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Climate Change Impact on Lake Ziway Watershed Water Availability, Ethiopia

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Background and Objective

According to the International Panel on Climate Change (IPCC) report, by 2100 global average temperature would rise between 1.4 and 5.8°C and precipitation would vary up to ±20% from the 1990 level. Being one of the very sensitive sectors, climate change can cause significant impacts on water resources. Developing countries, such as Ethiopia, will be more vulnerable to climate change mainly because of the larger dependency of their economy on agriculture. Hence, assessing vulnerability of water resources to climate change at a watershed level is very crucial. This gives an opportunity to plan appropriate adaptation measures that must be taken ahead of time. Moreover, this will give enough room to consider possible future risks in all phases of water resource development projects. Hence, the objectives of this study were:

- To develop temporal climate change scenarios of precipitation and temperature for the Ziway Watershed from the year 2001 to 2099,
- To quantify the possible impacts of the climate change on the water resource availability of the Lake Ziway Watershed from the year 2001 to 2099, and
- To suggest possible adaptation measures against this impact.

Study Area

Lake Ziway is found in the Great East African Rift Valley lakes of Ethiopia. It has an open water area of 434 km^2, average depth of 4 m, and an elevation of 1636 m.a.s.l. The Ziway Watershed falls in between 7°15'N to 8°30'N latitude and 38°E to 39°30'E longitude covering a total area of about 7300 km^2 (figure 1). It is composed of two main rivers flowing into the lake, Meki and Katar, and one river flowing out of the lake, Bulbula. The climate is characterised by semi-arid to sub-humid with mean annual precipitation and temperature of 650mm and 25°C, respectively.

Methodology

Climate change scenarios were developed for maximum temperature, minimum temperature and precipitation based on the HadCM3 GCM model outputs that are established on the A2 and B2 SRES emission scenarios. The outputs of HadCM3 were downscaled into a watershed scale using the Statistical DownScaling Model (SDSM). The scenario-years from 2001 to 2099 were divided into four periods of 25 years and their respective changes were determined as monthly temperature changes (in °C) and monthly precipitation changes (in %) from the base period (1981-2000) values. Flow was simulated using the ArcView 3.2 integrated SWAT (Soil and Water Analysis Tool) hydrologic model called AVSWAT. First, the model was calibrated and validated, and the total inflow volume into the lake was simulated for the base period under normal conditions. Then, the total inflow volumes of the future periods were simulated by applying the respective future changes of temperature and precipitation. Finally, the changes in total inflow volume from the base period volume were calculated to see the impact on the lake-water-level and -water-surface-area.

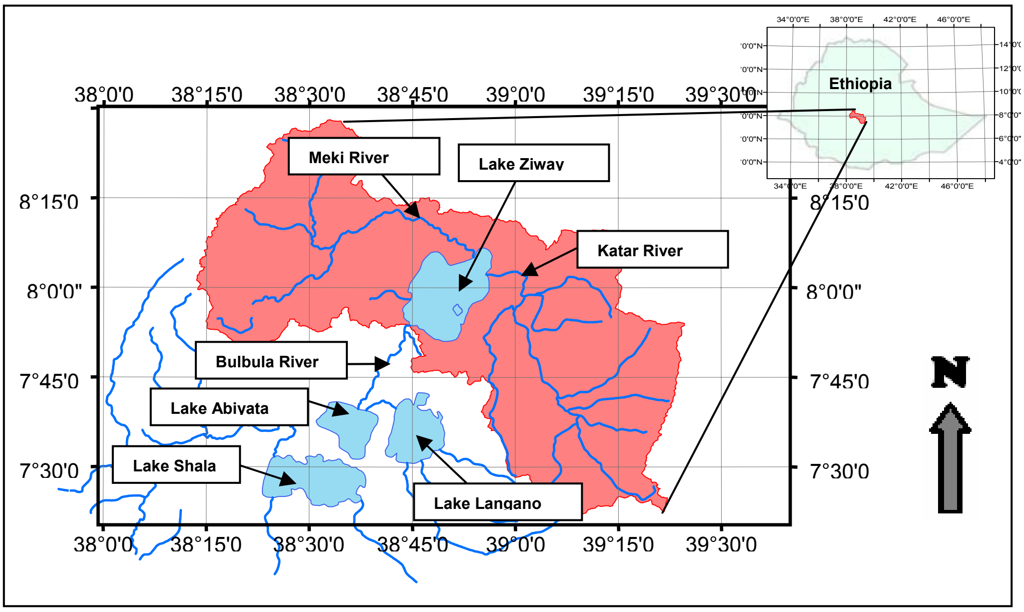

Figure 1: Location map of the study area

Results

Climate Change Scenarios Developed for the Future

The generated future scenarios for precipitation, maximum temperature, and minimum temperature generally showed an increasing trend from the base period values (figure 2 and 3).

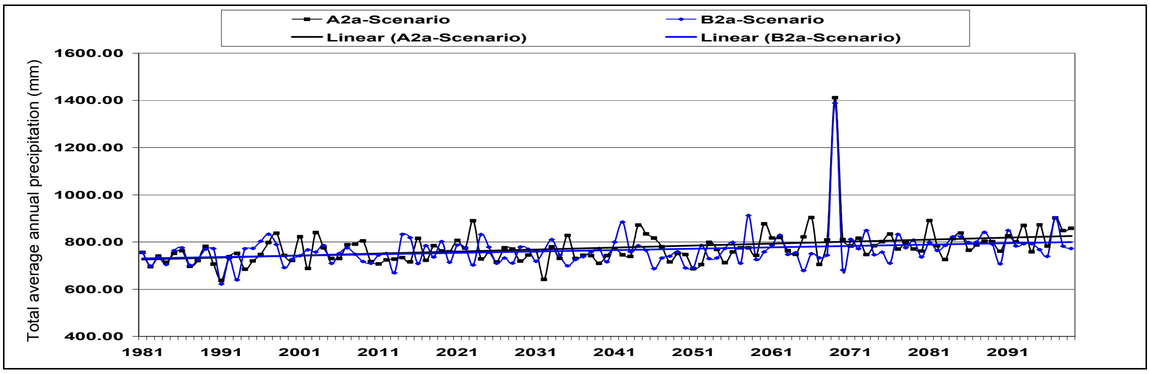

Figure 2: Future pattern of annual precipitation amounts

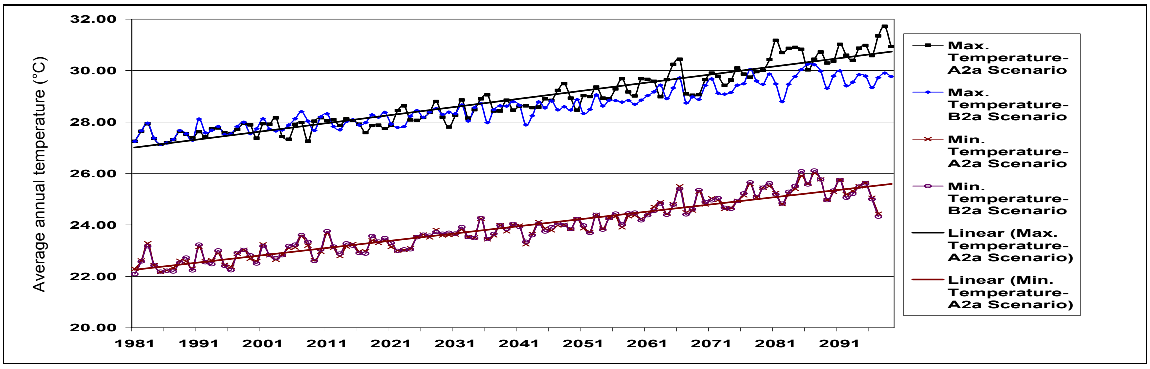

Figure 3: Future pattern of average annual maximum and minimum temperature

The average monthly and annual precipitation in the watershed might increase up to 29% and 9.4%, respectively (figure 4). Besides, as shown in figure 5 and 6, the average monthly maximum temperature might rise up to 3.6°C and 1.95°C; and the average minimum temperature up to 4.2°C and 2°C monthly and annually, respectively. Seasonally, the *Belg*[1] season is likely to exhibit a decrease of the total precipitation share along the periods. In contrary, the *Bega*[2] season might exhibit an increase in the total share. The main rainfall season, *Kiremt*[3]; however, might keep on possessing more or less the same share along the periods. Regarding maximum and minimum temperatures, the most remarkable increase of up to 2.6°C might be observed during *Kiremt*. The *Bega* season might show only a relatively minor increment.

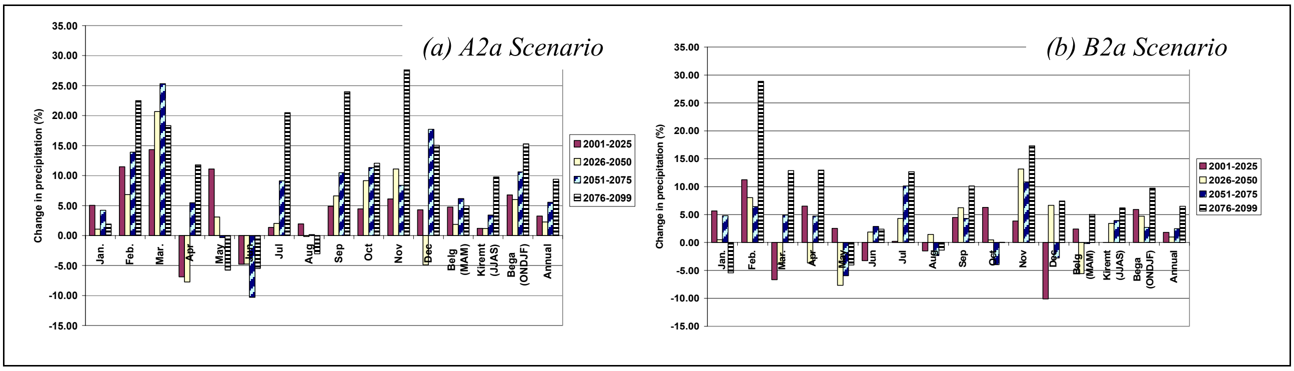

Figure 4 (a & b): Change in average monthly precipitation in the future (2001-2099)

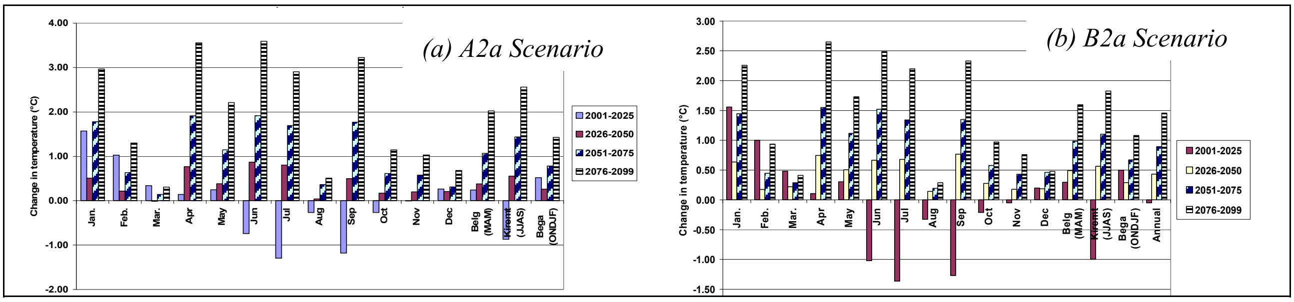

Figure 5 (a & b): Change in average monthly maximum temperature in the future (2001-2099)

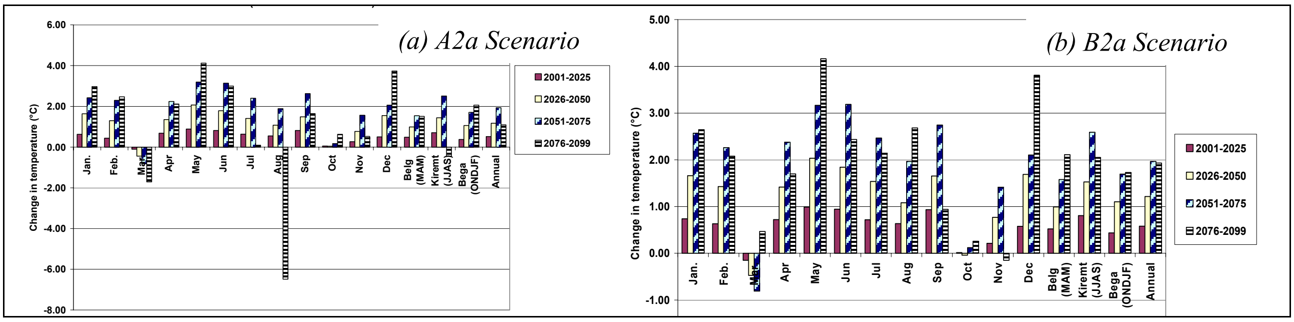

Figure 6 (a & b): Change in average monthly minimum temperature in the future (2001-2099)

Impact of the Changing Climate on Seasonal and Annual Inflow Volume

The total average annual inflow volume into Lake Ziway might decline significantly up to 19.47% for A2a- and 27.43% for B2a-scenarios. The decreasing trend of the average annual inflow volume is mainly associated with the decrease in the *Kiremt* inflow volume by between 11.8 and 28.4% for the A2a scenario and between 16.5 and 27.8% for the B2a scenario (figure 7).

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[1] *Belg* is a small rainfall season from March to May and contributes 20-30% of the total annual rainfall
[2] *Bega* is a dry season, which extends between October and February and contributes 10-20% of the total annual rainfall
[3] *Kiremt* is the main rainfall season from June to September and contributes 50-70% of the total annual rainfall

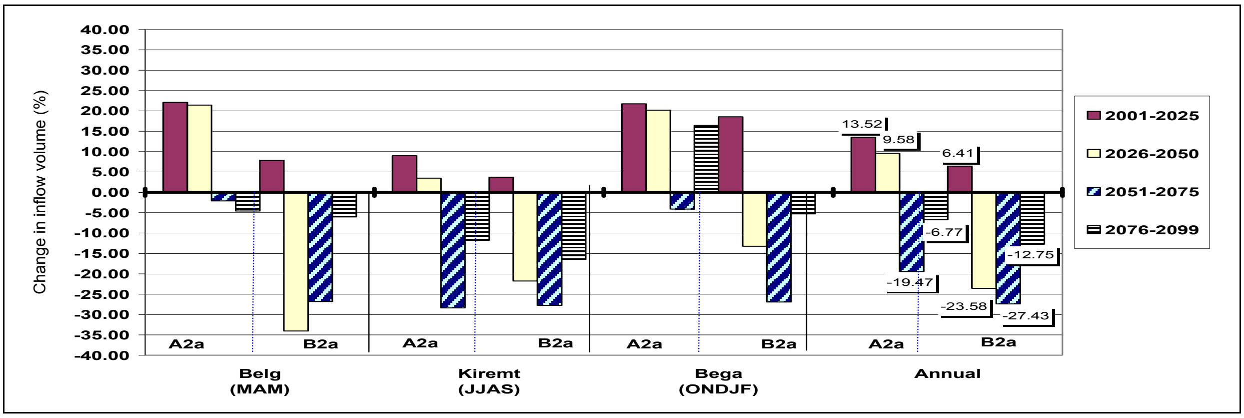
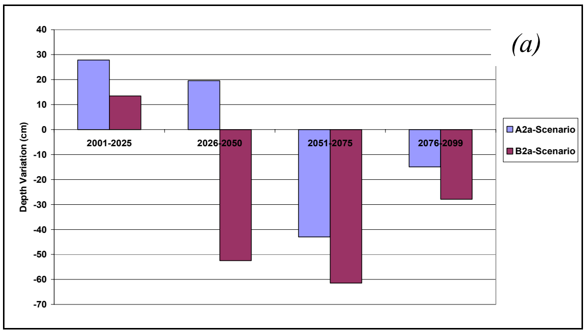


Figure 7: Percentage change of total seasonal and annual inflow volume into Lake Ziway

Impact on Lake Ziway Water Level and Water Surface Area

Both scenarios show a significant decline of the Lake water level and shrinkage of the lake water surface area. The reduction might be especially eminent during the 2051-2075 period, where the lake level decline might reach up to 62 cm (figure 8 (a)). Consequently, the water surface area might also shrink up to 25 km^2 (figure 8 (b)).



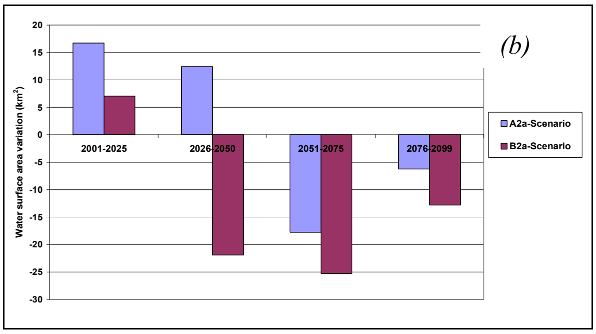


Figure 8: (a) Water level variation and (b) Water surface area variation of Lake Ziway from base period

Adaptation Options

The main objective of adaptation options is to reduce impacts of climate change. Hence, the adaptation options should focus on increasing water utilization efficiency, increasing water availability, and ensuring better management of the available water resources. Besides, watershed based integrated water resources management should be the central part of the whole adaptation option.

Conclusion

The scenarios developed for the years 2001-2099 showed that both temperature and precipitation are likely to increase from the 1981-2000 level. These changes are likely to have significant impacts on the inflow volume into the lake. Despite the increasing trend of both climatic variables, the increase in precipitation seems to be obscured by increases in temperature. Hence, the total average annual inflow volume into Lake Ziway might decline significantly. This is likely to drop the lake level up to two third of a meter and shrink the water surface area up to 25 km^2, which is about 6% of the base period water surface area. This combined with the unbalanced supply-demand equation in the watershed is expected to have significant impact on the lake water balance. Therefore, in Lake Ziway Watershed, runoff is likely to decrease in the future and be insufficient to meet future demands for water of the ever increasing population.