Dry spell frequency in West Java, Indonesia

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Abstract. The climatology and variability of dry spells are valuable information for scientists, engineers, planners, and managers working in water-related sectors such as agriculture, ecology, hydrology, and water resources. The dry spell concerns consecutive dry days which are the largest number of consecutive days with less than 1 mm of daily precipitation within a year. The objective of this study is to analyse the spatial and temporal characteristics of dry spells and also specifically investigate the frequency patterns of the dry spell distribution based on historical observed daily precipitation from 1981 to 2010. The longest dry spell occurred at Pasirukem with the length of 252 days. The northern coast of West Java have higher probabilities of dry spells more than 5, 10, 15, and 20 days.

1. Introduction
Changes in climate indicators such as surface temperature, sea surface temperature, sea levels, rainfall, extreme weather and climate events, resulted in broad changes of the global climate which impacts various aspects of life [1]. According to Surmaini et al. [2], agriculture is one of the areas most vulnerable to climate change, particularly food crops that are mainly annual crops and relatively sensitive to stress associated with the excess and shortage of water. Three major factors associated with global climate change which also impacts the agricultural sector is the change of rainfall patterns, increased extreme climate events (floods and droughts), as well as increased air temperature and sea levels [3]. Changes in rainfall patterns and the rise of temperatures caused significant decline in agricultural production, furthermore, extreme climate events such as floods and droughts lead to increased number of parched crops [2].

Zhang et al. [4] mentioned some properties of extreme climates which have great impact on agriculture of which is dry spells or series of dry days. Dikshit et al. [5] conducted research on twenty varieties of rice and found that with the dry spell occurring for sixteen days, caused delays in the harvest time about two to twenty-seven days and a decline in yields about 10-91%. Furthermore, Niewolt [6] stated that in the tropics, the occurrence of dry spell for seven days or more have serious impacts on crops.

The objective of this study is to analyse the spatial and temporal characteristics of dry spells, by investigating the frequency patterns of its distribution and the probability for some given length of dry spells. The results of this study are expected to provide improved climate information which can be used to reduce the vulnerability of the climate sensitive agricultural activities towards extreme weather/climate events in West Java.
2. Data and Methods

The data used in this study consisted of daily rainfall records obtained from Indonesian Agency for Meteorology Climatology and Geophysics (BMKG) for the period 1981 to 2010. There are 54 rain gauge stations used and the distribution is shown in Figure 1.

![Figure 1. The area and the distribution of rain gauges of this study.](image)

The analysis of dry spell uses the definition given by the Expert Team on Climate Change Detection and Indices (ETCCDI) which concerns consecutive dry days in which are the largest number of consecutive days with less than 1 mm of daily precipitation within a year [7]. Frequencies of dry spells were derived from daily data obtained from certain locations during the period of study using the following equation:

\[ F_{ijk} = \sum_{i=1}^{m} F_{ijk} \]

where \( i \) is dry day occurrences in a month \((j)\) and year \((k)\), with \((m)\) the total number of years [8]. The probability density function (PDF) is used to calculate the probability of dry spells which has values more than 5, 10, 15, and 20 days at each stations using the following equation:

\[ P(X > x) = 1 - P(X < x) = 1 - F(x) \]

3. Results and Discussions

The observed frequency of dry spells during the period of study showed that a one-day dry spell has the highest frequency of occurrence at every location, see the example in Figure 2. The picture shows dry spell distribution of two different stations. It can be seen that the incidence of dry spell in Darmaga is no more than 30 days, while in Pasirukem a dry spell of more than 200 days have occurred. This shows that there are sizeable differences in the incidence of dry spell between stations due to differences in rainfall patterns.

The Meteorology, Climatology and Geophysics Agency divides the West Java region into 36 rainfall patterns that consists of 34 Seasonal Zones (Zona Musim/ZOM), and two Non Seasonal Zones (Non Zona Musim/Non ZOM). ZOM areas have a clear distinction between the dry season and the rainy period, while Non ZOM areas generally do not have a clear distinction between the dry season and the rainy season, with rainfall mainly all high or all low throughout the year. Non ZOM areas in
West Java are Bogor, North Sukabumi and North Cianjur where maximum incidences of dry spell are less than 50 days.

![Dry spells distribution at Darmaga (Bogor) and Pasirukem (Karawang)](image)

**Figure 2.** The observed frequency of dry spells at Darmaga (Bogor) and Pasirukem (Karawang).

The spatial observed distribution of maximum runs of dry spells are presented in Figure 3. The longest run of dry spell of 252-days was observed during mid-April to mid-December 1982 at Pasirukem. It can be seen that most stations in West Java have experienced dry spells of more than 150 days. Dry spells with durations of less than 100-days were dominant over high lands and close to large water bodies.

![Maximum dry spells](image)

**Figure 3.** The spacial distribution of maximum dry spells.

Most of the maximum incidence of dry spells at each station occurs during the El Nino phenomenon. The maximum incidence of dry spell mostly occurred in 1982, 1991 and 1997 in which the El Nino intensities are moderate and strong.

Figure 4 shows the example of PDF graphs at Darmaga and Pasirukem. From these graphs we can see the probable period occurrence of dry spells. The probability of dry spells between 1-3 days at Darmaga is 82% and above. While the probability of dry spells between 1-25 days in Pasirukem is 94% and above. This shows that in Darmaga, dry spells only lasts for one to three days, while in Pasirukem dry spells lasting for one to twenty-five days occur frequently. It can be said that the Pasirukem region is drier than the Darmaga region. For other stations, dry spells occurrence varies between 1 to 20 days.
Figure 4. The PDF graphs of dry spell at Darmaga and Pasirukem.

Figure 5 shows the probability of dry spell occurrence which takes on a value of more than 5, 10, 15, and 20 days over West Java. The probability of dry spell of more than 5 days ranged between 10% - 50% with the highest probability of occurrence is in the northern coast of West Java and the lowest odds is in the western regions of mid West Java. The probability of dry spell events over 10 days ranged from 0-40% and the probability of dry spell events over 15 days and 20 days ranged from 0-20%.

Figure 5. Probability of dry spells more than 5 days (a), more than 10 days (b), more than 15 days (c), and more than 20 days (d).
Based on the analysis results, it can be said that the area around the northern coast of West Java tend to be more prone to dryness which could disrupt agricultural activities in the region. Therefore, efforts should be made to reduce or avoid the impact of the drought events by arranging the planting calendar in which time and cropping patterns are adjusted.

4. Conclusions
Based on the frequency distribution of dry spell events, almost the entire region of West Java have experienced dry spells of more than 150 days. The regions which experienced dry spells event of less than 100 days were in mountainous areas or near reservoirs. Based on the analysis of probability occurrences, the north coast of West Java is more prone to the incidence of dry spells, so it is necessary to regulate irrigation and cropping pattern settings so that agricultural activities can be ran well.

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References
[1] Kementrian PPN/Bappenas 2014 Rencana Aksi Nasional Adaptasi Perubahan Iklim.
[2] Surmaini E, Runtunuwu E, Las I 2011 *J. Litbang Pertanian* **30**(1) 1-7
[3] Salinger MJ 2005 *J. Climate Change* **70** 9-29
[4] Zhang X and Yang F 2004 RClimdex(1.0) User manual. Ontario (CA): Climate research Branch Environment Canada
[5] Dikshit UN, Parida D, Satpathy D 1987 *IRRN* **12** 6-7
[6] Niewolt S 1989 *J Agriculture and Forest Meteorology* **45** 251-263
[7] Nastos PT and Zerefos CS 2009 *J. Am Research* **94** 616-628
[8] Tilya FF and Mhita MS  2007 Frequency of Wet and Dry Spells in Tanzania *Climate and land degradation* (Berlin: Springer Berlin Heidelberg) 197-204