The Influence of Global Climate Indices on Rainfall Distribution Pattern and Its Impact on Crop Yield in Gunung Kidul, Yogyakarta, Indonesia

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Abstract

The correlation between the global climate index (SOI/SST), rainfall distribution and crop yield in rain-fed highland areas was investigated. For this analysis, rainfall data were collected during the rainy season (October-March) for the period 1981 to 2009 in Gunung Kidul district of Yogyakarta Province, which is one of the important rain-fed crop producers in Indonesia. The rainfall distribution pattern found indicates that most of the rainfall occurs in coastal areas, especially in the southern hilly areas, where the occurrence of the Southern Oscillation Index (SOI) and Surface Sea Temperatures (SST) Niño.West are also highly correlated with rainfall. Soybean yield is highly correlated with rainfall while dry land paddies, peanuts and wetland paddies yields show a good correlation with SOI during January-February-March-April (JFMA).

Keywords: crop yield, rainfall, rain-fed area, SOI/SST

Introduction

Research on rainfall variability in Indonesia related to rain-fed agricultural areas is a critical issue due to its relationship with El Niño and La Niña events. The delay of rainfall has a negative effect on agricultural production in Indonesia. El Niño occurrences delayed rice harvesting in Indonesia and creates instability in food security (Harger, 1995). In 1997, rice farming in the sub-districts (Kecamatan) of Java decreased dramatically by 58% in wetland areas and 52% in dry land areas (Irawan, 2002). The abnormal weather caused by El Niño events seriously disturbed crop cultivation and the production of food and other commodities in the affected areas, mainly those located in the rain-fed dependent highland areas.

Rain-fed highland areas are more affected by rainfall variability because of the topography characteristics (Haylock and McBride, 2001). Rainfall variability in Indonesia correlates well with global climate index, such as the Southern Oscillation Index (SOI) and the Sea Surface Temperature (SST) pattern (Saji *et al*., 1999). At the same time, crop production in Indonesia is influenced by rainfall variability and highland topography. Therefore, it is necessary to estimate rainfall variability as influenced by the global climate indices (SOI and SST) in rain-fed highland areas and its correlation with crop yields.

The aims of this study are to analyze the relationship between rainfall, global climate indices SOI/SST and agricultural crops production based on the rainfall variability during the rainy season from 1981-2009 in rain-fed highland areas.

Materials and Methods

Study Area

Gunung Kidul district is one of the rain-fed highland areas of Java Island, located between 7°46'-7°09' S latitude and 110°21'-110°50' E longitude. Based on elevation, Gunung Kidul district as reported by the Agricultural Service for Food Crops and Horticulture (ASFCH) is divided into three areas of which the northern border ranges between 200-700 meters above the sea level (m); the center area is the lowland area with an elevation of 150-200 m, and the south area with a hilly topography ranges from 0 to 300 m. A total of 92% of the agricultural land area in Gunung Kidul district depends on rainfall, especially on October precipitation, as reported by the ASFCH (2006) and the remaining 8% is irrigated. The mean annual rainfall in Gunung Kidul district is 2041 mm/year based on the record data from 1989-1998.

Secondary Data

Crops yield from 1990 to 2009 and rainfall data from 1981 to 2009 at twelve locations were collected from the rainfall observation stations of ASFCH (2009). The SOI and SST data were collected from the Japan Meteorology Agency (JMA) website (http://www.data.jma.go.jp/gmd/cpd/db/elnino/index/dattab.html) and were averaged in Niño3 (5°N-5°S and 150°W-90°W), Niño.West (15°N-EQ and 130°E-150°E) and IOBW (20°N-20°S and 40°E-100°E) areas, respectively. Spatial data of Gunung Kidul district with a scale of 1:25000 were taken from the National Coordinating Agency for Survey and Mapping (Bakosurtanal) of Indonesia (2007).

Rainfall data were the average of cumulative rainfall during the rainy season (from October to March) from 1981 to 2009 at each station. Steps in the data analyses were as follows: first, mapping of rainfall during the rainy season (6 months, Oct-Mar and then separately Oct-Dec (OND) and Jan-Mar (JFM) from 1981-2009. Second, in order to analyze the distribution of rainfall in Gunung Kidul district, a regression analysis was conducted between rainfall during the rainy season, 6 months and 3 months (OND and JFM) from 1981 to 2009 and the averages of SOI/SST, to identify the global climate indicators that influence rainfall. Third, correlation analysis was conducted between the average of rainfall during the rainy season and crop yields, and finally, correlation analysis between the average of global climate indicators and crop yield during the rainy season was conducted.

Correlation analysis between rainfall in the rainy season and crop yield, global climate SOI/SST and crop yield was calculated only for the period 1990-2009 because of the data availability on crop yield for this period.

Results and Discussion

Distribution of rainfall during the rainy season for the period 1981 to 2009

The analysis of rainfall distribution from 1981 to 2009 was carried out based on a six months (Oct-Mar) and three months (OND and JFM) analysis. The distribution analysis shows that in the southern coastal areas and in the inland western areas rainfall ranged from 1800-2200 mm, while in the lowland central and northern areas rainfall was around 1500-1600 mm (Fig. 1). The southern area is a mountainous area with a maximum elevation of 700 m. It caused moisture from the Indian Ocean carried by the wind and moving horizontally produces dense clouds along the mountain ranges. These clouds cause rain in the upper region known as orographic precipitation (Roe, 2005), which is the reason why the windward side of the mountain range receives much more precipitation than the leeward side.

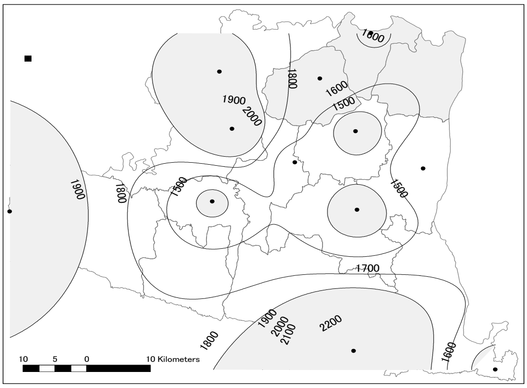

Figure 1. Distribution rainfall map during rainy season in Gunung Kidul district 1981 – 2009.

Relationship between the averages of rainfall and SOI/SST during 1981-2009

In Correlation analysis between the averages of rainfall during the rainy season and the averages of SOI and SST Niño.West in all sub districts, only three sub district, which has significant correlation, Panggang (r = 0.58), Playen (r = 0.44) and Rongkop (r = 0.49) sub-districts in $p<0.01$ and $p<0.05$. Panggang and Rongkop are the southernmost sub districts in the Gunung Kidul district, which directly border with the Indian Ocean, whereas Playen sub district, located in the middle of Gunung Kidul district, is poorly influenced by the Indian Ocean. Therefore, the area along the coast shows a stronger correlation with SOI - SST Niño.West than the center area. The average rainfall for the 9 other sub districts do not have significant correlations with the averages of SOI - SST Niño.West, which are probably influenced by the mountainous terrain indirectly affecting the correlation of rainfall and SOI.

Relationship between average rainfall and crop yield

Correlation analyses between average rainfall and crop yield during JFMA (January-February-March-April) can be seen at Table 1.

Table 1. Correlations between the average of rainfall in rainy season and crops yield in JFMA

Dry land paddy	Maize	Soybean	Peanut	Wetland paddy
-0.15	-0.31	0.60**	-0.04	-0.21

Pearson correlation coefficient
** Significant with $p < 0.01$

Based on Table 1, a strong correlation between average rainfall and crop yield during JFMA is only for soybean yield. Therefore, from PS 2 farmers tend to grow soybean as the main crop rather than dry land paddy in rain-fed highland areas. In the case of cassava yield, statistical analysis cannot be done during JFMA from 1990 until 2009, because it is not harvested during these months. Cassava is an annual plant, which is well adapted to drought and is harvested between July and August.

Relationship between the averages of SOI and crop yield

The relationships between the averages of SOI/SST and crop yield indicated that SOI is correlated with crop yield (dry land paddy, r = 0.50; peanut, r = 0.55 and wetland paddy, r = 0.55), whereas no correlation between SST Niño.West and crop yield was found (Table 2). Based on Table 2, average SOI during JFMA corresponds well with dry land paddy, peanut and wetland paddy yields, and changes in the value of SOI influencing dry land paddy, peanuts and wetland paddy yields.

Table 2. Correlation between average SOI and crops yield in JFMA

Dry land paddy	Maize	Soybean	Peanut	Wetland paddy
0.50*	0.28	0.25	0.55*	0.55*

Pearson correlation coefficient
* Significant with $p < 0.05$

The usefulness of global climate index and rainfall pattern to determine suitability of crops is needed to help farmers in their decision taking, especially in rain-fed highland areas. Our results indicate that averages of SOI and SST Niño.West are correlated with rainfall, especially in the seaside southern hills areas.

In general, increases in the average SOI/SST Niño.West will influence the amount of rainfall, and directly influence the cropping pattern. Our study found that increasing rainfall during the rainy season (JFMA) from 1990 to 2009 increased soybean yield. Different results show that averages of SOI corresponded well with dry land paddy, peanut and wetland paddy yield during JFMA. Increases of SOI averages in JFMA by +1 will cause the increase of dry land paddy yield during JFMA periods. The same trend can be observed for peanut and wetland paddy yield, in JFMA.

Overall, our results show that most of the crops yield trend during the rainy season does not correspond to global climate indices and rainfall. The main reason may be local cropping patterns that still dominate regardless of the rainfall pattern and global climate index. Further analysis of other rain-fed highland areas, which are different in elevation and in micro-scale (village) by including crop yield data, is necessary.

References

Agricultural Service for Food Crops and Horticulture (ASFCH), GunungKidul district. 2006. Profil Tanaman Pangan Kabupaten GunungKidul (In Indonesian). Pp 5 –34.

Agricultural Service for Food Crops and Horticulture (ASFCH), GunungKidul district. 2009. Rainfall database in Gunung Kidul district. Pp 10-130.

Harger, J.R.E. 1995. Air-temperature variations and ENSO effects in Indonesia, the Phillipines and El Savador: ENSO Patterns and Changes from 1866-1993. *Atmos. Environ* 29: 1919-1942.

Haylock, M. and McBride J. 2001. Spatial coherence and predictability of Indonesian wet season rainfall. *J. Climate* 14: 3882-3887.

Irawan, B. 2002 Stabilization of upland agriculture under El Nino-Induced climatic risk: Impact Assessment and Mitigation Measure in Indonesia, Economics and Social Commission for Asia and the Pacific, CGPRT Center WORKING PAPER No. 62.

Japan Meteorological Agency, 2010 El Nino Index data, retrieved from the statistical climate service at http://www.data.jma.go.jp/gmd/cpd/db/elnino/index/dattab.html

National Coordinating Agency for Survey and Mapping (Bakosurtanal) Republic of Indonesia. 2007 Spatial data for Gunung Kidul district at scale 1: 25000.

Roe,G.H. 2005. Orographic Precipitation. *Annu. Rev. Earth Planet. Sci* 33: 645-71.

Saji,N.H., Goswami, B.N.,Vinayachandran, P.N. & Yamagata,T. 1999. A dipole mode in the tropical Indian Ocean. *Nature* 401: 360-363.

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