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Climate projections and the parallel energy availability in the case of Kombolcha town, South Wollo Ethiopia

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ABSTRACT

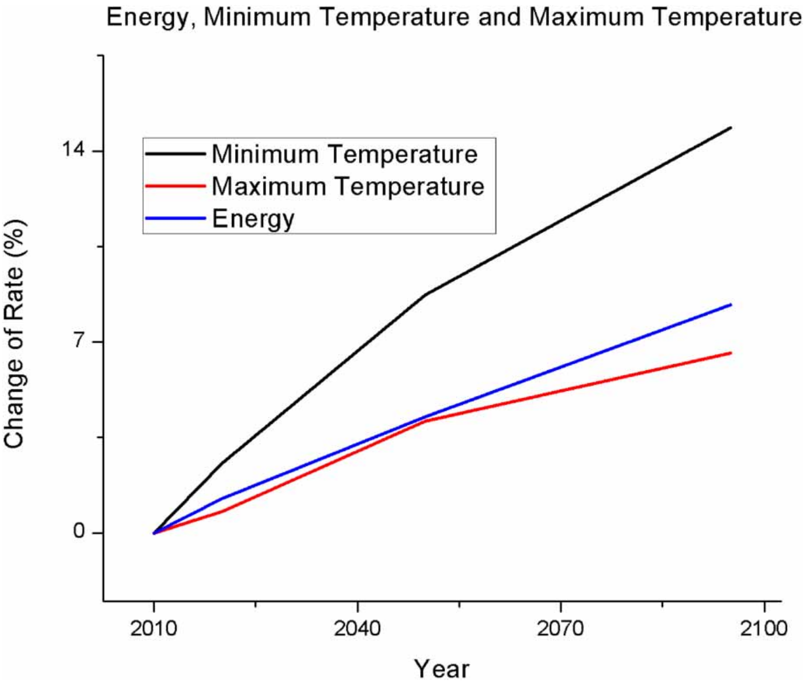
This paper focused on climate projection on energy availability in Kombolcha town, central north Ethiopia, which is one of the most industry-occupied places in the country. Marksim climate data generator model with all ensemble models and representative concentration pathway (RCP) 8.5 scenario is used. The climate projection outputs are drawn from the model based on the given input latitude, longitude, and climate parameters (maximum temperature, minimum temperature, and precipitation). The result showed that the mean monthly maximum temperature, mean monthly minimum temperature, and mean monthly precipitation have an increased pattern over the study area with a rate of change of 8.4, 14.85, and 6.6%, respectively, over the past 4.5 decades. The mean monthly minimum temperature showed the highest rate of change (14.85%). As a result, the change in temperature causes a change in energy. Since temperature cause motions of particles over the area, the parallel energy availability will increase. Therefore, the energy rate of change for the 4.5 decades is 8.36%. Since the research is based on online data from the model and more industries are established in the study area, industry-related research with baseline climate data should be conducted to reduce climate-related hazards in the study area.

Key words: climate projection, energy, Kombolcha town, Mark–Sim weather generator, temperature

HIGHLIGHTS

- Climate forecasting
- Climate and energy relation
- Society service from climate
- Water resources and climate projection
- Climate change impacts

GRAPHICAL ABSTRACT



1. INTRODUCTION

Climate projection is important for the exploring of climate variability and its purpose in ecology. Unrelated integration between ecology and climate science has limited the understanding of the available climate data and their appropriate use. Better focus on the climate projections is essential to update decisions about the choice of a climate model, emissions scenarios, baseline period, and the spatial and temporal resolution of the data (Harris *et al.* 2014). Based on the study by Hayhoe *et al.* (2017), the greenhouse gas concentration causes an increase in temperature by 0.6 °C, and the world temperature projection will increase from 0.3 to 0.7 °C, for the coming decades, the magnitude of climate change depends on cumulative emissions of greenhouse gases aerosol, global mean atmospheric carbon dioxide concentration increased to 400 ppm which occurred about 3 million years ago, the observed increase carbon emission in the past two decades has been consistent with higher scenarios. In 2014 and 2015, emission growth rates slowed as economic growth has become less carbon-intensive. Studies showed that climate change's impact on wind energy, hydropower, and bioenergy at a global level has mixed (both negative and positive) in different regions (Yalew *et al.* 2020). Using renewable energy is a vigorous solution to alleviate the hazard of global warming and climate change-related occurrences (Beyaztas *et al.* 2019). Developing and using hybrid technics for climate variability and energy increased the accuracy of forecasts. Hybrid network techniques have better performance than a single network (Shamshirband *et al.* 2019). Energy plays a vibrant part in the current society which quickens fiscal development and has been considered a serious matter in the past decades (Samadianfard *et al.* 2019).

The extreme precipitation in Adama city increased over the year 1965–2016. Under future climate change scenarios, the extreme precipitation would increase up to 2080 and the changes will be higher during 2050–2080. This extreme precipitation causes frequent and severe floods during the coming 60 years due to the change in global climate (Bulti *et al.* 2021). According to Chaemiso *et al.* (2016), there is an overall increasing trend in future annual temperature and significant variation of monthly and seasonal precipitation from 1985 to 2005. The annual potential evapotranspiration is showing an increasing trend for future climate change scenarios. Temperature and radiation showed an increased pattern in representative concentration pathway (RCP) climate models and cause increased water demand in the awash river basin (Yadeta *et al.* 2020). The African continent is an exceptionally vulnerable region to climate change and weather variability especially regions in semi-arid areas of the continent which are dependent on seasonal rainfall. In recent periods, severe drought causes famine and death in the Horn of Africa and climate models have difficulties in simulating key elements of climate (Hernández-Díaz *et al.* 2013). During the last 50 years, the global climate showed warming due to the greenhouse gases amount in the earth's atmosphere which has a big role in the day-to-day activities. From time to time, increments of solar radiation have been recorded in recent times around the world (Gharbia *et al.* 2016). Based on the observed and projected data drawn from climate models on precipitation and temperature analysis, there is a significant increase in temperature and less precipitation change. Different models showed different results of climate variability results due to the data they used for future climate systems (Asitatikie & Gebeyehu 2021). An increase in temperature in the world is observed in the late twentieth century related to the frequency and magnitude of extreme events and greenhouse gas emissions due to human activities in different countries. By the end of the 20th century, the maximum and minimum temperatures increased and caused stress on water bodies due to high evapotranspiration (Hassan & Nile 2021). The maximum temperature recorded showed increasing over the minimum temperature. Climatic parameters change has a role impact on horticulture and agricultural production which have consequences for world food security in the future. At the end of the areas covered forests in low-risk zones increased from 1 to 4.43% and for high-risk areas, the forest cover decreased from 8.2 to 4.7%. As a result, high-risk areas are in danger of hazard pruning in the future and proper action would be assigned for those areas (Rahimi *et al.* 2018). Evapotranspiration is a vital role in determining water flux in agricultural activities followed by temperature, humidity, wind speed, and solar radiation (Tyagi *et al.* 2019). The minimum mean temperature increased faster than the mean maximum temperature between 1981 and 2010 which cause the increased warming during nighttime in Ghana (Bessah *et al.* 2018). In long-term climate analysis in the Geba catchment, Ethiopia showed increased climate variables except for minimum temperature (Asnake *et al.* 2021). In assimilated water management, combined climate variable scenarios should include various climate parameters to resolve climate-related problems in water resources (Hussen *et al.* 2018). For water resources affected by different climate variability, restoration should be done including environmental, social, agricultural, hydrological, soil, climate, and ecological parameters. The energy due to the particle is directly proportional to temperature motion (Manatsa *et al.* 2008). The amount of energy due to temperature change is given by $E = 3/2KT$ (1), where E is energy, K is constant and T is temperature. Despite the fact that more papers looked at climate impacts on energy systems: until now, relatively few comprehensive papers have been published on the impacts of climate change on energy systems as a whole. Papers focused on climate change impacts on agriculture activities and water. The use of varied methods in the energy sector studies also limits the comparability of climate change effects across different studies. We briefly discuss these systematic shortcomings next and recommend possible steps forwards. Since Kombolcha town is found between hills and an industrial town in Ethiopia, more energy-related research works are expected. Therefore, different research works in different areas showed that climate change causes a change in water resources demand, production, food security, environmental features, and health. As a result, there is no research works about energy with climate change and projection conducted in the study area. Therefore, this paper is designed, to assess climate projection and the parallel energy availability in Kombolcha town, south Wollo, Ethiopia by using the Marksim climate generator model.

2. MATERIALS AND METHODS

2.1. Study area

As shown in Figure 1, the study area is located in Eastern Africa, central north Ethiopia with a latitude of 10.8°–11.4°N and a longitude of 39.65°–40°E. It is found at 1,842–1,905 m elevation above sea level and its topography is more low land. Agroecologically, the area is semi-desert. Having such a great proportion of semi-desert in Kombolcha implies that, a great proportion of the area is drought prone which is affected by climate variability and change. It has an average maximum temperature of 25.8 °C, an average minimum temperature 11.3 °C, average annual rainfall of 1,027 mm, and annual rainy days over the area is ($\geq$10 mm/day) 101. The average relative humidity in the area is 56%. Regardless of its lower area compared to other areas of the country, Kombolcha town is surrounded by large hills and has more factories (steel, meat processing, leather, bear, and plastic factories and, more than 15 combined factories in Kombolcha industrial park have been established in recent times). Kombolcha is selected as a study area because of its distinct location in a semi-desert surrounded by hills, its low-level economy society, and its potentials to establish renewable energy sources for society in future.

2.2. Data and methodology

2.2.1. Model description

The Marksim weather generator model is an agricultural model developed for decision support system for agricultural technology transfer (DSSAT). It has 20 ensemble models and 4 RCPs; RCP 2.6 for projection of carbon dioxide, RCP 4.5 for non-renewable energy sources, RCP 6 for high irradiative force stabilization and RCP 8.5 for projected temperature and sea

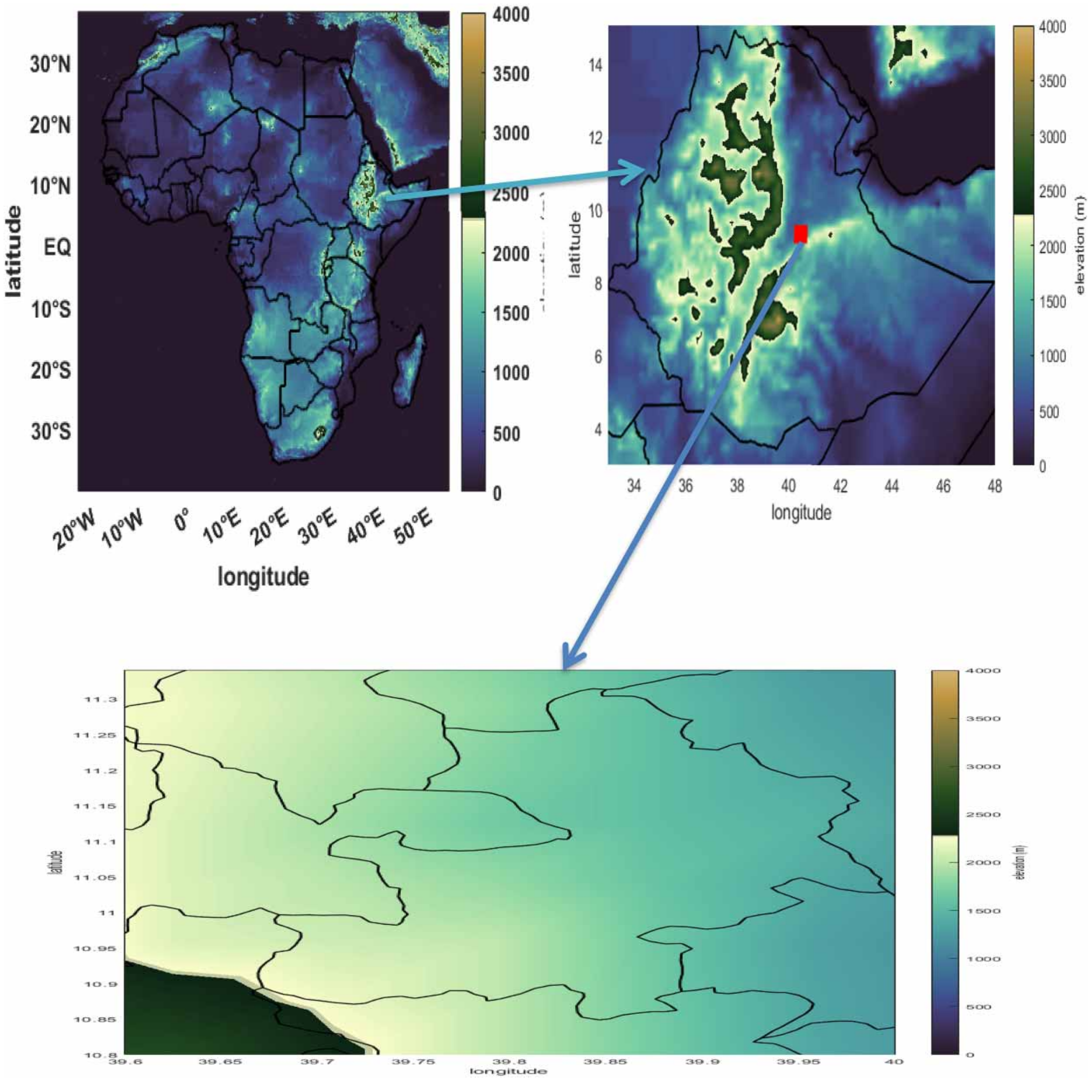


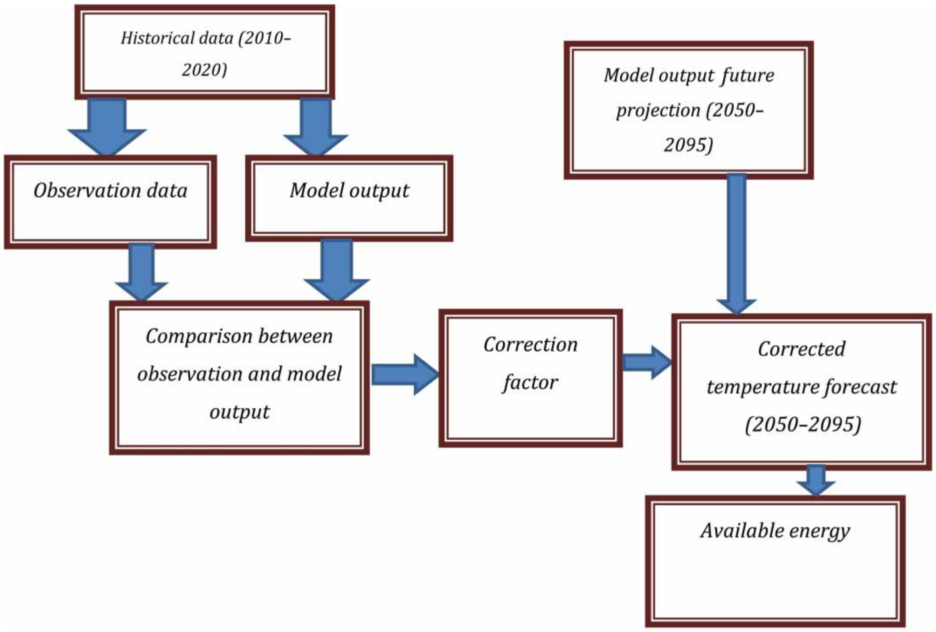
Figure 1 | Topography of the study area.

level. Marksim weather generator is used for temperature projection with hybrid models and revealed more accurate outputs Ayugi *et al.* (2021). Marksim weather generator is selected because it gives point data for the study area and is easy to feed and draw the model output. Since temperature projection and the parallel energy availability are related to RCP 8.5 scenario, it is selected with all ensemble models.

2.2.2. Data and method

Observational data (minimum and maximum temperature) for the time 2010–2020 are collected from Ethiopian Meteorology Institute and the model output data (minimum and maximum temperature) for the same period (2010–2020) are generated from the model output. Statistical analysis is commonly used for the depiction of water-related monthly variables and events (Chebana & Ouarda 2021). To study the characteristics of climate extremes (flood and drought) frequency analysis should be applied. Popular Hydrological phenomena are described by correlation characteristics (Burgan *et al.* 2017). For the time 2010–2020, historical data are compared and corrected. The correction factor for temperature is calculated from the observation data and model output $CF = T_O - T_M$, where CF is the correction factor, T_O is the monthly mean observation temperature, and T_M is the monthly mean model output. The bias is corrected based on model output and baseline data. Consequently on the corrected temperature data future projections are predicted. Projected model output data for the time 2050–

2095 is forecasted and corrected by the correction factor. Forecasting is planned to be decadal and 2020 is selected as a recent year for the first half-century of 2100. The next 4.5 decades 2050–2095 are considered. With the projected temperature the energy availability is estimated.



Data Flow chart

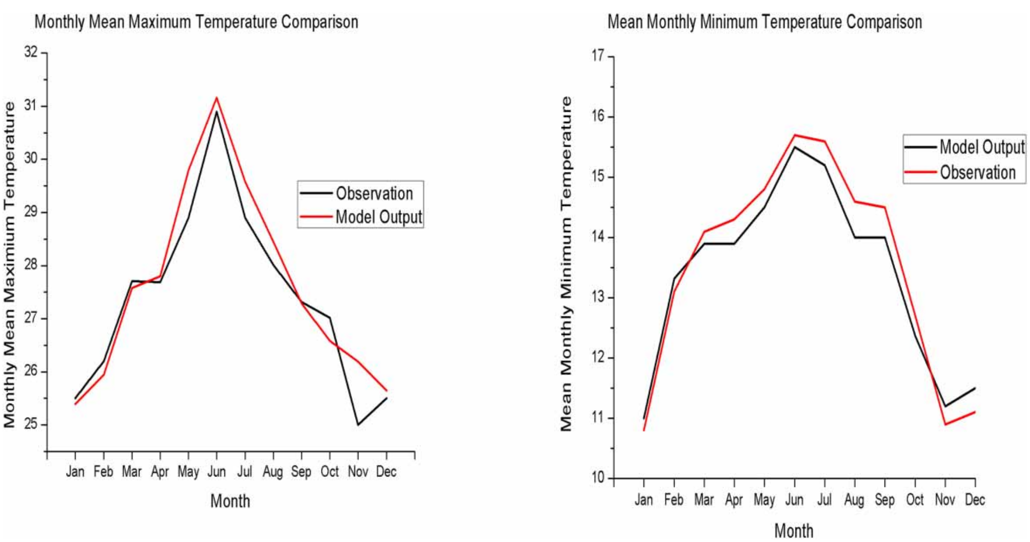


Figure 2 | Historical data comparison.

Table 1 | Correlation (*r*) and coefficient of determination (R^2)

	Correlation between observation and model (*r*)	Coefficient of determination (R^2)
T_{min}	0.991***[1]	0.98 (98%)
T_{max}	0.964***[2]	0.93 (93%)

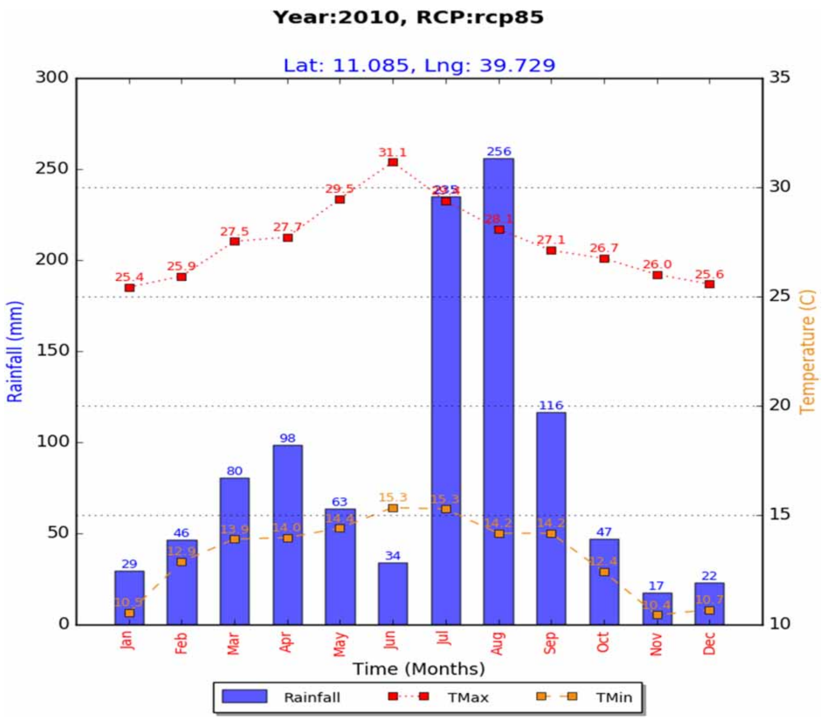


Figure 3 | Climate projection diagram (2010).

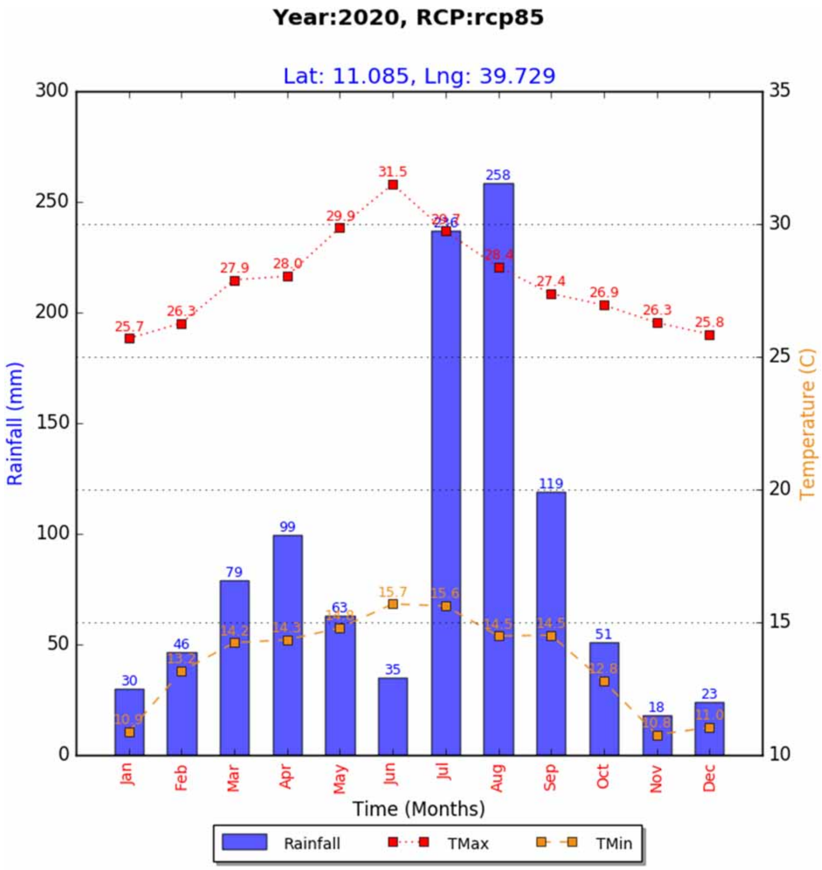


Figure 4 | Climate projection diagram (2020).

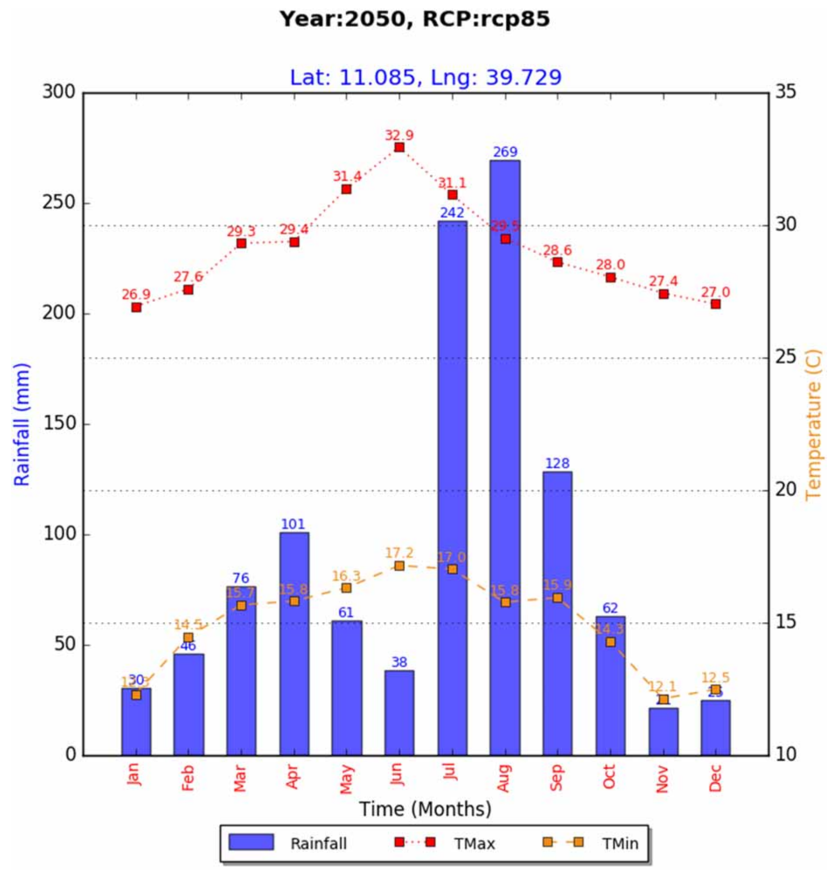


Figure 5 | Climate projection diagram (2050).

3. RESULTS AND DISCUSSION

Figure 2 shows a comparison of the historical monthly mean maximum and minimum temperature of observation and model output data for the time 2010–2020. For the month (September–January), the model output is underestimated and for the month (February–August), the model output data is over estimated. According to Table 1, the coefficient of correlation (*r*) and coefficient of determination (R^2) for monthly mean maximum and monthly mean minimum temperature are 0.991, 0.994 and 98%, and 93%, respectively. For both minimum and maximum temperatures, the variation between observation and model output is very small and has low bias. Based on Figure 3, the past climate data (2010) indicate that the monthly mean maximum temperature and minimum temperature were recorded in June with a value of 31.1 and 15.3 °C, respectively. The monthly maximum rainfall was recorded in August and it was 256 mm. implicated in Figure 4 after a 10-year interval the monthly mean maximum and minimum temperature were recorded in June and 31.5 and 15.7 °C, respectively. The maximum monthly mean rainfall was recorded in August and it was 258 mm as indicated in Figure 5 in 2050 after a 41 time, the monthly mean maximum and minimum temperatures are increased to 32.9 and 17.2 °C, respectively. The maximum monthly mean rainfall is increased to 269 mm and recorded in August. As shown in Figure 6 2095, the mean monthly maximum and minimum temperatures recorded are 35.9 and 20.2 °C, respectively. The maximum mean rainfall is 288 mm and was recorded in August. As shown in diagram 7 in 2095, the rate of change in temperature and rainfall showed an increased rate from the past (2010) and present. Therefore, the forecasted climate variability, the mean monthly minimum temperature showed a fast rate of change over the study area. From all diagrams, the rate of change in temperature and rainfall increased over the area.

Based on Table 1, the decadal climate variability of the monthly mean minimum temperature shows a maximum rate of change than the monthly mean maximum temperature and precipitation. For the last 4.5 (2050–2095) decades, the rate of change of mean monthly maximum temperature, mean monthly minimum temperature and, mean monthly rainfall is 8.4, 14.85, and 6.6%, respectively. Therefore, the mean monthly minimum temperature showed a faster rate of change and

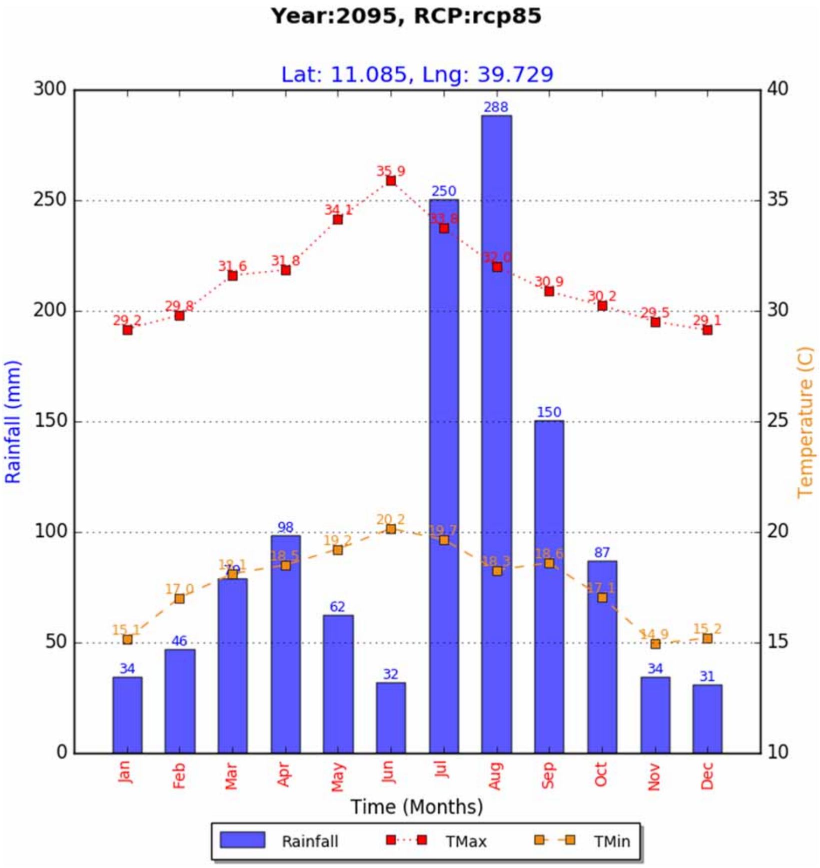


Figure 6 | Climate projection diagram (2095).

precipitation showed a lower rate of change. Since the minimum temperature is recorded in the morning and nighttime, its increase will affect the sea breath during nighttime. Subsequently, kinetic energy is directly proportional to the amount of temperature, the increase in temperature results in an energy increment.

Combined with Table 2 and Figure 7, energy and temperature have direct relation and the rate of energy change for the first decade (2010–2020) is 1.27%, 4.255% for the second three decades (2020–2050) and 8.36% for the last 4.5 decades (2050–2095). Therefore, from the forecast, there will be more energy availability in the study area. The study by Kabite *et al.* (2020) describes the mixed impact of climate change on energy in both regional and global levels. Conversely, Shamshiraband *et al.* (2019) indicated that hybrid network is important for the effectiveness of energy forecast and the importance of energy in development. Hassan & Nile (2021) indicated projected temperature stress on water bodies. Therefore, this paper tried to estimate future energy availability by temperature projection for the society and combined models used for a better forecast.

Table 2 | Rate of energy change

Year	T_{max} (°C)	Rate of change	T_{min} (°C)	Rate of change	Precipitation (mm)	Rate of change
2010	31.1	NA	15.3	NA	256	NA
2020	31.5	1.270%	15.7	2.55%	258	0.78%
2050	32.9	4.255%	17.2	8.72%	269	4.09%
2095	35.9	8.357%	20.2	14.85%	288	6.60%

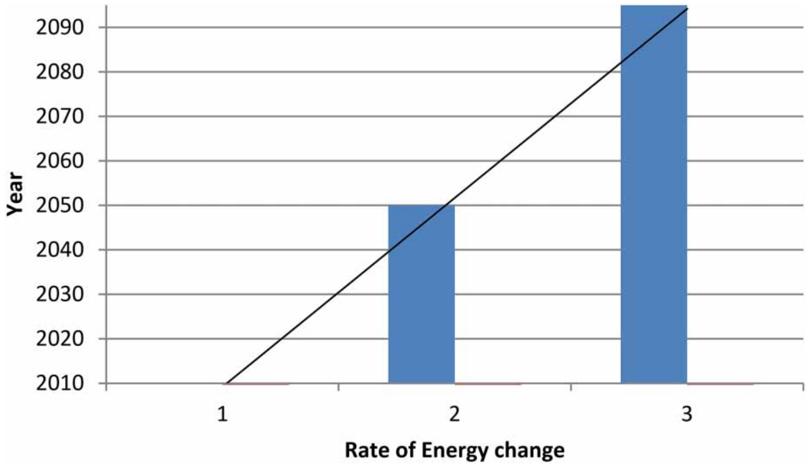


Figure 7 | Energy rate of change.

4. CONCLUSION

As compared to the past, present, and, future temperature and precipitation in central north Ethiopia, Kombolcha town by using the general circulation model, the measured parameters showed an increased pattern with a faster change of rate in monthly mean minimum temperature. During the baseline period (2010–2020) the historical data (model output and observation) are tested and showed good linkage. Based on the correction factor, the future projection (2050–2095) was corrected. As a result, the minimum and maximum temperature increase over time and the parallel energy availability forecasted showed an amplified pattern. Therefore, projected temperature enables future energy estimation.

4.1. Recommendation

This study is conducted based on the climate data from the climate model and meanwhile, Kombolcha is an industrial town in the country, for future studies industries' effects should be considered to see their effects on climate change in Kombolcha. Grounded on the result to overcome temperature-related effects on the area appropriate actions should be done to reduce climate change-related effects on societies. On the other hand, more energy availability is estimated over the study area due to temperature projection and more technological devices will be used to convert the energy into useful forms for the society. Since Kombolcha is a semi-desert area, industry-related climate change and variability are not considered in this study and the society is in lower life standard, more research and project works related to renewable energy and industry-related climate impact should be conducted to use wind, hydropower and solar radiation energies wisely and alleviate climate-related hazards in the area. Originated on this, wind energy projects should be proposed around the town (free hills) and technologies should be practised in the town for solar radiation.

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AUTHOR CONTRIBUTION

The authors contribute in material collection data gathering, data organizing, paper reviewing, manuscript preparation, editing, data analysis, and discussion.

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DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories: (https://www.bing.com/search?pglt=41&q=mark-sim+weather+generato).

CONFLICT OF INTEREST

The authors declare there is no conflict.

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