Analysis of climate change impact on rainfall pattern of Sambas district, West Kalimantan

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Abstract. Climate change is one of the most important issues being discussed globally. It caused by global warming and indirectly affecting the world climate cycle. This research discussed the effect of climate change on rainfall pattern of Sambas District and predicted the future rainfall pattern due to climate change. CRU and TRMM were used and has been validated using in situ data. This research was used Climate Modelling and Prediction using CCAM (Conformal Cubic Atmospheric Model) which also validated by in situ data (correlation= 0.81). The results show that temperature trends in Sambas regency increased to 0.082°C/yr from 1991-2014 according to CRU data. High temperature trigger changes in rainfall patterns. Rainfall pattern in Sambas District has an equatorial type where the peak occurs when the sun is right on the equator. Rainfall in Sambas reaches the maximum in March and September when the equinox occurs. The CCAM model is used to project rainfall in Sambas District in the future. The model results show that rainfall in Sambas District is projected to increase to 0.018 mm/month until 2055 so the flow rate increase 0.006 m³/month and the water balance increase 0.009 mm/month.

1. Introduction
Climate Change is one of the events on earth that is caused by rising air temperature (global warming) and can cause changes in the earth in many aspects. One effect that can be caused by climate change is the change in rainfall patterns. Previous research has shown that in recent years climate change has resulted in changes in rainfall patterns of different regions [1-3].

Sambas is one of the areas in West Kalimantan that has an important role in the availability of food, especially in the province of West Kalimantan. Rainfall is certainly an important aspect in meteorological agriculture that can support water supply in West Kalimantan and can affect food availability. Therefore, it is necessary to ascertain how the effect of climate change on the availability of water in Sambas so that in the future if any event of extreme dry or flood in Sambas will soon be mitigated.

Other studies about the effects of climate change on water availability and agricultural conditions have been conducted by researchers in various parts of the world. This study has been conducted in China and stated that climate change may affect the frequency of extreme weather events such as drought and flood [4]. Other research cites the need for adaptation and mitigation related to climate change impacts on agricultural conditions and water availability in China [5]. Climate change in China itself is the impact of human activity, and can change hydrological cycle and spatio temporal distribution in China [6].
The aim of this study is to determine the impact of climate change on water availability in Sambas and forecast the future projection of water availability in Sambas due to climate change.

2. Material and Method
The research stage used in this research is the first to analyze the rainfall pattern based on in situ data. The in situ data used is the in situ data based on BMKG station measurement. Further analysis of climate change conditions based on CRU data and TRMM satellite data is done. Simulation of rainfall by CCAM model was done for the next step. Both satellite data and CCAM model data are validated by observational data. If the validation result is good, it means that the model is quite representative in describing the climatic conditions, then the monthly rainfall projection by the CCAM model can be done. If rainfall data based on the CCAM model has been simulated and projected, then the projection of Sambas River discharge condition by ArcSWAT model based on CCAM rainfall input data can be done. The last stage is the projection of the Sambas River discharge condition by the ArcSWAT model based on CCAM rainfall input data.

2.1. Data

2.1.1. Insitu Data
The insitu data used in this research is monthly BMKG rainfall data from 2010-2015.

2.1.2. GFS Data
GFS (Global Forecast System) data is a global datasets used for CCAM (Conformal Cubic Atmospheric Model) input. This data were downscaled to 14 km resolutions.

2.2. Methods

2.2.1. Rainfall Estimation with TRMM Satellite Data and CRU
The Tropical Rainfall Measuring Mission (TRMM) is a satellite that used in precipitation measurement, TRMM 3B43 have 0.25° spatial resolution and monthly temporal resolution [7].

2.2.2. Climate Modeling Methods with CCAM
The Conformal-Cubic Atmospheric Model (CCAM) has been developed at CSIRO [8, 9] and includes a fairly comprehensive set of physical parameterizations, mostly similar to those of the Mk 3 GCM [8]. Conformal-Cubic Atmospheric Model (CCAM) is an atmospheric numerical model which developed by CSIRO, Australia. This model previously developed for the limited-area in Division of Atmospheric Research Model (DALRAM). CCAM is a global model which have variable-based conformal cubic grid resolution. CCAM use Schmidt transformation for regional and local forecasts with multiple nesting techniques for downscaling and having topographic and land use data that has been integrated with the system [10].

2.2.3. Hydrological Modeling Methods with ArcSWAT
The SWAT (Soil and Water Assessment Tool) is a driver basin model that can predict the impact of land use and water management to watershed condition. This model use HRUs data such as topography data, soil type data, land-use data, and weather data to predict and determine the watershed condition (discharge, nutrition, etc.) [11].

3. Results and Discussion
Based on figure 1 it can be seen that generally Sambas District has flat topography. The lower altitude reaches 37 meters above mean sea level. While the plateau with 730-1.407 meters above mean sea level is located only in the north eastern district of Sambas. Topography certainly has big influence for drainage of river water [12].
If viewed from the location of Sambas that Sambas is close to the equator, then there is a hypothesis that the rainfall pattern of Sambas District is equatorial. However, this is not simply assured. Based on rainfall observation data, rainfall composite in 2010-2015 shows that rainfall in Sambas Regency tends to be flat. However, the maximum value of rainfall are in December and January (figure 2).

The TRMM 1998-2009 data shows that the rainfall fluctuation in Sambas is not so fluctuate (figure 3). The standard deviation value is only reached 73 with a minimum value is about 154 mm. TRMM rainfall data shows the maximum rainfall pattern in Sambas is on December while in February to September is tend to be flat.
Similar to observation data, CCAM simulation results show that rainfall in Sambas is fluctuate even though the maximum value is seen in March, August, and November (figure 4). However, although there are significant differences in patterns, but the correlation between observation data and CCAM has high value around 0.81. This can be interpreted that CCAM simulation can adequately describe the trend or rainfall pattern in Sambas District.

The pattern of rainfall itself has an important role in the analysis of water availability in a region. This is due to rainfall patterns can regulate the condition of ground water and river water discharge in a river. Rainfall, topography, and vegetation can also affect run-off conditions in an area [13]. Based on the latest condition analysis, monthly rainfall in Sambas in a year tends to be equally distributed and
reach maximum in December and January. However, it is not possible that there are other factors such as climate change which can affect the rainfall patterns so the water availability also can change.

Based on the graph 4, the CRU data shows that there is temperature increase about 0.25°C per 30 years. 1991-2014 became the hottest year with 27-28°C (figure 5). This can be indicated as the occurrence of global warming in Sambas District with an temperature increase around 0.3-1°C in the last 100 years.

Graph of Average 30 Years Temperature based on CRU Data

![Graph of Average 30 Years Temperature based on CRU Data](image)

Figure 5. Graph of average 30 months Temperature based on CRU Data.

The global warming can impact the agricultural welfare and water availability [14]. This is due to climate change can also affect the rainfall pattern in an area [15]. This also applies in Sambas district.

The CCAM temperature simulation plot states that in 1971-2000 temperatures in Sambas reached 300-302 °K (figure 6a). In 2040-2069 there is an increase up to 302.5-304.5 °K (figure 6b). This increase in temperature ranges from 1.9-2.4 °K across Sambas (figure 6c).

![Figure 6](image)

Figure 6. (a) Plot of average temperature in 1971-2000, (b) Plot of average temperature in 2040-2069 (c) Plot of temperature anomaly.

The CCAM simulation states that in the future, in 2040-2069 there will be an increase of rainfall in Sambas regency around 250-400 mm (figure 7b), while 1971-2000 reaches only 200-350 mm (figure 7a). This increase averages around 10-40 mm in each region (figure 7c).
Figure 7. (a) Plot of average rainfall in 1971-2000, (b) Plot of average rainfall in 2040-2069 (c) Plot of rainfall anomaly.

Rainfall increase also occurs in rainfall projections as seen in monthly rainfall plot of temperatures from 2006-2055 that expected to be increase (figure 8). This increase is estimated to occur around 0.018 mm/month based on the linear regression that has been done.

Figure 8. Graph of rainfall projection on Sambas River based on CCAM Model.

Changes in rainfall can lead to change in water availability. In this case, the water availability is measured as river flow or water balance. The simulation of discharge conditions is done in Sambas River using ArcSWAT model based on climate data input which obtained from CCAM output. ArcSWAT simulation results show that the rainfall increase in Sambas Regency is also expected to have an impact to the increase of flow rate in Sambas River (figure 9). The increase reached 0.006 m³/month based on the linear regression plot in 2006-2055.
Water availability is also measured from the existing water balance conditions in Sambas District. Based on the simulation of water balance conditions, it is estimated that in the future the water balance conditions in the Sambas River will also increase (figure 10). This is reinforced by a linear regression analysis which states that the water balance in Sambas River will increase by 0.009 mm/month until 2055.

Based on analysis of flow rate and water balance in Sambas River, it is estimated that in the future, water availability in Sambas Regency (based on CCAM climate model simulation for SWAT input data) will increase. This is due to climate change can make rainfall increase so that flow rate and water balance will increase. High rainfall and increasing water supply conditions are expected to cause flood. Therefore, prevention of flood potency should always be held.
4. Conclusions
Observation data state that climate change has occurred in the Sambas region and causing its temperature to rise in the last 30 years. Climate change is expected to lead to rainfall increase in Sambas regency around 0.018 mm/month until 2055. Increased rainfall causes increased Sambas River flow around 0.006 m³/month and increased water balance around 0.009 mm/month. Knowing these conditions, it is hoped that this will become the foundation in the regional planning system, starting from infrastructure planning and community social system as a form of climate change mitigation and adaptation.

Acknowledgments
The authors would like to thank the Atmospheric Science and Technology Centre which have provided moral and material support so that this research can be realized.

References
[1] Storch H V, Zorita E, Cusbasch U 1993 Downscaling of global climate change estimates to regional scales: an application to Iberian rainfall in wintertime Journal of Climate 61 161–1171
[2] Trenberth K E 1998 Atmospheric Moisture Residence Times and Cycling: Implications for Rainfall Rates and Climate Change (Berlin: Springer)
[3] Williams S E, Bolitho E E, Fox S 2003 Climate Change in Australian Tropical Rainforests: An Impending Environmental Catastrophes (Royal Society Publishing)
[4] Jun X, Qing-Yun D, Yong L, Zheng-Hui X, Zhi-Yu L, Xing-Guo M 2017 Climate Change and Water Resources: Case Study of Eastern Monsoon Region of China Advances in Climate Change Research 8 63-67
[5] Xing-Guo M, Shi H, Zhong-Hui L, Su-Xia L, Jun X 2017 Impacts of Climate Change on Agricultural Water Resources and Adaptation on the North China Plain Advances in Climate Change Research 8 93-98
[6] Yu-Jie W, Da-He Q 2017 Influence of Climate Change and Human Activity on Water Resources in Arid Region of Northwest China: An Overview Advances in Climate Change Research 8 268-278
[7] https://mirador.gsfc.nasa.gov/collections/TRMM_3B43__007.shtml accessed 28 September 2017
[8] McGregor J L 2005 CCAM: Geometric Aspects and Dynamical Formulation (CSIRO)
[9] McGregor J L, Dix M R 2008 An Updated Description of The Conformal Cubic Atmospheric Model (New York: Springer)
[10] Thatcher M, McGregor J L 2009 Using a scale-selective filter for dynamical downscaling with the conformal cubic atmospheric model Monthly Weather Review 137 1742-1752
[11] Arnold J G, Moriasi D N, Gassman P W, Abbspour K C, White M J, Srinivasan R, Santhi C, Harmel RD, van Griensven A, Van Liew MW, Kannan N, Jha MK 2012 SWAT: model use, calibration, and validation American Society of Agricultural And Biological Engineers 55 1491-1508
[12] Price K 2011 Effects of Watershed Topography, soils, land use, and climate on baseflow hydrology in humid regions: A review Progress in Physical Geography 35 465-492
[13] Dunne T, Zhang W, Aubry B F 1991 Effects of rainfall, vegetation, and microtopography on infiltration and runoff Water Resources Research 27 2271-2285
[14] Vorosmarty C J, Green P, Salisbury J 2000 Global Water Resources: Vulnerability from Climate Change and Population Growth Science 289 284-288
[15] Udayanshankara T H 2016 Impact of climate change on rainfall pattern and reservoir level Journal of Hydrology: Regional Studies 3 473-493