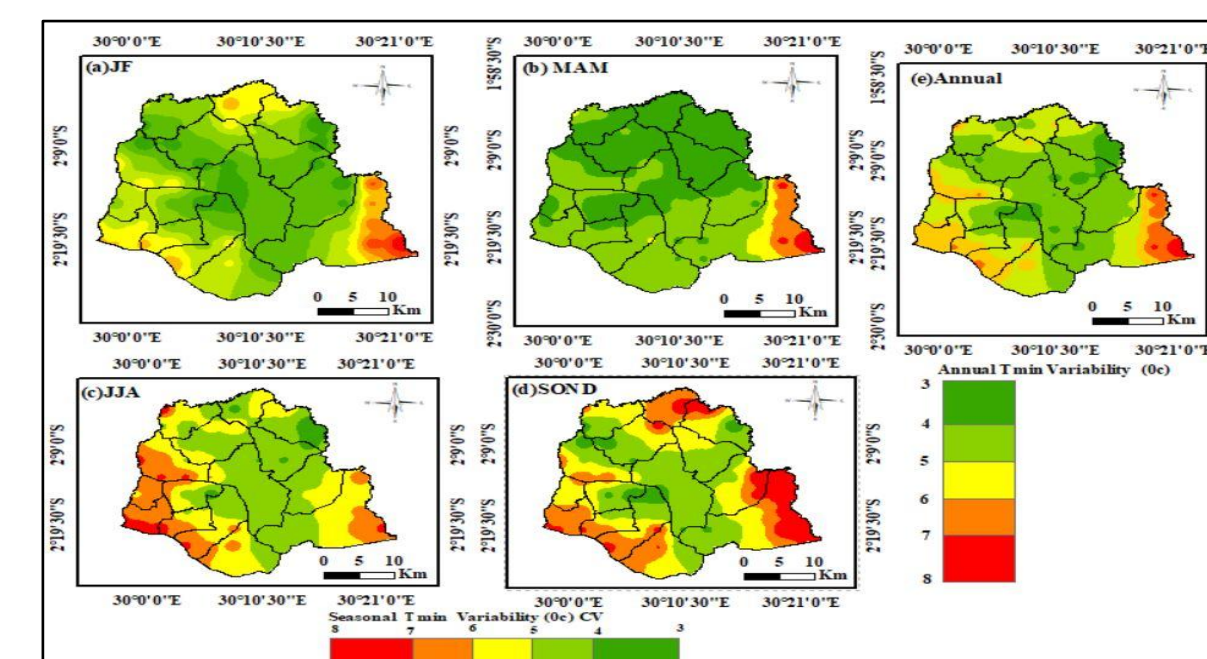


Figure 9: Spatial variability of seasonal and annual minimum temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021

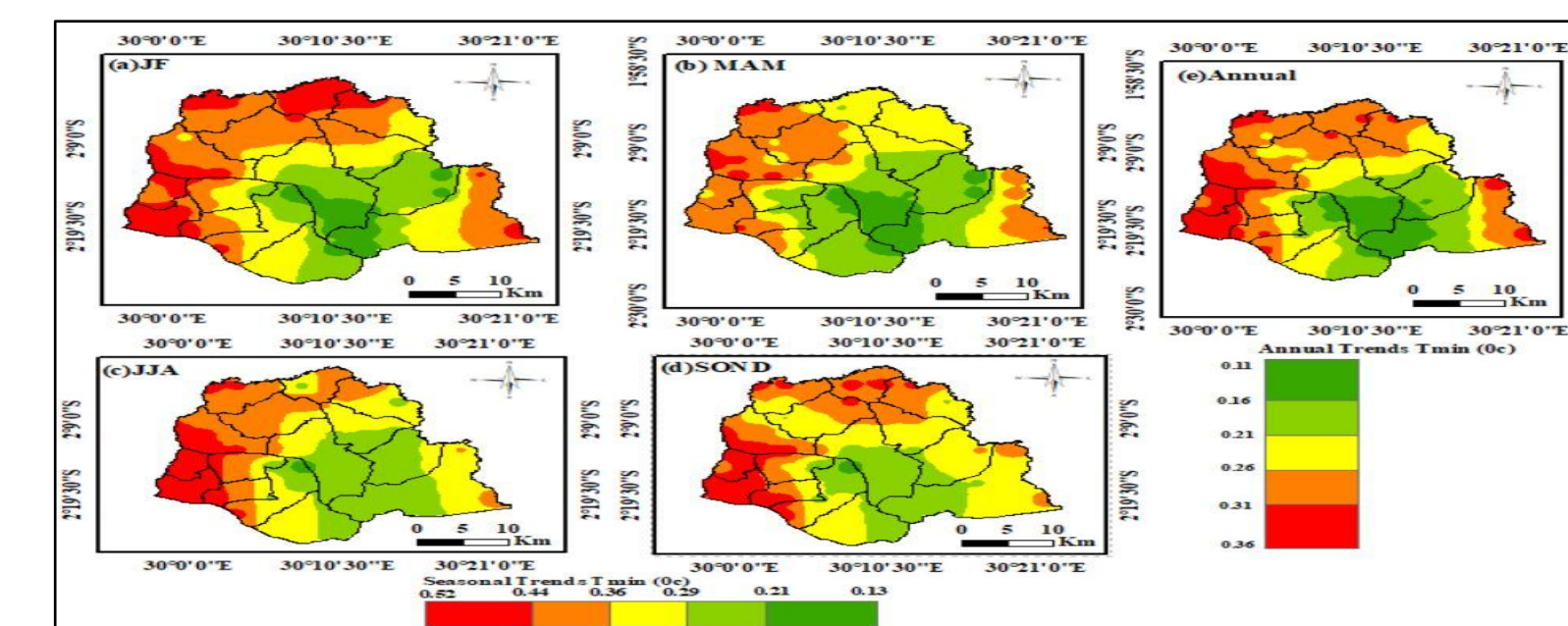


Figure 10: Spatial trends of seasonal and annual minimum temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021.

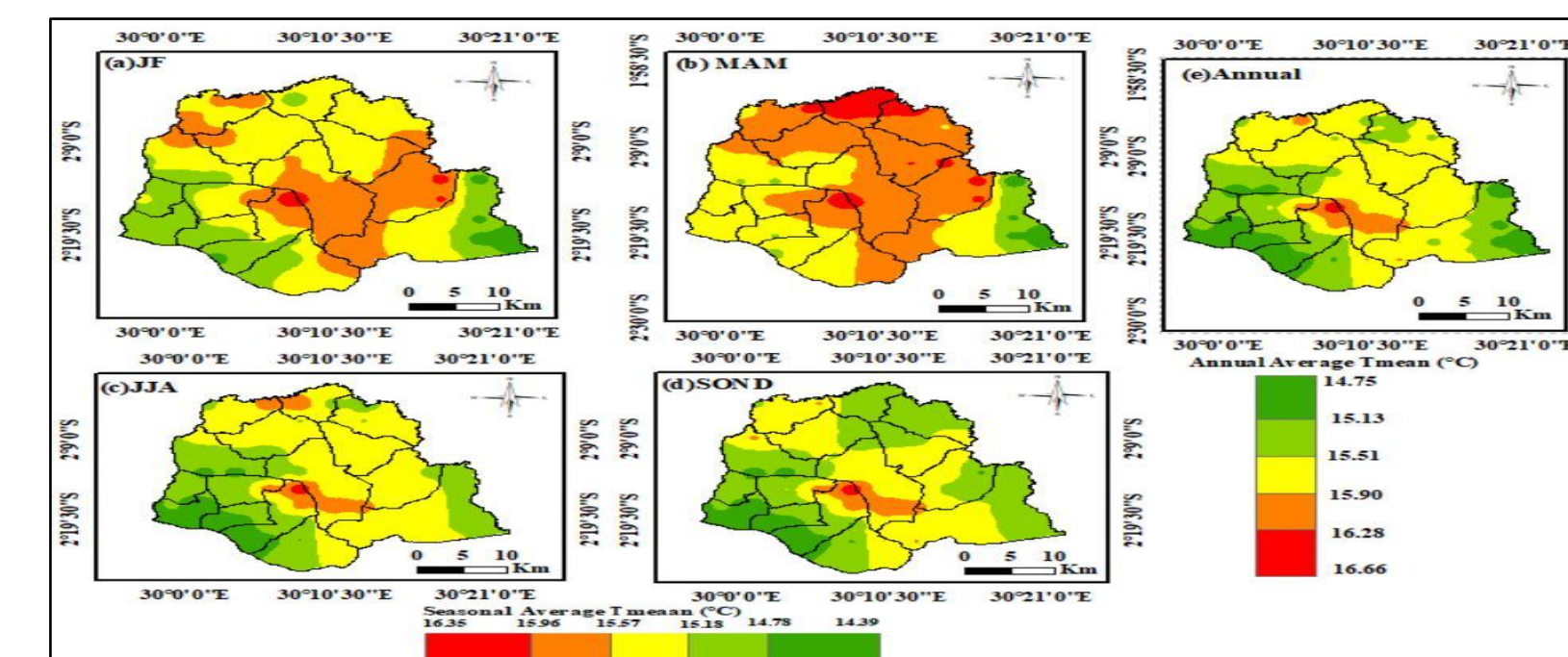


Figure 11: Spatial distribution of seasonal and annual mean temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021

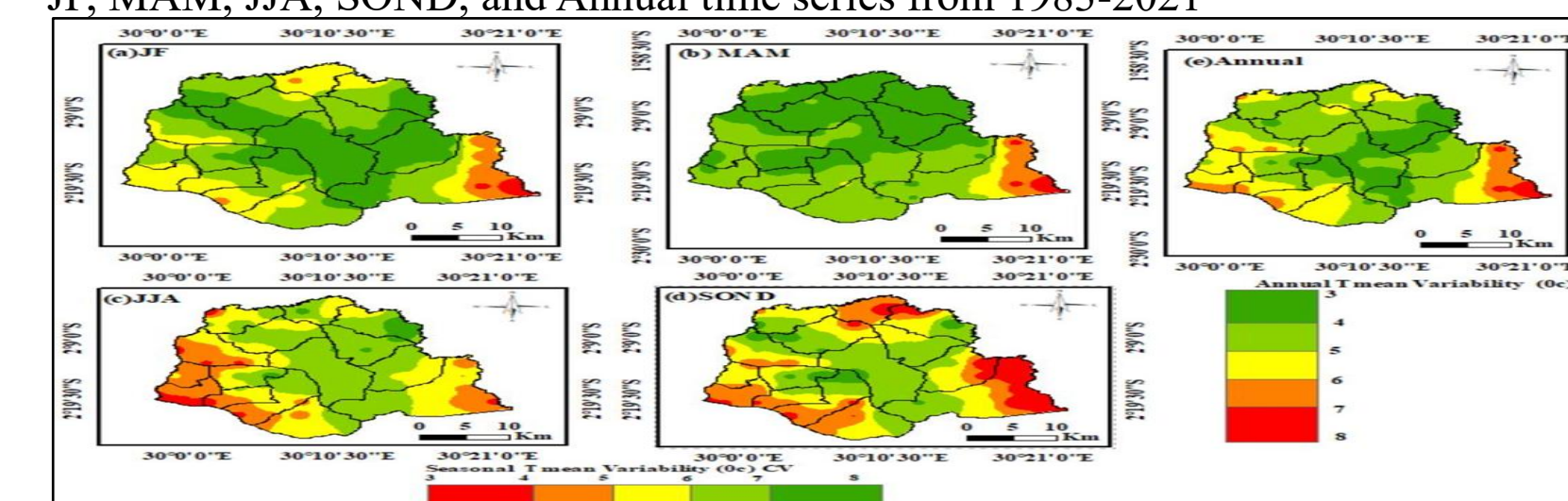


Figure 12: Spatial variability of seasonal and annual mean temperature during JF, MAM, JJA, SON, and Annual time series from 1983-2021.

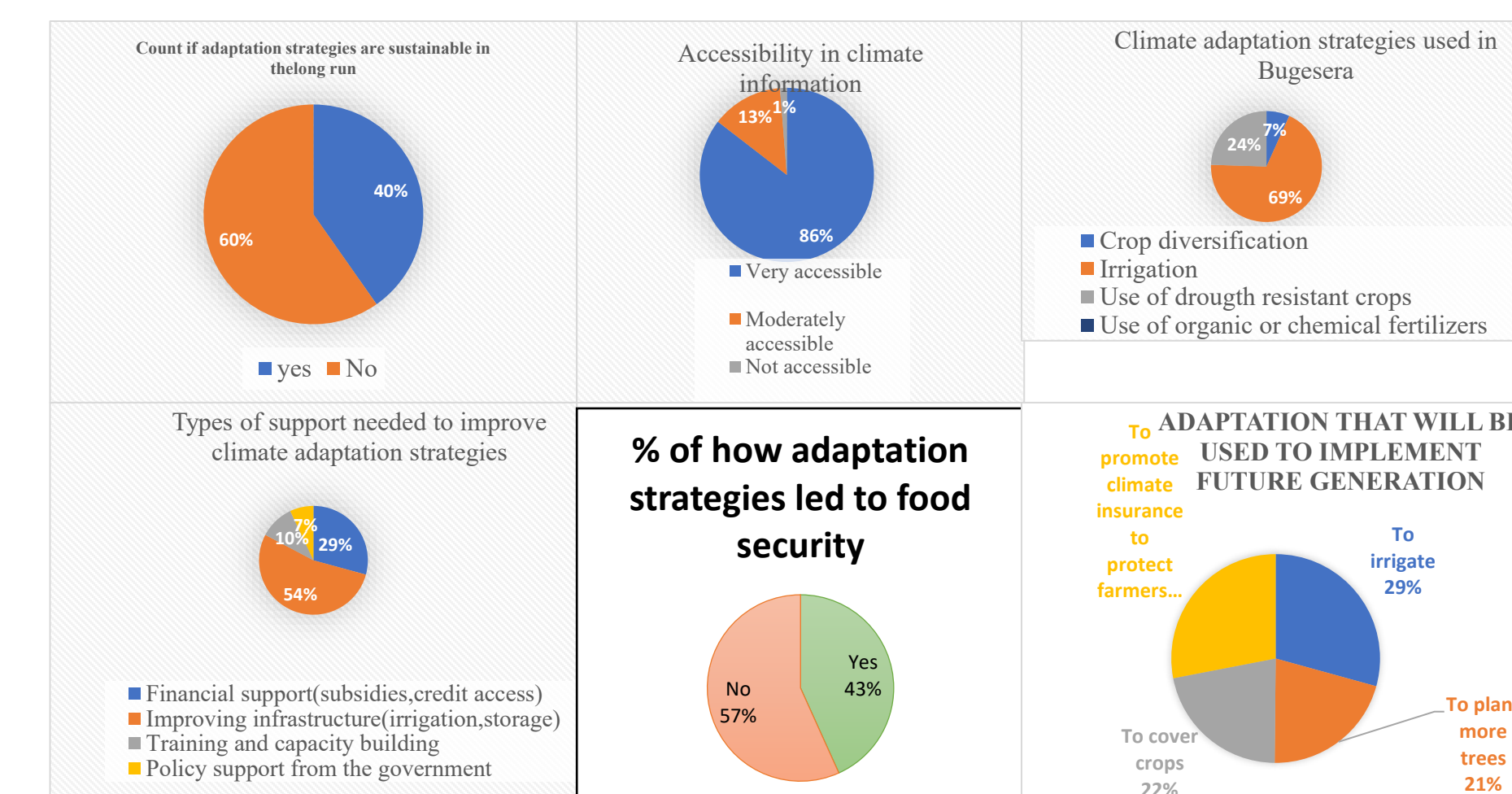


Figure 13: Farmers knowledge of climate variability and adaptation strategies in Bugesera districts

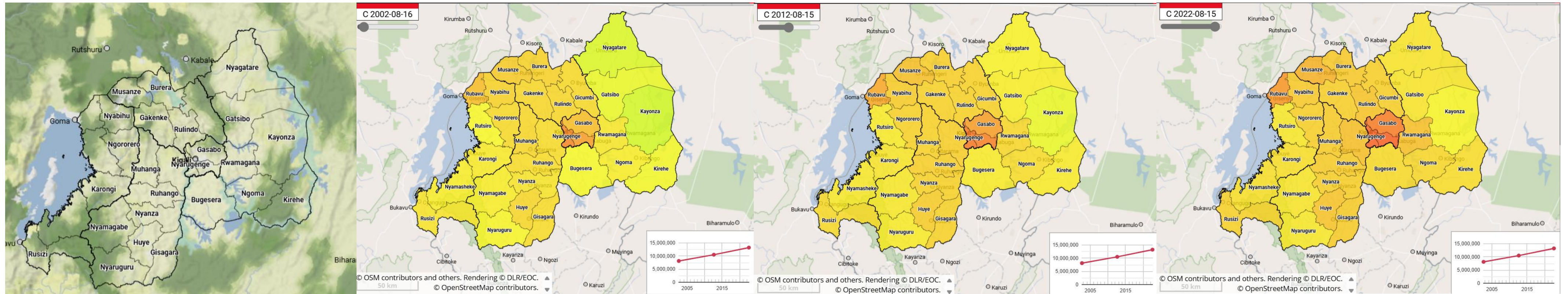
Title: Future Climate Scenarios and Their Impacts on Rwanda: Projections, Risks, and Adaptation Strategies (2002-2022)

Authors: Isaac NZAYISENGA*, Fidele MWIZERWA, Jeanne d'Arc MUKASHEMA, Jeanne UWAMAHORO, Dyna UWAMBAJIMANA

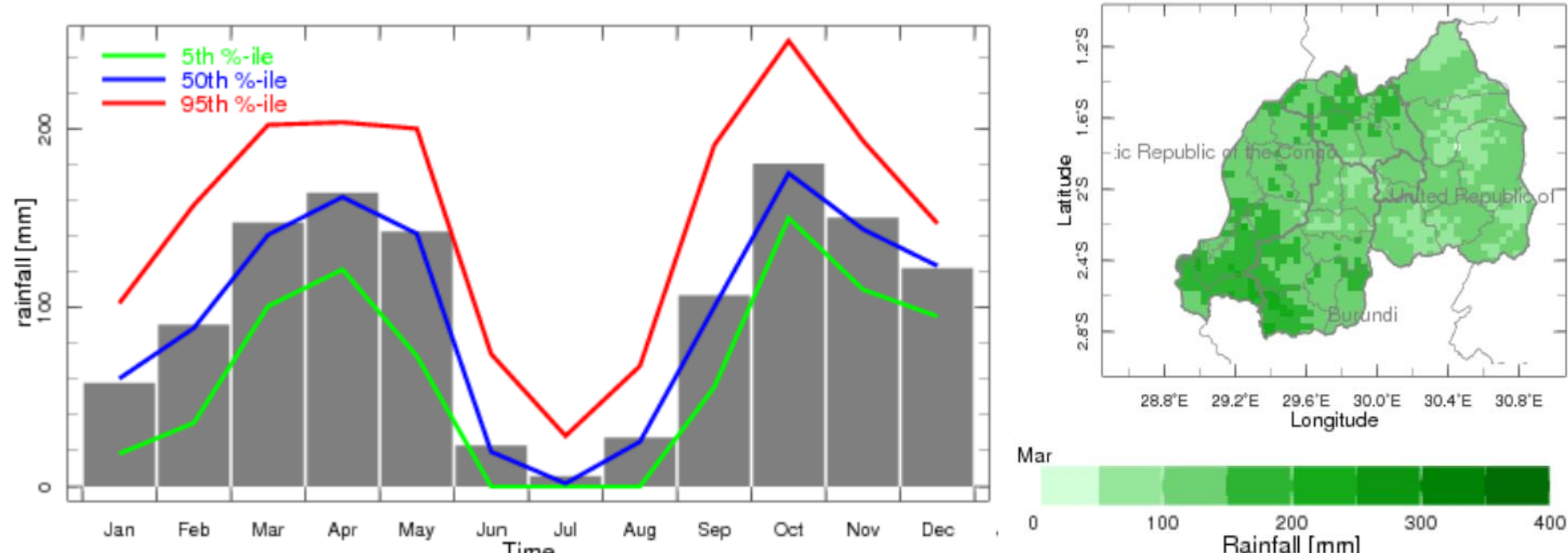
Affiliation: Department of Spatial Planning, School of Architecture and Built Environment, College of Science and Technology, University of Rwanda, Kigali P.O. Box 3900, Rwanda

Corresponding Author: nzayisaac85@gmail.com, +250781732472

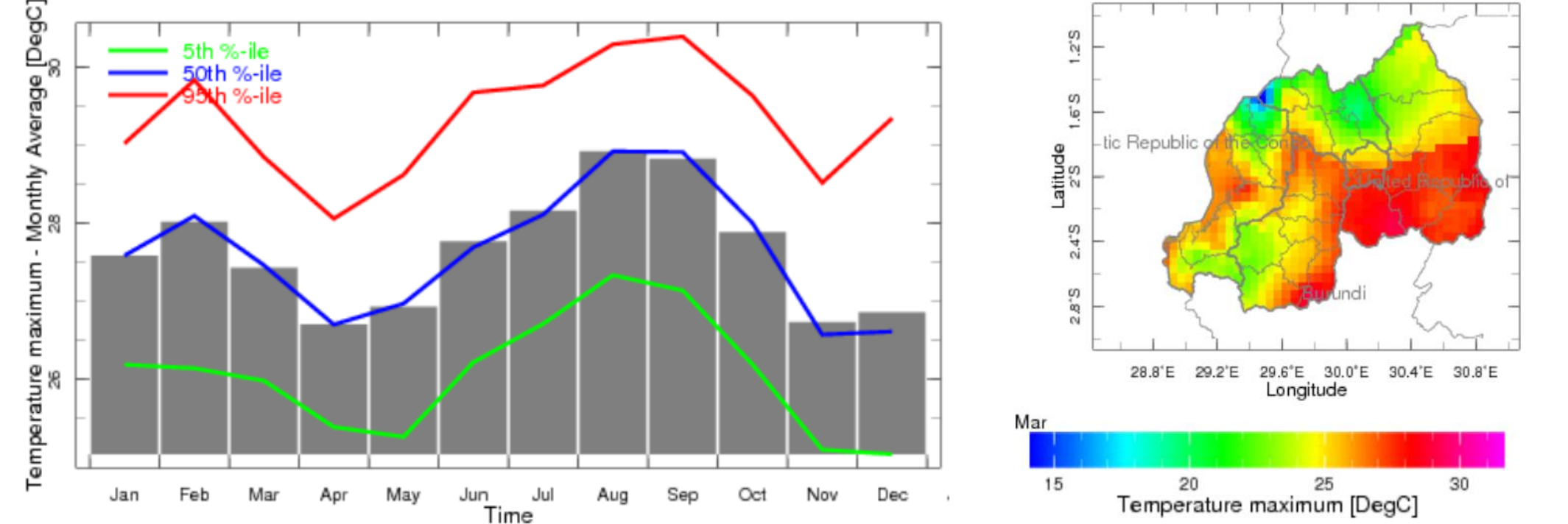
Climate change presents significant challenges to Rwanda, particularly in the areas of agriculture, water resources, and public health. The country's reliance on rain-fed agriculture, mountainous terrain, and rapid population growth heightens its vulnerability to temperature shifts, rainfall variability, and extreme weather events. This has led to environmental degradation, threatened food security, and increased pressure on infrastructure, necessitating comprehensive and sustainable climate action. This study examines the impacts of climate change on Rwanda from 2002 to 2022, focusing on the effects of climate variability, population growth, and urban expansion. It explores the influence of these factors on key sectors such as agriculture, health, and infrastructure while assessing Rwanda's vulnerability to climate-related risks. The research also investigates climate adaptation strategies aimed at mitigating these impacts. Time-series data from the Rwanda Meteorology Agency, the National Institute of Statistics of Rwanda, and other sources were analyzed using satellite remote sensing, climate modeling, and risk assessment tools. A key method used for predicting future scenarios is the Coupled Model Intercomparison Project (CMIP6), which models temperature and precipitation trends under different greenhouse gas emission pathways. Additionally, the study employs the Community Climate System Model (CCSM4) for high-resolution projections of climate variables



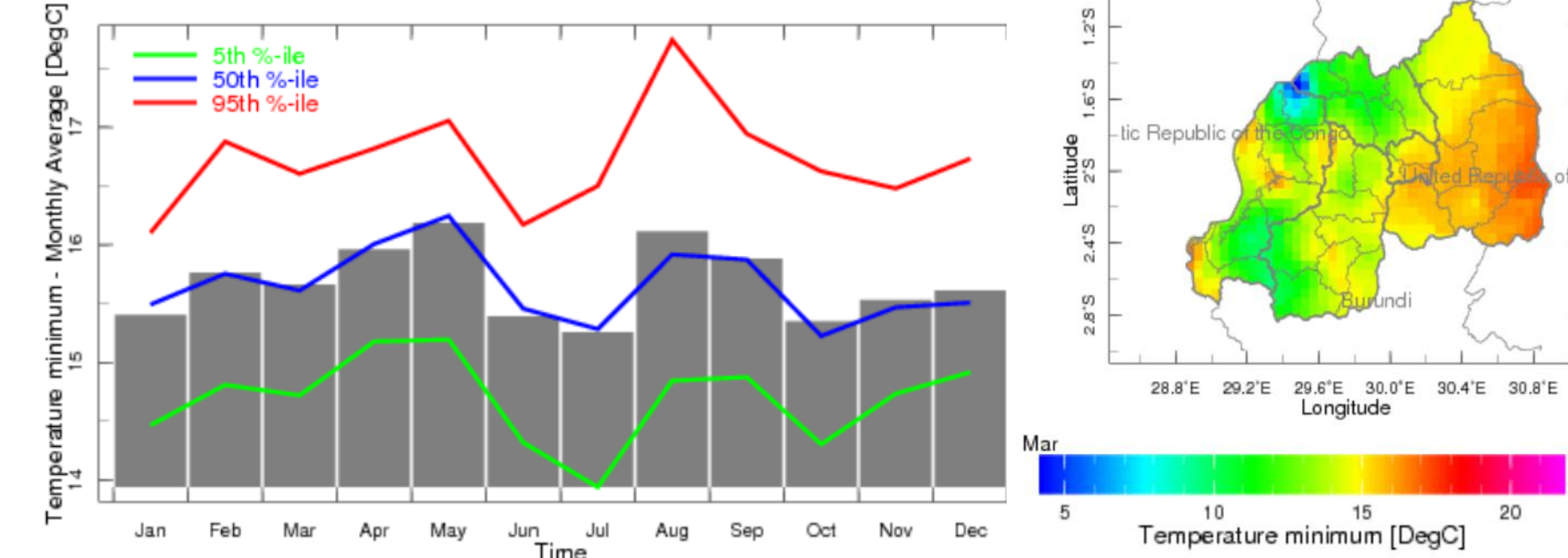
Monthly Rainfall Climatology



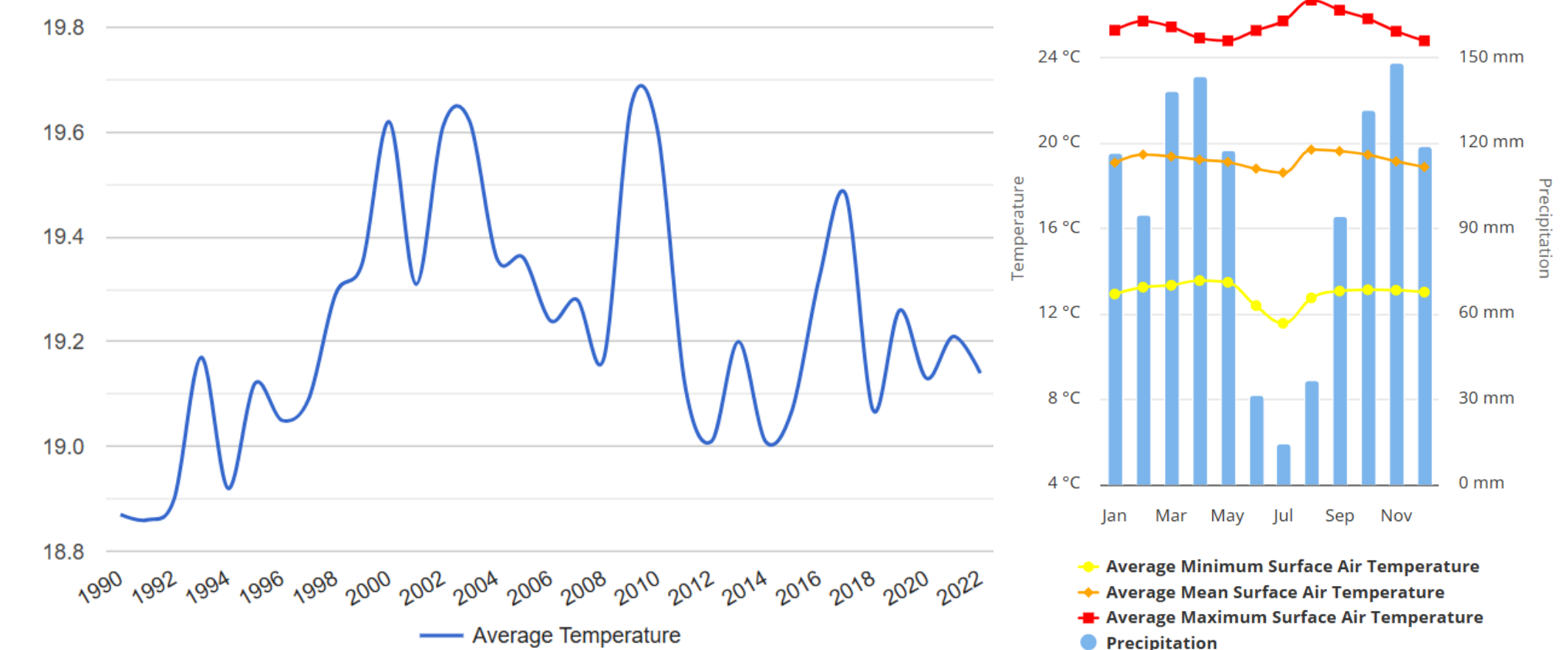
Monthly Maximum Temperature Climatology



Monthly Minimum Temperature Climatology



Annual Average temperature of Rwanda (1990-2022)



Name	Status	Population Census 2002-08-16	Population Census 2012-08-15	Population Census 2022-08-15
Est (Intara y'Iburasirazuba) [Eastern]	Province	1,700,137	2,595,703	3,563,145
Bugesera	District	266,775	361,914	551,103
Gatsibo	District	283,456	433,020	551,164
Kayanza	District	209,723	344,157	457,156
Kirehe	District	229,468	340,368	460,860
Ngoma	District	235,109	336,928	404,048
Nyagatare	District	255,104	465,855	653,861
Rwamagana	District	220,502	313,461	484,953
Kigali	City	765,325	1,132,686	1,745,555
Gasabo	District	320,516	529,561	879,505
Kicukiro	District	207,819	318,564	491,731
Nyarugenge	District	236,990	284,561	374,319
Nord (Intara y'Amajyaruguru) [Northern]	Province	1,560,862	1,726,370	2,038,511
Burera	District	320,759	336,582	387,729
Gakenke	District	322,043	338,234	365,292
Gicumbi	District	359,716	395,606	448,824
Musanze	District	307,078	368,267	476,522
Rulindo	District	251,266	287,681	360,144
Ouest (Intara y'Iburengeruzuba) [Western]	Province	2,043,555	2,471,239	2,896,484
Karongi	District	278,944	331,808	373,869
Ngororero	District	282,249	333,713	367,955
Nyabihu	District	268,367	294,740	319,047
Nyamashake	District	325,032	381,804	434,221
Rubavu	District	292,653	403,662	546,683
Rusizi	District	331,950	400,858	485,529
Rutsiro	District	264,360	324,654	369,180
Sud (Intara y'Amajyepfo) [Southern]	Province	2,058,674	2,589,975	3,002,699
Gasagara	District	262,128	322,506	397,051
Huye	District	265,446	328,398	381,900
Kamonyi	District	261,336	340,501	450,849
Muhanga	District	287,219	319,141	358,433
Nyamagabe	District	280,007	341,491	371,501
Nyanza	District	225,209	323,719	365,718
Nyaruguru	District	231,496	294,334	318,126
Ruhango	District	245,833	319,885	359,121
Rwanda	Republic	8,128,553	10,515,973	13,246,394

Source: National Institute of Statistics Rwanda.

Data Source	Description	Link
City Population (Rwanda)	Population and demographic statistics for Rwanda.	https://www.citypopulation.de/en/rwanda/
Climate Change Portal (Rwanda)	Government portal for climate change information and policy.	https://climatechange.gov.rw/
Climate Knowledge Portal (World Bank)	Climate data and projections for Rwanda.	https://climateknowledgeportal.worldbank.org/country/rwanda/
DIVA-GIS Data	Geospatial data on climate and environmental factors.	https://diva-gis.org/data.html
Maproom (Meteo Rwanda)	Provides meteorological and climate data for Rwanda.	http://www.maproom.meteorwanda.gov.rw/maproom
National Institute of Statistics of Rwanda	Official statistics covering various aspects of Rwanda's economy and society.	https://statistics.gov.rw/
Zenodo Repository	Global 30-m LULC Changes data	https://zenodo.org/records/8239305

Over the past 20 years, Rwanda has experienced a 0.5°C rise in average temperatures, coupled with a 20% decrease in rainfall during dry seasons, leading to a 10-15% reduction in agricultural yields, particularly in maize and beans. The country's population growth by 25%, from 9 million in 2002 to 13 million in 2022, along with a 10-12% expansion in urban areas, has put significant pressure on resources, exacerbating food insecurity and water scarcity. Future projections predict continued temperature increases by 1.2°C to 2.4°C by 2050, alongside further reductions in dry-season rainfall, likely worsening these issues. These climatic changes, along with the rapid population and urban growth, pose serious risks to Rwanda's food security, water resources, and overall economic stability. To address these challenges, urgent strategies for climate adaptation are essential. For example, the implementation of climate-smart agriculture practices such as drought-resistant crops and water-efficient irrigation systems can help mitigate the impact of reduced rainfall on crop yields. Additionally, integrated water resource management, including the construction of rainwater harvesting systems and the rehabilitation of wetlands, can improve water availability and help manage floods. Lastly, sustainable urban planning that incorporates green spaces, flood mitigation, and efficient resource use can help reduce the pressures of urban expansion.

Future research should focus on regional climate modeling, the long-term impacts on agriculture and water availability, and sustainable urban development to ensure the country's resilience in the face of these climatic shifts.

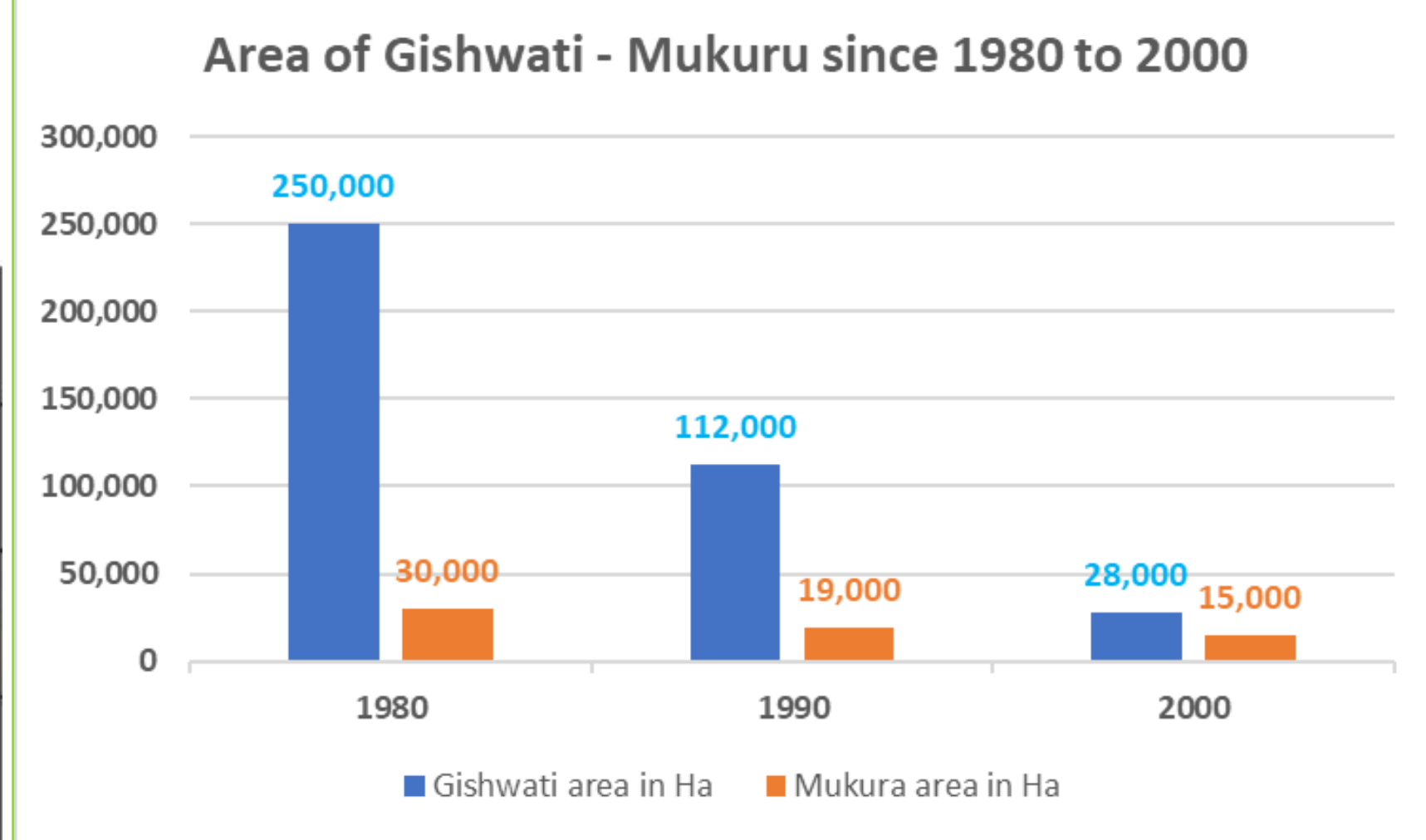
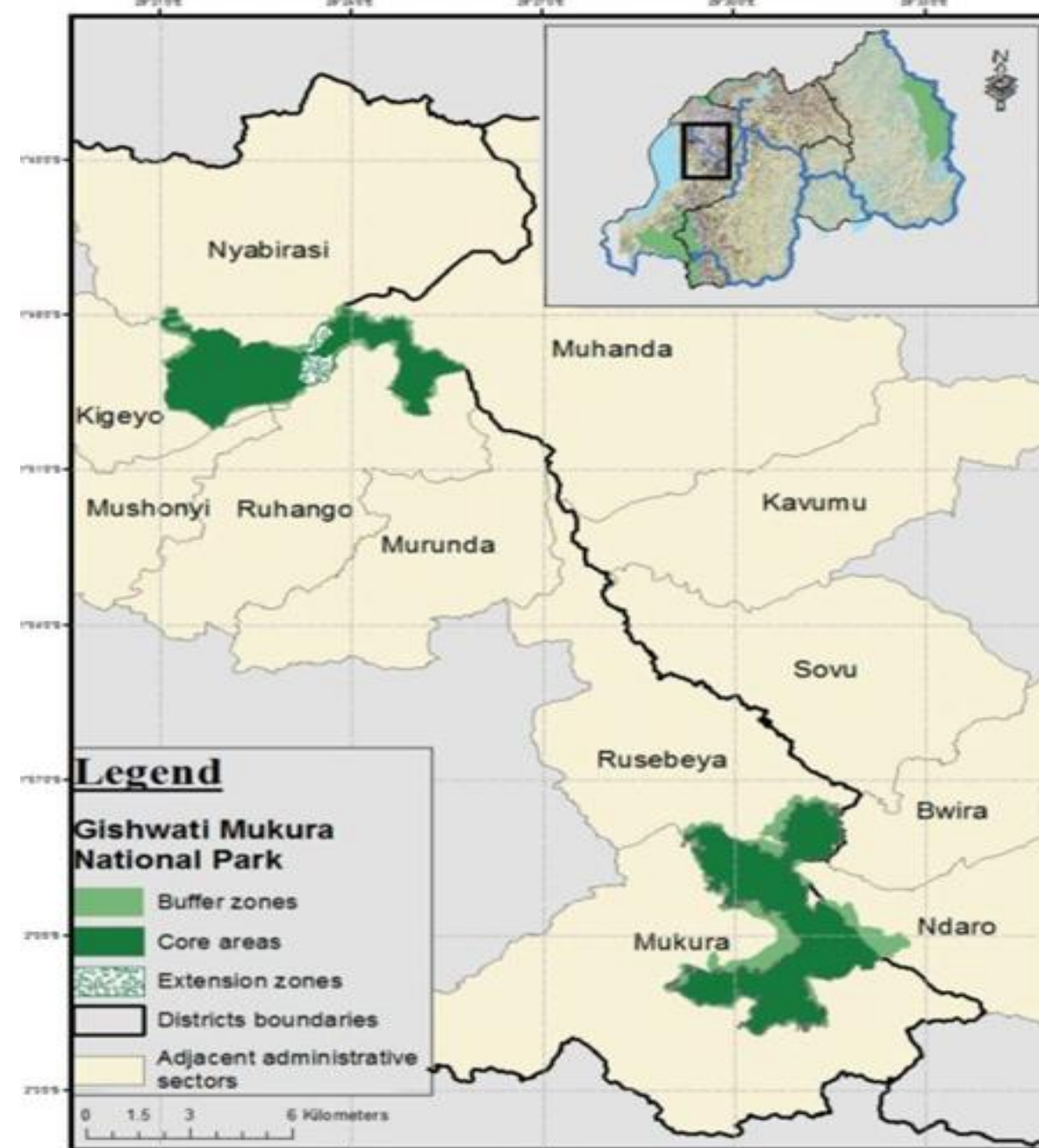


Title: Enhanced climate change adaptation in Rwanda through Landscape Approach to Forest Restoration and Conservation (LAFREC) project

Author(s): Alexis Nizeyimana & Bernardin Bavuge

Affiliation: Rwanda Environment Management Authority (REMA)

Gishwati – Mukura landscape covers 4 district of Western Province: Rubavu and Nyabihu in North, Ngororero in its Eastern and Southern parts and Rutsiro in West.



BACKGROUND AND RATIONALE

Gishwati-Mukura landscape has long endured severe environmental degradation due to the pressure of human activities including: deforestation, poor land use, illegal mining, human settlement. These issues have heightened vulnerability to climate change impacts, including soil erosion, landslides, reduced water retention, falling of agricultural productivity, settlement destruction, livelihood degradation and lost of lives. This context prompted the launch of the Landscape Approach to Forest Restoration and Conservation (LAFREC) project to restore ecosystems and strengthen community resilience.



OBJECTIVE

The objective of this research is to highlight the achievements of LAFREC project toward adaptation interventions planned by the country into its National Determined Contributions (NDC). The research took into consideration the Intended Nationally Determined Contribution (INDC) for the Republic of Rwanda of 2015 and the Rwanda's updated Nationally Determined Contributions (NDCs) of 2020.

NDC adaptation interventions in relation with LAFREC project intervention activities

Sector	Adaptation intervention
Agriculture	Develop climate resilient crops and promote climate resilient livestock
	Develop sustainable land use management practices
Land and Forestry	Development of Agroforestry and sustainable agriculture
	Promote afforestation / reforestation of designated areas
	Improve forest management for degraded forest resources
Human settlement	Storm water management
	Livelihood improvement
Transport	Improved transport infrastructure and services
Mining	Climate compatible mining
	Disaster risk monitoring
Cross Sectional	Establish an integrated early warning system, and disaster response plans

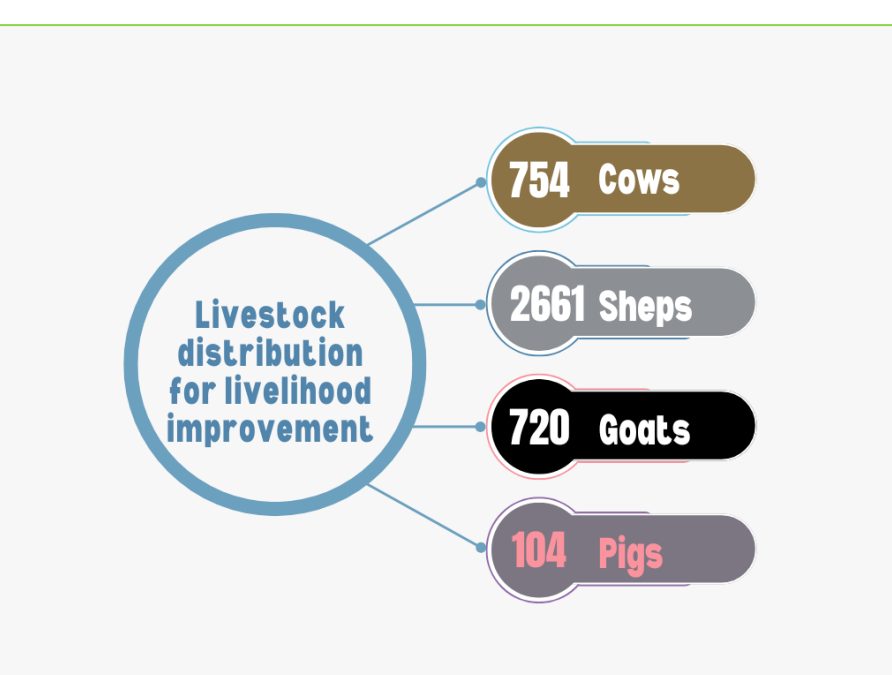
METHODS

1. The strategic alignment assessment method has been used for evaluating the contribution of LAFREC project to national adaptation interventions planned into NDC
2. To reach its goals, LAFREC applied a participatory, cross-sectoral approach involving reforestation, agroforestry, and sustainable land practices. It restored degraded forest areas and established ecological corridors. Farmers received training in climate-smart agriculture and soil conservation. To ease pressure on forests, the project introduced alternative livelihoods such as beekeeping and eco-tourism. Community involvement and institutional coordination were essential to ensure long-term, locally adapted restoration.

DATA

Used data have been collected from various evaluation reports of LAFREC project and other official reports and documents on Gishwati – Mukura National Park.

LAFREC project major successes achievement



The project achieved major successes: reforesting thousands of hectares, improving water catchments, and boosting biodiversity. Communities gained resilience to climate shocks through higher crop yields and more diverse income. LAFREC also aligned restoration with Rwanda's national climate goals, supporting its Green Growth and Climate Resilience Strategy. In sum, the project demonstrated that combining ecosystem restoration with community empowerment and sustainable land use can effectively build climate resilience in vulnerable rural areas.

BACKGROUND

Climate change is accelerating global warming, droughts, and floods, with East Africa (EA) among the most vulnerable regions due to its limited adaptive capacity and reliance on rainfed agriculture. Predicting future climate in EA remains challenging, especially for the key March–May (MAM) rainfall season, often described as the East African Climate Paradox. Recent advances in Global Climate Models (GCMs), especially the CMIP6 models, offer improved climate projections. NASA's NEX-GDDP-CMIP6 dataset enhances these models through bias correction and high-resolution downscaling ($0.25^\circ \times 0.25^\circ$). However, their accuracy and reliability over EA have yet to be comprehensively evaluated

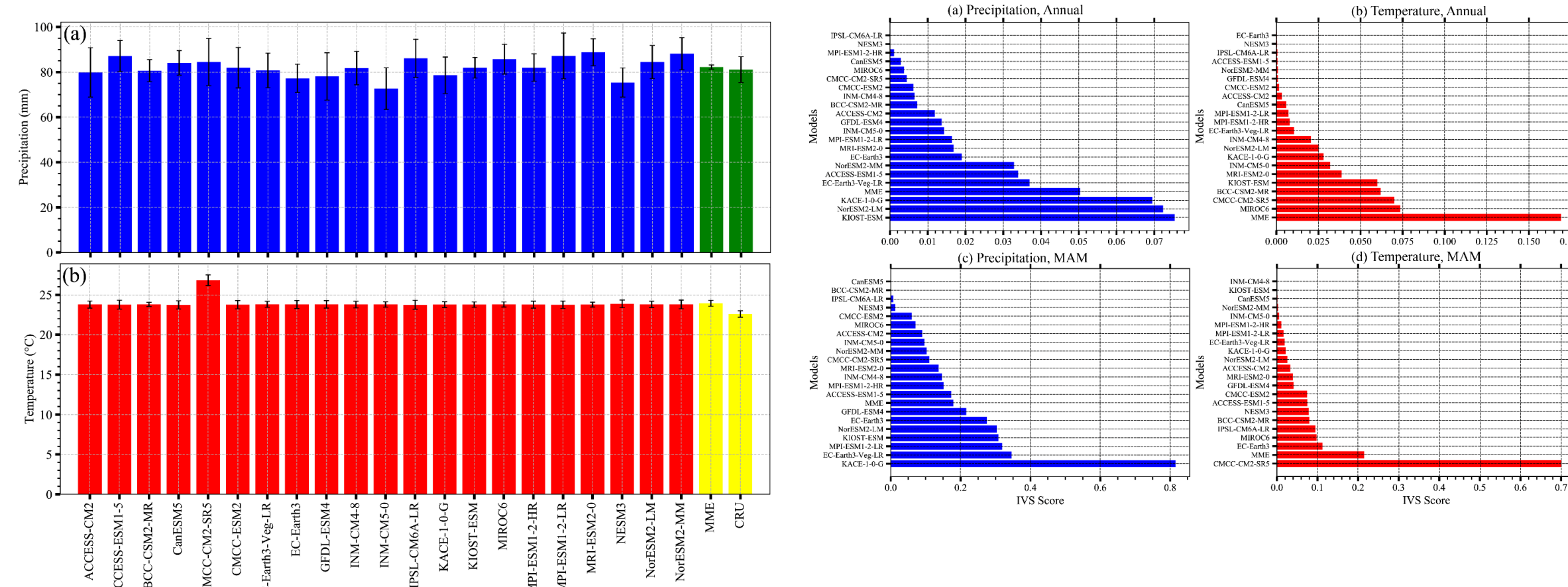
OBJECTIVES

- Evaluate the performance of the NEX-GDDP-CMIP6 multi-model ensemble (MME) in simulating historical annual and MAM precipitation and temperature.
- Assess future projections of annual and MAM precipitation and temperature under three Shared Socioeconomic Pathways (SSPs): SSP1-2.6, SSP2-4.5, and SSP5-8.5.
- Bridge critical knowledge gaps in understanding EA's future climate to inform decision-making, regional adaptation strategies, and sustainable development planning

METHODS

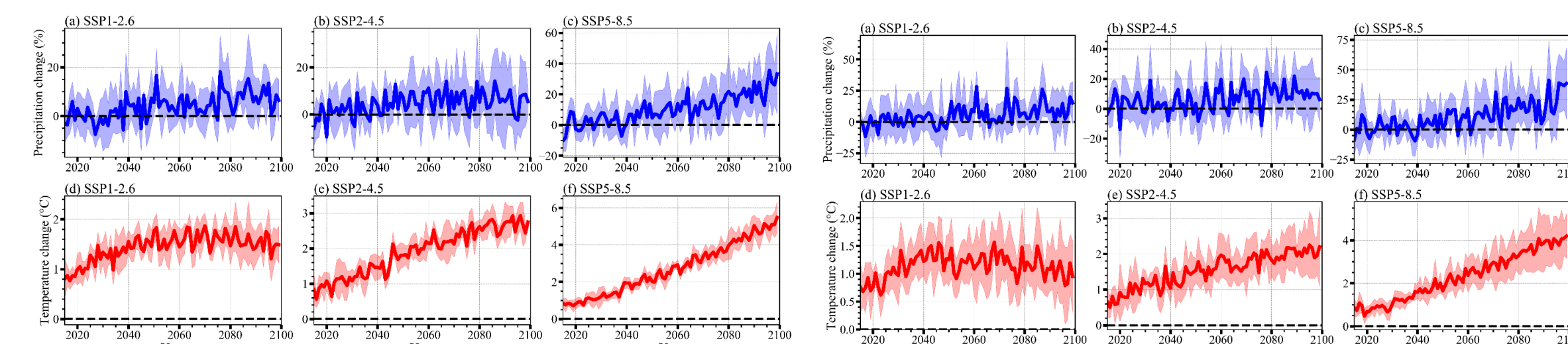
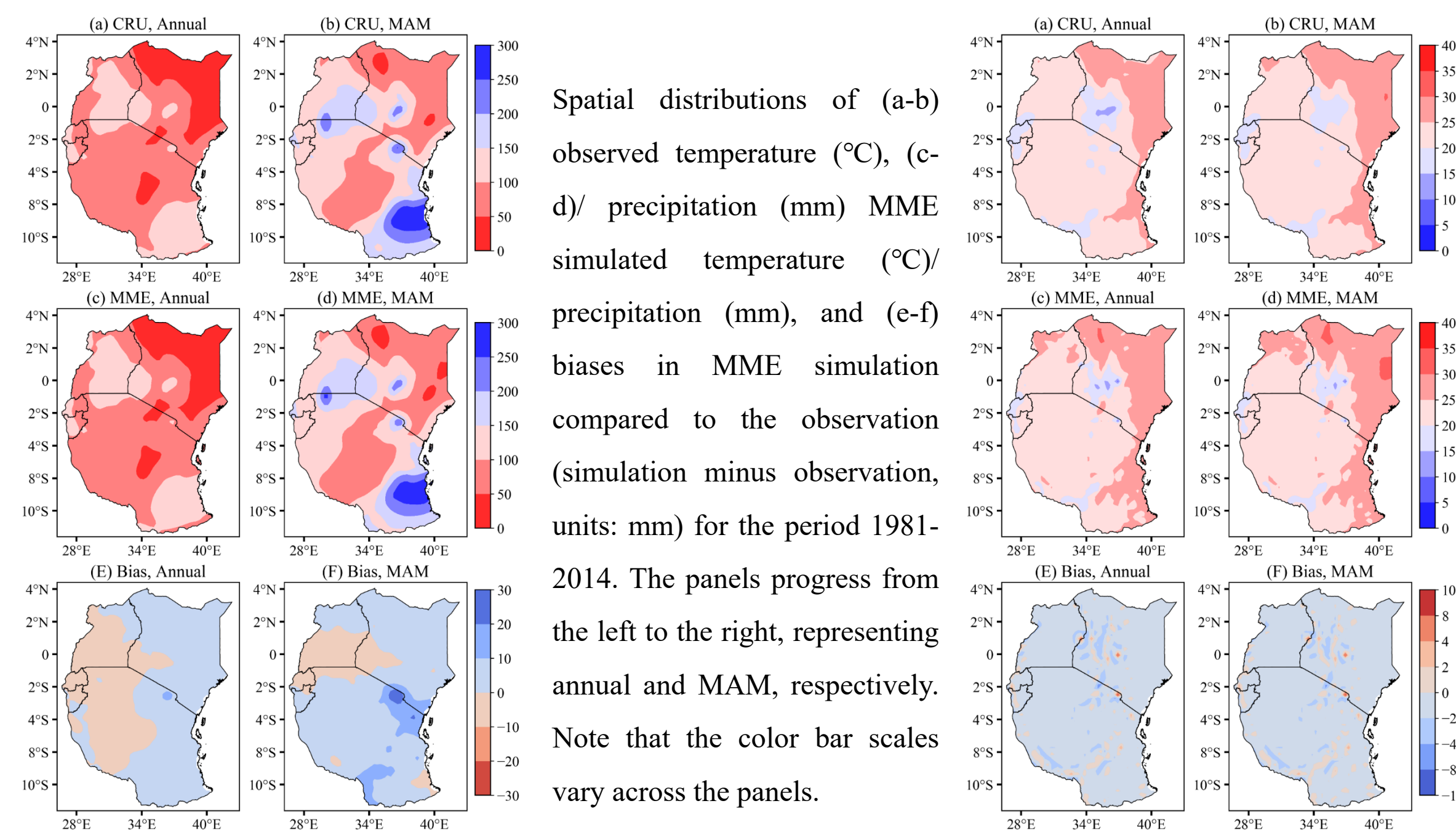
The study evaluated historical (1981–2014) and future (2031–2100) climate over EA using high-resolution NEX-GDDP-CMIP6 data. Focusing on the annual and March–May (MAM) season, 21 models were assessed against CRU data using Taylor diagrams, IVS scores, and trend analysis. The top five performing models per variable were selected to create multi-model ensembles (MMEs) under three SSPs.

RESULTS



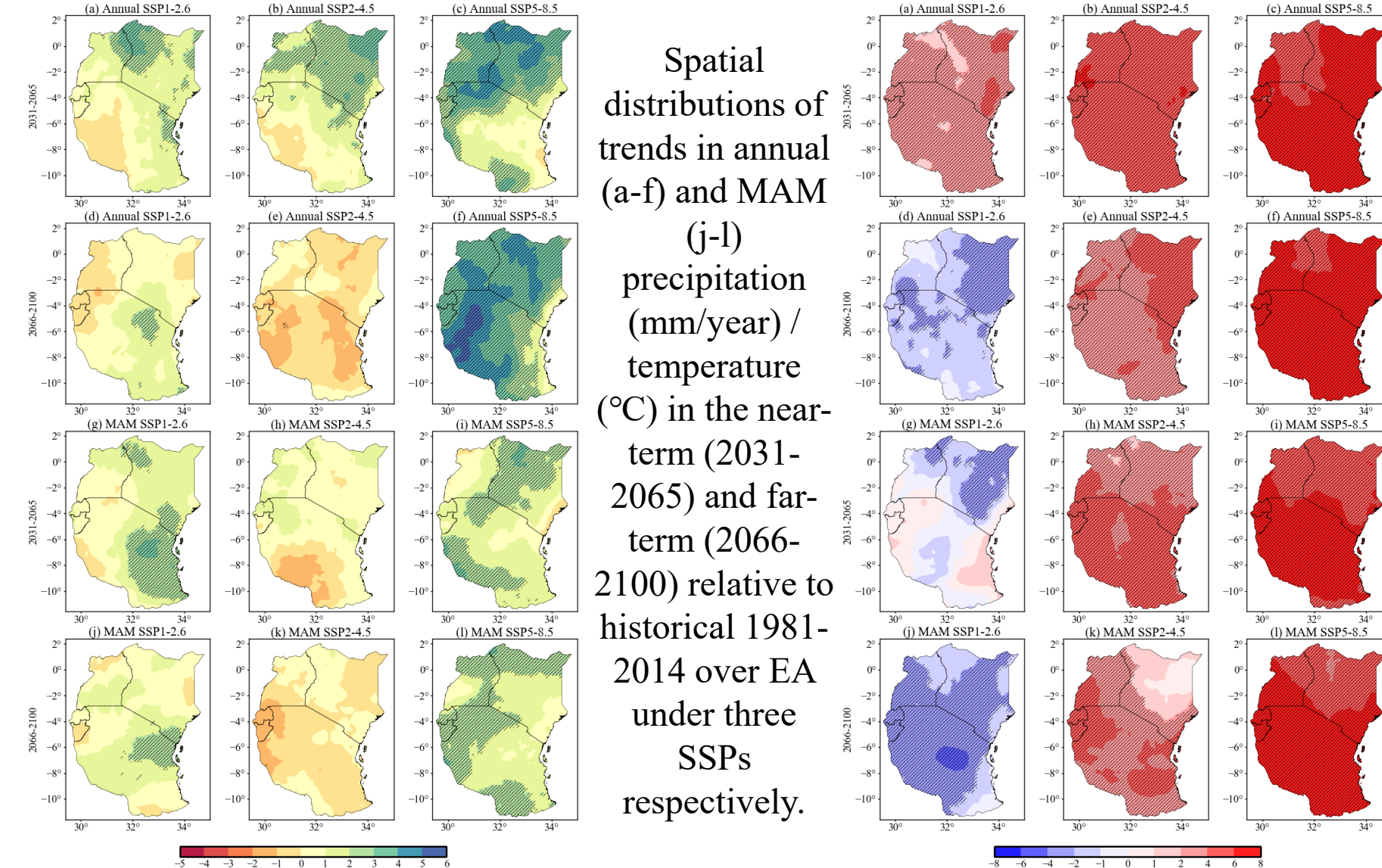
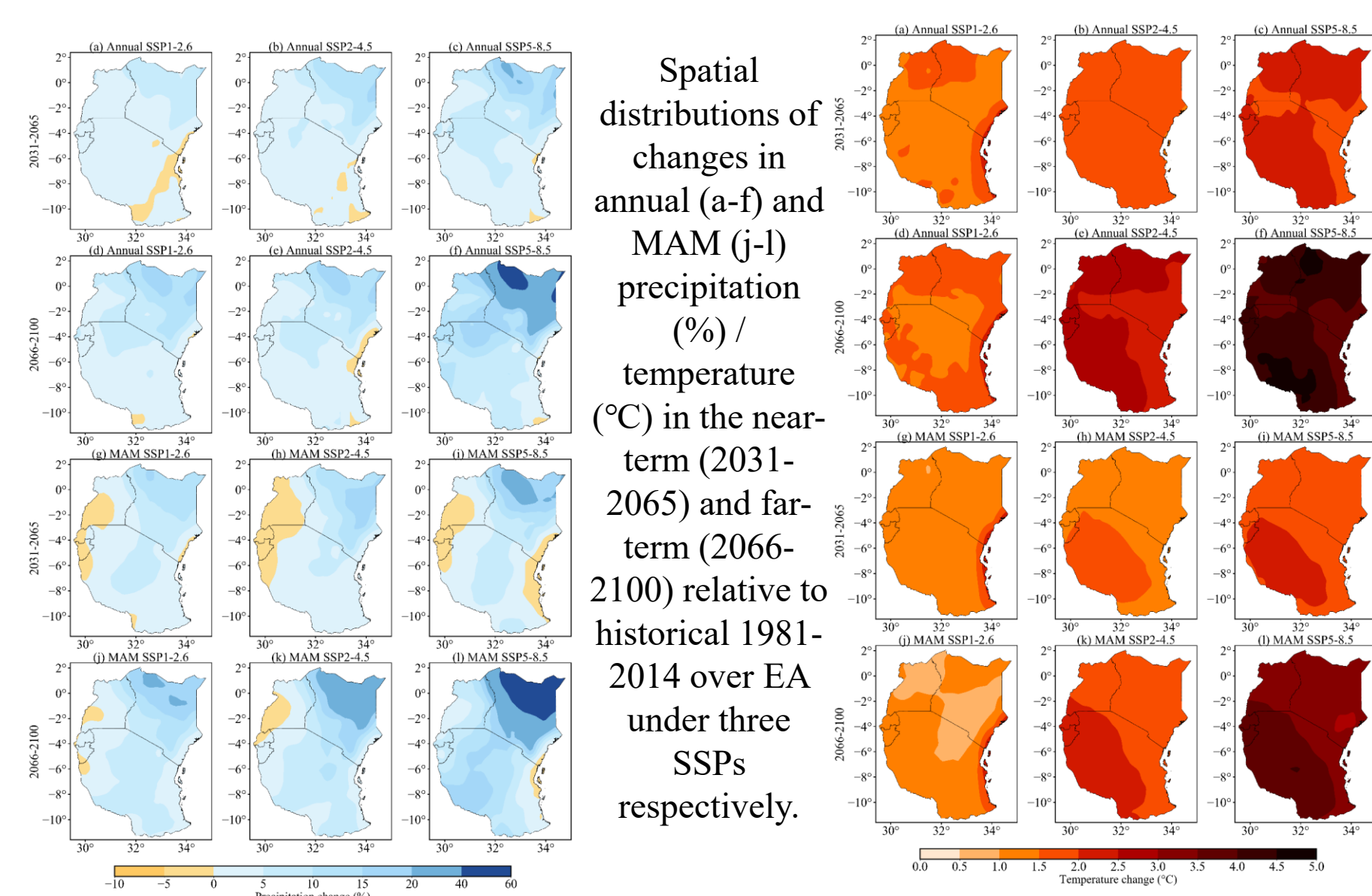
Long-term mean (a) precipitation (units: mm) and (b) temperature (units: °C) from the selected CMIP6 models relative to observations (CRU) data over EA during 1981–2014.

Interannual variability skill score (IVS) of the CMIP6 models for both annual and MAM, (a and c) precipitation, and (b and d) temperature over EA.



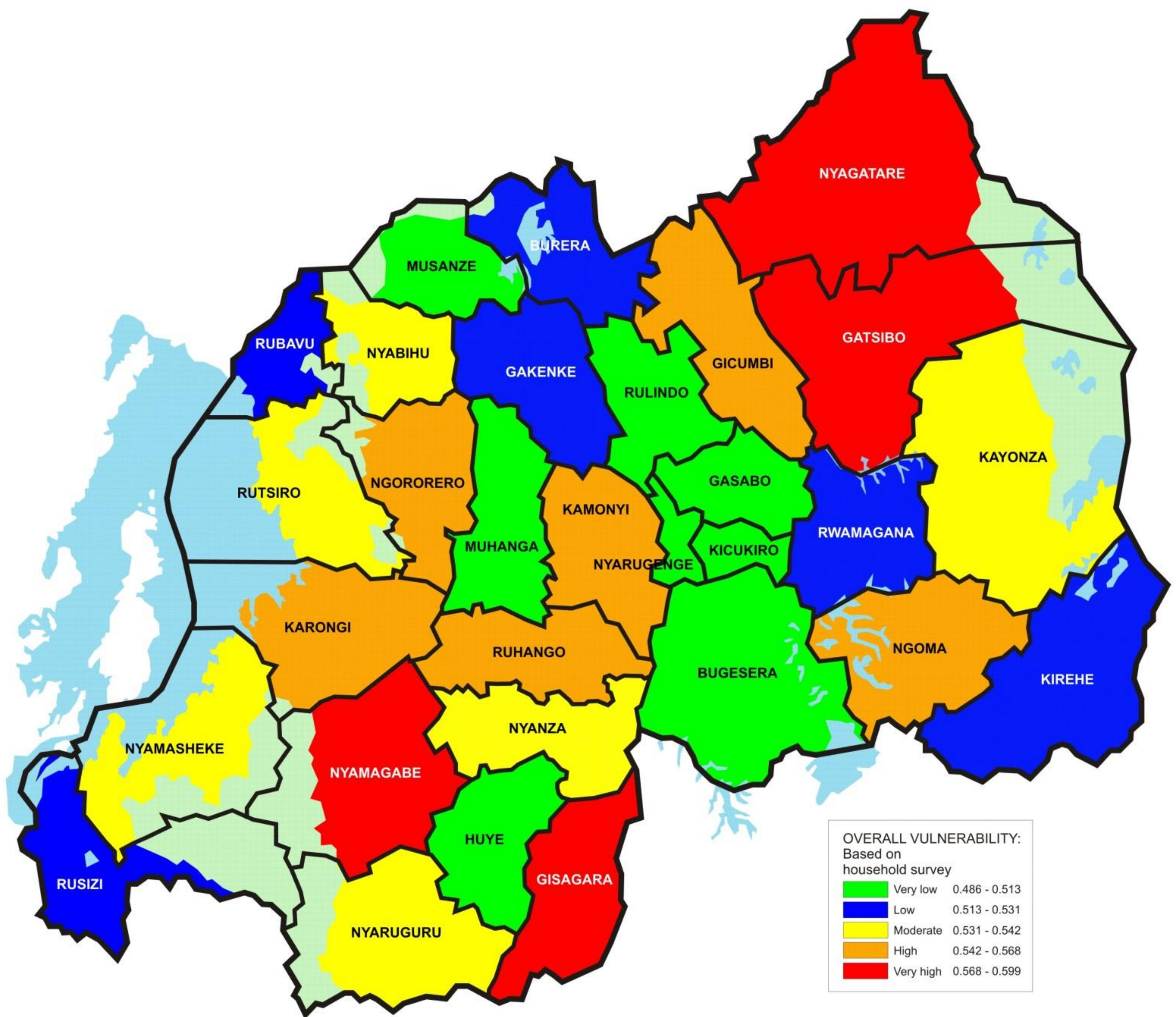
Time series of the annual (left) and MAM (right) mean precipitation and temperature from the best-performing models under SSPs over EA. The blue and red shadings are the corresponding model spread about the MME for the near (2031–2065) and far (2066–2100).

RESULTS

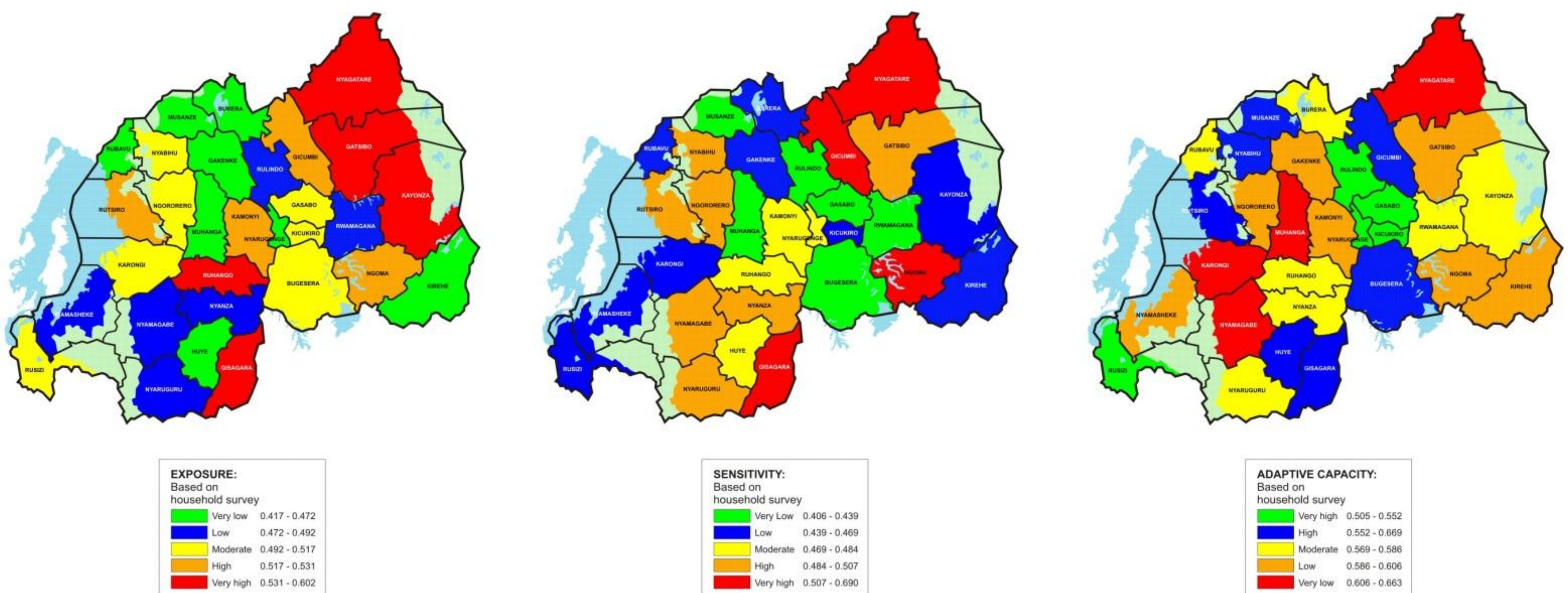


CONCLUSIONS

The study confirmed the reliability of NEX-GDDP-CMIP6 MMEs in projecting rising temperature and precipitation trends across EA, especially under SSP5-8.5. MMEs outperformed individual models, making them valuable for forecasting and adaptation planning. Under SSP5-8.5, temperatures are projected to rise by 2–6 °C, with some areas exceeding 6 °C. The study recommended strengthening GHG mitigation efforts and further research on land use and extreme climate events to enhance regional resilience.



CLIMATE VULNERABILITY INDEX - RWANDA 2025



Title: Investigating The Relationship Between Urban landscape and Non-chronic Respiratory Diseases

Author(s): Linda INGABIRE

Affiliation: University of Rwanda

INTRODUCTION

Rwanda, a densely populated country with a tropical highland climate, faces increasing vulnerability to environmental and health challenges due to rapid urbanization. The shift toward urban living worldwide has transformed natural landscapes, posing public health risks, particularly for respiratory health. Nyagatare, Rwanda's largest district and second most populous area, exemplifies these trends, as its rapid urban growth pressures infrastructure and essential services while exacerbating air pollution. The most common Air pollutants are ozone, particulate matter, sulfur dioxide, and nitrogen oxides often threaten respiratory health. Acute respiratory infections, driven by urban pollution, burden healthcare systems globally. This research focuses on Nyagatare district, examining the intricate relationship between urban expansion, landscape changes, and respiratory health risks to inform public health and urban planning in Rwanda.

METHODOLOGY

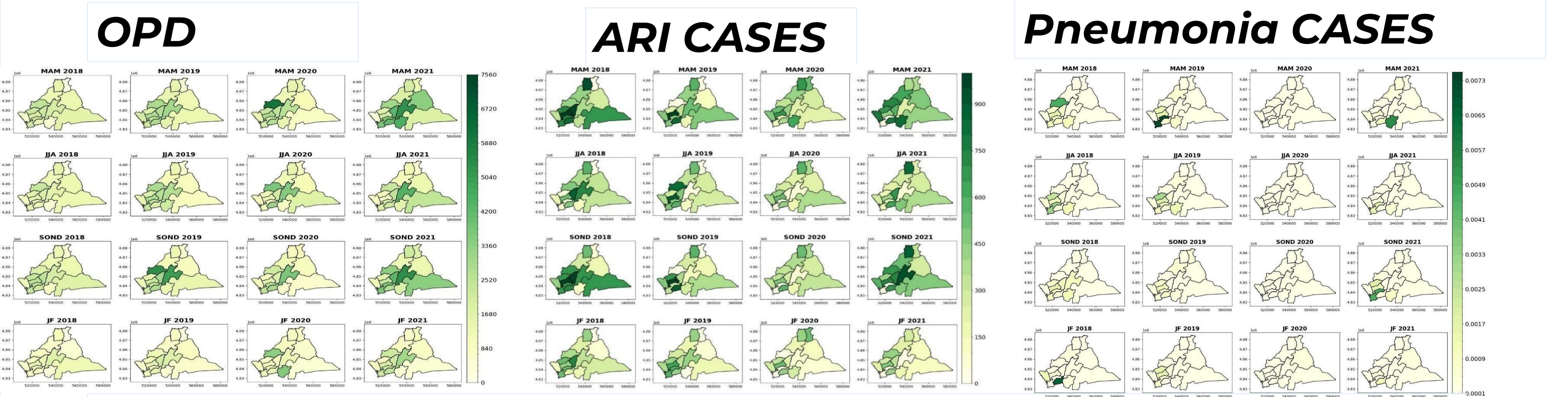
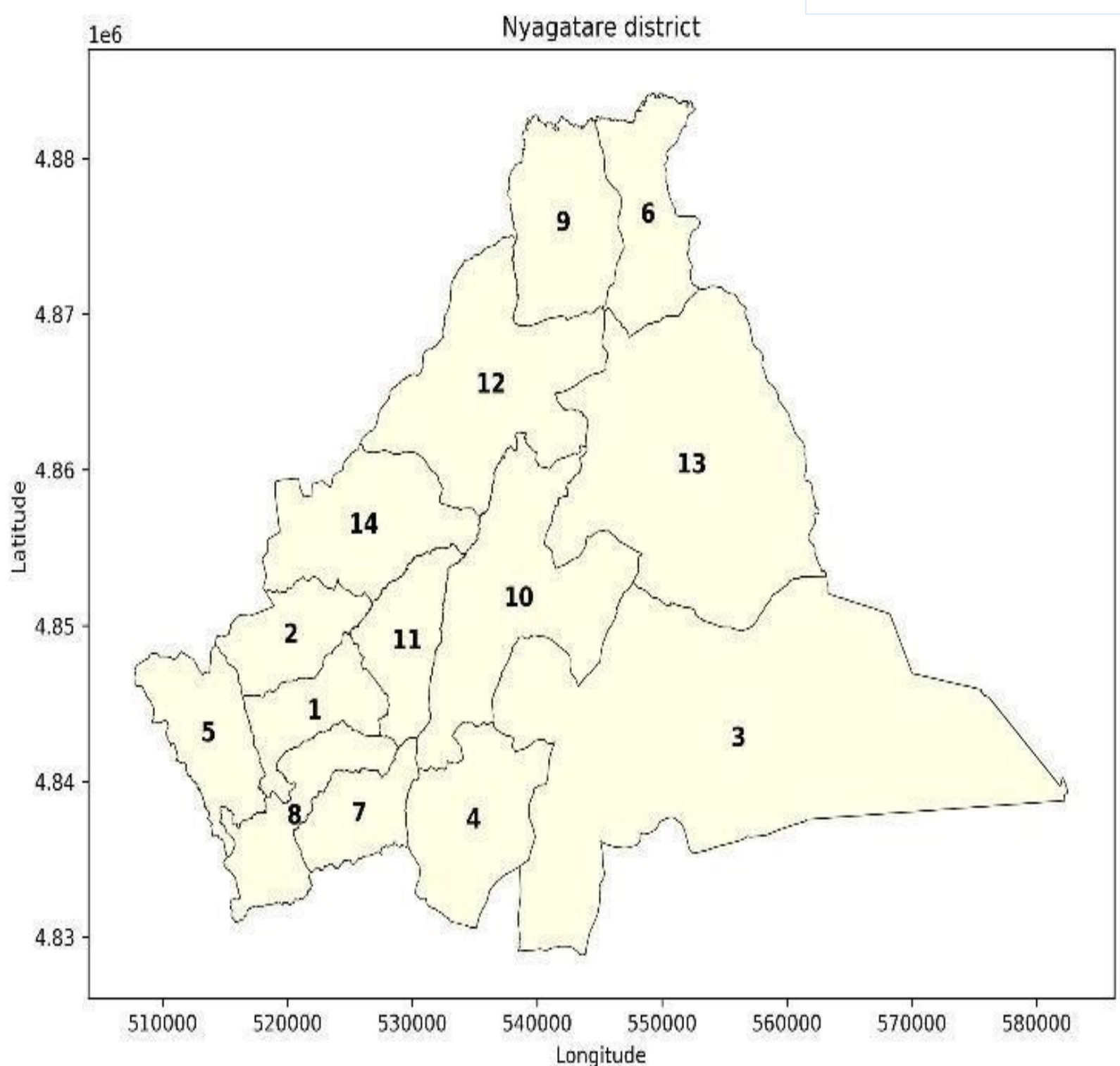
- **Study Area:** Nyagatare District, located in Eastern Rwanda.
- **Data Collection:** Data from 2018 to 2021 includes:
 - **Urban Indices:** Collected via Landsat 8 imagery.
 - **Population Density:** National Institute of Statistics Rwanda.
 - **Respiratory Health Data:** Rwanda Biomedical Center, focusing on acute respiratory infections, obstructive pulmonary diseases, and pneumonia.

Data Analysis: Using Google Earth Engine and python, urban indices (NDBI, IBI, UI) were assessed across different seasons. Spatial analysis and Timeseries were used to evaluate the relationship between landscape and Respiratory diseases in four years.

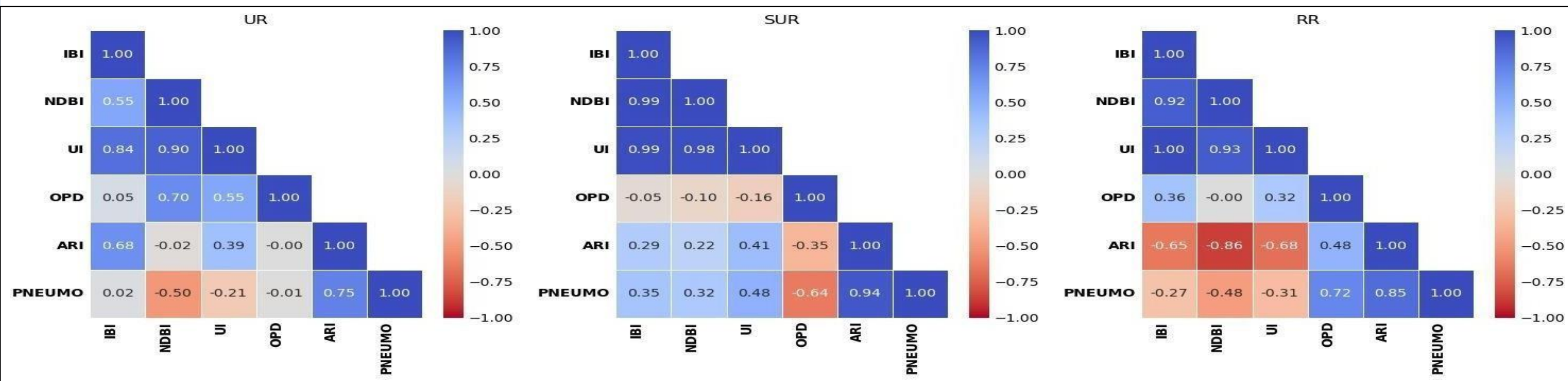
CONCLUSION

The study reveals a significant association between urban expansion and respiratory health risks in Nyagatare. Results emphasize the importance of integrating health considerations into urban planning to improve air quality and manage urban growth. Public health strategies should target high-density areas to reduce respiratory disease incidence effectively.

RESULTS



Correlation Between Urban indices and Respiratory Diseases



Adaptation to the Impacts of Climate Change in Kigali, Rwanda: Challenges and Opportunities.

IRAGUHA Pacifique

Rwanda Ministry of Environment, City of Kigali, Water and Sanitation Corporation (WASAC), University of Rwanda (UR), Rwanda Young Water Professionals (RYWP)

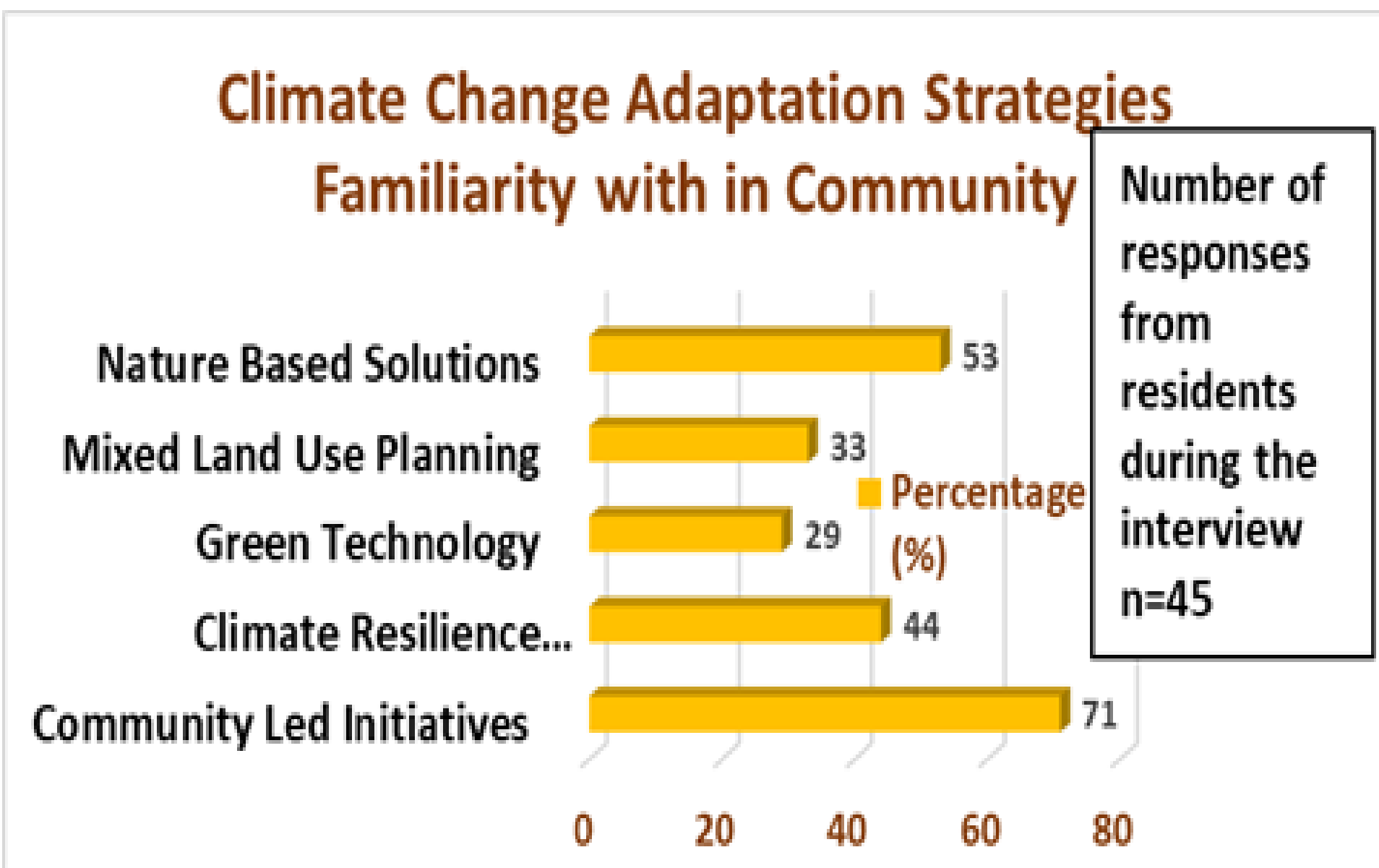
INTRODUCTION

Climate change poses significant challenges to Kigali, Rwanda, with rising temperatures, heavy rainfall, and extreme weather impacting urban land uses, infrastructures, and public health. This research examines adaptation strategies to enhance resilience in vulnerable urban communities.

OBJECTIVES

This research aims to identify effective adaptation strategies for key sectors, evaluate the success of community-led initiatives towards climate resilience adoption, and address barriers like funding and governance.

PRELIMINARY FINDINGS

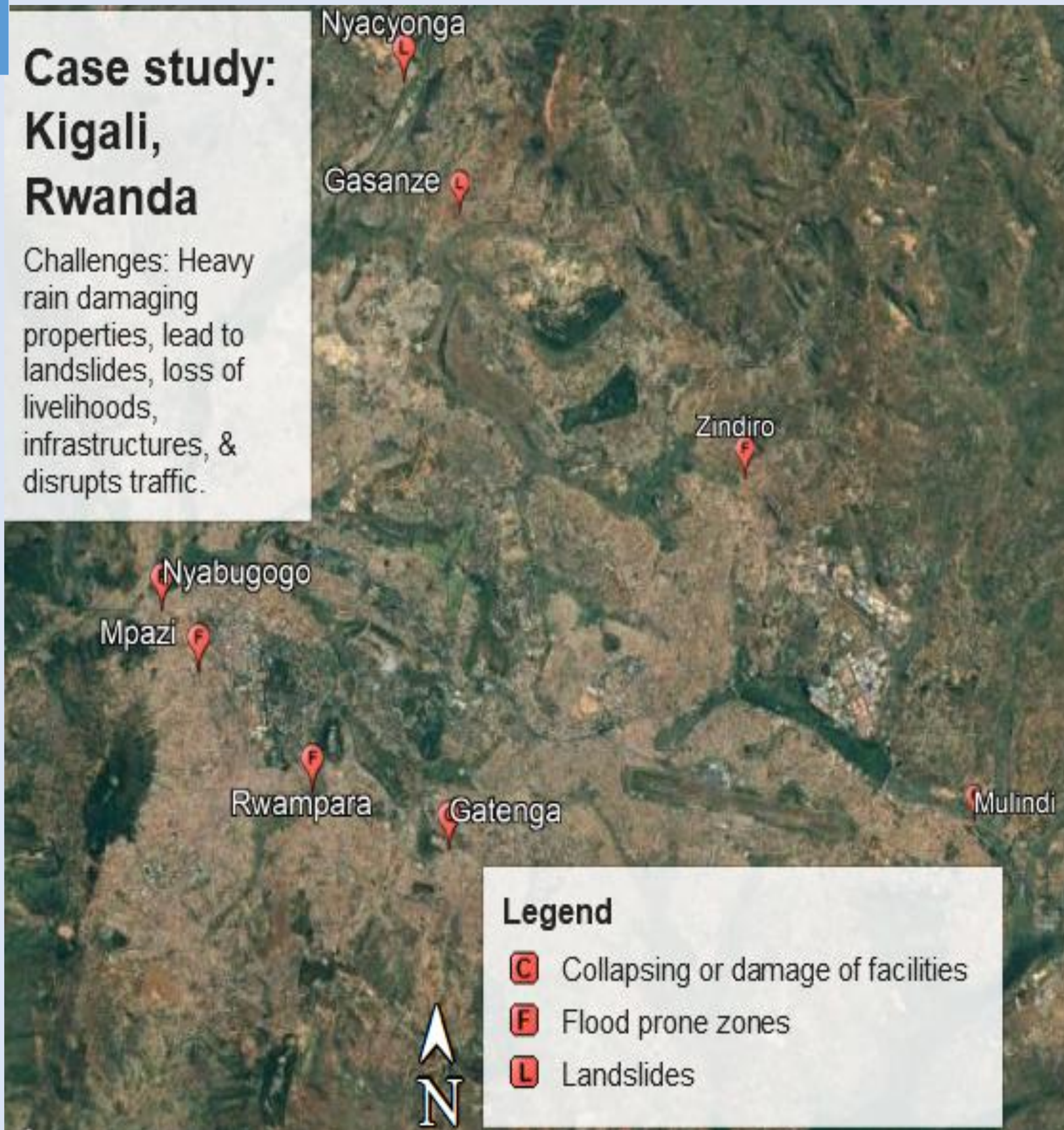


METHODOLOGY

Mixed-Methods Approach combining qualitative (interviews, workshops) and quantitative (surveys, GIS) data. The method uses GIS mapping to Identify flood-prone areas, participatory workshops to Integrate local knowledge for sustainable solutions, and case studies to review adaptation practices in similar contexts.

Case study: Kigali, Rwanda

Challenges: Heavy rain damaging properties, lead to landslides, loss of livelihoods, infrastructures, & disrupts traffic.

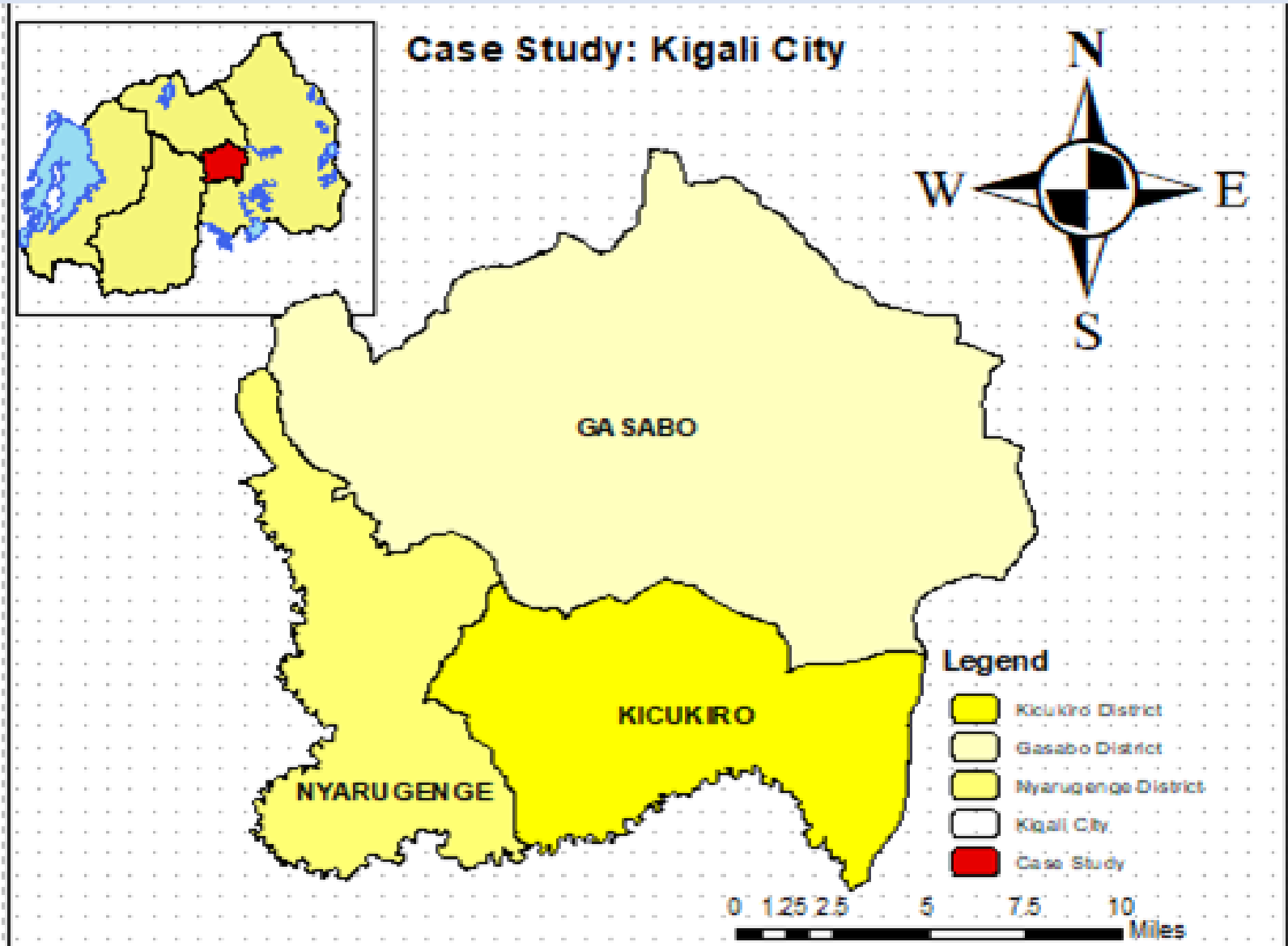


IMPLICATIONS

- Incorporate climate change adaptation policies with urban land use plans.
- Strengthen community participation and governance.
- Secure funding for scalable, sustainable practices.
- Promote climate-resilient adoption

ACKNOWLEDGEMENT

I express my sincere gratitude to the residents and community leaders of Kigali for their invaluable insights and participation in this study. Their willingness to share experiences with climate change impacts has been instrumental. I also appreciate the support of colleagues and mentors who provided feedback and encouragement for this research.



Title: Rwanda's Greenhouse Gas Inventory from 2006 - 2022

Author(s): Eric R Mudakikwa, Herman Hakuzimana, Pearl Nkusi, David Ukwishaka, Olive Byukusenge, Bernardin Bavuge, Anne Marie Rutabuzwa

Affiliation: Rwanda Environment Management Authority

The Rwanda Greenhouse Gas Inventory covers the period from 2006 to 2022, detailing emissions and removals across key sectors including energy, agriculture, waste, industry, and land use

INTRODUCTION

Addressing climate change requires a clear understanding of greenhouse gas (GHG) emission sources and trends. However, many countries, including developing nations, face challenges due to data limitations. As a non-Annex I Party to the UNFCCC, Rwanda has developed and submitted its National GHG Inventory as part of the first Biennial Transparency Report, aiming to strengthen climate policy, planning, and international reporting.

OBJECTIVE

“The inventory aims to present Rwanda's greenhouse gas emissions and removals by identifying the key contributing sectors and activities, and analyzing how these have evolved over time

METHODOLOGY

The national GHG inventory was developed using the 2006 IPCC Guidelines and the 2019 Refinement, which provide internationally standardized methods for estimating emissions and removals across sectors. The process includes identifying key emission categories, collecting reliable activity data, and applying appropriate emission factors either default values provided by the IPCC or country-specific factors where available to calculate emissions.

RESULTS (A)

In 2022, total emissions (with Forestry and other land use) reached about 7.8 million tonnes of CO₂ equivalent (MtCO₂e), marking a significant increase from the baseline year 2006.

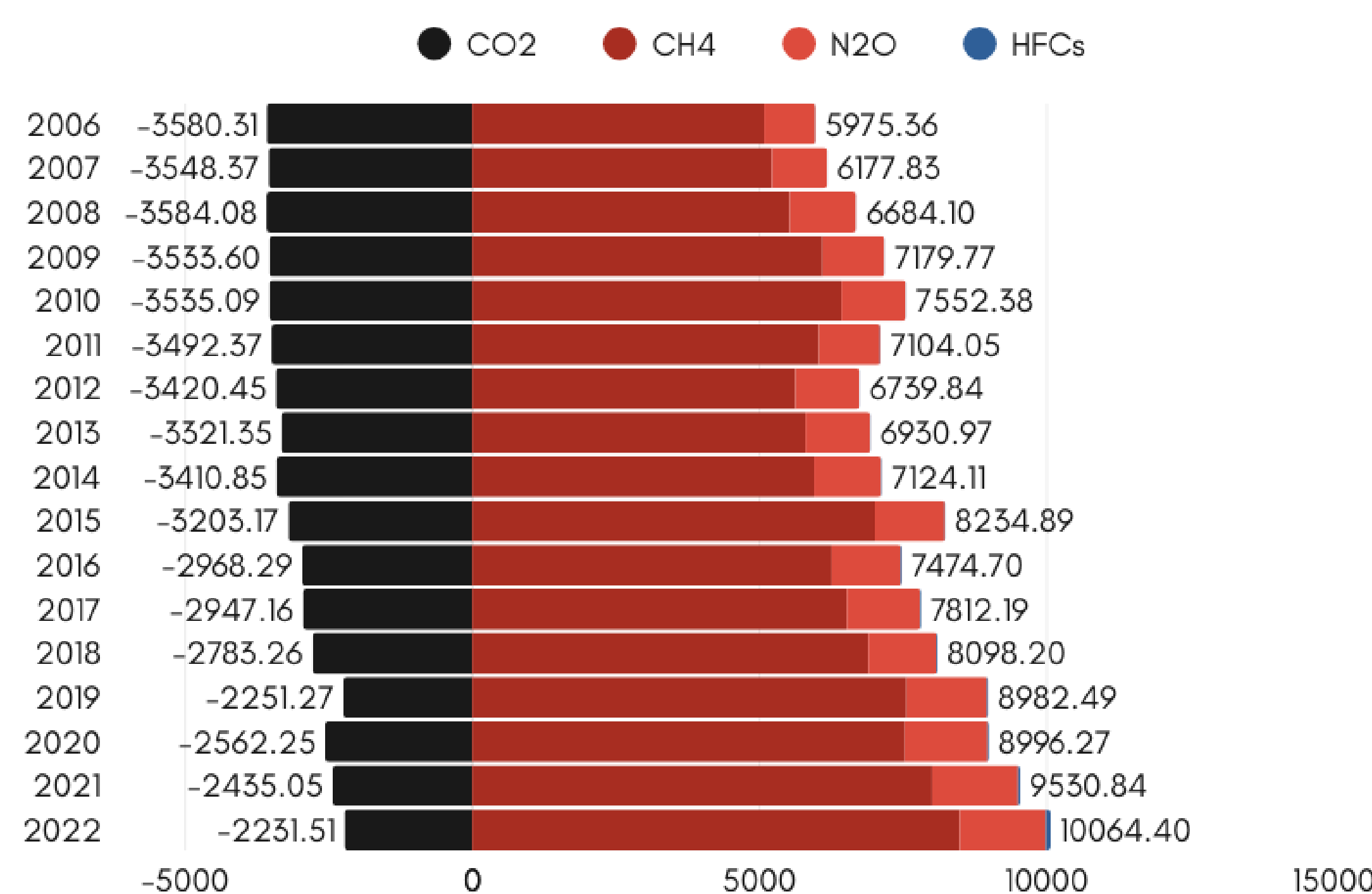


Figure 1: Trends in Greenhouse Gas Emissions by Gas Type (2006–2022)

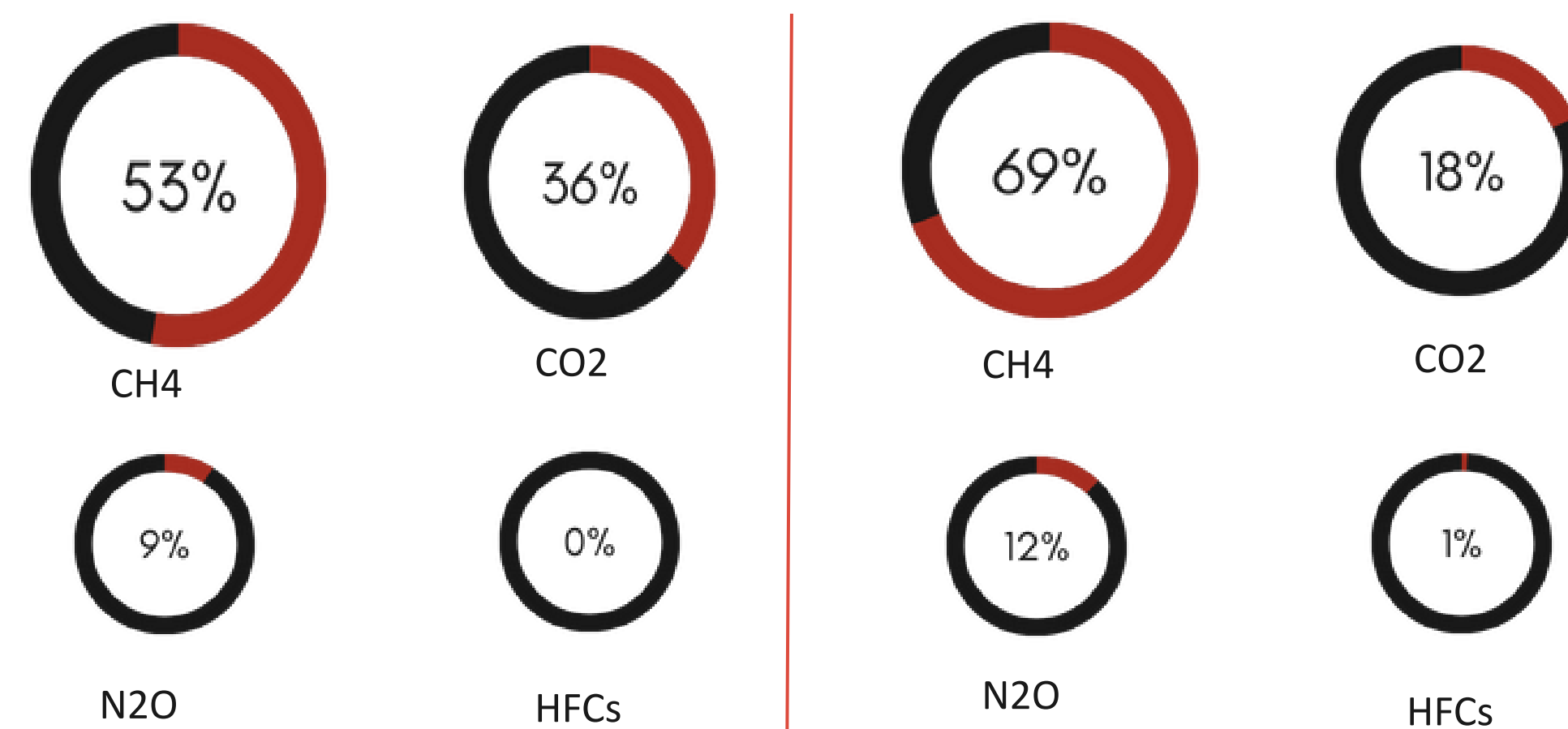


Figure 2: Share of Emissions per greenhouse gas in 2006

Figure 3: Share of Emissions per greenhouse gas in 2022

RESULTS (B)

In 2022, agriculture remained the largest contributor to Rwanda's total GHG emissions, accounting for approximately 39%. The energy sector followed with 18%, while waste contributed 9%, and industrial processes and product use (IPPU) accounted for 2%. Meanwhile, the forestry and other land use (FOLU) sector contributed to net removals, offsetting about 28% of total emissions

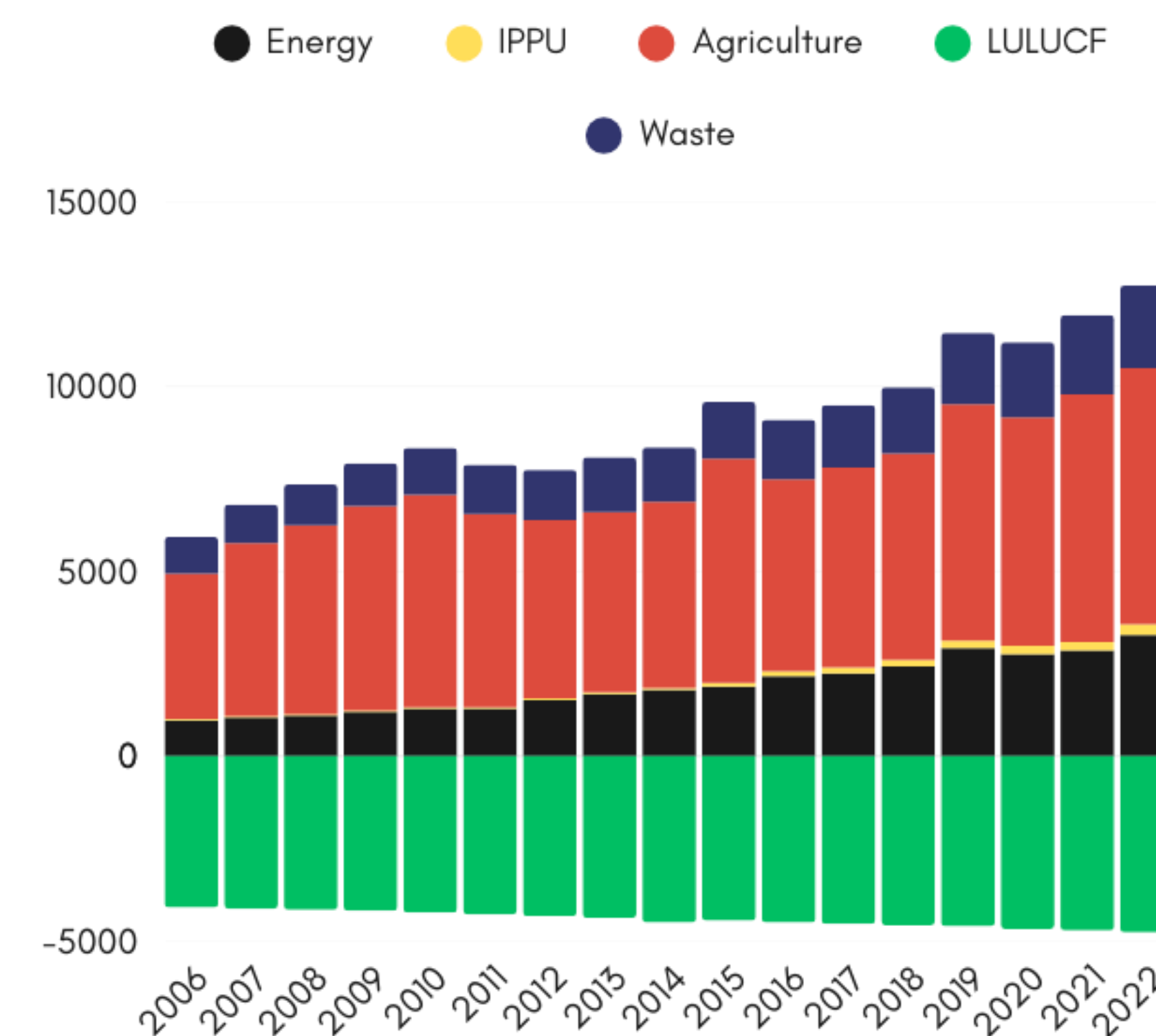


Figure 4: GHG Emissions Trend by sector from 2006 - 2022

CONCLUSION

Methane was the dominant greenhouse gas in 2022, accounting for 69% of total emissions, primarily from enteric fermentation in the agriculture sector. While Rwanda remains a low emitter globally, the rapid increase in emissions from the energy and waste sectors highlights the need for enhanced investment in mitigation measures to ensure sustainable, low-carbon development

Title: Community-Driven Adaptation Strategies to Climate Change

Author(s): **Guy Nobel IRAKOZE**

Affiliation: **UNIVERSITY OF RWANDA**

Background

Climate change severely affects ecosystems and communities, especially in vulnerable regions. Increasing temperatures, erratic rainfall, and extreme weather events challenge livelihoods. There is a critical need for locally grounded strategies to build resilience.



Objective

To assess the effectiveness of community-based strategies in reducing climate vulnerability and to identify practical, scalable approaches informed by local knowledge.



Methods

A mixed-methods approach was used, combining:

Surveys

Interviews

Participatory workshops

Focus areas included agriculture, water management, early warning systems, and livelihood diversification.

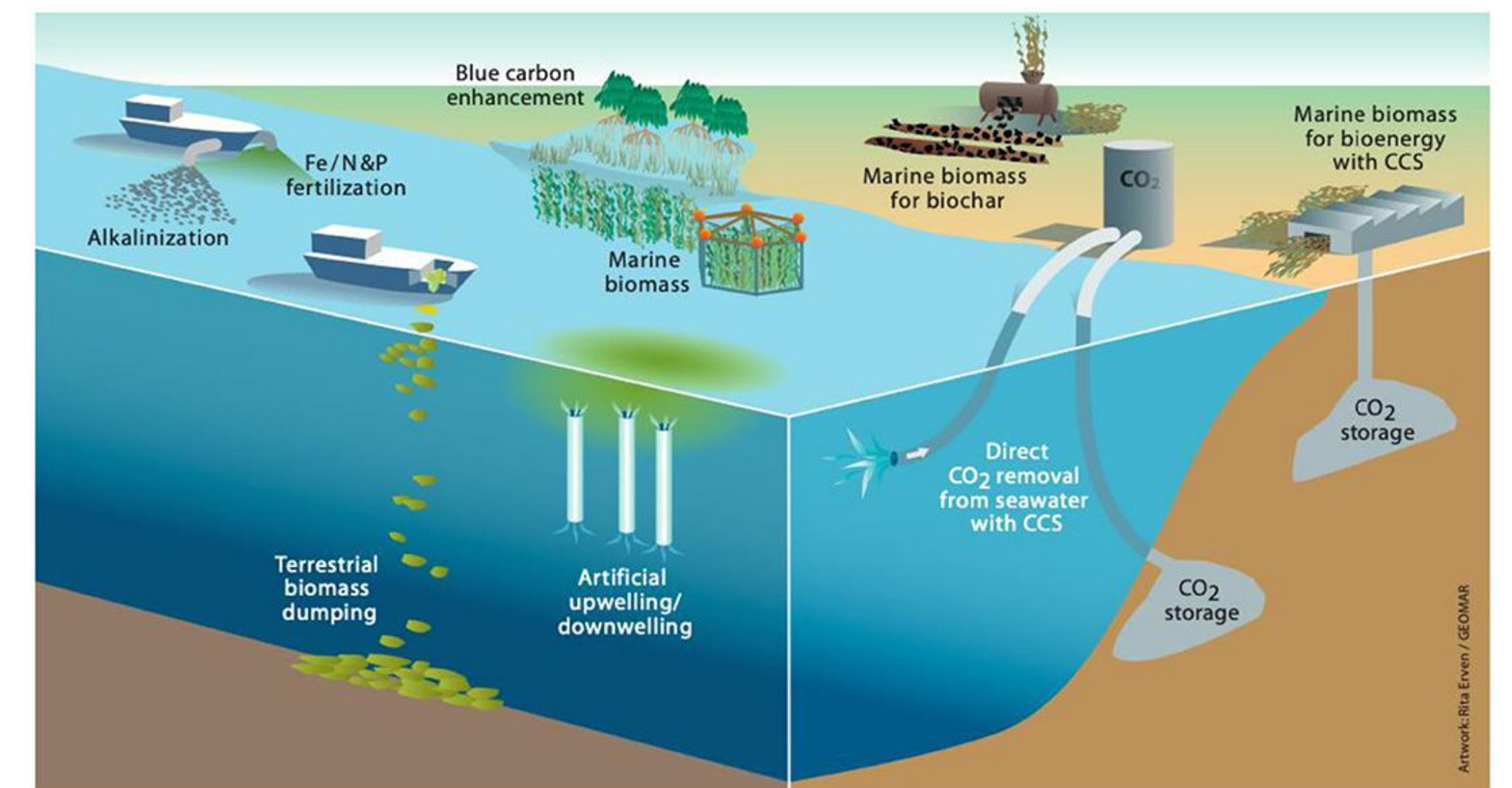
Results

Community-led efforts integrating indigenous and scientific knowledge improve resilience. Notable successes include diversified livelihoods and improved water use.

Challenges include funding, institutional support, and policy gaps.

Conclusion

Community-based adaptation is impactful but needs stronger support. Scaling successful practices and embedding local voices in policy is key to building long-term climate resilience.



1. Problem statement

One of the most important issues facing the world today is climate change. Global average temperature has increased about -16.8°C from 1970 to 2023 which has profound effects on ecosystems, economies, and human welfare as reported by UN Environmental Protection Agency. Rising temperatures, changing weather patterns, sea level rise, and an increase in the frequency of extreme weather events are all signs of its effects. Both human and ecological systems are seriously at risk from these changes, especially in areas that have limited potential for adaptation. The necessity for thorough risk assessments to direct efficient actions has become more pressing as the urgency to comprehend and confront these risks has increased.

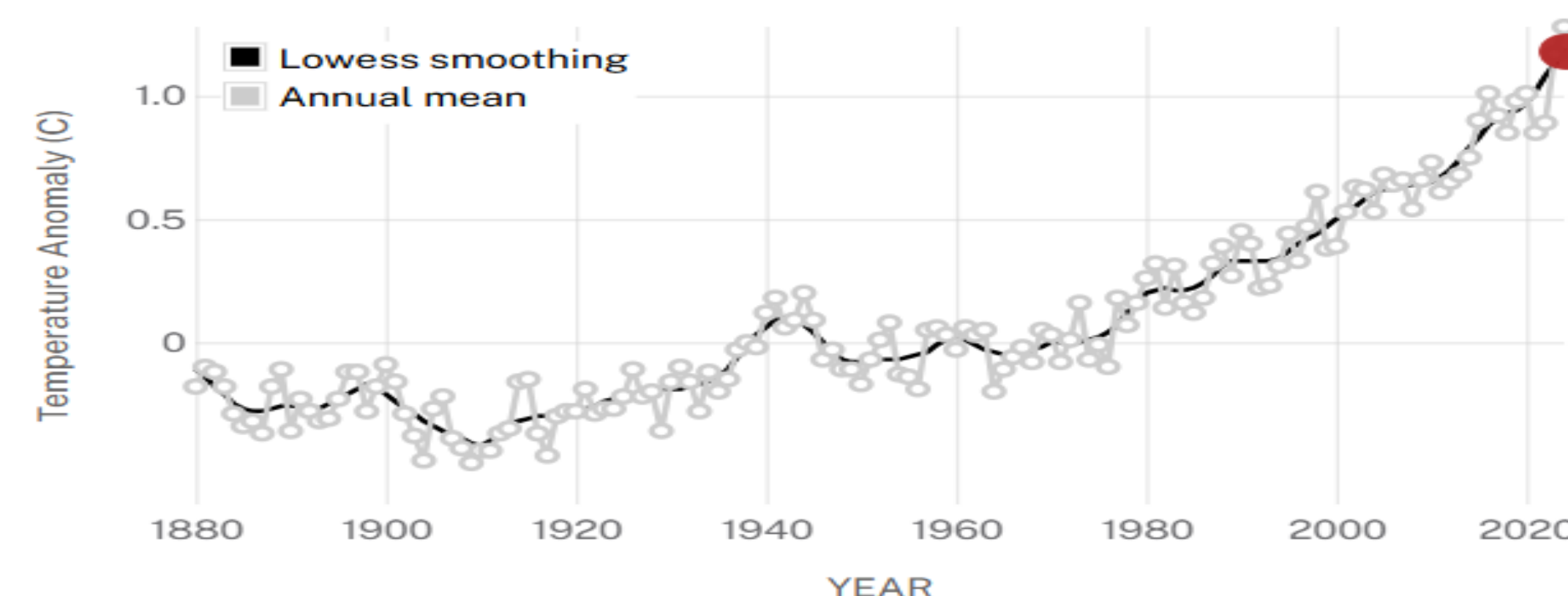
2. Objective

The complex effects of climate change and the hazards that come with it on a regional and global scale. Determining climate-related hazards, identifying the most vulnerable communities and industries, and guiding adaptive actions that can lessen long-term vulnerability are some specific objectives. To support evidence-based policymaking by identifying important areas that require intervention.



GLOBAL LAND-OCEAN TEMPERATURE INDEX

Data source: NASA's Goddard Institute for Space Studies (GISS). Credit: NASA/GISS



3. Methodology

The study uses an interdisciplinary method, integrating socioeconomic risk evaluations (Organization for Economic Co-operation and Development forecasts that by 2060, the annual GDP growth loss due to climate change could be around 2%, with negative impacts on public health and agriculture being significant drivers.), geospatial analysis and climate modeling to accomplish these goals. Both quantitative and qualitative techniques were used to assess the data, which came from field surveys, historical documents, and climatic projections. Exposure, sensitivity, and adaptation ability were assessed across various areas and industries using risk assessment frameworks.

4. Key findings and conclusion

The results show that low-income and coastal communities are disproportionately impacted by climate change, with higher risks of floods, food insecurity, and health emergencies. The study comes to the conclusion that in order to lessen these effects, proactive risk management, early warning systems, and locally specific adaption plans are crucial. Furthermore, strengthening resilience and guaranteeing sustainable development in the face of climate uncertainty depend on incorporating scientific insights into planning and policy processes. This research is still ongoing.

Title: **Advances in Measurement and Reduction Strategies for Greenhouse Gas Emissions**

Author(s): Darcy RUTABINGWA

Affiliation: UNIVERSITY OF RWANDA

This research addresses the urgent need to improve the measurement and reduction of greenhouse gas (GHG) emissions, a key driver of climate change. It focuses on advancing methodologies for tracking emissions across energy, agriculture, and transport sectors, and evaluating mitigation technologies like carbon capture, methane leak repair, and renewables. Using a combination of field data, satellite sensing, and life-cycle modeling, the study improves emission inventory accuracy and policy relevance. Preliminary results show significant emission reductions up to 45% from methane LDAR programs with ongoing research aiming to guide national and global mitigation strategies.

