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Trend Analysis of Precipitation Extreme Related to Climate Change in Province Sulawesi Selatan, Indonesia

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Abstract

Weather Extremes can cause natural phenomenon such as flood, drought, landslide, and storms. Some researchers showed that increasing temperature is related to heavy precipitation doe to the increased atmospheric water vapor and warmer air. In this study, we investigated characteristic of precipitation extreme related to climate chance in Province Sulawesi Selatan using Quantile Regression Model. Quantile value of 0.25 was used as representation of low level precipitation extreme as well as quantile value of 0.75 and 0.9 for high level precipitation extreme. Interior point method was used in parameter model estimation. Using daily rainfalls and temperature data at Tamangapa and Takalar stations for region with Monsoon precipitation pattern, Sukamaju and Salubarani stations for Equatorial precipitation pattern, stations of Biru Bone and Bulo-Bulo for Local precipitation pattern in Province Sulawesi Selatan, the results showed that low level precipitation extreme in all precipitation patterns have positive association with climate chance as well as for high level precipitation extreme which quantile value is 0.75. Meanwhile, for quantile value is 0.9, both of Salubarani and Bulo-Bulo showed negative association, and other stations have positive association.

INTRODUCTION

Weather Extremes can cause natural phenomenon such as flood, drought, landslide, and storms. Weather Extremes make socio-economics, infrastructure, are being vulnerable. In the last decades, extreme events tend to occur more frequently and have highly societal impacts (Zhang et al., 2012; Zolina et al., 2010). Therefore, weather extremes research has increasing in the last year.

Some researchers showed that increasing temperature is related to heavy precipitation doe to the increased atmospheric water vapor and warmer air (Zhang et al., 2010). Climate change cause Torrential precipitations are occurring with greater frequency. It cause natural disasters are increasing (Boecheva et al., 2009). Trend of precipitation extremes are point of management and mitigation of natural disaster. Estimation of the frequency of precipitation extremes is often needed when evaluating peak river flows by using conceptual rainfall-runoff models or when deriving flood frequency curves from precipitation frequency curves (Merz et al., 2008; Castellarin et al., 2009) or evaluating urban flood damages.

Generally, association of precipitation extreme and other variables is investigated by linear regression model. However, GLM cannot calculate trend of precipitation extreme properly (Fan and Chen, 2016). For extreme event analysis, Quantile Regression (QR) methods have been used by researcher extensively (Lee et al., 2013; Fan and Chen, 2016). Roth et al. (2014), investigated precipitation extremes in Netherland and North Germany using QR. Fan and Xiaong (2015) using QR to detect characteristic of precipitation extremes in Northern China.

Province of Sulawesi Selatan Indonesia is one of the big provinces in Indonesia. Bureau of Meteorology and Climatology of Indonesia divided Province of Sulawesi Selatan into three cluster precipitation pattern due to difference of source of rainfalls and geographic condition. The three clusters of precipitation in Province of Sulawesi Selatan are Monsoon Pattern, Equatorial Pattern, and Local Pattern.

Study of trend precipitation extremes in Province of Sulawesi Selatan has not been done yet. Furthermore, trend precipitation extremes in three clusters also have not been done yet, even though trend analysis of precipitation extremes is necessarily in management and mitigation natural hazard. The objective of this research is to analysis characteristic of precipitation extremes in Province Sulawesi Selatan, especially for trend of precipitation extreme in each cluster precipitation pattern.

DATA

Daily precipitation data is reported from six stations from each cluster for period of 1991-2015. The days with precipitation < 1 mm were considered as no rainy days and rainy days for precipitation ≥ 1 mm. For objective studies precipitation extremes was characterized by intensity.

Temperature data were used as representation of climate factor.

METHODOLOGY

Quantile Regression is an approach in regression analysis and introduced by Koenker and Basset (1978). The approach in the analysis quantiles values of a Y distribution as a function of X. Quantile regression is very important and useful for heterogeneous and non-standard distributed data such as asymmetrically or truncated distribution.

Let Y is a random variables, with F_Y distribution function and τ is constant, $0 < \tau < 1$. Quantile- τ of F_Y denoted by $q_Y(\tau)$ is a solution for $F_Y(q) = \tau$ as follows:

$$q_y(\tau) \coloneqq F_y^{-1}(\tau) = \inf\{y : F_Y(y) \geq \tau\}.$$

$100\tau\%$ $(100(1-\tau)\%)$ of mass probability of Y lies on under (above) $q_y(\tau)$.

The - τ value of F_Y can be obtained by minimize the equation (1) to q as follows:

$$\tau\int_{y>q}|y-q|dF_Y(y) + (1-\tau)\int_{y<q}|y-q|dF_Y(y) \qquad (1)$$

$$= \tau\int_{y>q}(y-q)dF_Y(y) - (1-\tau)\int_{y<q}(y-q)dF_Y(y).$$

therefore

$$0 = -\tau\int_{y>q}dF_Y(y) + (1-\tau)\int_{y<q}dF_Y(y)$$

$$0 = -\tau[1-F_Y(q)] + (1-\tau)F_Y(q)$$

$$0 = -\tau + F_Y(q)$$

and

$$\tau = F_Y(q),$$

Quantil - τ is a solution of F_Y.

Let Y is a function of X and probability distribution function $F_{Y|X}(y)$ is given, Quantile - τ is defined by $Q_{Y|X}(\tau) \coloneqq F_{Y|X}^{-1}(\tau)$. $Q_{Y|X}(\tau)$ is a function of X can be solved by equation (2) as follows:

$$\min_q\left[\tau\int_{y>q}|y-q|dF_y(y) + (1-\tau)\int_{y<q}|y-q|dF_y(y)\right]. \qquad (2)$$

$Q_{Y|X}(0{,}5)$ is a median of Y of a function of X which denote a symmetric point of $F_{Y|X}$. For τ value closed to 0 or 1, $Q_{Y|X}(\tau)$ denote as left tail or right tail of $F_{Y|X}$ respectively. If $Q_{Y|X}(\tau)$ is linear function of $\boldsymbol{X'\beta}$, where $\boldsymbol{\beta}$ is unknown, equation (2) become:

$$\min_\beta\left[\tau\int_{y>X'\beta}|y-X'\beta|dF_Y(y) + (1-\tau)\int_{y<X'\beta}|y-X'\beta|dF_Y(y)\right] \qquad (3)$$

Solution of equation (3) is denoted by β_0 and quantile of Y (as a function of X) is $Q_{Y|X}(\tau) = X'\beta_0$.

Let (x_t, y_t) is given, $t = 1,2,3,\ldots,n$, and x_t is k x 1, QR equation is denoted by:

$$y_t = x_t'\beta + \varepsilon_t.$$

where $Q_{Y|X}(\tau) = x_t'\beta$ is quantile-τ. An estimation value of β for quantile-τ can be obtained by minimize absolute value of error with weight of τ for positive error $(1-\tau)$ for negative error as follows:

$$\hat{\beta}(\tau) = \arg\min_\beta\left\{\tau\sum_{t:y_t\geq x_t}|y_t - x_t'\beta| + (1-\tau)\sum_{t:y_t<x_t}|y_t - x_t'\beta|\right\} \qquad (4)$$

or

$$\hat{\beta}(\tau) = \arg\min_\beta\sum_{i=1}^n\rho_\tau(u_i) \qquad (5)$$

where

$\hat{\beta}(\tau)$: Estimated parameter value

τ : Index of Quantile, where $\tau \in (0,1)$

$\rho_\tau(u_i)$: Loss Function

for

$$\rho_\tau(u_i) = \begin{cases}\tau u_i & \text{for } u_i \geq 0\\ (\tau-1) & \text{for } u_i < 0\end{cases}$$

Solution of equation (4) and (5) could not be obtained by analytic method then the solution use numeric approach to obtain the result. Numerical approach such as simplex method, interior point method, usually used in estimated parameters of QR model.

Interior Point Method

Interior point method generally used to solve linear problems. Interior point method was introduced by Karmakar in 1984. Interior point methods find solution iteratively in feasible solution domain. Initially, interior point method used an initial value as a prior solution then the solution move to the next point which objective value function is more optimal. The iterative process will stop if optimally condition was reached.

RESULTS AND DISCUSSION

Using six location stations as representative of three cluster precipitation pattern, the relationship between precipitation extremes with climate change in each station was denoted by a QR model. Dependent variable is intensity of rainfall and independent variable is temperature. Interior point method was used in estimation process and significance of temperature variable will use p-value. Station of Tamangapa and Takalar are represented of Monsoon Pattern, Station of Sukamaju and Salubarani were represented of Equatorial Pattern, and Stations Biru Bone and Bulo-Bulo were represented of a region with Local pattern of precipitation.

Table 1 provided a p-value of each station, for quantile of 0.25 denoted low level extreme value, 0.75 and 0.9 denote high level extreme values.

Table 1: p-value of QR model for monsoon, equatorial, and local pattern in Province of Sulawesi Selatan

CLUSTERS	STATIONS	Quantile-		
		0.25	0.75	0.9
MONSOON	TAMANGAPA	0.000	0.000	0.000
	TAKALAR	0.006	0.000	0.000
EQUATORIAL	SUKAMAJU	0.001	0.001	0.000
	SALUBARANI	0.000	0.001	0.007
LOCAL	BIRU BONE	0.000	0.000	0.000
	BULO-BULO	0.026	0.094	0.108

According to p-value in Table 1, each station in Monsoon cluster showed the existence of the relationship between precipitation and climate change. The relationship of precipitation extreme and climate change also occured in Equatorial and Local pattern cluster except in Bulo-Bulo station.

Table 2 showed estimated parameter value of QR model on each cluster in Province of Sulawesi Selatan. Positive estimated value denotes positive relationship between precipitation extremes and climate change. Negative estimated values denotes different pattern between precipitation extremes and climate change.

Table 2: Parameter estimated value of temperature predictor for QR model in Province of Sulawesi Selatan

CLUSTERS	STATIONS	Quantile-		
		0.25	0.75	0.9
MONSOON	TAMANGAPA	36.854	104.480	160.457
	TAKALAR	9.318	9.317	22.173
EQUATORIAL	SUKAMAJU	25.238	25.425	26.385
	SALUBARANI	39.587	40.996	-47.534
LOCAL	BIRU BONE	44.047	67.655	68.130
	BULO-BULO	9.267	12.116	-18.510

There are two possibility patterns of the relationship between precipitation extremes and climate change that are positive and negative. If the relationship positive, it means that intensity of precipitation extreme will increase as level of temperature increase. Contrary, if the relationship is negative, then the intensity of precipitation extreme will decrease if the temperature is increase.

According to Table 2, for low level precipitation extremes (quantile value is 0.25) intensity of low precipitation extremes will increase if the temperature is increase. The positive relationship between precipitation extremes and temperature also occurred for quantile value is 0.75. For 0.9 quantile value, stations Salubarani and Bulo-Bulo showed difference pattern of other stations. The difference pattern of Salubarani and Bulo-Bulo stations were caused by the differences of altitude of sea water surface. Salubarani dan Bulo-Bulo locations located at higher altitude than other stations.

CONCLUSIONS

In this study, monthly intensity of precipitation data are investigated using QR method to characterized precipitations extreme in Province of Sulawesi Selatan indices in both time and space. The conclusion is drawn as follows:

1. Both of the precipitations extreme in Province of Sulawesi Selatan showed the relationship with climate change for region with Monsoon, Equatorial, and Local precipitation pattern clusters.
2. Low level precipitation extreme has positive relationship with all stations on each cluster. It means that low level precipitation extreme will increase as temperature increase. The same phenomenon also occurred for high level precipitation extreme (quantile is 0.75). Meanwhile, for higher level of precipitation extreme (quantile is 0.9) both of stations Salubarani and Bulo-Bulo which are located in higher altitude than other stations showed the negative relationship with the temperature. Both of stations showed that the intensity of precipitation extreme will decrease if temperature is increase. Difference pattern of intensity of precipitation extreme occurred for other stations which have higher intensity if temperature will increase.

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