Determinant of priority locations to support climate change adaptation

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Abstract. Climate change has had a significant impact on the agricultural sector and the impact is different in each place due to spatial variations in Indonesia. One of the efforts that must be made to reduce risk is to adapt. The purpose of this paper is to determine the key locations and their relationship to rice production for adaptation to climate change. Rainfall data and Oceanic Nino Index (ONI) are used to see the relationship between these two parameters through regression analysis and significance in El Niño and La Niña conditions. In El Niño conditions 24 key locations were obtained and in La Niña 3 priority locations. From the selected key locations, regression analysis was performed to determine the relationship between rainfall and rice production. The regression results at the sample locations show a fairly high $R^2$ value, namely 0.4 to 0.9, namely in Juntinyuat (West Java), Palasari (Bali), and Detusoko (East Nusa Tenggara). Other key locations are also found in several provinces. This key location is a priority location where the rainfall is strongly influenced by the extreme climate phenomenon El Niño and La Niña so that it can be used to assess the impact and monitor its impact on food farming. Socialization of the use of climate information to extension workers and farmers will greatly help reduce risks and increase capacity to adapt to climate change.

1. Introduction

Climate change has an impact on almost all economic activities and aspects of human life. The phenomenon of climate change that is best known to affect seasonal climate variability is ENSO which causes changes in rainfall patterns and world temperatures [1]. ENSO can be monitored and predicted with the ENSO index, which studies fluctuations in sea surface temperature (SST) that have an impact on rainfall intensity. One of the most frequently used indices to determine El Niño and La Niña events is the ONI (Ocean Nino Index) [2]. Predictions of El Niño and La Niña events through the ENSO index are often used as information by the government, companies, and the community as a first step to anticipate climate change for the agricultural sector, water management, and even health.

Disasters due to climate change such as droughts and floods are directly related to food security because they can reduce agricultural production and fisheries as well as disrupting food supply and people’s income [3]. Agriculture is one of several sectors most affected by climate change, especially in tropical areas such as Indonesia. Whereas the agricultural sector is a mainstay sector that has an important and strategic role for Indonesia. According to the Ministry of Agriculture [4], the agricultural sector contributed 13.7% to GDP, the second-highest after the manufacturing industry. The absorption of labor in the agricultural sector is also quite high, reaching 30% of the workforce in all major employment fields [5]. The increasing number of people also increases the need for rice as a staple food of the Indonesian people.
The impact of global climate change in Indonesia is marked by changes in surface climate parameters, namely air temperature, and rainfall. Climate change has implications for the production of various food crops based on the spatial variation of rainfall in Indonesia [6]. Differences in the impact of El Niño and La Niña on Indonesian agriculture require an analysis to see the correlation between rainfall and ONI and which locations are more affected by climate change. The purpose of this paper was to determine priority locations based on ONI in El Niño and La Niña events and to know the correlation between rainfall and rice production in a priority location. Thus, these key locations can be used as a reference to see and monitor the impact of climate change on the agricultural sector, so that socialization actions can be carried out to agricultural extension workers to minimize risks and increase the adaptation capacity of climate change disasters.

2. Materials and methods

2.1. Materials

This research was conducted in 2018 covering all regions of Indonesia. The data used in this study are (1) monthly rainfall throughout Indonesia with a period of more than 20 years sourced from the Meteorology, Climatology, and Geophysics Agency (BMKG) and Agroclimate and Hydrology Research Institute (IAHRI), (2) Oceanic Niño Index data (ONI) sourced from the NOAA website, and (3) rice production data from Statistics Indonesia and Ministry of Agriculture for the 1986‒2016 period.

The ONI tracks the rolling 3-month average sea surface temperatures in the east-central tropical Pacific observed in the Niño-3.4 region (5°N–5°S, 120°–170°W) [7,8]. ONI is the main indicator for El Niño and La Niña monitoring. If the ONI index was greater than or equal to +0.5 °C, then it was categorized as El Niño, indicating the east-central tropical Pacific was significantly warmer than usual. If the ONI index was less than or equal to 0.5 °C, it was categorized as La Niña.

2.2. Methods

The initial stage of the analysis was the preparation and quality control of ONI data and rainfall. Furthermore, the data that had been selected were analyzed for correlation and significance at lags of 1, 2, 3, and 4 months. The confidence level used was >90%. Lag is the time between the global process indicated by the ONI and the occurrence of rain. One-month lag means that global processes in the atmosphere occurred one month before, then the impact in the form of rainfall can be seen the next month. Likewise with the same approach for lag 2, 3, and 4 months [9,10]. The results of correlation and significance were used to determine the rain station which has a strong correlation (>0.5 or < -0.5) and significant correlation (p<0.1). A priority location is a location where rainfall in the region is influenced by global phenomena that can be represented through an index [11,12]. One of the global indices used in this study is the ONI which is the main indicator for monitoring El Niño or La Niña [2]. Rain stations and their surrounding areas are key and priority locations in the context of monitoring the impact of extreme climates.

The next analysis objective was to determine the relationship between rainfall and rice production. For this reason, a regression analysis was carried out between rainfall and rice production in El Niño and La Niña conditions at priority locations that had been obtained from the previous analysis. Monitoring of El Niño and La Niña developments related to the probability of occurrence and intensity is an important input to determine the impact of extreme climates and the monitoring on rice production. The flow chart of the analysis stages is presented in Figure 1.
3. Results and discussion

The results of the selection of rain stations that meet the requirements for analysis are 621 rain stations spread throughout Indonesia. The correlation analysis on El Niño conditions show that lag 1, 2, and 4 are dominated by negative correlations, while lag 3 is dominated by positive correlations. The highest negative correlation of -0.655 in lag 2 occurs at Detusoko Station, Ende District, East Nusa Tenggara. The other locations are in Palasari, Subang, Halim, Kemaron Station, Ringinharjo Station, Dawan, Kambat, Teluk Dalam, and Tanah Grogot with a correlation value of -0.4 to -0.6. At lag 4, the correlation value is obtained between 0.4 to 0.6. The highest positive correlation value was obtained in Juntinyuat Station, Indramayu District, West Java (0.616). The other locations are in Cigudeg, Leles, Losarang, Jatiwangi, Cimalaka, Jiken Station, Nglangon Station, Banyubiru Station, Rancasumur-Cisoka, Puyung, Alas Dawar, Muara Station Central Teweh, Tarakan Meteorological Station, Lattapareng, and Class III Moanamani Meteorological Station. Based on the results of determining the identification of key locations in El Niño conditions and all lags, 24 locations were obtained, which are completely presented in Table 1.

In La Niña conditions, most locations produced negative correlations with a range of -1 to -0.4, while for positive correlations between 0.4 and 1. Jeneponto Station in South Sulawesi shows a very strong correlation value both in lag 3 and lag 4. Areas that have a high negative correlation dominance are in lag 3 with a value of -1. Other high negative correlations are found in South Sulawesi, Central Java, Bali, and South Kalimantan.

The second parameter that becomes the basis for determining the priority location is the significance value (p). Values with the very significant category are in the p<0.1. In El Niño conditions, lag 2 has the highest number of stations with a class p-value<0.1 with a total of 174 stations or 28% of the total 621 locations (stations). In La Niña conditions, spatially, lag 3 and lag 4 are within the very significant category. Lag 3 has the highest significance value p = 0 and has 143 stations or 23% of the total 621 locations (stations). The results of this correlation and significance then become the basis for determining key locations, which is by taking strong (>0.5 or <-0.5) and significant (p<0.1) correlation values. This location becomes a priority location to determine the impact of extreme climate on rice production and monitoring its impact.

In El Niño conditions, lag 1 consists of four stations that become key locations: Subang (West Java) and Bantul (Special Region of Yogyakarta) with a strong negative correlation – very significant as well as Blora (Central Java) and West Kotawaringin (Central Kalimantan) with strong positive correlation – very significant. In lag 2, seven stations become key locations: Jembrana (Bali), Ende (NTT), and Pasir (East Kalimantan) with a strong negative correlation–very significant, and Tasikmalaya (West Java), Blora (Central Java), West Kotawaringin (Central Kalimantan), and Nabire (Papua) with a strong positive correlation – very significant. The key locations in lag 3 consist of four stations: Garut (West Java)}
Java), Semarang (Central Java), Tarakan (North Kalimantan), and Nabire (Papua). The four stations are included in the class of strong positive correlation–very significant. In lag 4, five stations are included in the key location with a strong positive correlation–very significant, namely Bogor, Indramayu, Majalengka (West Java), Central Lombok (NTB), and Nabire (Papua) (Figure 2).

**Table 1.** Priority Location of Indonesian climate diversity based on correlation and significance of rainfall anomalies with ONI in El Niño conditions.

| Province          | District          | Rainfall station        | Correlation | Significance | Lag | Classification |
|-------------------|-------------------|-------------------------|-------------|--------------|-----|----------------|
| West Java         | Subang            | Subang                  | -0.521      | 0.04         | 1   | Snc-vs         |
| Central Java      | Blora             | Jiken                   | 0.598       | 0.005        | 1   | Spc-vs         |
| Yogyakarta        | Bantul            | Ringinharjo             | -0.508      | 0.008        | 1   | Snc-vs         |
| Central Kalimantan| Kota Waringin Barat | Pangkalanbun           | 0.578       | 0.008        | 1   | Spc-vs         |
| West Java         | Tasikmalaya       | Singaparna              | 0.545       | 0.013        | 2   | Spc-vs         |
| Central Java      | Blora             | Jiken                   | 0.659       | 0.002        | 2   | Spc-vs         |
| Bali              | Jembrana          | Palasari                | -0.613      | 0.004        | 2   | Snc-vs         |
| East Nusa         | Ende              | Detusoko                | -0.655      | 0.011        | 2   | Snc-vs         |
| Tenggara          | Kota Waringin Barat | Pangkalanbun           | 0.544       | 0.013        | 2   | Spc-vs         |
| East Kalimantan   | Paser             | Tanah Grogot           | -0.530      | 0           | 2   | Snc-vs         |
| Papua             | Nabire            | Stamet Kls III Banamani | 0.575      | 0           | 2   | Spc-vs         |
| West Java         | Garut             | Leles                   | 0.503       | 0.024        | 3   | Spc-vs         |
| West Java         | Subang            | Subang                  | -0.508      | 0.037        | 3   | Snc-vs         |
| Central Java      | Semarang          | Banyubiru               | 0.508       | 0.026        | 3   | Spc-vs         |
| East Kalimantan   | Paser             | Tanah Grogot           | -0.509      | 0           | 3   | Snc-vs         |
| North Kalimantan  | Tarakan           | Stamet Tarakan         | 0.532       | 0.007        | 3   | Spc-vs         |
| South Sulawesi    | Jeneponto         | Tamanroya               | -0.557      | 0.075        | 3   | Snc-s          |
| Papua             | Nabire            | Stamet Kls III Banamani | 0.624      | 0           | 3   | Spc-vs         |
| West Java         | Bogor             | Cigudheg               | 0.508       | 0           | 4   | Spc-vs         |
| West Java         | Indramayu         | Juntinyuat             | 0.616       | 0.003        | 4   | Spc-vs         |
| West Java         | Majalengka        | Jatiwangi              | 0.528       | 0.012        | 4   | Spc-vs         |
| West Nusa         | Central Lombok    | Puyung                 | 0.523       | 0.013        | 4   | Spc-vs         |
| Gorontalo         | Lombok            | Gorontalo              | -0.605      | 0.01         | 4   | Snc-vs         |
| Papua             | Nabire            | Stamet Kls III Banamani | 0.588      | 0           | 4   | Spc-vs         |

Note: Snc-vs=strong negative correlation–very significant, Spc-vs=strong positive correlation–very significant, Snc-s=strong negative correlation–significant
Figure 2. Map of key locations based on correlation and significance of rainfall and ONI in El Niño conditions.

In the results of data processing between rainfall anomalies and the ONI index in La Niña conditions in all lags, there are a total of three stations that become key locations. In lag 1, there is one station that becomes the key location located at Candi Kuning station, Tabanan District, Bali with a strong negative – very significant correlation class. In lag 3, there are two stations, each of which has a strong positive correlation – very significant and a negative correlation – very significant. The station with a strong positive correlation – very significant is Garut District, West Java, while the station with a strong negative correlation – very significant Cilacap District, Central Java. In lag 2 and lag 4, there are no stations that fit into the key location criteria (Figure 3 and Table 2).

Figure 3. Map of priority locations based on correlation and significance of rainfall and ONI in La Niña conditions.

The identified key locations illustrate that rainfall in these locations is strongly influenced by global anomalies represented by ONI at lags 1, 2, 3, or 4. ONI is one of the many indices used as an anomaly indicator on a global scale. This means that ONI patterns and characteristics can be used to explain the occurrence of rainfall in lags 1–4 at those locations. Furthermore, these patterns and characteristics can be used as indicators to determine whether extreme climate events such as El Niño and La Niña will
occur or not. To determine the impact on agriculture, a regression analysis was carried out between rainfall and one of the agricultural indicators, namely rice production.

Table 2. Priority location of Bali, West Java and Central Java climate diversity based on correlation and significance of rainfall anomalies with ONI in La Niña conditions.

| Province     | District       | Rainfall station | Correlation | Significance | Lag | Classification |
|--------------|----------------|-----------------|-------------|--------------|-----|----------------|
| Bali         | Tabanan        | Candi Kuning    | -0.624      | 0            | 1   | Snc-vs         |
| West Java    | Garut          | Leles           | 0.520       | 0.001        | 3   | Spc-vs         |
| Central Java | Cilacap        | Sidareja        | -0.505      | 0            | 3   | Snc-vs         |

Note: Snc-vs=strong negative correlation-very significant, Spc-vs=strong positive correlation-very significant

From 24 key locations in El Niño conditions and three locations in La Niña conditions, the regression equations with $R^2$ are quite diverse. As an illustration, three key locations are taken (1) Juntinyuat Station, Indramayu District, West Java Province, (2) Pulasari Station, Jembrana District, Bali Province, and (3) Detusoko Station, Ende District, East Nusa Tenggara Province. The results of the regression equation (Table 3) show the connection between rainfall and rice production in the three locations. This is indicated by the value of $R^2$ which is quite high. The variable $x$ which represents rainfall is strongly influenced by global anomalies, one of which is ONI. Monitoring of ONI in the future through models that have been produced by many National institutions such as BMKG and International institutions such as NOAA, IRI, etc will be very helpful to provide an overview of the opportunities for extreme climate events of El Niño, La Niña and the estimated time of its occurrence. Likewise, for rainfall, information about its predictions for the future can be accessed, so that the estimated value of rainfall can be known. By entering the results of the rainfall forecast as the value of $x$, the value of $Y$, which is the rice production, can be estimated. By comparing the forecast value of $Y$ with the average data or data from the previous year, an idea of whether the future rice production in this key location will increase or decrease can be obtained.

Tabel 3. Regression results of rainfall and rice production in three key sample locations.

| Rainfall station | District       | Province       | Equation               | $R^2$ |
|------------------|----------------|----------------|------------------------|-------|
| Juntinyuat       | Indramayu      | West Java      | $Y=277.59x +1E+06$     | 0.996 |
| Pulasari         | Jembrana       | Bali           | $Y=-12.116x +54542$   | 0.625 |
| Detusoko         | Ende           | East Nusa Tenggara | $Y=12.11x +22262$     | 0.453 |

Information of weather/climate predictions is now widely available and can be accessed quickly, such as the results of weather/climate forecasts on the BMKG website, integrated planting calendar on the Indonesian Agency for Agricultural Research and Development (IAARD) website, and other information [14]. This is important as an effort to monitor climate extremes not only by the Central Government but also by the regions. Therefore, understanding and attention to climate for agriculture needs to be improved, for example through training, technical guidance involving the agriculture office, extension workers and farmers. In addition, you can do independent access through a website that provides related information.

The role of extension workers is needed to be able to provide simple explanations to farmers to increase the capacity of farmers to adopt climate change [15]. Information on the impact of extreme climates on the agricultural sector, especially rice production, is important so that anticipatory measures can be taken as an effort to adapt the climate change. If based on the results of climate monitoring there are indications of an extreme climate event of El Niño or La Niña, this information can be disseminated in stages. The results of the study on the vulnerability level of food farming can also be used to strengthen the selection of priority sites for adaptation [16,17,18]. Data, information, the distribution of priority locations, and the connection to rice production and other commodities can be developed into
an information system that is easily accessible and utilized by users so that it is expected to help reduce risk and as a real step in realizing adaptation efforts to climate change. Operational monitoring of extreme climate impacts can be carried out by involving field extension workers or using certain applicable equipment.

4. Conclusions
Twenty-four key locations have been identified in El Niño conditions and three key locations in La Niña conditions with strong correlation values >0.5 or <−0.5 and very significant/significant. Rainfall in these key locations is strongly influenced by global phenomena represented by ONI at lag 1, 2, 3, or 4. This Key location becomes a priority location to determine the impact of extreme climate on rice production and monitoring its impact.

The impact of climate anomalies on food farming can be known and monitored by knowing the close relationship between rainfall and rice production. There is a strong relationship between rainfall and rice production in several priority locations which are indicated by $R^2$ values of 0.4-0.9.

Height value of $R^2$ in priority locations shows that rainfall in key locations can be used as an indicator to analyze the impact of extreme climates on rice production and monitor their impacts to anticipate and reduce risks to support adaptation to climate change. Developing an information system with the information of priority locations and the connection to rice production that is easily accessible by field extension workers and farmers can help to reduce risk, as a real step in realizing adaptation support to climate change.

Acknowledgement
This research was supported by the Indonesian Agency for Agricultural Research and Development (IAARD) through Indonesian Agroclimate and Hydrology Research Institute (IAHRI) 2018 fiscal year. Dariin Firda is the main contributor and Woro Estiningtyas is the coauthor.

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