Climate Change Effect in Central Dry Zone, Myanmar

Aye Myint Khaing[1], Win Win Zin[2], Cho Cho Thin Kyi[3]

[1] Ph.D Student, Department of Civil Engineering, Yangon Technological University, East Gyogone Township, Yangon City

[2 & 3] Associate Professor, Department of Civil Engineering, Yangon Technological University, East Gyogone Township, Yangon City

Email - [1]ayemyintkhing410@gmail.com, [2] winwinzin@gmail.com, [3]ccthinkyi@gmail.com

Abstract: This research evaluates the possible effects of climate change on meteorological variable of central dry zone of Myanmar. These variables are important indicators of climate change. One of the commonly used tools for detecting change in climatic and hydrologic time series is trend analysis. Annual rainfall data was analyzed in order to detect climate change. The growing water scarcity due to climate change will pose a serious threat to food security, poverty reduction and protection of the environment. In this study, the Mann-Kendall non-parametric test, which is widely used to detect trends, was applied. Seven General Circulation Models (GCMs) were bias corrected using the linear scaling approach to construct climate change scenarios. Coefficient of determination (R^2) and root mean square error (RMSE) are determined before and after bias correction. The future projection period from 2010-2100 is classified into 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099) for analyzing meteorological parameters.It is important to investigate present and probable future climatic change patterns and their impacts on water resources so that appropriate adaptation strategies may be implemented.

Key Words: climate change, trend analysis, central dry zone, Mann-Kendall, GCM models, Bias correction.

INTRODUCTION:

Climate variability has relevant importance on the hydrology and water resources availability in the world. Changes in temperature and precipitation patterns as consequence of the increase in concentrations of greenhouse gases may affect the hydrology process, availability of water resources, and water use for agriculture, population, mining industry, aquatic life in rivers and lakes, and hydropower. One of the most important impacts of climate change is on hydrology, which results in changes in river flows and regional water resources. Climate change is expected to intensify the global hydrological cycle resulting in major impacts on regional water resources. A change in the total amount, frequency, and the intensity of precipitation will directly affect the amount and timing of runoff and intensity of floods and droughts.

Trend detection in hydrological data has become increasingly popular in connection with climate change (Hamed 2008). Trend analysis has been widely used to evaluate the potential impacts of climate change in hydrologic time series throughout the world, including the US, Western Europe, Canada, and Western Britain (Hamed 2008). Climate change also causes trends not previously experienced or detected, which provide new challenges. In recent year, with growing concerns about the impacts of climatic changes (IPCC 2007), researchers have employed various statistical and stochastic techniques to identify trends and shifts in hydrological series at different temporal scales of aggregation.

Changes in precipitation and streamflow characteristics directly impact hydrology, water resource management, agricultural practices and ecosystems. Therefore, it is vital to investigate the climate change impact on spatial and temporal rainfall characteristics to facilitate better water management practices and strategy. One of the commonly used tools for detecting changes in climatic and hydrologic time series is trend analysis. In this study, the Mann-Kendall non-parametric test, which is widely used to detect trends, was applied. The change per unit time in a time series having a linear trend was estimated by applying a simple non-parametric procedures namely Sen's estimator of slope. Trend detection is an active area of interest for both hydrology and climatology in order to investigate climate change scenarios and enhance climate impact research. Therefore, it is vital to investigate the climate change impact on precipitation and streamflow characteristics to facilitate better water management practices and strategy.

General Circulation Models (GCMs) to predict the future changes in meteorological parameters such as temperature and precipitation. However, their outputs are temporally and spatially very coarse (IPCC, 2001). Although these outputs are useful at continental and global levels, finer resolution outputs are needed at regional and local levels for investigating the affects of climate change on the environmental flows and water cycle. To use the local and regional scales of 0-50 km and 50 × 50 km, many methods for downscaling have been developed .As climate models are not perfect, the predicted climatology can differ from baseline climatology. The model state will drift towards a model climate as the forecast progresses and this shift will be confounded by the climate advancement that is being predicted. For this intention, near-term climate projections are usually bias corrected. Bias correction can be handled in order to use the decadal projection results

The correct selection of GCM for a modeller is important to explain the magnitude and variability of local variables (Temperature, Precipitation). According to Smith and Hulme in 1998, a modeller will consider the vintage and resolution of a GCM. A modeller will choose GCM with a higher resolution because it can apprehend more local weather information than that of a rough resolution. It will be important to find more sound and current climate producing GCM during the period of validation. For a level of region, a different range of climate variables can be simulated by various GCMs. Therefore, where many models are to be chosen, then representation of climate changes range in area will be considered for these models (Sharma *et al*., 2007).

The statistical bias correction methods are applied in order to preserve the variability given by the GCM. There are:

1. Delta change for precipitation and temperature
2. Linear scaling for precipitation and temperature
3. Power Transformation for precipitation
4. Local intensity scaling for precipitation
5. Variance scaling of temperature
6. Distribution mapping for precipitation and temperature

In this study, Linear Scaling Method was used. The linear scaling method is the straightforward method for correcting the coarse scale climate projections by reference to a high resolution observed climate baseline. It is also a simple bias correction method, which can improve the decadal forecast skill.

The data network used in this study consists of fourteen stations of Central Dry Zone of Myanmar. This paper examines the possible effects of climate change on meterological variables in Central Dry Zone of Myanmar.

STUDY AREA:

The Dry Zone is one of the most climate sensitive and natural resource poor regions in Myanmar. The dry zone lies between latitudes 19° 20" and 22° 50" north and longitudes 93° 40"and 96° 30" east, stretching across the southern part of Sagaing Division, the western and middle part of Mandalay Division and most parts of Magway Division. It is situated in the rain shadow area of the Yakhaing Yoma and obtains most of its rainfall from the southwest monsoon. The zone covers approximately 54,390square kilometers and represents about 10% of the country's total land area. The present population in the Dry Zone is estimated at 18 million people. It constituted 34% of the country's total population.

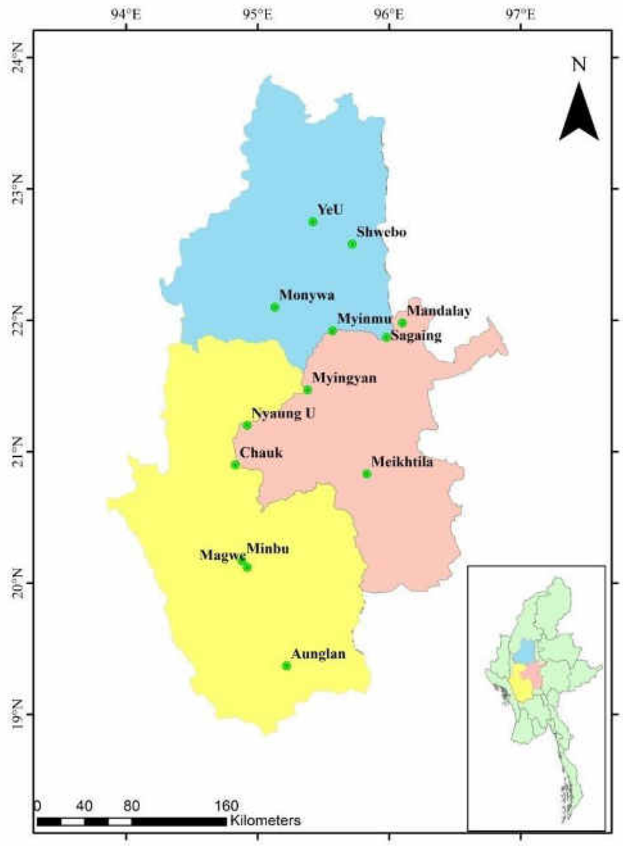

Figure1. Location map of study area

The population density is 123 people per square kilometer, making it the third most densely populated region in Myanmar. Across the Dry Zone, water is scarce, vegetation cover is thin, and soil is degraded due to severe erosion. The region is characterized by low annual rainfall that ranges between 508 and 1016 mm per annum with high variability and uneven distribution. The monsoon rain is bimodal with a drought period during July when dry desiccating winds blow from the south. The undulating land, composed mainly of sandy loam with low fertility, is subjected to severe erosion under rain and strong winds. The average mean temperature in the Dry Zone is about 27˚ C and the temperature often rises to about 43˚ C in the summer period. This dry environment with its other natural limiting factors has led to conditions of growing food insecurity and severe environmental degradation.

The major economic activities in the Dry Zone are subsistence farming and small agricultural crops such as paddy, sesame and groundnut. Agricultural productivity is low and the farmers are heavily dependent on products from the natural forest especially fuel wood, pole, post and fodder to support their living and livestock. Many landless people are working as seasonal farm labourers, migrating to urban regions during non-planting time to find temporary employment. Location of study area is shown in Figure 1.

Methodology: The steps involved in analysing are as follows:

1. The first step was to choose the variables to be studied. Rainfall and temperature variables were used, as they tend to reflect an integrated response of the catchment area as a whole.
2. The second step was to choose the stations that have sufficient long time records of data.

3. The third step was to check for the present of trends in the data. This was done using the Mann-Kendall non-parametric test.
4. The fourth step was to determine the significance of the detected trends.
5. The fifth step was to prepare climate change scenarios.
6. The next step was to quantify the uncertainty of climate projection and change in water resources of central dry zone.

DISCUSSION:

There are various statistical methods for detecting trend, step change, differences in means or medians between two data periods and randomness in hydrological time series data. The Mann-Kendall method was applied to know the existence of trends in temperature and precipitation time series. All the trend results in this research have been evaluated at 10%, 5% and 1% level of significance to ensure an effective exploration of the trend characteristics of the study region. Significance level indicates the trend's strength. In this study, the time series of temperature and precipitation in central dry zone during the period 1985-2015 were tested for gradual trend and abrupt change at the annual total and maximum scales. The results of Mann-Kendall test showed some strong significant decreasing trends in the annual total rainfall. The largest negative was occurred in Minbu station. Sagaing station indicated negative trend in annual maximum rainfall. A noticeable increase in the total rainfall was observed mostly in Magway station.GCM selection is prior to use the GCM data for hydrological analysis. Seven GCM are analyzed in this study. It is seen that three out of seven GCM are seen statically reliable. Can ESM2, MIROC-ESM and MIROC-ESM CHEM have higher R^2 value for the case of precipitation. It is seen that most GCMs performs well in stations which have high rainfall amount. Among the tested GCMs it was seen that MIROC- ESM CHEM is the best one in most cases. MIROC-ESM and Can ESM2 are also good.

ANALYSIS: The monthly and annual precipitation for the current time period and future were analysed.

RESULT: The monthly average precipitation of observed and simulated value for Meikhtila station is shown in figure 2. The result of Meikhtila station observed that the model well simulate the average monthly value of precipitation of observed and simulated are close. Figure 3 and 4 shows the future average monthly precipitation of Meikhtila station under two scenarios RCP 4.5 and RCP 8.5. Figure 5, 6 and 7 shows differences among the highest values of annual precipitation projections under RCP4.5 and 8.5 scenarios of the Meikhtila station. Meikhtila station shows best R^2 value when R^2 value is compared with other stations.

Table 1. Comparison of R^2 value before and after bias correction for Minimum Temperature

Stations		Can ESM2	GFDL-CM3	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR
		R²	R²	R²	R²	R²	R²
Aunglan	BC	0.746	0.626	0.857	0.872	0.817	0.842
	AC	0.93	0.907	0.92	0.924	0.916	0.918
Chauk	BC	0.692	0.675	0.878	0.878	0.859	0.881
	AC	0.915	0.908	0.928	0.926	0.888	0.904
Magway	BC	0.688	0.664	0.841	0.845	0.857	0.858
	AC	0.9	0.9	0.898	0.899	0.882	0.882
Mandalay	BC	0.714	0.665	0.874	0.887	0.915	0.923
	AC	0.903	0.917	0.925	0.928	0.932	0.937
Meikhtila	BC	0.619	0.736	0.854	0.865	0.89	0.896
	AC	0.887	0.931	0.918	0.919	0.895	0.902
Minbu	BC	0.741	0.699	0.852	0.864	0.896	0.887
	AC	0.938	0.921	0.92	0.926	0.92	0.911
Monywa	BC	0.735	0.623	0.724	0.747	0.912	0.915
	AC	0.907	0.902	0.901	0.919	0.921	0.92

Myingyan	BC	0.761	0.657	0.789	0.807	0.936	0.935
	AC	0.934	0.933	0.942	0.954	0.947	0.948
Myinmu	BC	0.754	0.636	0.771	0.782	0.935	0.931
	AC	0.938	0.928	0.938	0.945	0.945	0.941
Nyaung Oo	BC	0.73	0.63	0.755	0.747	0.842	0.875
	AC	0.882	0.879	0.892	0.886	0.877	0.9
Sagaing	BC	0.68	0.632	0.842	0.857	0.901	0.901
	AC	0.893	0.913	0.909	0.911	0.926	0.923
Shwebo	BC	0.773	0.664	0.8	0.797	0.924	0.922
	AC	0.919	0.907	0.932	0.93	0.927	0.928
Ye U	BC	0.716	0.603	0.735	0.713	0.828	0.831
	AC	0.854	0.826	0.884	0.865	0.83	0.928
Yemethin	BC	0.591	0.695	0.845	0.86	0.88	0.886
	AC	0.9	0.929	0.931	0.936	0.901	0.909

Table 2. Comparison of R^2 value before and after bias correction for Maximum Temperature

Stations(Max)		Can ESM2	GFDL-CM3	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MPI-ESM-MR
		R^2	R^2	R^2	R^2	R^2	R^2
Aunglan	BC	0.241	0.453	0.429	0.417	0.492	0.391
	AC	0.815	0.795	0.796	0.81	0.833	0.812
Chauk	BC	0.421	0.399	0.629	0.579	0.623	0.673
	AC	0.795	0.732	0.79	0.777	0.653	0.713
Magway	BC	0.398	0.47	0.649	0.583	0.69	0.702
	AC	0.856	0.812	0.87	0.852	0.75	0.777
Mandalay	BC	0.062	0.236	0.558	0.566	0.671	0.699
	AC	0.625	0.689	0.509	0.474	0.668	0.711
Meikhtila	BC	0.015	0.513	0.675	0.738	0.728	0.728
	AC	0.659	0.799	0.627	0.709	0.696	0.706
Minbu	BC	0.385	0.467	0.633	0.569	0.675	0.692
	AC	0.853	0.8	0.861	0.845	0.729	0.758
Monywa	BC	0.089	0.213	0.504	0.544	0.649	0.66
	AC	0.735	0.758	0.568	0.646	0.744	0.791
Myingyan	BC	0.126	0.234	0.553	0.581	0.667	0.687
	AC	0.751	0.758	0.595	0.653	0.736	0.796
Myinmu	BC	0.118	0.234	0.531	0.591	0.657	0.661
	AC	0.677	0.704	0.531	0.631	0.701	0.747
Nyaung Oo	BC	0.148	0.252	0.563	0.6	0.66	0.706
	AC	0.711	0.717	0.526	0.6	0.736	0.783
Sagaing	BC	0.102	0.234	0.445	0.62	0.652	0.638
	AC	0.576	0.704	0.326	0.514	0.625	0.626
Shwebo	BC	0.114	0.212	0.553	0.574	0.658	0.682
	AC	0.677	0.69	0.537	0.584	0.671	0.741
Ye U	BC	0.118	0.217	0.501	0.556	0.662	0.668
	AC	0.657	0.662	0.457	0.554	0.678	0.729
Yemethin	BC	0.039	0.499	0.666	0.724	0.701	0.693
	AC	0.619	0.78	0.584	0.678	0.666	0.673

Comparison of R^2 value before and after bias correction for Maximum Temperature and Minimum Temperature are shown in Table 1 and 2.

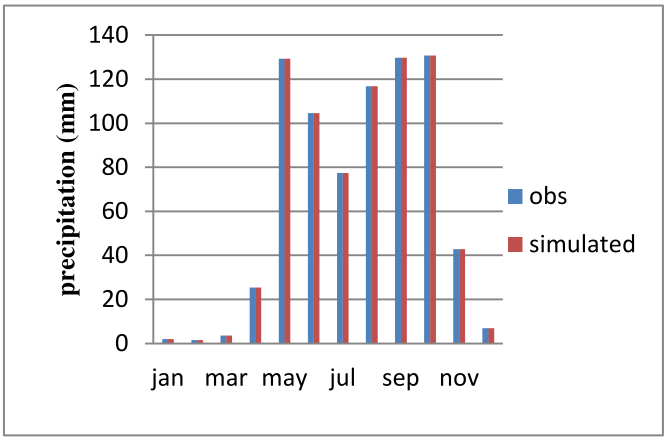

Figure 2. observed and simulated value for Meikhtila station

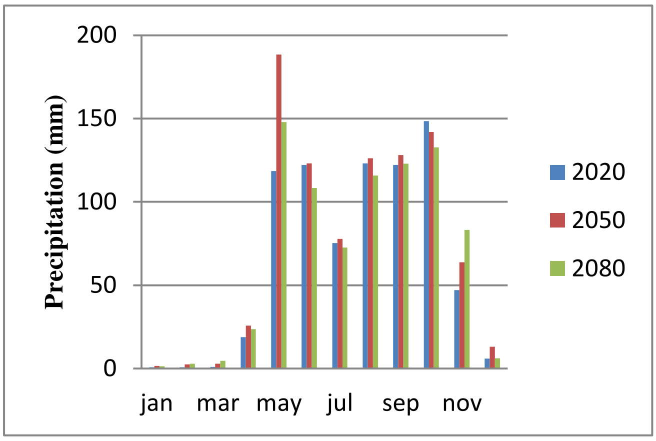

Figure 3.future average monthl precipitation of Meikhtila station for RCP 4.5

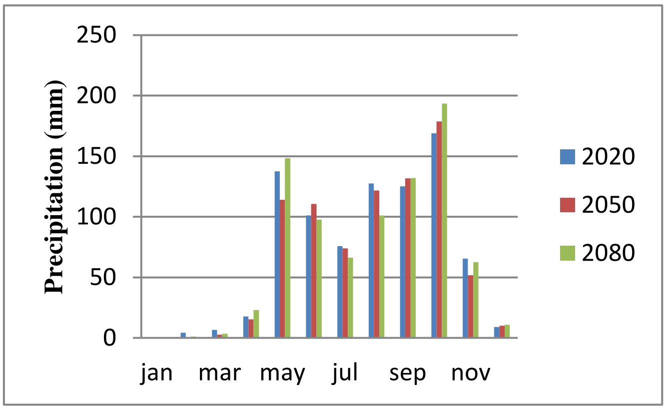

Figure 4. Future average monthly precipitation

Meikhtila station for RCP 8.5

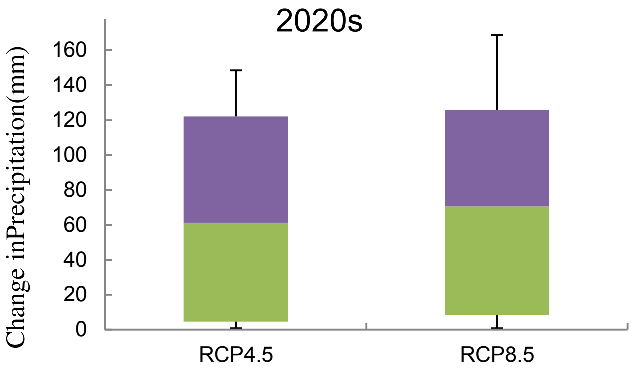

Figure 5. Changes in Precipitation

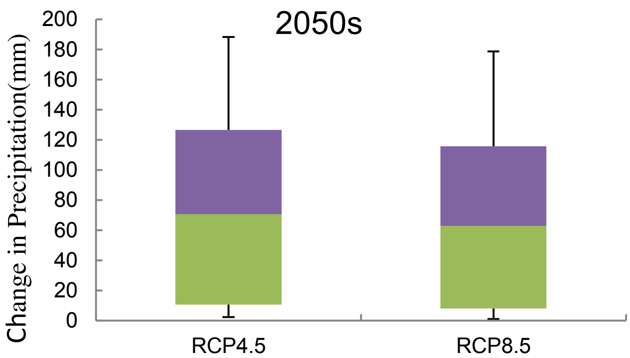

Figure 6. Changes in Precipitation

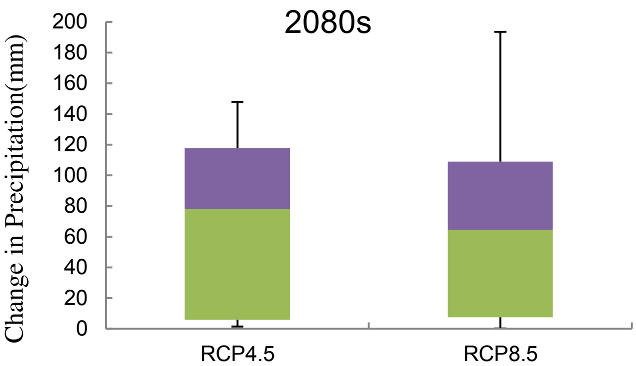

Figure 7. Changes in Precipitation

RECOMMENDATIONS:

Other CMIP5 GCMs should be tested. Other bias correction methods should be applied for further studies.

CONCLUSION:

The monthly and annual precipitation and temperature for the current time period and future were analysed. It is seen that different patterns of changes in monthly precipitation as well as annual precipitation.

MIROC-ESM and MIROC-ESM-CHEM are statistically best out of six GCMs in simulating precipitation for the central dry zone. MIROC-ESM model results are reliable at Sagaing, Magway, Monywa and Chauk stations. The more significant increase in annual precipitation is occurred in 2080s (2070-2099) for the Meikhtila stations.

REFERENCES:

1. Kite, G. "Looking for Evidence of Climatic Change in Hydrometeorological Time Series". Western Snow Conference, April 12-15, Washington to Alaska, 1991.
2. NRC (National Research Council), Opportunities in the Hydrologic Sciences. Washington, D.C: National Academy Press, 1991.
3. IPCC, Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge. Cited in Sharma, K.D., and Singh, P. 2007. "Impact of Climate Change on Hydrological Extremes: Floods and Droughts". Hydrology Journal 30: 129-145, 2001.
4. IPCC, Climate Change 2001: Synthesis Report. Contribution of Working Group I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, 2001a.
5. IPCC, Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, 2001c.
6. Burn, D.H., and Elnur, "Detection of Hydrologic Trend and Variability". Journal of Hydrology 255: 107-122, M.A. 2002.
7. Von, Impacts of Climate Change on Water Resources of Nepal: The Physical and Socioeconomic Dimensions, 2006.
8. IPCC, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, 2007.
9. Chang, H. "Comparative Stream flow Characteristics in Urbanizing Basins in the Portland Metroplitan Area". Hydrological Processes 21: 211-222, 2007.
10. Hamed, K.H. "Trend Detection in Hydrologic Data: The Mann-Kendall Trend Test Under the Scaling Hypothesis." Journal of Hydrology 349: 350-363, 2008.
11. Addressing Climate Change Risks on Water Resources and Food Security in the Dry Zone of Myanmar, Durban,12 December,2011.