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PROJECTED RAINFALL AND TEMPERATURE CHANGES OVER BUNGOMA COUNTY IN WESTERN KENYA BY THE YEAR 2050 BASED ON PRECIS MODELING SYSTEM

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Abstract

This study investigated projected changes in rainfall and temperature over Bungoma County by the year 2050 based on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) A1B and A2B emission Scenarios (IPCC, 2007) using the Providing Regional Climates for Impacts Studies (PRECIS); (Giorgi, 2007). The PRECIS regional Climate Model (Hadley RM3P) was configured in 0.22°×0.22° horizontal grid resolution was forced at the lateral boundaries by the UKMO-HadAM3P and UKMOHadCM3 global Models. The future projection of temperature indicates warming over Bungoma County by the year 2050 coupled with reduced precipitation. Time series analysis revealed a cyclic and seasonal trend in rainfall and temperature over the area of study. Temporal characteristics revealed a warmer and colder September-October-November (SON) season under A1B and A2B scenarios respectively. The results also revealed increasing temperatures and reducing rainfall across all seasons under both scenarios except in March-April-May (MAM) season where rainfall amounts increased and temperature reduced. A two paired t-test for the two climate variables revealed a ρ value of less than 0.05 ($\rho<0.05$) suggesting a statistically significant relationship between each pair of the two variables. The study recommends further evaluation of the model performance in simulating the present day climate over the area of study.

Key Words: *Climate Change, Regional Circulation Model, PRECIS, Bungoma County*

Introduction

According to the recently released report of Intergovernmental panel on climate Change (IPCC, 2013,), global mean surface temperature of the earth has increased since the beginning of the instrumental record. This warming has been about 0.85°C from 1880 to 2012 with an increase of about 0.72°C from 1951 to 2012. Each of the last three decades has successively been the warmest on record. The three decades have been the warmest in both the last 800 years and the last 1400 years even if the rate of warming over the last 15 years is smaller than the rate since the 1950s (IPCC, 2013). Developing Countries will be hit most by impacts of a changed Climate (IPCC 2014). Recent climate Change projections over Kenya reveal a warmer future (Muthama *et al.,* 2014).

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Equilibrium simulations using the best-available general circulation models to estimate the sensitivity of the climate to a doubling of the atmospheric carbon dioxide concentration are in broad general agreement that the global annual average surface air temperature would increase 2.5 to 4.5 K. However, at finer spatial scales, the range of changes in temperature and precipitation predicted by different computer models is much broader. Many shortcomings are also apparent in the model simulations of the present climate, indicating that further model improvements are needed to achieve reliable regional and seasonal projections of the future climatic conditions (Grotch, 1991)

The problem of projecting regional climate changes can be identified as that of representing effects of atmospheric forcings on two different spatial scales: large-scale forcings, i.e., forcings which modify the general circulation and determine the sequence of weather events which characterize the climate regime of a given region (for example, greenhouse gas abundance), and mesoscale forcings, i.e., forcings which modify the local circulations, thereby regulating the regional distribution of climatic variables (for example, complex mountainous systems). General circulation models (GCMs) are the main tools available today for climate simulation (Giorgi, 1991). Geoffrey (2008) conducted a study on "analysis of the trends in the observed rainfall records indicated an increase in rainfall variability both in space and time". Results of his findings revealed that the observed trend in minimum and maximum temperatures was increasing. The skill for the PRECIS model to simulate the climate of the Region was examined and judged to perform reasonably well. Studies by Majaliwa *et al. (*2012) carried out a study to assess the skill of the United Kingdom (UK) Regional Climate Model (RCM) PRECIS (Providing Regional Climates for Impacts Studies) in simulating rainfall and temperature over Uganda. Results showed that the models captured fairly well the large scale flow signals influencing rainfall and temperature patterns over Uganda. According to Xiong *et al.* (2007), future crop yields will greatly vary due to increasing temperature variability. Studies by Githui *et al.* (2009) on Climate change impact on SWAT simulated streamflow in western Kenya revealed that temperature will increase in this region, with the 2050s experiencing much higher increases than the 2020s with a monthly temperature change range of 0–1.7 °C. Studies by Herrero *et al*. (2010) revealed that there will be future temperature increase in Africa. Therefore, it is vital to investigate future climate variability over Kenyan Regions, defined by Counties. This research makes attempts to investigate future rainfall and temperature projections over Bungoma County.

Objectives of Study

The broad objective was to determine projected trends in rainfall and temperature over the area of study by the year 2050

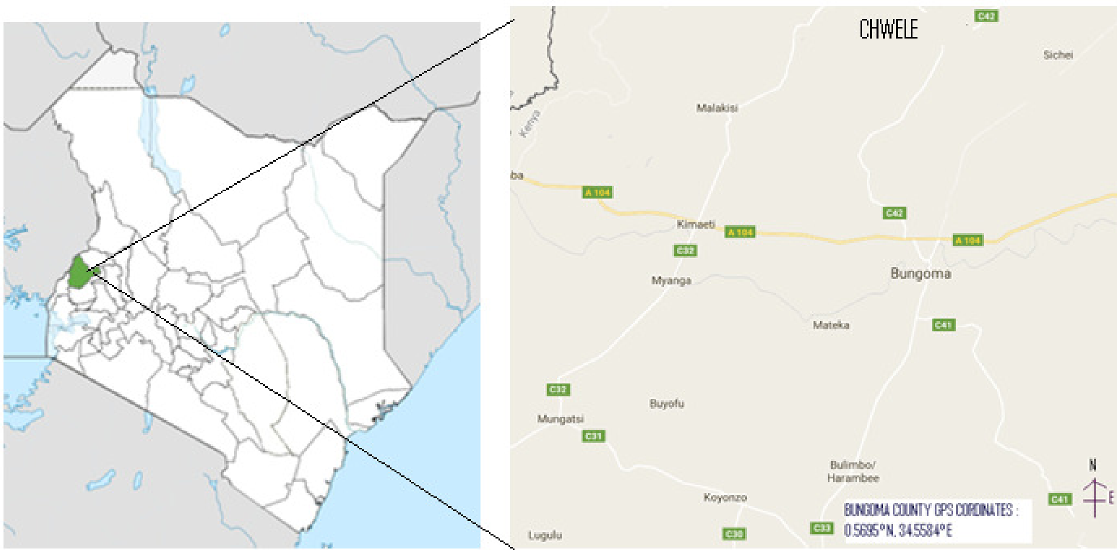
Specific Objectives

- Generate rainfall and temperature scenarios by the year 2050
- Determine Temporal Characteristics of simulated rainfall and temperature

Study Area

Bungoma County, located in western Kenya on the southern slopes of Mount

Elgon covers an area of about 3,032 km^2. The County is divided into 9 sub counties namely Bumula, Bungoma Central, Bungoma North, Bungoma South, Bungoma west, Kimilili, Mt.Elgon, Webuye East and Webuye West. Climate in Bungoma is tropical with significant amounts of rainfall especially in the early months of the year. Bungoma experiences average annual temperatures estimated at 22.5 °C and an approximate average annual Rainfall of 150 mm. Figure 1 below shows the map of area of study located in western part of Kenya at 0.5695° N, 34.5584° E respectively.



(Edited from Map data 2013@google)

Figure 1: Map of study area

Methodology

The methodology entailed nesting the RCM within the coarse GCM outputs over the region of study. The PRECIS regional Climate Model (Hadley RM3P) was configured in 0.22°×0.22° horizontal grid resolution is forced at the lateral boundaries by the UKMO-HadAM3P and UKMOHadCM3 global Models. Temperature and Rainfall simulations were generated under A1b and A2 scenarios. Temporal characteristics of simulated data were determined using Statistical Package for Socio-Scientists (SPSS).

Emission scenarios

A Climate scenario is a plausible representation of future climate that has been constructed for explicit use for investigating the potential Impacts of Anthropogenic climate change (IPCC, 2007). Climate scenarios are developed by use of climate projections (modelled response of the climate system to estimated GHG and aerosol concentration) by manipulating model outputs then with the observed climate data. There are inherent uncertainties in the key assumptions and relationships about future Population, socio-economic development and technical changes that are the bases of the IPCC SRES Scenarios. The uncertain nature of these emission paths has been well documented.

The A1 IPCC SRES Scenario

This scenario family describes a future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter and the rapid introduction of new and more efficient technologies.

Major underlying themes are: Convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. This scenario family develops into three groups that describe alternative directions of technological change in the energy system.

A1F1: Fossil intensive.

A1T : Non-fossil energy sources

A1B: Balance across all energy sources. “Balanced” being defined as not relying too heavily on one particular energy source.

The B1 IPCC SRES Scenario

This scenario family describes a convergent world with the same global population that peaks in the mid-century and declines thereafter but with a more rapid change in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies.

The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity but without additional climate initiatives.

The A2 IPCC SRES Scenario

This scenario family describes a very heterogeneous (fragmented world).The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuous increasing population .Economic development is regionally oriented and per capita economic growth and technological growth more fragmented and slower. The A2 scenario describes a world that consolidates into a series of roughly continental economic regions, emphasizing local cultural roots.

The B2 IPCC SRES Scenario

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Results and Discussion

Figures 2 and 3 show temperature trend by the year 2050 under A1B and A2B scenarios. It can be seen that average temperature exhibited a cyclic pattern with an increasing trend over the years across all scenarios.

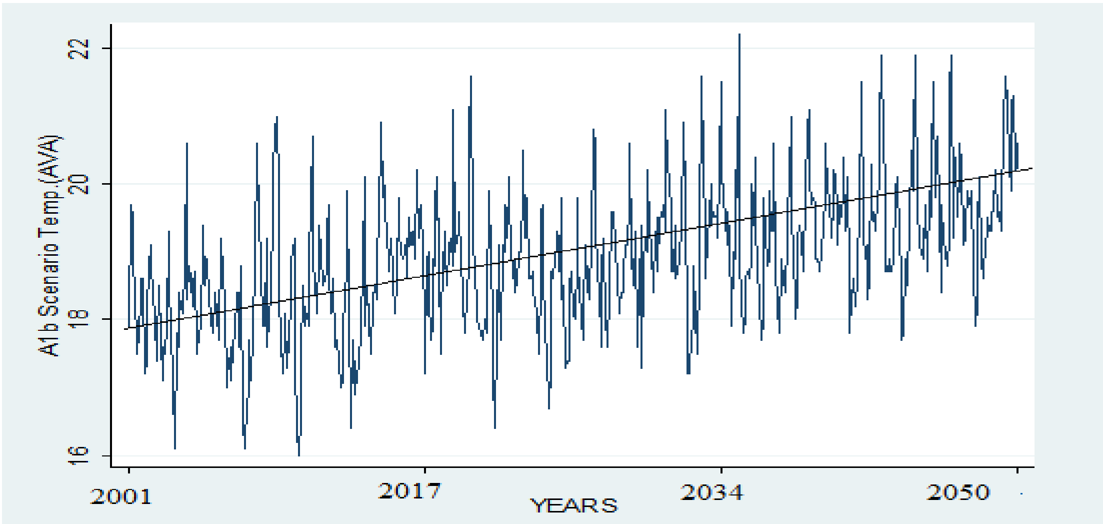


Figure 2: Temperature trend by the year 2050 under A1B Scenario

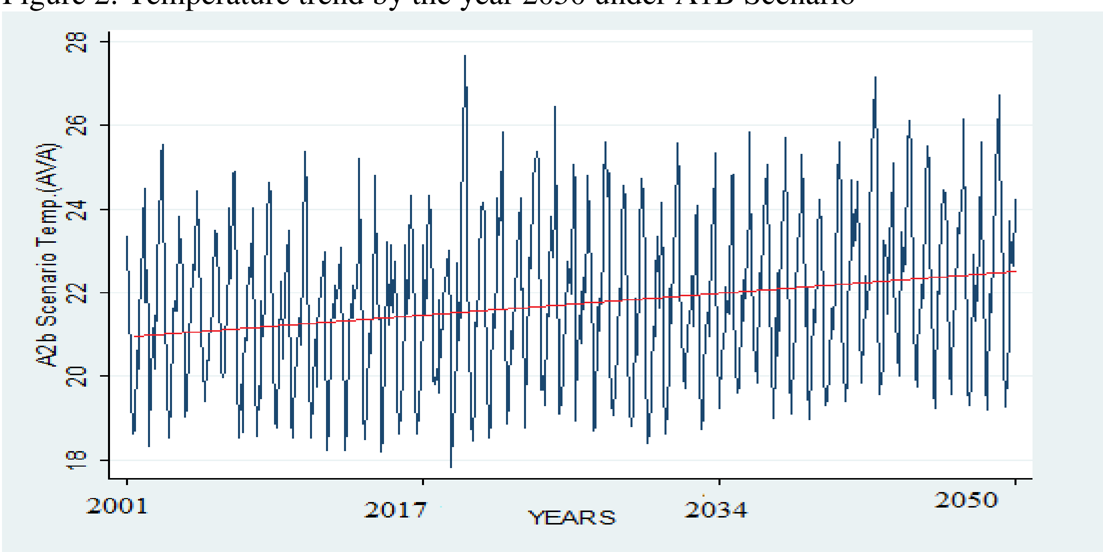


Figure 3: Temperature by the year 2050 under A2B Scenario

Figures 4 and 5 show rainfall trend by the year 2050 under A2B and A1B scenarios. It can be seen that average rainfall exhibited a cyclic pattern with a reducing trend under both scenarios over the years of study.

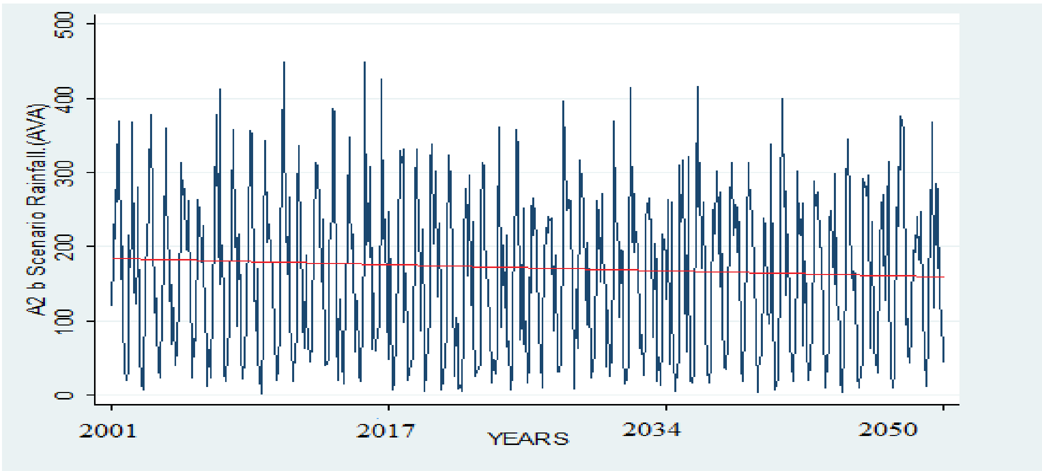


Figure 4: Rainfall trend by the year 2050 under A2b Scenario

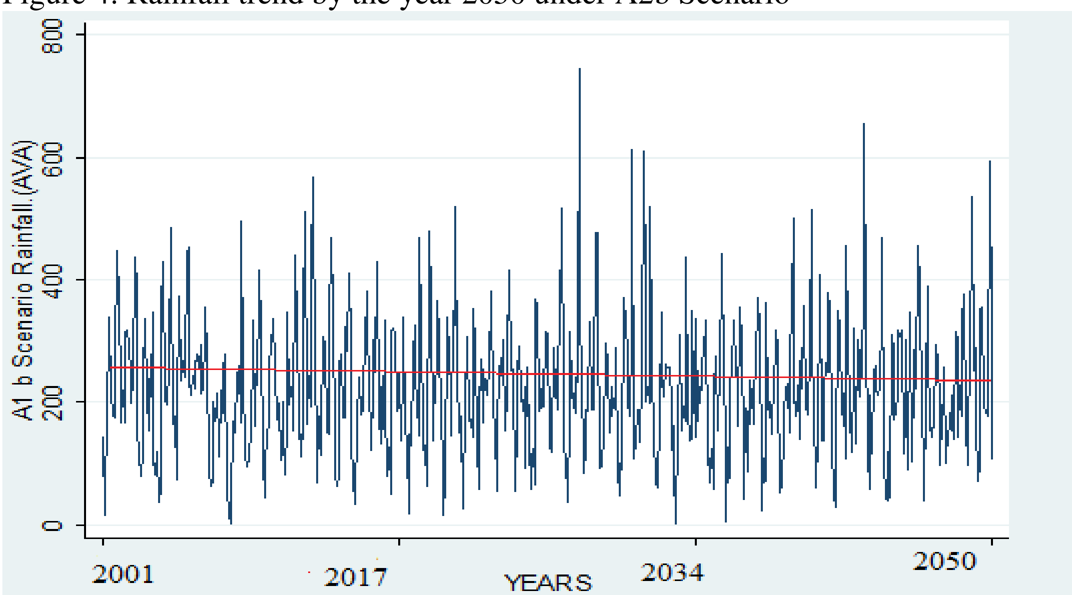


Figure 5: Rainfall trend by the year 2050 under A1B Scenario

Figures 6 and 7 show spatial characteristics of temperature during the SON season by the year 2050 under A1B and A2B Scenarios. It can be seen that average temperature exhibited increasing climate variability over the years of study under both scenarios.

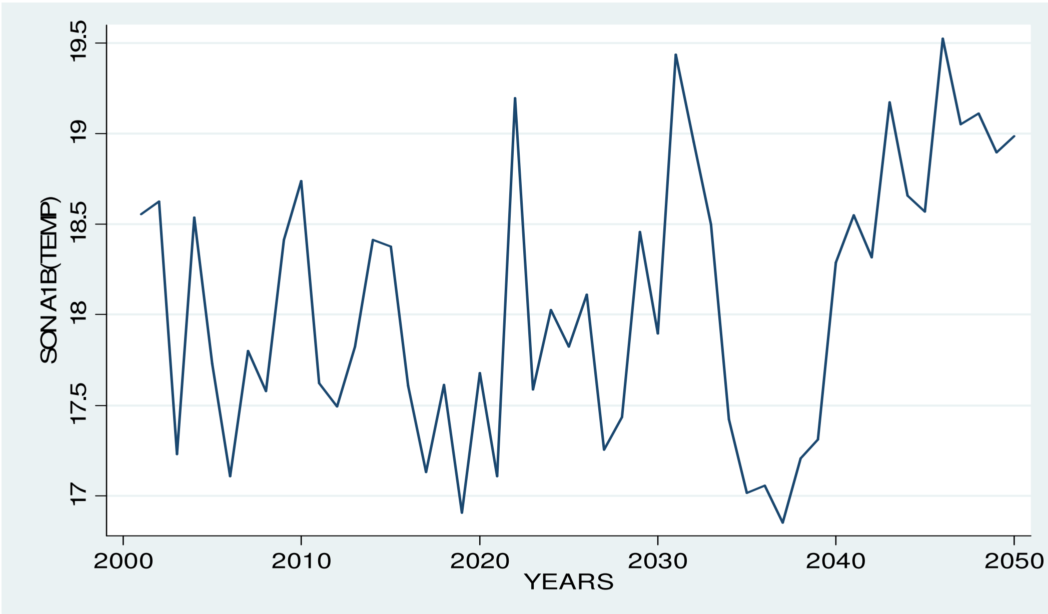


Figure 6: Temporal characteristics of temperature during the SON season under A1B Scenario

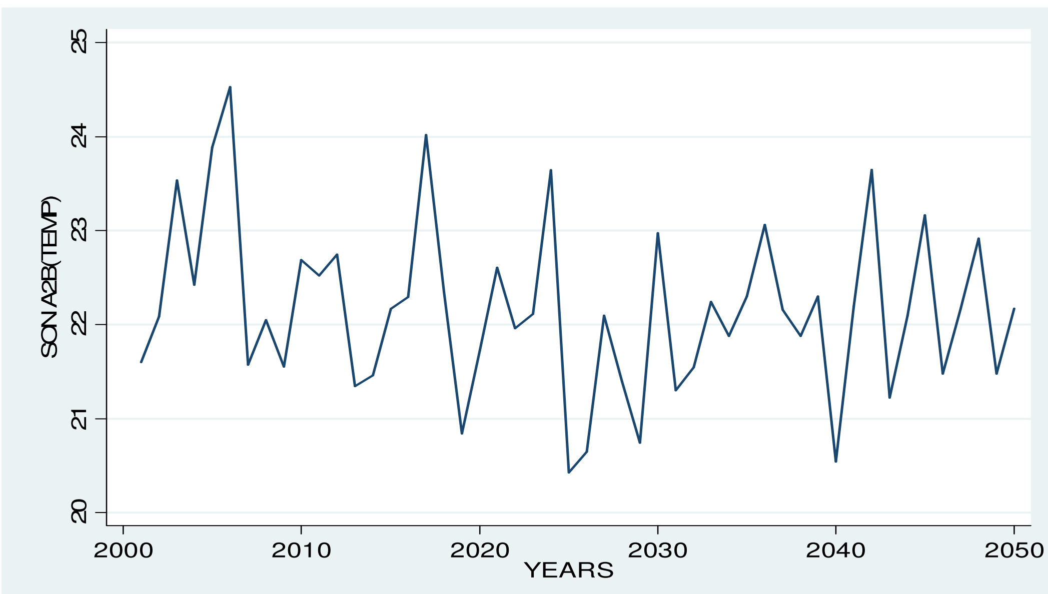


Figure 7: Temporal Characteristics of temperature during the SON season under A2B scenario

Figures 8 and 9 show spatial characteristics of rainfall during the SON season by the year 2050 under A1B and A2B scenarios . It can be seen that average rainfall exhibited an increasing climate variability over the years of study under both scenarios.

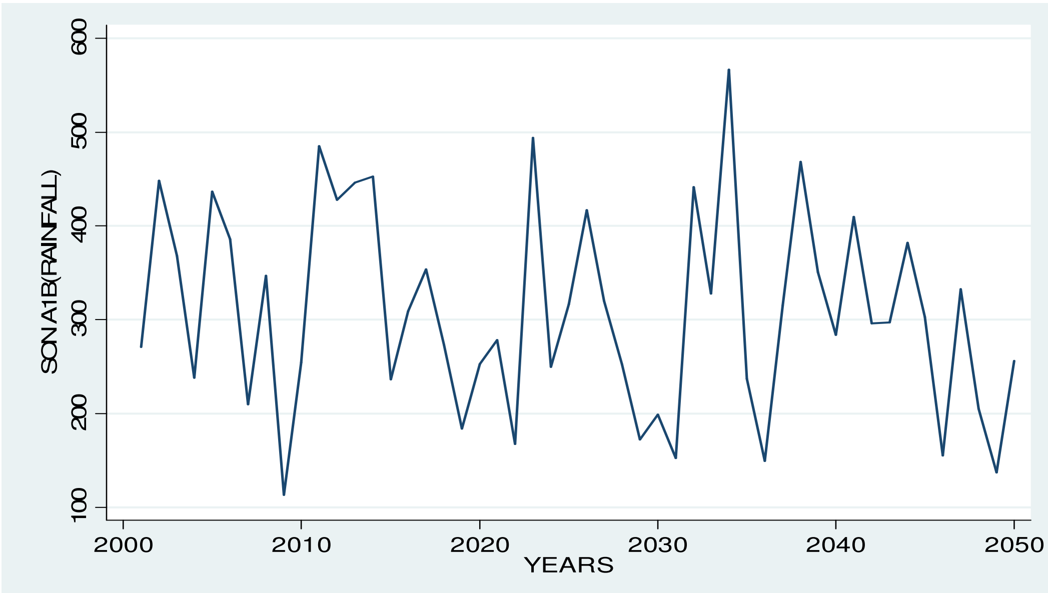


Figure 8: Temporal Characteristics of Rainfall during the SON season under A1B Scenario

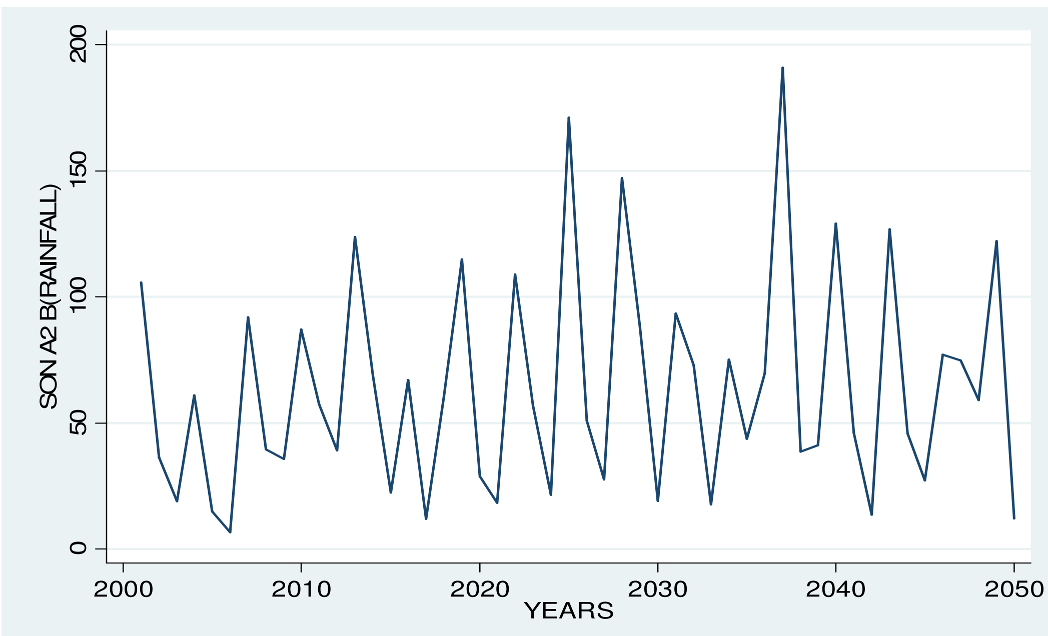


Figure 9: Temporal characteristics of Rainfall during SON season under A2b Scenario

Figures 10 and 11 show spatial characteristics of temperature during the MAM season by the year 2050 under A1B and A2B scenarios. It can be seen that average temperature exhibited increasing climate variability over the years of study under both scenarios

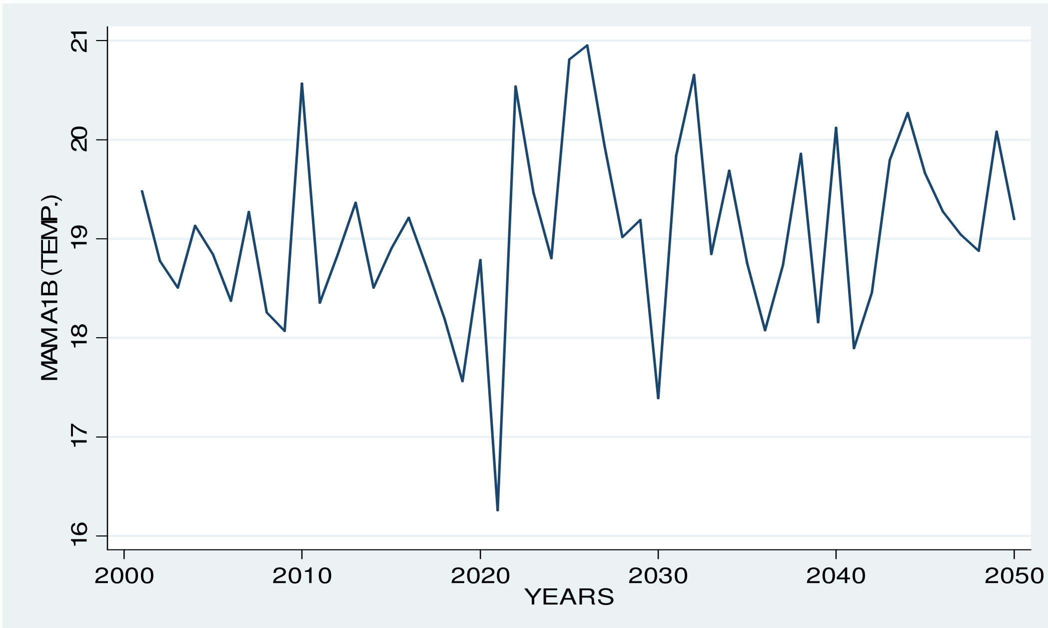


Figure 10: Temporal Characteristics of temperature during MAM under AIB Scenario

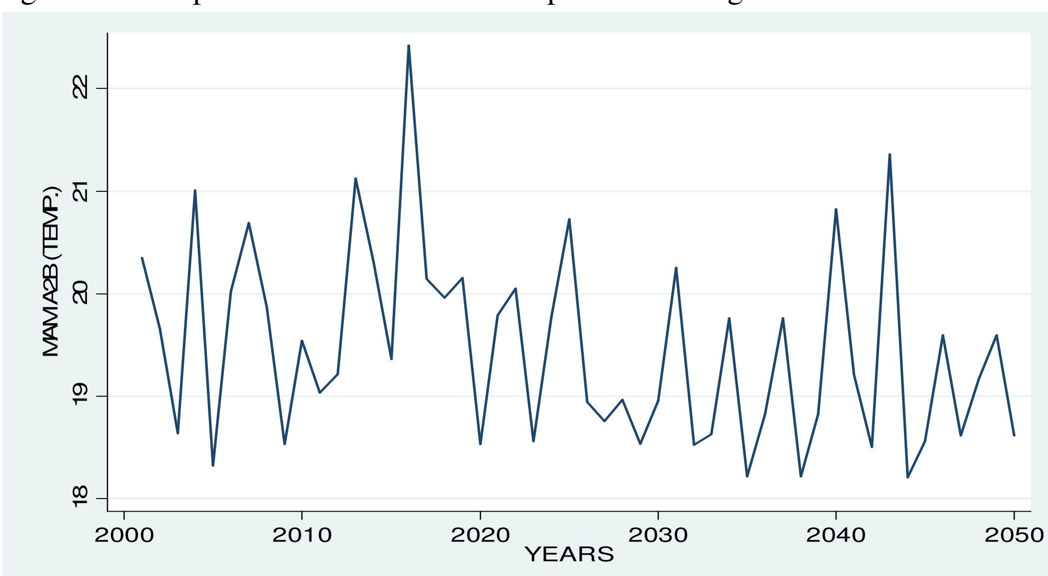


Figure 11: Temporal Characteristics of temperature during MAM season under A2B Scenario

Figures 12 and 13 show spatial characteristics of rainfall during the MAM season by the year 2050 under A1B and A2B scenarios. It can be seen that average Rainfall exhibited an increasing climate variability over the years of study under both scenarios

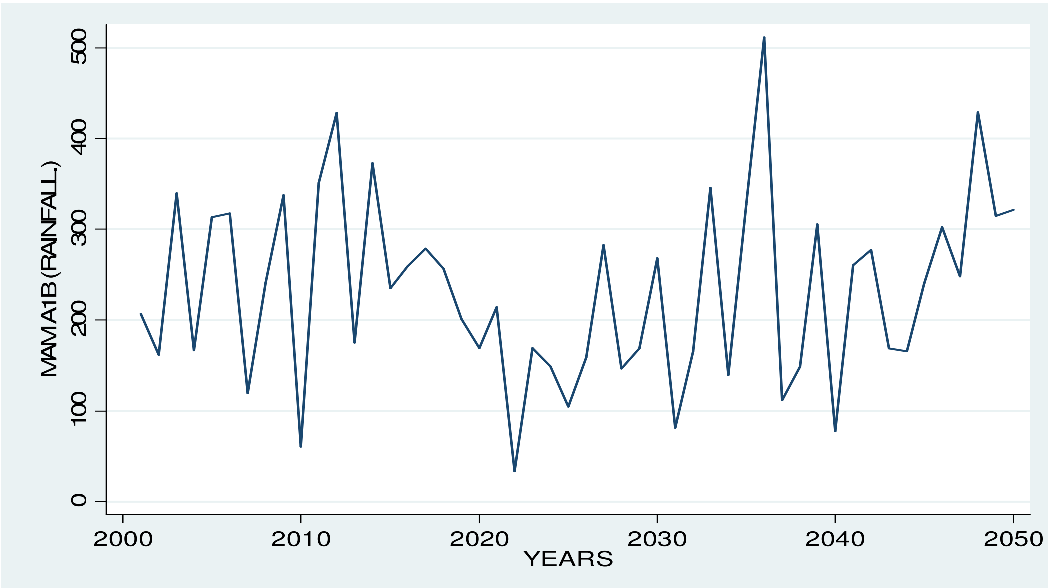


Figure 12: Temporal Characteristics of Rainfall during MAM under A1B Scenario

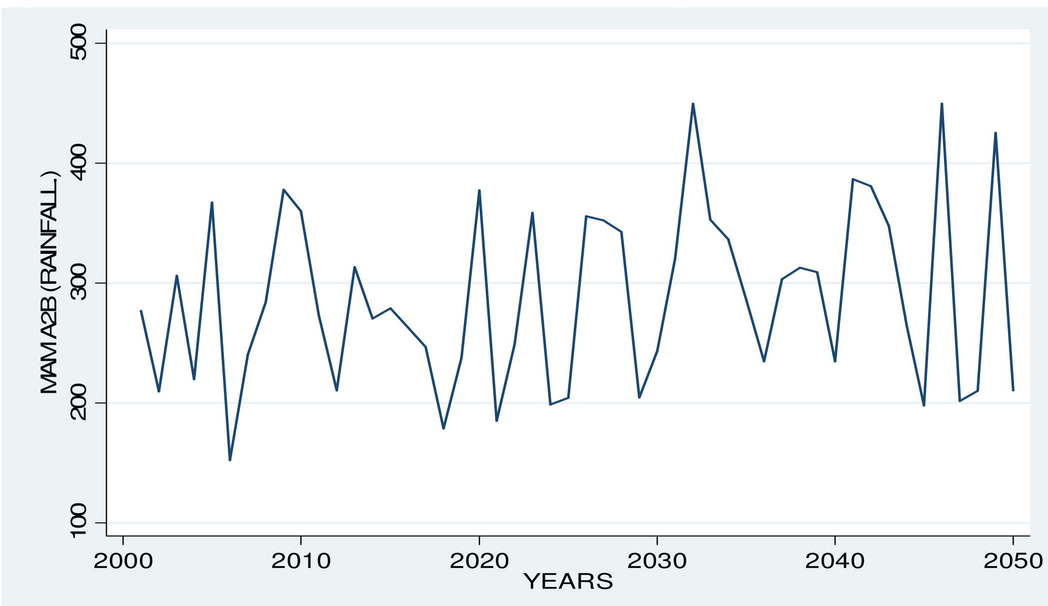


Figure 13: Temporal Characteristics of Rainfall during MAM season under A2B Scenario

Figures 14 and 15 show spatial characteristics of temperature during the DJF season by the year 2050 under A1B and A2B Scenarios. It can be seen that average temperature exhibited increasing climate variability over the years of study under both scenarios

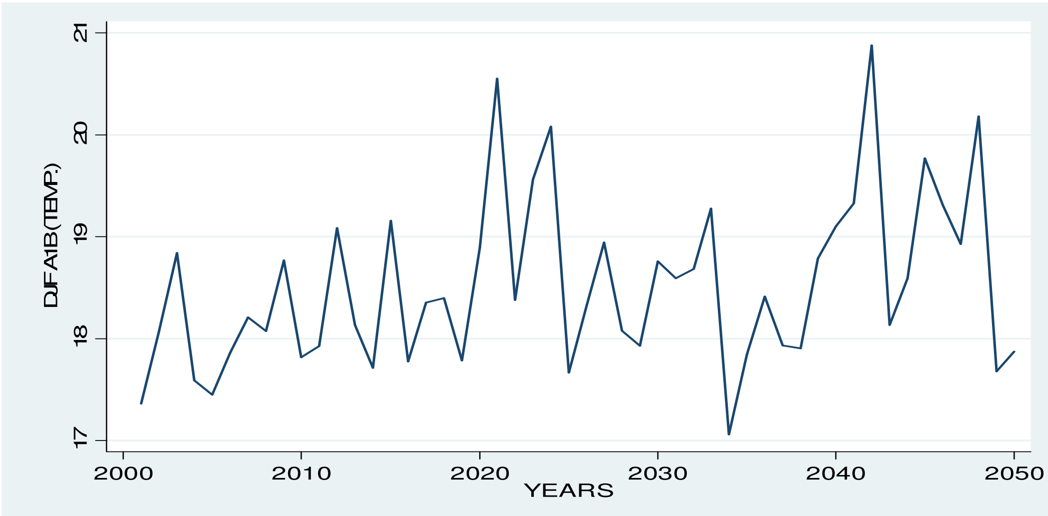


Figure 14: Temporal Characteristics of temperature during DJF season under A1B Scenario

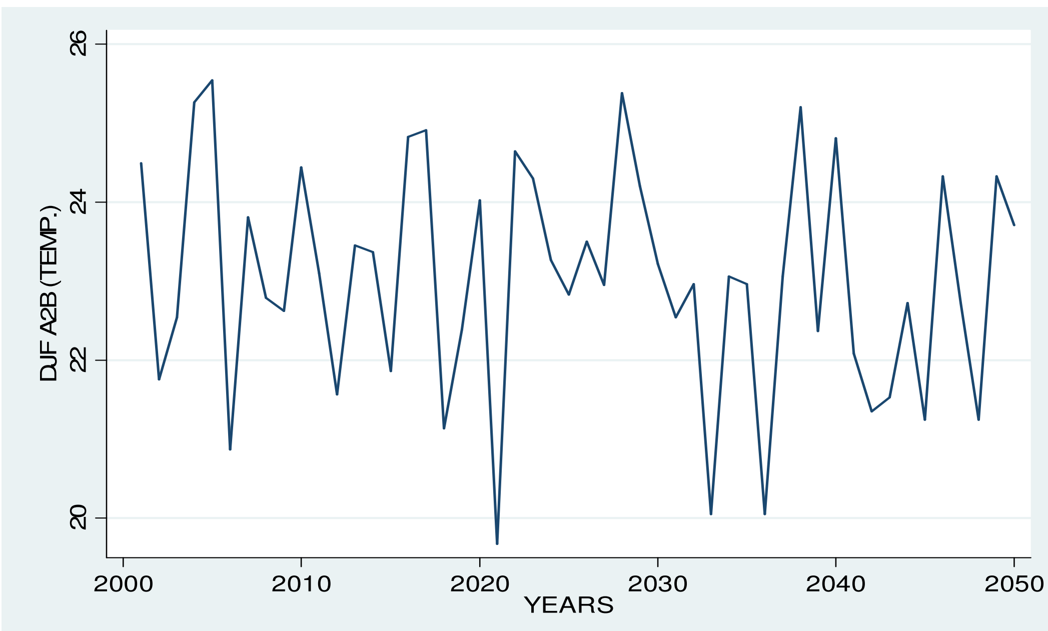


Figure 15: Temporal Characteristics of temperature during DJF season under A2B Scenario

Figures 16 and 17 show spatial characteristics of rainfall during the DJF season by the year 2050 under A1B and A2B scenarios. It can be seen that average Rainfall exhibited an increasing climate variability over the years of study under both scenarios

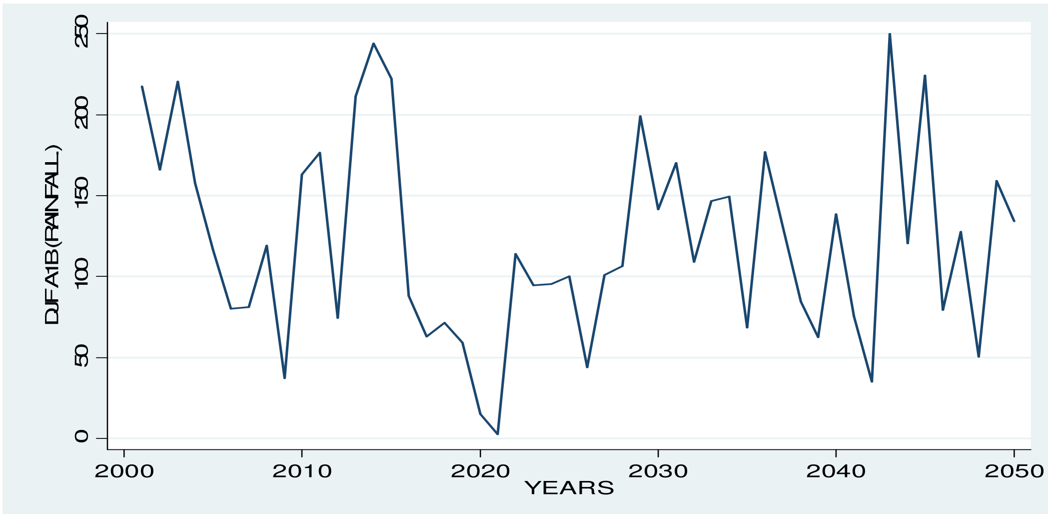


Figure 16:Temporal Characteristics of Rainfall during DJF season under A1B Scenario

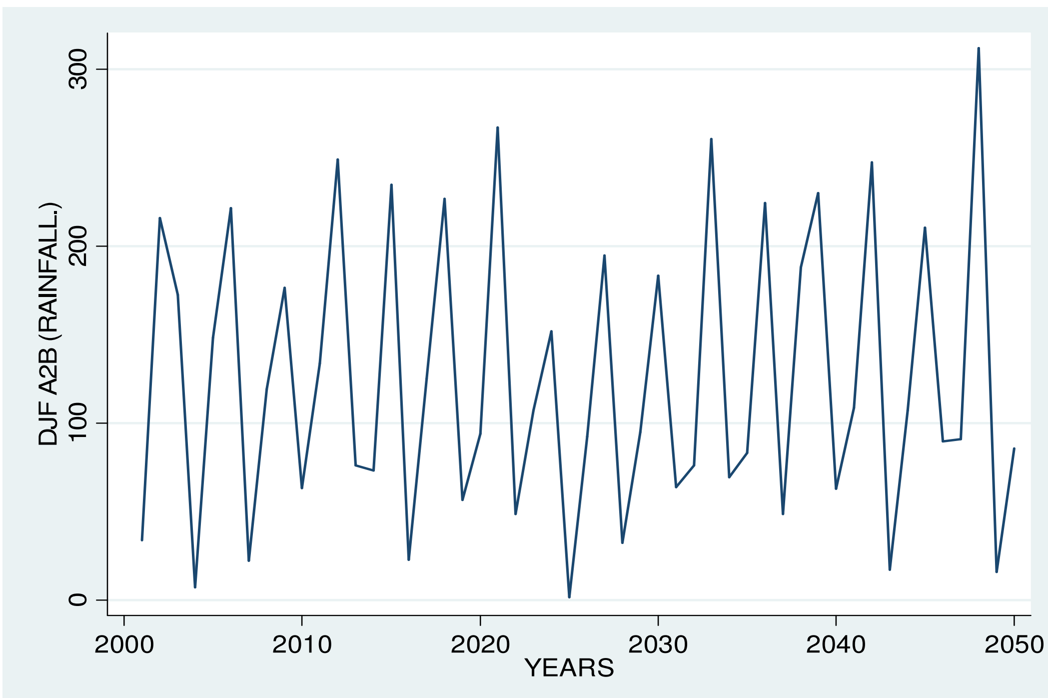


Figure 17: Temporal Characteristics of Rainfall during DJF season under A2B Scenario

Figures 18 and 19 show spatial characteristics of temperature during the JJA season by the year 2050 under A1B and A2B scenarios. It can be seen that average temperature exhibited increasing climate variability over the years of study under both scenarios

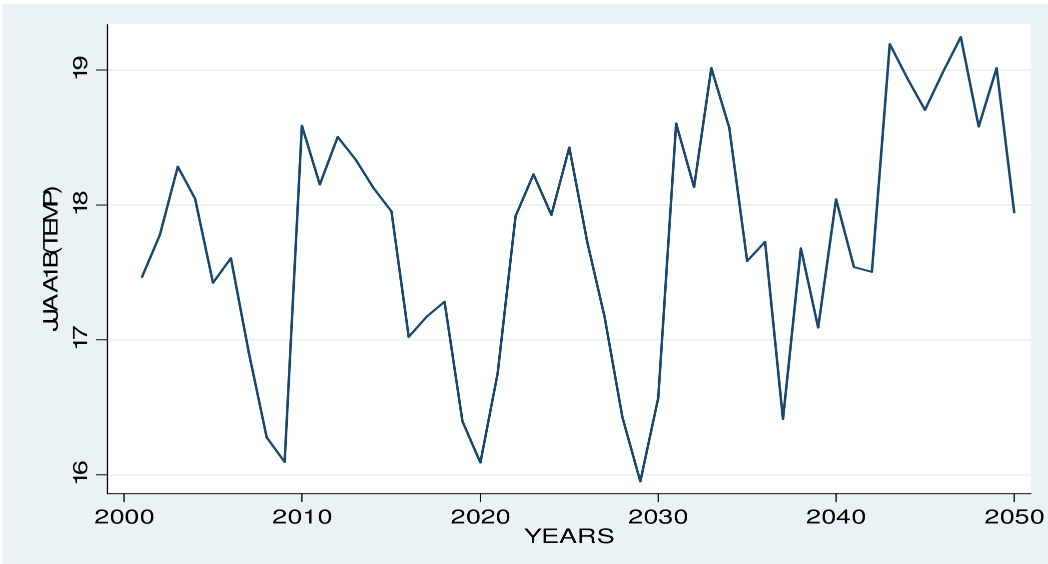


Figure 18: Temporal Characteristics of temperature during JJA season under AB Scenario

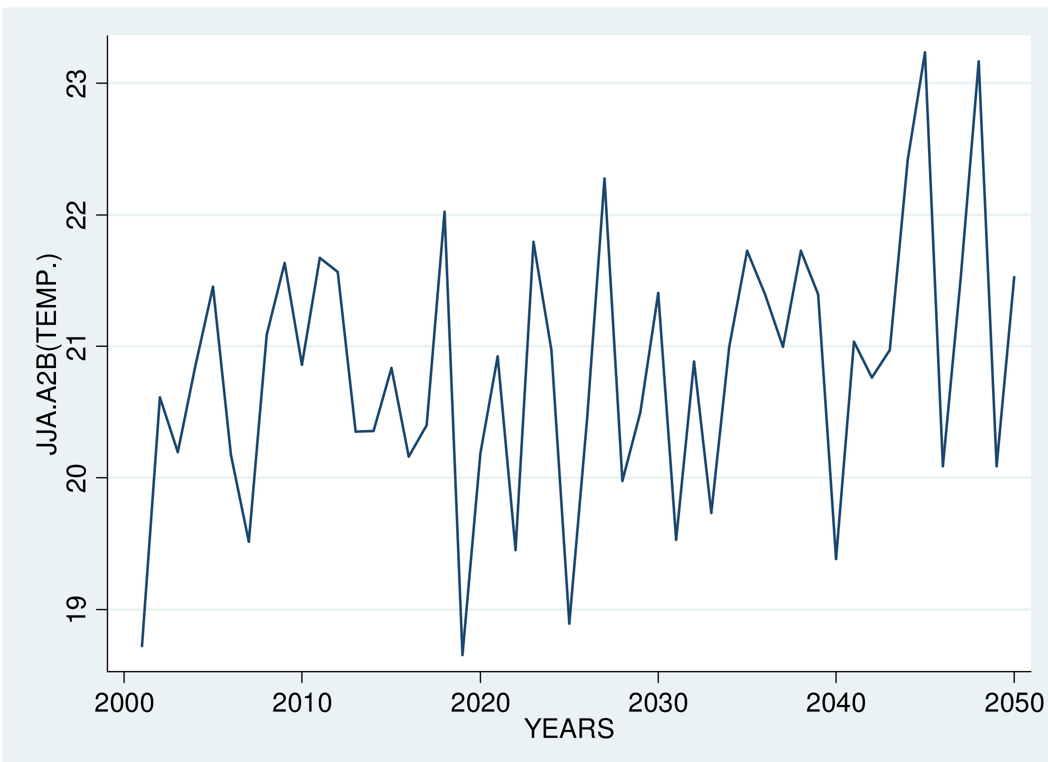


Figure 19: Temporal Characteristics of temperature during JJA season under A2B Scenario

Figures 20 and 21 show spatial characteristics of rainfall during the JJA season by the year 2050 under A1B and A2B scenarios. It can be seen that average Rainfall exhibited an increasing climate variability over the years of study under both scenarios.

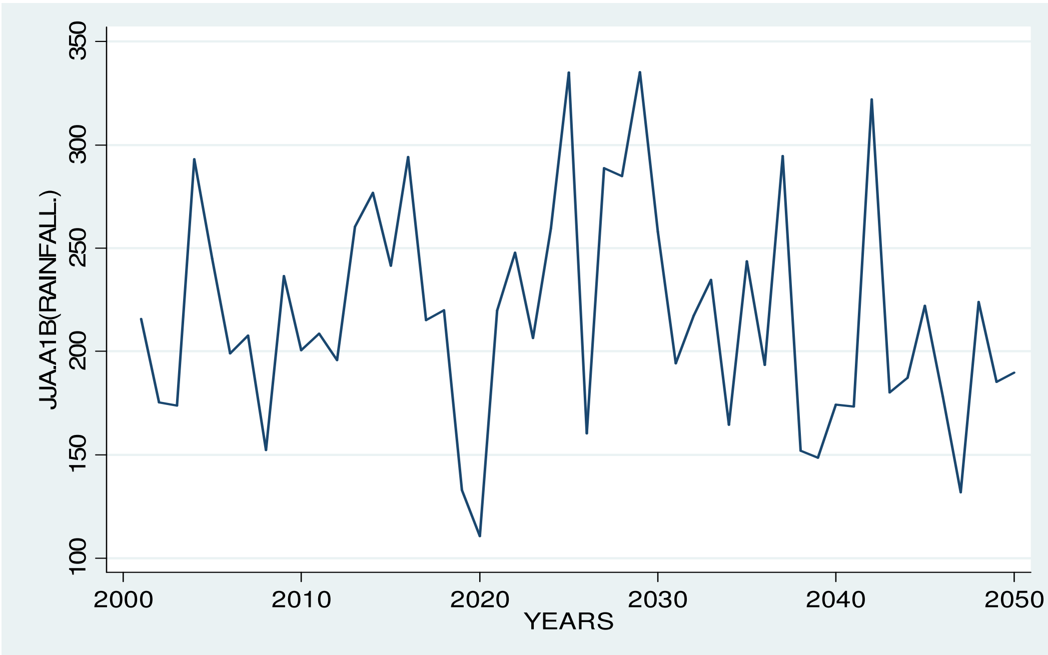


Figure 20: Temporal Characteristics of Rainfall during JJA season under A1B Scenario

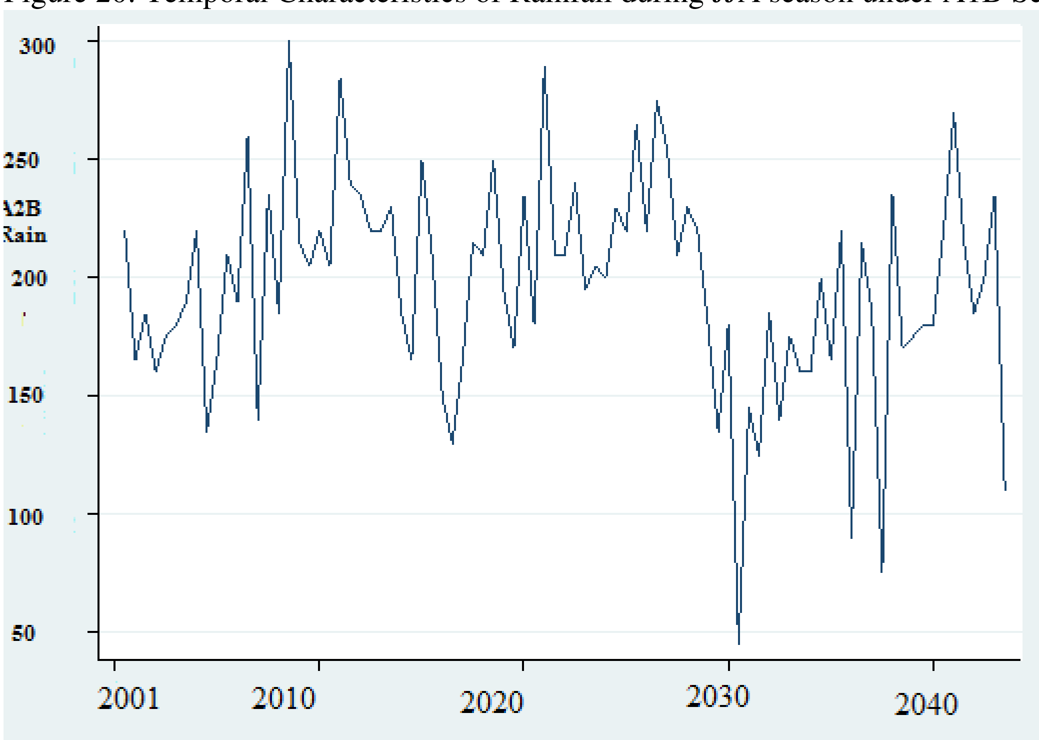


Figure 21: Temporal Characteristics of Rainfall during JJA season under A2B Scenario

The results suggest success in the ability of PRECIS to simulate future climate over the area of study. This is in agreement with studies by Rajib *et.al.*

(2011) who successfully used PRECIS to project climate in Bangladesh; Tadross *et.al*. (2005) who successfully predicted decadal and interannual climate variability in Southern Africa; Sabiiti (2008) who simulated climate scenarios in the Lake Victoria Basin and Rwigi (2014) who used climate projections from PRECIS to drive a hydrological Model over Mau Forest, Kenya.

Conclusions

The study revealed that the area of study will experience average temperatures of up to 22.2 °C and 27.7 °C under A1B and A2B scenarios respectively by the year 2050. However, there will be reduction in average amount of rainfall up to means of 220.6 mm and 160.0 mm under A1B and A2B scenarios respectively. Model validation results indicated that the Model over-estimated Rainfall projections by 50 mm and 10 mm under A1B and A2B respectively. The Model performed well in projecting temperature over the area of study. The Results of the study also revealed a cyclic and seasonal trend in climate variables with increasing temperatures and reducing rainfall across all seasons except during the MAM season that exhibited reducing temperatures and increasing rainfall. The results of this study are vital in providing future climate scenarios for scientists and policy makers while at the same time setting a platform for comprehensive projections over the area of study.

Recommendations

The study recommends further evaluation of the model performance in simulating the present day climate.

Acknowledgement

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