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Research Paper

Characterization of changing trends of baseline and future predicted precipitation and temperature of Tigray, Ethiopia

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ABSTRACT

Precipitation and temperature data of Tigray region of Ethiopia for baseline (1950-2000), future climate projection for mid-century (2050) and end-century (2070) based on medium emission scenario (RCP 4.5) and high emission scenario (RCP 8.5) were obtained from climate model ensembles, Coupled Model Intercomparison Project 5 (CMIP5). Arc GIS 10.1 and Diva GIS 7.5.0 was used for mapping climatic variables and area coverage. Area coverage were computed based on number of cell (1km2). The result indicted that precipitation of the study might be increased 308-1054 mm to 301-1236 mm under both scenario compared with baseline. Temperature of the study area might be increased from 8.1-29 to 11.3-32.4ºC. The area coverage is decreasing at 8.1-16.2 and 16.2-24.3ºC temperature classes at both time slices and RCPs. In the 24.3-32.4ºC the area might be increased at both time slices and RCPs compared with the baseline. In addition, the area coverage for 301-612mm precipitation class might be increased but decreased at 612-924mm at both RCPs and time slices. The area coverage for 924-1236mm class increased at both time slices and RCPs compared with the baseline. Overall, amount of precipitation and temperature might increase at both time slices and RCPs.

Keywords : Climate change, Worldclim, global warming, Tigray, climate scenarios

Climate change is one of recent century main problem to the world (Perelet, 2007). It is caused due to change in global climate system through increased amount of greenhouse gases (GHGs) to the atmosphere (Sexton *et al*., 2001). Accordingly, the globe were experienced increment of an average warming of about 0.6°C during the ٢٠th century and a rise in temperature is expected by about 2-3°C by the end of the 21st century (Pachauri *et al*., 2014). Climate change is a serious hazard and have visible impacts on natural resources, ecosystems, biodiversity, food security and decrease agricultural productivity and availability. As a result, there has been a growing interest on study of climate extreme events and trends.

Temperature and precipitation are the most important climate variables used for analyzing of past, and future scenarios, climate change impacts (Abrha *et al*., 2018). Those are among influential factors for species survival or distributions (Kaeslin *et al.,* 2012), climate extremes (Cooper *et al.,* 2008). Change of these parameters are threats to agricultural and natural resources production and utilization (Challinor *et al*., 2007). Sub-Saharan Africa is vulnerable to climate change because of their strong dependence on rainfed agriculture (Cooper *et al*., 2008). A number of methods are developed to support farmers, investors, decision makers in order to adapt to the changing conditions. The most common scientific method to climate change adaptation and mitigation is the use of models to project the impacts and trend of climate (Challinor *et al*., 2009; Yadav *et al*, 2021). Those predictions are used to find appropriate adaptation approaches (Boomiraj *et al,* 2010). Those spatial and temporal prediction of climate change also used to find climate analogues areas (Hallegatte *et al.,* 2007).

In analogue area identification, the projected future climate of a site is used to select a location where those conditions can be found today (Luedeling and Neufeldt, 2012). The procedure assumes that the analogue location used to learn lessons for adaptation from practices that are currently being used at the analogue site (Hallegatte *et al*., 2007). In addition, estimation of temperature and precipitation are used for niche assessment in order to find suitable area in response to climate change in the study area (Abrha *et al*., 2018).

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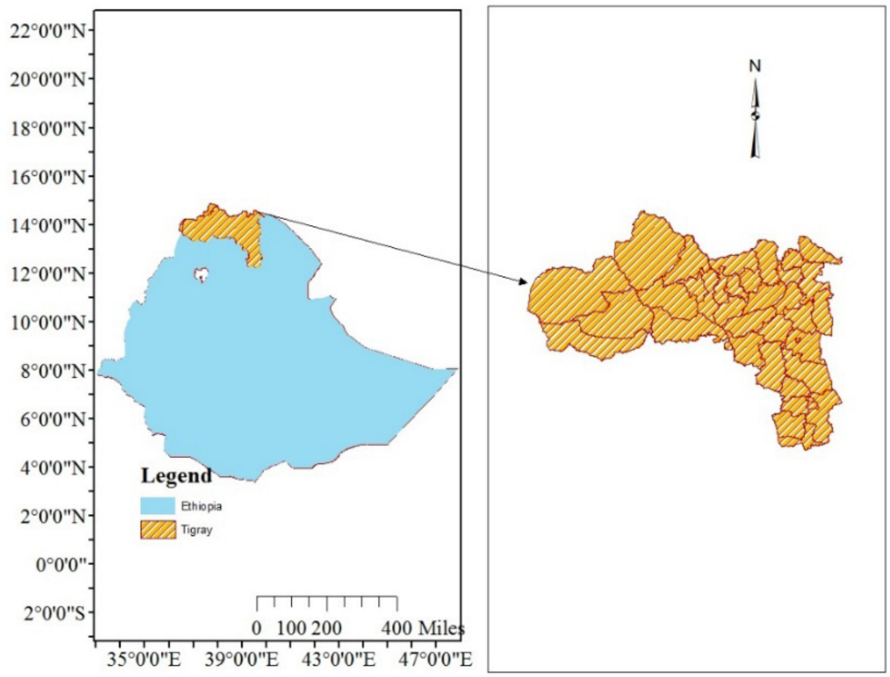

Fig. 1: Study area location

In general, study on the climate change trend is used for development of mitigation strategies and development of international agreements on reducing greenhouse gases and global warming (Vaz and Nabout, 2016). It is therefore important to study the trend of climate change in the study area. As a result, in this study, we aim to characterize trend of climate change for the whole state of Tigray to indicate the trend and events of climate change in order to develop mitigation and adaptation strategies by decision makers, researchers and other beneficiaries.

MATERIALS AND METHODS

Tigray state is located between latitude 12°15' N and 14° 57' N and longitude 36° 27' E and 39° 59' (Fig. 1). Average annual temperature of the state was between 8.1 to 2.9ºC. In addition, annual precipitation of the study area is found between 308-1054mm.

For climate change study, we used a high-resolution (30 arc-second resolution grid or 1km^2) data set of annual average rainfall and temperature downscaled from 17 global climate model (GCM) simulations included in Coupled Model Intercomparison Project 5 (CMIP5). This dataset has 1 km2 a spatial resolution and was created by interpolation using observed climate at weather stations, with latitude, longitude, and elevation as independent variables (Hutchinson, 1995). It consists of baseline (1950–2000) and mid-century (2050) and end-century (2070) based on medium emission scenario (RCP 4.5) and high emission scenario (RCP 8.5). The values of those parameters were classified in three in equal interval to describe their changes easily. Arc GIS 10.1 and Diva GIS 7.5.0 were used to extract, process and analyze the datasets for study area.

RESULTS AND DISCUSSION

Amount of annual mean precipitation might be increased from 308-1054 to 301-1236. In both time slices and RCPs amount of precipitation increased compared with the baseline. In baseline, 2050 RCP 2.6, 2050 RCP 8.5, 2070 RCP 2.6 and 2070 RCP 8.5 the amount of precipitation might be 308-1054, 310-1157, 322-1231, 335-1166 and 301-1236mm respectively. Similarly, annual mean temperature of the area might be increased at both scenario and time slices (Figs. 2 and 3). Temperature might be increase from 8.1-29 to 11.3-32.4ºc. In baseline, 2050 RCP 2.6, 2050 RCP 8.5, 2070 RCP 2.6 and 2070 RCP 8.5 the amount of temperature might be 8.1-29, 8.5-29.4, 10.3-31.3, 9.3-30.3 and 11.3-32.4ºc respectively. In both temperature and precipitation, Figs 2 and 3, similar colors are climate analogue sites for baseline and future climate.

For the baseline, the area coverage for precipitation classes of 301-612mm, 612-924mm and 924-1236mm were 10530 km^2, 53818 km^2 and 1396 km^2 respectively (Table 1). The area coverage for 301-612mm precipitation class decreased by 9.8%, 13.4%, 13.5% and 12.5% for the 2050 RCP 2.6, 2070 RCP 2.6, 2050 RCP 8.5 and 2070 RCP 8.5 respectively as compared to the baseline. The area coverage for 612-924mm precipitation class for 2050 RCP 2.6, 2070 RCP 2.6 and 2050 RCP 8.5 increased by 4.0%, 1.3% and 0.5% respectively. Whereas for 2070 RCP 8.6 of the same precipitation class it decreased by 1.4%. This indicted that the amount might be reduced at 2070 RCP 8.5 compared with the baseline. In the 924-1236mm precipitation class the area coverage increased by 5.8%, 8.2%, 12.9% and 13.9% for the 2050 RCP 2.6, 2070 RCP 2.6, 2050 RCP 8.5 and 2070 RCP 8.5 respectively. This indicted that the amount might be increased at both time slices and RCPs compared with the baseline (Table 1).

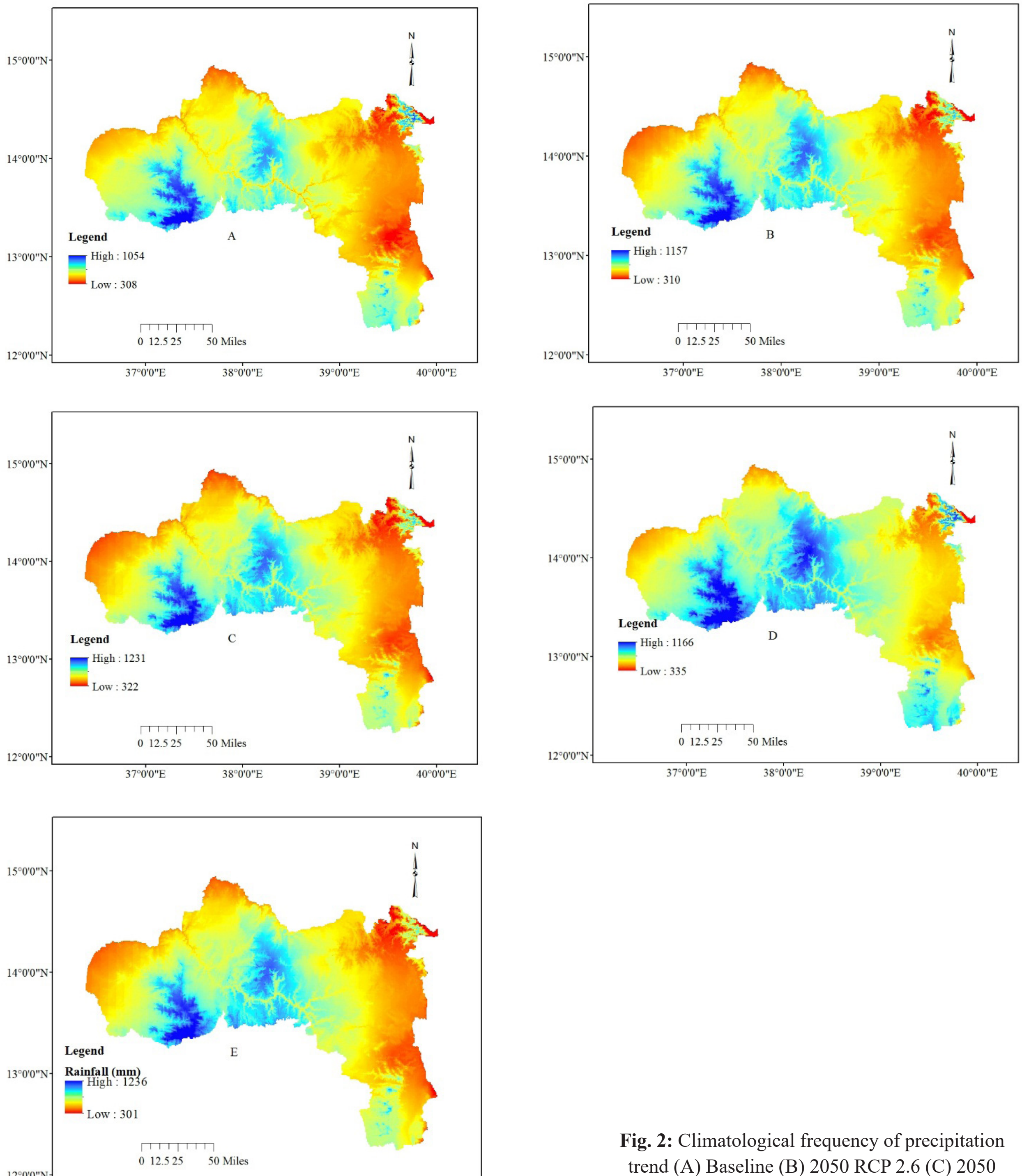

Fig. 2: Climatological frequency of precipitation trend (A) Baseline (B) 2050 RCP 2.6 (C) 2050 RCP 8.5 (D) 2070 RCP 2.6 (E) 2070 RCP 8.5

Table 1: Area coverage (km^2) for different precipitation classes (Percentage of increase and decrease are in brackets).

Precipitation class (mm)	Baseline	RCP 2.6		RCP 8.5	
		2050	2070	2050	2070
301-612	10,530	4087 (-9.8%)	1624 (-13.5%)	1690 (-13.4%)	2327 (-12.5%)
612-924	53,818	56413 (4.0%)	57297 (5.3%)	54171 (0.5%)	52884 (1.4%)
924-1236	1,396	5234 (5.8%)	6813 (8.2%)	9873 (12.9%)	10523 (13.9%)

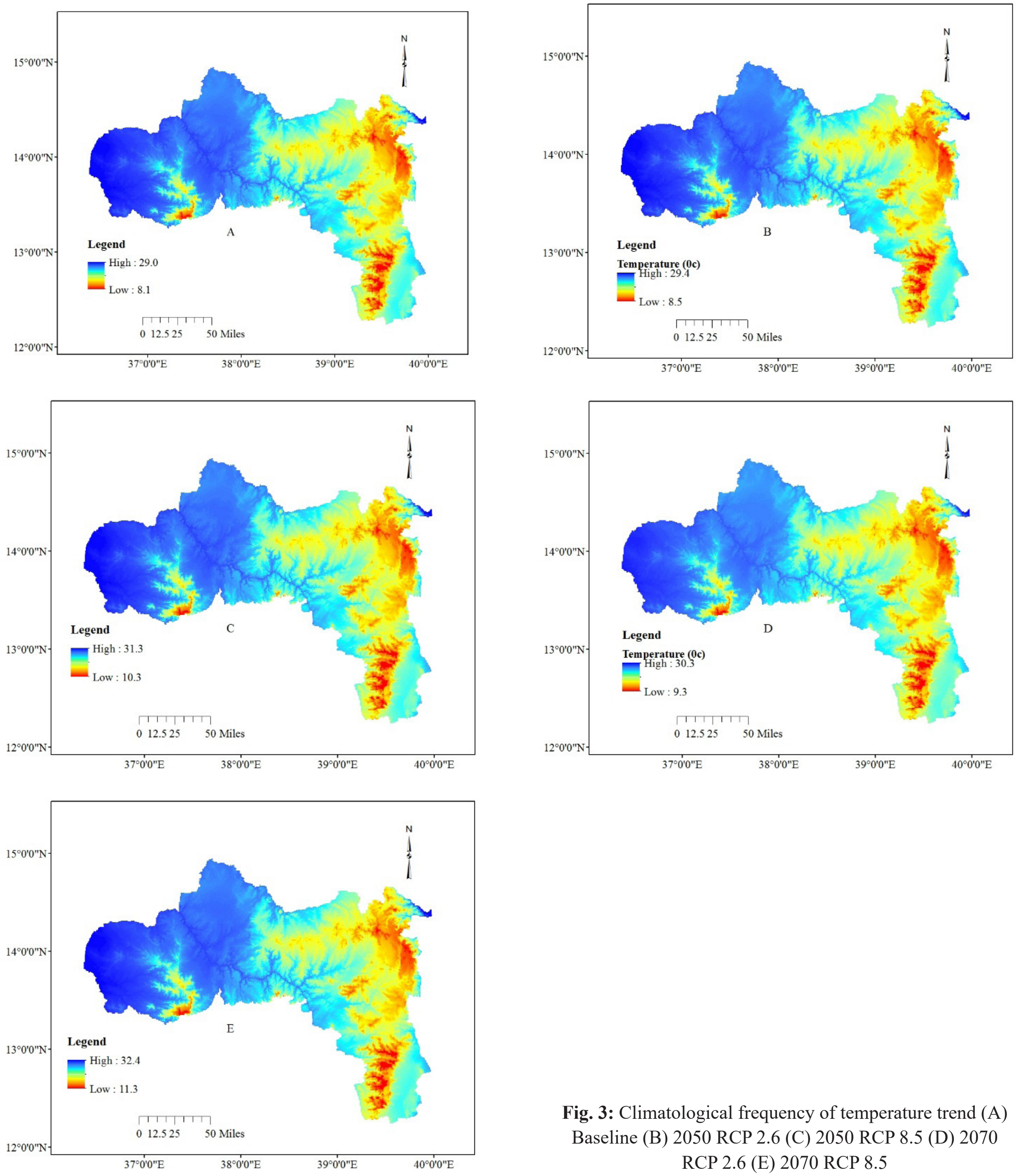

Fig. 3: Climatological frequency of temperature trend (A) Baseline (B) 2050 RCP 2.6 (C) 2050 RCP 8.5 (D) 2070 RCP 2.6 (E) 2070 RCP 8.5

Table 2: Area coverage (1km^2) for different temperature classes (Percentage of increase and decrease are in brackets).

Temperature class (ºC)	Baseline	RCP 2.6		RCP 8.5	
		2050	2070	2050	2070
8.1-16.2	4139	4043 (-0.1%)	2015 (-3.2%)	896 (-4.9%)	335 (-5.8%)
16.2-24.3	34699	32785 (-2.95%)	31273 (-5.2%)	26514 (-12.4%)	21847 (-19.5%)
24.3-32.4	26906	28916 (3.1%)	32446 (8.4%)	38324 (17.4%)	43552 (25.3%)

For the baseline, the area coverage for temperature classes of 8.1-16.2 ºc, 16.2-24.3ºc, and 24.3-32.4ºc might be 6.3%, 52.8%, and 40.9% respectively (Table 2). The area coverage of temperature class 8.1-16.2 ºc for 2050 RCP2.6 might remain the same with the baseline. For the same class, the area coverage might be decreased by 3.2%, 4.9%, and 5.8% for 2070 RCP2.6, 2050 RCP8.5, and 2070 RCP8.5 respectively. For the 16.2-24.3 ºc temperature class, the area coverage might decrease by 2.9%, 5.2%, 12.4%, and 19.5% for 2050 RCP2.6, 2070 RCP2.6, 2050 RCP8.5, and 2070 RCP8.5 respectively. However, for the 24.3-32.4ºc temperature class, the area coverage might increase by 3.1%, 8.4%, 17.4%, and 25.3% respectively. This indicted that the amount of temperature might be increased at both time slices and RCPs compared with the baseline (Table 2).

In this study area, temperature of RCP 4.5 might increase by1.2- 3.2°C and in RCP 8.5 might increase by 1.3-3.4°C up to 2070. Precipitation might be also increased by 7-14mm in RCP 4.5 and might change from -7 to 182mm in RCP 8.5 up to 2070. Similar with this study, the globe has experienced increment of an average warming of about 0.6°C during the 20 th century (Pachauri *et al.*, 2014) and is expected to increase by about 2-3°C by the end of the 21 st century (Team *et al.,* 2007). Global temperature increased by 0.89°C by 1901–2012 (Solomon, 2007). It will increase by 1.48-5.88°C during 2100 (Pachauri *et al.,* 2014). In sub-Saharan Africa, temperature increment is expected to be higher than the global (Team *et al.,* 2007). Though, global precipitation trends are both increment and reduction. It shows both heavy rains and severe droughts Traore (2014). Similar trend was evaluated in sub-Saharan Africa (Cooper *et al.,* 2008).

CONCLUSION

The result indicted that in Tigray state of Ethiopia, the amount of precipitation and temperature might increase at both time slices and RCPs. This shows increment of temperature by 1-2-3.4°C while precipitation change by -7 to 182 mm up to 2070. Utilizing climate model projections are useful for climatologists, other beneficiaries and decision makers. In addition, awareness creation on climate change is necessary. Hence, management plan for reducing global warming impacts should be conducted. Dry spells, length of rain period, evaporation and other climatic variables and extremes such as agro-hydro-meteorological-socioeconomic drought and wind should studied in order to develop more decisions.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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