Relationships among Global Climate Indices and Rainfall Pattern to Detect Impact of Climate Change in Yogyakarta Special Region, Indonesia

B D A Nugroho\(^1\), R K Nurrohman\(^1\), P Sudira\(^1\)

\(^1\)Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora No. 1, Bulaksumur, Yogyakarta 55281, Indonesia

Corresponding author’s e-mail address: bayu.tep@ugm.ac.id

Abstract. Indications of climate change can be known from the changes in rainfall distribution pattern and its volume. Yogyakarta Special Region lately often experiences drought, and has an impact on decreasing agriculture productivity and crop failure in several districts. Some of the research that has been done has not reviewed specifically in the Special Region of Yogyakarta with several Global Climate Indices and has not been spatially displayed. The aims of this research is to determine the relationship between the global climate indices with rainfall patterns in the Special Region of Yogyakarta. Global Climate Indices data used are: Southern Oscillation Index (SOI), Sea Surface Temperature Nino 3.4, Sea Surface Temperature Nino West, and Indian Ocean Basin-wide Warming (IOBW), and rainfall data for 2009-2013. The analysis process uses Principal Component Analysis (PCA) method to determine the relationship between the Global Climate Index and rainfall patterns and then change the data to be spatial using GIS. Based on the results, overall rainfall is negatively correlated with SOI, the area with a quite strong negative correlation (> -0.462) in the northernmost areas namely Cangkringan, Pakem and Ngemplak Districts, and the correlation value continues to decline to the southern regions. The correlation of rainfall with SST Nino 3.4 is dominantly negatively correlated and the area with strong enough negative correlation (> -0.492) in the northern and southernmost regions, namely Pakem, Cangkringan, Ngemplak, Saptosari, Tanjungsari, and Girisubo Districts, and the correlation value continues to decrease to the middle area. Then the correlation of rainfall with Nino West overall has a positive value, the northern region has a strong correlation (> -0.455) in the Districts of Pakem, Cangkringan and Ngemplak, while other regions have a strong enough correlation (> -0.455). The last correlation is with IOBW, it is divided into 2 areas that have positive correlations in the north and south areas and the negative correlation of the middle part is almost entirely, areas with strong positive correlations (> 0.57), namely in Tanjungsari and Girisubo Districts and areas with strong negative correlations (-0.556) in Pandong District. Thus it can be concluded that the Global Climate Indices (SOI, SST Nino 3.4, Nino West, and IOBW) influences the pattern of rainfall distribution in the Special Region of Yogyakarta.

Keywords: Rainfall Distribution, Global Climate Indices, Climate Change, Yogyakarta

1. Introduction
Several studies have been conducted on the relationship between the global climate index and climate in Indonesia and its effect on agricultural productivity. Nugroho [1], states that Sea Surface
Temperature affects the volume and rainfall patterns in Central Java Province in the south, besides that the Sea Surface Temperature (SST) Nino 3.4 also influences agricultural productivity in Banyumas Regency [2], and in Indonesia generally [3, 4, 5, 6].

This year, Yogyakarta is getting the worst drought in Indonesia and is almost evenly distributed throughout the region [7], [8]. BMKG has also given a warning of drought in the Special Region of Yogyakarta due to more than 61 days without rain and only has a rainfall value below 10mm / 10 days [9]. Directorate General of Food Crops of the Ministry of Agriculture noted, since the beginning of the April planting season to July 4, 2019 a drought has hit Yogyakarta with an affected area of 6.139 hectares and resulted in crop failure on an area of 1,757 hectares [10].

This must be well handled by the government, one of the efforts is to analyze the causes of changes in the pattern of rainfall distribution and volume in Yogyakarta. Furthermore, also by mapping the highest affected areas, to be used by the government as a basis for mitigation or policy planning to anticipate drought disasters, and to minimize the rice crop failures in the future.

2. The Methods

Special Region of Yogyakarta is a province in Indonesia, and is located between 70 33 'SL - 8 12' SL and 110 00 'EL - 110 50' EL. The data used in this research is the rainfall data of Special Regions of Yogyakarta [11], and global climate indices, among others: Southern Oscillation Index (SOI) [12], Sea Surface Temperature (SST) Nino 3.4 [13], Nino West [14] and Indian Ocean Basin-wide Warming (IOBW) 2009 – 2013 [15]. The Rainfall data that obtained for analysis in the Special Region of Yogyakarta, consisting of 14 data stations spread both within the Yogyakarta area and its surrounding districts, the data station can be seen in Figure 1.

![Figure 1. Rainfall Data Station in Yogyakarta Special Region](image)

Daily rainfall data is changed to monthly to have the same time unit as the global climate indices, then used as input analysis using the Principal Component Analysis (PCA) method. Principal Component Analysis (PCA) used to find relationships between input data parameters [16], [17], which can be seen from the distribution in the PCA quadrant and the obtained correlation values. The obtained correlation values are used as input data to be converted into spatial data using the IDW interpolation method in ArcGIS.
The Inverse Distance Weighting (IDW) method is used because it has a high accuracy value compared to other methods [18], [19].

3. Results and Discussion

3.1. Principal Component Analysis (PCA)

The obtained results in the Principal Component Analysis (PCA) process, is the correlation values and PCA quadrant graphs that represent the relationship between input data. Correlation values between input data can be seen in Table 1, and the PCA quadrant graph can be seen in Figure 2.

| Data Station | SOI  | SST Nino | Nino West | IOBW |
|--------------|------|----------|-----------|------|
| R1           | -0.628 | -0.670   | 0.757     | 0.741 |
| R2           | **-0.669** | -0.633   | 0.725     | 0.735 |
| R3           | -0.125 | 0.123    | 0.221     | **-0.714** |
| R4           | -0.362 | -0.142   | 0.475     | -0.396 |
| R5           | -0.649 | -0.542   | **0.784** | 0.350 |
| R6           | -0.462 | -0.197   | 0.591     | -0.247 |
| R7           | -0.270 | 0.080    | 0.306     | -0.598 |
| R8           | -0.292 | 0.028    | 0.344     | -0.556 |
| R9           | -0.361 | -0.089   | 0.455     | -0.429 |
| R10          | -0.334 | -0.025   | 0.412     | -0.488 |
| R11          | -0.072 | -0.715   | 0.473     | **0.938** |
| R12          | -0.129 | **-0.800** | 0.561     | 0.920 |
| R13          | -0.479 | -0.082   | 0.466     | -0.336 |
| R14          | 0.026  | -0.629   | 0.328     | 0.911 |
| **Average**  | -0.343 | -0.307   | **0.493** | **0.059** |
Based on these data it can be seen that the distribution of data contained in the PCA quadrant graph represents the correlation/relationship of one data with other data. Principal Component Analysis (PCA) conducted between rainfall in the Special Region of Yogyakarta, and the Global Climate Indices: Southern Oscillation Index (SOI), Sea Surface Temperature (SST) Nino 3.4, Nino West, and Indian Ocean Basin-wide Warming (IOBW) have eigenvalues or degrees of confidence of 91.45%.

The correlation between rainfall with the Southern Oscillation Index (SOI) in the Special Region of Yogyakarta with the highest value is the rainfall data at the R2 data station, with a strong negative correlation. This means that the relationship between the Southern Oscillation Index (SOI) and the rainfall in the area of the R2 station is inversely proportional, the higher value of the Southern Oscillation Index (SOI), the lower rainfall value, and vice versa. Overall, the Southern Oscillation Index (SOI) has a low correlation with rainfall in the Special Region of Yogyakarta.

Than the correlation between rainfall with Sea Surface Temperature (SST) Nino 3.4 with the highest value is the rainfall data at the R12 data station with a very strong negative correlation. This indicates that the Sea Surface Temperature (SST) of Nino 3.4 greatly influences rainfall in the R12 data station area and is inversely proportional, ie the higher Sea Surface Temperature (SST) of Nino 3.4, the lower rainfall value, and vice versa. Overall, Sea Surface Temperature (SST) Nino 3.4 has a low correlation with rainfall in the Special Region of Yogyakarta.

The next is correlation between rainfall with Nino West with the highest value is the rainfall data at the R5 data station, with a strong positive correlation. This means that Nino West is directly proportional to strongly affect rainfall in the R5 data station area, ie the higher the Nino West the higher the rainfall in the area, and vice versa. Overall, Nino West has a fairly strong correlation with rainfall in the Special Region of Yogyakarta.

The last is correlation between rainfall with Indian Ocean Basin-wide Warming (IOBW) has the two highest values, with a very strong positive correlation at R10, R11 and R14 data stations, and with a strong negative correlation with R3 data station. This means that Indian Ocean Basin-wide Warming (IOBW) has a variety of effects, both affecting directly proportional and inversely proportional. This is possible because of topographic factors in each region, so it has a different effect. The relationship between Indian Ocean Basin-wide Warming (IOBW) with rainfall cannot be averaged over a large area, because it has two relationships, positive and negative with relatively high values. Extensively, the relationship can be known with the average correlation value between Indian Ocean Basin-wide
Warming (IOBW) with rainfall in the Special Region of Yogyakarta, it has a very low correlation, which is only 0.059, it certainly cannot represent the actual relationship.

3.2. Data Transformation

Data transformation phase is very necessary to do, in order to know the correlation value/relationship of rainfall in all areas of the Yogyakarta Special Region with Global Climate Indices, and with this phase we can find out the correlation value/relationship in areas not covered by the Inverse Distance Weighting (IDW) interpolation method.

Based on Figure 3, it can be seen that the northern area has a high negative correlation, and the south the correlation value between rainfall and the Southern Oscillation Index (SOI) is getting smaller. Chen and Zhu [20], Zhu et al., [21] also stated in his research that the Southern Oscillation Index (SOI) significantly affected the rainfall and erosive level. It can be interpreted that the topography influences the impact of the Southern Oscillation Index (SOI) on rainfall, where the northern region of the Yogyakarta Special Region has a higher sea level than the southern area. Rainfall that has a strong negative correlation with the Southern Oscillation Index (SOI) in the Special Region of Yogyakarta, namely in the districts of Turi, Pakem, Cangkringan, Ngemplak, Kalasan, Prambanan, Gedang Sari, Ngawen and Semin.
Based on the analysis results, in Figure 4 it can be seen that SST Nino 3.4 has a high negative correlation with rainfall in the south and north, the more to the middle has a low correlation. Nugroho [1], also stated the same thing, SST Nino 3.4 affects rainfall in the Special Region of Yogyakarta in the southern and mountainous areas especially in the rainy season. Rainfall that has a strong negative correlation with SST Nino 3.4 in Yogyakarta Special Region, namely the districts of Pakem, Cangkringan, Ngemplak, Kalasan, Prambanan, Gedang Sari, Ngawen, Sapto Sari, Tanjungsari and Girisubo.

From Figure 5, it can be seen that Nino West has a positive correlation with rainfall in the northern area of Yogyakarta, and is getting smaller in the western and southwest regions. Rainfall has a strong
correlation with Nino West in, namely the districts of Pakem, Cangkringan, Ngemplak, Kalasan, Prambanan, Gedang Sari, Ngawen, Tanjungsari and Girisubo.

![Figure 6. Correlation Map between Rainfall and Indian Ocean Basin-wide Warming (IOBW) in the Special Region of Yogyakarta](image)

The last, from Figure 6 it can be seen that Indian Ocean Basin-wide Warming (IOBW) has a high positive and negative effect on rainfall in the Special Region of Yogyakarta. The north and southeast regions have strong positive correlations, while the central, southwest, west and northwest regions have strong negative correlations. Rainfall that has a strong positive correlation with Indian Ocean Basin-wide Warming (IOBW), namely the districts of Cangkringan, Ngemplak, Kalasan, Prambanan, Gedang Sari, Ngawen, Sapto Sari, Tanjungsari and Girisubo, and other regions have negative correlations.

4. Conclusion

From this study, it can be concluded that the Global Climate Indices: Southern Oscillation Index (SOI), Sea Surface Temperature Nino 3.4, Nino West and Indian Ocean Basin-wide Warming (IOBW) have varied effects on rainfall in the Special Region of Yogyakarta.

The Southern Oscillation Index (SOI) has a high negative correlation with rainfall in the north, and the further south the correlation value decreases. Sea Surface Temperature Nino 3.4 has a high negative correlation with rainfall in the south and north, towards the middle has a low correlation. Nino West has a positive correlation with rainfall in the northern area of Yogyakarta, and getting smaller in the west and southwest. Indian Ocean Basin-wide Warming (IOBW) has a high positive and negative effect on rainfall in the Special Region of Yogyakarta. The north and southeast regions have strong positive correlations, while the central, southwest, west and northwest regions have strong negative correlations.

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