Study about The Impact of Climate Change Using Hadcm3 Climate Change Scenario and The Ipcc A2 And B2 Emission Scenario Against The Amount of Daily And Monthly Rain At Progo Hulu Watershed

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ABSTRACT

Climate change has become a global issue, it shows from the universally accepted result from the United Nations convention about climate change (UN Framework Convention on Climate Change, UNFCCC) at Rio de Janeiro, Brazil on the year 1992. The implication of climate change does not only affect the rising of the temperature, but also affects other climate parameters. This study focuses on the projection of rainfall as the climate parameter at Progo Hulu watershed, because rainfall has a big enough variability in terms of space and time. The rainfall projection in this study is executed as an early effort of disaster mitigation which is the implication of climate change at the Progo Hulu watershed. The method used for the climate change modeling in this study is the HadCM3 method. The emission scenario used in this study is the A2 and B2 emission scenario. The B2 scenario is considered to be the basic scenario which contains sustainable local environment handling and A2 scenario simulated that is indicated by the high increase of the growth of the population and low economic development. The rainfall projection yielded data from year 2011 until year 2100. The result from this study shows that in general, the rainfall projection using the A2 and B2 scenario has different characteristics on 10 rain stations at Progo Hulu watershed. On both of the scenarios, 8 out of 10 rain stations showed an increasing rainfall trend, while on the other 2 stations, which is Parakan and Kintelan showed a declining trend. The highest monthly rainfall rate occurs on year 2100 with the B2 scenario occurs on the Magelang station as big as 1173.38 mm that occurred on December, while for the A2 scenario is as big as 1923.8 mm that occurred on February.

Key words: rainfall, rainfall projection, climate change, HadCM3, Progo Hulu watershed

1. Introduction

Among climatic parameters, rainfall (precipitation) is one of the most important parameters in the field of meteorology, especially in Indonesia as one of the tropical countries. It is due to Indonesia's position is in a region that has more dominant sun radiation than the higher latitudes region (Susandi, Tamamadin, and Nurlela, 2008).

Rainfall is also one of the weather element which has a great diversity in space and time. Diversity according to space influenced by topography layout (oceans and continents), topography, altitude, wind direction and the location of the latitude. Variability of rainfall also occurs locally in a place, which is caused by the differences in topography, such as the presence of a hill, or mountains, which causes rain occurs unevenly. Asdak (1995, Tanjung, 2011).

Climate change has caused a lot of negative impacts to the human life (Ratag, 2008). Some impacts of climate changes are (1) Increased rainfall trends reported in Argentina (Viglizzo et al, 1995) as well as in Australia and New Zealand (Plummer et al, 1999) and (2) the trend of decreasing rainfall causing drought in Iran (Marsoudi and Afrough, 2011), Africa (Mason, 1996), and China (Zhai et al. 1999). As for Indonesia itself, most of Sumatra region experincing delayed rainy season 10 to 20 days and the beginning of the dry season has been delayed 10 to 60 days (Naylor, 2007).

In order to reduce the risk of negative impacts of climate change, mitigation efforts are needed, including to predict the impact of future climate change at the local level so that adaptation and mitigation efforts can be better prepared.

In 2000, IPCC prepare climate conditions scenarios based on the condition of greenhouse gas emissions (GHG) and published in the Special Report on emmision Scenarios (SRES). Emission scenarios which frequently used (WWF and ITB, 2007; Kurniawan et al, 2009) are the A2 and B2 scenarios. A2 scenario is characterized by an increasing number of high population and low economic growth will result temperature increase in Indonesia which will reach over 3°C in the Year 2100 In contrast to A2, B2 scenario is considered as the baseline scenario (reference scenario) which produces a projected temperature maximum of 1.4°C in 2050 and further increased up to 2.6°C by 2100.

Model HadCM3 developed by performing calculations on each grid with latitude and longitude resolution 3,75° x 2,5° (Collins et al, 2001) and this model is able to determine the interaction of the atmosphere and oceans to the daily time scale in long term (Johns et al, 2003). Utilization of the model developed in the Hadley Climate Center in the UK Meteorological Office for Upstream Progo Watershed (especially rainfall in the Year 2011 to 2040, Year 2041-2070 and Year 2071-2100) are expected to be used to determine the impact of climate change in the future in the local level, so, the plan can be prepared to mitigate the impact of climate change to reduce the risks that may arise in the future.

This paper is part of Dr. Slamet Suprayogi, MS.'s research (Hibah Bersaing Postgraduate School Universitas Gadjah Mada 2014) entitled "Estimasi Dampak Perubahan Iklim Terhadap Produktivitas Pertanian Sampai Tahun 2100 Berdasarkan Skenario Perubahan Iklim HadCM3 dan Skenario Emisi A2 dan A3 di DAS Progo Hulu".

2. Literature Review

2.1. Climate Change Definition

Climate change is the movement of the parameters or elements of climate caused by the change of climate parameters or the interaction of climate parameters (temperature, humidity, rainfall, wind direction and speed) (IPCC, 1996). Climate changes are based on the shift of the meteorological conditions in long term. These changes are caused by a single parameter, such as rainfall or temperature, but is usually caused by a combination of several components that cause much different weather conditions (more cold, wet, cloudy, and windy) (Burroughs, 2005).

Statistically, climate change is a change of its elements that have a tendency to rise or fall significantly that accompany daily, seasonal, and cycle diversity (Tremberth, Houghton, and Filho, in Mahmud 2008). WMO stated statistical standards allowed for processing and estimating the climatic conditions are climate data for 30 years, for example in 1971-2000. (Barry and Chorley, 2003).

2.2. Causes of Climate Variability

Natural variability is characteristic of the global climate and occur in short and long intervals. Some climatologists believe that climate fluctuations in the short as well as long term is not a constant occurrence but the patterned events. This incident is controlled by the strength or energy caused by the combined phenomenons of the earth with the solar system. Extreme changes of climate variability caused by human activity. The release of greenhouse gases (GHG) into the atmosphere over these past year led to some changes of climatic conditions (Mavi and Tupper, 2004).

2.3. Climate Change Scenarios

Climate and weather have a great influence to the life on Earth and has become part of every aspects of the human daily activities such as health and food production. Due to the increasing human activity, an increase in the greenhouse gas levels in the air. Increased levels of greenhouse gases lead to further increase in the temperature of the earth significantly from year to year are referred as global warming. Global warming results in changes in other atmospheric components, such as rainfall and humidity, causing climate change (IPCC, 2000).

In effort to mitigate climate change and global warming, we need an estimate (assessment) to predict how future climate conditions with a relatively long time span.

Climate change scenario is logical representation of the climatic conditions in the future with simplified based on the data and the relation of consistent climatological parameters (IPCC, 2000). Climate change scenario is closely related to projections of future climate conditions (UKCIP, 2009). Santoso and Forner (2006) explains that the climate conditions in the future is difficult to predict, so the future climate scenarios needed to support the analysis of vulnerabilities and potential impacts from climate change. IPCC (2000) explained that the construction of the scenario is structured as a result of the lack of methods well enough to make predictions about future climate change.

Estimating the impact of climate change and global warming begins with the preparation of one or more scenarios of greenhouse gas emissions. Scenarios are organized because of the unavailability of other methods well enough to predict climate change. Therefore, as an alternative solution climate scenarios that take into account some of the possibilities that will occur in the future used. Emission scenario is the most widely used emission scenarios developed by Intergovermental Panel of Climate Change (IPCC) in Special Report on Emmision Scenario (SRES). Gas emission scenarios done by the IPCC (2002) in SRES drawn up in the year 2099 with the scheme shown in Figure 2.3.

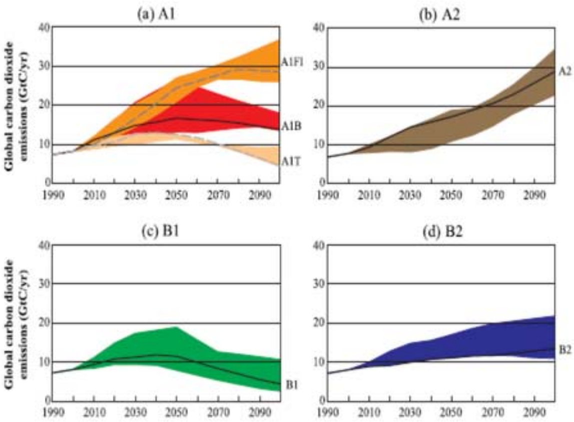


Figure 2.3. CO2 Emissions Scenario Graphs based on SRES (IPCC, 2002)

Scenario A1 and A1 Family describe a future where very rapid economic growth, global population that peaks in mid-century reached and then decreased, and the rapid growth of new technology which more efficient. The main theme of this scenario are convergence among regions, capacity building, and the increase of socio-cultural interaction, with a reduction in per capita income differences between regions. Family Scenario A1 is divided into three groups that describe alternative directions from the use of technology in the field of energy. The three A1 groups are distinguished in the technology applied, namely: intensive fossil fuel (A1F1), non-fossil energy resources (A1T), or a balance across all energy sources (A1B).

Scenario A2 describes a heterogeneous world. The main theme of this scenario is the self confidence and the maintenance of local identity. Convergence occurs in fertility patterns across regions with very slow rate, which have an impact on the increasing global population.

Scenario B1 describes the future where there is convergence between regions, the global population reached a peak in mid-century and then decrease, as scenario A1, but with rapid growth in economic structure that leads to the field of services and information, and a reduction in the use of intensive raw materials, and the introduction of clean and efficient technologies. The emphasis on global solutions in the of economic, social, and environmental sustainability areas, including improved equality, but there is no addition of the initiative on global climate policy.

Scenario B2 describes a world that emphasizes local solutions in the field of economic and environmental sustainability. In this scenario there is a growing global population, although more slowly than the scenario A2, economic growth is moderate, as well as technological change is relatively slow and uneven compared to scenario B1 and A1. This scenario is oriented towards environmental protection and social equality.

2.4. General Circulation Model (GCM)

General Circulation Model (GCM) is a model to predict the response of climate to projected concentrations of greenhouse gases to the global level (Praskievicz and Chang, 2009). GCM is a three-dimensional model that is intended to model the whole complexity of the climate system of earth, where the GCM is able to represent quite well the main features of the climate parameters which are the basis for global distribution (Barry and Chorley, 2003). In GCM, whether greenhouse gas emission scenarios developed by IPCC or other organizations are used as the input of the GCM. Based on the amount of greenhouse gas emissions in the air, GCM would predict an increase in the temperature, wind speed, air pressure, and other climatic parameters. GCM models are generally prepared by the central meteorological agencies in each country, eg HadCM3 developed by the British, and CGCM developed by the Canadian. The output generated from GCM climate parameters are contained in the global level with a low resolution.

2.5. Downscaling Process

Downscaling process is a process done to transfer the results of GCM predictions which are generally used at the global level, into a narrower area coverage, ie at the regional, local, or for rainfall stations point. Lately, it has been developed various methods of downscaling in the whole world. As its importance in water resources management, procedures performed including preparation of the relation between climate variables for global level with the results of observations that have been done on specific parameters (eg precipitation and temperature). If that relation can be arranged, the projected changes in climate resulting from the GCM can be used to predict the changes results in the parameters analyzed (Nguyen, 2005).

Produced output of GCM models have a scale that is too large to be used in local applications, eg hydrology applications. Therefore downscaling process should be done for a narrower area, one of them is by using the technique of Regional Climate Model (RCM) or statistical downscaling techniques. RCM locally simulate topography and other influences from climatic factors. While preparing statistical downscaling projections change in the future based on the climate data recorded statistically in the past (Figure 2.5) (Praskievicz and Chang, 2009).

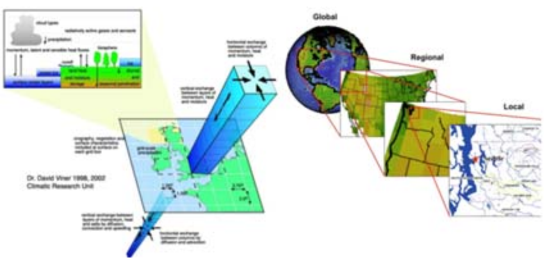


Figure 2.5. Downscaling technique with local climate approach scheme (Wilby and Dawnson, 2008)

Statistical downscaling is based regional climate conditions that are influenced by two factors: the climatic conditions of the global level, and physical condition of the regional/ local (eg. topography, the distribution of land and sea, and land use). Based on this perspective, local or regional climate information can be derived from statistical models linking climate variables to scope a broader scale as independent variables (predictors) with local or regional variables as the dependent variable (predictand). The output of GCM simulations used in the statistical model to estimate the characteristics of the related local or regional climate. The main advantage of using this technique is a low cost, and can be applied easily from various GCM experiments. Another advantage is that this technique can be used to provide information on the specific location, which is useful in studies of climate change. (Wilby et al, 2004). Wilby et al (2004), as further explained that there are three main groups in the statistical downscaling techniques, including weather classification, regression models, and weather generators.

3. Research Method

3.1. Data

Data, data types, and data sources used in this study may be presented in the Table 3.1.

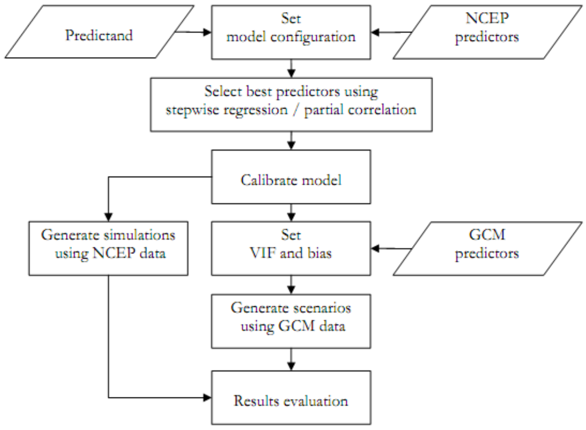
Table 3.1. Data, data types, and data sources used in this study

Data Type	Description	Data Source	Used for
Daily Rainfall	Year 1971-2001	BMKG DIY and PSDA Progo Hulu-Oya	Predictant fileforDownscaling
General Circulation Model	Year 1961-2099 Grid Upstream Progo Watershed HadCM3 Scenario A2 and B2 climate model	http://www.cccsn.ca	Input for Downscaling
NCEP/NCAR Reanalysis	Year 1961-2000 Skenario A2 and B2	http://www.ncep.noaa.gov	Input for Downscaling

3.2. Climate Modeling

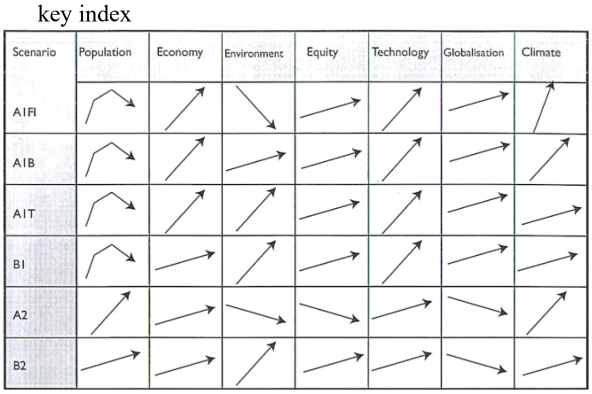
The value of of future climate conditions is obtained based on Global Circulation Model (GCM). GCM model using HadCM3 model issued by the UK Hadley Centre. However, with a grid of 2.5 ° x 3.75 °, the produced model is quite coarse (O'Hare et al., 2005). GCM conversion result into finer resolution using downscaling techniques (Wilby et al., 2008).

Downscaling technique used in this study is the ASD (An automated regression-based statistical downscaling model) (Hessami et al., 2008). ASD is a MATLAB software-based downscaling model (Hessami et al, 2007). In downscaling, large-scale observational data derived from data on NCEP (National Centre for Environmental protetion). This data is a data set that is used in conjunction with observational data to validate and calibrate the prediction results of the GCM (Kistler et al., 2001). Picture prediction scheme with GCM and NCEP to produce value scenarios climatic conditions may be seen in Figure 3.1. Emission scenarios used in this study include scenarios A2 and B2. The difference of the two scenarios can be seen in Table 3.2.



Gambar 3.1. Downscaling process using ASD scheme (Hessami et al.,2007)

Tabel 3.2. Qualitative representation of change in the SRES key index



(Source: Viner and Sayer, 2004)

3.3. Research Method Diagram

This research flowchart diagram is presented in Figure 3.6

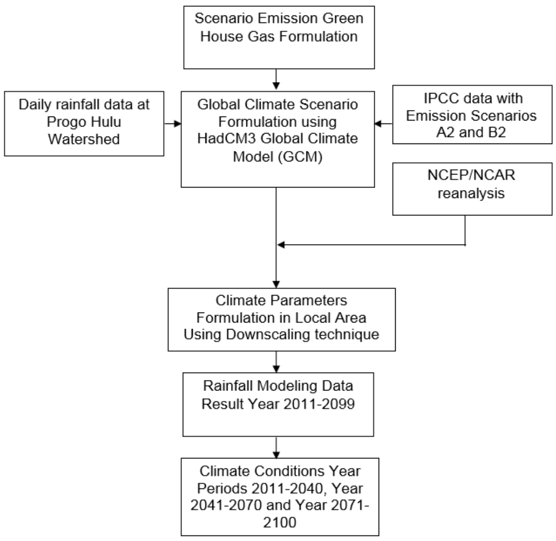


Figure 3.2. Research flowchart diagram

4. Results and Discussion

4.1. Climate Modeling Results Year 2011-2100 in Upstream Progo Watershed

4.1.1. Modeling results with A2 Emissions Scenario

a. Pattern Changes in Average Daily Rainfall

Climate modeling Study using the HadCM3 climate scenarios with scenario A2 resulted in daily rainfall characteristics that vary at 10 rain post upstream Progo watershed. Figure 4.1 to Figure 4.5 present the daily rainfall changes every month graph from historical data, 2020's, 2050's and 2080's predictions in all the rain post used. Some stations have similar pattern, where in June, July, August and September tend to be lower rainfall and increased rainfall began in November to reach its peak in February or March. Station that has a pattern like this are Babadan, Cebongan, Dukun, Jumprit, Kaliangkrik, Kalijoho, Kintelan, Magelang and Parakan. Given the rainy conditions have lasted from November and peak rainfall occurs in January and February, then in those region will have a high vulnerability to floods in January and February.

Different conditions are found at Borobudur Station where rainfall has increased in the dry season from year 2050’s to 2070’s, whereas in the rainy season rainfall tends to decrease. This condition is very good hydrology, considering the rain will temporally well distributed. Which is, during the rainy season make flood oftrn, but the rainfall decreases so that the flood vulnerability becomes smaller, and on the other hand in the dry season in which very little rain usually be increased.

Figure 4.1. Changes in average daily rainfall at the Babadan and Cebongan Station with A2 emission scenario

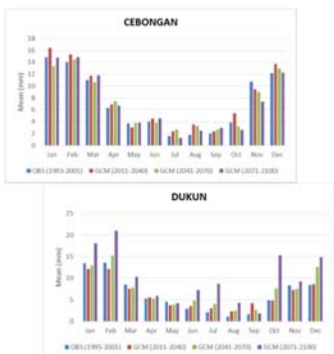


Figure 4.2. Changes in average daily rainfall at the Cebongan and Dukun Station with A2 emission scenario

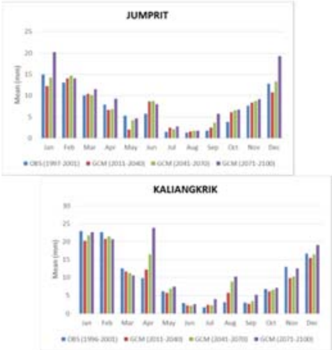


Figure 4.3. Changes in average daily rainfall at the Jumprit and Kaliangkrik Station with A2 emission scenario

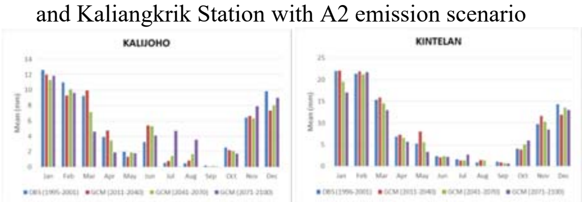


Figure 4.4. Changes in average daily rainfall at the Kalijoho and Kintelan Station with A2 emission scenario

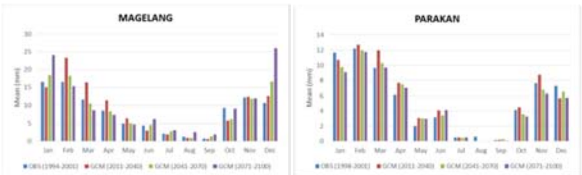


Figure 4.5. Changes in average daily rainfall at the Magelang and Parakan Station with A2 emission scenario

b. Pattern Changes in Average Monthly Rainfall

The study of climate change with the A2 emissions scenario generates data on the impact of climate change on the mean monthly rainfall at different stations in the study as shown in Figure 4.6 to Figure 4.10. The analysis showed that in this scenario, the monthly rainfall tends to rise, there are only a few stations that do not experience such a case, Cebongan station, Jumprit station, Kintelan station and Parakan station. Hydrologically, increase in monthly rainfall in the rainy months would certainly increase the vulnerability to future floods.

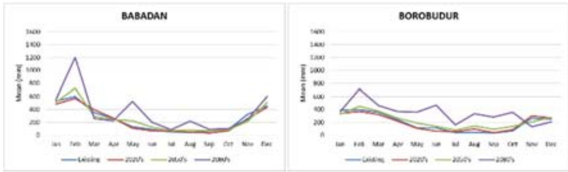


Figure 4.6. Changes in average monthly rainfall at the Babadan and Borobudur Station with A2 emission scenario

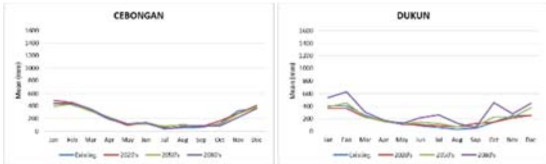


Figure 4.7. Changes in average monthly rainfall at the Cebongan and Dukun Station with A2 emission scenario

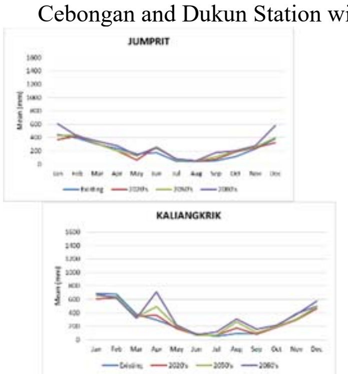


Figure 4.8. Changes in average monthly rainfall at the Jumprit and Kaliangkrik Station with A2 emission scenario

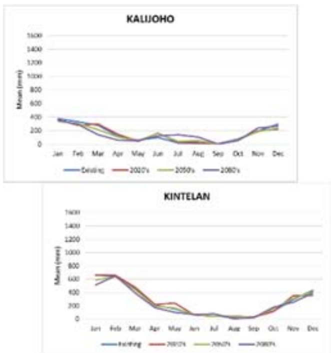


Figure 4.9. Changes in average monthly rainfall at the Kalijoho and Kintelan Station with A2 emission scenario

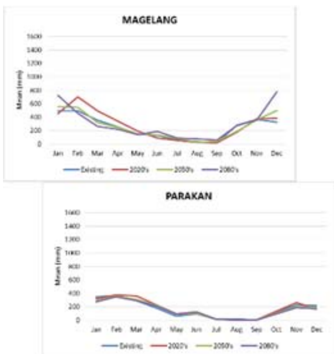


Figure 4.10. Changes in average monthly rainfall at the Magelang and Parakan Station with A2 emission scenario

The highest average monthly rain projections in 2100 occurred in February at Babadan station that is equal to 1923.8 mm. Borobudur station, Shamans station, and Kalijoho station also produces the highest average monthly rain value on February in the amount of 1229.7 mm; 922.98 mm; 428.79 mm. While Cebongan station, Kaliangkrik station, Kintelan station and Magelang station has the highest average monthly rain value on January in the amount of 505.27 mm; 792.59 mm; 533.47 mm; 1057.2 mm.

c. Pattern Changes in Average Annual Rainfall Result of Climate Modeling Prediction

Climate modeling results using the A2 emission scenario shows different effect. Figure 4.11 up to Figure 4.15 show that some stations experienced a rising trend as Babadan Station, Borobudur Station, Dukun Station, Jumprit Station, Kaliangkrik Station and Magelang Station, while the other stations showed a decreasing trend of annual rain namely Cebongan Station, Kalijoho Station, Kintelan Station and Parakan Station.

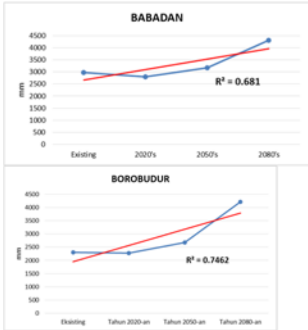


Figure 4.11. Changes in annual rainfall trend at the Babadan and Borobudur Station with A2 emission scenario

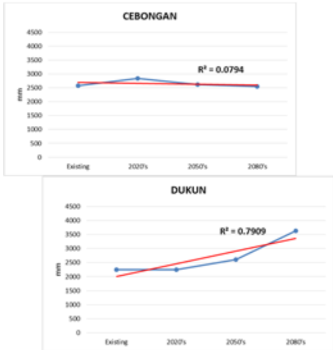


Figure 4.12. Changes in annual rainfall trend at the Cebongan and Dukun Station with A2 emission scenario

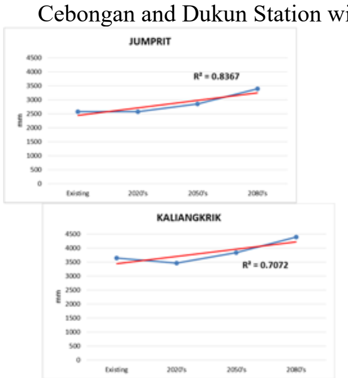


Figure 4.13. Changes in annual rainfall trend at the Jumprit and Kaliangkrik Station with A2 emission scenario

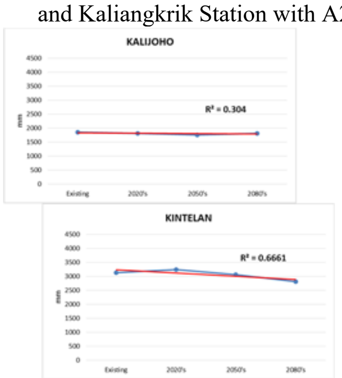


Figure 4.14. Changes in annual rainfall trend at the Kalijoho and Kintelan Station with A2 emission scenario

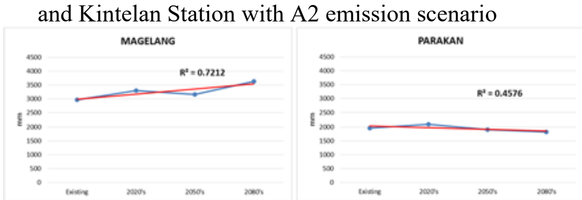


Figure 4.15. Changes in annual rainfall trend at the Magelang and Parakan Station with A2 emission scenario

When viewed with the scale per climate period (Figure 4.16. Until 4.20.), It is known in more detail that some stations have changing trends during the three climate periods. Station which has changing trend during three climate periods, namely Cebongan. In Cebongan station, the trend tends to rise in the 2020s, while 2050's and 2080's the trend tends to go down. For Magelang station and Kalijoho station, its trend tends to rise to three climate periods, but the value of the annual rainfall in late 2050 was lower than in the 2020s. Stations which havr consistent rising trend are babadan, Borobudur, Dukun, Kaliangkrik and Jumprit. Thus, the possibility of flooding at these station has a high chance in the future due to the increasing value of its annual rainfall. Parakan station had the trend of annual rainfall tends to go down in three climate periods, as well as Kintelan station. Still, Kintelan station had an increase trend in the 2050's.

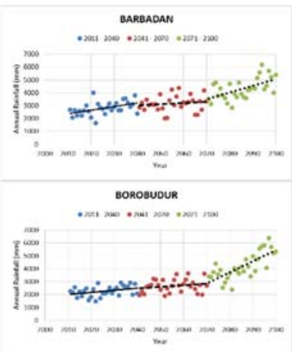


Figure 4.16. Changes in rainfall trend per climate periods at the Babadan and Borobudur Station with A2 emission scenario

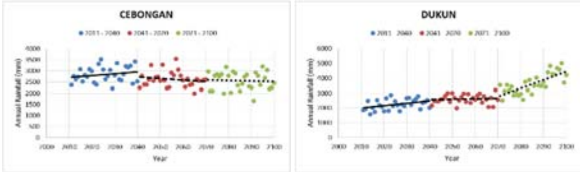


Figure 4.17. Changes in rainfall trend per climate periods at the Cebongan and Dukun Station with A2 emission scenario

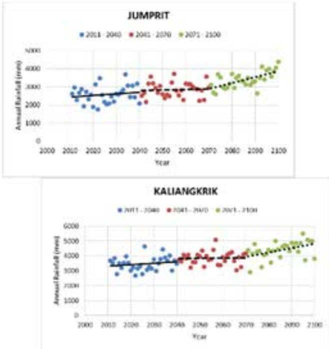


Figure 4.18. Changes in rainfall trend per climate periods at the Jumprit and Kaliangkrik Station with A2 emission scenario

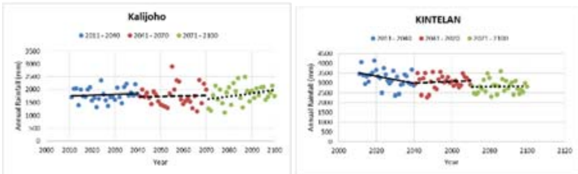


Figure 4.19. Changes in rainfall trend per climate periods at the Kalijoho and Kintelan Station with A2 emission scenario

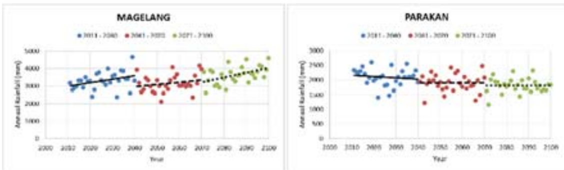


Figure 4.20. Changes in rainfall trend per climate periods at the Magelang and Parakan Station with A2 emission scenario

d. Occurrence of Extreme Rainfall Frequency Result of Climate Modeling Prediction

Figure 4.21 presents the frequency of extreme rainfall events increased significantly from late 2050s climate period to late 2070s climate period on Barbadan station and Borobudur station up to 83-90 extreme rain events in late 2070s climate period.

Kaliangkrik station show the increase in frequency and intensity of extreme rainfall are consistent. Similarly on Jumprit station, Kalijoho station, and Dukun station, it's just frequency of extreme rainfall in these stations ranges between 2 to 20 for 100-150 mm/day rainfall intensity and extreme rainfall events was not found with intensity greater than 200 mm/day.

While Parakan station did not reveal any extreme rain events. The decrease in the frequency of extreme rainfall occurred 56 extreme rainfall events at Kintelan station in the 2020s climate period to 33 events in the 2070's climate period with 100-150 mm / day rainfall intensity.

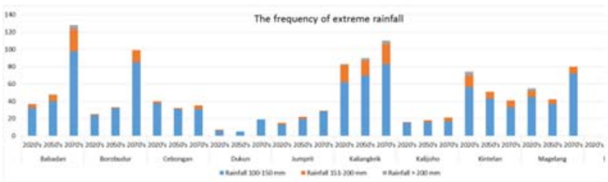


Figure 4.21. The frequency of extreme rainfall with A2 emission scenario

4.1.2. Climate Modeling Results with B2 Emissions Scenario

a. Pattern Changes in Average Daily Rainfall

HadCM3 climate change scenarios modeling using B2 scenario shows different results with the A2 scenario. B2 IPCC SRES emission scenarios based on the concept of sustainable management of local environments. Unlike the A2 scenario, the temperature rise in the B2 scenario will climb slowly but the trend will continue to rise. While the A2 scenario based on the concept of regional economic development, rising temperatures increase significantly but the starting point of decreasing temperature tended to occur faster than the B2 scenario. The implications of rising temperatures on the B2 scenario based on rainfall in the upstream Progo watershed shown in the graph are presented based on historical data, 2020's, 2050's and 2080's predictions at the 10 stations used.

In general, the pattern of rainfall in upstream Progo watershed following monsoonal pattern as upstream Progo watershed located in areas with strong monsoon influence. Throughout the year there are two peaks of rain, in the early months and the end of the year. Changes in Average daily rainfall varies in each of station. Figure 4.22 up to Figure 4.26 show predicted increasing rainfall occurred at Babadan station, Borobudur station, Dukun station, Jumprit station and Kaliangkrik station. While the predicted decreasing rainfall occurs in Kalijoho station, Kintelan station, Magelang station, and Parakan station. Differences in consistent rainfall changes spotted at the Cebongan station where the 2020s rainfall predicted as an increase, then decrease back on late 2050, but rebound in late 2080. Potential vulnerability to flooding need to be considered for Babadan station and Borobudur station area in late 2080. The increase in rainfall is predicted to increase significantly and occurred almost throughout the year.

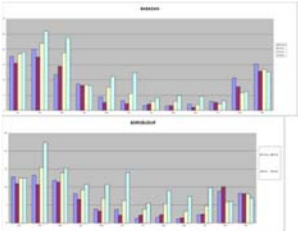


Figure 4.22. Changes in average daily rainfall at the Babadan and Borobudur Station with B2 emission scenario

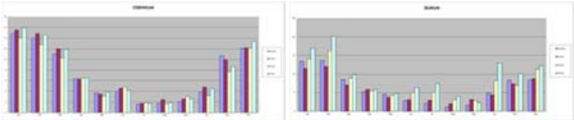


Figure 4.23. Changes in average daily rainfall at the Cebongan and Dukun Station with B2 emission scenario

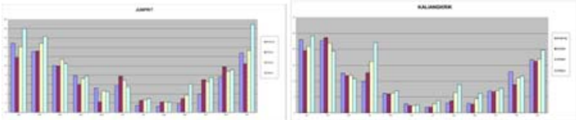


Figure 4.24. Changes in average daily rainfall at the Jumprit and Kaliangkrik Station with B2 emission scenario

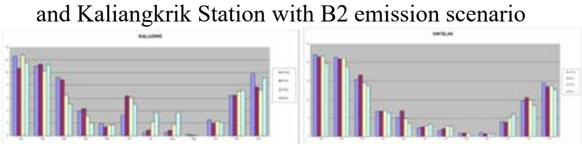


Figure 4.25. Changes in average daily rainfall at the Kalijoho and Kintelan Station with B2 emission scenario

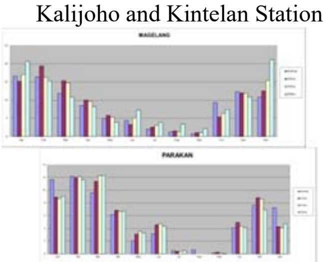


Figure 4.26. Changes in average daily rainfall at the Magelang and Parakan Station with B2 emission scenario

b. Pattern Changes in Average Monthly Rainfall

Figure 4.27 up to Figure 4.31 show the monthly rainfall pattern changes. When comparing rainfall patterns predicted modeling results between A2 and B2 scenarios, it appears in the B2 scenario, there is no significant difference from A2 scenario. In Cebongan station, Kintelan station and Parakan station rainfall changing patterns in 2020s, 2050s, and 2080s do not look significant. While on Babadan station, Shaman station, Jumprit station, Kaliangkrik station, Kalijoho station, and Magelang station rainfall fluctuated, but generally pattern does not limp from monsoonal pattern.

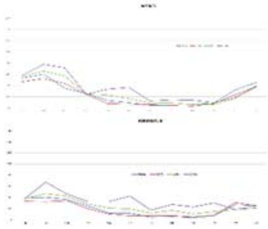


Figure 4.27. Changes in average monthly rainfall at the Babadan and Borobudur Station with A2 emission scenario

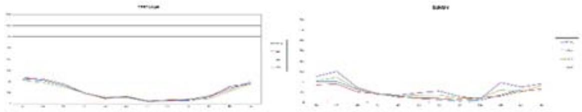


Figure 4.28. Changes in average monthly rainfall at the Cebongan and Dukun Station with A2 emission scenario

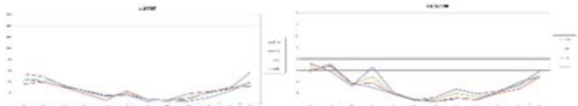


Figure 4.29. Changes in average monthly rainfall at the Jumprit and Kaliangkrik Station with A2 emission scenario

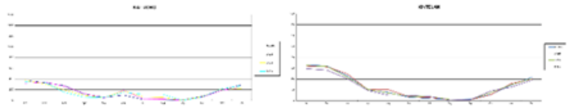


Figure 4.30. Changes in average monthly rainfall at the Kalijoho and Kintelan Station with A2 emission scenario

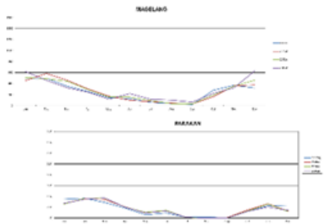


Figure 4.31. Changes in average monthly rainfall at the Magelang and Parakan Station with A2 emission scenario

There is one station that is experiencing prominent changing rainfall patterns, namely Borobudur station. At Borobudur station rainfall patterns previously (based on historical data) following the monsoonal pattern, predicted changes periodically. Rainfall is higher in the early years previously, decreased in the middle of the year, then up again at the end of the year changes to high at the beginning of the year then continued to decrease until the end of the year. It can influence the cropping systems in the area due to changing patterns of water availability.

c. Pattern Changes in Average Annual Rainfall Result of Climate Modeling Prediction

Based on the results of climate predictions model change with B2 emissions scenario, there are eight observation stations which have increased rainfall trend in the graph in Figure 4.32 to Figure 4.36, namely: Babadan station, Borobudur station, Cebongan station, Dukun station, Jumprit station, Kaliangkrik station, Kalijoho station, and Magelang station. While the stations which predicted to experience a decrease in rainfall trend are Kintelan station and Parakan station. However, there is a trend of its own rainfall in each period. More specifically, the trend in each period is shown in Figure 4.37 up to 4.41

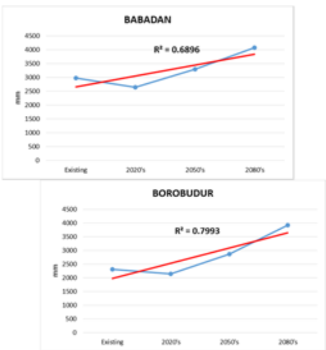


Figure 4.32. Changes in annual rainfall trend at the Babadan and Borobudur Station with B2 emission scenario

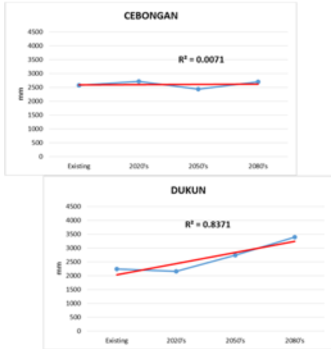


Figure 4.33. Changes in annual rainfall trend at the Cebongan and Dukun Station with B2 emission scenario

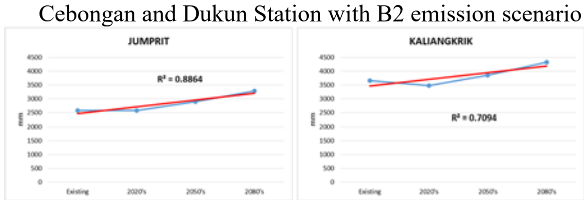


Figure 4.34. Changes in annual rainfall trend at the Jumprit and Kaliangkrik Station with B2 emission scenario

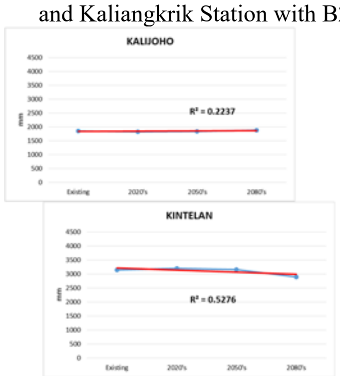


Figure 4.35. Changes in annual rainfall trend at the Kalijoho and Kintelan Station with B2 emission scenario

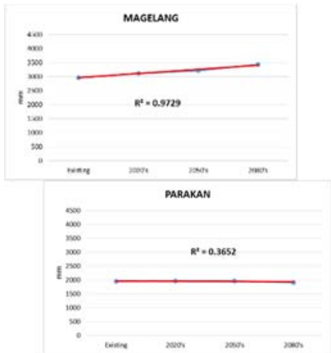


Figure 4.36. Changes in annual rainfall trend at the Magelang and Parakan Station with B2 emission scenario

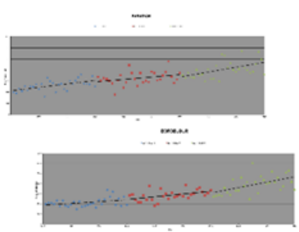


Figure 4.37. Changes in rainfall trend per climate periods at the Babadan and Borobudur Station with B2 emission scenario

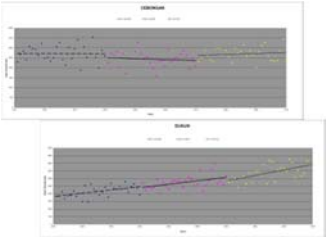


Figure 4.38. Changes in rainfall trend per climate periods at the Cebongan and Dukun Station with B2 emission scenario

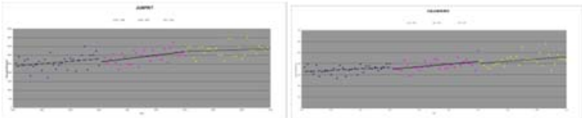


Figure 4.39. Changes in rainfall trend per climate periods at the Jumprit and Kaliangkrik Station with B2 emission scenario

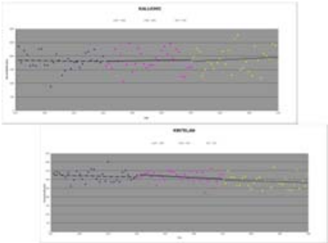


Figure 4.40. Changes in rainfall trend per climate periods at the Kalijoho and Kintelan Station with B2 emission scenario

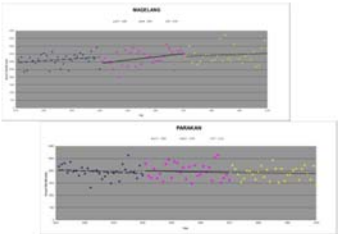


Figure 4.41. Changes in rainfall trend per climate periods at the Magelang and Parakan Station with B2 emission scenario

d. Occurrence of Extreme Rainfall Frequency Result of Climate Modeling Prediction

The value of extreme rainfall according to BMKG is rainfall with value above 100 mm/day (Supiatna, 2008). Figure 4.42 showed that the frequency of extreme rainfall that occurs on every station mostly increased in every climate period, but there are some stations that actually have decreasing occurance frequency. Decreasing frequency of extreme rainfall events occurred in Cebongan station, but in this station the intensity of extreme rainfall has increased up to 176mm/day. As for Magelang station, although the frequency of extreme rainfall events in the station is not the highest, but the highest monthly rainfall in 2100 at the B2 scenario found on this station was 1173.38 mm which occurs in December. At two stations which have decreased rainfall trend (Kintelan and Parakan), found that the incidence of extreme rainfall at both stations did not experience an increased frequency at the end of the period. Even at Parakan station, same with A2 scenario there is no extreme rain events encountered.

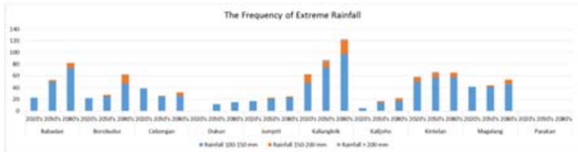


Figure 4.42. The frequency of extreme rainfall with B2 emission scenario

5. Conclution

This study uses two IPCC emission scenarios, A2 and B2. The projected rainfall of 2011 to 2100 showed that the majority of study target stations showed increasing trend in rainfall. In both scenarios run by IPCC, 8 of the 10 rain stations showed an increasing trend of rainfall, while the two other stations, namely Parakan and Kintelan showed a decreasing trend. There are differences in the characteristics of rainfall projection of each station. At the station Cebongan for example, 90 years rainfall trend projections (2011-2100) at this station increased. However, when subdivided into three climate periods, it was found that no consistent increasing trend due to decreasing trend in the late 2050 period is then up again in the late 2080 period.

Some stations have a similar pattern, where in June, July, August and September trend to be lower rainfall and increased rainfall began in November to reach its peak in January or February. Stations which have a pattern like this are Babadan, Cebongan, Dukun, Jumprit, Kaliangkrik, Kalijoho, Kintelan, Magelang and Parakan. Consider that rainfall are occurred from November and peak rainfall occurs in January and February, then those region will have a high vulnerability to floods in January and February.

The frequency of extreme rainfall events in both scenarios mostly increased. In addition to the increase in frequency, an increase in the intensity of the rain also found even though it does not happen to all stations. The increasing trend of rainfall and the frequency of extreme rain feared could affect the likelihood increasing in water-related disasters incidence such as floods or landslides.

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