Mapping of drought distribution using the deciles index in Rokan Watershed, Province of Riau, Indonesia

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Abstract. Among natural hazards, droughts are known to cause extensive damage and affect a significant number of people. Droughts also have wide impacts across the economy, society, health, and education. This research is expected to be a reference to estimate the existence of droughts. After performing the calculation of drought indices, a drought distribution map was made using a Geographic Information System (GIS). The results showed that the worst drought occurred in 2013 to 2014. The average comparison between the discharge data and the level of decile data of both rain stations is 50%. It is evident that the discharge and decile-level data have good conformity. The result of the analysis, when associated with the incidence of El Nino, has a suitability of 32%, which could be due to other factors that affect rain conditions in the study location. Based on the results of the analysis of the annual trend of rainfall accumulation, the year when climate change initially occurred was in 2003. From 1990 to 2003 the drought distribution conditions tended to be “Dry” to “Very Dry”, whereas from 2003 to 2014 the drought-level distribution conditions were likely to be “Dry” to “Very Dry”.

Keywords: Drought Map, GIS, Deciles Index, Rainfall

1. Introduction
Drought is a type of natural disaster that occurs slowly, lasts long until the rainy season arrives, has a very broad impact, and is cross-sectoral (the economy, society, health, education, and so on). Drought is a natural phenomenon that cannot be avoided and is a normal variation of weather that needs to be understood [1], [2], [3]. Drought is analysed using the Deciles Index. The Deciles Index (DI) [4] involves points, scores, or values that divide all frequency distributions from the investigated data into 10 equal parts that are equal to 1/10. According to another study [5], the third decile is a point that limits 30% of the lowest frequency in distribution.

The Rokan Watershed is one part of the Rokan River Basin, which has a watershed area of 19,150 km². Rokan Watershed has an important role for the people of Rokan because the water in the watershed is used to supply clean water and water for agriculture. According to temporary data of the Technical Implementation Unit (UPT) for the Protection of Food Crops and Horticulture in the Province of Riau, up to the present, 4 regencies have reported the status of drought [6]. The regencies that have reported drought status are the Kampar, Indragiri Hulu, Kuantan Singingi, and Rokan Hulu Regencies. Therefore, a simple drought index analysis is needed for the Rokan watershed to determine the level of drought occurring in the study area.
The purpose of this study is to obtain insights by the calculation of drought using the Deciles Index in order to provide information for early detection of the symptoms of drought and anticipation of occurrences of drought in the Rokan Watershed of the Province of Riau, so as to reduce the negative impacts caused by drought.

**Figure 1.** Rokan Watershed

### 2. Materials and Methods

#### 2.1. Research Study
This study was conducted in the Rokan Watershed of the Rokan River region, which has an area of 22,454 km² and is geospatially located between 99.622 and 101.809 East Longitude and between 0.068 and 2.307 North Latitude. The Rokan River region is upstream of the Bukit Barisan range, which stretches on the west side of the island of Sumatra; the river flows towards the east and empties into the east coast of the island, into the Malacca Strait.

#### 2.2. Analysis Method
The following are the data needed to complete this study:
1. A digital earth map that covers the entire area of the Rokan Watershed.
2. Maps of Rokan Watershed boundaries and rain stations.
3. Monthly rainfall data for rain stations in the Rokan Watershed of the Province of Riau from 1990-2014.
4. Automatic Water Lever Recorder (AWLR) data from 2007-2014.
5. Southern Oscillation Index (SOI) data from 1990-2014.

#### 2.3. Stages of Analysis
1. Collection of secondary data in the form of digital maps, rainfall data, and AWLR data.
2. Analysis of rain data.
3. Drought index analysis, which in this study utilizes the Deciles Method.
4. Modelling of the isohyet distribution of drought.
5. Evaluation of the initial point of climate change from the graph of annual rainfall accumulation in the Rokan Watershed.

Drought analysis utilizes the deciles method. According to a study [4], a decile is a point, score, or value that divides all frequency distributions from the data investigated into 10 equal parts which are equal to 1/10. According to another study, the third decile is a point that limits 30% of the lowest frequency in distribution [5].
The deciles method has been applied in Australia to determine the severity of drought on farms.

These are the formulas involved in the Deciles Method:

1. Deciles of a single group of data:

   \[ D_i = \text{the value to } - \frac{(n+1)}{10} \]

   where:
   \( i = 1, 2, \ldots, 9 \)

2. Group data decile:

   \[ D_1 = Bb - \frac{(\frac{n}{10} - cf_{b})}{f_d} \]

   where:
   D1: Decile 1, the point that limits the lowest 10% of frequencies in a distribution
   Bb: The lower limit of the decile 1 interval range
   cf: Cumulative frequency below decile 1
   f: Frequency on the decile 1 interval
   N: Total frequencies in the distribution
   n: Decile sought (n-1)
   i: Width of interval

3. Results and Discussion

3.1. Consistency Test (Double Mass Curve)

Based on the results of the consistency testing using a double mass curve in the Rokan Watershed, deviant data was found, and thus the rainfall data needed to be corrected.

![Consistency Testing of Lubuk Bendahara Station](image)

**Figure 2.** Consistency Testing of Lubuk Bendahara Station

In the graph above, there is a broken line from 2004 to 2014, and this needed to be repaired. Data from 2004 to 2014 were corrected by multiplying the correction factor of 0.546. Because the curve still has irregularities or faults, it was necessary to make corrections again to obtain a curve that does not deviate. For the Lubuk Bendahara rain station, the new curve does not deviate as shown in Figure 3 below. After the rain data became consistent, the data could be used for further calculations.
3.2. Stationary Test (F Test and T Test)
The results of the t-test and f-test on data from the Rokan Watershed showed a stable or homogeneous value, which means that the data is stationary.

3.3. Deciles Method
Based on the results of drought analysis by the Deciles Index, it was found that the most severe drought occurred for 9 consecutive months, from August 2013 to April 2014.
1. 1-month deficit period of 28-32%
2. 3-month deficit period of 24-32%
3. 6-month deficit period of 28%
4. 12-month deficit period of 28%

3.4. Comparison of Drought Analysis Results with Discharge Data
Analysis of the calculation results can also be performed by comparing the results of calculations with the discharge data in the study area. A comparison was performed to find out if there is a relationship between the drought index and river discharge, which can be seen in Figure 4 and Figure 5.

Comparison of discharge and drought level only utilizes comparisons of two stations that are closest to the post; the estimation of water at Lubuk Bendahara was only to find out whether the discharge at the Lubuk Bendahara is suspected to be related to the drought that occurs. The trend that occurs from the two sets data being compared is not identical because there are factors that influence the river discharge other than rainfall, such as topography, evaporation and filling of the basin, the presence of tributaries, errors in recording data on discharge and rainfall, and the amount of development and urbanization.

The average of comparison between discharge data and decile level data in Figures 4 and 5 (Table 1 and Table 2) is 50.0%. This shows that the discharge and decile level data have good suitability. The trends that occur from the compared two sets of data are not identical because farther distances to other rain stations can affect the results of the comparison.

3.5. Drought Distribution Map
The drought distribution map was made using ArcGIS 10.1 software, and the interpolation process was carried out using the IDW (Inverse Distance Weighted) method. Based on the decile level of drought with a 12-month deficit period, the driest years were 2013 and 2014, which can be seen in Figure 4 and Figure 5. In 2013 the sub-districts that experienced the drought level of “Very Dry” were the Tanah Putih Tanjung Melawai, Tanah Putih, Bangun Purba, and Rambah Sub-Districts while in

![Consistency Test on Lubuk Bendahara Station](image-url)
2014, they were Kandis, Bagan Senimbah, Tambusai, and Kepenuh Sub-Districts. From the map of the distribution of decile level of drought, it was found that the sub-districts that most often experienced the “Very Dry” level of drought during the 25 years of observation were the Kandis, Ujung Batu, and Bangun Purba Sub-Districts.

**Figure 4.** Discharge Data of Lubuk Bendahara and Decile Level Data from Lubuk Bendahara Rain Station, 2007-2014

**Figure 5.** Discharge Data of Lubuk Bendahara and Decile Level Data from Bagan Batu Rain Station, 2007-2014
3.6. Drought Levels Before and After Climate Change

To find out the initial year of climate change in the Rokan Watershed, this can be performed by making a graph of the accumulation of rainfall data in the watershed.

From the Figure, it was found that the initial year of climate change in the Rokan Watershed within the span of 25 years from 1990 to 2014 is in 2003. Based on this evidence, analysis was performed on the level of drought before and after the climate change in 2003 through a distribution map of the decile drought level.

In Figure 8, it can be seen that from 1990 to 2003, the distribution of drought levels in the study location tended to be “Normal” to “Dry” and “Very Dry”, except in 1999 and 2003, which showed a “Normal” to “Wet” level of drought.
Figure 8. Distribution Maps of Drought Levels before the Climate Change in 2003

In Figure 9, it can be seen that from 2003 to 2014 the distribution of drought levels in the study area tended to be “Normal” to “Dry” and “Very Dry”, except in 2006 and 2011, which showed drought levels of “Very Very Dry” and “Normal” to “Wet” in 2007.

Figure 9. Distribution Maps of Drought Levels after the Climate Change in 2003
4. Conclusion

Based on the results of the previous discussion, several conclusions can be drawn: In the 25 years of observations of the Rokan Watershed, the percentage of drought events using the deciles method in a 1-month deficit period with conditions below normal rainfall (“Dry” to “Very Very Dry”) in all rain stations ranges from 28-32%. In a 3-month deficit period, the condition of below normal rainfall ranges from 24-32%. In a 6-month deficit period, the condition of below normal rainfall for all rain stations are 28%, while in a 12-month or annual deficit period, below normal rainfall is 28%. From the map of decile 1 rainfall distribution with 25 years of observation in the Rokan Watershed using the IDW method assisted by the Arc GIS 10.1 software, in periods of 1, 3, 6, and 12 months, the sub-districts that experienced the greatest drought are the Tanah Putih, Kuntodarrusalam, and Rokan Sub-Districts. For the distribution of decile drought levels of, the sub-districts that experienced the “Very Dry” level of drought during the 25 years of observation are the Kandis, Ujung Batu, and Bangun Purba Sub-Districts.

The results of the drought level analysis, when compared to the discharge data in the study area, show several similarities in trends. The average ratio between decile data and discharge data of both rain stations is 50.0%. The results of the analysis, when associated with El Nino events, show a similarity of trends with El Nino suitability values and drought index by the deciles method, by 32%. The results of the analysis showed trends of annual rainfall accumulation, wherein the beginning of the occurrence of climate change in the Rokan Watershed within the span of 25 years from 1990 to 2014 was in 2003. The distribution of drought level conditions from 1990 to 2003 and from 2003 to 2014 at the study location tended to be “Normal” to “Dry” and “Very Dry”.

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