ANALYSIS OF FLOODS AND DROUGHTS IN THE BAGO RIVER BASIN, MYANMAR, UNDER CLIMATE CHANGE

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ABSTRACT

This study investigates floods and droughts under climate change in the Bago River Basin (BRB) which has a major economic contribution in Myanmar economy by paddy agriculture. Rainfall Runoff Inundation Model was used to analyze the past flood events which are 2011, 2012 and 2014 flood events and to estimate the agricultural damage assessment for the paddy field. Satellite-based data were applied to calculate floodwater indices such as MGBM, NDVI, LSWI and MLSWI. For the future climate prediction, daily bias-corrected precipitation data of 20-km MRI-AGCM3.2S was used for 25 years for the current (1979-2003) and the future (2075-2099) climate conditions. Past floods and droughts were quantified by using the Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) at 1-, 6-, 12- and 24- month timescales. These indices provide the effective way for quantifying floods and droughts hazards in the BRB. In addition, comparative SPI (cSPI) was used to calculate increase of wet and dry conditions for the future climate on the basis of the present climate.

Keywords: *SPI, SPEI, RRI Model, MRI-AGCM3.2S, cSPI*

INTRODUCTION

The Bago River Basin plays an important role for agricultural production in Myanmar and paddy rice is the main stable crop cultivated in the Bago Region. Figure 1 shows the location of BRB in Myanmar. During recent years, frequent floods and droughts have affected the socio-economic development of the Bago Region. During the monsoon season, almost two thirds of the BRB is inundated by severe floods due to the torrential rainfall occurring at the end of July. At that time, paddy rice had already been planted and is in the early growth stage. Although water related disaster management system in the BRB is being developed considered to the effective countermeasures, potential climate change impacts have not been considered in the BRB.

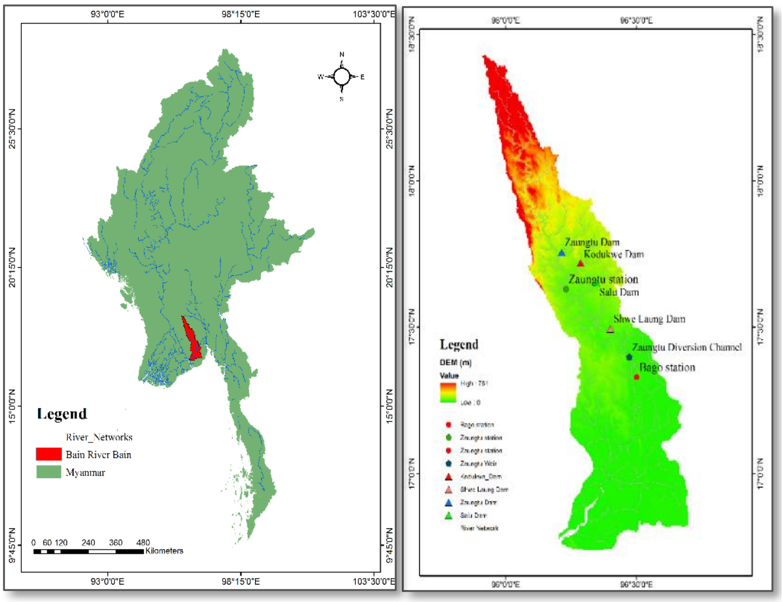

Figure 1: Location of Bago River Basin, Myanmar

For the future, we have to upgrade the effecti
impacts of water related disaster in the BRB.

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METHODOLOGY

This study aims to analyze the past water related disaster in the Bago River Basin and to investigate the change in precipitation and river flows under the future climate condition. Past floods and droughts were analyzed with standardized precipitation index (SPI) and standardized precipitation evapotranspiration index (SPEI) at 1-, 6-, 12-, and 24-month timescales (Mckee et al., 1993). The SPEI, which is an indicator of agricultural droughts, was available globally from 1950 to present which compared to the computed SPI. These indices provide the effective way for quantifying floods and droughts hazards in the BRB. The analysis of the past flood inundation was conducted by using the Rainfall-Runoff-Inundation (RRI) model (Sayama et al., 2012)and identified the flood prone areas, flood duration and depth were calculated. The digital elevation model, flow accumulations and flow direction of global dataset were used as the input to develop the 0.5-km grid RRI model for the Bago River basin. For the model calibration, the 2011 flood event was simulated by using the observed local rainfall data and model validation was done for the 2012 and 2014 flood events. In addition, flood inundation analysis by moderate-resolution imaging spectroradiometer (MODIS) remote sensing image was carried out to validate RRI simulation maps. Satellite-based data were applied to calculate floodwater indices such as Modified Gradient Based Method (MGBM) (Robin et al., 2016), Normalized Different Vegetation Index (NDVI), Land Surface Water Index (LSWI) and Modified Land Surface Water Index (MLSWI) (Kwak et al, 2013). Flood inundation extent was validated during the flood period (13-20 August 2011). The grid based distributed damage assessment method is used to evaluate flood paddy damages based on flood inundation depth and duration of RRI simulation at paddy fields obtained from land use/ land cover data. Rice cropping calendars and a relationship between growth phase of rice and flood damages was collected from the Department of Agriculture and Department of Agricultural Planning. To assess the effects of the climate change, daily bias-corrected precipitation data of 20-km MRI-AGCM3.2S was used for 25 years for the current (1979-2003) and the future (2075-2099) climate conditions (Kitoh and Endo, 2015). In addition, comparative SPI (cSPI) (Hasegawa et al., 2015) to calculate increase of wet and dry conditions for the future climate on the basis of the present climate.

DATA

Daily precipitation, river water level and river discharge data was collected from the Department of Meteorology and Hydrology, Myanmar. The GIS data such as the 15 seconds resolution data of Digital Elevation Model (DEM), flow accumulation (ACC) and Flow direction (DIR) were obtained from HydroSHEDS dataset. Land use and land cover data was downloaded from global map data download services to identify the paddy field, cropland and others land cover for estimation of agricultural damage assessment. The MODIS Terra Level-3 8-day composite surface reflectance products (MOD09A1) was used to validate the RRI model result. For the climate change simulation, the daily precipitation data set covered the year from 1979 to 2003 (25 years) is applied for the current climate condition. Future climate condition from 2075 to 2099 (25 years) was estimated by substituting the target data sets in the APHRODITE reference data set. The gridded rain gauges dataset in Asia, APHRODITE, was used as a reference observation for the BRB, Myanmar.

RESULTS AND DISSCUSSION

Standardized Induces

In the BRB, extreme droughts are indicated by 6-month SPI in 1978, 1979, 1982, 1987, 1988, 1991, 1998, 2001, 2008, 2010 and 2013. **Figure 2** shows the 6-month SPI for the Bago Station. These SPI values for different time scales indicate the severe dryness in the rainfed agriculture area of rice production. According to the statistical analysis, these results for the Bago station are consistent with the flood in 2011, recorded as the most severe flood in the BRB.

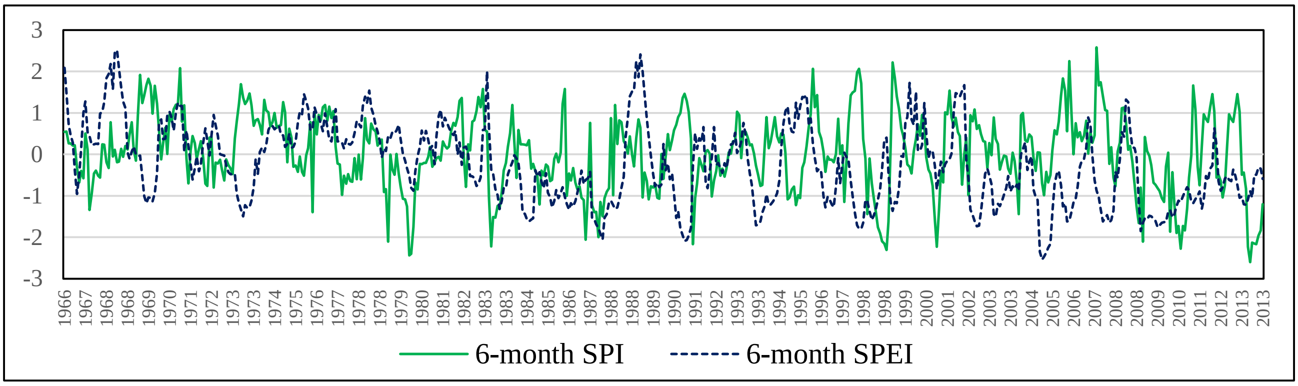

Figure 2: 6-month SPI for the Bago Station

Past Flood Analysis

The analysis of the past flood inundation was conducted by using the Rainfall-Runoff-Inundation (RRI) model and identified the flood prone areas, flood duration and depth were calculated. For the model calibration, the 2011 flood event was simulated by using the observed local rainfall data. Model validation was done for the 2012 and 2014 flood events with very good performance. However, the simulated discharge is a little different with the observed hydrograph after the validation; the model performance result was satisfactory. The flood inundation maps of the 2011, 2012 and 2014 flood events were produced with the RRI simulation **(Figure 3)**. These flood inundation maps demonstrate the flooded area, depth, duration, and can enhanced the disaster management such as flood warning, preparedness and responses in the BRB..

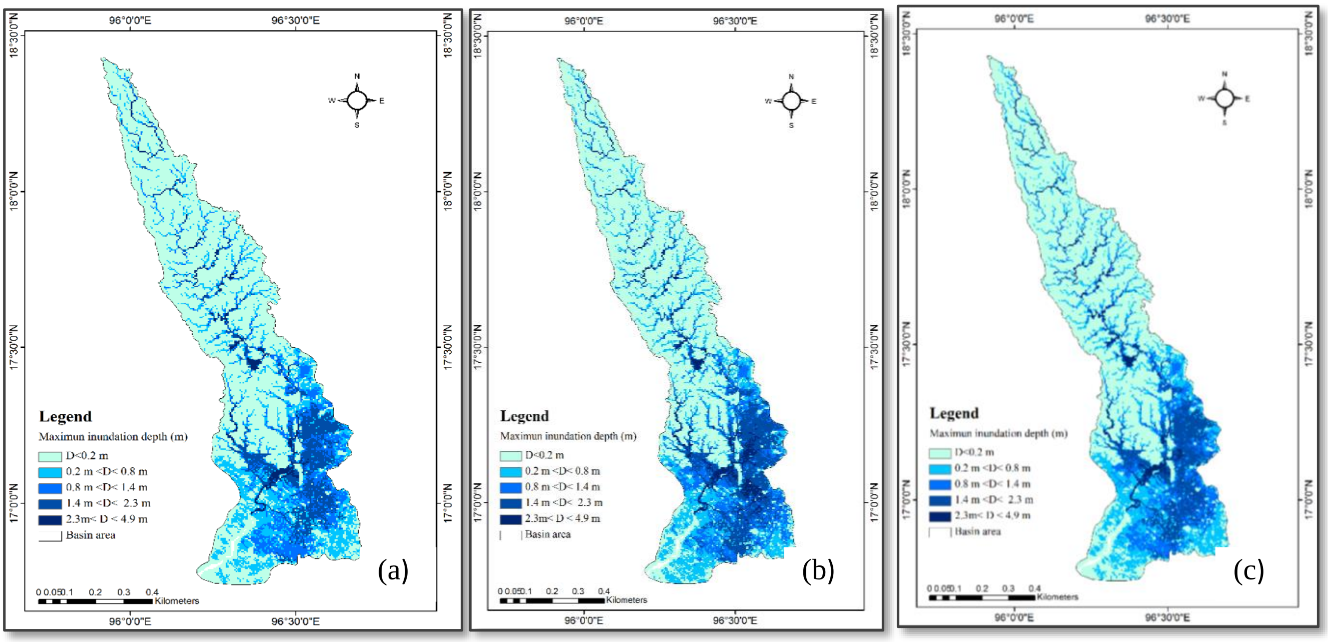

Figure 3: Flood inundation depth map for the (a) 2011, (b) 2012 and (c) 2014 flood events simulated with RRI model

Flood Extent analysis with MODIS Image

Satellite-based data were applied to calculate floodwater indices such as MGBM, NDVI, LSWI and MLSWI **(Figure 4)**. Among then the MGBM method is the best to identify the extent of flooded areas. Flood inundation extent was validated during the flood period (13-20 August 2011).

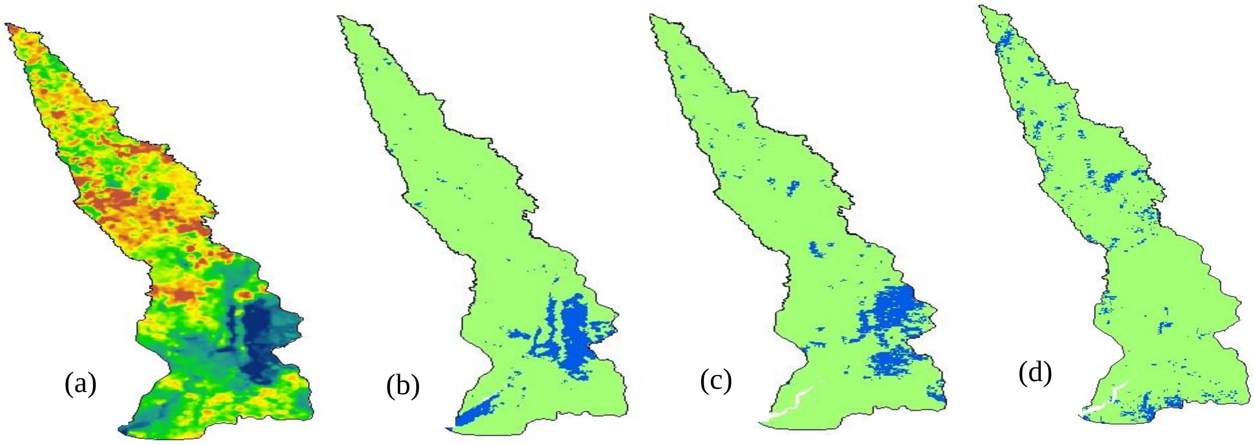

Figure 4: Flood extent area from applying the different water indices for (a) MGBM, (b) NDVI, (c) MLSWI and (d) LSWI

Agricultural damage assessment

Agricultural damage assessment for the 2011 flood event was estimated by using the RRI model. According to the RRI Model simulation, 12.5% of total area is prone to flooding causing above 15 million (Kyats) of damage for the rice paddy fields. As a result, a combined use of standardized indices, RRI model and remote sensing technology is a useful approach for the flood risk analysis.

Evaluation of MRIAGCM2.3S Data

To assess the effects of the climate change, daily bias-corrected precipitation data of 20-km MRI-AGCM3.2S was used for 25 years for the current (1979-2003) and the future (2075-2099) climate conditions. **Figure 5** shows the comparison mean monthly precipitation under current observed and future precipitation data. For the Bago Station, monthly average precipitation has slight increase in the future compared with the present climate. **Figure 6** shows the frequency of extreme rainfall events for present and future RCP8.5 emission scenario with three distributions sea surface temperature. The present and future precipitation is from bias-corrected MRIAGCM3.2S daily precipitation. The probability of extreme precipitation increases under the RCP8.5 scenario and this increasing trend of precipitation may intensify floods in the BRB in the future due to the impacts of climate change.

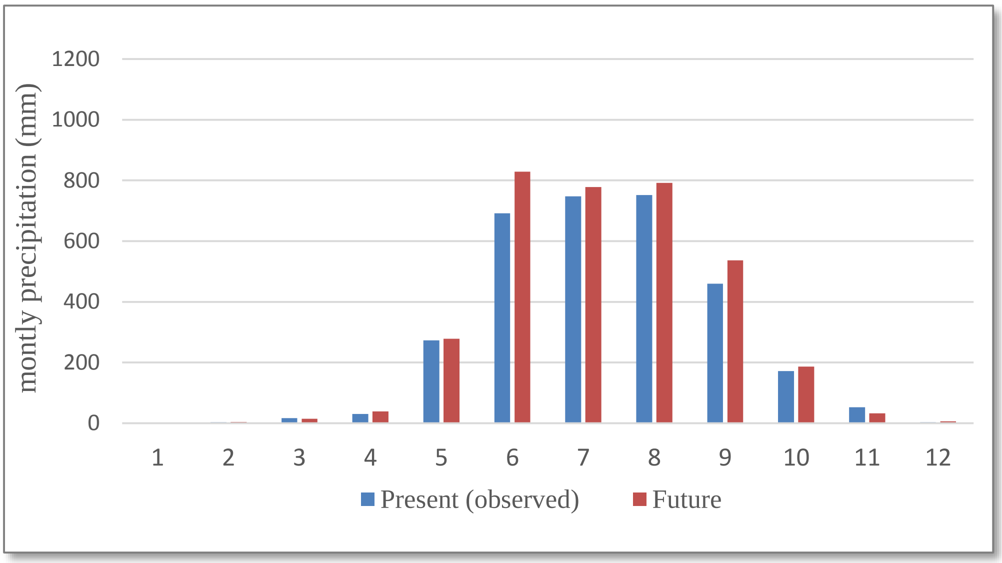

Figure 5: Comparison between present (observed) and future precipitation at Bago Station

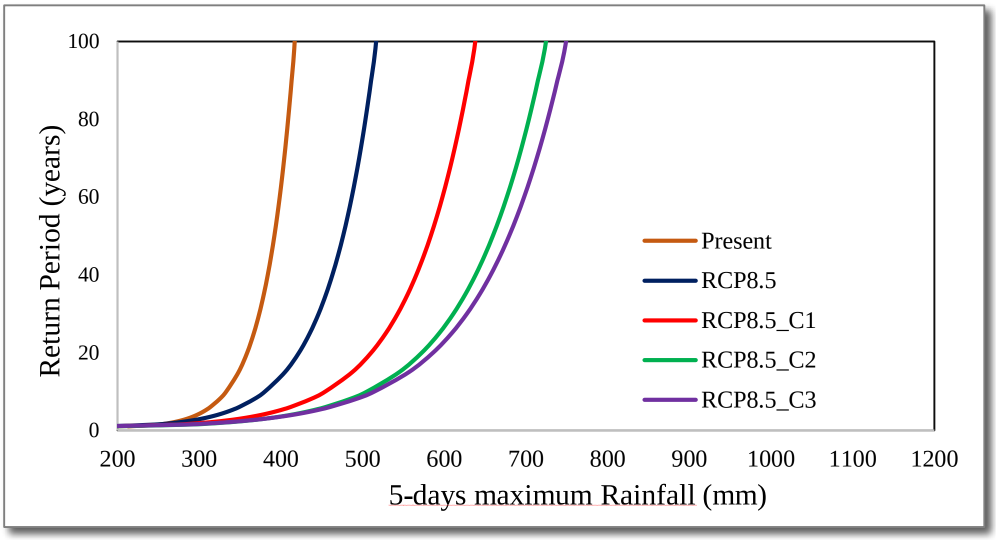

Figure 6: GEV probability distribution of precipitation under present and future climate condition of Bago Station

The comparative SPI approach for the climate change assessment

We calculated the median values of 3-, 6-, 12- and 24-month cSPI to compare the present and future climate condition. **Table 1** shows the comparison between median values of present and future climate condition at each time scale. According the results, median values was shifted to the increasing trend under the RCP8.5 scenario of future climate condition. Therefore, the BRB is characterized by increasing wet condition and flood severity also occur for the future

Time Scales	Present	RCP8.5	RCP8.5_C1	RCP8.5_C2	RCP8.5_C3
3-month	-0.06	0.33	0.39	0.50	0.54
6-month	-0.05	0.51	0.88	0.98	0.86
12-month	-0.07	1.02	1.42	1.84	2.09
24-month	0.07	1.58	2.29	2.72	3.08

Table 1: Comparison between median values of the present and future climate condition at 3-, 6-, 12- and 24-month cSPI

CONCLUSION

This study aim to analyze the past water related disaster in the Bago River Basin and to investigate the change in precipitation and river flows under the future climate condition. The analysis of floods and droughts was done with the Standardized Precipitation Index (SPI), which quantifies the flood and drought severity. The result of SPI was validated by using the Standardized Evapotranspiration Precipitation Index (SPEI). The rainfall-runoff-inundation (RRI) model was used to analyze the 2011, 2012 and 2014 flood events and to assess flood agricultural damages for the 2011 flood event. These flood inundation maps of the 2011, 2012 and 2014 flood events can be utilized for mitigating measures of future disaster prevention activities. For the damage assessment for the paddy field, we use the damage function of the reproductive phase to estimate the agricultural damages for August 2011 flood event. Considering the effects of climate change, the comparative SPI approach and RRI model with the MRI-AGCM3.2S precipitation data were used to assess the future floods and droughts in the Bago River basin. This MRI-AGCM3.2S data was bias corrected for current (1979-2003) and future (2075-2099) under the RCP8.5 scenario climate conditions. The climatic 5-day maximum rainfall data was analyzed to obtain annual maximum and from those annual maximum, extreme rainfall scenarios of the different return period were calculated. The cSPI results show the increasing dry condition in the summer while the amount of precipitation also increases in the future climate conditions. According the cSPI results, the winter is expected to have wetter conditions in the Bago River Basin increasing floods in the future climates on the basis of the present climate. For the assessing the river flow for the future climate condition, the MRI-AGCM3.2S precipitation data under current and future climate condition was used in the calibrated RRI model. As a result, 27% of river flow and 12.6% of precipitation will increase in the future leading to potential increase in flood inundation areas in the BRB under climate change.

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