Determination of the Growing Season for Dry Land Agriculture Based on Thornthwaite Method in Bulukumba Regency, South Sulawesi Province

Ramli Umar*, Muhammad Yusuf
Department of Geography Education, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, South Sulawesi, Indonesia

*Corresponding author: ramliumar707@yahoo.com

Abstract. Drought events in a region are strongly related to the surface water availability and low rainfall. Furthermore, drought conditions impact the threat of food security. Bulukumba Regency in South Sulawesi Province is one of the areas that are prone to drought and the risk of crop failure. Therefore it needs anticipatory action to understand the drought index in this region. This study aims to identify the conditions of drought and agitation in the Bulukumba District of South Sulawesi Province. The results of the identification then became the basis for determining the growing season in various types of dryland agriculture cultivation. This study used the Thornthwaite method with a water balance and drought index approach. The sampling method in this study was purposive sampling. Data collection techniques carried out are observation techniques, laboratory analysis techniques, and documentation techniques. Data processing used quantitative techniques and descriptive approaches. The results of the study show that the growing season in dryland agriculture in November, December, and January based on the availability of water in this region. Conversely, the availability of water is very low in May to September and not appropriate to handling the cultivation.

Keywords: rainfall, drought, farming cultivation

1. Introduction
A report “Intergovernmental Panel on Climate Change” states that the world is increasingly vulnerable to drought in the last 25 years, and climate projections indicate that this will get worse in the future [1]. The projection will have a significant impact, especially for developing countries. One crucial component of the drought mitigation strategy in Indonesia is a comprehensive drought monitoring system. This system can warn at the beginning and end of the drought, determine the level of severity, and disseminate information on various sectors, especially the agricultural sector, clean water, energy and health [2].

Indonesia's geographical location is closely related to climatological factors that cause flooding and drought. This geographical position causes Indonesia to be in the hemisphere with a tropical monsoon climate that is very sensitive to El Nino Southern Oscillation (ENSO) climate anomalies. ENSO causes drought if the condition of sea surface temperature in the middle of the Equator Pacific to the east warms up. Meteorological, Climatological, and Geophysical Agency recorded that since the 19th century the earth's surface temperature has increased by about 0.8°C. The increase in
temperature is estimated to be around 0.15ºC to 0.3ºC every decade from 1990-2005. This climate change has a negative impact on human life including the trend of decreasing rainfall which causes drought [3]. Drought is very low water availability compared to water needs for human needs. Drought occurs almost all over the world due to water scarcity and the existence of a prolonged dry season. Even extreme, droughts occur due to climate deviations such as El Nino, which occur in certain years in Australia, America, Mexico, the Philippines and Indonesia [4][5].

Drought is a routine problem that occurs in Indonesia. However, handling for prevention and mitigation is very slow. As a result, it has an impact on other problems such as food security and lack of water. Dryness of an area can be determined by calculating the drought index, which is by using the Thornthwaite Mather method. The Thornthwaite Mather method is a method based on the concept of the water balance in calculating the drought index. The Thornthwaite Mather method uses rainfall as input, evapotranspiration as output, soil physical properties and characteristics of land cover as processing [6].

A drought index is a primary tool for detecting, monitoring, and evaluating drought events. Several studies that have successfully analyzed the drought index using the Thornthwaite Mather method. This study aims to determine the growing season on dry land agriculture based on water availability and using the reliability of the Thornthwaite Mather method. Bulukumba Regency is one of the districts in the province of South Sulawesi. Based on the information obtained and the results of the using land map interpretation, it was found that agricultural activities dominated community activities. Also, there are also around 30% of farmers who manage drylands such as plantations, mixed gardens, and more. Dryland farming activities are very dependent on rainfall so that the farmers must estimate the months with enough rainfall to be planted to provide optimal yields. Based on information obtained in recent years, farmers often experience crop failure caused by drought due to rainfall prediction errors. As a result, dryness occurs when plants still need much water. Conversely, excessive rainfall at the time of harvest causes a decrease in the quality and quantity of crops. Based on this background, this study is a reference in predicting rainfall and drought. Furthermore, farmers can determine the right planting time according to the water needs of the cultivated plants.

2. Research Method

The conducted study type is quantitative descriptive. The data obtained in the field from each sampling point in the land unit is analyzed quantitatively. The monthly rainfall data of Bulukumba Regency in 1984-2014 is secondary data that supports the analysis. This study used an analytical approach to land units resulting from overlays from land type maps and land use maps. Sampling or land unit is carried out using the "purposive sampling" method or sample are taken based on considerations which the accessibility or representation of land units. The variables reviewed are the thickness of rainfall, air temperature and soil texture with the operational definition as follows: 1) the rainfall thickness is the amount of rainwater that falls on an area within a particular time, 2) air temperature is the state of heat or cold air, and 3) soil texture is a comparison of the fractions of sand, dust, and clay (clay) in soil aggregates.

Data collection uses three methods, namely direct observation or observation techniques, laboratory analysis techniques, and documentation techniques. Calculation of the drought index uses the Thornthwaite method [7]:

\[ I_a = \frac{D}{EP} \times 100\% \quad \text{...........................................(1)} \]

\[ I_a \quad = \text{Drought Index} \]
\[ D \quad = \text{Deficit} \]
\[ EP \quad = \text{Potential evapotranspiration} \]
3. Results and Discussion

3.1 Drought condition
Drought condition or drought level are widely used by three factors, namely rainfall, soil type and land using type. The drought level according to Thornthwaite is obtained from drought index value of a region. Drought index value of a region is a is the percentage of the ratio between the deficit value (D) to the corrected potential evapotranspiration value (EP). The results of the drought index calculation in Bulukumba Regency at six rain stations are presented in Table 1.

Table 1. Monthly drought index in Bulukumba Regency

| Stations       | Months | Drought index |
|----------------|--------|---------------|
|                | Jan    | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| Sangkala       | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 117 | 74   | 0   | 0   | 15.92 |
| Bulo-bulo      | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 47  | 120  | 53  | 0   | 0   | 18.33 |
| Bontomanai     | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 84  | 100  | 42  | 0   | 0   | 18.83 |
| Bontonyeleng   | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 100 | 103  | 69  | 139 | 104 | 42.92 |
| Padangloang    | 0      | 39  | 0   | 0   | 0   | 0   | 10  | 91  | 123  | 92  | 74  | 35  | 38.67 |
| Paenrelompoa   | 0      | 23  | 31  | 0   | 0   | 0   | 0   | 89  | 89   | 66  | 54  | 17  | 30.75 |

Source: Results of data processing, 2018

Drought index calculation is divided into three classes namely low, middle and high. The low class has a value between 0-16.7%, middle-class has a value >16.7-33.3% and the high class has a value >33.3%. The analysis result shows that Sangkala station has a low drought index (<16.70). While Bulo-bulo, Bontomanai, and Paenrelompoa stations have a middle drought index. Bonto Nyeleng and Padang Loang stations show a high drought index (>33).

![Drought index map of Bulukumba District](image)

Table 1 also shows that from January to July indicated a low drought index while the other five months indicated high drought index. The layout analysis of the map of station areas and
administration sub-district areas are shown in Figure 1. The figure shows that most of Bulukumba Regency area are experiencing the risk of drought in the medium category (yellow), while only a small area has a risk of drought in the low category (green).

### 3.2 Distribution of drought levels

Monthly distribution of drought levels at each station in Bulukumba Regency varies, and the distribution is presented in Table 2. Based on the table, Bulukumba Regency has a drought risk on August, September, and October. This data has a role in determining the planting time of cultural activities on dry land.

#### Table 2. Monthly distribution of drought levels at each station in Bulukumba Regency

| Months  | Drought levels | Area extent (km$^2$) | Extent percentage (%) |
|---------|----------------|----------------------|-----------------------|
| January | Low            | 1160.27              | 100                   |
| February| Low            | 752.72               | 65                    |
|         | Medium         | 92.08                | 8                     |
|         | High           | 315.47               | 27                    |
| March   | Low            | 1068.19              | 92                    |
|         | Medium         | 92.8                 | 8                     |
| April   | Low            | 1160.27              | 100                   |
| May     | Low            | 1160.27              | 100                   |
| June    | Low            | 1160.27              | 100                   |
| July    | Low            | 1160.27              | 100                   |
| August  | Low            | 92.8                 | 8                     |
|         | High           | 1068.19              | 92                    |
| September| High          | 1160.27              | 100                   |
| October | High           | 1160.27              | 100                   |
| November| Low            | 683.97               | 59                    |
|         | High           | 476.30               | 41                    |
| December| Low            | 684                  | 59                    |
|         | Medium         | 92.08                | 8                     |
|         | High           | 384                  | 33                    |

#### 3.3 Utilization of the distribution of drought levels for determining the growing season of dryland agriculture

Generally, drought level classification on an area could be beneficial in agriculture in that area. Drought level determination on a district can be calculated monthly or annually. This monthly drought index can show information of months in specific regions that have the potential for planting and bad months for planting especially dryland farming areas. Generally, crops will need a large amount of water during the planting period, so that a district with a high drought level is not suitable for planting rather than a district with a low and medium drought level.

According to land using map, Bulukumba Regency is dominated by plantations and moors. Both lands using types are dry land agricultural activities whose water sources only rely on rainfall. So that, the time for planting is very related to the rainfall conditions in the region. A high rainfall will have low drought level, and contrarily a low rainfall will have a high drought level. Crops which are cultivated in plantations and moors need lots of water in the planting period. Accordingly, the good months for planting moor and plantation crops can be explained.

Based on the statistic data of Bulukumba Regency, dry land farming productions especially food agriculture developed in Bulukumba Regency are rice, corn, sweet potato, cassava, peanuts, soybeans, and mung beans. This study elaborates the growing season for the cultivation of rice, corn, and
soybean. Corn crops usually have approximately three months of age. Corn crops also need lots of water on its planting time until its growing time. The good months for corn planting can be seen according to drought index and its distribution on each sub-district of Bulukumba Regency. Soybean crops on moorland and former rice fields. These crops need lands which are moist but not muddy. This situation occurs from planting to filling pods. However, in the harvest season, lands ought to be dry. In detail, the analysis of the growing season for three kinds of planting is presented in table 3, table 4 and table 5. Signs (√) indicate that water availability in a particular area is by cultivated plants. While the sign (×) indicates the inappropriate time for planting in a certain area.

Table 3. Analysis rice growing season in sub-districts of Bulukumba Regency

| Sub-District | Jan | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Des |
|--------------|-----|-----|-------|-----|-----|------|------|-----|------|-----|-----|-----|
| Bangkala Barat | √   | √   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Bangkala     | √   | √   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Bontoramba   | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Tamalatea    | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Binamu       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Turatea      | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Arungkeke    | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Batang       | √   | x   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Tarowang     | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Kelara       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Rumbia       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |

Table 3 shows that the suitable planting time for rice cultivation in January, November, and December on all sub-district area. May until September is terrible months for rice planting. The analysis of the growing season of corn is presented in Table 4.

Table 4. Analysis corn growing season in sub-districts of Bulukumba Regency

| Sub-District | Jan | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Des |
|--------------|-----|-----|-------|-----|-----|------|------|-----|------|-----|-----|-----|
| Bangkala Barat | √   | √   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Bangkala     | √   | √   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Bontoramba   | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Tamalatea    | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Binamu       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Turatea      | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Arungkeke    | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Batang       | √   | x   | x     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Tarowang     | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Kelara       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |
| Rumbia       | √   | √   | √     | x   | x   | x    | x    | x   | x    | √   | √   | √   |

Table 4 shows that all sub-districts allow for corn cultivation. While the growing season in January, November, and December. This condition causes farmers to leave their land for six months a
year, especially in Batang District and Tarowang District. Low rainfall and soil conditions that store less water cause drought. Analysis of growing season for soybean is presented in Table 5.

Table 5. Analysis soybean growing season in sub-districts of Bulukumba Regency

| Sub-District | Jan | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Des |
|--------------|-----|-----|-------|-----|-----|-----|------|-----|------|-----|-----|-----|
| Bangkala Barat | ✓   | ✓   | x     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Bangkala      | ✓   | ✓   | x     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Bontoramba    | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Tamalatea     | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Binamu        | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Turatea       | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Arungkeke     | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Batang        | ✓   | x   | x     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Tarowang      | ✓   | x   | x     | x   | x   | x   | x    | x   | x    | ✓   | ✓   |
| Kelara        | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |
| Rumbia        | ✓   | ✓   | ✓     | x   | x   | x   | x    | x   | ✓    | ✓   | ✓   |

Table 5 shows that all sub-districts are potential for soybean cultivation but only in January, November, and December. While the other months are not recommended for soybean. Study results show that the three cultivation types can be applied in Bulukumba Regency on November, December, and January. Water balance calculation on December shows the occurrence of surplus water and sufficient plant water needs. With high rainfall, it causes good soil water content. This condition enables the crops to absorb well for its growth. The former study said that areas with rainfall that more significant than 100 mm/month enable drylands in Indonesia could be managed as cultivation lands. The results also require the existence of farmers’ knowledge about water balance, causes of drought and determination of growing season [7][8]. Drought risk analysis in Bulukumba Regency is a necessary determination of various crops planting time. The accuracy of planting time has an impact on the harvest optimization, and indirectly it is contributed to the food security in the study area.

4. Conclusion

Based on the monthly drought conditions, in Bulukumba Regency from April to July the entire area is in a small state or without water shortages. On August and October, all areas are in a state of high water shortages. While in other months it has a level of drought that varies between low, medium and high and with different regions for each month. Planting time in rice, corn and soybean cultivation in Bulukumba Regency is on January, November, and December. The bad months for planting is in August, September, and October because, in this three months, the entire area is in a state of high water shortages.

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