JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR
MASTERS PROGRAM IN HYDRAULIC ENGINEERING

PERFORMANCE EVALUATION OF THE CORDEX AFRICA REGIONAL CLIMATE MODELS IN SIMULATING RAINFALL AND AIR TEMPERATURE THE CASE OF WABI SHEBELE BASIN, ETHIOPIA

BY: SISAY GUTA ALEMU

A thesis Submitted to the School of Graduate Study of Jimma University in partial fulfillments of the requirement for the degree of Masters of Science in Hydraulic engineering

September 2021
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Name of the advisors:

1. Tamene Adugna (PhD)
2. Chala Hailu (MSc.)

September 2021
Jimma, Oromia, Ethiopia

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

SISAY GUTA -------------------------- --------------------------

Candidate Signature Date

This thesis has been submitted for examination with my approval as a university Supervisor.

TAMENE ADUGNA (PhD) ------------------------------ --------------------------

Advisor Signature Date

CHALA HAILU (MSc.) ---------------------------- ---------------------

Co-Advisor Signature Date

ABSTRACT

The impact of the climate change such as an increase in the temperature, and rainfall seasonal shift are observable in the world and particularly in Ethiopia. These changes may affect the socio economic life of the people if it is not assessed and predicted well. Regional Climate Models (RCMs) are mostly used in local scale assessment of climate change. But due to reflection of the inherent and methodological uncertainties in climate modeling, the reliability of individual models needs to be assessed before using their output for impact and climate change assessment. The objective of this study is to evaluate the performance of RCMs under the project of Coordinated Regional Climate Down-Scaling Experiment (CORDEX) African domain under Representative Concentration Pathways (RCP) of 4.5 and 8.5 scenarios. The RACMO22T, CCLM4, RCA4 and, HIRHAM5 models which were driven by ICHEC-EC-EARTH are evaluated against observed rainfall and air temperature data for a period of (1986 to 2005) over the Wabi Shebele basin, Ethiopia. The *statistical measures like Bias, RMSE and, r were used for model performance evaluation. The evaluation is mainly on how best RCMs performed in simulating annual rainfall, maximum, and minimum air temperature over the study area. All models best simulated in dry months. In air temperature simulations, all models under simulated the maximum temperature and overestimated the minimum temperature in most months***.** *Based on statistical result for performance evaluation, monthly cycle, annual and seasonal variability of the RCMs, RCA4 was well performed in both simulating rainfall and air temperature. After the models performance was checked, the best performed model, RCA4 was selected and bias corrected. With the use of Rstudio software wich is high programming language trend was analysised for time series of annual rainfall, maximum and minimum air temperature for observed (1986-2005). Further,the best performed model bias corrected data under both RCP scenarios for a period of 2031-2050 and 2051-2070 years was done. The results of trend analysis indicated that a decrease in annual rainfall and an increasing trend in average maximum and minimum air temperature for selected scenarios over the Wabi Shebele basin. In this regard, RCA4 regional climate models have to be used for any climate change impact study and for local-scale climate projections over the Wabi Shebele basin.*

Keywords: Climate change, CORDEX, Performance, Regional climate models (RCMs), Trend

ACKNOWLEDGEMENTS

First, I would like to thank God almighty from the depths of my heart for endowing me with the courage, strength as well as health throughout my life in general and during my study period in particular for the successful accomplishment of this thesis project.

My gratitude and appreciation also go to my advisor Tamene Adugna (PhD) and co-advisor: Chala Hailu (MSc.) for their general constructive comment and suggestion to implement this thesis. I would like to thanks Jimma institute of technology for granting me free and enjoyable Scholarship to attend master’s program in hydraulic engineering.

Moreover, I wish to express my deepest gratitude to my family and all of my friends for providing strength and motivation to success in my study. Finally, my deepest gratitude and humble thanks go my mother for her never-ending support, encouragement and motivation.

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ACRONYMS AND ABBREVIATIONS

AR5	Fifth Assessment Report
Arc GIS	Aeronautical Reconnaissance Coverage Geographic Information Systems
CH4	Methane
CLM	Climate Limited-Area Modelling
CMhyd	Climate model for Hydrologic Modelling
CMIP5	Coupled Model Inter Comparison Project Phase 5
CORDEX	Coordinated Regional Climate Down-Scaling Experiment
CRCM5	Fifth-Generation Canadian Regional Climate Model
CV	Coefficient of Variation
DEM	Digital Elevation Model
DM	Distribution Mapping
DNI	Denmark
ESGF	Earth System Grid Federation
GCM	Global Climate Model
GEM	Global Environment Model
GHGs	Green House Gases
HIRHAM5	High-resolution Hamburg climate model 5
IDE	Integrated Development Environment
IPCC	Intergovernmental Panel on Climate Change
LS	Linear Scaling
MAB	Mean Absolute Bias
MK	Man Kendall
MPI	Model Performance Index
MPIM	Max-Planck Institute for Meteorology
NMA	National Metrology Agency
PCI	Precipitation Concentration Index
PT	Power Transformation
QM	Quantile Mapping
RACMO	Regional Atmospheric Climate Model
RCA4	Ross by Centre Regional Atmospheric Climate Model

RCM	Regional Climate Model
RCPs	Representative Concentration Pathways
RegCM3	Regional Climate Model Version 3
RMSE	Root Mean Squared Error
S	Mann-Kendal statics
SST	Sea Surface Temperature
VARI	Variance Scaling
WAM	West African Monsoon
WCRP	World Climate Research Program
WMO	World Metrological Organization
Z	Standardized test statics

1. INTRODUCTION

1.1 Background

The climate-change impact is associated with global warming. The global warming is due to an increase in greenhouse gases (GHG) emissions and has been given ample attention worldwide. In the last recent decades, climate change caused severe impacts on the natural and human systems around all continents and oceans (Pachauri *et al*., 2014). These impacts are due to observed climate change, indicating the sensitivity of natural and human systems to climate change. Impact evidence from the observed climate change is strongest and most comprehensive for the natural system (Parry *et al*., 2007). The continued emissions of greenhouse gases would cause more warming and long-term changes in all components of the climate system. Climate change is expected to have a severe effect on the population of developing countries like Ethiopia. Most of the population in developing countries depend on agriculture for their income, have a high percentage of the impoverished rural population who mostly rely on agriculture and financially and technically least equipped to adapt to changing conditions (Conway and Schipper, 2011).

Climate models are important tools for understanding and predicting the complex Earth's climate (Kamworapan and Surussavadee, 2019). Several Global Climate Models (GCMs) have been developed by several research centers around the world. The GCMs are designed to simulate the earth's climate over the entire planet, however, its limitations are when it comes to describing local details of climate features owing to their coarse spatial resolution. The need for climate change information at the regional-to-local scale is one of the central issues within the global change debate. Such information is necessary to assess the impacts of climate change on human and natural systems and to develop suitable adaptation and mitigation strategies at the national level. Therefore, information suitable for local-scale impact assessment (e.g. river flood or crop production), is further downscaled by employing high-resolution Regional Climate Models (RCMs) from GCMs which can better resolve small-scale features such as topography and heterogeneous land use (Dosio., 2018).

The coarse resolution prohibits global models from providing an accurate description of extreme events concerning the regional and local impacts of climate variability and change (Dibaba *et al.*, 2019). Therefore, downscaling of the climate from the coarse resolution GCMs to regional scale for the computation of the local details to obtain the relevant temporal-spatial pertinent for climate change studies is required. Coordinated Regional Climate Down-Scaling Experiment (CORDEX) is highly used to analyze the impact study all over the world. The CORDEX essentially has a twofold purpose to provide a framework to evaluate and benchmark model performance (model evaluation framework); and design a set of experiments to produce climate projections for use in impact and adaptation studies (Giorgi *et al*., 2009). CORDEX Africa domains are used to provide RCMs over Africa. Output from the CORDEX-Africa domain has been used for impact studies especially over Africa (Giorgi *et al*., 2009; Endris *et al*., 2013). Hence, communication between climate modeling and impact assessment is essential.

Before using climate simulation data from the RCMs, evaluation through comparisons of model results with observations data are very important. This helps to assess the ability of the RCMs to simulate climate conditions at particular locations and quantification of uncertainties in climate models simulations for use in climate change impact studies and policy decisions at different locations (Luhunga *et al*., 2016). Further, for various reasons, the impact and climate simulation modelers may not be able to consider the full ensemble; rather they need to select several simulations runs. Since the launch of the CORDEX Africa program, a few studies have evaluated the RCM performance over parts of the continent, including Africa. (Luhunga *et al*., 2016) evaluated the performance of the CORDEX RCMs in simulating minimum and maximum air temperature and rainfall over Tanzania. They evaluated CORDEX RCMs against observed station data that are scattered over complex topographical terrain. They found that CORDEX RCMs perform differently in simulating rainfall over different regions in Tanzania.

Previous work about RCMs in Ethiopia examined the performance of multimodal numerical simulations and multi observational databases focusing on seasonal cycles and spatial variations of precipitation over Ethiopia change (Dibaba *et al.*, 2019). Most of the studies used globally available gridded data sets and satellite-based data sets as a reference to evaluate the CORDEX-Africa RCMs output. Besides, some of the studies are based on a single parameter to represent the overall model performance. All the RCMs are not found to be equally important in all regions. The study on the performance of the RCMs in Africa and Ethiopia shows that the performance of the RCMs are varies based on the topography of the watershed and climatic conditions. Hence, this study is aimed to evaluate the performance of the RCMs in simulating air temperature and rainfall over Southeast Ethiopia, Wabi shebele basin, where the topography and climate conditions highly vary.

The study further considered the RCMs rainfall and air temperature trend. Multiple models are considered for this study. The selection of multiple models is preferable than a single to give enough judgment for a further study impact study. The ICHEC-EC-EARTH driver under the African CORDEX projection has numbers of RCMs that widely performed well in multiple studies in Africa and but were not checked for performance in Wabi Shebele basin. Hence, this study attempted to evaluate the performance of four RCMs driven by ICHEC-EC-EARTH CORDEX Africa namely RACMO22T, CCLM4-18-17, RCA4, and HIRHAM5 in simulating rainfall and air temperature over Wabi shebele basin. The output from this study will be used for climate change impact assessment on hydrology and water resources management over Wabi Shebele basin.

1.2. Statement of the problems

Impacts of climate variability and change are increasingly becoming a challenge in tackling food and water security problems worldwide. Intense research during recent decades concluded that the increase in the atmospheric greenhouse gas concentration due to anthropogenic emissions has begun altering the global climate (IPCC 2013, 2014). As the ongoing climate change has been confirmed, assessing its impact on regionally important sectors has become a major concern, especially for policy makers who develop action plans to mitigate and adapt to the impacts of future climate change. For this purpose, regional climate models (RCMs) data are essential.

There is immense public concern on unpredictable or extreme weather and climate-induced events, and keen interest is in the dynamic behavior of such events (Langat *et al*., 2017) in the coming decades. Therefore, understanding climatic historical changes are necessary for the optimization of water resources and food production.

Farmers in the Horn of Africa, including Ethiopia, are frequently vulnerable to climate change extremes such as floods and droughts. The economy of these contries are highly bases on rain-fed agriculture, which is highly vulnerable to the impacts of climate change, mainly changes in rainfall patterns (Jilo *et al.*, 2019). In Ethiopia, particularly in the Wabi Shebele basin, the day to day activities of the people are highly based on agricultural product and it is vulnerable to minor intensifying climate change impact.

This basin is among the most vulnerable areas due to uncertain water availability, climate change, and the frequency of extreme conditions, which result in a more frequent hydrologic disaster, such as floods and droughts (MWAR –LAC, 2016).

On the other hand, the basin has a large land area for irrigation development and massive biomass production, which make it one of the growth and development corridors in the Growth and Transformation Plan (GTP) of the country

A regional climate model (RCM) was used to advance the predictive model of the Earth's climate in the scientific analysis of the dominant sets of the governing processes. Hence, the evaluation of best performing RCMs at a local scale in simulating rainfall and temperature variable is very important. It is expected that future climate change may exacerbate the level of water stress or increase the water resource across the river basin and it is, therefore, important to assess and check the ability of RCMs to forecast future climate trends and to get detail, reliable information for running future water resource development. The performance of RCMs were varies based on the land features and so checking more models and selecting the best one is preferable. The well-performed RCMs datasets are important means of obtaining information on the temporal patterns of rainfall and air temperature time series for climatological and hydrological applications. Some of the important information obtained from climate models are Hydrological modeling, climate variability, water resources planning, and management for various uses including agricultural production, environmental flows, and engineering designs.

1.3 Objective

1.3.1 General objective

The main objective of this study was to evaluate the performance of CORDEX African domain regional climate models in simulating rainfall and air temperature over the Wabi Shebele basin.

1.3.2 Specific objectives

Specific objectives of this study were:

1. To evaluate the performance of CORDEX African domain regional climate models in simulating rainfall and air temperature in the Wabi shebele basin
2. To analyze the mean monthly cycle and annual variability of rainfall and air temperature over the study area
3. To analyze the trend of annual rainfall and air temperature over the Wabi shebele basin.

1.4 Research questions

1. What is the performance of RCMs under CORDEX African domain well performed over Wabi shebele basin in simulating rainfall and air temperature?
2. Is there the monthly cycle and annual variability of the rainfall and air temperature over the Wabi shebele basin?
3. What are the annual rainfall and air temperature trend look like?

1.5 Significance of the study

The output of this study will be used as an input for climate change impact assessment in agriculture, health, and economy, which in turn could be used to formulate appropriate policies, design effective evaluation, and development programs. It could also be a good input at times for planning future watershed management strategies. The study further will be used at the local level to increase understanding of economical, societal, and environmental implications of land-use change in the face of a changing climate. The more performance check will help the water resources planner as easily select the best-performed models for further water resources management.

1.6 Scope of the study

The study was focused on the Wabi Shebele basin to evaluate the performance of the RCMs. The study was not compared all the available RCMs but only the more commonly used and performed over Africa. Four RCMs were driven by ICHEC-EARTH for historical, RCP4.5, and RCP8.5 scenarios selected. The observed data at stations within the basin from 1986-2005 were used to evaluate the performance of simulated RCMs and to bias correct. This paper also presented the monthly cycle of rainfall and air temperature between observed and simulated data. Furthermore, the study estimated variability and trends of air temperature and rainfall, which is essential for the design, operation, and management of water resources projects which are prerequisites parameters for climate impact assessment especially in rain-fed agricultural areas prone to water deficits.

2. LITERATURE REVIEW

2.1 Climate change and Global Warming

Climate change is described as a long-term substantial change in the normal weather patterns of a particular region, state, or zone over a sufficiently long period. Climate change is becoming a major environmental concern because increasing scientific evidence shows the high concentration of greenhouse gases (GHGs) in the atmosphere, and frequent hydro meteorological extreme events are becoming the 21st-century phenomenon (Jilo *et al.*, 2019). Greenhouse gases cause the warming of the world because these gases particles absorb outgoing, long-wave radiation, and therefore less radiation is lost to space. The global climate has varied significantly since the last deglaciation period and main changes in climate happened at almost the same time all over the world (Nigeria., 2019).

African countries because of their dependence on agriculture and their lower financial, technological, and institutional capacity to respond are more affected by climate change. Sub-Saharan Africa has been portrayed as the most vulnerable region to the impacts of global climate change because it relied on agriculture, which is highly sensitive to weather and climate variables such as temperature, rainfall, and light and extreme events, and low capacity for adaptation. Annual rainfall in most of North Africa and Northern Sahara is expected to decline, while winter rainfall in most of Southern Africa is expected to fall (Kotir and Sustainability, 2011).

There will likely be an increase in annual mean rainfall in tropical and East (Hirpa *et al.*, 2019). Ethiopia is among those countries most face climate risks in Africa. Consequently, agricultural and livestock production, people's livelihoods, and food security depend strongly on weather conditions mainly on rainfall patterns such as magnitude and timing. Hence, the largest proportion of Ethiopia's population is very vulnerable to climate change. Hence, understanding the availability of potential water supplies in this area, as well as studies that offer insights into climate change and its effects on hydrology is important.

2.2 Climate Change Scenarios

Climate scenarios are plausible representations of future climate conditions (temperature, precipitation and other climatological phenomena). These scenarios provide plausibly descriptions of how the future might unfold in several key areas socioeconomic, technological and environmental conditions, emissions of greenhouse gases and aerosols, and climate (Moss., 2010).

When applied in climate change research, scenarios help to evaluate uncertainty about human contributions to climate change and the response of the Earth system to human activities. Emissions scenarios are descriptions of potential future discharges to the atmosphere of substances that affect the Earth‘s radiation balance, such as greenhouse gases and aerosols (Bjornaes., 2015). Along with information on other related conditions such as land use and land cover, emissions scenarios provide inputs to climate models and aerosols.

The words concentration pathway are meant to emphasize that these RCPs are not the final new, fully integrated scenarios. A new set of scenarios, the Representative Concentration Pathways (RCPs), are used for the new climate model simulations carried out under the framework of the Coupled Model Inter comparison Project Phase 5 (CMIP5) of the World Climate Research Program. Four RCPs pathways are named according to radiative forcing levels of 8.5, 6, 4.5, and 2.6 W/m2, by the end of 2100. RCP 2.6 is likely to keep global temperature rise below 2 °C by 2100. Hence, climate projections over the 21st century are performed using the IPCC RCP4.5 and RCP8.5 scenarios, developed in the framework of the CMIP5.

In all RCPs, atmospheric CO2 concentrations are higher in 2100 relative to the present day as a result of a further increase of cumulative emissions of CO_2 to the atmosphere during the 21st century (IPCC, 2013). The RCP spans a range of radiative forcing from 2.6 to 8.5 W/m_2 and represents various possible climate outcomes

RCP8.5: High Emissions; This RCP is consistent with a future with no policy changes to reduce emissions. Compared to the total set of Representative Concentration Pathways (RCPs), RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions (Riahi *et al*., 2011)

RCP6: Intermediate Emissions; The national institute develops intermediate emission this RCP for Environmental Studies in Japan. Radiative forcing is stabilized shortly after the year 2100, which is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions.

RCP4.5: Intermediate Emissions; The Pacific Northwest National Laboratory in the US develops this RCP. Here radiative forcing is stabilized shortly after the year 2100, consistent with a future with relatively ambitious emissions reductions.

RCP2.6: Low Emissions; This RCP is developed by Netherlands Environmental Assessment Agency. Here radiative forcing reaches 3.0 W/m2 before it returns to 2.6 W/m2 by 2100. To reach such forcing levels, ambitious greenhouse gas emissions reductions would be required over time.

2.3 Climate Model

2.3.1 Global Climate Models (GCM)

Numerical models (General Circulation Models or GCMs), representing physical processes in the atmosphere, ocean, cryosphere, and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. Global climate models (GCMs) are complex, computer-based, mathematical representations of the Earth‘s climate based on fundamental scientific principles. Many different climate processes are represented in the global climate models (Pachauri *et al*., 2014). Precipitation, wind, cloudiness, the ocean currents, air and water temperatures, the amount and type of vegetation, the concentration of greenhouse gases (GHGs) and atmospheric aerosols (fine particles), and other global climate models are the principal tools used by climate scientists to quantitatively explore potential future climates, globally and regionally. GCMs are the most popular instruments used to forecast climate change.

A systematic comparison of near-surface temperature and precipitation simulated by the regional and the global model is done (Teichmann *et al.*, 2013). In general, the historical time is well represented by the GCM and the RCM. Some different biases occur in the RCM compared to the GCM as in the Amazon Basin, northern Africa, and the West Asian domain.Their confirmation with measurements from the twentieth century has shown that they are capable of simulating the Earth's simple climate characteristics (Sen., 2013). However, owing to the inherent uncertainty of GCMs, they still suffer from spatial and temporal differences in their climate outputs, particularly in precipitation.

since GCMs typically have a poor spatial resolution (Mehr *et al*., 2017), they are unable to address substantial catchment-scale features such as topography and land use, which are needed for hydrologic modeling and impact assessment. One way to make an informed decision associated with a specific region is to obtain fine-scale regional information (i.e. downscaling) using one or more regional climate models (RCMs) that take boundary conditions from different GCM.

The climate data of high-resolution regional climate models of CORDEX-Africa (Coordinated Regional Climate Downscaling Experiment (Giorgi *et al*., 2009) obtained from CORDEX-Africa database website. the driving model or GCMs are selected depending on the performance evaluation of Regional Climate Model output. Accordingly, the ICHEC driving model is selected for this study to evaluate the performance of RCMs.

2.3.2 Regional climate models (RCM)

The daily large-scale RCM predictors from regional climate model REMO developed at the Max-Planck Institute for Meteorology (MPIM) in Hamburg, Germany was used to simulating future climate changes. Downscaled rainfall and temperature (minimum and maximum) projected climate data for the period 1951-2100 were obtained from the CORDEX-Africa database at a spatial resolution of 55 km ($0.44^{o}\times0.44^{o}$) for the RCP4.5 scenario (Kahsay *et al*., 2018). To obtain climate change information suitable for local-scale impact assessment (e.g. river flood or crop production), the output from global climate models (GCMS, whose spatial resolution may be too coarse) is further downscaled by employing high-resolution regional climate models (RCMs.) which can better resolve small-scale features such as topography and heterogeneous land use (Dosio., 2018).

According to (Hernández-Díaz, Laprise, et al. 2013) new fifth-generation Canadian Regional Climate Model (CRCM5) has been applied to CORDEX-Africa, which appears a good opportunity to study the model performance in simulating the key elements of the African climate, including the west African monsoon (WAM).

The first realization of the MPI-ESM historical experiment and the RCP 2.6, RCP 4.5, and RCP 8.5 experiments are downscaled with REMO to the CORDEX domains for Africa, Europe, South America, and West Asia (Teichmann *et al*., 2013). CRCM5 uses the dynamical core and several subgrade-scale physical parameterization modules of the Canadian Global Environment Multiscale (GEM) model and The CORDEX program with Africa as its main target region provided the impetus for testing the new, fifth-generation Canadian Regional Climate Model (CRCM5) outside its ‘‘native’’ region, as recommended by the World Climate Research Program.

2.4 Coordinated Regional Downscaling Experiment (CORDEX)

The coordinated regional climate downscaling experiment (CORDEX) is a program sponsored by the World Climate Research Program (WCRP) that aims to lead an international coordinated framework to develop an improved projection of climate change at the regional scale (Nengker *et al.*, 2018). This program is initiated to study the regional climate change scenarios globally. Down scaling is the method of post-processing native-scale global climate model (GCM) effects of global climate responses to modifying global atmospheric structure with additional statistical or dynamical simulations to produce a series of results at a finer spatial scale that is more significant in the form of local and regional impacts.

The vision of the Co-Ordinated Regional Climate Downscaling Experiment (CORDEX) is to advance and coordinate the science and application of regional climate downscaling through global partnerships. There are a total of fourteen official CORDEX domains.World Climate Research Program (WCRP) has initiated the Global Coordinated Regional Down-scaling Experiment(Giorgi *et al*., 2009) aims to create a framework for evaluating and comparing the range of dynamical and statistical RCD techniques in use around the world.

The general aim of CORDEX is, for a range of limited-area regions, to downscale several GCM climate scenarios/predictions derived from the CMIP5 set of integrations: to produce an ensemble of high-resolution climate change projections by down-scaling GCM simulations from Coupled Model Inter-comparison Project Phase 5 (CMIP5) data archive (Taylor *et al*., 2012) on 25Km and 50Km grid spacing for 14 regions of the Globe. Africa was selected as the first target region.

CORDEX-Africa RCMs generate an ensemble of high-resolution historical and future climate projections at a regional scale by down-scaling different GCMs forced by RCPs based on the Coupled Inter-comparison Project Phase 5 (CMIP5). In the Recent study, results of CORDEX-Africa ensemble RCMs simulations for the historical (1951–2005) and future (2006–2100) climate projections downscaled from different GCMs under RCP2.6, RCP4.5, and RCP8.5 with a spatial resolution of 0.44 (50km) is used.

Output from the CORDEX-Africa domain has been used for impact studies especially over Africa such as one carried out by (Endris *et al.*, 2013). They evaluate the ability of 10 regional climate models (RCMs) from the Coordinated Regional Climate Downscaling Experiment (CORDEX) in simulating the characteristics of rainfall patterns over eastern Africa. They adopted two general criteria to assess the ability of CORDEX RCMs to simulate East African rainfall.

After standardization and curation, CORDEX simulations are archived in a distributed database of Earth System Grid Federation (ESGF). Standardization and archiving, on the other hand, take time and some simulations are only accessible from local suppliers (modeling centers). To keep users updated about current simulations, the CORDEX SAT receives inventories from both ESGF and local suppliers daily and makes them available on the CORDEX web page. The first criterion assesses the ability of the RCMs to reproduce the rainfall climatology. The second criterion assesses the ability of the RCMs to capture the inter-annual rainfall variability and tele connection signals.

To assess the consistency of the models in representing the spatial distribution of rainfall with time, spatial correlation between observed and simulated rainfall is computed for each year. The study carried out in southern Africa on extreme rainfall events and future climate, found out that the simulated climate output correlates well with the observation of station data, Among, the four RCP (RCP2.6, RCP4.5, RCP6, and RCP8.5) only the RCP6 is not used in the study because the characteristics of RCP6 is more or less similar with that of RCP4.5 as in both cases they are stabilizing scenario.

2.5 Performance Evaluation criteria

This literature review demonstrated that the scientific community cannot agree on how to assess the best-performing climate models. What success metrics are used is up to the researchers. The efficiency of GCM-RCM combinations in terms of precipitation realization is examined in most researches by using five measurements comprising (i) scatter plots of simulation/observation, (ii) bias (simulation– observation), (iii) mean absolute bias (MAB), (iv) root mean squared error (RMSE), and (v) model performance index (MPI). The first four measurements are only used to describe individual climatic data, while the last (MPI) is used to represent the model's overall performance.

The scatter map, bias, MAB, and RMSE concepts and mathematical expressions are well known in a variety of model success studies (Mehr *et al.,* 2017). The MPI is an overall performance evaluation index, which measures the reliability of a model based on the scaled normalized error variance (I^2) of a broad range of climate variables (v)

2.5.1 Bias correction for RCM

Despite RCM models' high-resolution data, operational errors during the first data correction are a disadvantage. Bias will arise as a result of theoretical and practical flaws, which can be resolved using bias correction techniques. Under the assumption of a stationary error model, the bias is then used to update the climate models for the control time (Rojas *et al*., 2011). Validation against E-OBS climatology in the control period demonstrates that the correction process removes bias in average and extreme statistics important for flood modeling across the majority of the European domain in all seasons. corrected RCM simulations will perfectly agree in their monthly mean values with the observations (Teutschbein and Seibert, 2012).

The following are some basic methods for bias correction of temperature and precipitation in downscaling RCM simulations, five typical precipitation correction methods, and three temperature correction methods. Linear scaling (LS), local intensity scaling (LOCI), power transformation (PT), distribution mapping (DM), and quantile mapping (QM) are used to correct precipitation, while LS, variance scaling (VARI), and DM are used to correct temperature. Before being used as meteorological inputs to a distributed hydrologic model to analyze their impacts and performance, the adjusted precipitation and temperature were compared to observed meteorological data.

In this study, the CMhyd tool was used for bias correction of air temperature and rainfall based on the station's latitude and longitude. All the above methods are packaged in the tool and easily extract and correct model data with the observed one. Bias correction procedures employ a transformation algorithm for adjusting RCM output. The the underlying idea is the identification of possible biases between observed and simulated climate variables, which is the basis for correcting both control and scenario RCM runs. Bias correction methods are assumed stationary, i.e., the correction algorithm and its parameterization for current climate conditions are also valid for future conditions.

2.5.2 RCM Performance Evaluation by Simulating Climate variable

The annual cycle of rainfall, area-averaged for each region, is computed for both observed and simulated data to determine how well the RCMs capture rainfall seasonality in the respective regions. Globally, there has been a marked increase in the number of RCM simulations. However, finding from different researches indicated that only a few of them are participating in a simulation of the African climate domain regardless of their reliability. Assessment on the performance of CORDEX regional climate models in simulating East African rainfall indicated that only four RCMs (CRCMP5, RACMO, RegCM3, RCA4) among the ten models of CORDEX-Africa captured the shape of the monthly rainfall distribution and the annual rainfall anomaly with high spatial correlations together with consistency in reproducing spatial patterns of rainfall. However, they overestimated the mean monthly rainfall amount of Jun- September (Endris *et al*., 2013). The performance of the CORDEX rainfall simulations is statistically based and includes Bias, Root Mean Squared Error (RMSE), Correlation coefficient, and Coefficient of Variation (CV) of the models.

3. MATERIALS AND METHODS

3.1 Description of the study area

Ethiopia has 12 river basins of which Wabi Shebele is one of them. It is a transboundary river basin shared by Ethiopia and Somalia. It is originated from the high plateau of eastern Ethiopia. The river basin lies between 4°45’ N to 9° 45’N latitude and 38°45’E to 45° 30’E longitude. The basin is spread over three regional states namely; the Oromia region in the North West part of the basin, the Somali Region in the south East, and the Harari region fully in the middle of the basin. Oromia and Somali regional states cover about 38% and 60% of the basin area respectively. It rises about 4000 meters above sea level in the Bale mountain ranges of the Galama and Ahmar and drains into the Indian Ocean through Somalia. About 72% of the catchment is lying in Ethiopia (Abebe and Foerch 2006). The location of the study area was shown in figure 3.1

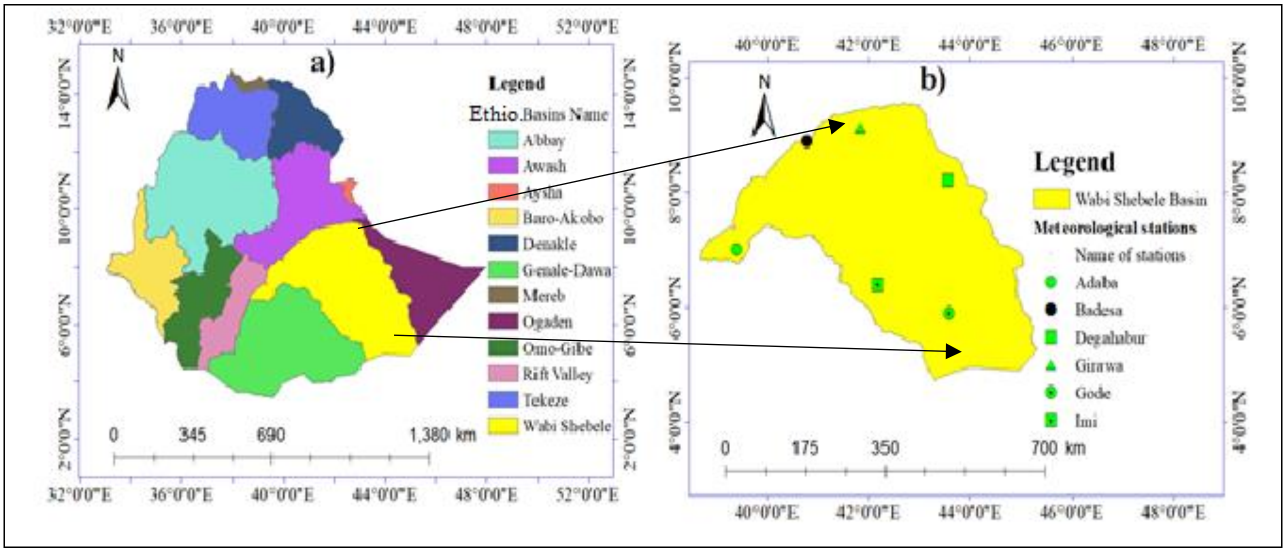


Figure 3.1 Location of the study area

Table 3.1 List of meteorological stations in the study area

stations	Latitude	Longitude	Elevation (m)
Adaba	7.01667	39.4	3420
Badesa	8.90833	40.7712	1703
Girawa	9.1333	41.833	2100
Degahabur	8.217	43.55	1070
Gode	5.9	43.58	290
Imi	6.4007	42.187	492

3.2 Climate of Wabi shebele basin

For the past four decades, the average annual temperature in Ethiopia has been increasing by $0.37C^0$ every ten years, in case it is slightly lower than the average global temperature rising (Emerta., 2013). According to Emerta, the greater part of the temperature rise was observed during the second half of the 1990s and temperature rise is more pronounced in the dry and hot spots of the country, which are located in the northern, northeastern, and eastern parts of the country. The lowland areas are the most affected, as these areas are largely dry and exposed to flooding during extreme precipitation in the highlands. Future temperature projections of the IPCC mid-range scenario show that the mean annual temperature will increase in the range of 0.9 to 1.1ºC by 2030, in the range of 1.7 to 2.1ºC by 2050, and in the range of 2.7 to 3.4ºC by 2080 in Ethiopia compared to 1961 to 1990 (Emerta., 2013). However, the country has had both dry and wet periods over the past four decades. Precipitation has been a general decreasing trend since the 1990s (Abayneh., 2011).

The decrease in precipitation has multiple effects on water availability for irrigation and other farming uses, especially in the north, northeastern, and eastern lowlands of the country. The average change in rainfall is projected to be in the range of 1.4 to 4.5 percent, 3.1 to 8.4 percent, and 5.1 to 13.8 percent over 20, 30, and 50 years, respectively, compared to 1961 to 1990 usual. Accordingly, the overall trend in the entire country is more or less constant. Related to rainfall and temperature change and variability, there were recurrent draught and flood events in the country.

There was also observation of water level rise and dry up of lakes in some parts of the country depending on the general trend of the temperature and rainfall pattern of the regions. Some literature stated that a possible correlation with climate change needs to be considered a given the air temperature that varies with altitude in the Wabi Shebele basin.

The climate of the Wabi Shebele basin is dependent on the basin altitude. The highland areas are cool and suitable for people settlement while the lowland areas are arid and not suitable for settlement (Adane., 2009). The rainfall amount within the Wabi Shebele basin ranges from 200 mm on the arid part of the basin to 1250 mm towards the upper part of the basin. The major reason for the variability of the rainfall amount is the difference in altitude. Figure 3.2 indicated the digital elevation model classification of the basin for traditional climate zone.

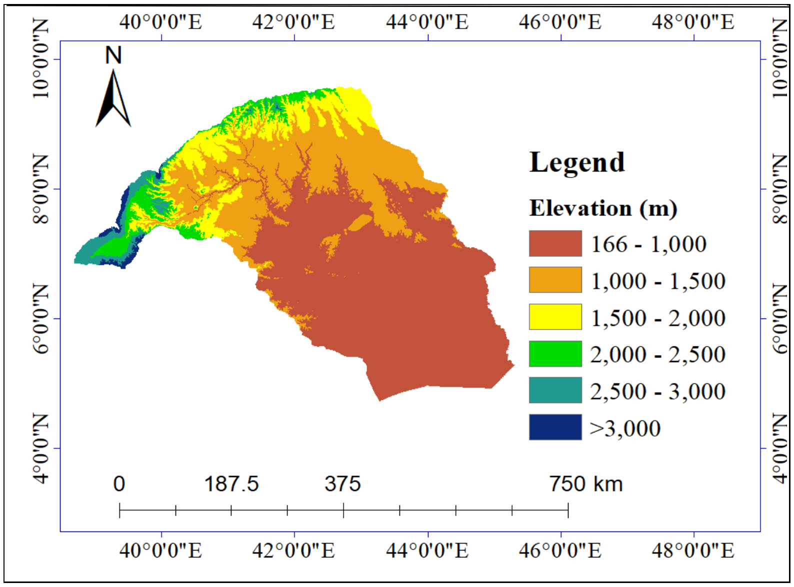


Figure 3.2 DEM classification over the study area

Table 3.2 Traditional climate zones and their characteristics as adopted partially from Negash and Ermias (1995) and NEDECO (1997)

Altitude (m a.s.l.)	Mean temperature (◦C)	Traditional Climate zone	Interpretation for the traditional climate zones
1000–1500	24–27	Kolla	Hot
1500–2000	21.5–24	Weina Kolla	Warm
2000–2500	15–21.5	Weina dega	Tepid
2500–3000	11.5–15	Dega	Cool
>3000	<11.5	Wurch	Very cool

Based on altitude and mean temperature for traditional climate zone interpretation, the climate around Degahabur, Gode, and Imi are Kolla (hot) while climates around Adaba, Badesa, and Girawa are Wurch (very cool), Weina kola (warm), and Weina Dega (Tepid) respectively (Table 3.2). The distribution of stations over different climate zone played a great role in the performance evaluation of RCMs specifically on a local scale.

3.2 Data type used

3.2.1 Observed data

The performance evaluation of the RCMs model simulation need observed or reference data. Full datasets with no holes or complete data are needed for climate analysis. The meteorological rainfall and air temperature data were obtained from the meteorological station regularly. The data was collected from the National Meteorological Service Agency (NMSA) of Ethiopia for 12 stations located around the watershed for the available period of records. However, out of the 12 stations, 6 of them were found to have relatively better-recorded data (Figure 3.1). Observed rainfall and air temperature data collected from NMSA to verify the potential of RCM by measuring Variability, cycle, and trend analysis in this study.

3.2.2 CORDEX- RCMs data

For future and current climate projections, data from the Coordinated Regional Climate Downscaling Experiment (CORDEX) is used. CORDEX is an international effort supported by the World Climate Research Program (WCRP) that aims to provide a series of climate change forecasts for various regions of the world using multiple RCMs and multiple pollution scenarios. These regional climate projections were based on (CMIP5) projects. There are about 10 RCM participants over the African domain.

The rainfall and air temperature CORDEX African data for this study were downloaded from the earth system grid federation infrastructure (ESGF). The ESGF home website is freely available at (https://esgf node.llnl.gov/projects/esgf-llnl) server. Both rainfall and air temperature data were downloaded from the RCMs such as; RACMO22T, HIRHAMS, CCLM4-18-17, and RCA4 models derived by (ICHE EARTH-EC CORDEX Africa) (Table 3.3). The data were based on the Representative Concentration Pathways (RCPs), RCP8.5, and RCP4.5 scenarios for future period analysis. The spatial grid resolutions of all CORDEX Africa RCMs are set to longitude 0.44° and latitude 0.44° using a rotated pole system coordinate (Luhunga *et al*., 2018)

Table 1.3 List of CORDEX – RCMs were used

No.	RCM	Model center	Short name of RCM
1	CLMcom COSMO CLM (CCLM4)	Climate Limited-Area Modelling (CLM) Community	CCLM4-18-17
2	DMI HIRHAM5	Danmarks Meteorologiske Institut (DMI), Danmark	HIRHAM5
3	SMHI Ross by Center Regional Atmospheric Model (RCA4)	Sveriges Meteorologiska och Hydrologiska Institut (SMHI), Sweden	RCA4
4	KNMI Regional Atmospheric Climate Model, version 2.2 (RACMO22T)	Koninklijk Nederlands Meteorologisch Instituute (KNMI), Netherlands	RACMO22T

3.3 Bias correction of RCM data

The downloaded data were in NetCDF file format and extracted by a tool called CMhyd. It is designed to work with the CORDEX data archive, which provides downscaled regional climate model data (Geleta and Gobosho 2018). It is also used to correct the bias of climate change models minimum and maximum temperature simulation for a historical and future period of analysis under both RCP4.5 and RCP8.5 scenarios.

The rainfall, maximum and minimum air temperature obtained from four RCMs were bias-corrected with observed data of Wabi shebele, and overlapped ones are taken for evaluation of the trend of the models. CMhyd tool has the potential for bias correction and extracts regional Climate model data of study area for increase quality and relevance of data. It is a statistical downscaling tool developed to extract data of global and regional climate models and perform bias-correction over data (Rathjens et al., 2016).

This tool includes numerous approaches for temperature and precipitation bias correction methods. Those are; linear scaling (multiplicative), Linear scaling (additive), Delta-change correction (multiplicative), Delta-change correction (Additive), Precipitation Local intensity scaling, power transformation of precipitation, and variance scaling of temperature and distribution mapping of temperature and precipitation.

Teutschbein and Seibert have provided a full review of the bias correction techniques. According to Teutschbein and Seibert, all the bias correction techniques in the CMhyd tool have improved the simulation of rainfall and temperature. Most methods were able to bias correct daily mean values to a certain extent, while only higher-skill approaches, such as power transformers and linear scaling methods, performed well in hydrological extremes (Luo et al., 2018). Therefore, for this study, temperature data was extracted by linear scaling (multiplicative) bias correction method in CMhyd tool, while rainfall was by power transformation of precipitation bias correction method.

3.3.1 Performance RCM data

The performance of the different methods depends on the type of bias of the model, and the investigated statistics. The atmosphere, ocean, soil, and sea surface temperature (SST) conditions were used to establish the historical simulations of the ICHE EARTH-EC model, which were then forced by observed natural and anthropogenic CO_2 and aerosol concentrations (Taylor *et al.*, 2012). There were criteria used to measure performance of climate models in simulating rainfall of the study area. The first criterion assesses the ability of the RCMs to reproduce the rainfall climatology and characteristic of rainfall events. This criterion compared the magnitude of mean annual and seasonal rainfall, mean monthly rainfall pattern, distribution and frequency of rainfall events and return period of RCMs outputs to that of the observed data (Worku et al .,2018). The others evaluation uses statistical metrics, including BIAS, Root Mean Squared Error (RMSE) and Correlation Coefficient (Correl) between areal averaged rainfall of RCMs and observation.

To assess the RCMs performance in simulating rainfall and air temperature, the mean Bias (BIAS), the Root Means Square Error (RMSE), and Pearson Correlation (r) were used severly time **(**Dibaba *et al*., 2019, Demissie and Sime 2021). The smaller the absolute value of RMSE and Bias shows the better performance of the model and vice versa. The value of r ranges from (-1 to 1). -1 for A perfect downhill (negative) linear relationship and 1 for A perfect uphill linear relationship between the RCMs and the observed climate variables and the value close to 0.0 indicates poor performance (poor correlation) of the model (Pai and Saraswat, 2011). The equation used for Bias, RMSE, and r respectively (equation 3.1, 3.2, 3.3).

$$\mathrm{Bias} = \frac{\sum_{\mathrm{i=1}}^{\mathrm{n}}(Si-Oi)}{\mathrm{n}} \qquad 3.1$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Si - Oi)^2} \qquad 3.2$$

$$r = \frac{\sum_{i=1}^{n}(Si - Sm)(Oi - Om)}{\sqrt{\sum_{i=1}^{n}(Si - Sm)^2}\ \sqrt{\sum_{i=1}^{n}(Oi - Om)^2}} \qquad 3.3$$

Where, Si is Oi simulated and Observed value of the RCMs and O is the observed value of the climate variable, i refer to the simulated and observed pairs, n is the total number of the pairs and m refers to mean.

3.4 Data Analysis and Techniques

3.4.1 Filling the missing temperature and rainfall

A temporary break in the record of rainfall at a station is caused by the failure of some rain gauge or the absence of an observer from the stations. The breaks or gaps should be estimated first before used data for any analysis. The surrounding stations located within the catchment help to fill the missing data on the assumption of hydro-meteorological similarity of the group of stations. In this study, XLSTAT 2019 and the arithmetic mean method was used to fill missing rainfall and air temperature data of the stations over the study area.

3.4.2 Consistence test

Rainfall and air temperature data reported from stations may not always be reliable throughout records. When the catchment rainfall at rain gages and temperature stations is irregular over time, it is important to check and convert the recorded data to make it reliable. A consistent record is one where the characteristics of the record have not changed with time. Inconsistency may also result from change (unreported shifting of the rain gauge) in gauge location, significant construction work in the area might have changed the surroundings, change in observational procedure incorporated from a certain period and heavy forest fire, earthquake or landslide might have taken place in that area. Such changes at any station are likely to affect the consistency of data from a station. It is difficult to set out direct analysis to detect possible errors. However, through checking the consistency of individual stations, the data qualities concerning possible temporal variations or errors have been investigated.

For the recorded data, the Double Mass Curve analysis would be used to determine data consistency. For the same time, cumulative values of a given station are plotted against accumulated values of the average value of other stations. Through the use of double mass curve non-homogeneities of data in time series (in particular jumps) can be investigated, if for a change in observer record, in rain-gauge type, etc.

This is indicated in a double mass curve plot, with an inflection point in the straight line. The inconsistent data series can be adjusted to consistent values by proportionality. The consistency of the rainfall around the Adaba station is shown in Figure 3.3. Consistence for the other stations was found in (Appendix 3a).

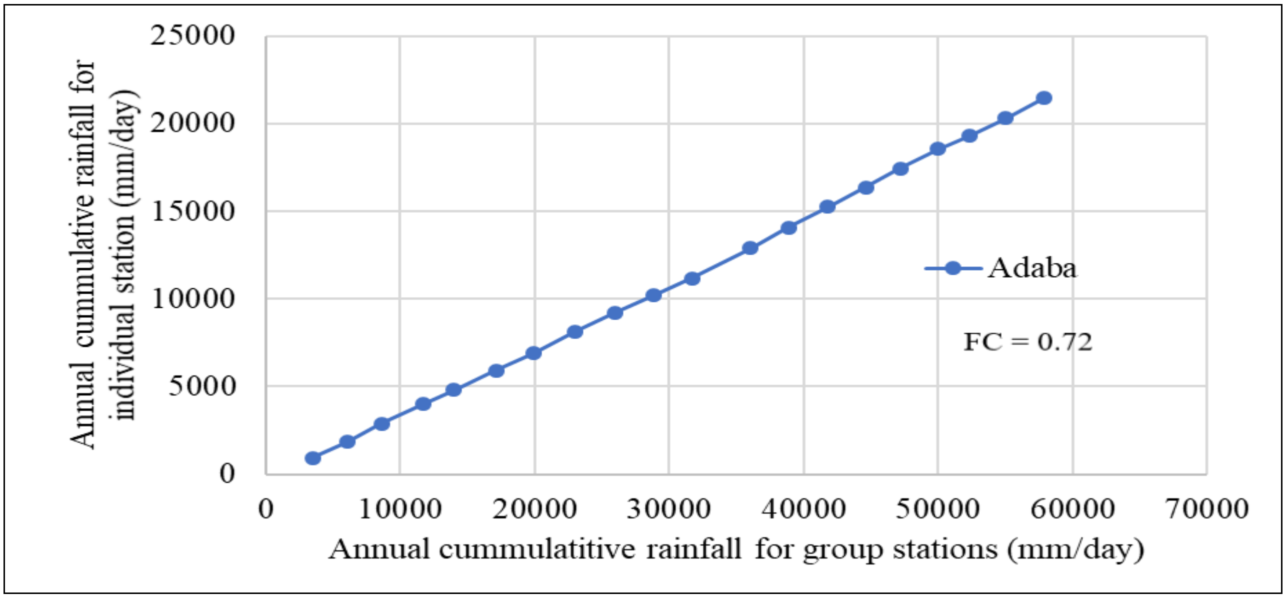


Figure 3.3 Consistence test of rainfall for Adaba station

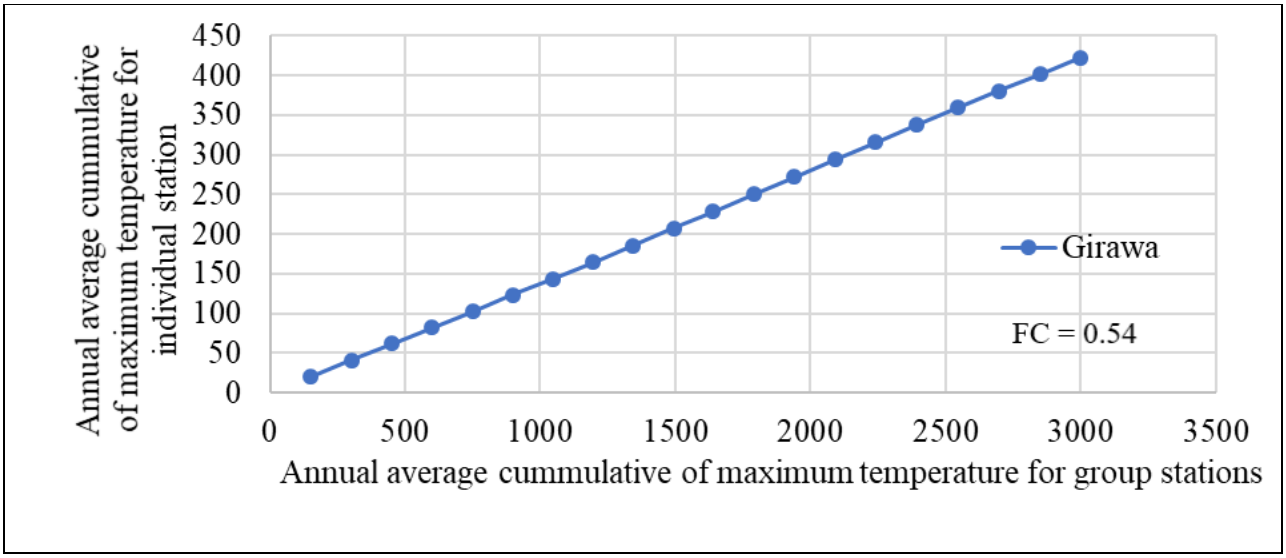


Figure 3.4 Consistence test of maximum temperature for Girawa station

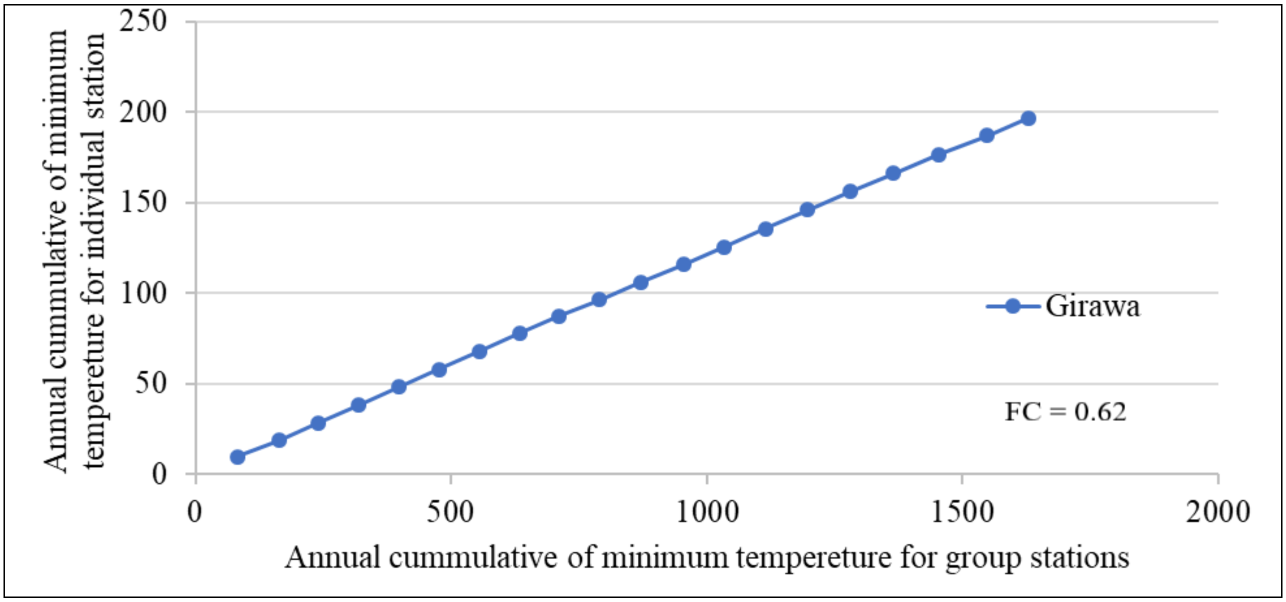
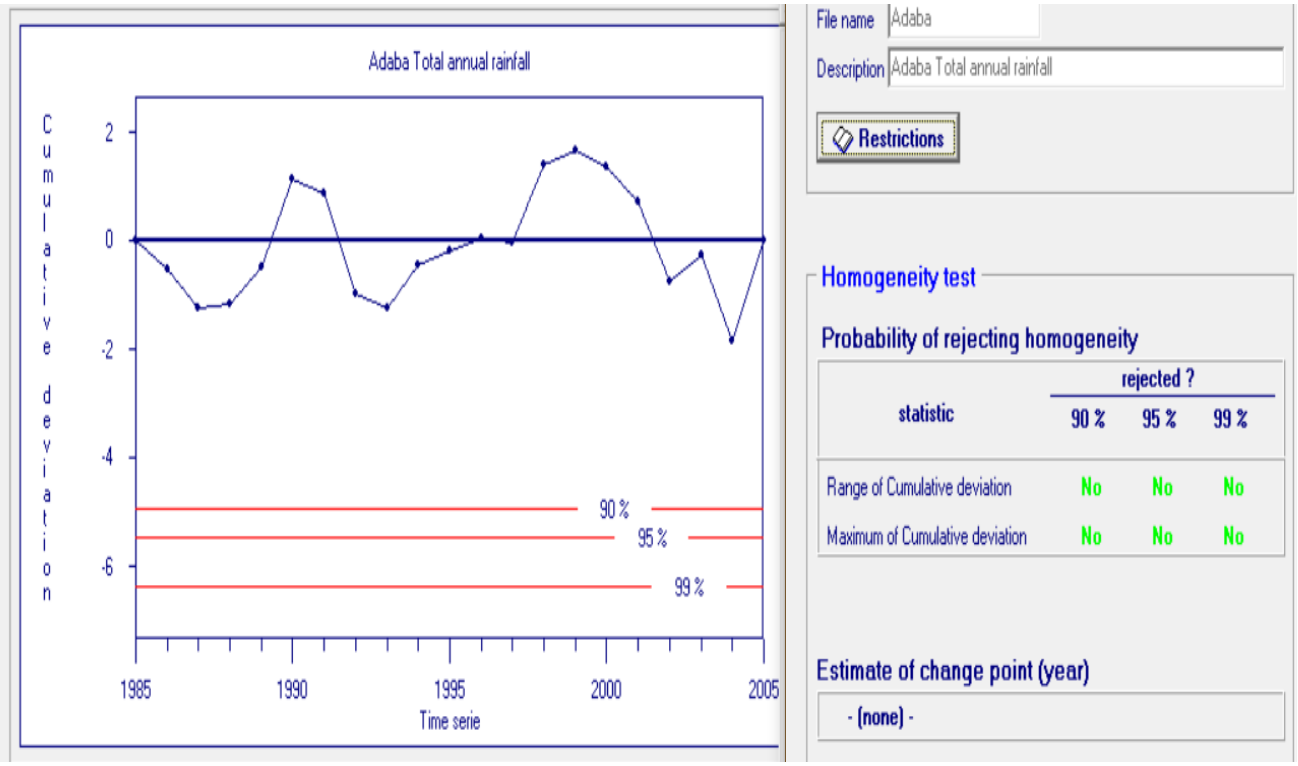


Figure 3.5 Consistence test of minimum temperature for Girawa station

3.4.3 Homogeneity test

Rainbow is the software package for analyzing climatological/hydrological data frequency analysis to test homogeneity. It requires the data to be of long series; they should be homogeneous and independent. The probability of rejecting homogeneity test is accepted at all significance levels (90, 95, and 99 %) for both ranges of cumulative deviation and maximum of the cumulative deviation

The selected stations were plotted for total annual rainfall versus time series; for illustration, figures 3.6 shows the homogeneity test result of rainfall around Adaba station and Appendix 3b also has figures plotted to check homogeneity of other selected stations. The stations selected are homogenous since the probability of rejecting is not acceptable at (90, 95, and 99 %) Significant level.



File name: Adaba

Description: Adaba Total annual rainfall

Homogeneity test

Probability of rejecting homogeneity

statistic	rejected ? 90 %	rejected ? 95 %	rejected ? 99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -

Figure 3.6 Homogeneity test of rainfall for Adaba station

3.5 Materials used

3.5.1 RStudio software

R is a free and yet very robust and powerful software for statistical analysis and graphics. It runs under both Windows and Unix environments. The R language environment is aimed at making it easy to build modern scientific computing methods. The software gives you access to the most up-to-date methodology from leading statisticians and other experts. If computational efficiency is needed, computer-intensive components can be managed by a call to a C or Fortran function.

For designing mathematical applications and data mining, statisticians and data miners often use the R programming language. For this study, R was used to perform anomalies for observed and simulated RCMs rainfall and air temperature to analyze the variability of drought class around the Wabi shebele basin. Additionally, this software was used to analyze trends with man Kendall test for observed and simulated annual rainfall and temperature with Orginpro 2018 graphing and analysis software. The future period trend analysis was carried out using the climatology of bias-corrected and extracted model data over the Wabi Shebele basin. Because of the possible impacts on human society and habitats, temperature and precipitation trends, as well as their extremes in measurements and climate models, have been the focus of intensive research over the last decade (Diaconescu et al., 2018).

It is about determining the probability distribution of the collected statistical data and whether the rainfall or air temperature value collected for a long period is increasing or decreasing. It describes the rate of change in values in terms of mean or median. Mann–Kendall test is a non-parametric test for randomness against time for correlation and has, in the last half-decade, become useful in water resources research for examining significance in trends within river basins. The MK test is commonly applied to detect significant trends in hydro-meteorological time series and is highly recommended by the World Meteorological Organization (WMO). Before applying the MK test to the time series of annual rainfall and precipitation levels, they were checked for serial correlation. Where serial correlation existed, a modified Mann–Kendall test was used to account for it i.e the serial correlation present in the rainfall and air temperature so that to obtain an improved significance test for monotonic trend. The annual data did not require the use of MMK and PW methods because yearly data have less noise and the autocorrelation test reveals no serial correlation in most of the cases (Ragatoa *et al*., 2018).

The standardized man-Kendall statics (Z), Kendall's Tau, Man-Kendall statics (S), Variance (S), and P-value are computed by Rstudio with “trend” package while the magnitude of trend (slope estimator) (Sen’s slope) was computed by XLSTAT 2019. This is a statistical test widely used for the analysis of the trend in climatological variables (Pingale *et al*., 2016). If p-value less is than the significance level (α=0.05), the null hypothesis (Ho) is rejected (statistically significant), while for a p-value greater than the significance level (α=0.05), Ho is accepted (statistically non-significant. Failing to reject Ho does not mean that there is no trend, rather, it is a statement that represents when the evidence available is not enough to conclude on the existence of trends. The positive and negative values of the S statistic and Z indicate upward and downward trends, respectively. The null hypothesis is tested at a 95% confidence level for rainfall and temperature data for the six meteorological stations.

Further details about the MK test can be found in (Pingale et al., 2016). The simple formula for coefficient of variation (CV) is calculated by Microsoft exell for the recorded and model rainfall and air temperature data.

The CV was measured for both the gauged and RCM virtual rainfall and air temperature levels to see how well the RCMs captured and reflected the network stations' rainfall and air temperature variations. The larger the values of CV, the larger the variability of the data, and the smaller the values of CV, the smaller the variability of the data (Asfaw *et al*., 2018)

Table 3.2 CV value and Variability of an Event

CV values	Variability of the Event
CV<20	Less
20<CV<30 μ	Moderate
CV>30 σ	High CV

$$CV = \frac{\sigma}{\mu} * 100 \quad 3.4$$

CV is coefficient of variation, σ is standard divition, and μ is the mean precipitation

Rainfall and air temperature anomalies were used to examine the nature of the variability and were unable to identify the wet season and dry season in a recorded year. It is also used to evaluate the drought frequency and severity. This is done by “precincton” package in Rstudio.

$$Z = \frac{(X_i - \bar{X}_i}{s} \quad 3.5$$

Where Z is standard rainfall anatomies, Xi = annual rainfall of a particular year, $\bar{X}_i$ is the long-term mean annual rainfall throughout observations, s is the standard division of annual rainfall throughout the observation

Table 3.3 Value of rainfall anomalies and Severity class

Z values	Drought Severity class
Z < -1.65	Extreme drought
-1.28 >Z > -1.65	Severe drought
-0.85>Z>-1.28	Moderate drought
Z > -0.85	No drought

(Agnew and Chappel, 1999).

4. RESULT AND DISCUSSIONS

4.1 Performance Evaluation of the CORDEX African RCMs

4.1.1 Performance evaluation of RCM in simulating average annual rainfall

In this section, basic statistical properties of the rainfall time series of six rainfall stations in the Wabi shebele basin are presented in figure 4.4. Based on statical property like Bias,RMSE,and r value at Wabi Shebele basin, HIRHAM5 over estimates rainfall at Badesa stations with the highest Bias of 0.9 mm/day while under estimated at most stations with the average value of Bias -0.25 mm/day in the study area. CCLM4-18-17 under estimated for five stations with an average Bias of -0.25 mm/day. The other models, RACMO22T and RCA4 simulate rainfall differently over most stations (underestimation in some stations and overestimation in other stations).

Interims of the RMSE statistics indicated the largest systematic error was produced by ensemble while the smallest error by RCA4 and RACMO22T. Based on the summary of Bias, RMSE, and r, the use of an individual model is more useful than using an ensemble average of models for rainfall simulation in the Wabi shebele basin.

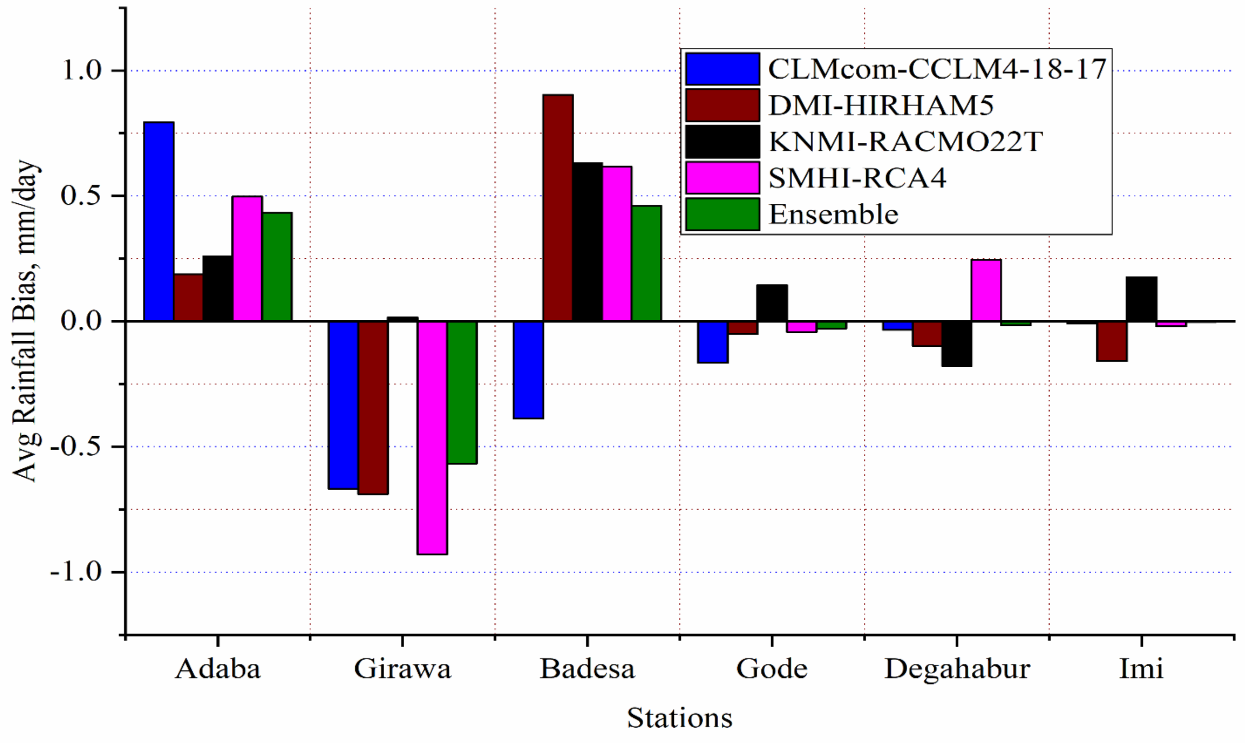


Figure 4.1 Bias of the average annual rainfall in Wabi Shebele basin

Some models can be ignored as ensemble models, because they demonstrated poor performance in simulating rainfall. Some study suggested that the best model in simulating monthly and annual rainfall is individual model while precipitation biases are typically located in the ±30% range (Kotlarski *et al*., 2014).

In this study, RCA4 and RACMO22T simulate rainfall well over most stations better than the others two models and ensembles. According to (dibaba et al., 2019) CRCM5 and RACMO22T simulate rainfall over most stations better than the other models over Fincha and didesaa catchment in case selected as better model over study area. The better peformed RCMs are selected over specific study area with comparing evaluation creteria of performance accordingly. The use of correlation coefficients in the study area to simulate rainfall indicated that most of the RCMs were unable to match the observation stations well. The correlation between the annual rainfall from most of the RCMs and the observed rainfall is weak in most of the stations in the basin. However, the RCA4 model showed a good correlation coefficient rather than ensembles and others models (Figure 4.4).

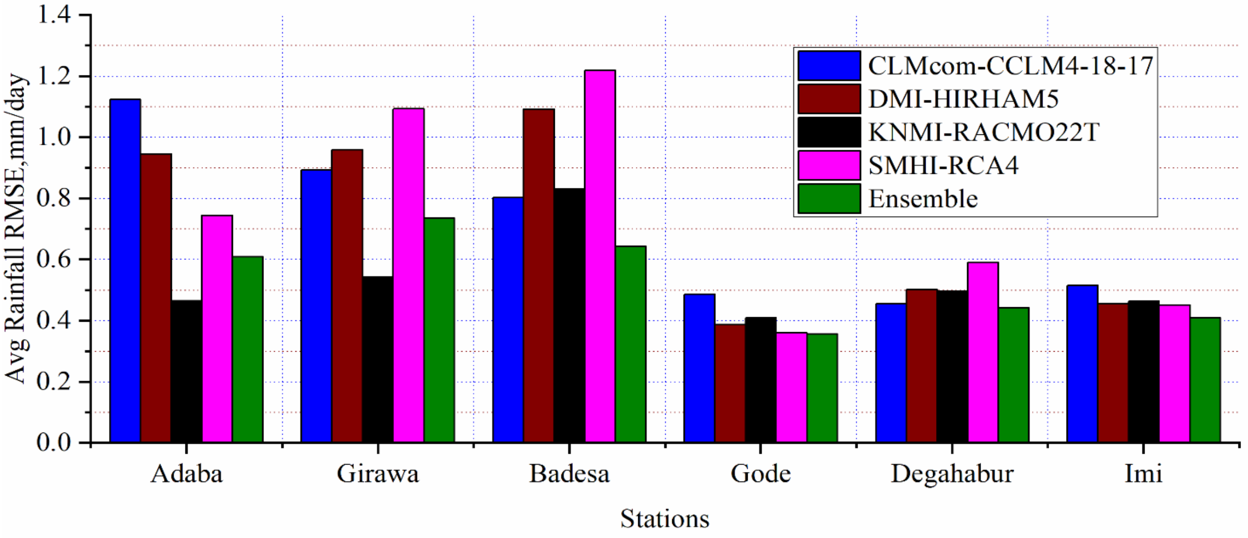


Figure 4.2 RMSE of the average annual rainfall in Wabi shebele basin

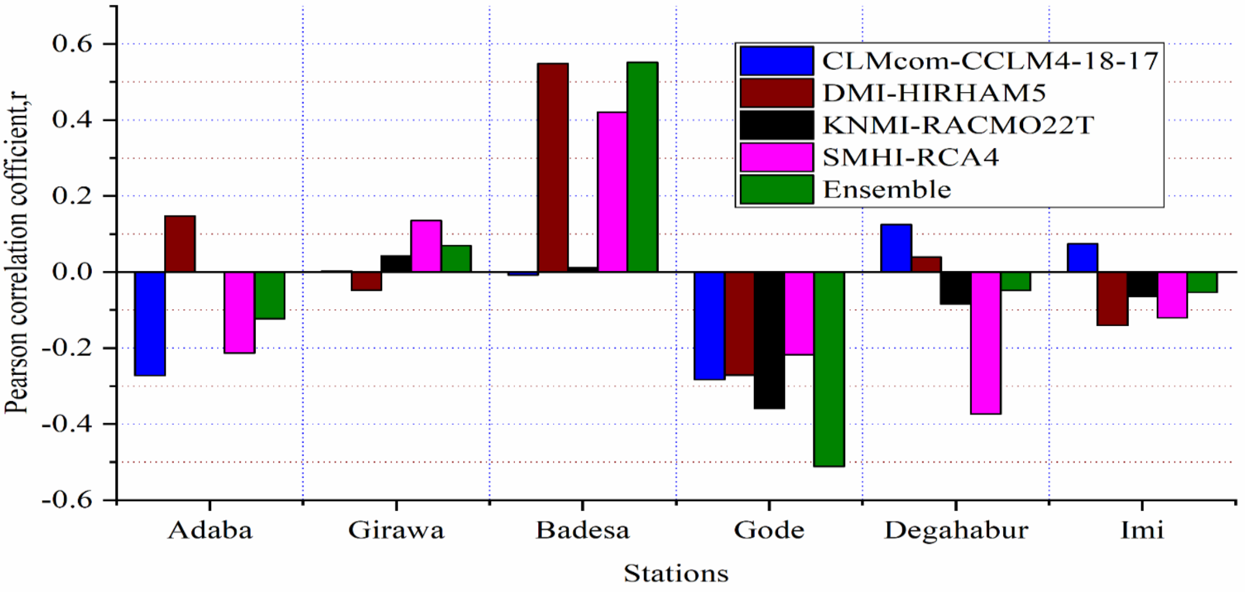


Figure 4.3 Personal correlation coefficient of average annual observed and simulated rainfall in Wabi shebele basin

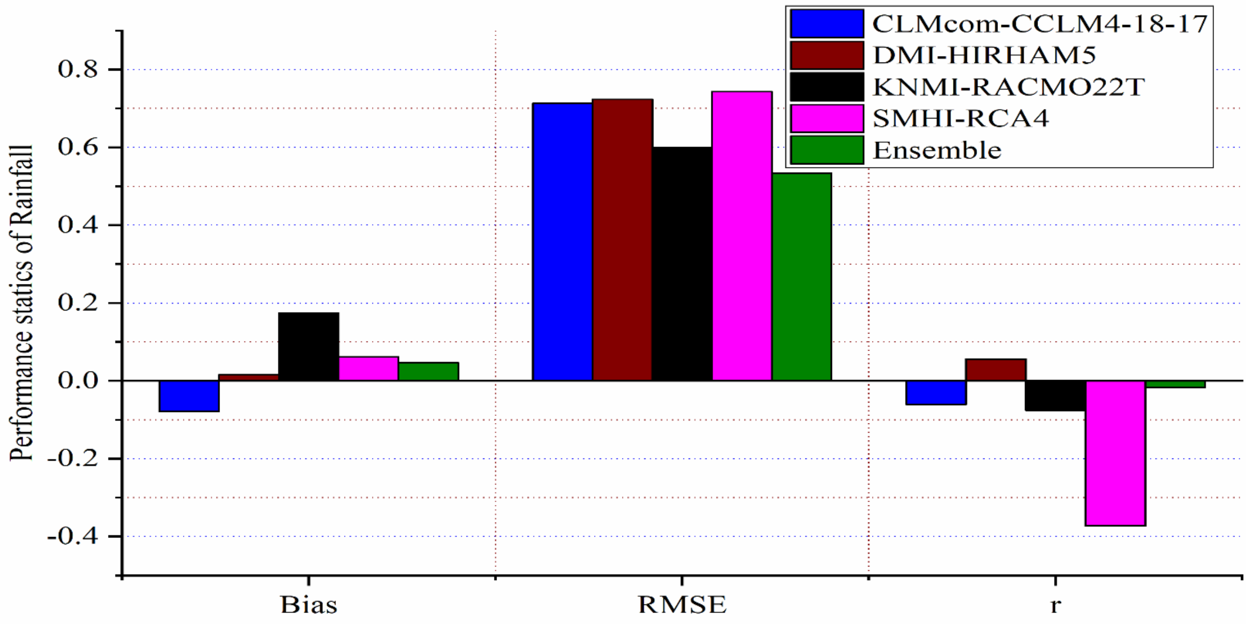


Figure 4.4 The model's statistical indices in simulating average annual rainfall in Wabi shebele basin

RCA4, RACMO22T, and ensemble simulate observed rainfall over the study area annually other than CCLM4-18-17 and HIRHAM5 as shown in figure 4.4 above. RCA4 simulates the annual mean observed rainfall based on the overall average performance statics discussed. In terms of ensembles, the ensembles of RCA4 and RACMO22T performed the best performance rather than all RCMs ensemble over the study area in simulating rainfall accordingly.

4.1.2 The RCMs performance in simulating average annual maximum air temperature

The Bias value of maximum air temperature over all stations of the Wabi shebele basin is negative and this showed that all models underestimated the maximum temperature. CCLM4-18-17 and HIRHAM5 showed -3.2 and -3.4 ^{0}C Bias respectively over all stations of Wabi shebele (Figure 4.8). RACMO22T, RCA4, and ensemble have also an average Bias of -2.3, -2.1, and -2.8 ^{0}C respectively over the study area. The study by Kim et al. (2014) indicated RCM skill is higher for maximum temperature than the minimum temperature for Ethiopian highlands. RCA4 has more estimate the maximum air temperatures other than three RCMs models and their ensembles. RMSE value over study area indicated that all models range 0.6 ^{0}C to 7.6 ^{0}C with high value by HIRHAM5 and minimum value by RCA4 models at Adaba and Imi stations respectively. RACMO22T and Ensemble resulted in 3.31 and 3.43 ^{0}C in average over the study area. In general, CCLM4-18-17, HIRHAM5, RACMO22T, RCA4, and their ensemble showed RMSE values of 4.0 3.6, 3.3, 2.8, and 3.4^{0}C respectively in the Wabi Shebele basin (figure 4.8).

Pearson’s correlation coefficients (r) in simulating maximum air temperature were shown in Figure 4.7. The correlation between simulated and observed maximum temperature is positive for most models over stations in Wabi shebele basin. RCA4, RACMO22T, HIRHAM5, and ensemble have equal value 0.2 while CCLM4-18-17 result negative value of -0.01 over the study area. Generally, except CCLM4-18-17 others modes showed better correlation coefficient over Wabi shebele basin including ensemble.

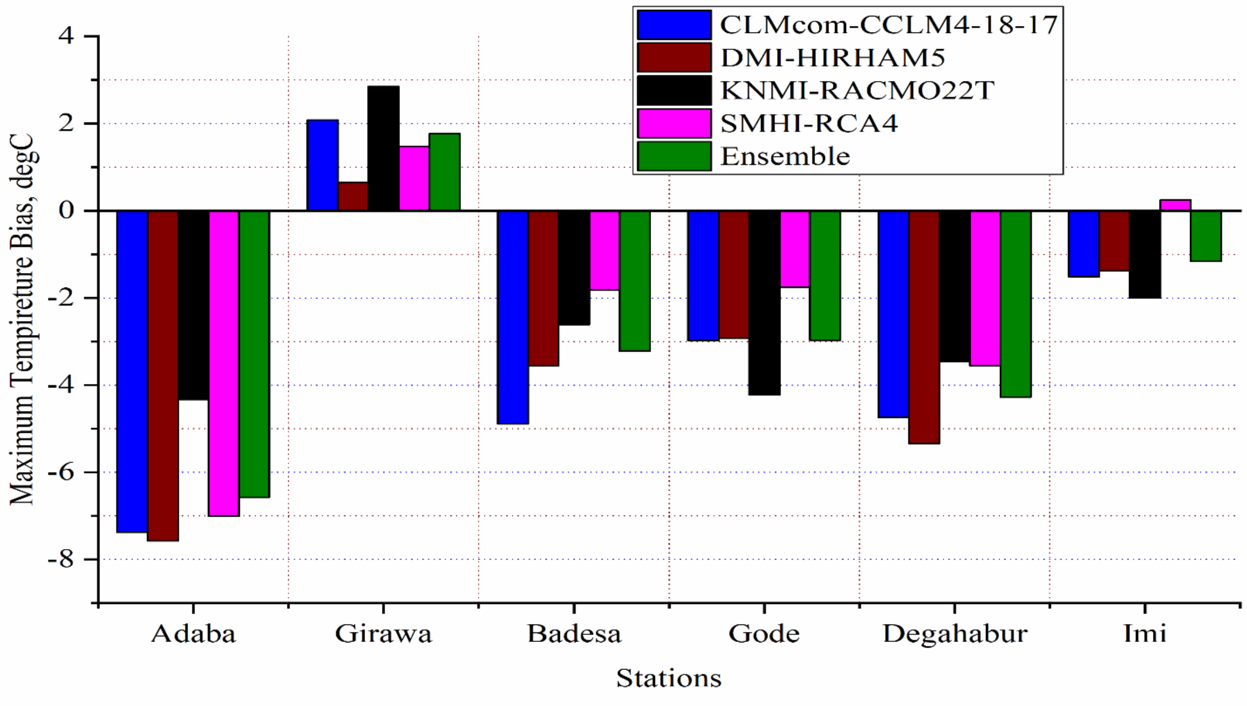


Figure 4.5 Bias of average annual maximum air temperature in Wabi Shebele basin

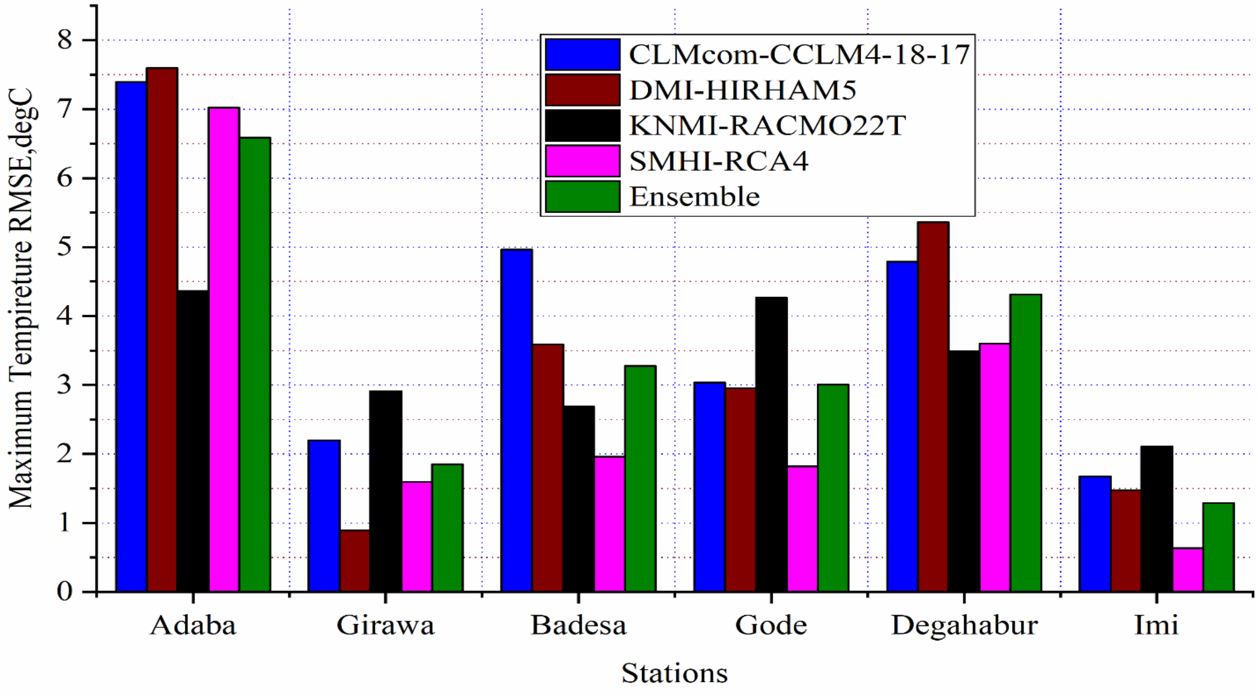


Figure 6.6 RMSE of average annual maximum air temperature in Wabi Shebele basin

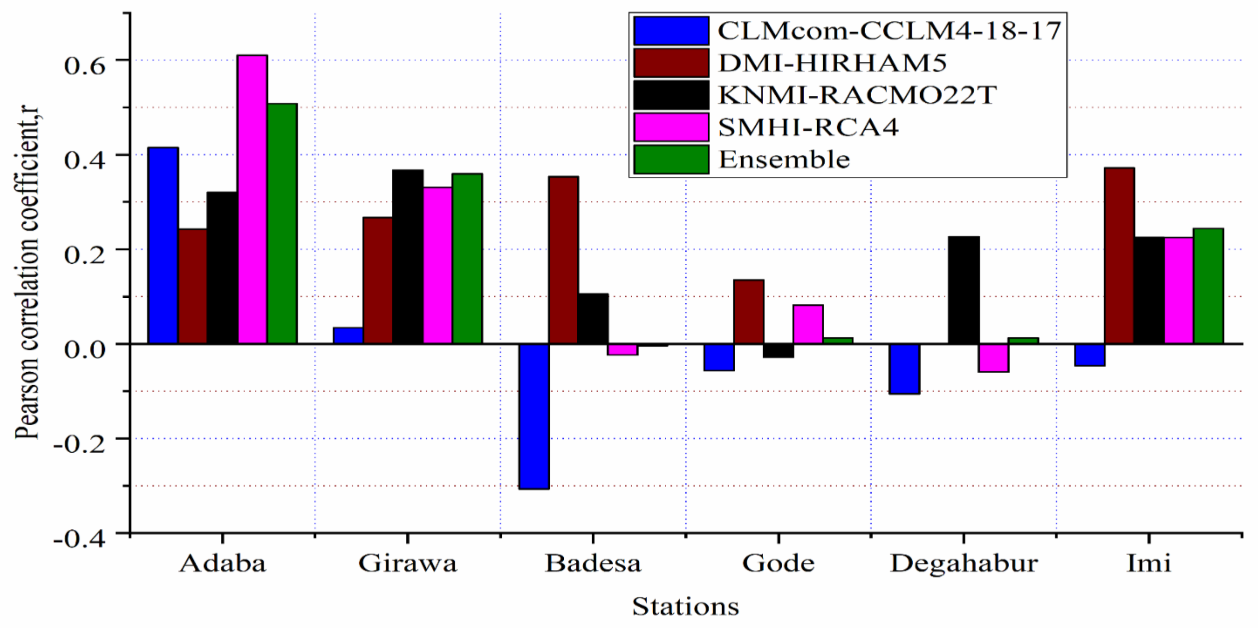


Figure 4.7 Personal correlation coefficient between the observed and simulated maximum air temperature in Wabi shebele basin

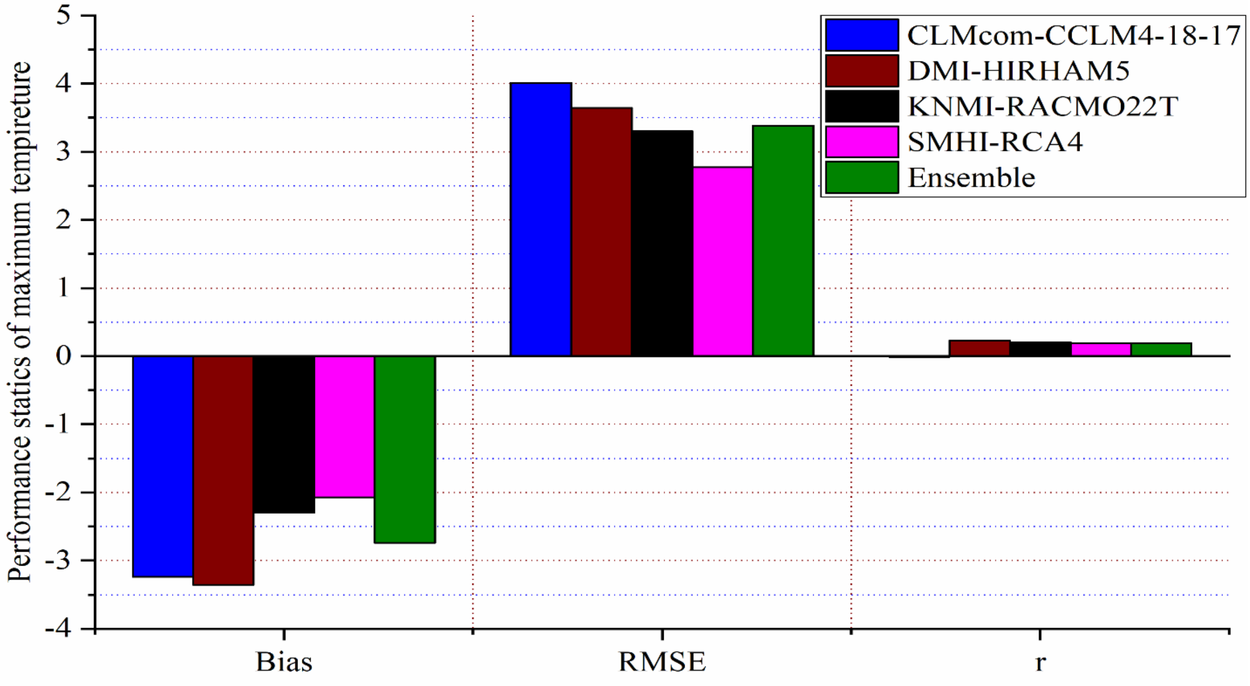


Figure 4.8 The model's statistical indices in simulating average annual maximum air temperature in the Wabi Shebele basin

4.1.3 The performance in simulating average annual minimum air temperature

In minimum air temperature simulation, Most of the models overestimated the average annual minimum air temperature over all stations of the Wabi shebele basin. CCLM4-18-17 overestimate with the highest Bias of 3.6 ^{0}C over Adaba station and 0.7 ^{0}C on average all over the study area. HIRHAM5, RACMO22T, and the ensemble also overestimate with average Bias values of 2.1, -0.6, and 0.5 ^{0}C in the Wabi Shebele basin. As cited in Flato et al. (2013), the study by (Suh et al., 2012) on 10 RCMs for Africa indicated that the models perform well for overall average and maximum temperature systematically overestimating the daily minimum temperature. This study also found that all the RCMs have overestimated the Minimum temperature.

RCA4 simulates minimum air temperature better than others models and ensemble with an average Bias value of -0.2 ^{0}C. RMSE result indicated that HIRHAM5 showed high systematic error by 2.85 ^{0}C and better RMSE by RCA4 which is 1.63 ^{0}C. RACMO22T, CCLM4, and ensemble resulted in 2.57, 2.28, and 2.35 ^{0}C respectively. The average of Pearson’s correlation coefficients in simulating average annual minimum air temperature is positive for all models over the study area (Figure 4.12). Simulations of minimum air temperature have shown a better correlation in most stations by RCA4 and Gode station have better correlation coefficient than all stations in Wabi Shebele basin (Figure 4.12).

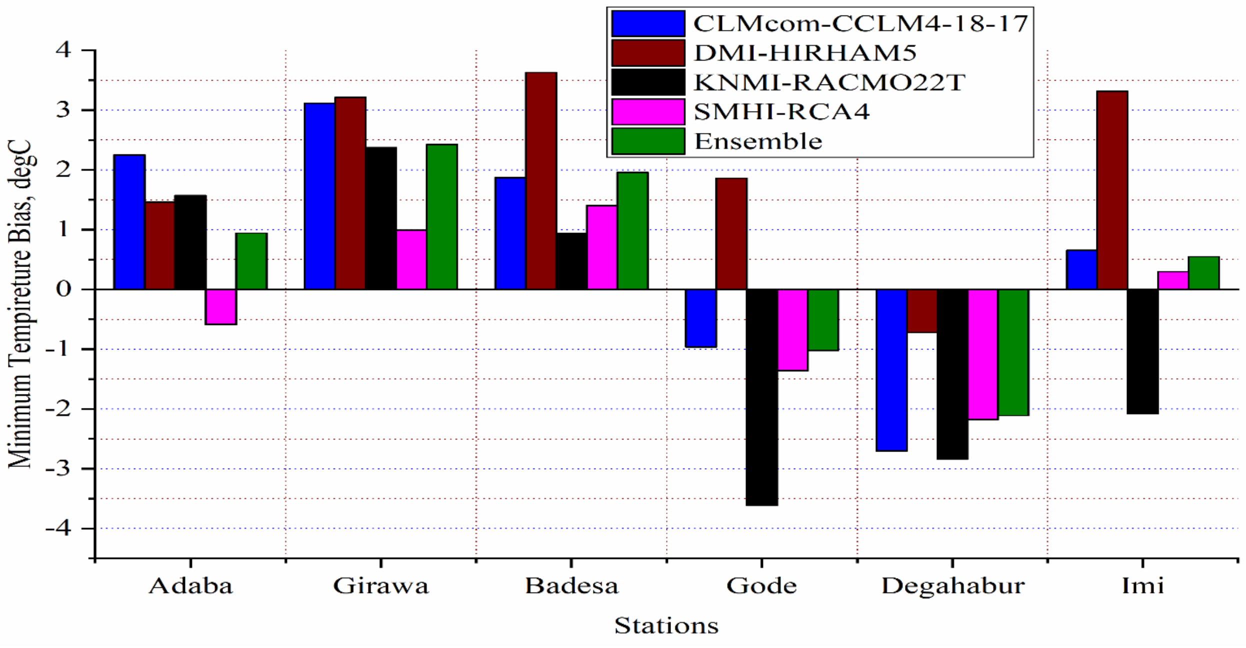


Figure 4.9 Bias of average annual minimum air temperature in Wabi Shebele basin

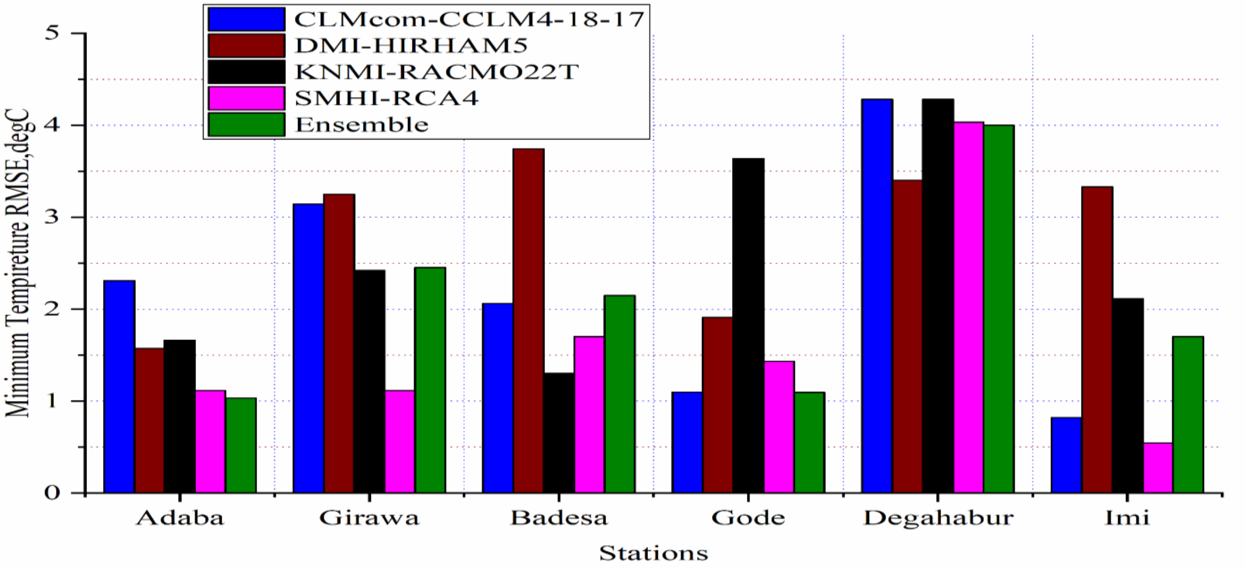


Figure 4.10 RMSE of average annual minimum air temperature in Wabi Shebele basin

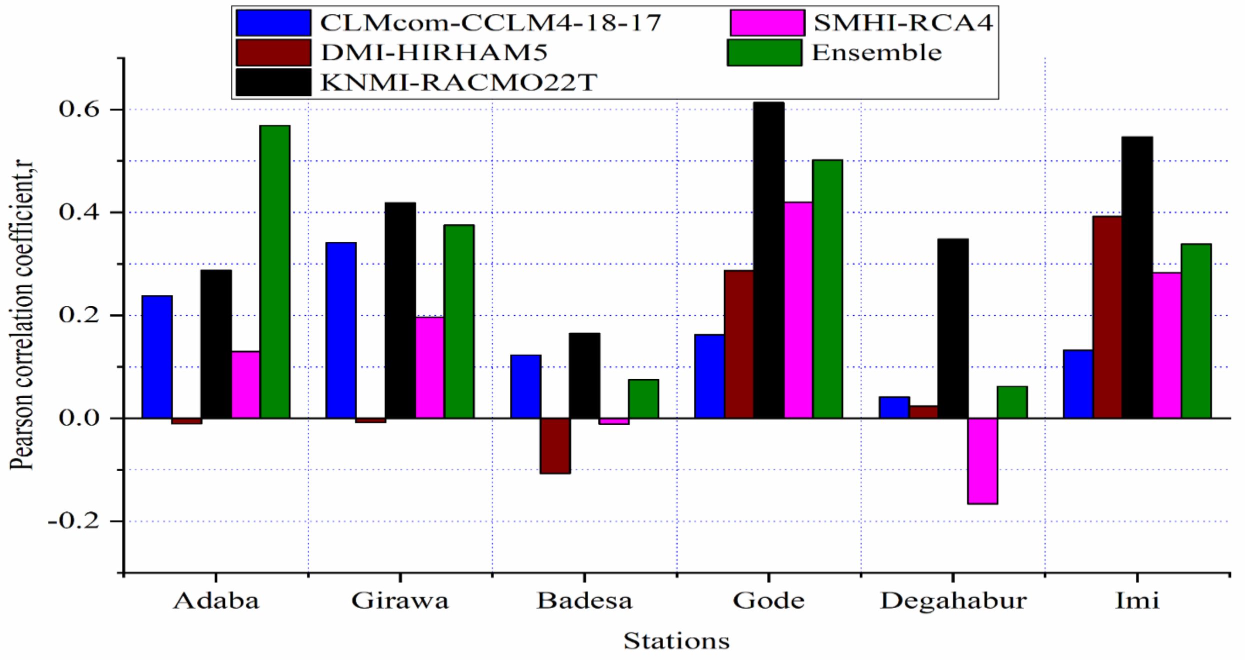


Figure 4.11 Personal correlation coefficient between the observed and simulated maximum temperature in Wabi Shebele basin

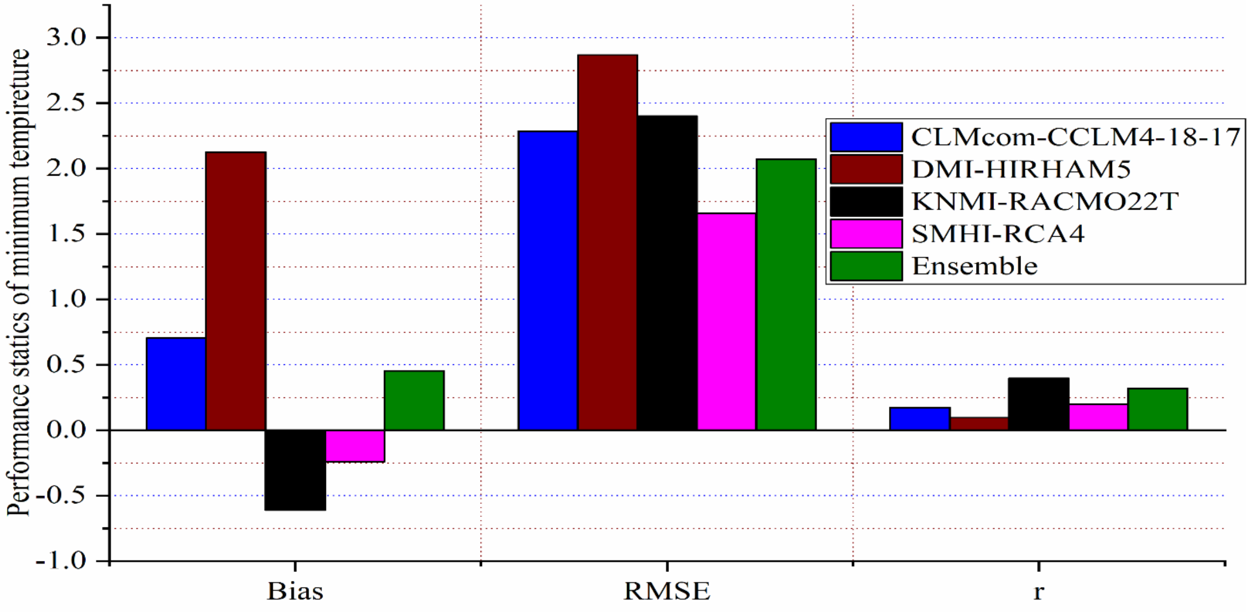


Figure 4.12 The model's statistical indices in simulating average annual minimum air temperature in Wabi shebele basin

Based on the evaluation of the performance of four RCMs and their ensembles by performance statics indices, RCA4 showed better performance in simulating average annual minimum air temperature as indicated in figure 4.12.

HIRHAM5 showed less in comparison with other models' performance in the study area in both simulations of average annual minimum and maximum temperature in the Wabi Shebele basin.

4.2 Mean monthly cycle and variability of rainfall and air temperature

4.2.1 Mean monthly cycle of rainfall

Analysis of the mean monthly patterns of rainfall over the study area is very important to analyze the annual cycle of the hydrologic extreme events (flooding or drought) in the Wabi Shebele basin. The mean monthly cycle showed the prominent features of rainfall in the basin. Adaba, Badesa, and Girawa stations showed main rainy months from June to September, small rainfall months from March to April, and dry months from November to February, and Degahabur, Gode, and Imi stations showed rainy months start from March to May and dry months from June to September. Variation of stations in climate zone contributed to identifying the more performing regional climate models at different stations of basin specifically. Some models constantly simulating the observed and pattern over most stations while others simulate differently. CCLM4-18-17 underestimated rainfall data over the study area, especially during rainy months. The study on assessment on the performance of CORDEX regional climate models in simulating East African rainfall indicated that only four RCMs (CRCMP5, RACMO, RegCM3, RCA4) among the ten models of CORDEX-Africa captured the shape of the monthly rainfall distribution and the annual rainfall anomaly.They overestimated the mean monthly rainfall amount of Jun- September (Endris *et al*., 2013). Most of simulated RCMs in this study also overestimated rainfall around wabi Shebele from Jun –September (Figure 4.14). RACMO22T overestimate the observed data at stations Adaba, Girawa, and Badesa from May to October and underestimate from Jan to April for Adaba and Badesa stations. It simulating observed data around Imi and Gode for January to June better than others models and ensembles.

HIRHAM5 dynamically simulating observed data over most stations. However, most of RCMs simulate observed data over the study area from June to September in the same way. RCA4 simulates most of the months of the years over Adaba, Imi, Gode and simulates peak rainfall overall stations of Wabi shebele basin while others models only simulating over some stations. The ensemble of RCMs also simulates the mean monthly cycle of observed rainfall better than some individual models over Wabi shebele basin as indicated in figure 4.14.

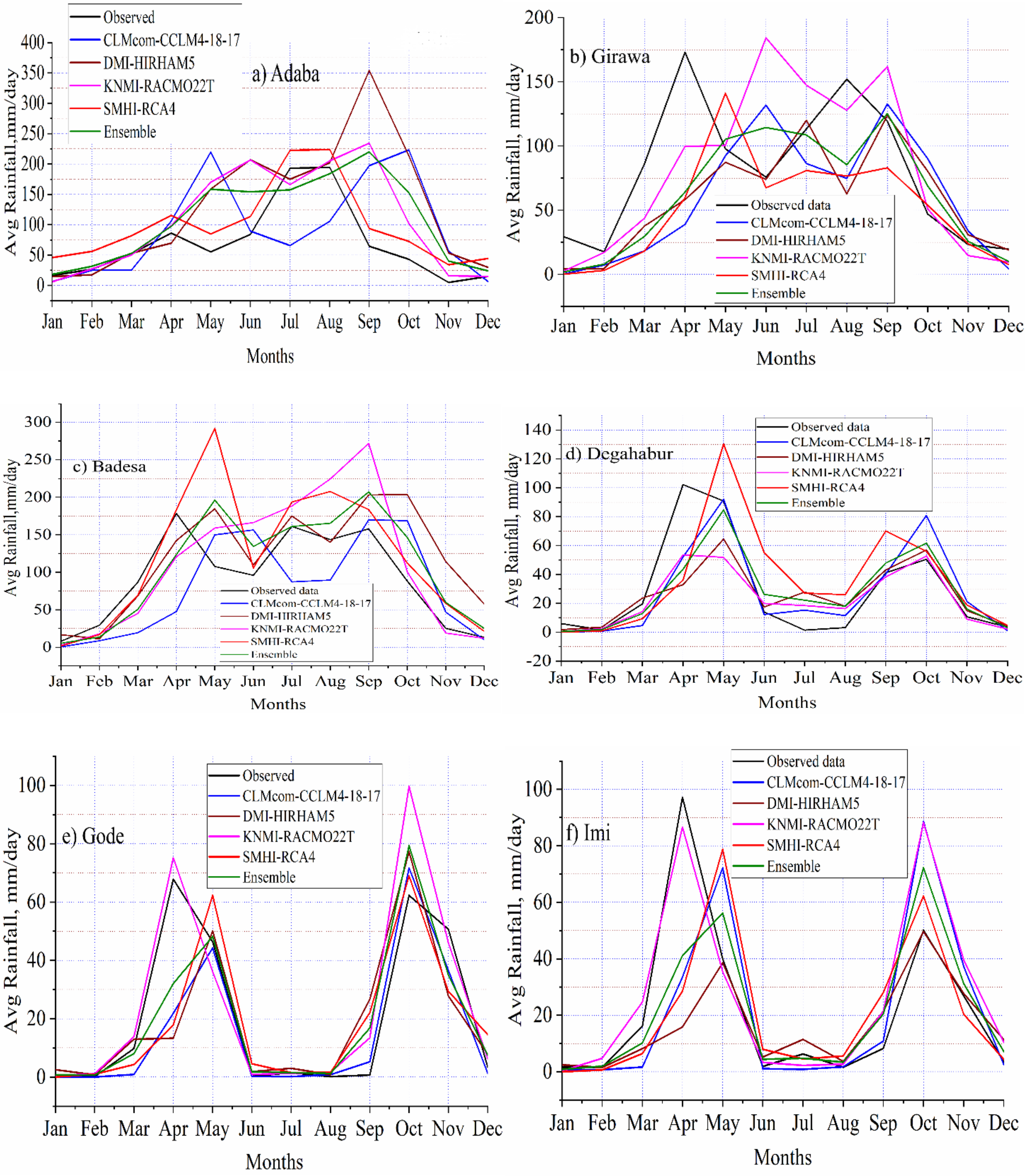


Figure 4.13 Mean monthly cycle of observed and simulated rainfall at different stations of Wabi shebele basin

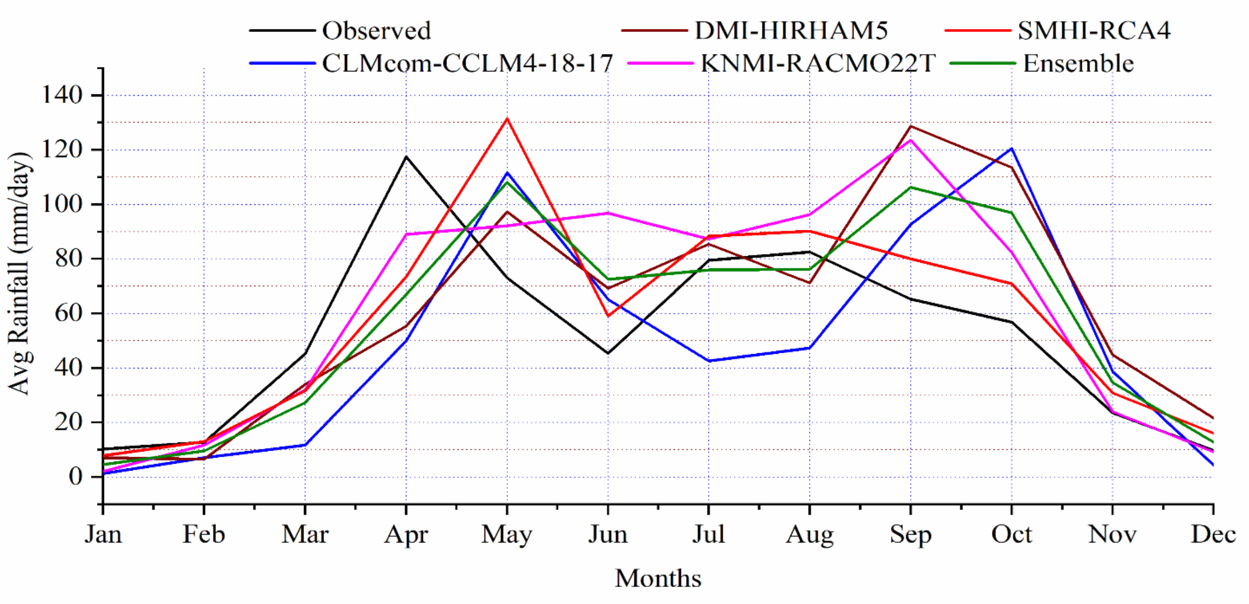
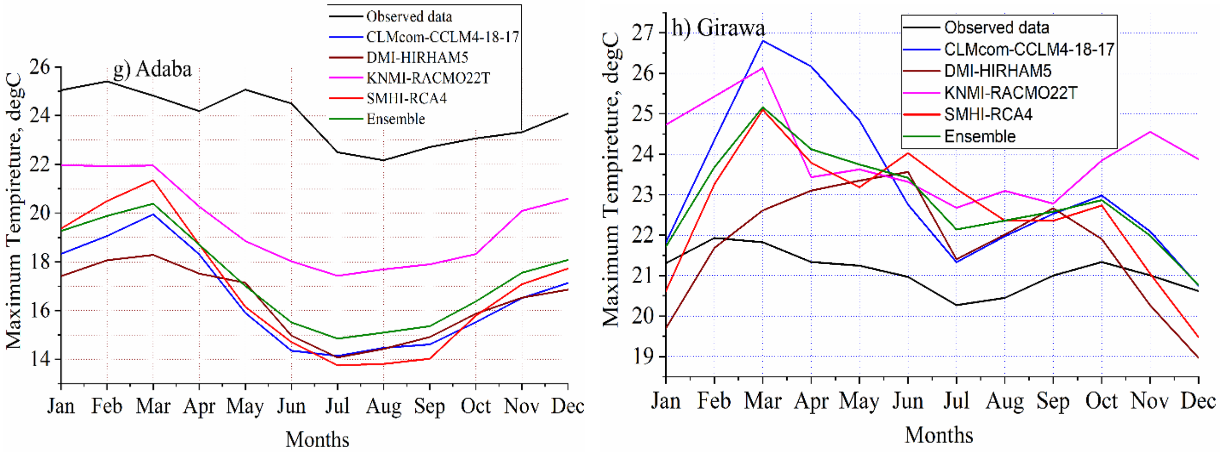


Figure 4.14 Mean monthly cycle of observed and simulated rainfall over Wabi shebele basin

4.2.2 Mean monthly cycle of maximum air temperature

The mean monthly cycle of maximum air temperature, underestimate over all stations except at Girawa and Imi stations. Only RCA4 simulate the high value of maximum air temperature over most stations while other RCMs and ensemble mean did not. However, in maximum air temperature, the RCMS has attained the cool and hot months of the observed air temperature. In comparing simulations of the RCMs and their ensemble for the basin with the observed maximum air temperature data, RCA4 is better performed.



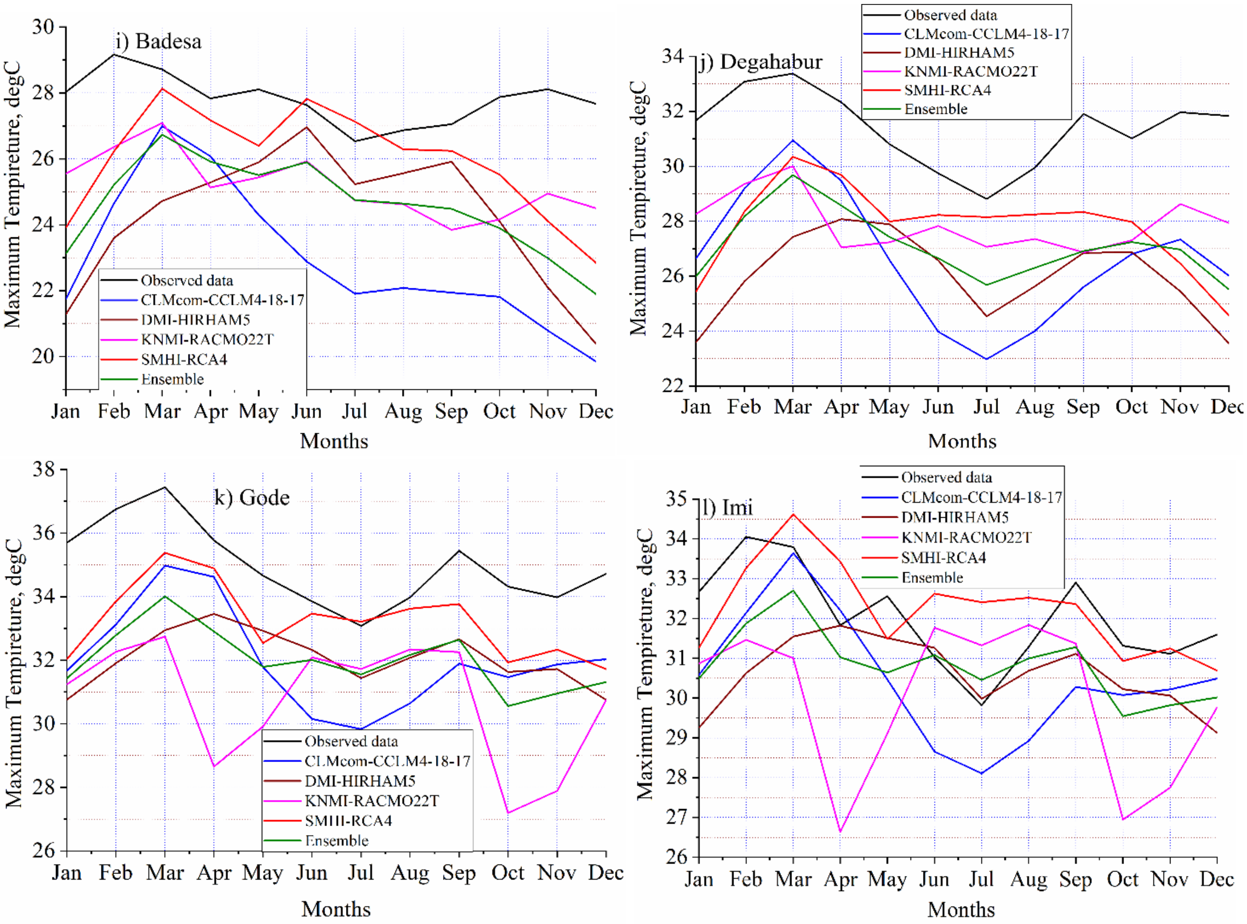


Figure 4.15 Mean monthly cycle of observed and simulated maximum air temperature at stations of Wabi shebele basin

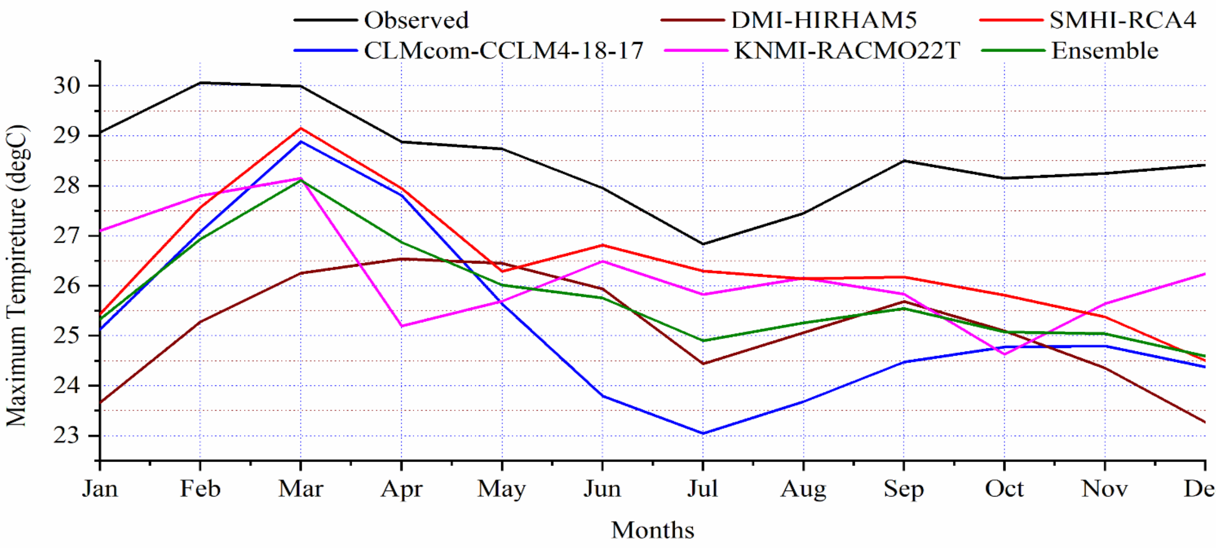
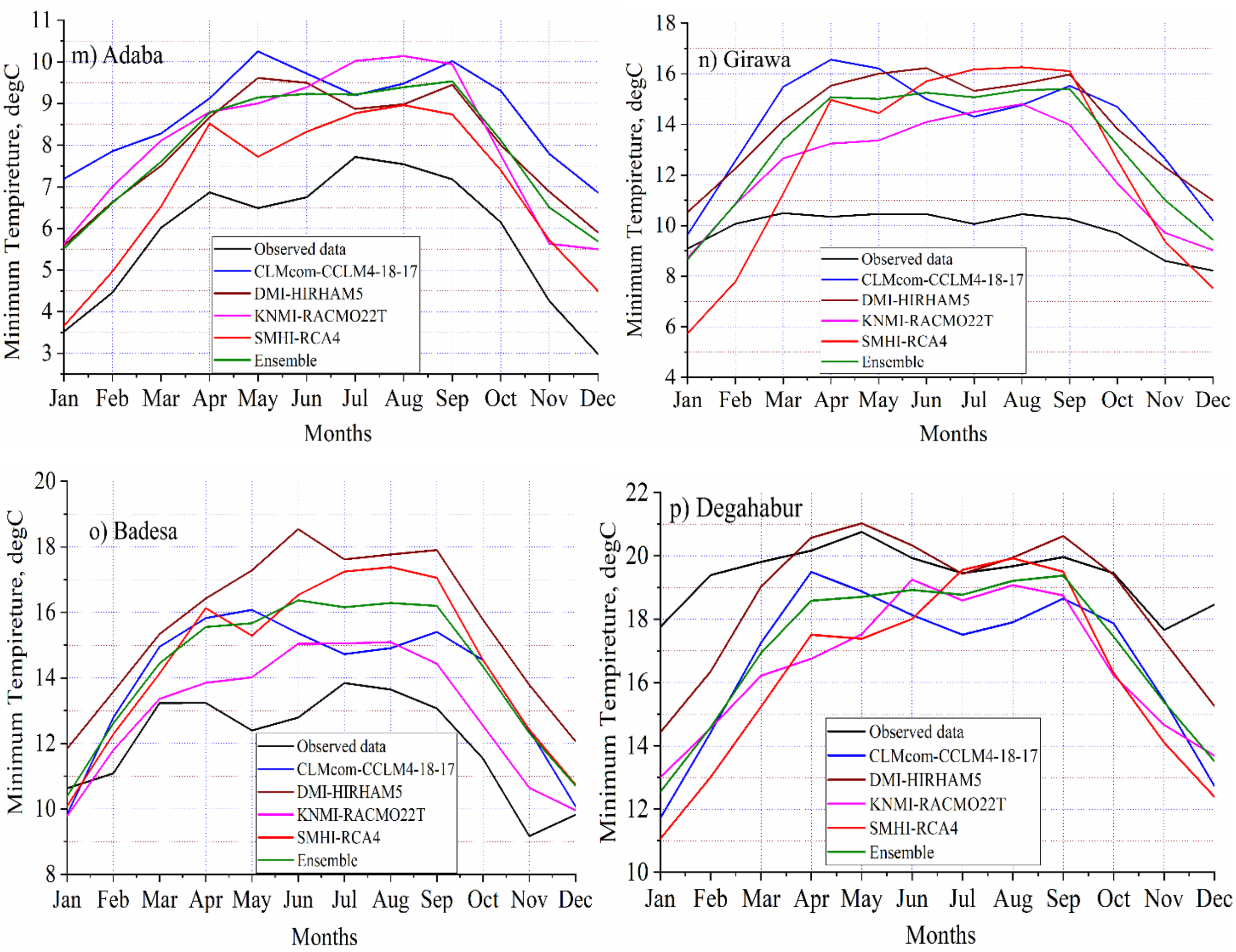


Figure 4.16 Mean monthly cycle of observed and simulated maximum temperature over Wabi Shebele basin

Generally, for mean monthly maximum air temperature, RCMs and their ensemble did not simulate the high value of observed mean data, and RCA4 were performed better than others simulated RCMs. On average, all models underestimated the mean maximum air temperature from January to December in the basin (figure 4.16).

4.2.3 Mean monthly cycle of minimum air temperature

The mean monthly cycle of minimum air temperature over and underestimated the stations of the study area throughout the months of the year in historical periods. In the simulation of minimum air temperature also, the RCMS has attained the cool and hot months of the observed air temperature like for maximum temperature. In comparing simulations of the RCMs and their ensemble for the basin with the observed minimum air temperature data, RCA4 is better performed again.



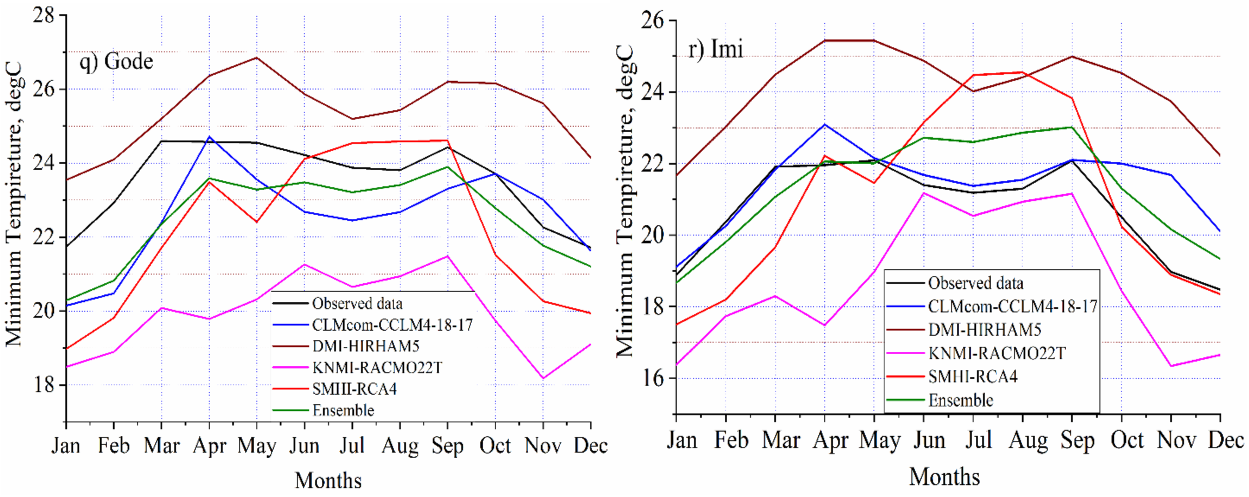


Figure 4.17 Mean monthly cycle of observed and simulated maximum air temperature at stations of Wabi Shebele basin

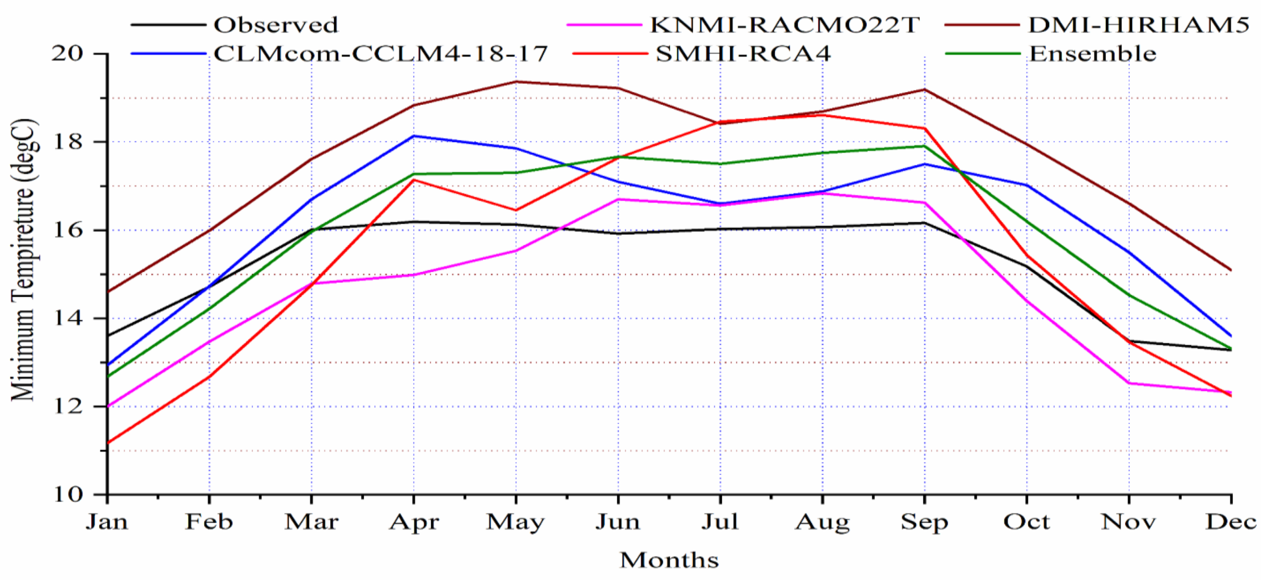


Figure 4.18 Mean monthly cycle of observed and simulated minimum air temperature in Wabi Shebele basin

All RCMs and their ensemble simulated a high value of mean monthly minimum air temperature and RACMO222T and RCA4 were performed better than others over the Wabi Shebele basin (figure 4.18). On average, all models except RACMO22T and RCA4 overestimate the minimum air temperature with exception of January to March in the basin.

4.2.4 Annual and seasonal variability of rainfall

The variability analysis of rainfall at timescales help in determining the likelihood of extreme (less, moderate, and high) events and management of water resources particularly for major consuming sectors; namely agriculture, hydropower, and domestic water supply within basins. For annual rainfall based on the coefficient of variations of stations resulted from observed and simulated RCMs, the HRMA5, CCLM4-17-18, and observed ranges above 30% for rainfall. While RCA4, RACMO22T, and ensemble range between 15% to 25% on average all over stations of the study area. The average observed data have the CV of 31.51% and related with CV value resulted from RCA4 which is 24.38%. Specifically, stations such as Adaba, Girawa, and Badesa showed less variability which with a CV of 15% while Degahabur and Imi stations resulted in 47% coefficient of variation in observed data (Table 4.1). Seasonally the coefficient of variation for observed data showed that 42.173%, 95.05%, 67.95%, and 116.64% for Spring, Summer, Autumn, and Winter seasons respectively. This showed high variation for observed data in all seasons in the Wabi shebele basin in the period of 1986-2005 as indicated in Table 4.2. The individual model data was in agreement with the observed data throughout the considered years annually, and agreed with the findings of (Ajayi .,et al 2020).

Table 4.1 Coefficient of variation over stations of Wabi shebele basin for observed and simulated rainfall

Stations	Basic Statics	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Adaba	mean	838.62	1128.56	906.99	933.15	1020.23	997.23
	min	623.20	784.14	294.48	784.61	616.70	765.32
	max	1052.10	1620.34	1402.86	1104.21	1182.72	1152.79
	SD	115.59	245.22	344.83	86.85	149.50	97.70
	CV%	13.78	21.73	38.02	9.31	14.65	9.80
Girawa	mean	954.04	710.89	702.87	960.08	615.13	747.24
	min	733.00	378.57	247.77	744.42	279.86	627.30
	max	1258.10	897.91	1151.20	1239.10	915.99	856.98
	SD	166.15	148.37	178.61	123.93	161.10	67.68
	CV%	17.42	20.87	25.41	12.91	26.19	9.06

Badesa	mean	1095.30	954.35	1426.16	1327.03	1445.23	1288.19
	min	732.70	551.05	722.97	1101.29	869.21	986.58
	max	1323.40	1415.55	1908.83	1535.61	2256.38	1472.77
	SD	159.92	207.43	274.98	125.45	310.57	127.51
	CV%	14.60	21.74	19.28	9.45	21.49	9.90
Gode	mean	243.19	182.95	224.74	295.94	227.95	232.90
	min	97.90	29.72	132.79	182.30	101.99	164.55
	max	535.30	416.93	415.97	459.72	325.50	344.50
	SD	105.87	108.25	72.68	66.22	62.74	42.88
	CV%	43.53	59.17	32.34	22.38	27.52	18.41
Degahabur	mean	344.48	331.81	308.66	279.11	434.31	338.47
	min	161.40	197.37	74.94	171.79	268.12	235.47
	max	847.50	488.88	498.07	413.71	666.58	424.51
	SD	155.49	90.60	105.48	65.77	103.38	51.17
	CV%	45.14	27.30	34.17	23.56	23.80	15.12
Imi	mean	254.82	251.59	196.85	319.44	247.28	253.79
	min	109.54	69.01	99.82	200.06	115.04	171.03
	max	740.40	574.95	290.79	464.92	379.69	363.18
	SD	139.12	144.49	61.05	72.35	80.62	57.53
	CV%	54.59	57.43	31.01	22.65	32.60	22.67

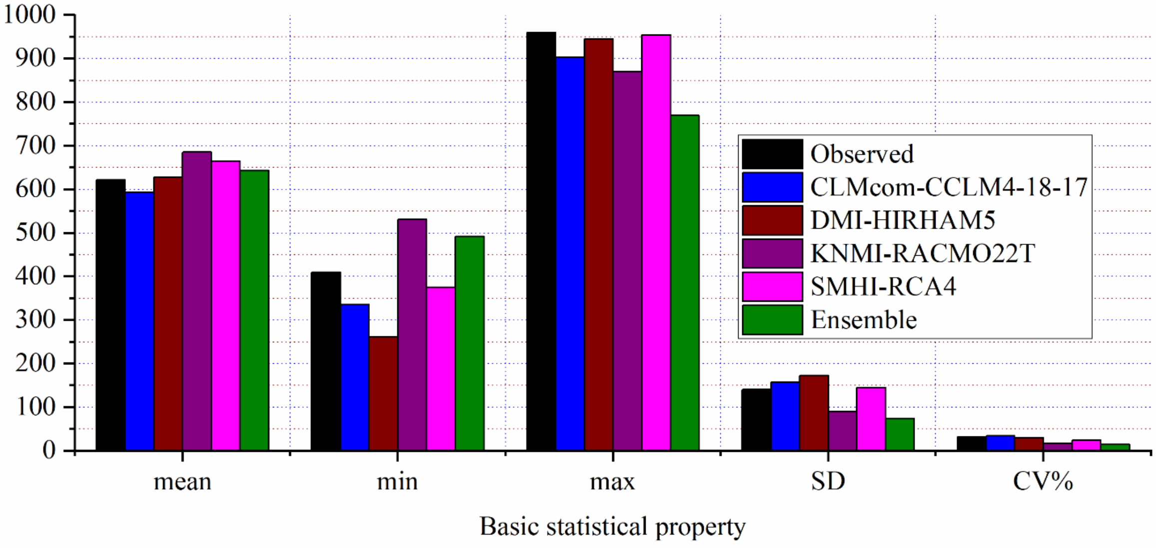


Figure 4.19 Annual coefficient of variation between observed and simulated rainfall at stations of Wabi shebele basin

Table 4.2 Seasonal coefficient of variation for observed and simulated rainfall over the study area

Seasons	Statistical Property	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Spring	mean	235.699	173.443	186.716	213.253	236.60	202.501
	min	111.768	68.963	52.698	111.852	66.41	121.161
	max	470.269	355.493	389.944	399.712	432.86	323.242
	SD	94.021	72.597	83.648	68.871	106.10	53.460
	CV%	42.173	51.780	50.870	33.776	45.197	28.098
Summer	mean	207.33	155.18	225.70	280.52	237.64	224.76
	min	94.05	64.94	116.30	201.66	89.03	165.05
	max	305.98	262.60	361.89	393.90	359.98	297.93
	SD	51.68	51.94	64.51	49.34	68.61	32.17
	CV%	95.05	64.34	50.58	49.10	54.38	31.73
Autumn	mean	145.82	252.01	286.23	230.02	181.99	237.56
	min	47.94	95.18	111.78	136.58	70.80	135.78
	max	380.24	561.06	531.46	352.15	308.12	354.04
	SD	83.84	134.96	100.58	58.01	67.40	55.51
	CV%	67.95	59.44	39.81	28.34	36.18	25.98
Winter	mean	31.49	12.98	25.19	23.54	21.28	20.75
	min	0.67	0.82	4.37	3.14	3.45	7.48
	max	102.23	42.88	75.46	67.21	62.58	41.46
	SD	27.96	13.61	18.99	17.32	16.09	9.15
	CV%	116.64	142.88	88.38	84.42	98.47	55.33

To have further identification of the wet and dry years and thereby substantiating the result, rainfall anomalies of the stations of the study area for the period of 1986-2005 were computed for observed and simulated RCMs (Appendix 4a). Accordingly, there are slight variations among the six stations in inter-annual rainfall variability for observed data.

At all stations of the basin, 12 out of 20 years (60%) showed no drought over study area continuously from 1993-2000. While the remaining 8 years showed extreme drought 6 out of 20 years and severe drought for 2 out of 20 years. For CCLM4-18-17 RCM also 12 out of 20 years (60%) showed no drought over the study area while 7 out of 20 years (35%) indicated extreme drought based on rainfall anomalies as indicated in table 4.6. HIRHAM5 resulted in no drought for 13 out of 20 years (65%) and 6 out of 20 years (30%) extreme drought while only 1 out of 20 years showed severe drought for both HIRHAM5 and CCLM4-18-17 models.

RACMO22T indicated 14 out of 20 years (70%) no drought, 4 out of 20 years (20%) extreme drought, and 1 out of 20 years severe and moderate drought over the Wabi Shebele river basin. RCA4 showed no drought 11 out of 20 years (55%), 6 out of 20 years (30%) with extreme drought, 2 out of 20 years moderate, and 1 out of 20- year severe drought. Ensembles of four RCMs resulted that 15 out of 20 years (75%) showed no drought while 3 out of 20 years' extreme drought and others two years are moderate and severe drought.

Table 4.3 Annual anomalies for observed and simulated rainfall in Wabi shebele basin

Years	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensembles
1986	2.56	0.95	1.93	-0.79	1.44	0.8
1987	-2.05	3.77	-8.06	0.79	-1.44	-1.24
1988	-1.30	-0.08	7.86	-1.28	1.28	1.95
1989	0.94	-3.99	-2.77	-0.50	-2.81	-2.52
1990	-1.68	-2.14	0.41	4.24	4.67	1.79
1991	0.99	-0.63	3.54	-1.95	1.10	0.52
1992	-2.34	-2.86	2.11	1.54	4.10	1.22
1993	1.29	0.31	0.14	-1.27	-1.74	-0.64
1994	1.39	5.58	2.05	2.34	-1.07	2.22
1995	-0.12	-1.74	-4.02	-0.15	-6.78	-3.17
1996	-0.36	-3.83	2.04	-0.68	4.65	0.54
1997	7.63	-0.80	-2.28	2.46	0.95	0.08
1998	0.55	2.91	0.84	-3.57	1.37	0.39
1999	-0.31	-0.65	1.50	-2.34	3.78	0.57
2000	-0.37	-2.58	0.14	-0.34	0.26	-0.63
2001	-2.20	2.74	1.71	2.97	-0.23	1.80
2002	-1.45	3.91	-1.63	-0.80	-4.16	-0.67
2003	-2.11	-1.34	0.36	-4.48	-2.17	-1.91
2004	-1.84	2.69	-2.74	3.73	-2.24	0.36
2005	1.21	-2.24	-3.12	0.08	-0.95	-1.56

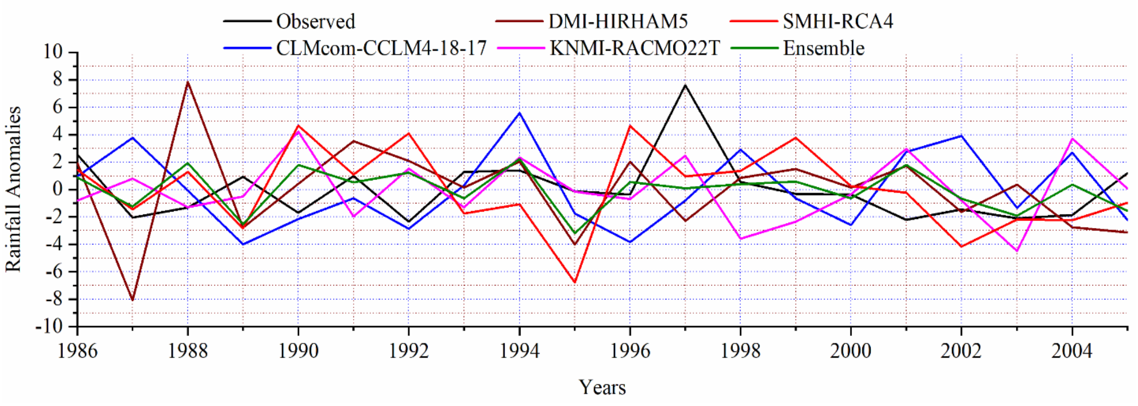


Figure 4.20 Annual anomalies of observed and simulated rainfall in Wabi shebele basin

4.2.5 Annual and seasonal variability of air temperature

The result showed in table 4.4 for observed, RCMs and ensemble have recorded less than 2.2% coefficient of variation for all stations around the study area. Therefore, the variability of the event is very less for all simulated and observed data around Wabi shebele river basin for maximum air temperature. Specifically, stations like Gode, Degahabur, and Imi showed less than 1.9% CV while Adaba, Badesa, and Girawa stations recorded above 2% CV under observed and most simulated RCMs. For all seasons all stations showed a very little variation of events which is less than 5% for observed and simulated maximum air temperature as discussed in table 4.5 accordingly.

Table 4.4 Coefficient of variation for observed and simulated maximum air temperature over Wabi shebele basin

Stations	S.P	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Adaba	mean	23.90	16.52	16.33	19.57	16.89	17.33
	min	22.97	15.68	15.81	18.98	16.02	16.71
	max	24.67	16.94	17.10	20.15	17.33	17.71
	SD	0.51	0.34	0.35	0.33	0.37	0.27
	CV%	2.13	2.04	2.16	1.69	2.16	1.57
Girawa	mean	21.11	23.19	21.76	23.95	22.58	22.87
	min	20.37	22.30	20.95	23.02	21.52	22.20
	max	22.20	23.88	22.63	24.88	23.08	23.27
	SD	0.60	0.44	0.38	0.50	0.44	0.31
	CV%	2.86	1.89	1.74	2.10	1.95	1.36
Badesa	mean	27.80	22.90	24.25	25.19	25.98	24.58
	min	27.12	21.74	23.52	24.49	24.80	23.94
	max	28.89	23.61	24.99	26.18	26.58	25.00
	SD	0.56	0.51	0.33	0.44	0.48	0.31
	CV%	2.00	2.23	1.36	1.73	1.85	1.27
Gode	mean	34.97	32.00	32.05	30.75	33.22	32.00
	min	34.35	30.95	31.51	29.88	32.21	31.32
	max	35.59	32.95	32.54	31.54	33.65	32.61

	SD	0.38	0.47	0.26	0.46	0.36	0.31
	CV%	1.08	1.46	0.82	1.50	1.08	0.96
Degahabur	mean	31.36	26.61	26.02	27.90	27.81	27.08
	min	30.31	25.60	25.50	26.81	26.69	26.29
	max	32.03	27.54	26.55	28.55	28.47	27.50
	SD	0.38	0.50	0.30	0.42	0.45	0.33
	CV%	1.20	1.89	1.15	1.52	1.61	1.20
Imi	mean	31.99	30.47	30.60	29.98	32.23	30.82
	min	31.01	29.36	29.94	29.06	31.24	30.18
	max	32.75	31.31	31.08	30.82	32.73	31.34
	SD	0.55	0.46	0.31	0.53	0.40	0.31
	CV%	1.72	1.50	1.00	1.77	1.25	1.01

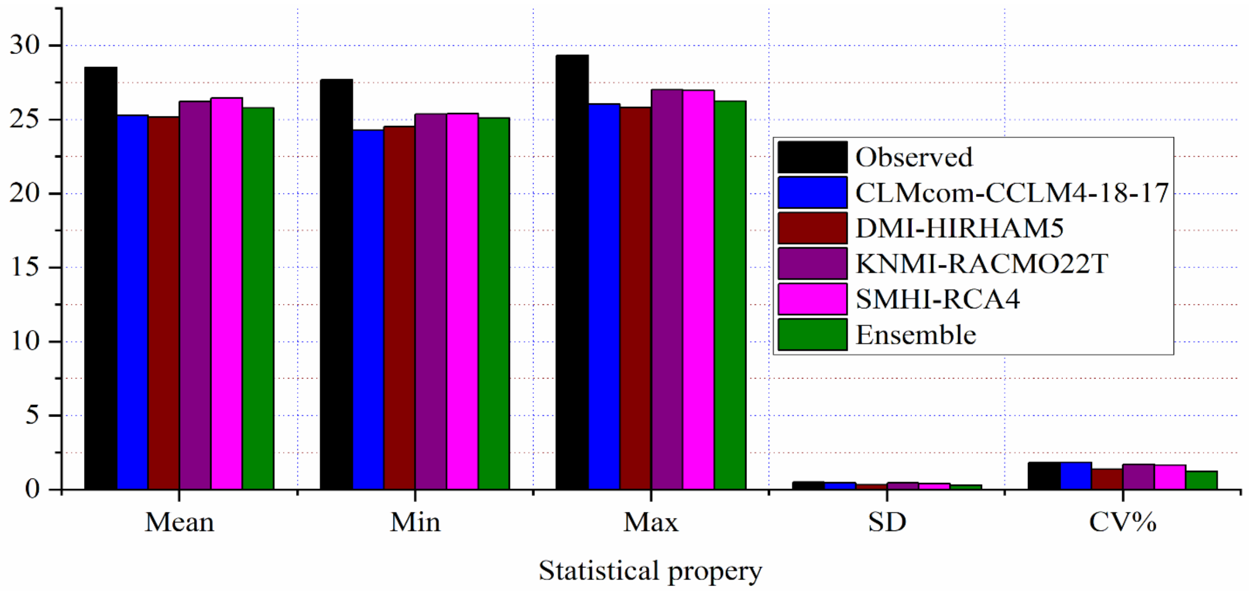


Figure 4.21 Average of basic Statistical property of observed and simulated maximum air temperature in Wabi shebele basin

Table 4.5 Seasonal coefficient of variation for observed and simulated maximum air temperature in stations of the Wabi shebele basin

Seasons	Basic statics	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Spring	mean	29.20	27.45	26.42	26.35	27.80	27.00
	min	27.79	25.53	25.39	23.51	26.37	25.47
	max	30.56	28.82	27.35	28.05	28.82	27.86
	SD	0.80	0.93	0.57	1.19	0.74	0.64
	CV	2.84	3.50	2.30	4.58	2.79	2.46
Summer	mean	27.41	23.51	25.15	26.16	26.42	25.31
	min	25.93	22.23	24.23	24.99	24.97	24.46
	max	28.86	24.91	25.82	27.39	27.72	26.10
	SD	0.73	0.73	0.42	0.64	0.67	0.46
	CV	2.76	3.29	1.82	2.64	2.68	1.91
Autumn	mean	28.30	24.68	25.05	25.37	25.79	25.22
	min	26.83	23.02	24.16	23.72	24.68	24.39
	max	29.48	26.66	26.17	26.88	26.87	26.21
	SD	0.68	0.99	0.46	0.83	0.63	0.52
	CV	2.52	4.19	2.03	3.31	2.52	2.12
Winter	mean	29.18	25.56	24.07	29.49	25.87	26.19
	min	28.01	23.78	23.03	26.10	24.83	24.92
	max	30.35	26.65	24.75	30.50	27.01	26.88
	SD	0.62	0.65	0.44	1.02	0.59	0.45
	CV	2.32	2.72	1.94	3.04	2.44	1.73

The coefficient of variation resulted from minimum temperature showed less variation of Observed and simulated RCMs except for observed and RCA4 data around Adaba station which was 25% and 21.64% respectively indicating moderate variability of event. For other three RCMs and observed data all over five stations of the study area resulted in less than 20% which means less variation of event. Regarding to the seasonal variation of minimum air temperature, all RCMs and observed data showed less than 20% CV around all stations of the study area. Generally, the network stations of the study area did not indicate variation in air temperature. However, some stations under the RCA4 model showed near the same variation with observed data at stations of the basin.

Table 4.6 Coefficient of variation for observed and simulated minimum air temperature over Wabi shebele basin

Stations	Basic statics	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Adaba	mean	5.83	8.76	7.97	8.08	4.50	7.33
	min	2.86	8.43	7.53	7.48	2.87	6.80
	max	7.21	9.27	8.46	8.95	6.46	8.03
	SD	1.49	0.24	0.26	0.36	0.97	0.30
	CV%	25.56	2.78	3.28	4.40	21.64	4.13
Girawa	mean	9.85	13.97	14.06	12.22	12.34	13.15
	min	8.79	13.35	13.52	11.13	11.60	12.77
	max	10.46	14.41	14.56	13.09	13.07	13.65
	SD	0.41	0.31	0.30	0.50	0.41	0.26
	CV%	4.20	2.19	2.11	4.13	3.35	2.00
Badesa	mean	12.04	13.91	15.66	12.97	14.49	13.81
	min	9.50	13.28	15.10	11.81	13.51	13.30
	max	13.58	14.30	16.14	13.64	15.34	14.22
	SD	0.88	0.28	0.25	0.49	0.45	0.30
	CV%	7.33	2.04	1.59	3.75	3.13	2.20
Gode	mean	23.53	22.57	25.39	19.91	22.17	22.51
	min	22.39	21.68	24.97	19.29	21.26	21.89
	max	24.12	23.33	25.83	20.54	22.98	22.96
	SD	0.46	0.36	0.23	0.39	0.37	0.26
	CV%	1.97	1.61	0.91	1.97	1.67	1.15
Degahabur	mean	19.37	16.67	18.65	16.53	16.18	17.01
	min	14.47	16.23	18.03	15.89	15.44	16.44
	max	30.29	17.36	19.08	17.16	16.88	17.40

	SD	3.40	0.34	0.30	0.41	0.36	0.26
	CV%	17.57	2.02	1.62	2.49	2.23	1.52
Imi	mean	20.76	21.41	24.07	18.68	21.05	21.30
	min	20.07	20.54	23.55	17.87	20.25	20.76
	max	21.30	22.29	24.45	19.23	22.00	21.89
	SD	0.35	0.42	0.26	0.44	0.43	0.30
	CV%	1.69	1.95	1.08	2.37	2.04	1.39

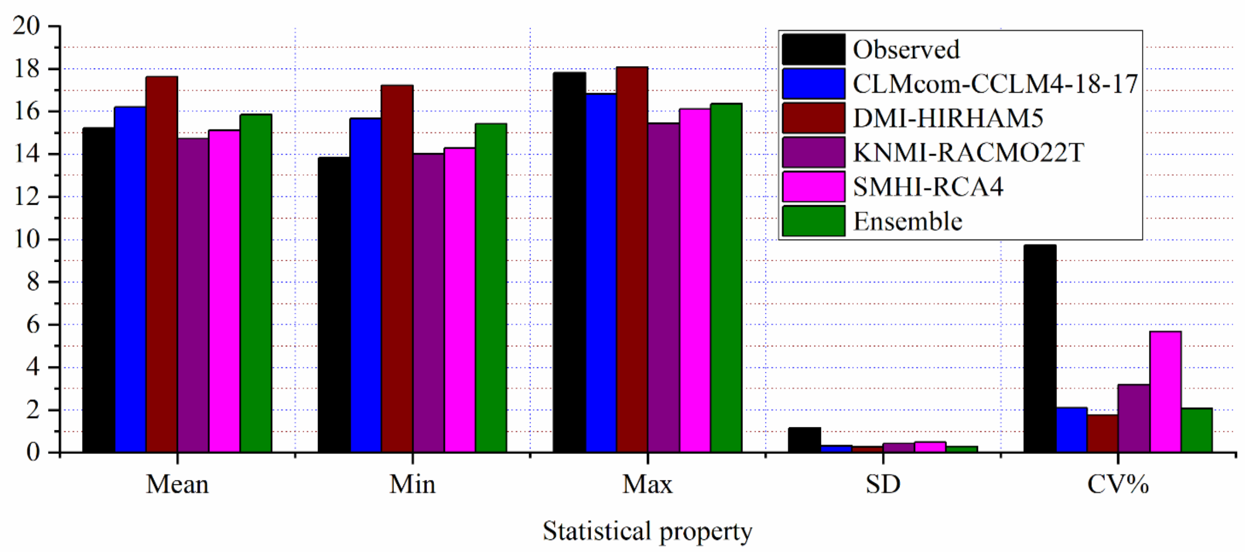


Figure 4.22 Average of statistical property of minimum air temperature over Wabi Shebele basin

Table 4.7 Seasonal coefficient of variation for observed and simulated minimum air temperature at stations of Wabi shebele basin

Seasons	Basic statics	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
Spring	mean	16.108	17.562	18.605	15.101	16.114	16.846
	min	13.048	16.668	17.733	14.202	14.963	16.085
	max	19.323	18.699	19.458	16.332	17.495	17.516
	SD	1.551	0.518	0.477	0.579	0.617	0.372
	CV	12.015	3.050	2.889	3.968	4.198	2.335
Summer	mean	15.899	16.857	18.773	16.698	18.235	17.641
	min	13.348	16.181	18.115	15.725	17.221	17.003

	max	18.721	17.628	19.315	17.720	19.250	18.194
	SD	1.284	0.410	0.311	0.481	0.511	0.297
	CV	10.395	2.453	1.805	3.141	2.873	1.790
Autum	mean	14.942	16.671	17.913	14.516	15.731	16.208
	min	12.684	15.783	17.170	13.246	14.813	15.672
	max	17.503	17.508	18.772	15.561	16.724	16.782
	SD	1.158	0.492	0.446	0.620	0.549	0.299
	CV	9.737	3.280	3.011	4.734	3.936	2.105
Winter	mean	13.875	13.794	15.229	12.611	12.052	13.582
	min	10.641	12.545	14.336	11.440	10.799	12.646
	max	17.246	15.421	16.061	13.880	13.832	15.024
	SD	1.734	0.719	0.437	0.671	0.721	0.554
	CV	16.812	5.787	3.728	6.244	7.843	4.716

The observed maximum and minimum air temperature data over the study area resulted in 10 out of 20 years (50%) no drought in the historical period. 7 out of 20 years (35%) are extreme drought for maximum temperature and 5 out of 20 for minimum air temperature while the remaining years showed moderate and severe drought. CCLM4-18-17 RCM Classified drought severity class for both maximum and minimum air temperature as discussed in table 4.8 and table 4.9. 13 out of 20 years (65%) showed no drought class for maximum temperature and 12 out of 20 years (60%) for minimum temperature. 6 out of 20 years (30%) and 5 out of 20 years (25%) are extreme droughts for maximum and minimum temperature respectively while others seven and eight years were classified under moderate and severe drought for maximum and minimum temperature respectively.

HIRHAM5 is classified as no drought class by 11 out of 20 years (55%) and 12 out of 20 years (60%) for maximum and minimum air temperature respectively. It classified for 7 out of 20 years (35%) extreme drought for maximum and 6 out of 20 years (30%) for minimum temperature while remaining years were moderate and severe drought class for Wabi Shebele basin under HIRHAM5 model. RACMO22T resulted in no drought class to maximum and minimum temperature for 15 out of 20 years (75%) and 14 out of 20 years (65%) respectively.

It classified extreme drought for 5 out of 20 years (25 %) and 6 out of 20 (30%) for maximum and minimum temperature over the study area. Generally, RACMO22T is classified under extreme and no drought class for both maximum and minimum air temperature over the study area in the historical period of 1986-2005. RCA4 showed 15 out of 20 years (75%) no drought and 5 out of 20 years (25%) extreme drought for maximum temperature and 12 out of 20 years (60%) no drought and 6 out of 20 years (30%) extreme drought for minimum temperature. Ensemble of the simulated RCMs classified drought based on temperature anomalies as discussed in table 4.32 and table 4.33. Hence, it resulted in 15 out of 20 years (75%) no drought, 3 out of 20 years (15%) extreme drought, and 2 out of 20 years (10%) severe drought class for maximum temperature. For minimum temperature also Ensemble data classified as no drought for 14 out of 20 years (70%) and 5 out of 20 years (25%) extreme drought for minimum temperature.

Table 4.8 Annual anomalies for mean observed and simulated maximum air temperature over Wabi shebele basin

Years	Observed	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	-1.00	-5.47	-4.11	-5.22	-9.12	-5.98
1987	0.67	-1.46	5.63	1.79	0.11	1.52
1988	0.96	0.97	-2.77	1.34	1.53	0.27
1989	-2.71	5.27	1.84	-0.39	0.50	1.81
1990	-1.66	1.46	1.63	-4.08	0.50	-0.12
1991	-1.39	1.30	-3.51	1.49	1.60	0.22
1992	-2.00	-2.20	-6.30	-6.67	-5.95	-5.28
1993	-3.22	-2.64	-5.51	0.12	1.98	-1.51
1994	-1.75	-8.95	-1.72	-3.31	-8.20	-5.55
1995	-0.97	1.63	2.93	-0.37	-2.11	0.52
1996	-2.09	3.21	-1.53	0.79	0.90	0.84
1997	-2.03	0.17	1.06	-3.09	1.33	-0.14
1998	0.88	1.45	-1.61	3.58	2.37	1.44
1999	1.77	1.34	-0.05	5.11	3.24	2.41
2000	2.37	4.82	3.91	1.40	4.71	3.71

2001	1.74	-2.04	0.89	-0.54	3.79	0.52
2002	3.24	-2.90	-1.94	1.38	-2.96	-1.61
2003	4.77	1.37	1.57	4.94	3.70	2.89
2004	1.88	0.98	6.04	1.19	1.53	2.44
2005	0.55	1.70	3.56	0.57	0.55	1.60

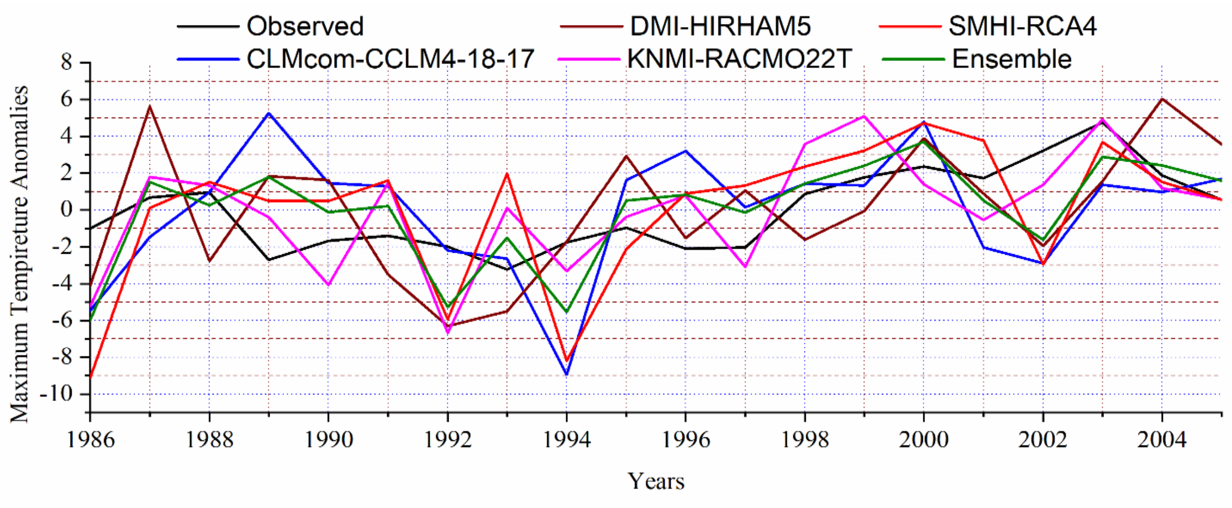


Figure 4.23 Annual anomalies of observed and simulated maximum air temperatures over Wabi shebele basin

Table 4.9 Annual anomalies of observed and simulated minimum air temperatures in Wabi shebele basin

Years	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
1986	-3.41	-4.29	-5.72	-3.20	-4.94	-4.54
1987	-1.79	-3.88	2.21	-4.43	-3.64	-2.44
1988	-2.36	-1.60	0.65	0.44	-0.77	-0.32
1989	-1.39	1.50	3.21	1.78	-3.38	0.78
1990	-0.28	0.62	0.96	0.57	1.45	0.90
1991	-0.92	1.00	2.88	2.78	1.31	1.99
1992	-0.19	-3.08	-4.38	-5.13	-4.38	-4.24
1993	-1.42	-4.10	-6.22	-4.70	-0.20	-3.80
1994	-3.09	-5.81	2.57	-6.63	-4.39	-3.56
1995	-2.75	-1.30	-2.31	0.27	-1.86	-1.30

1996	-0.27	3.05	-4.74	-1.66	0.62	-0.67
1997	0.33	3.74	0.16	-2.22	7.06	2.19
1998	0.79	3.32	-2.09	1.67	3.76	1.66
1999	-0.87	1.74	3.68	-0.81	-1.19	0.85
2000	0.22	6.08	5.58	4.51	3.84	5.00
2001	1.79	3.51	1.36	5.02	6.18	4.02
2002	4.00	-0.45	-1.15	1.35	-1.54	-0.45
2003	5.28	-0.23	0.14	3.80	-0.43	0.82
2004	5.60	1.77	4.29	3.10	1.08	2.56
2005	0.73	-1.59	-1.08	3.43	1.40	0.54

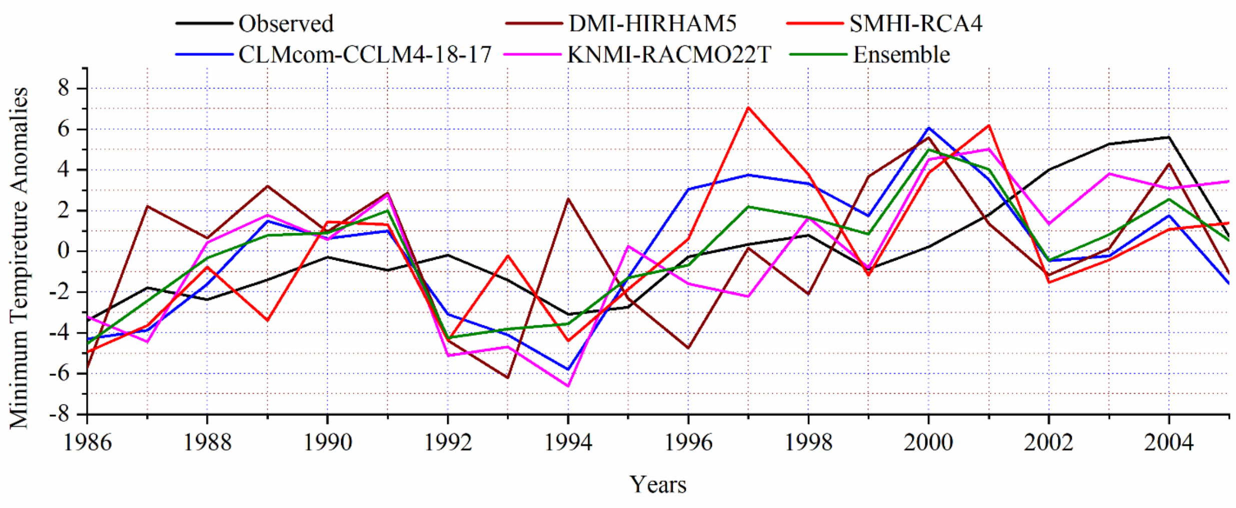


Figure 4.24 Annual anomalies of observed and simulated maximum temperatures in Wabi shebele basin

4.3 Trend analysis

The trend analysis was done for historical simulated and observed data (1986 to 2005) and future projected rainfall and temperature data. In the evaluation of the performance of the RCMs over the basin, RCA4 well performed over the study area in simulating both rainfall and air temperature better than others models including ensemble. So RCA4 will be used for climate impact study in this basin. Study on Projected Drought Events over West Africa (Ajayi.,2020) Using RCA4 model for trend and variability analysis over west Africa . RCA4 simulated bias-corrected rainfall and air temperature data served by data of the two illustrative concentration pathways (RCP), mid-range mitigation emission (RCP4.5) scenarios, and high emission scenario (RCP8.5) over the control period of the near future (2031 to 2050) and far future (2051 to 2070) data selected for future trend analysis over the Wabi Shebele basin.

4.3.1 Historical rainfall trend analysis

The MK test statistic for the rainfall in the periods of 1986-2005 showed that the observed and RCMs simulated including their ensemble have an anon-significant trend. The Sen's slope test indicated that the decreasing trend of rainfall by an average of -1.03, -5.38, -4.61 and -2.78 mm per annum for Observed, HIRHAM5, RCA4, and ensembles respectively. While non-significant increases by an average of 2.28 and 0.4678 mm per annum for CCLM4-18-17 and RACMO22T over the study area. However,specifically stations around u/s of the basin showed increasing while stations at d/s decreasing (Table 4.10) for observed and some models. The study by (Wudineh *et al*., 2021) also showed same trend, i,e less increasing trend is observed in annual rainfall in western and eastern upper basin whereas decreasing trend in middle and lower part of the basin . In general, all the models evaluated in this study showed insignificant trends during the historical period over Wabi Shebele basin.

Table 4.10 Man Kendall trend of observed and simulated rainfall during historical periods

Stations	Data sources	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	Observed	0.06	0.02	3	950	0.95	0.41	Accept Ho
	CCLM4-18-17	0.88	0.15	28	950	0.38	8.97	Accept Ho
	HIRHAM5	-1.07	-0.18	-34	950	0.28	-17.70	Accept Ho
	RACMO22T	-0.62	-0.11	-20	950	0.54	-2.82	Accept Ho
	SMHI-RCA4	-0.88	-0.15	-28	950	0.38	-4.93	Accept Ho
	Ensemble	-1.40	-0.23	-44	950	0.16	-4.07	Accept Ho
Girawa	Observed	-0.23	-0.04	-8	950	0.82	-5.13	Accept Ho
	CCLM4-18-17	0	0.00	0	950	1.00	0.20	Accept Ho
	HIRHAM5	-0.55	-0.10	-18	948	0.58	-1.63	Accept Ho
	RACMO22T	0.23	0.04	8	950	0.82	1.33	Accept Ho
	SMHI-RCA4	-0.62	-0.11	-20	950	0.54	-3.69	Accept Ho
	Ensemble	-1.46	-0.24	-46	950	0.14	-4.32	Accept Ho

Badesa	Observed	0.81	0.14	26	950	0.42	3.37	Accept Ho
	CCLM4-18-17	0.55	0.09	18	950	0.58	4.06	Accept Ho
	HIRHAM5	-0.55	-0.09	-18	950	0.58	-5.96	Accept Ho
	RACMO22T	1.46	0.24	46	950	0.14	7.40	Accept Ho
	SMHI-RCA4	-0.88	-0.15	-28	950	0.38	-9.60	Accept Ho
	Ensemble	-1.01	-0.17	-32	950	0.31	-3.69	Accept Ho
Gode	Observed	1.27	0.21	40	950	0.21	3.98	Accept Ho
	CCLM4-18-17	-0.16	-0.03	-6	950	0.87	-1.05	Accept Ho
	HIRHAM5	-0.49	-0.08	-16	950	0.63	-1.57	Accept Ho
	RACMO22T	0.03	0.01	2	950	0.97	0.08	Accept Ho
	SMHI-RCA4	-0.36	-0.06	-12	950	0.72	-1.50	Accept Ho
	Ensemble	-0.62	-0.11	-20	950	0.54	-0.96	Accept Ho
Degahabur	Observed	-1.46	-0.24	-46	950	0.14	-7.99	Accept Ho
	CCLM4-18-17	0.23	0.04	8	950	0.82	1.70	Accept Ho
	HIRHAM5	-1.20	-0.20	-38	950	0.23	-4.61	Accept Ho
	RACMO22T	-0.81	-0.14	-26	950	0.42	-2.45	Accept Ho
	SMHI-RCA4	-0.42	-0.07	-14	950	0.67	-1.95	Accept Ho
	Ensemble	-1.52	-0.25	-48	950	0.13	-2.92	Accept Ho
Imi	Observed	-0.16	-0.03	-6	950	0.87	-0.80	Accept Ho
	CCLM4-18-17	-0.10	-0.02	-4	950	0.92	-0.18	Accept Ho
	HIRHAM5	-0.16	-0.03	-6	950	0.87	-0.82	Accept Ho
	RACMO22T	-0.36	-0.06	-12	950	0.72	-0.78	Accept Ho
	SMHI-RCA4	-1.4	-0.23	-44	950	0.16	-5.97	Accept Ho
	Ensemble	-0.29	-0.05	-10	950	0.77	-0.69	Accept Ho

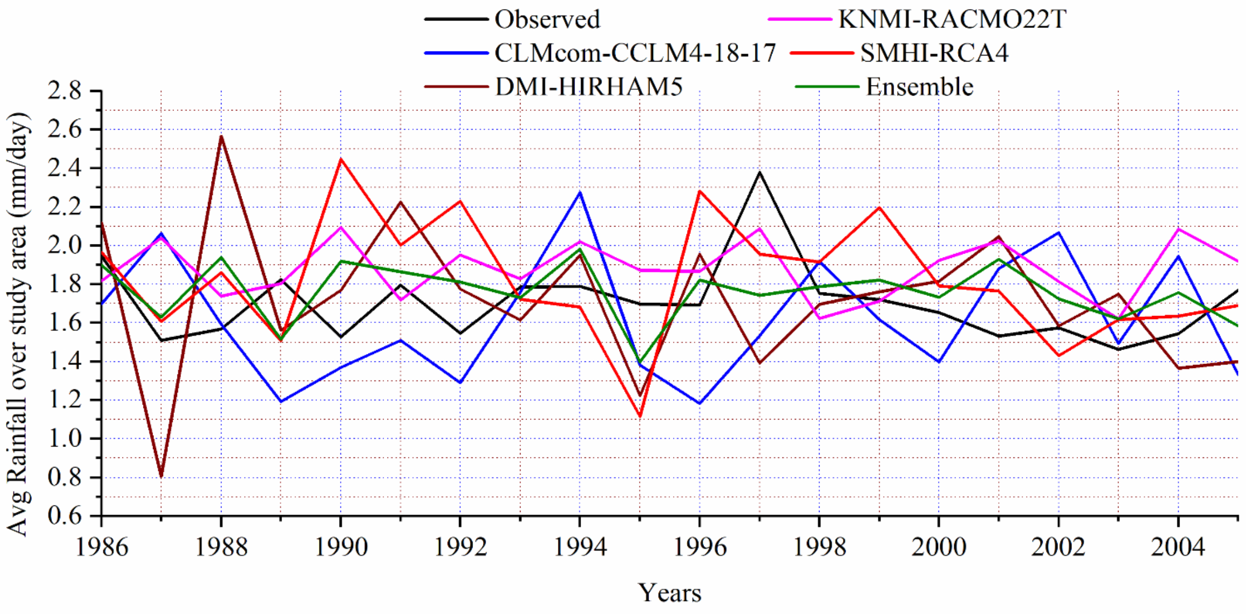


Figure 4.25 Average annual observed and simulated rainfall in Wabi shebele basin for historical periods

4.3.2 Projected rainfall trend analysis

Between 2031 and 2050 the MK test statistic (S) indicated a non-significant decreasing trend over most stations of Wabi Shebele. Only Imi station showed significant decreasing trend by -11.84 mm per annum for future projected rainfall under climate change scenarios of RCP8.5 as depicted in table 4.11. All stations with exception of Adaba station showed a non significant increasing trend under RCP4.5 in annual rainfall. Sen's slope test also indicated the non-significant increasing trend under RCP4.5 over the study area by an average of Sen's slope estimator 5.44 mm per annum.

Table 4.11 Man Kendall trend of simulated RCA4 rainfall for a future period (2031-2050)

Stations	scenario	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	RCP4.5	-0.36	-0.06	-12.00	950.00	0.72	-5.06	Accept Ho
	RCP8.5	0.29	0.05	10.00	950.00	0.77	3.10	Accept Ho
Girawa	RCP4.5	0.75	0.13	24.00	950.00	0.46	14.94	Accept Ho
	RCP8.5	-0.16	-0.03	-6.00	950.00	0.87	-4.67	Accept Ho
Badesa	RCP4.5	0.68	0.12	22.00	950.00	0.50	13.14	Accept Ho
	RCP8.5	-0.10	-0.02	-4.00	950.00	0.92	-1.50	Accept Ho
Gode	RCP4.5	0.68	0.12	22.00	950.00	0.50	1.99	Accept Ho
	RCP8.5	-0.49	-0.08	-16.00	950.00	0.63	-2.55	Accept Ho
Degahabur	RCP4.5	0.36	0.06	12.00	950.00	0.72	4.50	Accept Ho
	RCP8.5	-1.07	-0.18	-34.00	950.00	0.28	-12.09	Accept Ho
Imi	RCP4.5	0.94	0.16	30.00	950.00	0.35	3.14	Accept Ho
	RCP8.5	-2.95	-0.48	-92.00	950.00	0.01	-11.84	Reject Ho

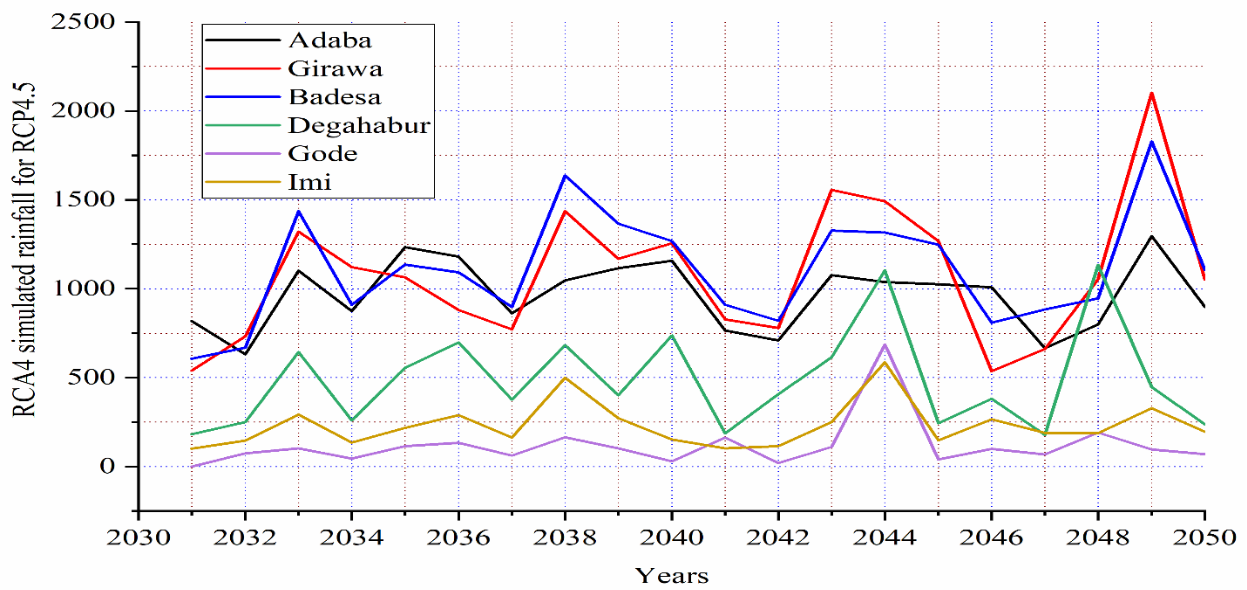


Figure 4.26 Annual simulated RCA4 rainfall at stations of study area under RCP4.5 for 2031-2050 periods

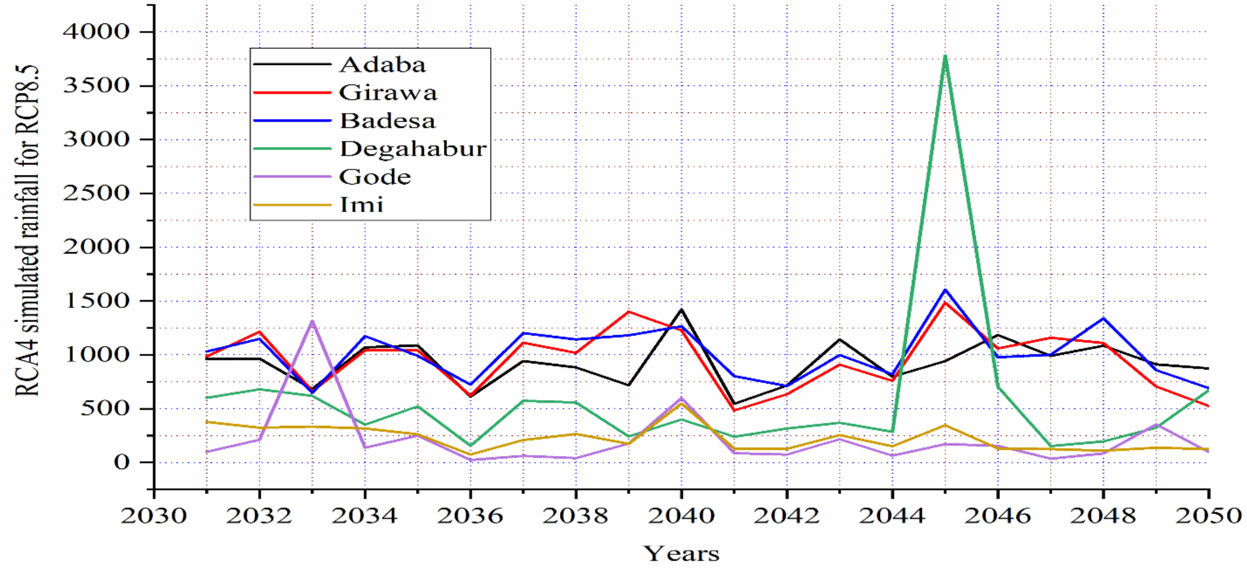


Figure 4.27 Annual simulated RCA4 rainfall over stations of study area under RCP8.5 for 2031-2050 periods

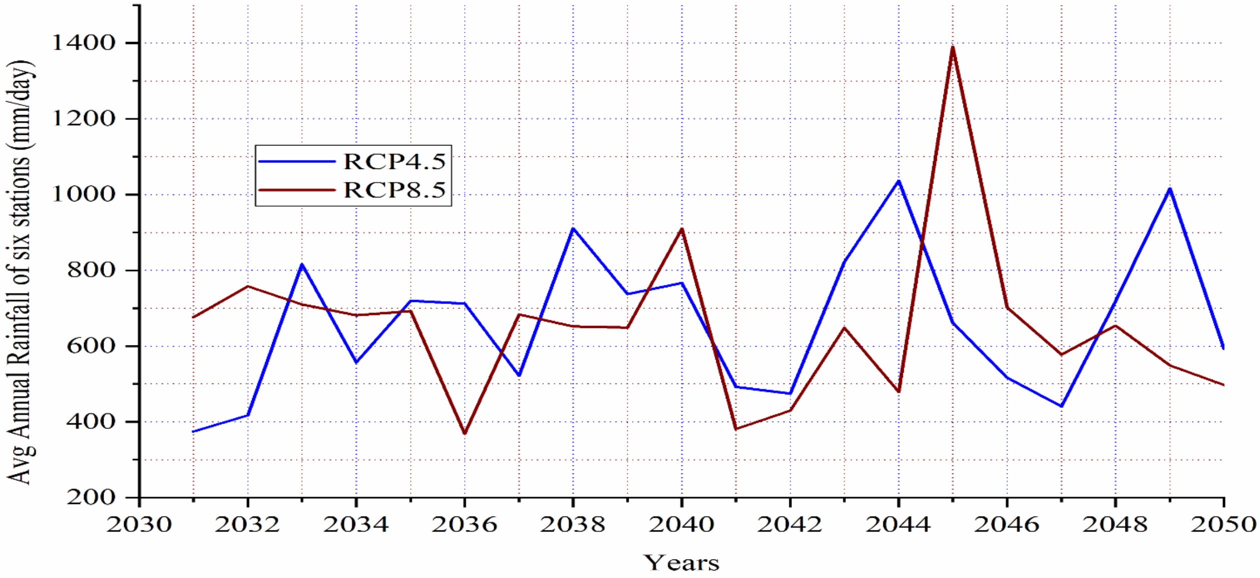


Figure 4.28 Average annual simulated RCA4 rainfall in Wabi shebele basin for 2031-2050 periods

For the future period of 251-2070, the rainfall shows a non-significant decreasing trend under RCP8.5 by an average of -2.22 mm per annum while no significant increasing trends under RCP4.5 by an average of 4.16 mm per annum over the study area.

Table 4.12 Man Kendall trend of simulated RCA4 rainfall for (2051-2070) periods

Stations	Scenarios	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	RCP4.5	1.85	0.31	58.00	950.00	0.06	0.41	Accept Ho
	RCP8.5	-0.03	-0.01	-2.00	950.00	0.97	-0.54	Accept Ho
Girawa	RCP4.5	0.03	0.01	2.00	950.00	0.97	0.39	Accept Ho
	RCP8.5	-0.42	-0.07	-14.00	950.00	0.67	-6.79	Accept Ho
Badesa	RCP4.5	-0.36	-0.06	-12.00	950.00	0.72	-3.58	Accept Ho
	RCP8.5	0.10	0.02	4.00	950.00	0.92	0.83	Accept Ho
Gode	RCP4.5	-0.26	-0.05	-9.00	949.00	0.80	-1.47	Accept Ho
	RCP8.5	2.04	0.34	64.00	950.00	0.04	6.76	Reject Ho
Degahabur	RCP4.5	0.94	0.16	30.00	950.00	0.35	8.76	Accept Ho
	RCP8.5	-1.46	-0.24	-46.00	950.00	0.14	-13.05	Accept Ho
Imi	RCP4.5	1.46	0.24	46.00	950.00	0.14	6.45	Accept Ho
	RCP8.5	-0.10	-0.02	-4.00	950.00	0.92	-0.54	Accept Ho

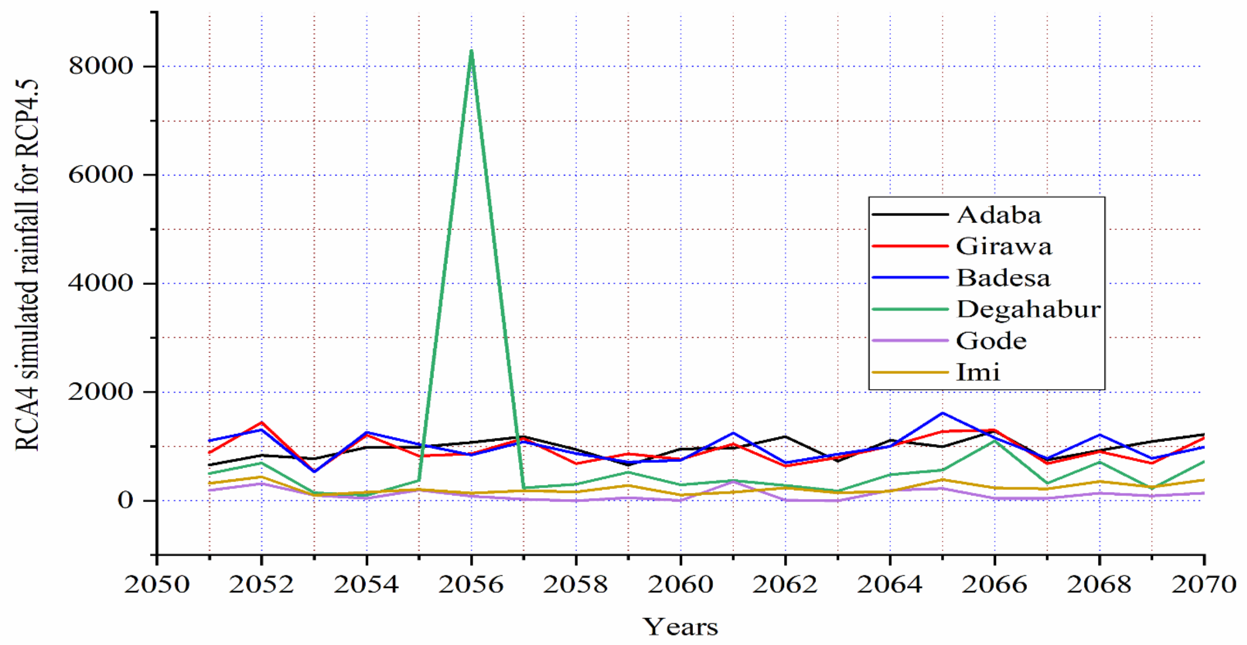


Figure 4.29 Annual simulated RCA4 rainfall at stations of study area under RCP4.5 for 2051-2070 periods

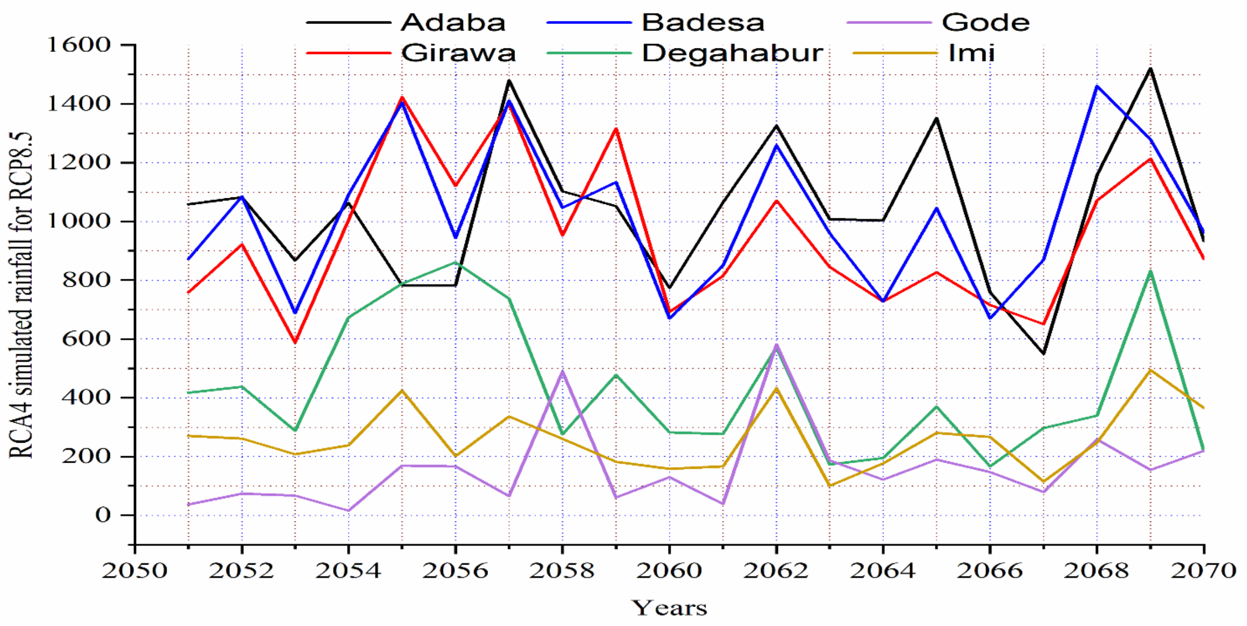


Figure 4.30 Annual simulated RCA4 rainfall at stations of study area under RCP8.5 for 2051-2070 periods

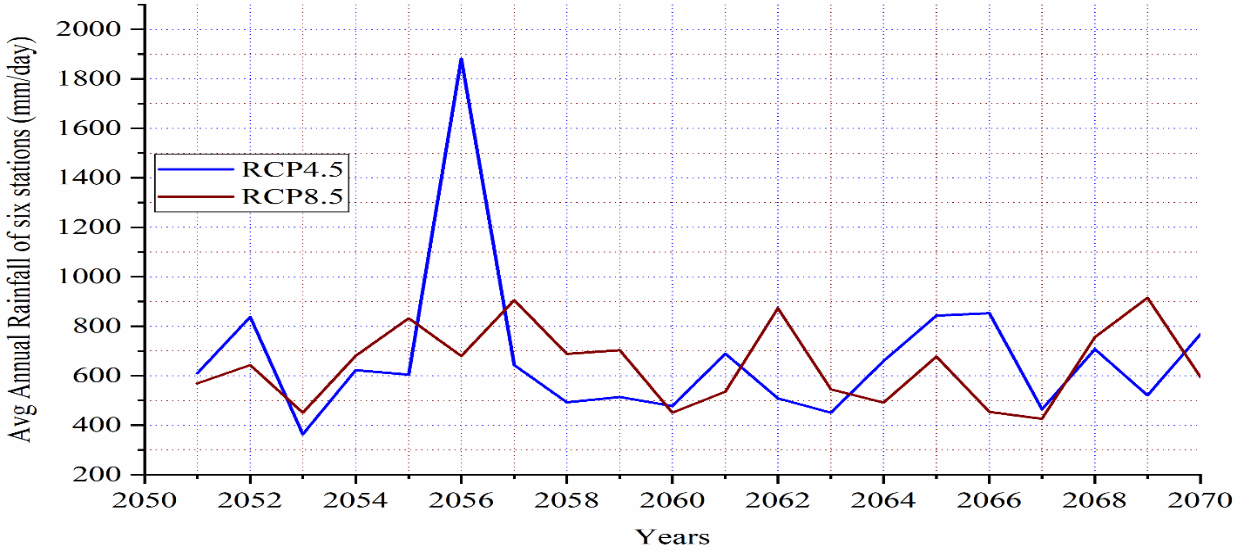


Figure 4.31 Average annual simulated RCA4 rainfall in Wabi shebele basin for 2051-2070 periods

4.3.3 Historical Air temperature trend analysis

The trend analysis of the annual trend of maximum air temperature during the historical period showed significantly increasing trends for observed and RCA4 over some stations. Observed data are significantly increased over Adaba, Girawa, and Degahabur at a 5% level of significance with slope estimator values of 0.05, 0.05, and 0.04 respectively while RCA4 0.02 ^{0}C per annum for

Adaba and Gode stations. On average other models showed non-significant increasing trends at all stations of the Wabi Shebele basin (Table 4.13).

Table 4.13 Man Kendall trend of simulated RCA4 maximum air temperatures for historical periods

Stations	Data sources	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	Observed	1.85	0.31	58	950	0.04	0.05	Reject Ho
	CCLM4-18-17	0.03	0.01	2	950	0.97	0.00	Accept Ho
	HIRHAM5	1.72	0.28	54	950	0.09	0.03	Accept Ho
	RACMO22T	1.27	0.21	40	950	0.21	0.01	Accept Ho
	RCA4	2.17	0.36	68	950	0.03	0.02	Reject Ho
	Ensemble	1.72	0.28	54	950	0.09	0.02	Accept Ho
Girawa	Observed	2.43	0.40	76	950	0.01	0.05	Reject Ho
	CCLM4-18-17	0.68	0.12	22	950	0.50	0.01	Accept Ho
	HIRHAM5	1.78	0.29	56	950	0.07	0.03	Accept Ho
	RACMO22T	1.78	0.29	56	950	0.07	0.03	Accept Ho
	RCA4	1.46	0.24	46	950	0.14	0.02	Accept Ho
	Ensemble	1.59	0.26	50	950	0.11	0.02	Accept Ho
Badesa	Observed	0.55	0.09	18	950	0.58	0.01	Accept Ho
	CCLM4-18-17	0.10	0.02	4	950	0.92	0.00	Accept Ho
	HIRHAM5	1.65	0.27	52	950	0.10	0.02	Accept Ho
	RACMO22T	1.33	0.22	42	950	0.18	0.03	Accept Ho
	RCA4	1.52	0.25	48	950	0.13	0.02	Accept Ho
	Ensemble	1.46	0.24	46	950	0.14	0.02	Accept Ho
Gode	Observed	-0.4	-0.06	-12	950	0.72	-0.01	Accept Ho
	CCLM4-18-17	0.55	0.09	18	950	0.58	0.01	Accept Ho
	HIRHAM5	1.46	0.24	46	950	0.14	0.01	Accept Ho
	RACMO22T	0.81	0.14	26	950	0.42	0.02	Accept Ho
	RCA4	1.98	0.33	62	950	0.04	0.02	Reject Ho
	Ensemble	1.14	0.19	36	950	0.26	0.01	Accept Ho

Degahabur	Observed	3.34	0.55	104	950	0.00	0.04	Reject Ho
	CCLM4-18-17	1.46	0.24	46	950	0.14	0.03	Accept Ho
	HIRHAM5	1.27	0.21	40	950	0.21	0.02	Accept Ho
	RACMO22T	1.46	0.24	46	950	0.14	0.02	Accept Ho
	SMHI-RCA4	1.33	0.22	42	950	0.18	0.02	Accept Ho
	Ensemble	1.72	0.28	54	950	0.09	0.02	Accept Ho
Imi	Observed	3.02	0.49	94	950	0.87	0.002	Reject Ho
	CCLM4-18-17	0.68	0.12	22	950	0.5	0.23	Accept Ho
	HIRHAM5	1.33	0.22	42	950	0.18	0.82	Accept Ho
	RACMO22T	1.10	0.18	34	950	0.28	0.78	Accept Ho
	RCA4	1.40	0.23	44	950	0.16	5.97	Accept Ho
	Ensemble	1.20	0.20	38	950	0.23	0.69	Accept Ho

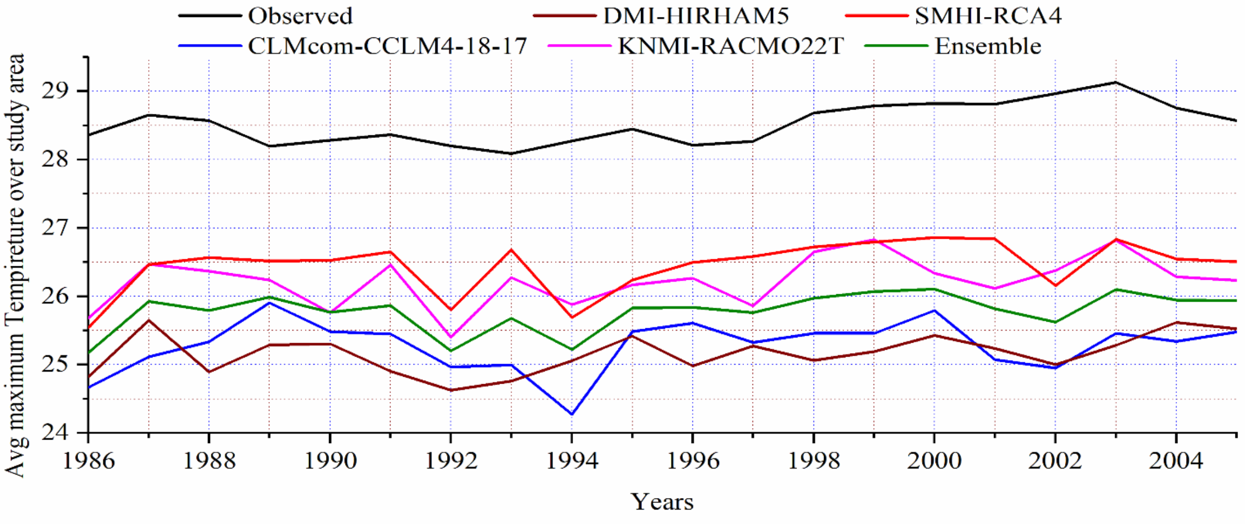


Figure 4.32 Average annual observed and simulated maximum air temperatures in Wabi shebele basin

The model interpretation for the historical period of 1986-2005 over Wabi shebele showed a significant and non-significant increasing trend for observed and simulated minimum air temperature. Observed data has significantly shown an increasing trend at 5% significance around Adaba, Girawa, and Imi stations with a magnitude of 0.15, 0.04, and 0.04 ^{0}C per annum respectively. CCLM4-18-17 also showed significant increasing trends over Adaba and Badesa with the value of 0.01 and 0.02 ^{0}C per annum.

RACMO22T has a significantly increasing trend over Adaba, Girawa, Badesa, Gode, and Degahabur with the value of 0.03, 0.05, 0.05, 0.04, and 0.04 ^{0}C per annum respectively. HIRHAM5 showed a non-significant increasing trend all over six stations of the study area with an average magnitude of 0.01 ^{0}C per annum.

RCA4 also has significant increasing trends over Gode and Imi stations with the value of sen's slope 0.02 and 0.03 ^{0}C per annum and non-significant increasing trend over other four stations, Adaba, Girawa, Badesa, and Degahabur as depicted in table 4.14. Finally, ensemble data showed a non-significant increasing trend over the study area with an average value of Sen's slope estimator 0.02 ^{0}C per annum.

Table 4.14 Man Kendall trend of simulated RCA4 minimum temperatures for historical periods

Stations	Data sources	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	Observed	2.56	0.42	80	950	0.01	0.15	Reject Ho
	CCLM4-18-17	2.30	0.38	72	950	0.02	0.01	Reject Ho
	HIRHAM5	1.27	0.21	40	950	0.21	0.01	Accept Ho
	RACMO22T	2.24	0.37	70	950	0.03	0.03	Reject Ho
	RCA4	0.49	0.08	16	950	0.63	0.01	Accept Ho
	Ensemble	1.20	0.20	38	950	0.23	0.02	Accept Ho
Girawa	Observed	2.82	0.46	88	950	0.00	0.04	Reject Ho
	CCLM4-18-17	1.91	0.32	60	950	0.06	0.03	Accept Ho
	HIRHAM5	0.16	0.03	6	950	0.87	0.00	Accept Ho
	RACMO22T	2.63	0.43	82	950	0.01	0.05	Reject Ho
	RCA4	1.65	0.27	52	950	0.10	0.03	Accept Ho
	Ensemble	3.01	0.49	94	950	0.00	0.03	Reject Ho
Badesa	Observed	1.85	0.31	58	950	0.06	0.06	Accept Ho
	CCLM4-18-17	2.04	0.34	64	950	0.04	0.02	Reject Ho
	HIRHAM5	0.62	0.11	20	950	0.54	0.01	Accept Ho
	RACMO22T	2.56	0.42	80	950	0.01	0.05	Reject Ho
	RCA4	1.27	0.21	40	950	0.21	0.03	Accept Ho
	Ensemble	2.70	0.44	84	950	0.03	0.03	Reject Ho

Gode	Observed	0.81	0.14	26	950	0.42	0.02	Accept Ho
	CCLM4-18-17	1.14	0.19	36	950	0.26	0.01	Accept Ho
	HIRHAM5	1.20	0.20	38	950	0.23	0.01	Accept Ho
	RACMO22T	2.43	0.40	76	950	0.01	0.04	Reject Ho
	RCA4	2.17	0.36	68	950	0.03	0.02	Reject Ho
	Ensemble	1.91	0.32	60	950	0.06	0.02	Accept Ho
Degah abur	Observed	0.49	0.08	16	950	0.63	0.05	Accept Ho
	CCLM4-18-17	1.91	0.32	60	950	0.06	0.03	Accept Ho
	HIRHAM5	0.29	0.05	10	950	0.77	0.01	Accept Ho
	RACMO22T	2.63	0.43	82	950	0.01	0.04	Reject Ho
	RCA4	1.72	0.28	54	950	0.09	0.03	Accept Ho
	Ensemble	2.50	0.41	78	950	0.01	0.03	Reject Ho
Imi	Observed	2.56	0.42	80	950	0.01	0.04	Reject Ho
	CCLM4-18-17	1.33	0.22	42	950	0.18	0.03	Accept Ho
	HIRHAM5	0.88	0.15	28	950	0.38	0.01	Accept Ho
	RACMO22T	1.72	0.28	54	950	0.09	0.04	Accept Ho
	RCA4	2.11	0.35	66	950	0.03	0.03	Reject Ho
	Ensemble	1.91	0.32	60	950	0.06	0.02	Accept Ho

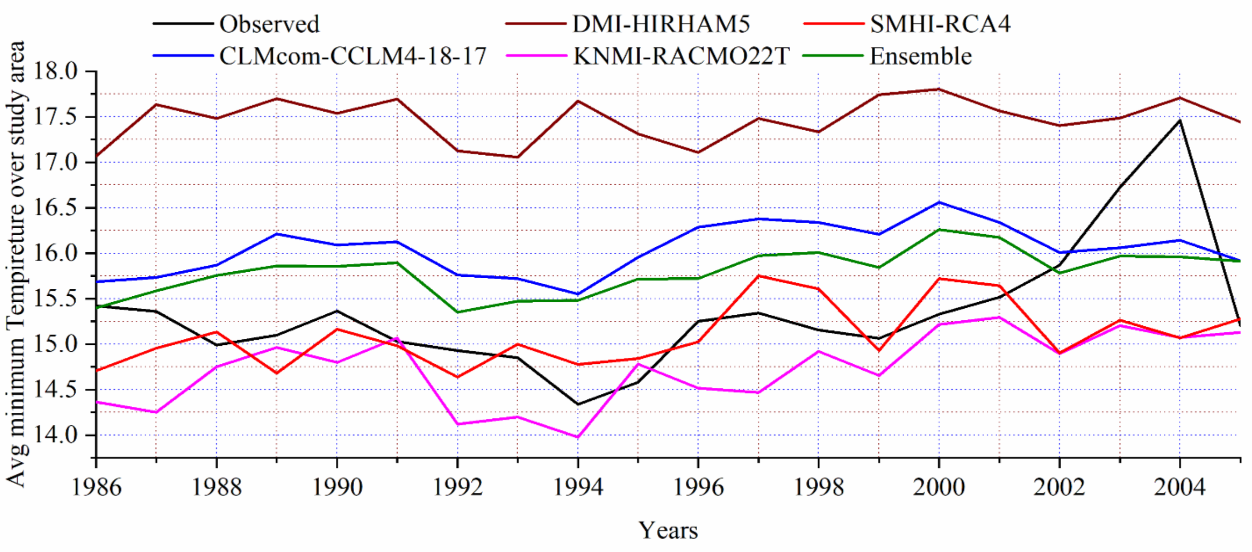


Figure 4.33 Average annual observed and simulate minimum air temperatures in Wabi shebele basin for historical periods

4.3.4 Projected air temperature trend analysis

The MK trend of maximum air temperature under RCA4 for a future time of 2031-2050 showed the non-significant increasing trend overall stations of Wabi Shebele under RCP4.5 with average Sen's slope estimator value of 0.042 ^{0}C per annum. For the RCP8.5 scenario, the maximum air temperature will be significantly increasing trend all over stations of Wabi Shebele at a 5% level of significance with average Sen's slope value of 0.06 ^{0}C per annum as discussed in table 4.18. The future period of 2051-2070 also showed the same trends with 2031-2050 under both RCP4.5 and RCP8.5 with an average value of 0.01 and 0.06 ^{0}C per annum respectively.

Table 4.15 Man Kendall trend of simulated RCA4 maximum temperatures for (2031-2050) periods

Stations	scenarios	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	RCP4.5	1.33	0.22	42.00	950.00	0.18	0.02	Accept Ho
	RCP8.5	3.54	0.58	110.00	950.00	0.00	0.06	Reject Ho
Girawa	RCP4.5	0.03	0.01	2.00	950.00	0.97	0.001	Accept Ho
	RCP8.5	3.28	0.54	102.00	950.00	0.00	0.07	Reject Ho
Badesa	RCP4.5	0.62	0.11	20.00	950.00	0.54	0.01	Accept Ho
	RCP8.5	3.15	0.52	98.00	950.00	0.00	0.08	Reject Ho
Gode	RCP4.5	1.72	0.28	54.00	950.00	0.09	0.02	Accept Ho
	RCP8.5	3.08	0.51	96.00	950.00	0.00	0.04	Reject Ho
Degahabur	RCP4.5	0.49	0.08	16.00	950.00	0.63	0.01	Accept Ho
	RCP8.5	2.37	0.39	74.00	950.00	0.02	0.06	Reject Ho
Imi	RCP4.5	0.55	0.09	18.00	950.00	0.58	0.01	Accept Ho
	RCP8.5	2.50	0.41	78.00	950.00	0.01	0.05	Reject Ho

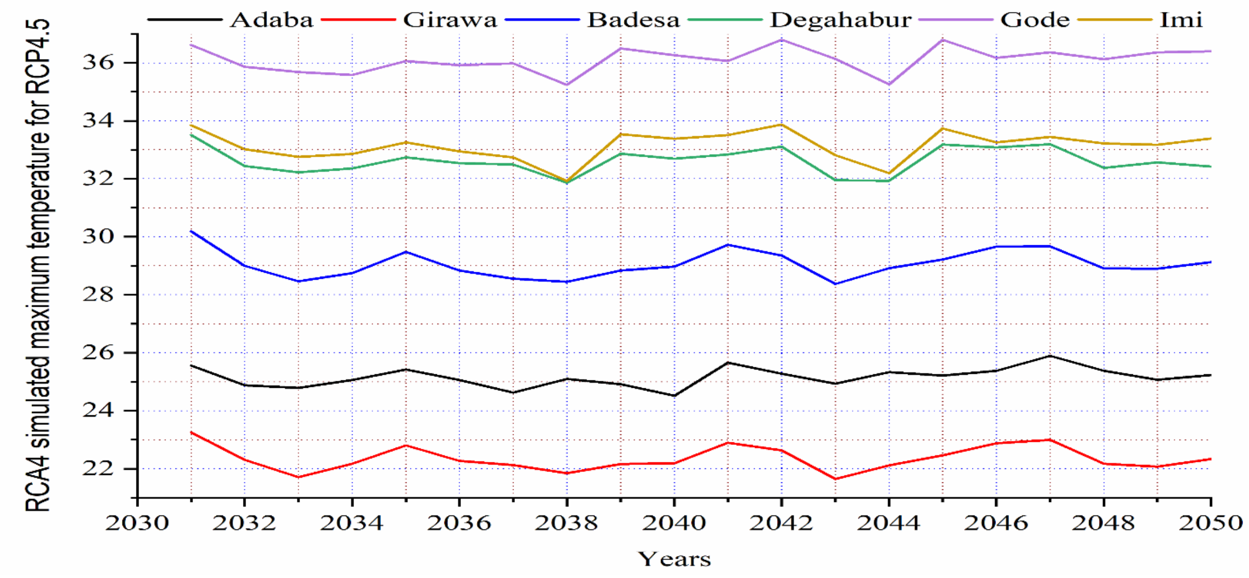


Figure 4.34 Annual simulated RCA4 maximum air temperature at stations of study area under RCP4.5 for 2031-2050 periods

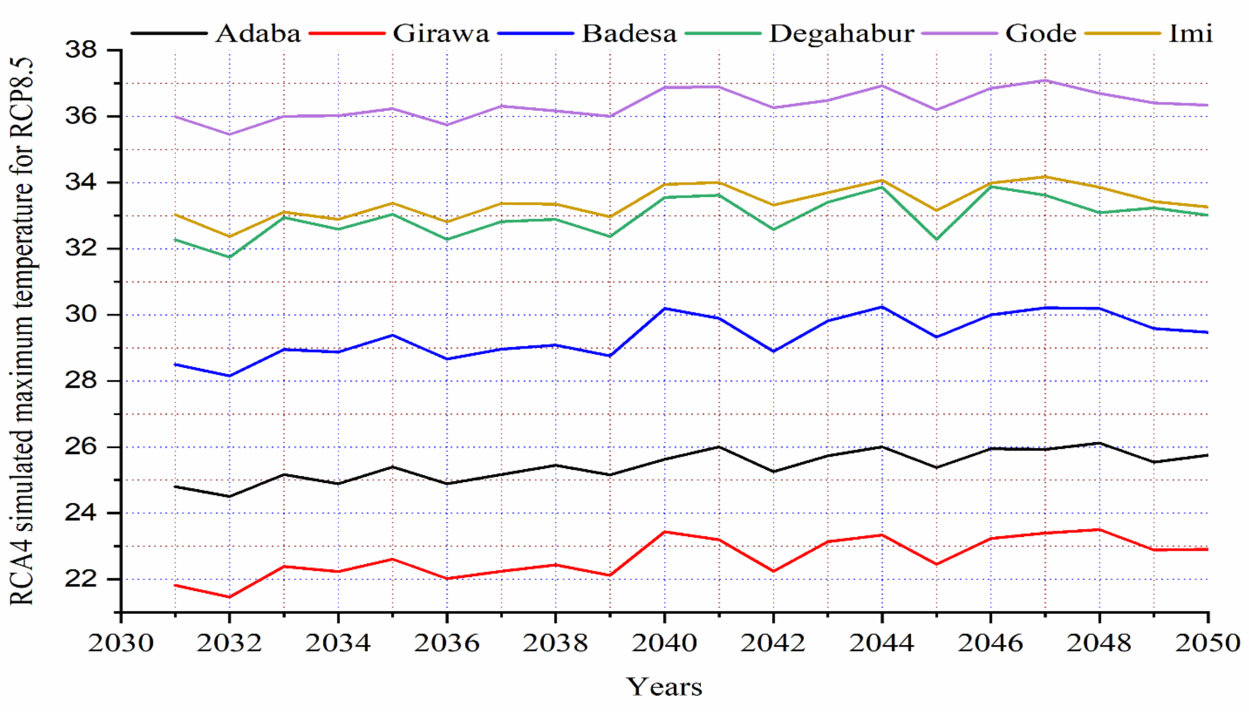


Figure 4.35 Annual simulated RCA4 maximum air temperature over stations of study area under RCP8.5 for 2031-2050 periods

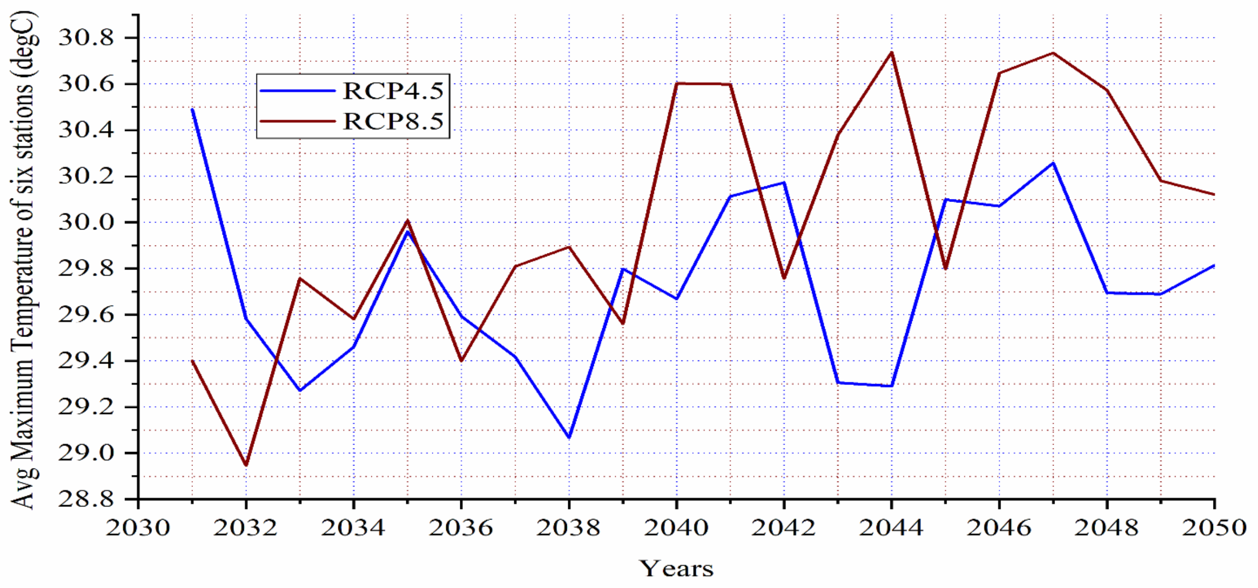


Figure 4.36 Average annual of simulated RCA4 maximum air temperature in Wabi shebele basin for 2031-2050 periods

Table 4.16 Man Kendall trend of simulated RCA4 maximum air temperatures for (2051-2070) periods

Stations	scenarios	Z	Kendall's Tau	S	Variance (S)	P-value	Sen's slope	Model output
Adaba	RCP4.5	-0.10	-0.02	-4.00	950.00	0.92	0.001	Accept Ho
	RCP8.5	4.57	0.75	142.00	950.00	0.00	0.06	Reject Ho
Girawa	RCP4.5	0.36	0.06	12.00	950.00	0.72	0.01	Accept Ho
	RCP8.5	3.67	0.60	114.00	950.00	0.00	0.06	Reject Ho
Badesa	RCP4.5	0.81	0.14	26.00	950.00	0.42	0.01	Accept Ho
	RCP8.5	3.54	0.58	110.00	950.00	0.00	0.07	Reject Ho
Gode	RCP4.5	0.49	0.08	16.00	950.00	0.63	0.01	Accept Ho
	RCP8.5	3.34	0.55	104.00	950.00	0.00	0.06	Reject Ho
Degahabur	RCP4.5	0.88	0.15	28.00	950.00	0.38	0.02	Accept Ho
	RCP8.5	3.21	0.53	100.00	950.00	0.00	0.06	Reject Ho
Imi	RCP4.5	0.42	0.07	14.00	950.00	0.67	0.01	Accept Ho
	RCP8.5	3.73	0.61	116.00	950.00	0.00	0.07	Reject Ho

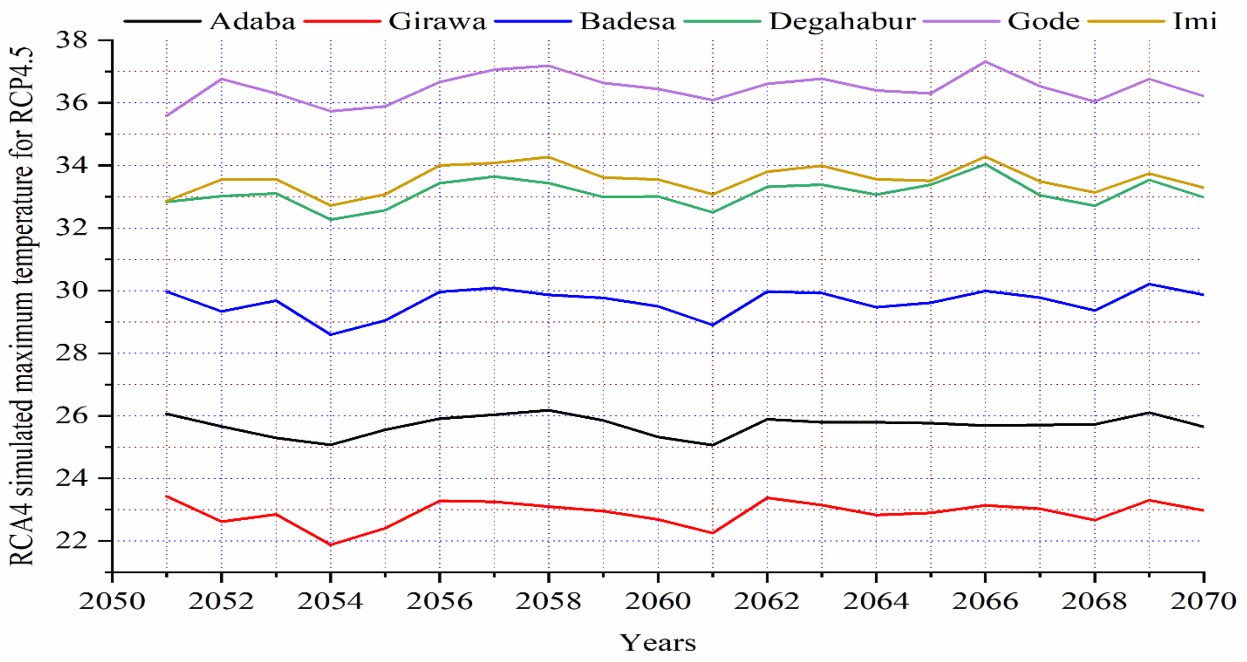


Figure 4.37 Annual simulated RCA4 maximum temperature over stations of study area under 4.5RCP for 2051-2070 periods

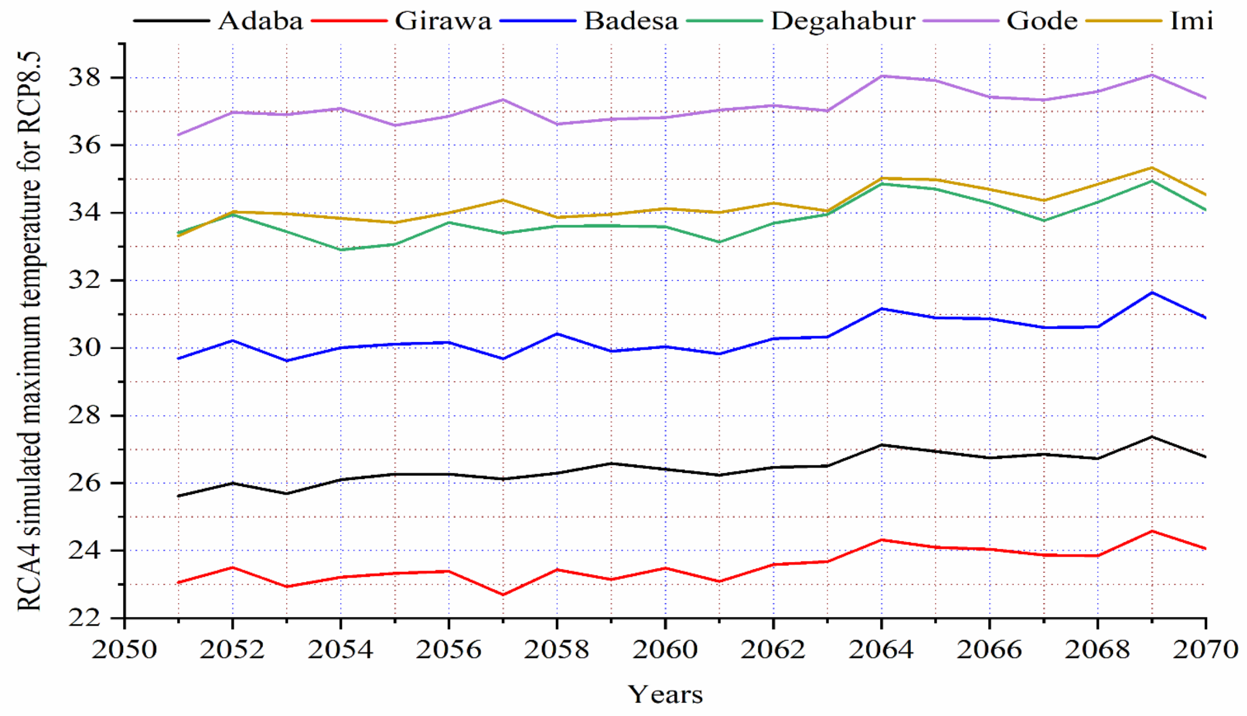


Figure 4.38 Annual simulated RCA4 maximum temperature over stations of study area under RCP8.5 for 2051-2070 periods

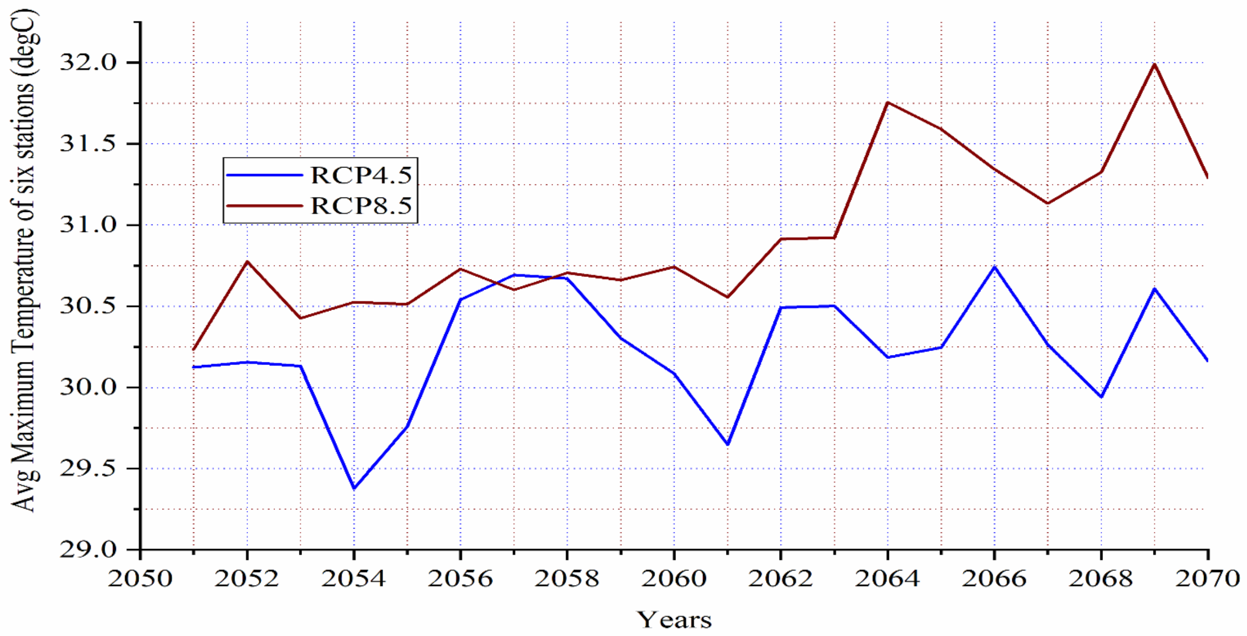


Figure 4.39 Average annual of simulated RCA4 maximum temperature in Wabi shebele basin for 2051-2070 periods

The MK trend of minimum temperature under RCA4 for the future time of 2031-2050 and 2051-2070 showed the non-significant increasing trend overall stations of Wabi Shebele under RCP4.5 with average Sen's slope estimator value of 0.04 and 0.02 ^{0}C per annum. For the RCP8.5 scenario, the minimum temperature has a significantly increasing trend all over stations of Wabi Shebele at a 5% level of significance with an average Sen's slope value of 0.07 and 0.06 ^{0}C per annum as depicted in table 4.17 and table 4.18.

Table 4.17 Man Kendall trend of simulated RCA4 minimum temperatures for 2031-2050 periods

Stations	scenarios	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	RCP4.5	1.98	0.33	62.00	950.00	0.06	0.05	Accept Ho
	RCP8.5	4.06	0.66	126.00	950.00	0.001	0.07	Reject Ho
Girawa	RCP4.5	1.78	0.29	56.00	950.00	0.07	0.03	Accept Ho
	RCP8.5	3.60	0.59	112.00	950.00	0.001	0.07	Reject Ho
Badesa	RCP4.5	1.33	0.22	42.00	950.00	0.18	0.03	Accept Ho
	RCP8.5	3.86	0.63	120.00	950.00	0.001	0.08	Reject Ho
Gode	RCP4.5	2.43	0.40	76.00	950.00	0.01	0.05	Accept Ho

	RCP8.5	3.02	0.49	94.00	950.00	0.001	0.06	Reject Ho
Degahabur	RCP4.5	1.58	0.31	58.00	950.00	0.06	0.03	Accept Ho
	RCP8.5	3.15	0.52	98.00	950.00	0.001	0.05	Reject Ho
Imi	RCP4.5	1.72	0.28	54.00	950.00	0.09	0.03	Accept Ho
	RCP8.5	2.89	0.47	90.00	950.00	0.001	0.06	Reject Ho

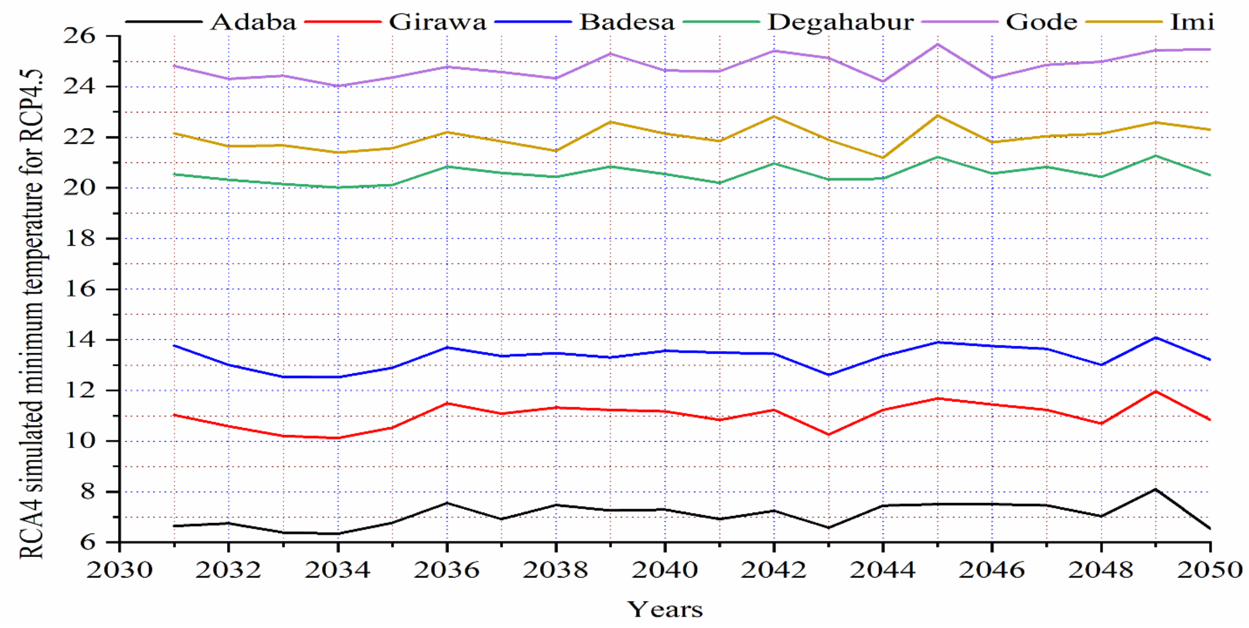


Figure 4.40 Annual simulated RCA4 minimum air temperature over stations of study area under RCP4.5 for 2031-2050 periods

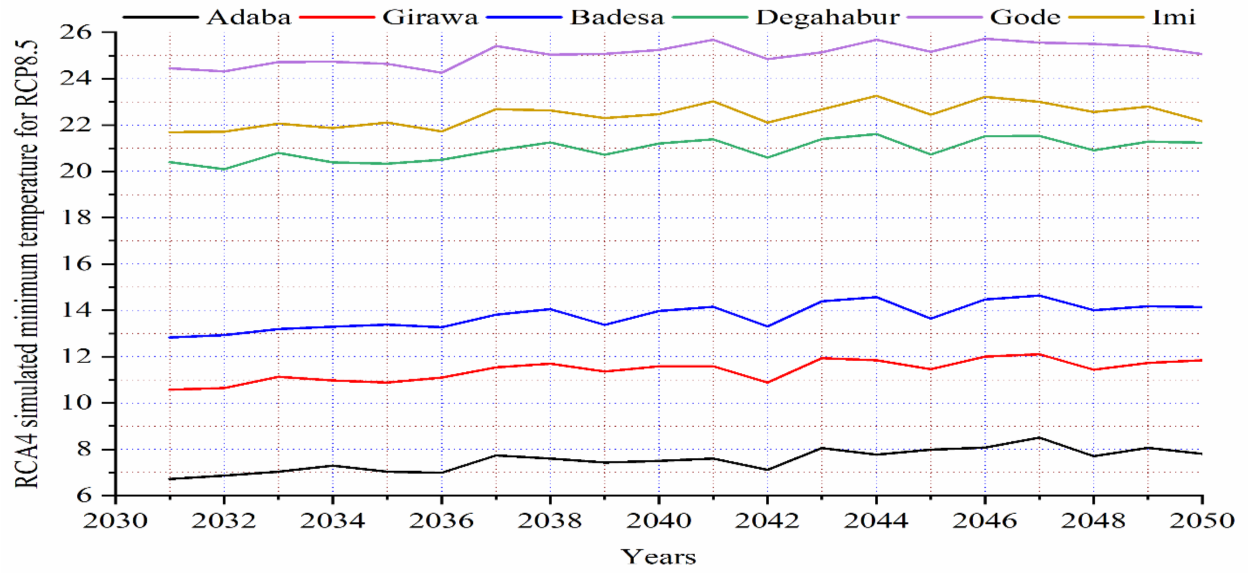


Figure 4.41 Annual simulated RCA4 minimum air temperature over stations of study area under RCP8.5 for 2031-2050 periods

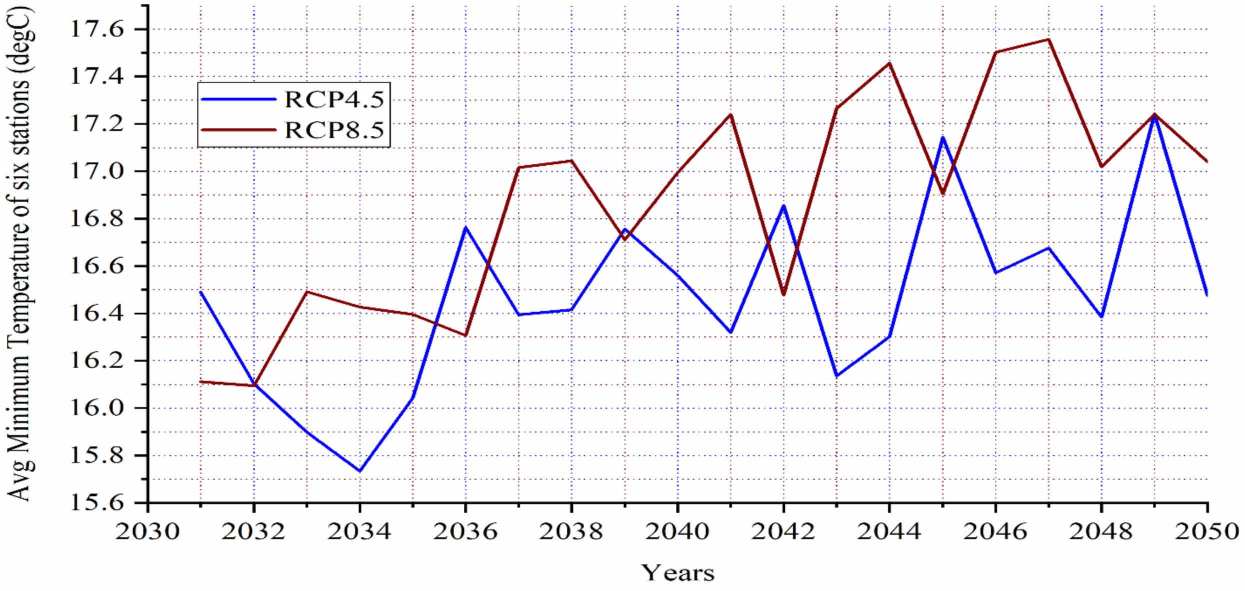


Figure 4.42 Average annual simulated RCA4 minimum temperature in Wabi shebele basin for 2031-2050 periods

Table 4.18 Man Kendall trend of simulated RCA4 minimum temperatures for 2051-2070 periods

Stations	Scenarios	Z	Kendall's Tau	S	Variance (S)	P value	Sen's slope	Model output
Adaba	RCP4.5	0.62	0.11	20.00	950.00	0.54	0.01	Accept Ho
	RCP8.5	3.02	0.49	94.00	950.00	0.00	0.06	Reject Ho
Girawa	RCP4.5	0.75	0.13	24.00	950.00	0.46	0.01	Accept Ho
	RCP8.5	2.56	0.42	80.00	950.00	0.01	0.06	Reject Ho
Badesa	RCP4.5	0.88	0.15	28.00	950.00	0.38	0.02	Accept Ho
	RCP8.5	2.24	0.37	70.00	950.00	0.03	0.05	Reject Ho
Gode	RCP4.5	1.07	0.18	34.00	950.00	0.28	0.03	Accept Ho
	RCP8.5	2.56	0.42	80.00	950.00	0.01	0.05	Reject Ho
Degahabur	RCP4.5	0.68	0.12	22.00	950.00	0.50	0.01	Accept Ho
	RCP8.5	2.76	0.45	86.00	950.00	0.01	0.05	Reject Ho
Imi	RCP4.5	0.36	0.06	12.00	950.00	0.72	0.01	Accept Ho
	RCP8.5	2.82	0.46	88.00	950.00	0.00	0.06	Reject Ho

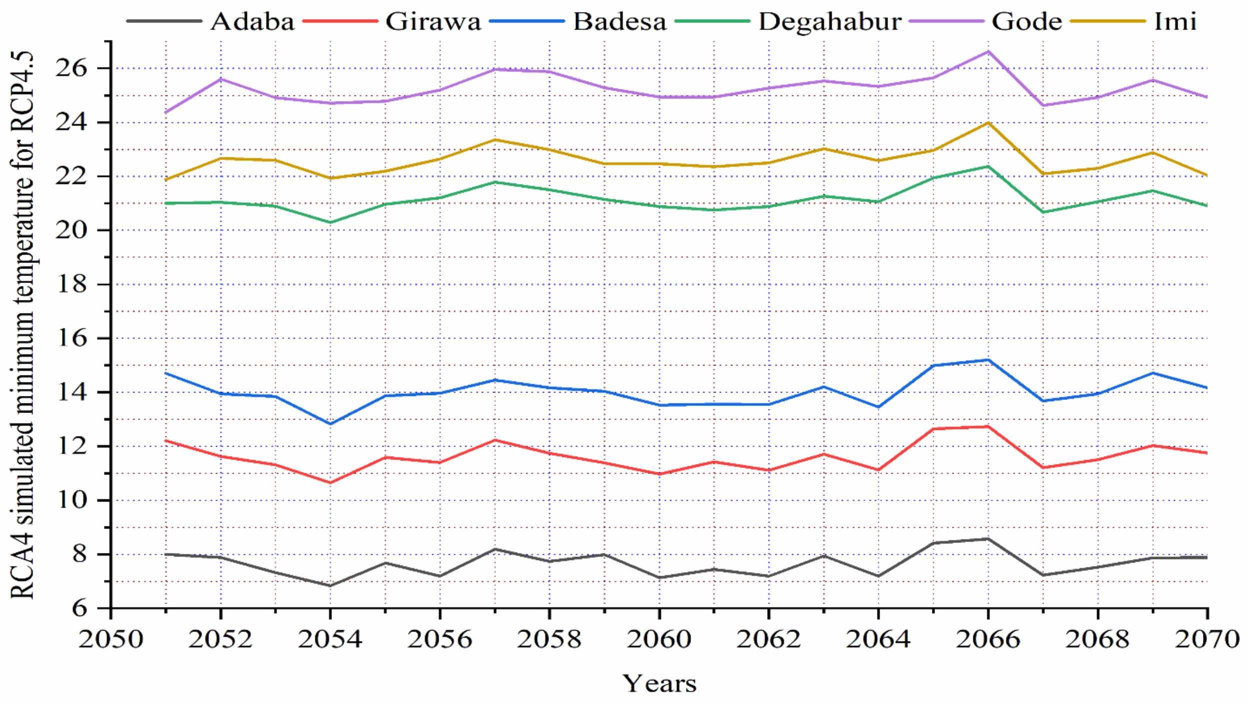


Figure 4.43 Annual simulated RCA4 minimum air temperature at stations of study area under RCP4.5 for 2051-2070 periods

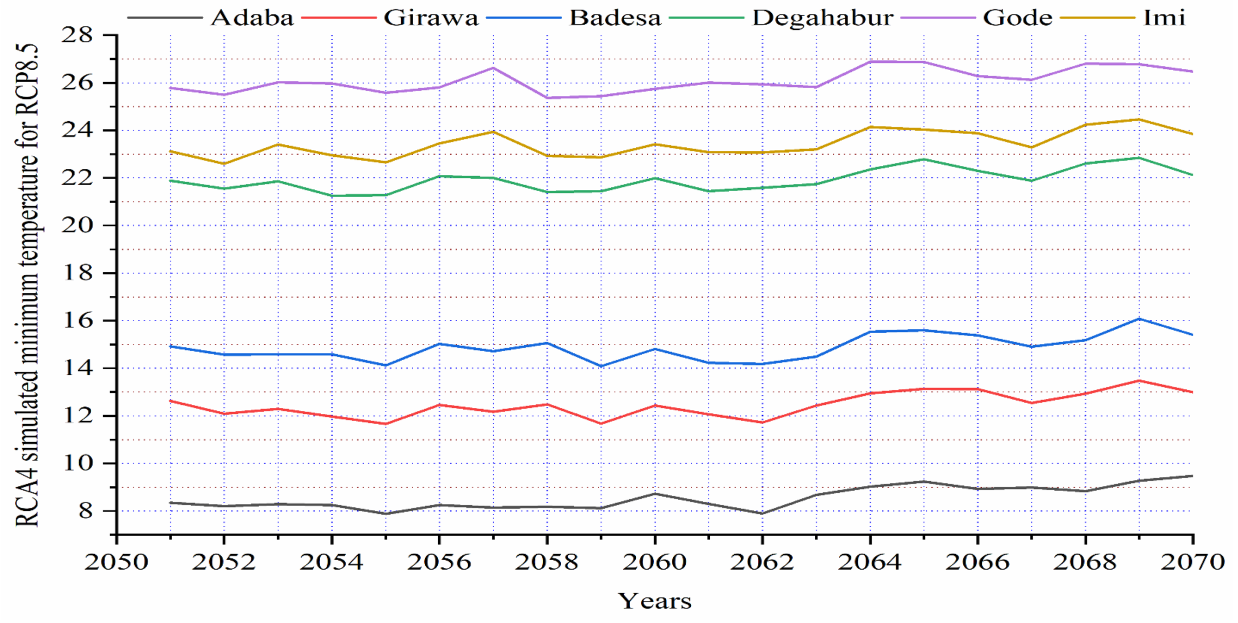


Figure 4.44 Annual simulated RCA4 minimum air temperature at stations of study area under RCP8.5 for 2051-2070 periods

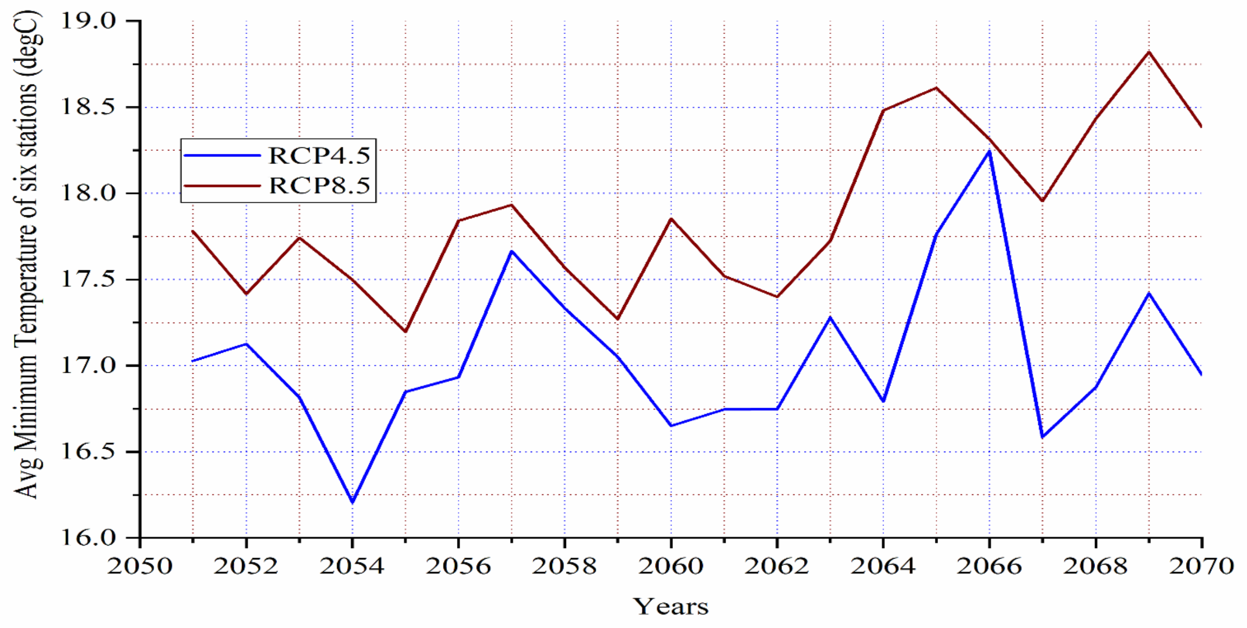


Figure 4.45 Average annual of simulated RCA4 minimum air temperature in Wabi shebele basin for 2051-2070 periods

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study has evaluated the performance of the individual models and ensemble average in detail for Wabi shebele basin in simulating rainfall and air temperature. Further, this study examined how well the CORDEX RCMs simulate Mean monthly, interannual variability, and trends of rainfall and air temperature. Some RCMs tended to simulate over and underestimation while others follow the path of observed data in the Wabi shebele basin. Based on mean annual common statistical property analysis, montly cycle, and variability analysis, RCA4 and RACMO22T simulate rainfall over most stations better than the other models and ensemble of them. RCA4 also showed better performance in simulating maximum and minimum temperature over the basin. The interannual variability of observed and simulated RCMs over the study area is discussed by the coefficient of variation and anomalies.

The study used bias-corrected rainfall and temperature under RCP4.5 and RCP8.5 scenarios for future trend analysis. The results of trend analysis for rainfall and temperature series are important for policymakers, water resources management, and agriculture. The trend is analyzed for observed, simulated RCMs and for ensemble in the historical period while the future trend is analyzed for best performing models in simulating rainfall and temperature accordingly. The MK test statistic for the period of 1986-2005 showed anon-significant increasing and a decreasing trend in rainfall over stations of basin for observed, simulated RCMs and ensemble. Therefore, it can be inferred that, no significant change in rainfall for observed and simulated RCMs during the 1986–2005 (historical) period in the study area. In both the future periods of 2031-2050 and 2051 -2070 the MK test statics indicated the non-significant increasing rainfall trend for RCP4.5 and non-significant decreasing trend for RCP8.5 over most stations of the study area with different trend magnitude. The maximum and minimum observed and simulated air temperature in historical periods showed a significant and non-significant increasing trend over Wabi shebele basin. For both future periods of 2031-2050 and 2051-2070 maximum and minimum temperature showed a non-significant increasing trend for RCP4.5 and a significant increasing trend for RCP8.5 over the basin.Generally, this study presents a first performance evaluation of individual RCMs and their ensemble average under African CORDEX over the Wabi Shebele basin.

5.2 RECOMMENDATIONS

From the perspective of this research, it is highly recommend evaluating and assess climate change impact over the Wabi Shebele basin with better performed and resolution RCMs data sets. Better performed Individual or ensemble of RCMs models set again recommended for the study of others hydrological analysis like flood forecasting and drought analysis of basin. Hence, in the study of Climate impact modelling over the Wabi Shebele basin RCA4 and RACMO22T performed better under African CORDEX. The results also suggest further investigations, to examine other meteorological series available in the Wabi Shebele basin and others RCMs under African CORDEX to know the best performed models in the study area.

Furthermore, RCA4 is highly recommended to estimate variability and trends of air temperature and rainfall for the others projected future periods, which is essential for the design, operation, and management of water resources projects. The study analysis suggests that the impact assessments of the climate change in the Wabi Shebele basin are well-represent by the RCMs simulations. However, the limited availability of several meteorological stations with full quality hydro-climatic data in the basin needs urgent attention to improve the performance evaluation of the models.

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APPENDIX

APPENDIX – 3a METEROLOGICAL DATA

Station name: Adaba

Element: Monthly total rainfall (mm/day)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	0	66	23.2	91.1	64.4	98.4	190	183.2	38.6	15	8.1	0	778.0
1987	10	22.1	115.7	75.6	86.6	14.7	105.3	165.3	38.4	114	2.6	7.3	757.4
1988	0	128	2.1	128.1	24.2	106.8	179.7	152.4	67	56.2	0	0	844.8
1989	0	25.1	100.3	188	15.2	69.6	250.8	123.4	75.7	16.8	3.1	50.5	918.5
1990	10.6	162	100.4	151.6	16.2	13.6	118.5	337.6	56.3	4.2	3.3	50.9	1025
1991	0	0	0	119.3	25.5	167.4	211.3	222.4	32.3	32.3	0	0	810.5
1992	0	0	0	0	76.9	78.7	138.5	264.8	0	31.6	1.7	31	623.2
1993	0	0	0	119.3	25.5	167.4	211.3	222.4	32.3	32.3	0	0	810.5
1994	0	0	16.1	98.3	147	126.6	173.6	244.6	81.3	14.4	27.5	0.6	929.7
1995	0.4	10	86.7	131.4	19.1	52.6	219	227	88.5	26.8	0.5	5.8	867.8
1996	30.1	14.2	72.4	82.6	81.2	75.1	177.7	230	94.9	0	6	0	864.2
1997	22.5	0	54.2	125.5	50	62.8	230.5	149.4	27.7	94.3	1	13.6	831.5
1998	107	69.9	31.2	48.2	48.6	67.6	143.1	219.6	118.6	146	3.7	1.5	1005.1
1999	23.9	0	68.3	12.1	55.1	97.8	250.4	165.8	101.5	90	0	0.2	865.1
2000	1.4	0	2.6	49.1	63.7	90.1	261.6	202.9	74.8	42.2	15.9	0	804.3
2001	21.6	7.1	139.3	17.7	87.7	96.7	157.2	137.8	59.7	28.6	2	9.4	764.8
2002	40.1	6.9	70.2	42.1	47.7	56.7	135	125.8	53.7	25.7	0.3	66.9	671.1
2003	13.3	4.8	53.3	86.8	31.3	125.2	275.3	163.3	80	14	0.8	43.8	891.9
2004	26.7	10.6	23.7	66.1	3	48.3	175.3	156.3	70.9	43.6	8.9	23.4	656.8
2005	27.1	9	94.8	91.2	143	69.8	261.6	201.6	100.5	39.3	14.2	0	1052.1

Station name: Adaba

Element: Monthly average of maximum tempireture (c^{o})

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	26.4	24.1	23.7	22.6	24.1	22.7	21.7	20.8	22.7	22.6	23.7	24.7	23.3
1987	25.8	28.0	24.8	22.0	23.3	24.6	23.8	22.3	23.4	23.6	24.6	25.2	24.3
1988	25.6	24.0	26.3	23.3	26.3	24.7	21.7	21.1	21.9	22.6	23.7	25.3	23.9
1989	26.1	24.7	23.1	22.8	24.2	24.2	22.4	23.5	23.5	23.8	23.4	22.8	23.7
1990	24.6	22.4	22.9	23.1	25.8	23.6	22.1	21.5	22.9	24.5	24.2	25.2	23.6
1991	25.3	25.6	24.9	26.0	26.0	26.2	25.1	24.8	22.0	23.6	22.4	24.1	24.7
1992	25.1	24.3	24.3	24.6	25.1	25.1	23.3	22.9	21.5	23.2	21.6	23.5	23.7
1993	25.0	24.9	24.1	23.9	24.7	25.0	22.5	22.0	21.3	23.0	21.1	23.3	23.4
1994	24.9	24.8	23.9	23.5	24.5	23.9	21.6	21.0	21.0	22.7	20.7	23.0	23.0
1995	24.9	24.7	23.8	23.2	24.3	25.0	21.8	21.7	23.0	22.3	23.5	23.4	23.5
1996	23.8	26.4	25.5	23.8	24.4	22.8	21.9	21.8	23.3	23.4	23.3	23.0	23.6
1997	25.1	26.3	26.6	23.6	25.0	24.8	21.9	22.7	23.8	22.2	23.3	23.4	24.0
1998	23.6	24.2	23.2	24.6	23.9	24.5	22.2	20.8	22.6	22.2	23.2	23.8	23.2
1999	24.5	26.7	25.4	25.8	25.4	25.4	21.8	22.5	23.2	22.4	23.5	24.3	24.2
2000	24.8	26.3	27.4	25.2	25.1	25.0	22.1	21.4	21.8	22.0	23.0	24.5	24.0
2001	24.7	25.6	23.3	24.8	25.6	23.2	22.2	22.5	22.9	23.4	23.7	24.3	23.8
2002	23.7	25.0	24.6	25.6	26.5	25.0	25.1	22.2	23.2	23.9	25.2	24.8	24.6
2003	25.6	27.1	26.5	25.3	26.3	25.1	22.9	22.1	22.8	23.5	24.2	23.8	24.6
2004	25.7	25.6	26.3	24.5	27.5	25.0	21.8	22.6	23.7	23.2	24.7	25.5	24.7
2005	25.6	27.1	25.7	25.6	23.4	24.2	22.1	23.2	23.6	23.2	23.5	24.1	24.3

Station name: Adaba

Element: Monthly average of minimum tempireture (c^{o})

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	1.9	4.9	4.3	5.7	5.2	6.0	5.8	5.6	5.4	4.6	3.1	1.4	4.5
1987	0.4	2.1	4.3	4.5	5.4	5.3	5.9	6.0	5.5	5.1	3.4	0.8	4.1
1988	0.4	4.6	2.6	3.9	3.8	4.2	6.0	6.1	5.3	5.0	1.2	-2.1	3.4
1989	-0.1	2.2	3.7	4.4	3.7	2.8	5.7	5.3	4.9	3.1	2.3	2.6	3.4
1990	3.8	4.6	1.8	2.4	2.0	2.4	3.7	4.4	4.8	2.7	1.7	-0.1	2.9
1991	1.4	3.4	4.0	4.2	3.9	4.4	4.9	5.0	6.9	4.5	4.0	2.2	4.1
1992	2.5	4.3	6.3	6.6	5.7	6.9	7.0	7.3	8.0	5.4	5.2	3.4	5.7
1993	3.0	5.0	7.4	7.8	6.7	7.4	8.1	8.5	8.5	5.8	5.8	4.0	6.5
1994	3.3	5.3	7.9	8.4	7.1	9.5	9.1	9.7	9.1	6.3	6.3	4.6	7.2
1995	3.5	5.5	8.5	9.3	7.6	7.8	9.3	9.2	7.1	7.3	5.8	4.9	7.2
1996	5.5	5.2	8.5	6.7	8.6	9.3	9.0	7.8	7.8	6.5	5.4	4.1	7.0
1997	4.7	4.0	7.6	9.6	7.0	7.2	9.0	7.4	6.8	8.6	4.7	3.1	6.6
1998	8.0	6.7	6.0	6.2	6.7	6.7	9.0	7.7	9.0	9.1	3.9	2.1	6.8
1999	3.3	5.4	7.9	7.5	7.0	7.5	9.1	7.5	7.3	7.7	3.3	3.7	6.4
2000	3.5	3.4	5.7	7.7	8.5	7.7	8.6	9.0	7.9	8.1	4.7	3.4	6.5
2001	4.3	3.9	7.4	8.5	8.3	8.4	9.0	9.6	7.6	7.5	4.8	4.6	7.0
2002	5.3	4.5	7.3	7.7	8.4	8.9	8.6	8.0	7.3	6.5	4.5	7.2	7.0
2003	4.6	4.7	6.2	8.4	7.9	8.5	9.0	9.3	7.9	5.7	5.4	4.2	6.8
2004	5.9	4.9	5.7	9.5	6.8	6.3	8.6	8.4	7.5	5.8	5.2	4.6	6.6
2005	5.2	4.6	7.1	8.6	9.6	7.9	8.9	9.0	9.0	7.7	4.5	1.2	6.9

Station name: Badesa

Element: Monthly total rainfall (mm/day)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	0.0	54.7	31.8	128.3	232.6	230.7	113.9	114.9	89.4	45.1	0.0	1.6
1987	0.0	16.8	143.8	89.4	253.5	22.8	0.0	31.1	127.6	47.7	0.0	0.0
1988	5.2	25.0	0.0	245.3	0.0	181.0	212.6	201.6	156.2	53.1	8.5	2.4
1989	4.2	64.0	25.1	232.3	23.2	111.0	80.6	152.1	184.7	55.7	16.9	66.1
1990	3.2	102.9	50.2	219.3	56.5	40.9	121.9	170.8	194.4	64.0	4.8	17.1
1991	1.5	50.6	201.9	238.3	67.0	48.2	173.1	163.0	192.3	61.2	10.5	8.6
1992	0.8	53.8	152.3	247.8	72.3	51.8	200.0	159.0	191.2	59.8	13.4	4.3
1993	0.4	55.3	127.4	252.6	74.9	53.6	212.1	157.1	190.6	59.1	14.8	2.1
1994	0.2	56.1	115.0	254.9	76.2	69.7	226.9	155.1	190.1	58.4	16.2	0.0
1995	0.0	56.9	102.6	257.3	77.5	55.4	224.2	126.2	129.1	34.2	0.0	8.9
1996	37.2	9.4	117.2	191.4	178.7	133.6	154.9	164.0	164.6	32.7	40.2	1.3
1997	1.7	0.0	149.0	105.3	87.0	195.7	173.1	95.2	70.4	307.0	133.2	5.8
1998	49	30.9	30.2	103	165	123	162	92.6	138.5	156	18.6	0
1999	9	0.6	135	75.4	76.3	92.3	215	211	132.3	302	26.3	0.5
2000	0	0	16	128	142	63.1	136	167.1	214.3	147	97.3	14.2
2001	0	7.6	58.8	106	149	109	166	153.4	181.7	41.9	7.4	17.2
2002	17	0	69.6	48.2	106	56.3	108	150.8	94.9	50.5	0	72.2
2003	1.5	0	55.2	117	65.9	136	212	149.1	106.3	3.2	18.3	10.8
2004	21	0	55	338	33.7	77.2	153	117.3	258.1	135	18.8	31.2
2005	9.3	2.1	99.3	191	215	66.3	179	138.2	152	50	58	0

Station name: Badesa

Element: Monthly average of maximum tempireture (c^{o})

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	29.0	29.5	29.1	27.2	28.0	27.8	28.6	28.4	29.3	29.6	29.6	29.2	28.8
1987	29.2	29.3	27.0	28.8	28.4	29.3	29.4	29.1	28.1	29.1	29.8	29.3	28.9
1988	29.6	28.7	31.4	29.3	29.5	28.0	22.4	28.5	27.4	28.5	28.5	28.4	28.4
1989	28.4	28.3	29.6	27.4	28.6	27.6	24.7	27.7	27.0	27.6	27.9	27.7	27.7
1990	27.9	28.1	28.0	25.6	28.1	27.3	27.0	26.8	26.6	28.0	27.2	27.0	27.3
1991	27.3	27.8	27.8	26.5	27.9	27.7	26.3	26.1	26.6	28.0	27.5	27.4	27.2
1992	27.7	27.7	27.2	26.9	27.8	26.7	26.0	25.8	26.6	28.0	27.7	27.6	27.1
1993	27.9	29.1	26.9	27.1	27.7	27.4	25.8	25.6	26.6	28.0	27.8	27.7	27.3
1994	28.0	29.3	28.2	27.3	27.7	27.5	25.6	25.4	26.6	28.0	27.9	27.8	27.4
1995	28.1	29.5	26.6	26.3	27.7	28.1	26.3	26.1	26.7	27.8	28.5	28.5	27.5
1996	27.4	29.8	28.9	27.0	26.7	25.9	25.6	25.7	26.1	27.2	28.2	27.1	27.1
1997	28.0	29.1	29.3	26.3	27.6	27.4	26.3	27.5	28.3	27.7	27.2	27.1	27.6
1998	26.6	28.2	28.9	29.7	28.7	28.2	27.3	26.6	27.1	26.9	27.6	27.8	27.8
1999	28.5	29.8	27.5	28.9	27.8	27.5	26.4	26.5	26.7	26.5	27.7	26.7	27.5
2000	29.2	29.7	30.8	29.5	27.9	28.1	27.6	26.6	26.2	27.5	27.3	27.1	28.1
2001	26.8	29.1	28.8	29.3	28.0	27.7	27.4	27.2	26.7	27.2	28.0	27.9	27.8
2002	27.3	30.0	28.8	27.6	29.4	29.0	28.4	27.4	27.5	29.1	29.0	27.6	28.4
2003	28.2	30.2	30.8	29.7	29.6	27.9	26.4	26.7	27.7	29.6	29.7	27.6	28.7
2004	29.1	29.6	29.4	27.8	28.6	26.9	26.8	26.7	26.4	26.5	27.9	26.8	27.7
2005	26.6	30.7	29.3	28.7	26.6	26.7	26.4	27.0	27.0	26.9	27.3	27.1	27.5

Station name: Badesa

Element: Monthly average of minimum tempireture (c^{o})

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	8.8	11.0	12.6	13.7	12.7	13.0	12.9	12.2	11.7	11.7	9.4	10.2	11.7
1987	9.5	11.4	12.7	12.3	11.9	11.4	10.7	11.1	12.4	10.6	10.8	11.3	11.3
1988	11.3	8.9	8.3	11.9	9.3	11.9	13.5	11.6	13.0	11.4	10.5	12.7	11.2
1989	11.7	11.2	11.4	11.5	10.6	12.3	13.7	12.8	13.3	11.8	10.3	11.9	11.9
1990	12.0	12.4	13.5	11.1	11.9	12.8	13.8	14.1	13.6	12.0	10.1	11.0	12.4
1991	12.2	13.5	14.6	11.9	10.6	11.1	14.0	14.2	13.3	12.1	8.9	10.8	12.3
1992	10.8	12.1	14.3	12.3	9.9	10.2	14.1	14.3	13.1	12.2	8.3	10.7	11.8
1993	10.1	12.0	14.1	12.4	9.5	9.8	14.1	14.3	13.1	12.2	8.0	10.7	11.7
1994	9.7	11.7	14.0	12.6	9.2	9.4	14.2	14.3	13.0	12.2	7.8	10.6	11.6
1995	9.4	11.5	13.9	14.4	13.0	13.6	14.2	14.4	13.0	12.2	7.6	10.6	12.3
1996	12.3	10.6	15.6	14.1	14.6	15.1	14.5	14.4	14.1	12.7	9.9	7.3	12.9
1997	10.4	9.9	14.0	14.3	12.9	13.7	14.7	14.7	13.2	13.8	13.9	12.0	13.1
1998	12.7	13.2	14.8	15.4	15.3	14.6	12.0	10.6	10.3	8.5	5.9	3.8	11.4
1999	6.3	6.8	10.0	10.0	12.7	12.8	13.7	13.5	13.2	7.4	4.9	2.8	9.5
2000	7.6	9.6	13.0	14.3	14.3	13.6	14.6	14.1	14.0	11.5	10.2	9.3	12.2
2001	9.4	10.8	14.2	14.2	14.1	13.6	14.5	14.4	12.9	11.7	7.4	9.6	12.2
2002	13.1	11.5	13.8	15.4	14.6	14.7	15.1	15.1	14.2	12.1	9.6	14.0	13.6
2003	11.5	13.0	14.6	15.7	14.2	14.6	14.5	14.8	13.5	11.2	11.2	9.8	13.2
2004	12.4	10.9	11.8	14.3	12.6	14.1	14.2	14.1	13.2	13.3	9.7	10.1	12.5
2005	11.5	9.7	13.5	13.0	14.1	13.7	13.9	14.1	13.1	10.2	9.1	7.3	11.9

Station name: Girawa

Element: Monthly total rainfall (mm/day)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	0.0	15.1	78.8	303.0	216.9	80.0	83.8	107.7	221.7	29.1	14.8	30.2	1181.1
1987	15.5	17.3	42.0	221.8	153.7	63.2	43.6	117.0	185.1	40.2	9.5	45.3	954.1
1988	13.8	19.4	5.1	145.2	52.4	56.6	71.2	107.6	166.8	45.7	6.9	52.9	743.4
1989	12.9	3.9	247.2	381.9	49.4	50.0	98.8	98.2	148.5	51.2	4.2	60.4	1206.6
1990	12.0	68.1	62.2	183.7	32.6	47.0	39.5	193.7	61.8	7.0	25.4	0.0	733.0
1991	31.0	35.1	218.7	129.0	123.1	42.8	119.6	176.0	66.9	25.1	34.3	4.1	1005.7
1992	60.2	17.6	111.4	148.4	150.9	33.9	102.3	195.2	113.7	43.2	43.2	8.2	1028.0
1993	89.3	0.0	4.0	167.8	178.7	25.0	85.0	214.3	72.0	29.5	0.0	5.4	871.0
1994	0.0	0.0	36.1	104.4	87.6	96.0	200.5	48.9	136.2	15.7	19.5	0.0	744.9
1995	0.0	48.8	174.9	182.0	65.5	24.6	224.2	103.2	111.3	10.0	0.0	18.6	963.1
1996	10.1	5.2	43.7	171.1	139.3	231.3	55.5	209.5	94.8	0.0	59.7	9.1	1029.3
1997	0.0	0.0	181.4	202.9	132.2	113.2	141.5	185.8	72.3	178.8	50.0	0.0	1258.1
1998	90.3	108.5	91.2	112.4	90.1	96.2	156.8	57.3	114.4	96.3	40.3	0.0	1053.8
1999	0.0	9.7	168.3	74.5	63.4	79.9	191.3	241.3	104.4	135.0	9.8	3.5	1081.1
2000	0.0	0.0	23.0	163.1	102.7	79.2	58.5	132.5	157.0	23.1	54.1	12.5	805.7
2001	55.9	1.0	100.0	59.8	171.6	78.5	95.5	248.8	80.7	21.2	36.0	33.6	982.6
2002	111.8	2.0	72.0	126.5	90.0	100.6	166.6	166.5	142.7	78.9	0.0	38.5	1096.1
2003	34.5	0.0	16.7	163.4	27.5	73.0	94.2	205.7	89.1	19.2	2.0	46.5	771.8
2004	21.4	0.0	24.3	226.1	9.1	71.6	127.2	85.5	134.4	54.4	36.4	0.0	790.4
2005	28.0	0.0	20.5	194.8	18.3	72.3	110.7	145.6	111.8	36.8	19.2	23.3	781.1

Station name: Girawa

Element: Monthly average of maximum tempireture (c^{o})

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	21.5	21.8	23.7	19.5	20.9	19.1	17.5	20.4	19.8	20.6	19.7	19.9	20.4
1987	20.9	21.3	22.5	20.9	21.4	21.2	19.3	20.7	20.1	20.7	20.1	19.9	20.7
1988	20.3	20.8	21.3	20.6	20.5	21.2	20.6	20.3	20.4	20.8	20.5	19.8	20.6
1989	20.4	20.6	22.4	21.0	20.7	20.7	20.3	20.0	20.4	20.4	19.0	20.0	20.5
1990	20.5	20.8	20.5	20.5	20.8	20.7	20.7	20.6	20.9	20.5	20.4	20.7	20.6
1991	20.9	20.5	20.4	20.3	20.7	20.9	19.9	20.3	20.7	20.7	19.9	19.5	20.4
1992	21.0	20.7	21.3	20.5	20.5	20.6	21.0	20.4	21.0	21.3	20.3	19.7	20.7
1993	20.7	20.9	20.5	20.4	20.9	20.7	20.1	19.4	20.5	20.6	20.9	20.6	20.5
1994	20.2	20.9	20.5	20.7	20.7	23.2	18.9	18.5	20.7	22.5	21.4	22.2	20.9
1995	23.7	24.5	20.7	24.2	20.9	21.3	19.6	18.7	20.8	22.4	22.9	22.7	21.9
1996	22.0	25.0	23.3	22.5	21.1	18.4	19.0	19.9	22.1	22.6	22.1	21.9	21.7
1997	22.9	23.1	21.0	21.2	21.6	21.4	20.2	20.9	21.8	22.5	22.2	14.1	21.1
1998	22.5	22.9	22.9	22.3	22.6	22.0	21.3	21.9	21.4	22.3	22.3	21.8	22.2
1999	22.5	22.9	23.4	22.3	22.1	21.4	21.5	21.8	21.7	20.3	21.0	21.1	21.8
2000	22.5	23.2	23.8	22.3	21.5	21.4	20.5	20.8	21.6	21.6	21.6	22.5	21.9
2001	21.4	22.3	22.3	22.7	21.8	21.4	21.9	21.6	21.8	22.2	21.8	21.4	21.9
2002	20.3	21.4	21.6	21.8	21.3	21.8	21.7	21.8	21.6	21.3	20.8	20.7	21.3
2003	20.9	22.3	22.1	21.9	22.4	20.3	20.1	19.7	21.3	21.5	21.5	20.7	21.2
2004	20.8	22.0	21.7	20.6	21.7	21.0	21.5	21.1	20.9	21.1	20.9	21.7	21.3
2005	20.2	20.8	20.4	20.6	20.8	20.7	20.0	20.1	20.5	20.9	20.4	21.2	20.6

Station name: Girawa

Element: Monthly average of minimum tempireture (c^{o})

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	6.1	9.6	9.8	11.2	11.8	10.9	9.8	10.1	9.9	9.5	7.7	8.3	9.6
1987	7.3	10.1	10.1	7.3	9.8	10.4	10.9	10.0	9.6	9.6	8.1	7.9	9.3
1988	8.6	10.6	10.3	10.2	10.5	10.4	9.5	8.6	9.3	9.7	8.5	7.6	9.5
1989	9.9	10.8	10.9	10.7	10.4	10.7	10.1	9.1	9.6	9.3	6.9	9.0	9.8
1990	10.6	10.3	10.3	9.5	10.3	10.1	10.3	10.8	10.3	9.0	9.1	9.6	10.0
1991	10.6	10.0	10.3	10.4	10.0	10.4	8.8	9.2	10.0	9.9	8.6	7.9	9.7
1992	10.8	10.6	10.3	10.5	9.7	9.9	10.5	10.6	10.3	10.1	9.0	8.4	10.1
1993	10.0	10.3	10.4	10.0	10.6	10.3	9.6	12.6	10.1	8.8	10.1	9.1	10.2
1994	10.2	10.0	10.4	10.4	9.4	10.5	8.1	14.6	10.3	7.5	7.0	6.1	9.5
1995	6.3	9.3	10.0	9.6	8.3	8.6	9.1	9.2	9.6	8.7	7.8	9.1	8.8
1996	8.2	9.5	10.8	10.5	10.7	10.0	9.5	9.6	10.1	9.3	10.4	10.0	9.9
1997	10.5	10.5	10.0	9.7	10.0	10.2	9.9	10.4	10.6	10.0	9.3	3.3	9.5
1998	10.4	7.8	9.7	10.1	10.5	9.8	10.9	11.2	11.1	10.7	8.3	7.4	9.8
1999	8.8	10.0	11.4	11.6	11.8	11.4	10.4	10.7	10.8	10.1	8.1	8.0	10.3
2000	7.8	10.2	10.9	11.3	10.9	11.1	10.7	9.9	10.9	9.7	8.6	9.1	10.1
2001	8.2	10.0	11.1	11.1	11.9	10.8	10.7	10.1	10.9	10.8	8.1	8.1	10.1
2002	8.7	9.8	10.8	11.1	11.1	10.4	10.8	10.7	10.6	10.4	8.6	10.6	10.3
2003	9.3	10.9	11.2	11.1	10.9	11.2	11.1	11.2	11.1	9.8	9.6	8.2	10.5
2004	10.4	10.4	10.3	10.8	10.5	11.0	10.8	11.1	10.9	10.8	9.1	8.4	10.4
2005	9.1	10.8	10.8	9.7	10.0	10.8	9.6	9.3	9.5	10.2	9.2	8.3	9.8

Station name: Gode

Element: Monthly total rainfall (mm/day)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	0.0	0.0	0.0	43.9	104.1	0.0	0.0	0.0	0.0	46.7	26.7	0.0	221.4
1987	0.0	0.0	0.0	27.4	64.0	0.0	0.0	0.0	3.5	40.8	34.0	0.0	169.7
1988	0.0	0.0	0.0	47.6	60.2	0.0	0.0	0.0	0.0	52.6	19.3	0.0	179.7
1989	0.0	2.2	0.0	5.0	42.1	0.0	0.0	0.0	0.0	90.4	0.0	13.8	153.5
1990	0.0	0.0	0.0	85.1	5.8	0.0	0.0	0.0	0.0	7.0	0.0	0.0	97.9
1991	0.0	0.0	0.0	87.6	17.2	0.0	0.0	0.0	0.0	100.5	95.8	7.8	308.9
1992	0.0	0.0	0.0	90.6	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	142.2
1993	0.0	0.0	74.4	126.3	22.4	0.0	1.4	0.0	0.0	95.8	142.3	0.0	462.6
1994	0.0	0.0	0.0	64.4	60.9	0.0	0.0	0.0	4.5	63.5	104.5	0.3	298.1
1995	0.0	0.0	2.6	101.4	3.2	0.0	0.0	0.0	0.0	36.0	42.2	0.2	185.6
1996	0.0	0.0	12.5	114.0	82.3	0.4	0.0	0.0	0.0	5.3	10.3	0.0	224.7
1997	0.0	0.0	22.4	126.5	29.5	2.4	0.0	0.0	0.0	238.5	100.3	15.7	535.3
1998	6.8	0.0	5.6	60.2	147.1	0.7	0.0	0.3	0.0	5.2	32.8	0.0	258.7
1999	0.0	0.0	62.3	37.7	34.7	0.0	0.0	0.0	0.0	37.2	23.3	1.6	196.8
2000	0.0	0.0	0.0	16.0	127.8	0.0	0.0	0.0	0.0	138.5	20.9	0.3	303.5
2001	0.0	0.0	0.0	8.9	29.7	0.0	20.7	2.3	0.0	69.9	4.1	0.3	135.9
2002	0.0	0.0	0.0	81.3	9.3	0.0	0.0	0.0	5.8	90.9	38.2	0.0	225.5
2003	0.0	0.0	0.0	84.8	1.8	0.0	7.4	0.4	0.0	10.7	119.7	18.4	243.2
2004	0.0	0.0	15.4	61.7	0.0	0.0	0.0	0.0	0.0	70.5	92.5	0.4	240.5
2005	0.0	0.0	0.0	87.0	32.1	0.0	0.0	0.0	0.2	45.3	106.1	9.4	280.1

Station name: Gode

Element: Monthly average of maximum tempireture (c^{o})

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	35.1	36.3	37.6	35.4	33.7	32.3	31.3	33.4	34.3	34.8	35.1	35.7	34.6
1987	35.2	37.0	38.1	36.1	36.1	32.4	33.7	34.7	35.0	34.0	33.5	35.5	35.1
1988	36.2	35.7	36.7	36.3	34.8	34.5	33.5	35.0	36.4	34.6	35.6	36.1	35.4
1989	36.1	36.9	38.3	36.3	35.9	35.8	33.6	34.4	35.5	34.1	35.6	34.5	35.6
1990	35.6	36.8	37.9	36.2	35.7	34.5	32.9	34.4	35.2	35.4	35.7	35.1	35.4
1991	35.1	36.7	37.5	37.1	34.5	34.4	33.8	34.4	35.7	33.8	32.6	34.1	35.0
1992	35.8	36.7	37.8	35.2	35.2	34.1	32.8	34.7	35.8	34.0	33.3	32.8	34.9
1993	35.7	36.7	36.2	33.6	34.7	33.0	32.2	33.1	34.5	34.6	35.4	35.5	34.6
1994	35.2	36.5	36.9	35.9	34.0	33.6	33.3	34.2	36.4	35.5	32.9	35.6	35.0
1995	35.4	36.8	36.7	34.2	34.4	33.7	33.4	33.5	34.9	33.9	33.5	35.3	34.6
1996	35.3	37.0	36.8	34.0	33.4	32.3	32.0	33.3	35.2	34.5	34.6	35.1	34.4
1997	35.1	37.2	36.8	33.7	34.1	35.1	33.6	34.6	35.9	32.1	31.2	32.9	34.3
1998	35.7	37.5	38.5	37.5	33.7	34.0	32.4	33.5	35.8	35.0	34.2	35.5	35.3
1999	35.7	36.6	36.4	36.4	35.3	34.0	33.0	34.4	35.6	34.6	35.5	34.5	35.2
2000	35.8	37.4	37.4	37.1	31.4	33.0	32.4	33.5	35.0	32.6	34.1	35.7	34.6
2001	35.6	36.4	37.7	36.7	35.4	33.9	32.8	33.5	35.4	34.5	34.9	35.6	35.2
2002	36.2	36.4	37.6	35.6	35.5	33.4	34.5	33.9	35.5	33.2	34.0	36.0	35.1
2003	35.9	38.1	38.3	37.3	35.3	34.8	33.7	34.2	36.0	36.0	33.1	33.9	35.6
2004	36.3	36.1	37.9	34.6	35.1	34.1	33.6	33.4	35.5	35.0	32.2	31.9	34.6
2005	36.7	36.4	37.8	36.1	34.8	34.3	33.3	33.4	35.2	34.1	32.6	32.9	34.8

Station name: Gode

Element: Monthly average of minimum tempireture (c^{o})

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	19.3	22.6	23.2	22.8	23.3	23.2	22.2	21.9	23.3	22.4	22.6	21.7	22.4
1987	22.1	24.1	25.6	25.2	25.5	24.1	23.8	24.4	25.0	23.5	22.2	22.0	24.0
1988	23.2	22.9	23.5	24.9	24.4	24.3	24.1	24.4	24.9	23.2	21.9	20.7	23.5
1989	22.1	22.6	24.4	24.9	24.9	24.3	23.3	24.1	25.1	24.3	23.9	22.5	23.9
1990	21.5	22.7	23.0	25.5	26.0	25.5	24.5	24.7	25.3	25.0	23.3	21.0	24.0
1991	20.9	22.8	24.4	25.9	25.0	25.6	24.8	24.9	25.6	23.7	22.7	19.9	23.8
1992	20.6	22.4	24.2	24.6	24.7	24.5	24.0	24.0	24.3	23.4	21.2	22.3	23.3
1993	22.1	22.8	23.8	23.6	23.8	22.8	24.0	23.5	23.8	23.9	23.3	22.4	23.3
1994	22.3	22.5	23.5	22.3	24.6	24.2	24.6	22.9	23.4	22.9	20.3	20.4	22.8
1995	20.0	22.8	24.5	23.4	23.6	23.0	24.0	24.1	23.8	23.2	20.6	21.0	22.8
1996	21.2	22.7	24.7	23.6	23.7	24.1	23.5	23.2	24.2	23.3	23.1	21.6	23.2
1997	22.5	22.6	24.8	23.8	23.8	24.5	24.1	24.0	24.8	23.2	22.9	21.0	23.5
1998	22.7	23.8	25.5	25.6	24.5	24.1	23.9	24.1	24.2	24.3	21.4	21.4	23.8
1999	22.0	23.1	24.3	24.2	24.6	23.8	23.9	23.6	24.4	24.1	23.0	21.2	23.5
2000	22.2	22.4	24.1	25.4	22.7	23.5	23.5	23.9	24.1	22.8	21.7	22.2	23.2
2001	21.2	22.8	25.4	25.4	25.1	24.2	23.8	23.2	24.5	24.1	22.6	23.5	23.8
2002	23.5	22.5	25.8	24.8	25.1	24.4	24.0	24.0	24.3	23.5	21.9	23.8	24.0
2003	22.3	23.9	25.9	25.5	25.3	25.4	23.9	23.6	24.3	24.7	22.1	22.6	24.1
2004	21.8	23.5	25.4	24.5	25.4	24.1	23.6	23.8	24.6	24.7	22.4	21.4	23.8
2005	21.3	23.0	25.9	25.6	24.9	24.8	24.1	23.9	24.7	24.1	22.3	22.0	23.9

Station name: Degahabur

Element: Total monthly rainfall (mm/day)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	41.0	0.0	0.0	509.0	253.8	0.0	0.0	1.5	18.3	23.9	0.0	0.0	847.5
1987	0.0	0.0	41.8	47.0	286.0	15.2	0.0	4.4	55.0	39.1	3.7	0.0	492.2
1988	0.0	0.0	4.9	201.2	51.1	1.5	0.0	2.3	56.5	27.4	0.0	0.0	344.9
1989	0.0	0.0	56.8	115.5	86.1	29.2	3.1	0.0	80.6	41.1	0.8	0.0	413.2
1990	0.0	3.3	8.0	106.7	6.5	3.8	0.0	0.0	38.2	7.3	5.3	0.0	179.1
1991	0.0	0.0	85.0	43.0	63.6	0.0	0.0	0.5	31.0	11.6	0.0	44.9	279.6
1992	13.0	0.0	4.7	114.3	29.1	11.0	0.0	3.0	28.8	43.0	1.2	3.5	251.6
1993	7.6	23.6	0.0	37.4	167.6	0.0	0.0	0.0	39.5	58.9	0.0	0.0	334.6
1994	0.0	0.0	0.0	112.9	136.8	0.0	2.6	5.0	23.2	30.6	13.0	0.0	324.1
1995	0.0	6.2	26.2	153.3	59.9	0.0	0.0	3.6	30.6	60.1	2.0	0.0	341.9
1996	0.0	0.0	0.3	24.5	92.5	4.0	0.0	0.0	26.1	7.1	6.9	0.0	161.4
1997	0.0	0.0	43.1	78.9	54.9	40.6	4.0	1.2	18.6	164.9	115.8	0.0	522.0
1998	25.6	0.4	0.0	6.1	132.1	21.3	4.9	0.0	7.8	53.4	13.6	0.0	265.2
1999	0.0	0.0	56.9	97.8	23.1	0.0	0.0	0.0	38.3	23.3	0.0	0.0	239.4
2000	0.0	0.0	0.0	103.2	59.7	0.0	0.0	6.7	42.6	189.3	34.1	0.6	436.2
2001	0.0	0.0	8.9	99.4	88.2	8.2	0.0	11.7	74.9	69.4	0.2	0.0	360.9
2002	0.0	0.0	31.8	51.3	96.2	7.6	7.3	0.0	96.0	110.7	0.4	0.0	401.3
2003	0.0	0.0	0.0	57.2	22.5	57.9	0.0	9.4	11.2	5.5	0.0	7.5	171.2
2004	21.2	0.0	4.3	39.6	64.0	32.9	3.7	6.3	66.1	26.7	16.7	10.1	291.6
2005	10.7	0.0	18.2	45.7	43.5	45.4	1.9	7.8	38.9	16.5	0.0	5.1	233.7

Station name: Degahabur

Element: Monthly average maximum tempireture (c^o)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	31.7	33.8	34.9	31.5	31.3	28.8	28.6	31.1	32.0	31.9	32.2	31.7	31.6
1987	30.3	33.5	34.6	33.6	30.0	28.1	28.2	30.4	31.6	31.1	31.2	30.7	31.1
1988	32.2	31.6	34.7	31.7	30.6	30.2	28.9	30.1	30.5	30.7	31.0	30.7	31.1
1989	30.8	32.1	31.4	29.3	30.0	30.0	27.4	29.5	30.4	30.2	31.6	31.2	30.3
1990	31.6	32.8	33.6	30.7	30.9	30.2	28.3	29.1	31.8	32.0	31.2	31.4	31.1
1991	32.5	32.8	32.4	31.7	29.9	29.0	27.0	28.7	31.7	32.6	31.7	30.5	30.9
1992	30.8	31.7	32.5	32.2	30.4	29.6	28.1	29.5	32.0	31.3	32.2	31.8	31.0
1993	31.4	33.2	32.5	32.5	30.6	29.9	28.5	29.9	32.1	30.7	32.4	32.5	31.3
1994	31.7	33.3	32.5	32.6	30.7	30.0	28.8	30.1	32.2	30.3	32.4	32.8	31.4
1995	31.8	33.4	32.5	32.6	30.7	30.1	28.9	30.2	32.2	30.2	32.5	32.9	31.5
1996	31.9	32.2	32.5	32.6	30.7	30.1	28.9	30.2	32.2	30.1	32.5	33.0	31.4
1997	31.5	33.5	32.5	32.7	30.8	30.2	29.0	30.2	32.4	30.4	32.2	31.9	31.4
1998	31.8	33.5	32.5	32.7	30.3	29.7	28.9	29.9	32.2	30.4	32.2	33.1	31.4
1999	32.0	33.5	32.5	32.7	30.8	30.2	29.0	30.3	32.2	30.0	32.5	33.1	31.6
2000	31.4	33.4	35.7	33.6	29.9	29.2	29.0	30.1	32.1	30.4	32.1	32.5	31.6
2001	31.1	33.2	33.8	33.3	30.6	30.1	29.1	29.9	32.0	30.7	32.5	31.3	31.5
2002	32.2	33.1	33.7	33.1	31.7	30.2	30.8	30.5	31.1	30.3	32.0	32.0	31.7
2003	32.1	34.2	34.7	33.0	32.4	29.7	29.0	30.0	32.7	33.3	32.7	30.8	32.0
2004	32.2	33.1	34.0	32.1	31.6	29.9	29.6	29.6	32.3	31.5	30.4	31.5	31.5
2005	32.1	33.7	33.9	32.6	32.1	29.8	30.2	29.8	32.5	32.4	31.9	31.1	31.8

Station name: Degahabur

Element: Monthly average minimum tempireture (c^{o})

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	23.1	23.9	24.3	23.4	24.2	23.7	19.8	23.9	22.0	24.5	24.7	19.5	23.1
1987	23.0	39.8	21.4	21.4	19.9	19.2	20.4	19.6	20.0	18.7	15.9	15.2	21.2
1988	16.9	27.2	18.4	19.3	20.0	20.4	19.1	20.0	19.3	18.5	13.9	13.6	18.9
1989	15.2	16.5	17.7	18.5	18.5	18.2	19.0	19.4	19.8	17.3	17.1	17.3	17.9
1990	15.6	18.2	19.5	19.8	19.2	19.5	19.2	19.7	20.2	17.8	16.8	16.5	18.5
1991	16.8	18.0	19.3	19.1	19.3	19.6	19.1	18.9	19.7	18.3	16.6	15.9	18.4
1992	16.0	16.4	18.6	18.7	19.3	19.0	18.7	19.0	19.0	17.2	16.2	15.1	17.8
1993	15.0	16.2	17.8	18.4	19.1	18.4	18.2	19.0	18.3	16.0	15.7	14.3	17.2
1994	13.2	13.8	11.3	15.5	16.0	15.4	14.7	15.7	15.5	13.5	14.9	14.1	14.5
1995	12.8	11.2	12.1	13.7	13.5	14.0	16.8	18.6	20.2	18.8	16.9	18.4	15.6
1996	16.8	18.2	19.4	20.4	19.4	20.3	19.3	19.5	19.1	17.4	15.5	13.4	18.2
1997	13.8	15.0	17.3	19.0	20.7	21.1	21.0	21.0	20.7	18.9	18.2	16.4	18.6
1998	15.1	16.0	17.5	20.8	20.1	20.0	19.1	19.3	19.2	17.3	16.7	13.1	17.9
1999	15.3	21.4	19.5	20.5	31.3	19.5	18.9	20.3	20.5	18.8	18.1	14.0	19.8
2000	15.5	16.9	17.8	19.5	20.4	20.5	20.3	20.7	20.9	20.1	18.3	22.2	19.4
2001	15.1	15.4	17.3	19.4	20.4	18.9	17.8	16.4	20.2	24.6	16	26.3	19.0
2002	23.3	15.6	25.5	19.1	18.5	17.3	15.2	12.1	20.8	19.6	13.6	28.3	19.1
2003	27.3	22.9	29.6	25.7	25.0	24.0	23.0	20.9	20.1	24.4	22.1	29.3	24.5
2004	31.4	29.1	33.7	32.3	31.3	30.7	30.7	30.0	24.3	29.1	30.5	30.3	30.3
2005	14.0	15.9	18.1	18.9	19.0	19.0	18.8	19.5	19.5	18.5	15.4	16.3	17.7

Station name: Imi

Element: Monthly total rainfall (mm/day)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	0.0	0.0	0.3	94.7	23.3	11.1	10.7	5.1	9.0	23.2	10.1	1.2	188.9
1987	0.0	1.3	5.2	30.4	137.3	2.9	1.7	0.3	2.9	12.1	2.7	3.1	199.9
1988	0.0	1.1	1.3	169.8	7.1	0.4	3.3	3.1	7.6	40.3	0.1	0.1	234.3
1989	3.6	0.0	29.7	112.3	25.2	1.5	19.5	1.2	13.8	37.7	40.0	2.0	286.5
1990	5.5	0.5	56.0	116.6	11.5	1.0	15.1	1.0	7.9	27.8	4.9	14.4	262.3
1991	0.0	6.3	21.9	68.4	165.1	2.8	0.6	1.2	2.7	18.6	24.3	0.6	312.5
1992	0.0	0.1	26.5	16.3	38.6	1.1	1.6	3.3	7.6	18.2	2.7	18.8	134.9
1993	5.2	1.5	4.7	107.6	62.9	1.0	4.0	0.3	1.0	40.7	1.6	0.5	231.0
1994	0.0	0.0	5.5	151.0	32.1	0.9	4.9	0.4	8.6	178.9	20.0	0.0	402.5
1995	0.0	13.5	16.2	128.6	35.0	0.7	0.7	0.7	4.6	82.0	1.7	3.4	287.2
1996	3.1	0.8	17.1	90.4	27.3	7.4	27.4	1.9	1.9	12.1	10.9	0.6	201.0
1997	0.0	0.0	47.7	113.3	7.6	1.3	1.3	0.2	30.6	250.4	282.0	6.1	740.4
1998	11.4	2.8	6.7	92.6	29.8	1.8	3.9	2.4	1.2	24.4	9.9	0.2	187.3
1999	0.0	0.2	36.5	47.3	2.5	0.1	7.1	0.2	1.6	5.0	9.0	0.0	109.5
2000	0.0	0.0	0.8	47.2	18.1	1.0	3.7	1.8	12.9	45.2	14.9	2.4	148.0
2001	0.1	0.2	0.4	47.8	0.7	0.3	4.2	3.3	4.1	37.9	4.2	7.7	110.9
2002	0.0	0.6	8.8	158.8	1.4	1.3	0.4	0.7	17.1	79.2	5.5	6.7	280.6
2003	0.4	0.0	4.1	129.1	31.5	0.1	12.6	3.0	7.5	15.3	45.1	0.0	248.6
2004	1.3	0.0	33.2	43.1	1.0	0.8	0.3	0.2	10.8	32.0	40.3	1.1	164.2
2005	1.0	0.7	1.4	179.1	140.5	0.1	1.9	0.5	11.9	20.8	7.7	0.1	365.9

Station name: Imi

Element: Monthly average maximum tempireture (c^{o})

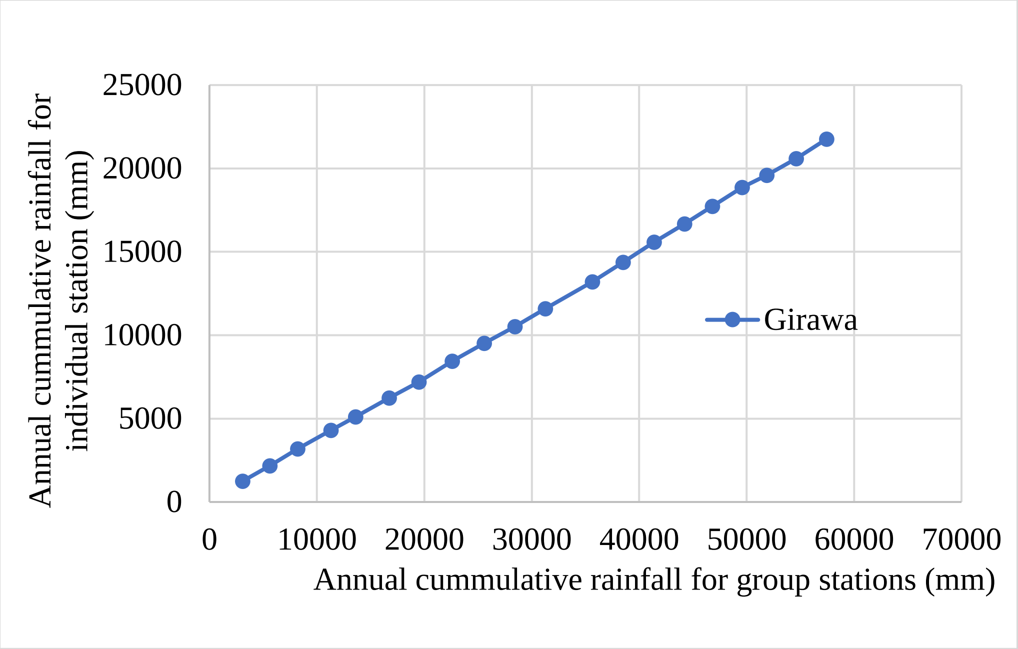
year	Jan	Jeb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	32.0	33.9	34.4	31.6	31.6	29.3	28.7	30.7	32.1	30.6	31.8	31.6	31.5
1987	31.5	33.7	33.0	33.2	29.5	31.6	30.3	32.0	33.1	31.4	31.2	31.3	31.8
1988	33.0	33.4	34.5	31.0	33.7	31.6	29.9	31.3	32.6	30.5	31.8	31.7	32.1
1989	32.4	34.1	31.3	30.3	32.0	30.8	29.0	31.3	32.5	30.8	30.3	31.6	31.4
1990	32.3	34.2	32.6	31.3	33.5	30.9	28.6	30.4	33.3	31.7	31.2	30.1	31.6
1991	32.8	33.5	32.9	32.4	31.6	30.7	30.5	31.7	33.8	32.6	30.6	31.6	32.1
1992	32.6	34.4	33.4	33.5	32.6	31.1	29.7	29.1	32.1	31.2	31.8	30.6	31.8
1993	31.0	33.3	34.0	30.7	31.2	30.1	28.8	30.4	33.2	31.5	31.5	31.6	31.4
1994	32.6	34.5	35.0	31.3	32.5	31.2	29.2	31.3	33.1	30.6	30.0	31.7	31.9
1995	32.6	33.2	33.1	30.2	33.7	30.5	30.3	31.7	32.5	30.9	30.9	31.0	31.7
1996	32.7	33.2	33.8	30.7	30.0	29.2	26.4	29.9	32.5	31.9	30.2	31.6	31.0
1997	33.1	33.5	32.0	30.5	32.7	31.7	30.4	32.3	32.5	27.5	26.6	30.3	31.1
1998	32.5	34.8	35.1	32.3	34.0	31.0	28.8	30.3	32.8	31.1	31.7	32.1	32.2
1999	32.8	34.2	32.9	33.0	33.3	31.3	31.0	32.0	33.2	32.1	31.5	31.9	32.4
2000	32.9	35.2	34.6	32.6	32.6	31.1	30.9	31.8	33.2	31.3	32.2	32.6	32.6
2001	33.1	34.4	34.8	33.7	34.2	31.7	29.6	32.1	33.5	31.3	32.1	31.9	32.7
2002	33.3	33.9	34.7	32.1	33.9	31.2	31.2	32.1	32.4	31.0	32.5	32.6	32.6
2003	33.5	35.0	35.3	31.8	32.9	32.4	31.1	31.4	33.7	32.6	31.0	31.9	32.7
2004	33.7	34.2	33.9	33.2	33.7	31.1	31.4	32.5	33.4	32.3	31.4	32.3	32.8
2005	32.8	34.4	34.7	31.3	31.9	32.1	30.6	31.6	32.9	33.3	31.7	32.0	32.4

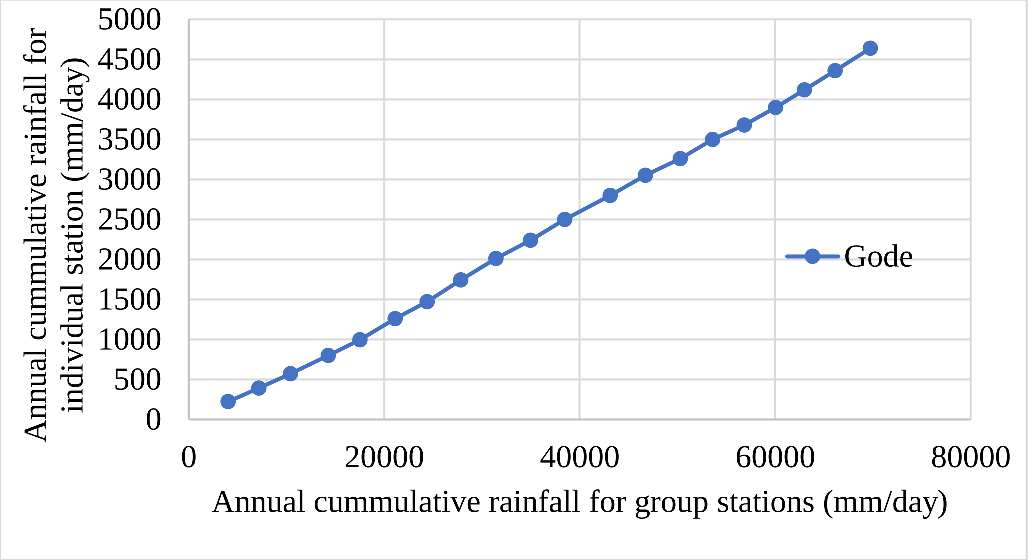
Station name: Imi

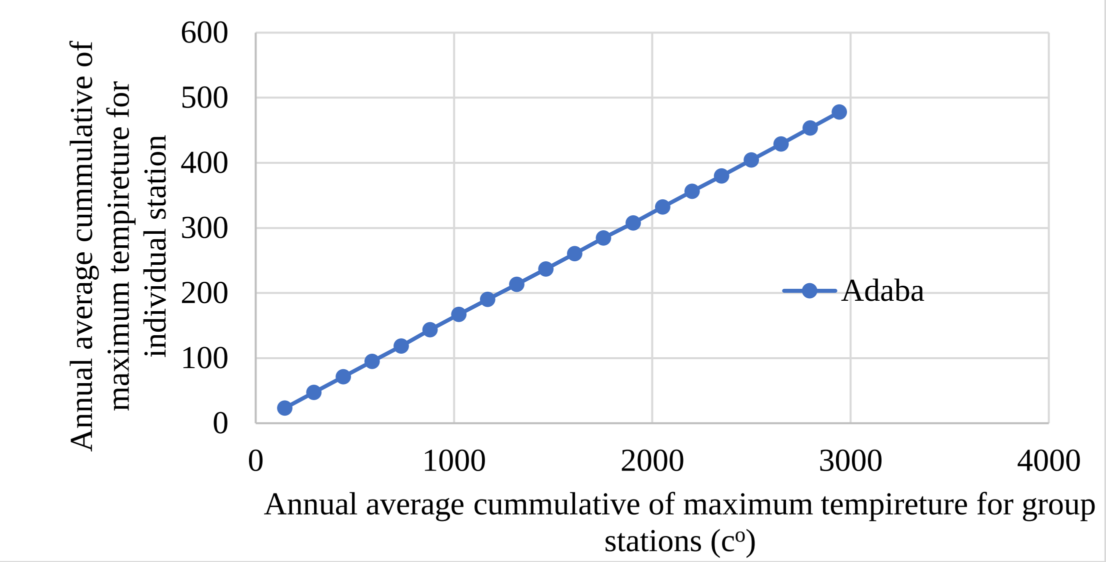
Element: Monthly average maximum tempireture (c^{o})

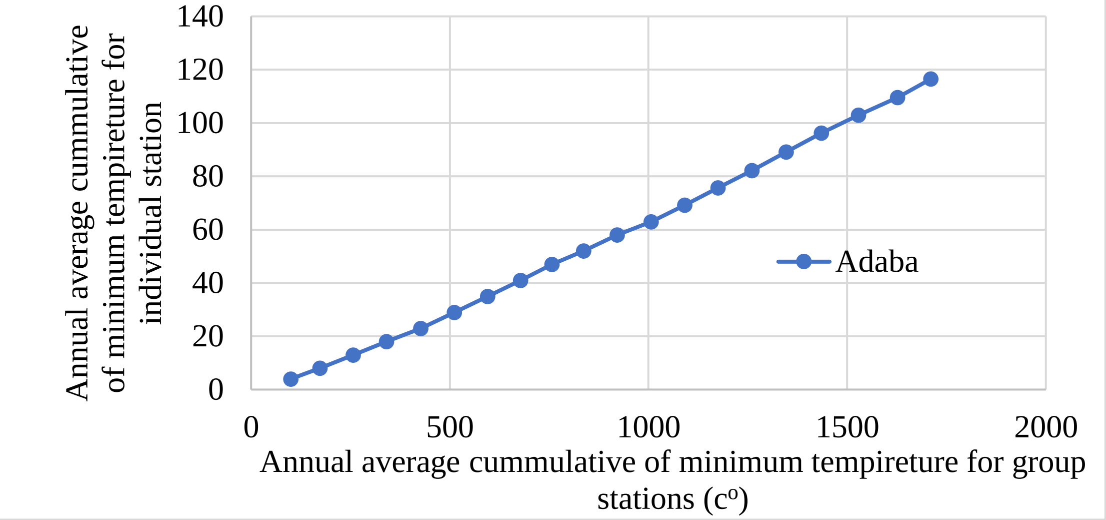
year	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	15.6	19.9	21.5	22.2	21.7	20.6	20.1	20.7	21.2	19.3	19.4	18.8	20.1
1987	16.1	21.1	22.6	21.7	21.1	21.2	20.7	21.5	21.9	21.0	18.9	18.1	20.5
1988	19.7	21.5	21.5	21.5	22.2	21.5	22.1	21.7	22.1	20.0	17.2	18.0	20.8
1989	20.0	18.8	21.1	20.8	21.4	21.0	20.6	20.9	22.1	20.2	20.5	20.7	20.7
1990	20.1	22.7	22.0	21.5	22.4	20.8	20.2	21.1	22.4	20.3	19.2	17.8	20.9
1991	19.4	21.3	22.4	22.2	21.9	21.3	21.5	21.4	22.0	19.7	18.9	17.4	20.8
1992	20.4	21.2	22.1	22.3	22.3	21.4	20.7	20.5	21.5	20.1	18.4	19.3	20.8
1993	20.2	20.1	20.4	21.3	21.4	21.1	20.7	20.2	21.7	20.9	18.3	16.6	20.2
1994	16.7	18.8	21.9	21.8	22.2	21.9	21.9	21.6	21.4	20.3	18.9	17.5	20.4
1995	17.6	21.4	21.8	21.4	22.4	21.2	21.6	21.9	21.8	21.0	18.0	19.5	20.8
1996	19.2	19.9	22.6	21.6	21.0	21.1	19.9	20.6	21.5	19.9	18.0	17.4	20.2
1997	18.6	17.9	22.0	21.1	22.1	21.8	21.2	21.4	22.0	19.9	19.8	20.2	20.7
1998	20.6	22.6	22.8	22.5	22.8	22.2	21.7	21.4	22.3	21.2	18.0	17.2	21.3
1999	17.9	21.0	22.1	22.2	22.1	21.4	21.8	21.3	22.6	21.0	19.3	17.2	20.8
2000	18.0	18.7	20.1	22.5	21.7	21.5	21.3	21.8	22.3	20.7	19.2	19.2	20.6
2001	18.1	19.8	22.3	22.8	22.9	21.3	21.0	21.6	22.3	20.8	18.8	19.8	21.0
2002	19.0	20.0	23.2	22.3	22.7	21.5	21.4	21.3	22.4	21.0	19.6	21.2	21.3
2003	19.1	20.2	22.2	22.5	22.7	22.0	21.9	22.1	22.8	20.9	20.2	18.3	21.2
2004	21.7	18.7	21.7	22.9	22.6	21.1	21.4	21.7	22.8	20.9	19.9	18.8	21.2
2005	19.5	21.8	21.7	22.0	22.1	22.2	21.7	21.3	22.5	21.0	18.8	16.6	20.9

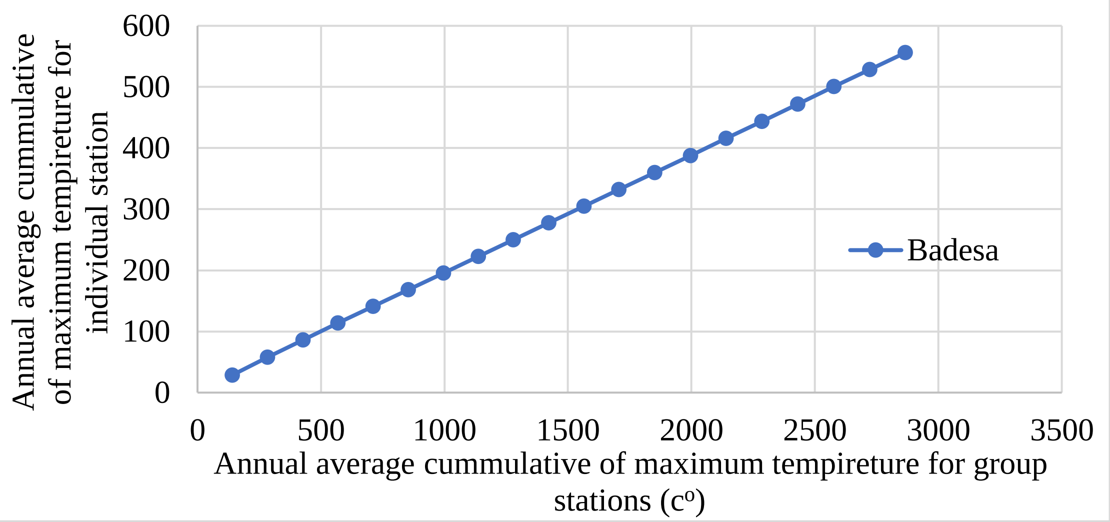
3b. Graphs ploted to check consistence of rainfall and tempireture over selected stations

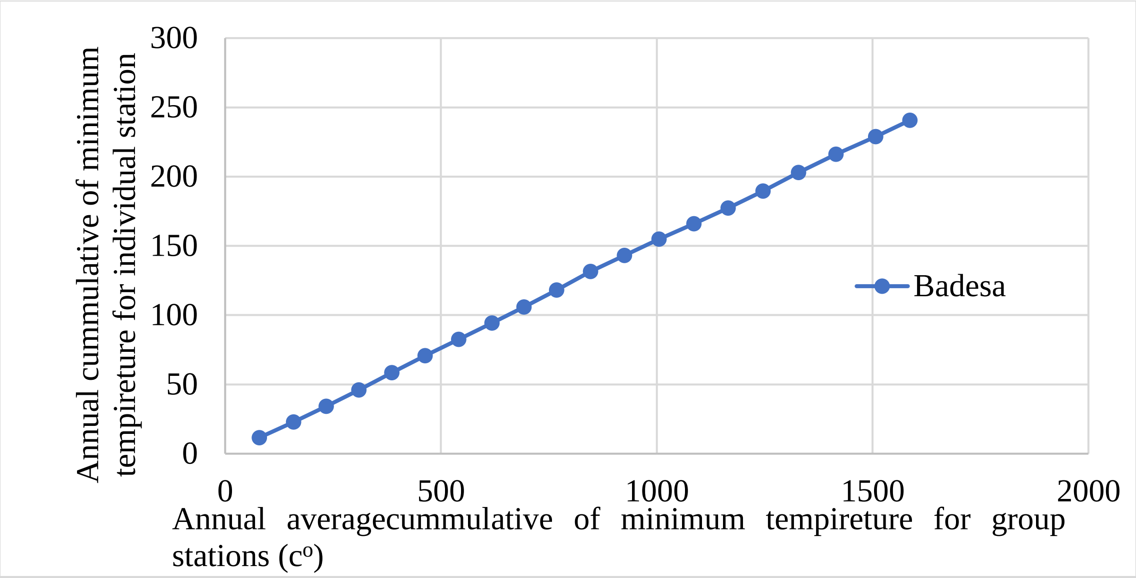


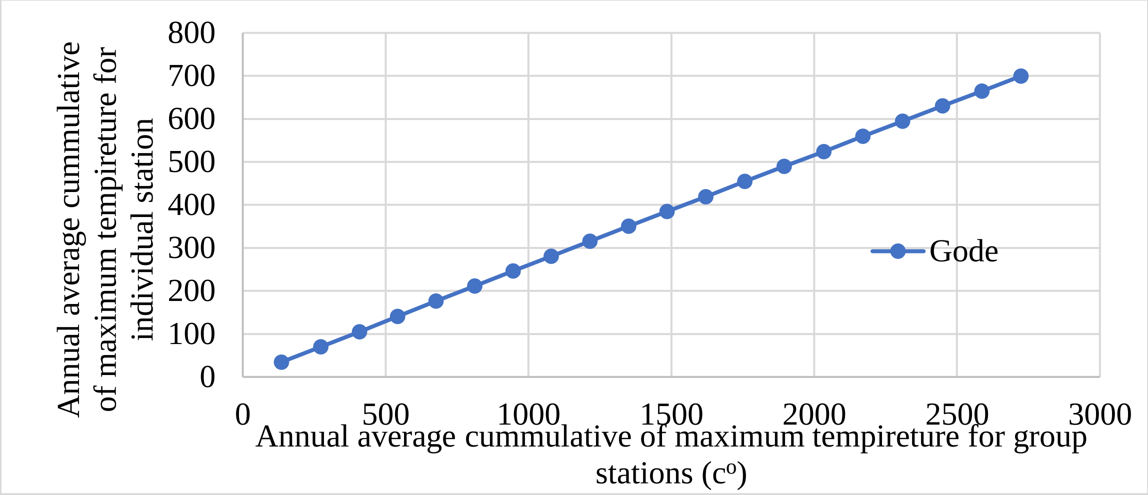


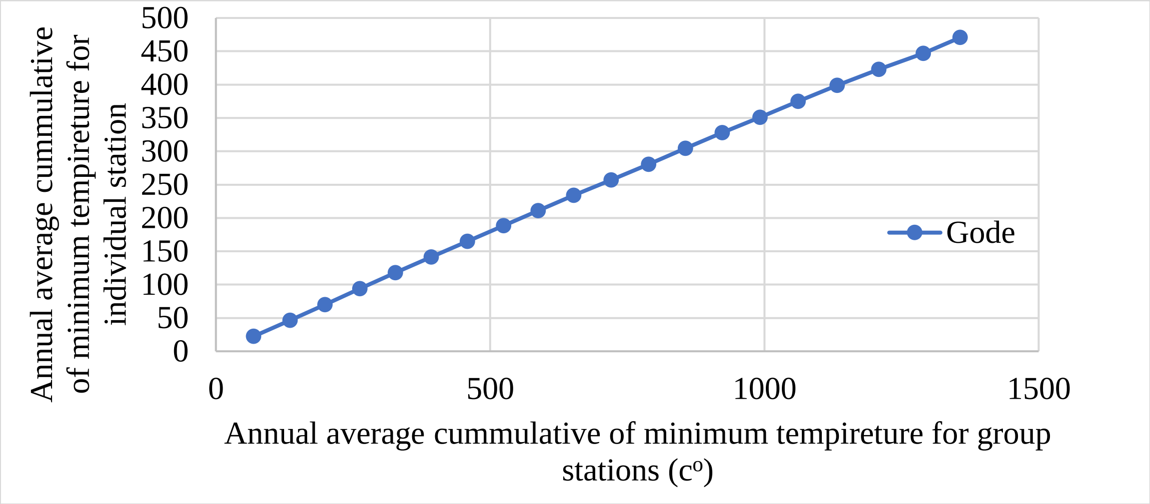

Annual average cummulative of maximum tempireture for individual station
600
500
400
300
200
100
0
0
1000
2000
3000
4000
Adaba
Annual average cummulative of maximum tempireture for group stations (cº)

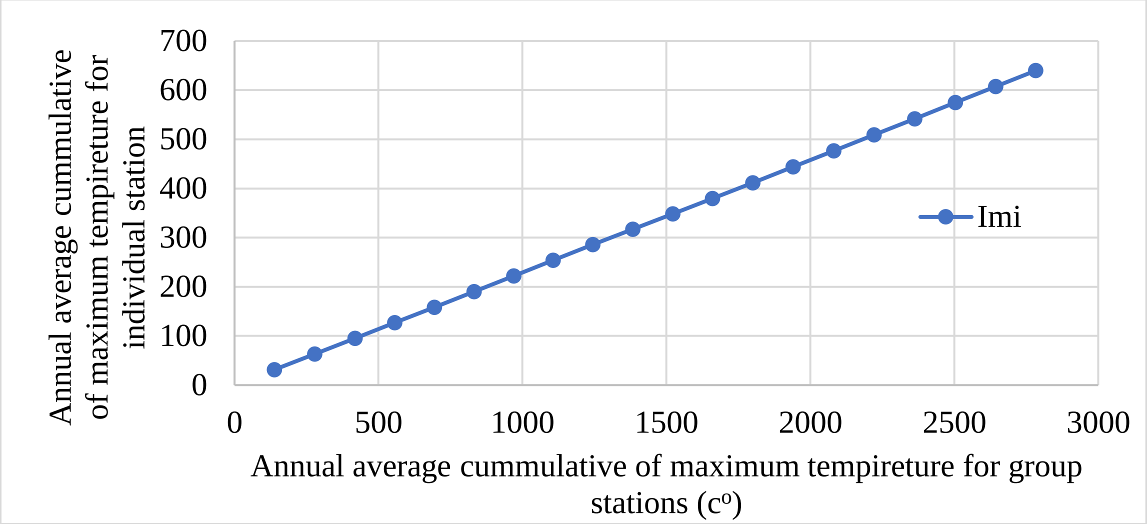

Annual average cummulative of minimum tempireture for individual station
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
Adaba
Annual average cummulative of minimum tempireture for group stations (cº)

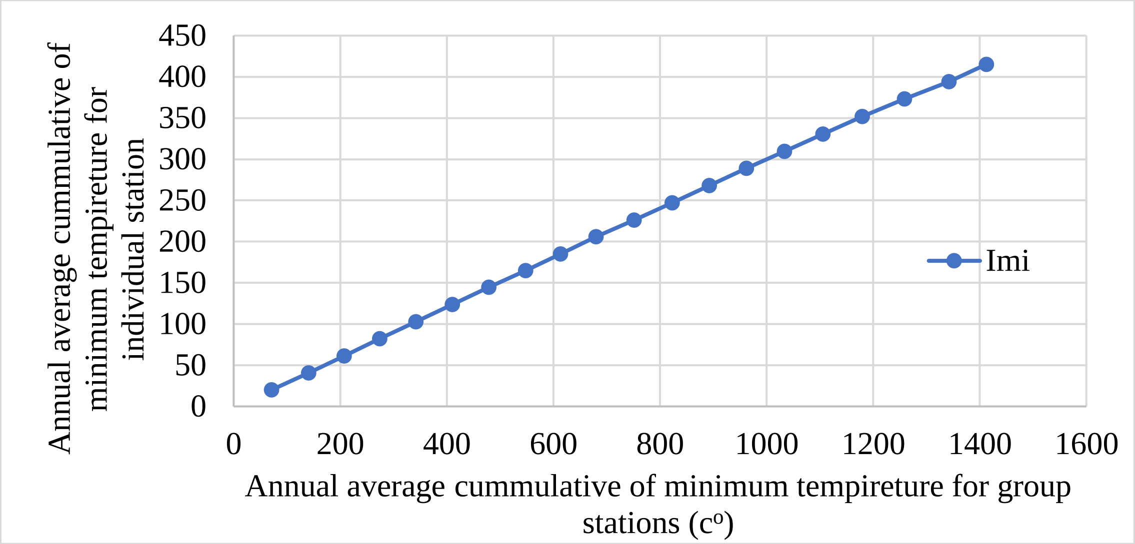

Annual average cummulative of maximum tempireture for individual station
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
Badesa
Annual average cummulative of maximum tempireture for group stations (cº)

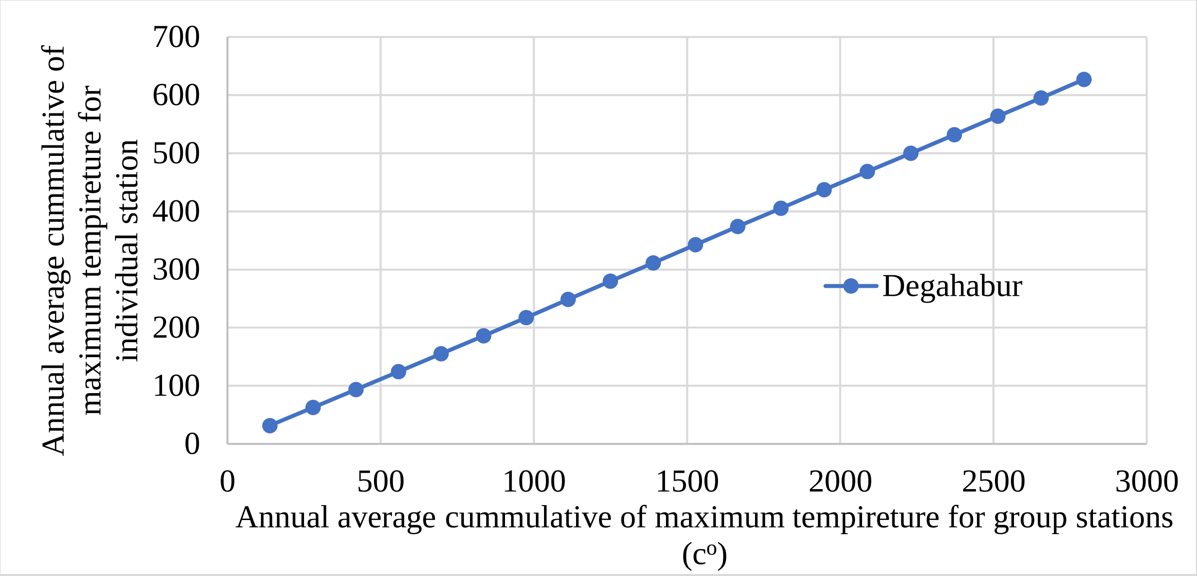

Annual cummulative of minimum tempireture for individual station
300
250
200
150
100
50
0
0
500
1000
1500
2000
Badesa
Annual averagecummulative of minimum tempireture for group stations (c°)

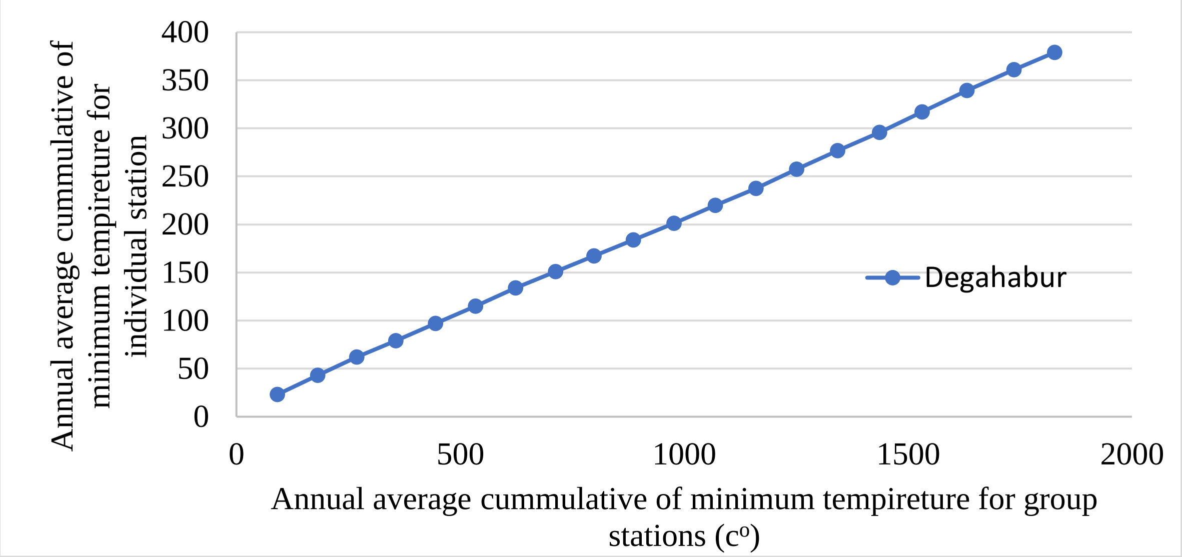

Annual average cummulative of maximum tempireture for individual station
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
Gode
Annual average cummulative of maximum tempireture for group stations (c°)


Annual average cummulative of minimum tempireture for individual station
500
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
Gode
Annual average cummulative of minimum tempireture for group stations (c°)

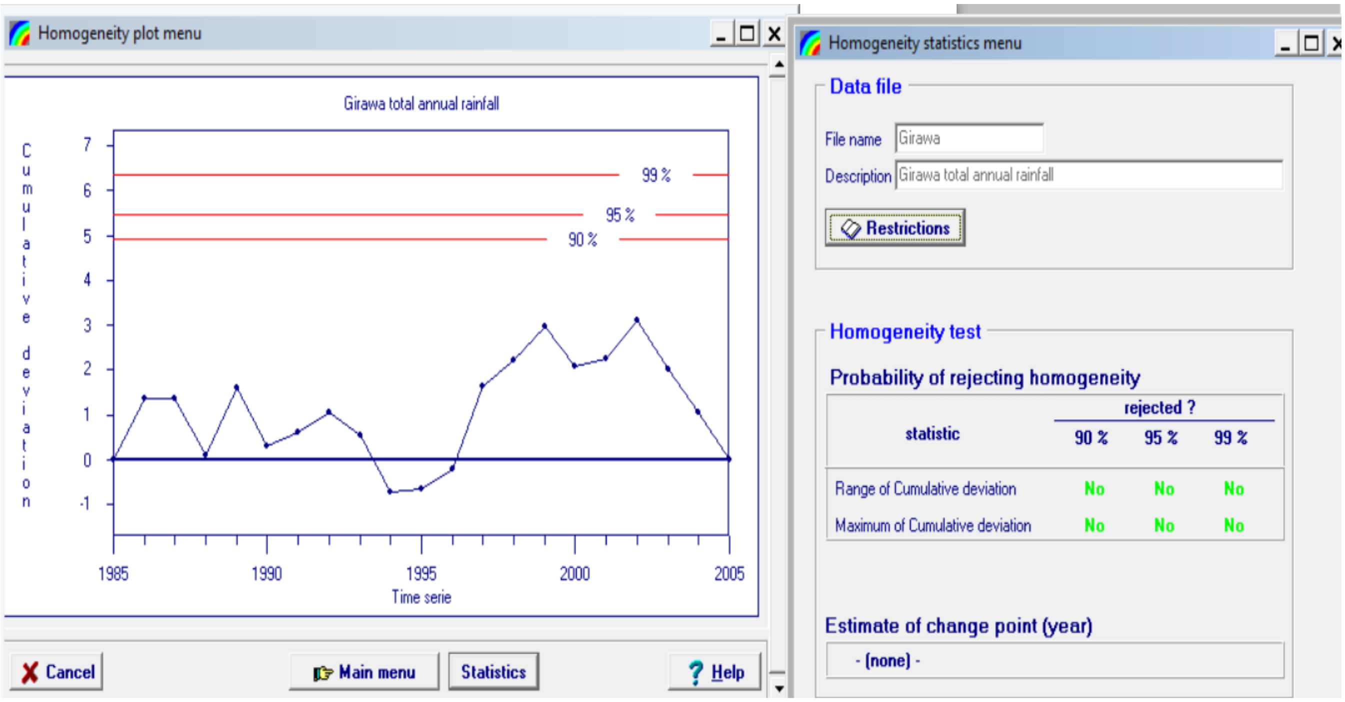

Annual average cummulative of maximum tempireture for individual station
0
100
200
300
400
500
600
700
0
500
1000
1500
2000
2500
3000
Annual average cummulative of maximum tempireture for group stations (c°)
Imi


Annual average cummulative of minimum tempireture for individual station
0
50
100
150
200
250
300
350
400
450
0
200
400
600
800
1000
1200
1400
1600
Annual average cummulative of minimum tempireture for group stations (c°)
Imi





3c Graphs ploted to test homogeinity test of rainfall data for selected stations



Data file

File name Girawa

Description Girawa total annual rainfall

Restrictions

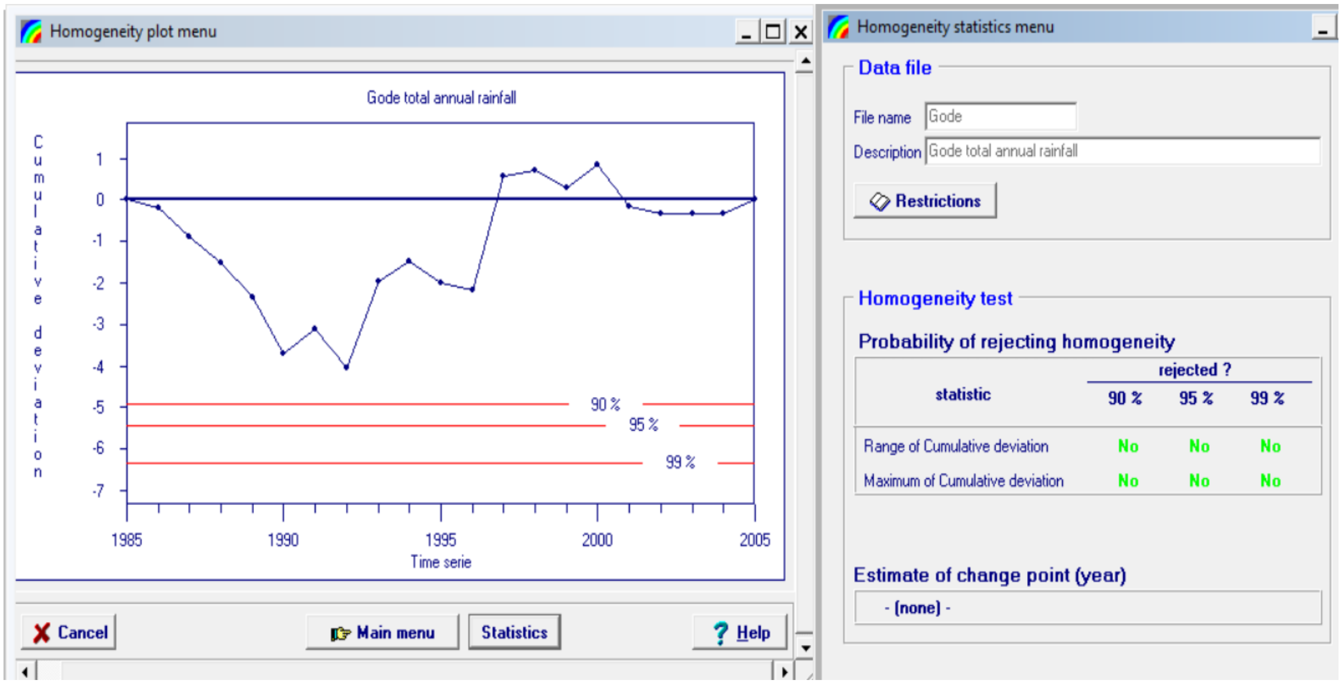
Homogeneity test

Probability of rejecting homogeneity

statistic	rejected ?		
	90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -



Data file

File name Gode

Description Gode total annual rainfall

Restrictions

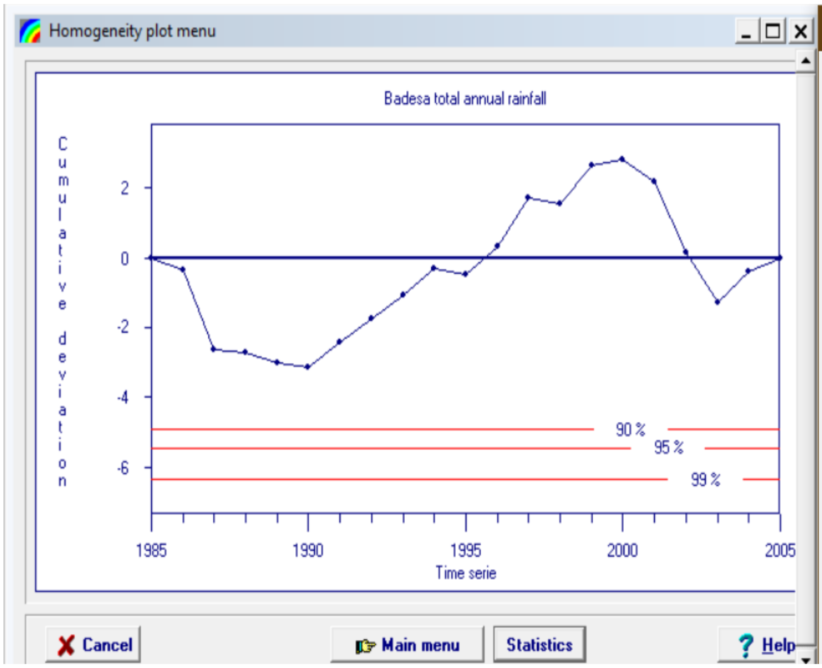
Homogeneity test

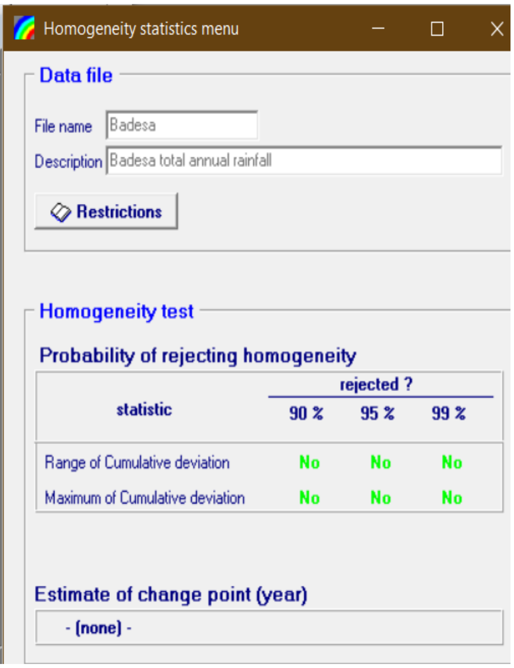
Probability of rejecting homogeneity

statistic	rejected ?		
	90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -





Data file

File name: Badesa

Description: Badesa total annual rainfall

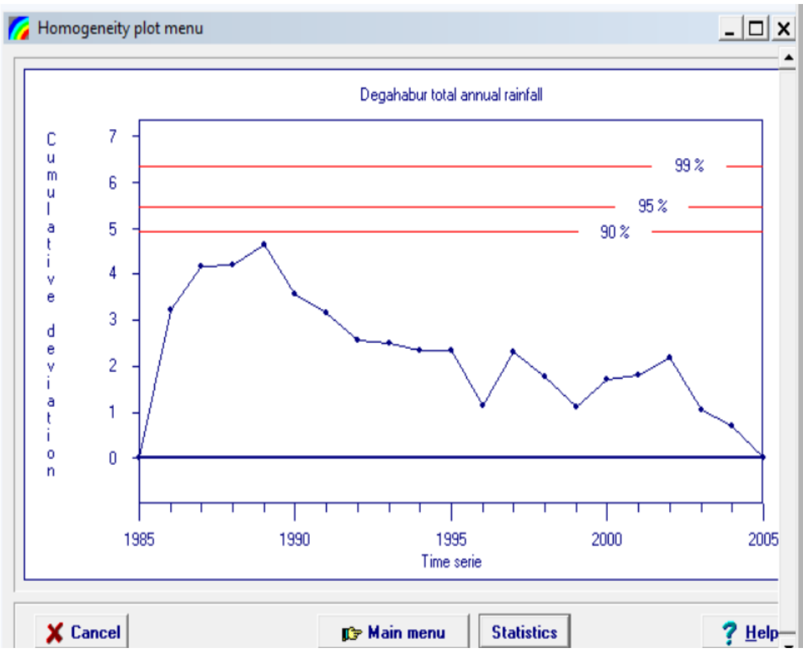
Homogeneity test

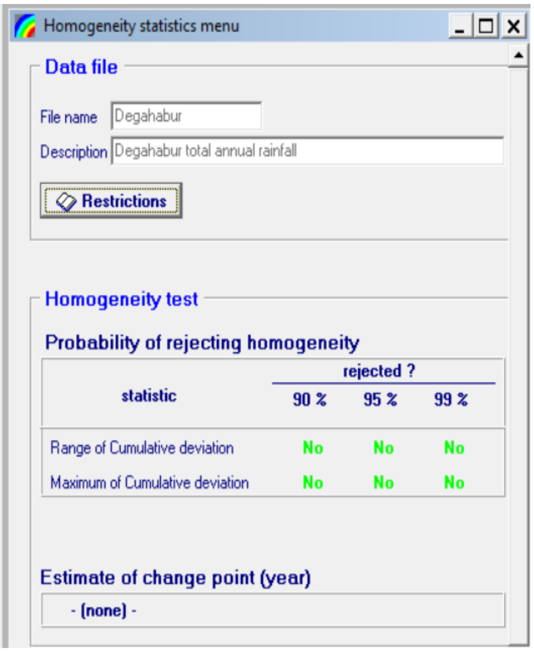
Probability of rejecting homogeneity

statistic	rejected ? 90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -





Data file

File name: Degahabur

Description: Degahabur total annual rainfall

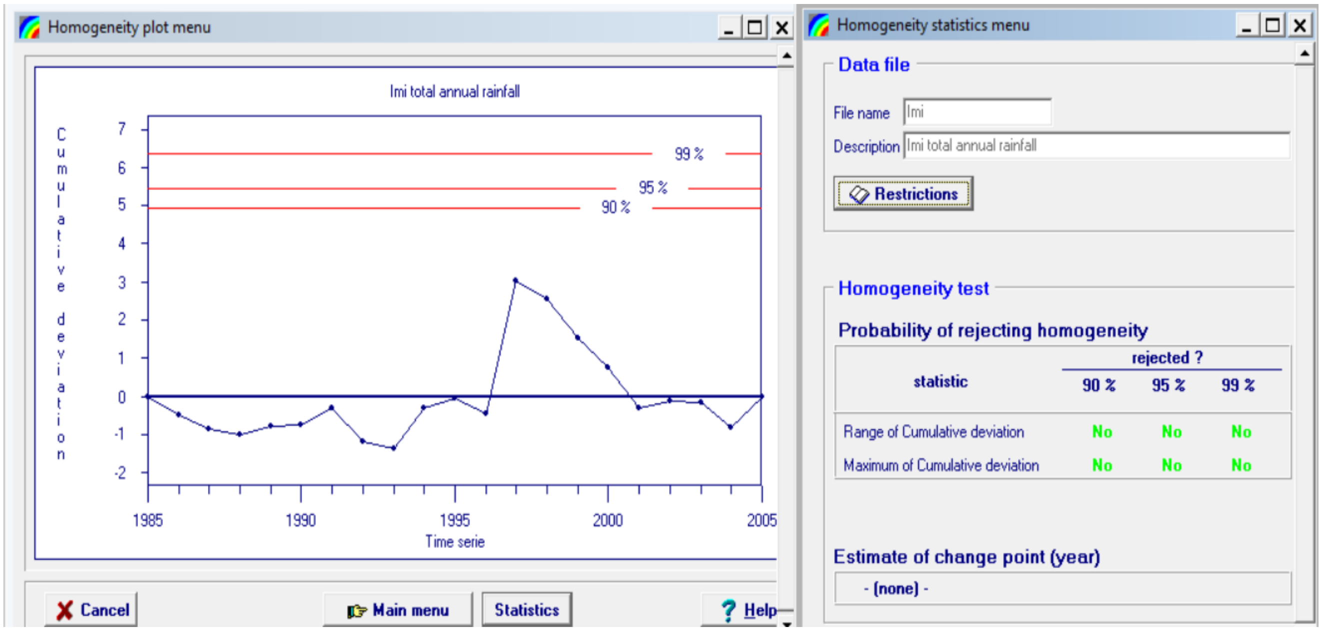
Homogeneity test

Probability of rejecting homogeneity

statistic	rejected ? 90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -



Data file

File name: Imi

Description: Imi total annual rainfall

Homogeneity test

Probability of rejecting homogeneity

statistic	rejected ? 90 %	95 %	99 %
Range of Cumulative deviation	No	No	No
Maximum of Cumulative deviation	No	No	No

Estimate of change point (year)

- (none) -

4a RAINFALL ANOMALIES FOR EACH STATIONS

Adaba station (Z)

Year	Observed	CCLM4-18-17	HIRHAM5	RACMO22T	RCA4	Ensemble
1986	-2.07	-1.49	2.26	-4.09	-4.81	-2.03
1987	-2.77	7.94	-5.98	7.53	3.63	3.28
1988	0.21	-2.69	5.90	-1.88	2.46	0.95
1989	2.73	-4.87	-0.51	0.99	-0.18	-1.14
1990	6.37	-0.55	2.97	4.20	1.23	1.96
1991	-0.96	-2.81	3.74	3.12	1.72	1.44
1992	-7.36	-4.17	1.03	0.27	4.57	0.43
1993	-0.96	4.66	-2.81	-4.13	3.73	0.37
1994	3.11	4.55	2.89	7.65	-0.02	3.77
1995	1.00	-1.62	-6.42	-5.82	-6.95	-5.20
1996	0.87	-5.56	3.44	0.51	-1.92	-0.88
1997	-0.24	-1.97	-4.37	2.80	0.05	-0.87
1998	5.69	1.22	1.01	-6.72	4.57	0.02
1999	0.90	-0.98	-0.51	-1.97	3.95	0.12
2000	-1.17	-2.43	0.03	0.88	3.65	0.53
2001	-2.52	1.86	4.18	-0.82	0.32	1.38
2002	-5.72	5.75	1.58	-3.17	-5.08	-0.23
2003	1.82	-2.41	2.00	-1.54	0.48	-0.37
2004	-6.21	6.65	-7.14	2.04	0.00	0.39
2005	7.29	-1.10	-3.30	0.11	-11.41	-3.92

Girawa station (Z)

year	Observed data	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	4.93	2.07	4.95	0.92	3.91	2.96
1987	0.00	2.85	-14.19	8.77	-3.48	-1.51
1988	-4.57	4.07	13.98	-5.14	-0.62	3.07
1989	5.48	-4.96	-2.79	-2.79	-2.44	-3.25
1990	-4.80	-5.15	-0.43	-0.31	6.96	0.27
1991	1.12	-2.13	10.99	-4.05	1.50	1.58
1992	1.61	-3.81	-1.43	1.41	2.02	-0.45
1993	-1.80	4.74	0.29	3.35	-2.60	1.44
1994	-4.54	3.99	-0.21	0.19	-2.55	0.35
1995	0.20	-4.41	-0.51	1.46	-7.75	-2.80
1996	1.63	0.98	-1.00	1.60	6.75	2.08
1997	6.60	1.76	-0.33	6.09	1.56	2.27
1998	2.17	2.24	-0.40	-6.78	1.13	-0.95
1999	2.76	-1.62	0.54	-4.37	3.58	-0.47
2000	-3.22	-0.32	-4.09	2.37	-1.36	-0.85
2001	0.62	0.00	-1.03	0.05	-0.22	-0.30
2002	3.08	4.50	-0.33	-2.18	-3.35	-0.34
2003	-3.96	0.81	-0.40	-4.62	-3.82	-2.01
2004	-3.55	2.79	0.54	2.06	-2.02	0.84
2005	-3.75	-8.42	-4.12	1.97	2.81	-1.94

Badesa station (Z)

year	Observed data	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	1.27	-0.62	2.55	-2.83	1.53	0.16
1987	-8.80	1.01	-10.48	5.94	-4.59	-2.03
1988	-0.11	0.71	7.19	-4.64	-1.36	0.47
1989	-1.93	-1.46	-3.04	-4.94	-4.70	-3.54
1990	-1.20	-5.50	-1.53	1.33	11.02	1.33
1991	2.93	-2.16	6.93	-6.75	3.36	0.34
1992	2.69	-1.49	0.29	-0.38	5.07	0.87
1993	2.54	1.39	0.29	-0.31	0.05	0.35
1994	3.00	8.98	3.97	1.73	-1.80	3.22
1995	-0.56	-5.58	-5.41	0.56	-7.83	-4.56
1996	3.15	-4.56	0.75	1.67	5.19	0.76
1997	5.54	0.19	-1.41	6.13	2.24	1.79
1998	-0.64	4.18	-1.59	-4.07	-0.75	-0.56
1999	4.39	6.11	4.01	-3.24	3.59	2.62
2000	0.72	2.32	0.89	6.24	-1.85	1.90
2001	-2.35	-0.95	2.88	0.83	-1.31	0.36
2002	-7.82	2.82	-2.30	-0.82	-3.12	-0.85
2003	-5.33	1.71	-1.96	-2.02	-1.87	-1.03
2004	3.47	0.76	0.54	2.67	-1.31	0.66
2005	1.57	-7.85	-2.58	2.92	-1.57	-2.27

Gode station (Z)

year	Observed data	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	-0.90	0.40	-1.52	-0.04	-1.28	-0.61
1987	-3.04	8.27	-3.97	-4.26	0.27	0.08
1988	-2.63	-2.60	10.27	-1.63	5.34	2.84
1989	-3.71	-3.46	-2.26	1.78	-1.59	-1.38
1990	-6.02	-0.26	1.20	5.29	-0.14	1.52
1991	2.72	-0.52	-2.33	-1.83	-2.35	-1.76
1992	-4.18	-2.62	4.73	1.88	4.44	2.11
1993	9.08	-3.21	-1.08	-4.90	-4.85	-3.51
1994	2.27	3.90	3.15	2.75	1.06	2.71
1995	-2.39	5.20	-4.94	1.80	-7.46	-1.35
1996	-0.77	-5.41	4.47	-5.05	5.78	-0.05
1997	12.10	-2.10	-3.42	0.84	-0.87	-1.39
1998	0.64	3.29	0.55	-0.74	2.98	1.52
1999	-1.92	-1.13	-0.70	0.85	4.34	0.84
2000	2.50	-5.26	2.09	-4.13	3.40	-0.97
2001	-4.44	6.34	4.51	9.94	1.14	5.48
2002	-0.73	2.72	-3.39	0.18	-5.45	-1.48
2003	0.00	-2.68	-0.26	-6.90	-2.74	-3.14
2004	-0.11	0.65	-4.57	4.70	-3.27	-0.62
2005	1.53	-1.54	-2.53	-0.52	1.24	-0.84

Degahabur station (Z)

Year	Observed data	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	14.37	1.05	4.90	0.50	3.22	2.42
1987	4.22	2.21	-8.11	-6.62	-2.75	-3.82
1988	0.01	1.76	6.57	5.72	0.64	3.68
1989	1.96	-5.30	-4.04	-1.14	-5.16	-3.91
1990	-4.73	-1.45	-0.09	8.30	3.16	2.48
1991	-1.85	1.35	4.27	-2.04	1.46	1.26
1992	-2.65	-1.74	3.33	5.27	3.28	2.54
1993	-0.28	-3.98	3.21	4.09	-1.70	0.41
1994	-0.58	3.43	-2.23	-0.92	-2.43	-0.54
1995	-0.07	-2.25	-3.85	-0.22	-4.66	-2.74
1996	-5.23	-3.52	-0.89	-0.03	8.25	0.95
1997	5.07	0.11	-3.38	-0.02	2.44	-0.21
1998	-2.27	6.32	2.43	-4.04	-1.02	0.92
1999	-3.00	-4.54	1.21	-4.80	4.89	-0.81
2000	2.62	-5.41	3.25	-2.47	0.26	-1.09
2001	0.47	2.39	0.91	-0.27	-3.81	-0.19
2002	1.62	6.09	-2.07	0.65	-5.90	-0.31
2003	-4.95	-1.65	-1.10	-5.76	-0.96	-2.37
2004	-1.52	5.28	-2.09	5.74	-1.60	1.83
2005	-3.21	-0.16	-2.24	-1.95	2.41	-0.49

Imi station (Z)

year	Observed data	CLMcom-CCLM4-18-17	DMI-HIRHAM5	KNMI-RACMO22T	SMHI-RCA4	Ensemble
1986	-2.27	4.31	-1.54	0.79	6.04	2.40
1987	-1.89	0.34	-5.63	-6.65	-1.75	-3.42
1988	-0.71	-1.70	3.25	-0.09	1.21	0.66
1989	1.09	-3.88	-4.01	3.08	-2.82	-1.91
1990	0.26	0.05	0.32	6.65	5.80	3.20
1991	1.98	2.49	-2.38	-0.14	0.92	0.22
1992	-4.12	-3.33	4.69	0.79	5.22	1.84
1993	-0.82	-1.73	0.95	-5.74	-5.05	-2.89
1994	5.08	8.64	4.75	2.64	-0.69	3.83
1995	1.11	-1.76	-2.99	1.33	-6.03	-2.36
1996	-1.85	-4.88	5.45	-2.78	3.83	0.41
1997	16.69	-2.78	-0.79	-1.06	0.27	-1.09
1998	-2.32	0.21	3.04	0.92	1.28	1.37
1999	-4.99	-1.72	4.48	-0.52	2.36	1.15
2000	-3.67	-4.37	-1.32	-4.95	-2.55	-3.29
2001	-4.95	6.77	-1.21	8.10	2.52	4.04
2002	0.89	1.59	-3.27	0.55	-2.04	-0.79
2003	-0.21	-3.85	3.85	-6.02	-4.10	-2.53
2004	-3.12	-0.01	-3.73	5.16	-5.25	-0.96
2005	3.82	5.61	-3.92	-2.05	0.82	0.11