ANALYSIS OF CLIMATE CHANGE IMPACT USING BIAS-CORRECTED PRECIPITATION IN ST. PAUL RIVER BASIN, LIBERIA

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ABSTRACT

The coastal area of Liberia usually has heavy rainfall which frequently causes flood along the river. A report on "National Policy and Response Strategy on Climate Change" in 2018 anticipated that average rainfall during 2010–2050 will increase by 2.0–5.0% and temperature will increase by 0.4–1.3°C, However, interpretation of climate change projection needs further consideration of uncertainties for implementing these results into practical flood risk management. This study mainly focuses on the climate change impact in St. Paul river basin, which is noted as one of the flood-prone areas in Liberia. Bias-correction method is first applied to the African country on CMIP5 Data Analysis System on Data Integrated and Analysis System (DIAS) by newly adding reference rainfall data into the system. Then, by comparing bias-corrected precipitation in the future under RCP 8.5 scenario with the past precipitation, the trend between the past and future is quantified. As a result, three Global Climate Models (GCMs) among the selected four suitable models in CMIP5 predicted the increase in monthly average precipitation in the future during 2080-2099 in the St. Paul River Basin while one model predicted decreasing trend.

Keywords: Climate Change, Bias Correction, Precipitation, CMIP5, GCM

INTRODUCTION

Liberia is positioned within the west coast of Africa. It is located between the longitudes of 7030` and 11030` west and latitudes 40 18` and 80 30` north. The population is 4.5m (the Republic of Liberia, 2004). A report on "National Policy and Response Strategy on Climate Change" was published in Liberia in 2018. The report anticipated that average rainfall during 2010–2050 will increase by 2.0–5.0% and temperature will increase by 0.4–1.3°C. It indicates that Liberia faces challenge with the impact of climate change coupled with many socio-economic problems like poverty, poor infrastructure, lack of information technology and access to finance, and weak institutions and resource competition, among others challenge. However, interpretation of climate change projection needs further consideration of uncertainties for implementing these results into practical flood risk management.

Considering the above, primary aim of this study is to analyze the climate change impact using Global Climate Models (GCMs) data in Couple Model Inter-comparison Project Phase 5 (CMIP5) on Data Integrated and Analysis System (DIAS), which stores earth observation data to convert it into information

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useful for disaster management and to make this information available within Japan and overseas. Bias-correction method is first applied to the African country on CMIP5 Data Analysis System on DIAS by newly adding reference rainfall data into the system. By using the bias-corrected precipitation data, the trend between the past and future precipitation is quantified. Through this analysis, it aims to recommend future approaches to reduce flood risk under climate change.

The target area of the study is St. Paul River Basin, which locates in Monsterrado County, Liberia. Figure 1 shows the location of St. River Basin in Liberia The St.Paul River is 25 km upstream of Monrovia. Major tributaries are Via, Wuni, and Tuma. It has the length of 495km. The total catchment area is 20, 500 km² (7,900 sq. miles), or of which 11,000 km² (4,450 sq. miles) are in Liberia and 9,000 km² (3, 450 sq. miles) in Guinea. The River has a dam which is called the Mount Coffee Dam, it is a Hydroelectric Plant built in 1966. Most of the basins are dominated by heavy rainfall and the Monsterrado tableland has the largest water flow during the rainy season from April to September. This gives a high-level raise ranging from 1 meter to 2 meters due to heavy precipitations. The St. Paul river basin has a serious history of flooding which was reported in 2018 that over 30, 000 people have been affected. Therefore, for future projection, there is a concern for mitigation. Figure 2 shows the elevation map of St Paul River Basin.

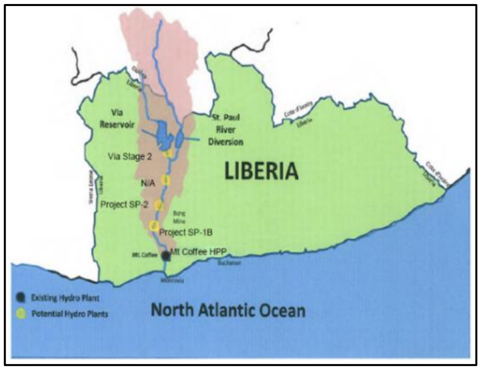

Figure 1: Location of St. Paul River Basin

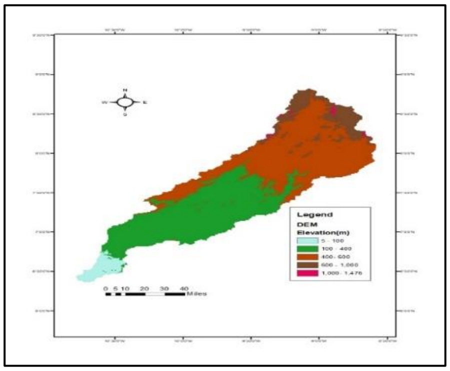

Figure 2: Elevation map of St Paul River Basin

METHODOLOGY

In this study, climate change impact is evaluated by analyzing the trends of past and future climate using bias-corrected precipitation of CMIP5 Data which is accumulated on DIAS. Figure 3 describes a flowchart of the methodology. DIAS has a set of tools that provide the easy display and analysis of data from the CMIP5, which has a wide-ranging spatiotemporal resolution. All the 44 models data in CMIP5 data can be downloaded from DIAS. Usually, each GCM has 7 climate components such as Precipitation, Air Temperature, Outgoing Longwave Radiation, Sea Level Pressure, Zonal Wind, Meridional Wind, and Sea Surface Temperature.

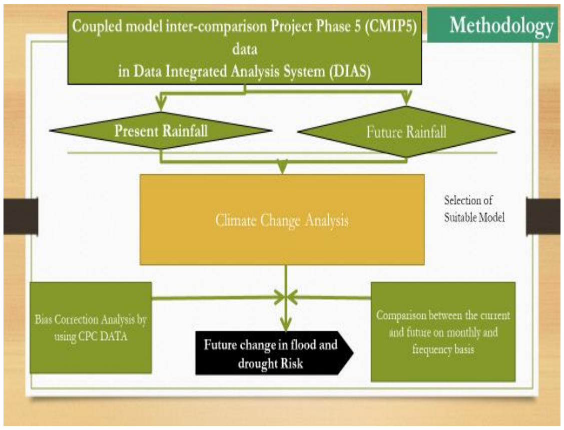

Figure 3: Methodological approach of the study

At first, 44 models data in CMIP5 are downloadedrom (DIAS). In order to find the suitable models for the target area, Spatial Correlation (S_Corr) and Root Means Square Error (RMSE) between each GCMs in CMIP5 data and climate reanalysis data (JRA55) are calculated for each climate components for 6 months (April-

September) in Liberia area. The most suitable GCMs for Liberia are selected by considering the values of S_Corr and RMSE.

For detail analysis of climate change impact, bias correction of the GCM data is essential. Although the CMIP5, DIAS provides a function of bias correction, this function didn't cover the African country because the reference data to be used with bias correction only covers Asian countries. Therefore, in this study, the reference data for African country is newly selected and added on CMIP5 Data Analysis System. Among the various data, daily precipitation data of CPC Gauge-based analysis is selected as it has been constructed over the global land areas. In this analysis, gauge reports from over 30,000 stations are collected from multiple sources including GTS, COOP, and other national and international agencies. Figure 5 shows CPC historical rainfall data from 1980 to 2005 at the location of four stations inside or near the St. Paul River Basin, whose locations are plotted in Figure 4. On CMIP5 Data Analysis System on DIAS, the bias correction of the selected GCMs data is conducted by using the CPC data in Figure 5 and climate change impact is quantified in the target river basin. Finally, based on the results, future approaches to reduce flood risk under climate change are recommended.

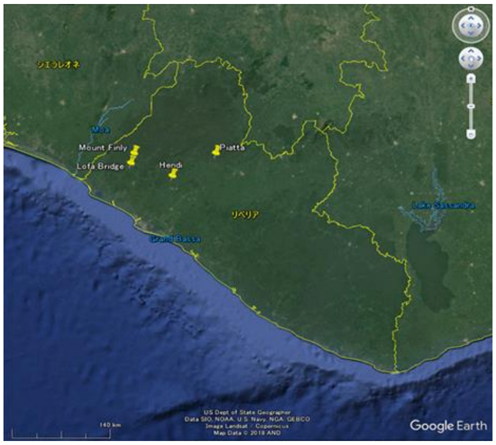

Figure 4: The locatoion of 4 stations inside and near the target river basin

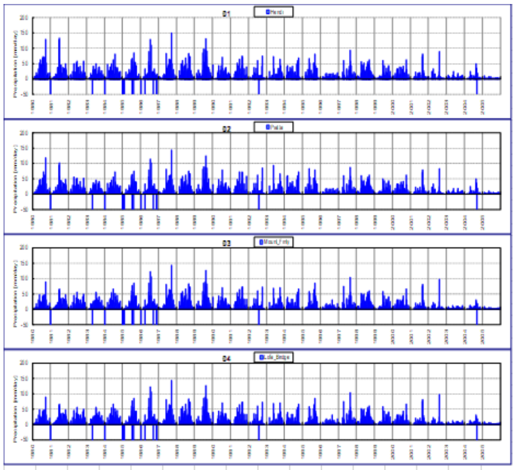

Figure 5: CPC historical rainfall data from 1980 to 2005 at the location of 4 stations

RESULTS AND DISCUSSIONS

Model Selection

Model selection is important to identify the different strengths and weaknesses of climate models; in some cases, especially over tropical region. As the first step, the most suitable GCMs for Liberia were selected using CMIP5 Data Analysis System, by comparing the 7 climate components of the models with climate reanalysis data (JRA55). As a result, four models listed below were selected as the suitable models for the target area. Figure 6 shows the spatial distribution of monthly average precipitation in September for 20 years during 1980 -1999 based on the reanalysis data, while Figure 7 illustrates that by the selected models.

A: Institute of Atmospheric Physics (LASG) and Centre for Earth System Science (CESS) FGOALS_g2.
B: Community Climate System Model, CCSM version 4. (CCSM4).
C: Community Earth System Model version 1 (CESM1) with CAM5.2 as its atmospheric component. (CESM1 CAM5).
D: A New Global Climate Model of the Meteorological Research Institute.

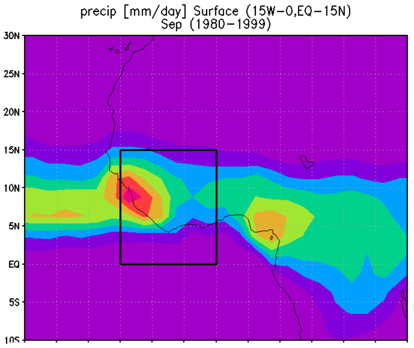

Figure 6: Monthly average Precipitation during 1980 -1999 based on the reanalysis data

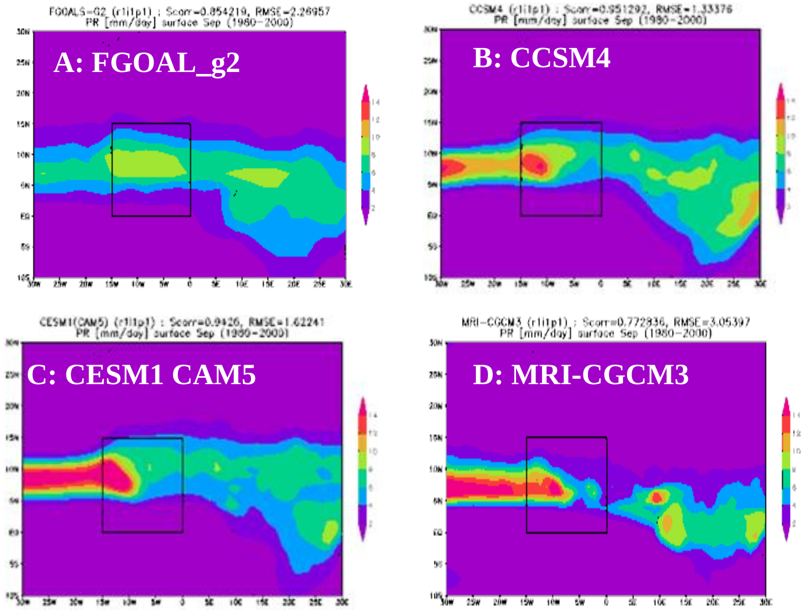

Figure 7 Selected Climate Models

Result of Bias Correction

With the change of the system on DIAS, the bias correction of the selected GCM data (Figure 7) was conducted and climate change impact was quantified in the target river basin. Figure 8 shows the monthly precipitation before and after the bias correction. The bias-corrected monthly precipitation in the past indicates that it increase in June. Precipitation of the models maintain consistency along with the historical data (insitu data) for July onward and up to September, gradually decrease in October.

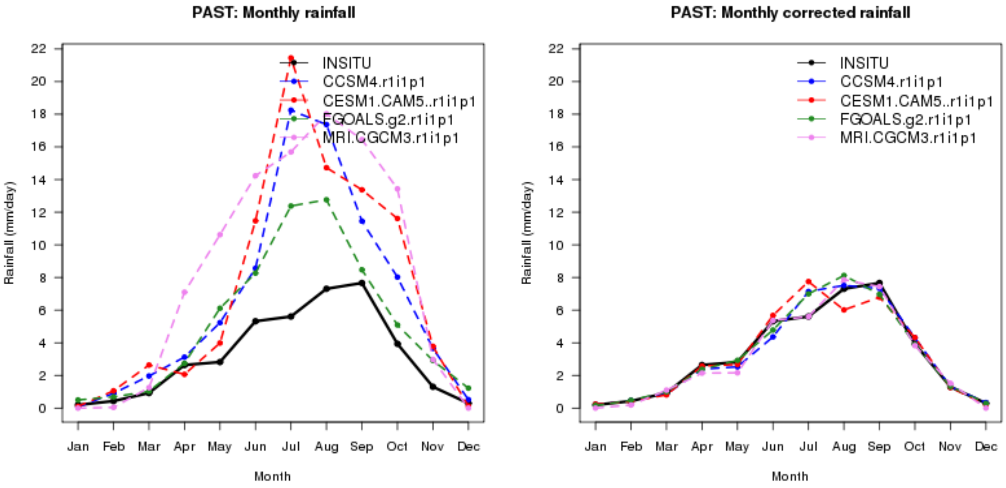

Figure 8: Monthly precipitation before and after the bias correction

Climate Change Impact on Monthly Average Precipitation

Figure 9 indicates the monthly average bias-corrected precipitation in 2025-2039, 2040-2059, 2060-2079 amd 2080-2099 in the future, which are predicted by the selected four models.The black line indicates the trend of historical data. In 2040-2059, three models show increase with one model slightly decreasing, while three models remain at increase upward December. In Mid-century, from 2060 to 2079, rhe figure indicates all four model shows increase at the beginning of the rainly seaseon at the end of the rainly season. At the end of the century, from 2080 to 2099, the figure displays a high increase in in all models. In August, one model show drastically decrease.

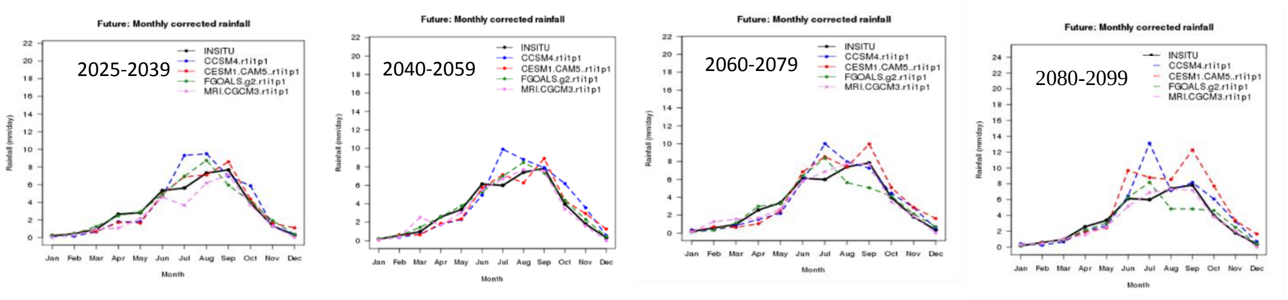

Figure 9: Monthly corrected precipitation

Climate Change Impact on Precipitation with Different Return period

Figure 10 indicates the precipipitation with different return period in 2025-2039, 2040-2059, 2060-2079 amd 2080-2099 in the future The black line indicates the trend of historical data. During the rainy season, frequently precipitation are anticipated to happen while some increasingly extreme dry spell occasions are probably going to happen with return period somewhere in the range of 5 and 20 in years. Within the timeline of the return period rainfall shows the quantity of to be expanded under this projected climate change situation.

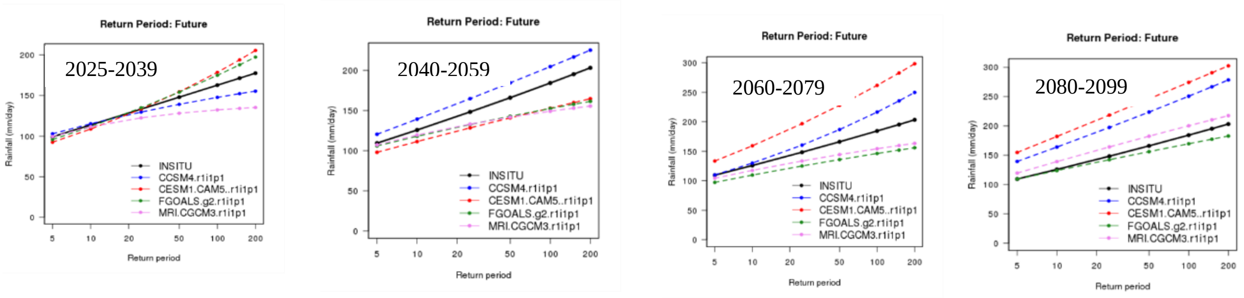

Figure 10: Precipitation with different return period in the future

Climate Change Impact Considering Trends in Population Growth

The population of Liberia was 3,476,608 persons in 2008 (LIGIS, 2008). By examining the age structure, it was found that the population is young and youthful and will continue to fuel further population growth for many years to come. By 2100 the population is expected to be 10,000,000. Therefore the impact of floods will be worst because the unplanned settlement of people, living in river basin and with houses that are not in accordance with building code and household regulation. In additional to lack of disaster prevention knowledge with limited climate change education, it is most likely that the effect of disaster on the population will be severe.

CONCLUSIONS AND RECOMMENDATIONS

This study has established a fact about Liberia climate condition by analyzing future and past bias-corrected precipitation of CMIP5 Data on DIAS. Considering the result, it has arrived at the point which states that the St. Paul River Basin in Liberia will experience heavy rainfall which will result in flood and drought in the Dry season. The wet month becomes wetter and the dry month begin drier. Moreover, different approaches from other cooperation need to be developed in order to realize the significant amount of output. The studies give rise to further studies that will cover the entire country river management and flood propagation system. Therefore, it is with an urgent need for policies development and immediate implementation. With effective policies implementation, there are many consequences to a disaster that can be addressed. Considering the outcome of this study, the country poses at the position where all effort should be diverted to Sustainable Development and mitigating the effect of Disaster. Therefore the below-listed recommendations should be implemented in the soonest possible time. a) The National Disaster Management Policy needs Amendment b) Development and understanding of Hazard Map, c) Capacity Building and Community awareness.

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