

Climate Projection Outlook in Lake Haramaya Watershed, Eastern Ethiopia

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Abstract

Smallholder farmers in Ethiopia generally face widespread problems driven by climate change. For this reason, the study of climate change at watershed level might be critical to solve the problem from its root. The study was conducted in Lake Haramaya Watershed, Eastern Ethiopia to project and characterize the climatic condition of the coming thirty years (2020-2050). Thirty-four years of rainfall, maximum and minimum temperature baseline data were collected from National Meteorological Agency of Ethiopia. Whereas, thirty years (2020-2050) projected rainfall, maximum and minimum temperatures were downscaled from MarkSim web version for IPCC AR5 data (CMIP5) using five climate models namely: BCC-CSM1-1, CSIRO-Mk3-6-0, HadGEM2-ES, MIROC-ESM, MIROC-ESM-CHEM, and MIROC5 under two Representative Concentration Pathways (RCPs): RCP4.5 and RCP8.5. The results of the study revealed that the annual mean rainfall will be increased by 20.70 and 24.14% under RCP4.5 and RCP8.5, respectively compared to baseline average value of 777.51 mm/yr. The annual rainfall under RCP4.5 ranges from 769.6 to 1090 mm/yr having the CV value of about 11%; whereas, under RCP8.5, it will range from 771.9 to 1129 mm/yr with the CV value of 13.17%. Kiremt (JJAS) season rainfall will increase from the baseline of 107.55 mm/yr to 135.79 and 136.27 mm/yr under RCP4.5 and RCP8.5, respectively. Moreover, a study indicated that the annual and seasonal temperature under RCP4.5 and RCP8.5 will be expected to increase during 2020-2050 period. Under high emission scenario of RCP8.5, the annual maximum temperature could rise from 24.73°C baseline to 25.41°C.

Keywords: Climate projection; Climate change; Lake Haramaya; Ethiopia

Introduction

Intergovernmental Panel on Climate Change (IPCC) has reported that by 21st century, the average global temperature would rise between 1.4 and 5.8°C and rainfall would vary up to $\pm 20\%$ from the 1990 level. Despite uncertainties on the directions and magnitude of climate changes, there is significant scientific evidence that shows an increase in average temperature and overall climate variability in the semi-arid tropics, with subsequent increases in the occurrence of droughts, floods and heat waves that affect people, their crops, and livestock [1,2].

Future climate projections for Eastern Africa countries vary, with high altitude areas of Ethiopia potentially benefiting from warming temperatures. However, without adequate adaptation measures, most of the region is likely to be deleteriously affected by rising temperatures due to increasing rates of evaporation and transpiration [3]. Moreover, spatial and temporal variability of rains, and an increase in the intensity of rainfall events, frequency and duration of droughts will affect the farming communities at large [4]. Some of these changes are already being experienced across the region; others are predicted in the near future [5-7].

Ethiopia's mean annual temperature is showing a significant warming trend leading to increasing rates of evapotranspiration and crop water requirements, further adding to the already frequent water stress of crops [8]. Future projections show that the mean maximum temperature will increase by 2-2.3 °C until 2030 and by 2.2-2.7 °C until 2050, while the mean minimum temperature will rise by 0.8-0.9 °C until 2030 and 1.4-1.7 °C until 2050, all in conjunction with a surge of hot days and nights and a decrease of cold days and nights [9].

Smallholder farmers in Ethiopia generally face widespread problems driven by climate conditions: water scarcity for drinking, industry, agricultural crop production, lack of pasture and livestock

feed. This vicious cycle of poverty, food insecurity and natural resources degradation is basically caused because of higher population growth but is being exacerbated by increasing weather variability and climate change. Specifically, the impacts of climate change on water bodies in Africa have become a prominent and hot agenda. Of Africa's total population, about 60% live in rural areas and almost more than 80% rely on water from seasonal rainfall for domestic and other needs [10].

In line with this, except few studies [4,8,9] conducted in Central and northern parts of Ethiopia, nothing has been done in eastern Hararghe on climate projection and its implications on the livelihoods of the farming communities. Therefore, this study aims to investigate climate projection outlook in Eastern Hararghe at watershed level, so as to enhance the resilience of the farming community against the impacts of climate change. This gives also an opportunity to plan appropriate adaptation measures that must be taken ahead of time. Moreover, it will give enough room to consider possible future risks in all phases of climate related projects.

Materials and Methods

Description of the study area

Lake Haramaya Watershed is located in Haramaya and partly in

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Kombolcha districts, Eastern Hararghe Zone, Oromia National Region State, and East Ethiopia. The Watershed lies between 9°23'12.27''-9°31'9.85'' N and 41°58'28.02''-42°8'10.26'' E (UTM Zone 38) (Figure 1) and covers an area of 15,329.96 ha. The elevation ranges from 1800 to 2345 meters above sea level. Information obtained from Ethiopian National Meteorological Agency indicates that the mean annual rainfall and mean maximum and minimum temperatures of Haramaya watershed are 800.9 mm, 24.18°C, and 9.9°C, respectively. Mixed farming system: cash crop production such as coffee (Coffea arabica) and chat (Catha edulis), vegetable crop production like: potatoes, carrots, onion, and green pepper are widely produced in the area. Animal fattening is observed with a number of households.

Research approach

Long term meteorological data, thirty-four years of rainfall, maximum and minimum temperature baseline data were collected from National Meteorological Agency of Ethiopia. Whereas, thirty years (2020 to 2050) projected climate data: rainfall maximum and minimum temperatures were downscaled from MarkSim web version for IPCC AR5 data (CMIP5). In the processes of downscaling, five climate models namely: BCC-CSM1-1; CSIRO-Mk3-6-0; HadGEM2-ES; MIROC-ESM; MIROC-ESM-CHEM; MIROC5 under two Representative Concentration Pathways (RCPs): RCP4.5 and RCP8.5. The models selected are highly applicable for African climate studies [3,11]. Thus, changes in climate over specific area, Lake Haramaya watershed over the determined period of 2020 to 2050 were noticed as monthly temperature changes in (°C) and monthly precipitation changes in (%) from the base period of 1980-2013.

Results and Discussion

Climate projection

Annual and seasonal rainfall projection: The results of the analysis of the projected data over Lake Haramaya revealed that the annual

mean rainfall will be about 938.5 and 965.2 mm/yr under RCP4.5 and RCP8.5, respectively compared with the baseline average value of 777.51 mm/yr (Table 1). The annual rainfall under RCP4.5 ranges from 769.6 to 1090 mm/yr having the CV value of about 11%. Whereas, under high representative concentration pathway (RCP8.5), the rainfall in the upcoming thirty years will range from 771.9 to 1129 mm/yr with the CV value of 13.17% (Table 1). This implies that the annual rainfall will increase certainly under both climate scenarios considered for this particular study.

Moreover, it has been pinpointed through this study that the seasonal rainfall over the specific watershed will rises up. For instance, the Kiremt (JJAS) season rainfall will increase from the baseline of 107.55 mm/yr to 135.79 and 136.27 mm/yr, respectively. However, comparing the CV values for both scenarios, rainfall under RCP8.5 could be highly variable, CV value of 56% (Table 2). Thus, Kiremt season rainfall under this scenario will not be promising to work with particularly, for those farming communities. The same trend could be observed for Belg (FMAM) season the watershed, where the highest CV value of 103% (Table 2).

The result of study also showed that there will be increments in the seasonal rainfall of Bega (ONDJ) season compared to the baseline. It will rise up from 22 mm/yr to 135 mm/yr and 18 mm/yr under RCP4.5 and RCP8.5 scenarios, respectively (Table 2). This indicates that there is probability that Bega season or dry period in the watershed could

| | Baseline | RCP4.5 | RCP8.5 |
|---------|----------|--------|--------|
| Mean | 777.51 | 938.45 | 965.2 |
| Minimum | 309.4 | 769.6 | 771.9 |
| Maximum | 1667 | 1090 | 1129 |
| SD | 321.83 | 104.31 | 127.12 |
| CV (%) | 41.39 | 11.12 | 13.17 |

Table 1: Descriptive statistics of annual rainfall totals in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Eastern Ethiopia.

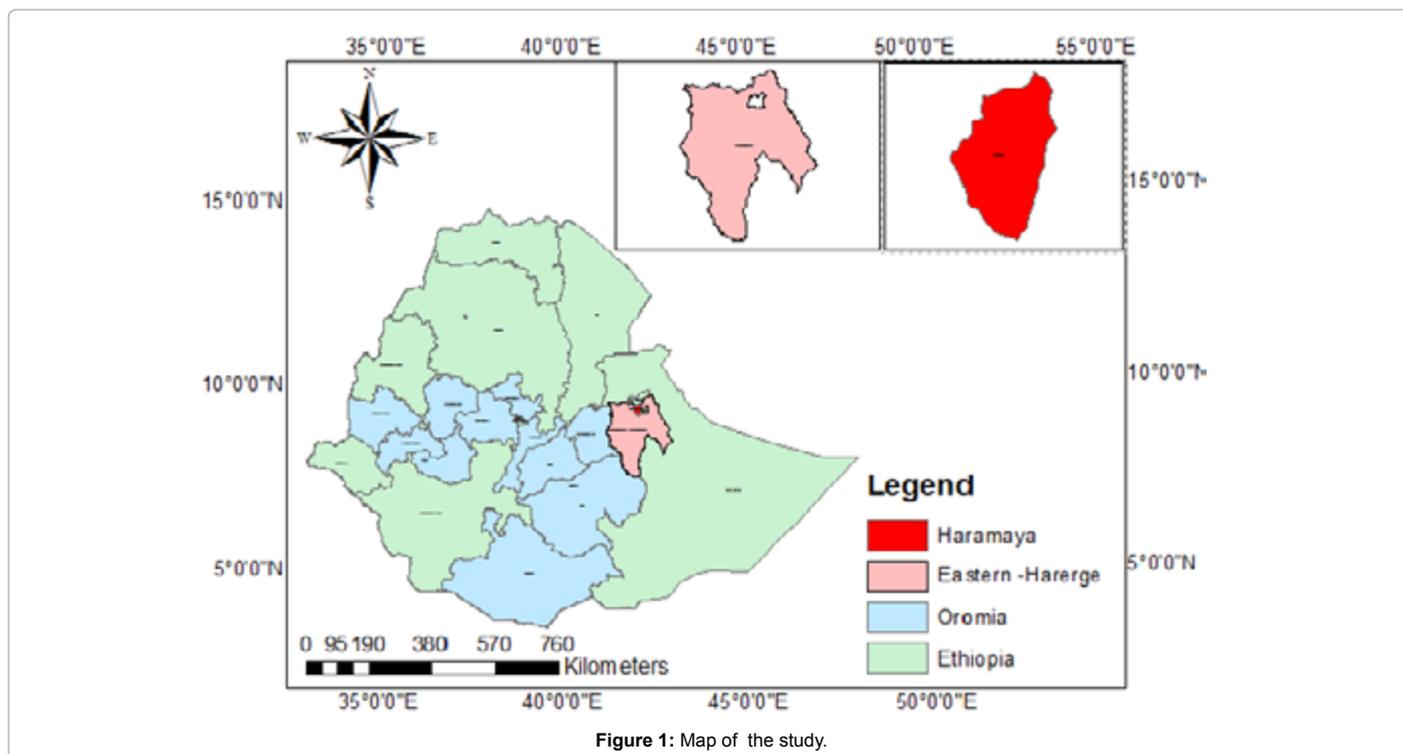


Figure 1: Map of the study.

| JJAS RF (mm) | Baseline | RCP4.5 | RCP8.5 |
|--------------|----------|--------|--------|
| Mean | 107.55 | 135.79 | 136.27 |
| SD | 16.3 | 2.7 | 76.68 |
| CV (%) | 15.15 | 1.98 | 56.27 |
| FMAM (mm) | Baseline | RCP4.5 | RCP8.5 |
| MEAN | 82 | 120.03 | 86.33 |
| SD | 60.77 | 0.69 | 89.24 |
| CV (%) | 74.11 | 0.58 | 103.37 |
| ONDJ (mm) | Baseline | RCP4.5 | RCP8.5 |
| Mean | 22.41 | 135.21 | 18.7 |
| SD | 21.85 | 1.01 | 7.02 |
| CV (%) | 97.49 | 0.75 | 37.53 |

Table 2: Descriptive statistics of seasonal rainfall in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Haramaya district, Ethiopia.

| Annual Temp (°C) | Tmax-baseline | Tmin-baseline | Tmax-RCP4.5 | Tmin-RCP4.5 | Tmax-RCP8.5 | Tmin-RCP8.5 |
|------------------|---------------|---------------|-------------|-------------|-------------|-------------|
| Mean | 24.73 | 11.5 | 24.9 | 12.01 | 25.41 | 11.8 |
| SD | 1.26 | 1.85 | 1.73 | 2.26 | 1.83 | 2.38 |
| CV (%) | 5.09 | 16.05 | 7.43 | 20.35 | 7.84 | 21.11 |

Table 3: Descriptive statistics of seasonal rainfall in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Haramaya district, Ethiopia.

| JJAS Temp (°C) | Tmax-baseline | Tmin-baseline | Tmax-RCP4.5 | Tmin-RCP4.5 | Tmax-RCP8.5 | Tmin-RCP8.5 |
|----------------|---------------|---------------|-------------|-------------|-------------|-------------|
| Mean | 23.89 | 12.66 | 24.06 | 12.91 | 25.9 | 13.1 |
| SD | 1.74 | 0.14 | 0.82 | 0.99 | 0.66 | 0.99 |
| CV (%) | 7.27 | 1.11 | 3.56 | 8.32 | 2.84 | 8.2 |
| FMAM Temp (°C) | Tmax-baseline | Tmin-baseline | Tmax-RCP4.5 | Tmin-RCP4.5 | Tmax-RCP8.5 | Tmin-RCP8.5 |
| Mean | 25.76 | 12.51 | 25.94 | 12.6 | 25.97 | 12.89 |
| SD | 0.5 | 1.36 | 1.53 | 2.31 | 1.67 | 2.53 |
| CV (%) | 1.93 | 10.9 | 6.15 | 19.1 | 6.69 | 20.76 |
| ONDJ Temp (°C) | Tmax-baseline | Tmin-baseline | Tmax-RCP4.5 | Tmin-RCP4.5 | Tmax-RCP8.5 | Tmin-RCP8.5 |
| Mean | 24.53 | 9.32 | 25.99 | 9.5 | 24.7 | 9.51 |
| SD | 0.38 | 1.07 | 1.44 | 2.37 | 1.81 | 2.68 |
| CV (%) | 1.57 | 11.51 | 6.53 | 25.65 | 8.18 | 28.2 |

Table 4: Descriptive statistics of seasonal temperatures in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Haramaya district, Ethiopia.

| | Rainfall (%) | Maximum Temperature (°C) | Minimum Temperature (°C) | Mean air Temperature (°C) |
|----------|--------------|--------------------------|--------------------------|---------------------------|
| Baseline | 777.51(mm) | 24.73 | 11.5 | 18.11 |
| RCP4.5 | 20.7 | 0.06 | 0.04 | 0.05 |
| RCP8.5 | 24.14 | 0.05 | 0.02 | 0.04 |

Table 5: Annual rainfall totals change in (%) and temperatures in (°C) in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Haramaya district, Ethiopia.

| Rainfall (%) | | | |
|----------------------|-------------|------------|------------|
| | JJAS | FMAM | ONDJ |
| Baseline | 107.55 (mm) | 82 (mm) | 22.41 (mm) |
| RCP4.5 | 26.27 | 46.38 | 503 |
| RCP8.5 | 26.7 | 5.28 | -14.73 |
| Air temperature (°C) | | | |
| | JJAS | FMAM | ONDJ |
| Baseline | 18.27 (°C) | 19.14 (°C) | 16.93 (°C) |
| RCP4.5 | 0.04 | 0.03 | 0.08 |
| RCP8.5 | 0.04 | 0.03 | 0.07 |

Table 6: Seasonal rainfall change in (%) and temperatures in (°C) in the upcoming thirty years (2020-2050) at Lake Haramaya watershed, Haramaya district, Ethiopia.

become wetter. This result agreed with what IPCC predicted for African climate, as there will be a shift of seasonal and monthly rainfall [2]. Therefore, a kind of adaptation to the coming events has to be well recognized at grass root level.

Annual and seasonal temperature projection: The annual temperature study over Lake Haramaya watershed revealed that both maximum and minimum temperature under the considered climate scenarios will be expected to increase for the upcoming thirty years (2020-2050). Under high emission scenario of RCP8.5, the maximum temperature could rise from the baseline 24.73°C to 25.41°C (Table 3). The same trends in the increments of minimum temperature will be expected due to the changing climate. Furthermore, the variability of maximum temperature under both scenarios (RCP4.5 and RCP8.5) will be less compared to the minimum temperature condition; this is on the basis of their CV values (Table 3).

On the basis of the present study, seasonal maximum and minimum temperature will rise up for both RCP4.5 and RCP8.5 scenarios in the coming thirty years as indicated in Table 4. During the Kiremt season or cropping season for the study area in particular, maximum temperature could reach about 24 and 25.9°C under RCP4.5 and RCP8.5, respectively, compared with the baseline 23.89°C (Table 4). This could have big implications on the production and productivity of crops in the area. Evaporation and transpiration could increase, leading those growing crops in higher water demand.

Conclusion

In this research work attempts were made to project and characterize the climatic condition of the Eastern Ethiopia at watershed level. The result of the finding indicates that the watershed will experience much wetter condition than today. In contrast, air temperature will rise up

relative to the baseline temperature condition. Tables 5 and 6 shows the annual and seasonal extent of changes in rainfall in % and temperature in °C in the upcoming thirty years relative to the baseline rainfall and temperature.

Generally, rainfall and temperatures will increase under both climate scenarios considered in the coming periods 2020-2050. Therefore, a typical adaptation mechanism to the event have to be well understood and undertaken at all levels; to be resilient against the consequences of climate change in Lake Haramaya watershed.

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