DROUGHT ANALYSIS TO SUPPORT URBAN AGRICULTURE IN WANGGU CATCHMENT AREA, INDONESIA

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ABSTRACT

Wanggu River is part of the Wanggu catchment area, Poleang WS - Roraya. Wanggu River passes through South Konawe District and Kendari City. Kendari is the capital city of Southeast Sulawesi Province. FAO (2017) issued data on per capita vegetable consumption per year from 1961 to 2013 for Indonesia which showed an upward trend with an average increase of 2.2% per year. The Indonesian Central Bureau of Statistics (2016) showed that vegetable consumption in Southeast Sulawesi Province is above the national average vegetable consumption. Urban agriculture may be one solution to overcome the increasing consumption of agricultural products and also the trend towards urbanization of population in developing regions..

Drought analysis might help to determine which plants are suitable for urban agriculture. Drought analysis in this paper uses the deciles and theory of run methods. Deciles method can show how severe drought in previous years. Theory of run method can provide information about the beginning and end of the drought period, drought return period, and the effect of the drought on the planted type of crop.

Crop water needs are used based on FAO (1986) for cabbage, soybean and tomatoes. The crop water needs used in this simulation are assumed to be the highest crop water needs with the longest crop duration. For paddy and secondary crops, a drought analysis with the "theory of run" method is also carried out. Crop water needs are used in accordance with the results of the study by Oldeman (1980).

Deciles method shows that drought had occurred in Wanggu Catchment Area in 1996, 1997, 1998, 1999, 2001, 2009, 2011 and 2012. Drought analysis with the theory of run method which is done on those five types of plants, cabbage has the shortest duration within longest average duration of drought which is 5 months and the smallest average drought intensity which is 78.19 mm/month. Suitable planting period for cabbage cultivation is in the period of December-January-February-March and April-May-June-July. This result shows that cabbage cultivation is suitable for the application of urban agriculture because of the small possibility of crop failure due to drought.

Keywords : Drought, Decile Method, Theory of Run Method, Urban Agriculture

1. INTRODUCTION

The Indonesian Central Bureau of Statistics in the WPS (World Food Programme) Indonesia Report (2017) states that the Indonesian population in both rural and urban

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areas is a net buyer of fruits and vegetables. In 2016, an average of 82.9% of vegetables and 76.3% of fruit consumed came from purchases. Vegetable consumption originating from own production for urban residents is 6.4%, while in rural areas it is 27%. On the other hand, consumption from own production is slightly higher for fruit compared to vegetables - 13.4 percent of the fruit consumed by the Indonesian population in urban areas comes from self-production, while the rural population produces almost half of the fruit they consume (40%).

WFP Indonesia(2017) analysed that current fruit and vegetable production can meet consumption needs, but the production must be increased significantly (for vegetables in particular), to meet the growing needs of fruits and vegetables. This is an opportunity for horticulture farmers to meet the demand, especially in overcoming supply chain efficiency.The level of consumption of fruits and vegetables between provinces in Indonesia is very diverse, where the highest consumption is almost twice the lowest. The highest fruit and vegetable consumption is found in the provinces of Bali, Yogyakarta and Sulawesi.

FAO (2017) issued data on per capita vegetable consumption per year from 1961 to 2013 for Indonesia which showed an upward trend with an average increase of 2.2% per year. The United Nations Population Division (2018) also shows an increase in the trend of urban population in Indonesia from 1960 – 2017 with an average increase of 0.69% per year. The Indonesian Central Bureau of Statistics (2016) showed that vegetable consumption in Southeast Sulawesi Province is one of the provinces above the national average vegetable consumption.

Kendari is the capital city of Southeast Sulawesi Province. Wanggu River is the largest river in Kendari City which is part of the Wanggu catchment area, Poleang WS - Roraya. This watershed area is about 330.50 Km^2. Administratively, Wanggu River passes through South Konawe District and Kendari City. Kendari City area is the middle-downstream area, while the Konawe Selatan Regency area is the midstream upstream area.

Urban agriculture may be one solution to overcome the increasing consumption of agricultural products and also the trend towards increasing urbanization FAO defines Urban and peri-urban agriculture as planting crops and raising livestock within and around cities. FAO also provided information that vegetables are suitable for urban farming because they have a short production cycle (some vegetables can be harvested within 60 days).

Mearns (1997) cited by Adidarma et al (2013) stated that one of the ways to show how changes in climate can change the frequency of droughts by analysing variability in rainfall. Agriculturre sector gets affected by climatic fluctuations.. Agricutural drought study is necessary for irrigation networks and reservoirs planning. This study is conducted to produce drought characteristics due to water stress on agriculture. Drought analysis requires long term data on rainfall, therefore the research location was chosen by the rainfall data availability.

2. STUDY CASE

2.1 Kendari City

Kendari is located between 3˚ 54` 40``- 4˚ 5` 05` South Latitude and stretches from West to East between 122˚ 26` 33``-122˚ 39` 14`` East Longitude. Kendari land area is 267.37 km^2 or 0.70% of the total land area of Southeast Sulawesi Province. The population of Kendari City in 2016 was 359,371 people with population growth rate of 3.37% per year. The soil of Kendari City consists of clay mixed with fine and rocky sand. The type of alluvium is whitish brown and covered with pratersier rock consisting of polymeric clay rock, sandstone and quartz. USAID (2017) explained that the economic potential in agriculture, especially food crops in Kendari tends to increase from year to year both in quality and in production.

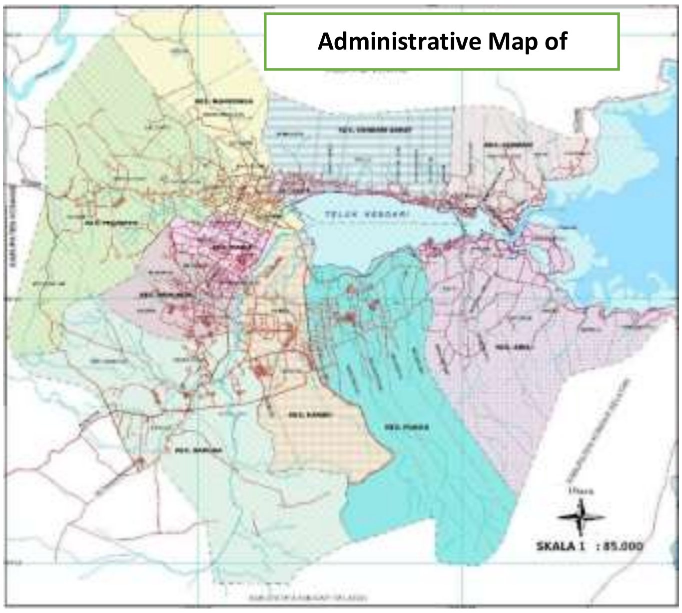


Figure 1 Administrative Map of Kendari

2.2 Climatology

The climatology data in Kendari is available from 1995-2017 for average daily rainfall data and 2014-2017 for average daily evaporation data. Based on the average rainfall indicates that the wet month of Kendari occurs in January to July with the average daily rainfall as 5.2 mm/day, while the dry month falls between August and December with an average monthly rainfall of 2.4 mm/day. Average daily evaporation is 3.8 mm/day. The climatology characteristic of the area is presented in Figure 2. From the figure, it is noted that the evaporation exceeds rainfall in August to November. It means that drought period during these 4 months has to be considered carefully related to agriculture and irrigation development in the area.

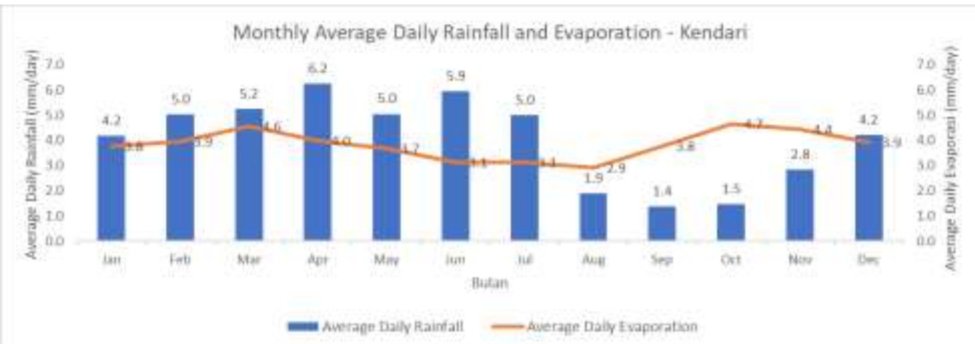


Figure 2 Average Daily Rainfall and Evaporation of Kendari

2.3 Crops Characteristics

FAO (1986) gave an indication of the sensitivity of various crops to drought. There are several classifications of sensitivity to drought, namely low, medium and high. High sensitivity means that the plant is not resistant to drought in contrast to the low sensitivity which is relatively drought resistant and can withstand poor water conditions. Cabbage, soybean and tomatoes were chosen for this study. Cabbage represents a low-medium group while soybean and tomatoes represent the medium-high group. Paddy and secondary plant crops also be analyzed because it is a staple crop in Indonesia. The following table presents the characteristics of each crop used in this study, based on FAO (1986) and Oldeman (1980) cited by Adidarma (2015).

Table 1 Crops Characteristics

No.	Crops	Total growing period (days)	Crop water need (mm/total growing period)	Sensitivity to drought	Sources
1	Cabbage	120-140	350-500	medium-high	FAO (1986)
2	Soybean	135-150	450-700	low-medium	FAO (1986)
3	Tomato	135-180	400-800	medium-high	FAO (1986)
4	Secondary Crop		120		Oldeman (1980)
5	Paddy		220		Oldeman (1980)

3. METHODOLOGY

3.1 Deciles Method

Gibbs and Maher (1967) cited in Adidarma (2015) stated that drought indices can be determined by deciles method which is calculated from yearly or season rainfall data. Deciles mean one tenth where the data is sorted from largest to shortest become 10 groups. The data classification by Adidarma (2015)can be seen in Table . The 10th (tenth) group is rainfall with smaller probabilistic, 10% of the total events. The 9th (nineth) group is rainfall with smaller probability, 20% of the total events and so on.decile level number 1 can be described as very very dry (much below the average), number 2 can be described as very dry (but less than number 1) and so on.

Table 2 Probability Groups and Deciles Level

Class	Probability (%)	Decile Levels
Extremely above the average	90 - 100	10
Very above the average	80 - 90	9
Above the average	70 - 80	8
Average	30 - 70	7 - 4
Below the average	20 - 30	3
Very below the average	10 - 20	2
Extremely below the average	0 - 10	1

Interpolation formula that is used for calculation decils presented as follows:

$$D = B_b + \left(\frac{1}{10}n - cf_b\right) \times i \quad \textbf{Equation 1}$$

Where:

D : Calculated deciles level
B_b : Lower threshold rainfall level that will be interplated
N : Number of data

cf_b : Cumulative frequency lower threshold
i : Rainfall deviation lower and upper threshold

3.2 Theory of Run Method

Adidarma (2015) explained that Run is a series of natural data that is above or below the threshold value, a calculation made based on the number of rows that are above the threshold (surplus) or below (deficit). The threshold is the nominal value of the data series (average or median) or it can also be a value that represents water requirements such as a probability of 10% or 20% not exceeded.

Yevjevich (1967) cited by Syahrial (2017) stated that the principle of theory of run calculation follows an univariate process. By determining the long-term monthly rainfall average as threshold values, the data series is cut in several places, giving rise to new variables. New definitions arising from these intersections produce variables such as:

a. Parts above the normal line (positive run), are called surplus.
b. Parts below the normal line (negative run), are called deficits.
1. The number of parts experiencing a continuous deficit is called the number of droughts in units of mm.
2. The duration or duration of the ongoing deficit is called the duration of drought in months.

4. RESULTS AND DISCUSSION

4.1 Yearly Drought Indications

Determination of drought by the decile method can determine the historical annual drought. Regions are categorized as drought if the analysis results are less than decile level 4or decile level below the lower threshold. The determination of the dry year in this analysis uses annual rainfall data. The results of the decile analysis show that during the period of 1995-2017 droughts have occurred 8 times, namely in 1996, 1997, 1998, 1999, 2001, 2009, 2011 and 2012. The worst drought occurs at decile level 1 or Extremely below the average class, namely in 1997, 1999 and 2001. The overall results of the drought analysis using the decile method is presented in Figure 3.

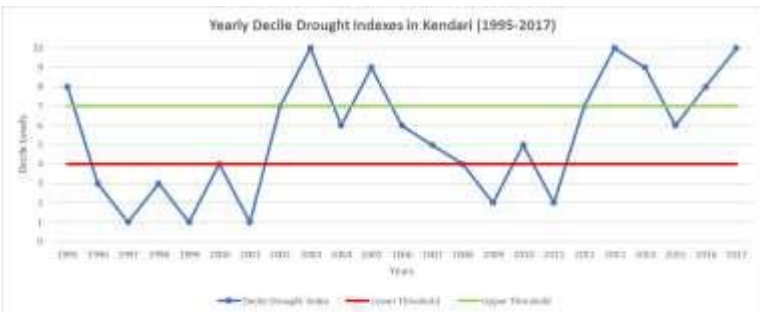


Figure 3 Yearly Decile Drought Indexes

Further analysis is done to find out when drought actually occurs in the area. The comparison of monthly rainfall and average monthly rainfall (Figure 4) shows that the years in lower threshold category are always below the monthly rainfall average.A comparison is also done between average monthly rainfall for all years and average rainfall in lower threshold years (1996, 1997, 1998, 1999, 2001, 2009, 2011 and 2012).Pattern which is formed between the two analytic data has similarities, where rain starts to rise in April to June, decreases from July to November and returns to the average values from December to March. The monthly rainfall conditions for the two analyzed data in August, September and October were less than 50 mm and the lowest occurred in September at 25 mm for All Years Data Available and 15 mm for the lower threshold years. The complete comparison, the two data can be seen in Figure 5.

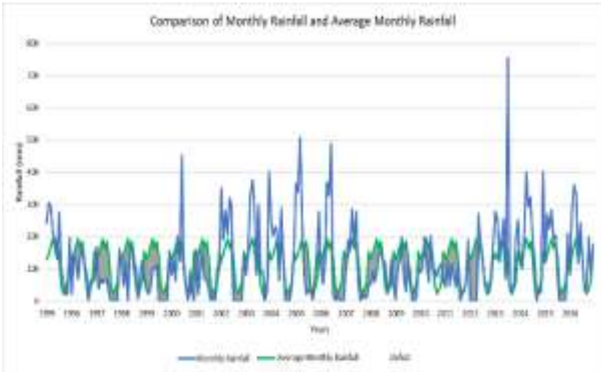


Figure 4 Comparison of Monthly Rainfall and Average Monthly Rainfall

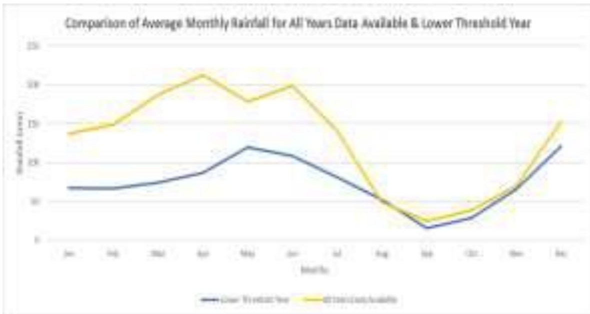


Figure 5. Comparison of Average Monthly Rainfall for All Years Data Available & Lower Threshold Years

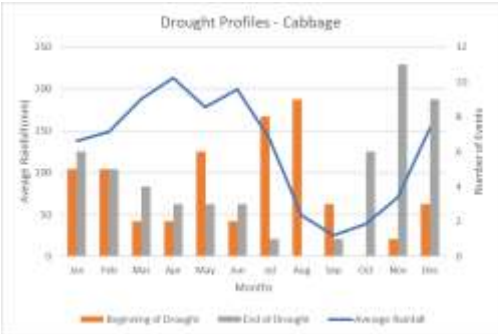
5. 4.2 Drought Duration and Intensity

Theory of Run method can determine the duration and intensity of drought based on the type of plant. Crop water needs are used based on FAO (1986) for cabbage, soybean and tomatoes. The crop water needs used in this simulation are assumed to be the biggest crop water needs with the longest planting time. For paddy and secondary crops, the crop water needs are used in accordance with the results of the study by Oldeman (1980). The summary of crop water needs that is used in this analysis can be seen in Table 3.

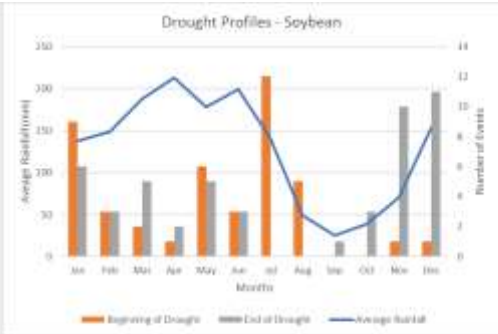
Table 3. Water Needs of Analysed Crops

No.	Crops	Total growing period (days)	Crop water need (mm/total growing period)	Crop water need (mm/days)	Crop water need (mm/months)
1	Cabbage	140	500	3.6	107.1
2	Soybean	150	700	4.7	140.0
3	Tomato	180	800	4.4	133.3
4	Secondary Crop				120.0
5	Paddy				220.0

Drought profiles can also be obtained from the analysis using theory of run method. The result is different for each crop. The comparison between drought profiles and the average monthly rainfall can help and simplify the determination of when these crops should be planted. Crops water needs are assumed to only be fulfilled from rainfall. In general, drought periods for those crops are July, August, September, October and November. Results of the analysis for each crop are presented in graphical form and presented in Figure 6.



(a)



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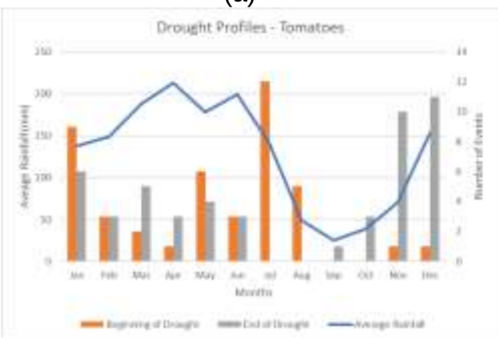

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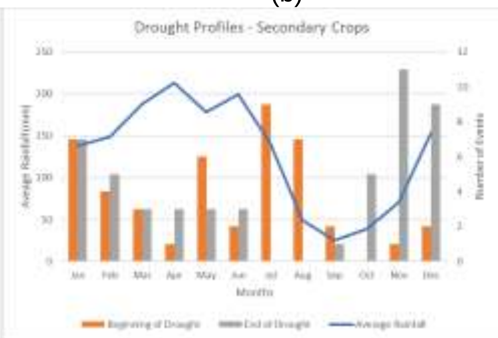

(d)

(e)

Figure 6. Drought Profiles of (a) Cabbage, (b) Soybean, (c) Tomatoes, (d) Secondary Crops and (e) Paddy

The level of frequency of the occurrence of drought can be described as a return period. In this study, only 2, 5, 10 and 20 years were calculated. The drought duration and drought intensity are directly proportional to crop water needs, the higher crop water needs (table 3), the longer the drought duration and the greater drought intensity. This can be proven by the shortest duration occurring is cabbage, while the longest duration is paddy. Then, this also applies to drought intensity.Soybean and tomatoes have coincided line ofthe return period of longest drought duration because the crop water needs are not much different. As aresult,it is not recommended paddy as crop for urban agriculture. Return period of longest drought duration and highest drought intensity for each crop can be seen in Figure 7and Figure 8.

Cabbage is considered the most suitable crop for urban agriculture because it has the lowest drought characteristics in terms of duration and intensity. Cabbage has drought duration for 6 months for return period of 2 years and 10 months for return period of 10 and 20 years. The drought intensity is 90.13 mm/month for return periods of 2 years and 107.10 mm/month for the return period of 20 years. To meet the shortage of known crop water needs from drought intensity, another water source is needed to fulfilit.

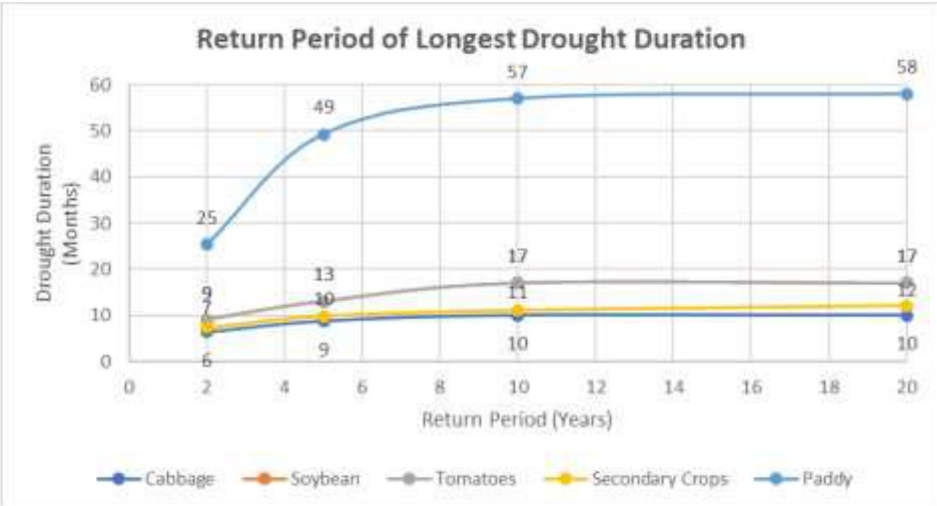

Figure 7 Drought Duration of Cabbage, Soybean, Tomatoes, Secondary Crops and Paddy

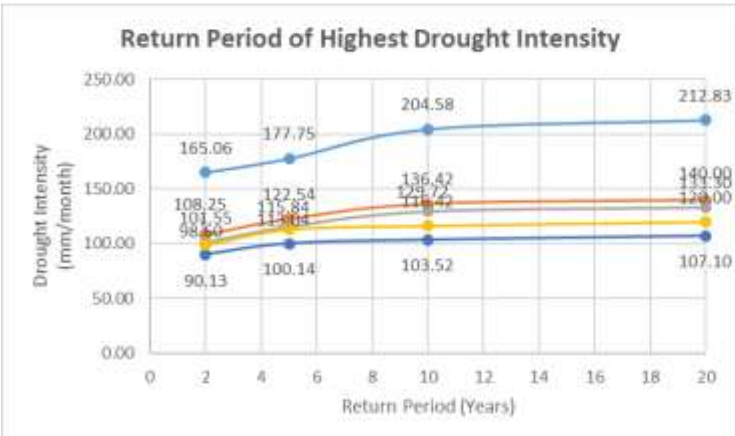

Figure 8 Drought Intensity of Cabbage, Soybean, Tomatoes, Secondary Crops and Paddy

6. CONCLUSIONS

In anticipation of drought, historical events of drought can be studied using the decile method. The determination of the dry year in this analysis uses annual rainfall data which shows that the drought occurred in 1996, 1997, 1998, 1999, 2001, 2009, 2011 and 2012. The worst drought occurs in 1997, 1999 and 2001at extremely below the average class.

Both decile method and theory of run method provide an indication that drought in the Wanggu Catchment Area occurs between July and November. Therefore, it is not recommended to carry out urban agriculture activities in that period.

The drought duration and drought intensity are directly proportional to crop water needs, the higher crop water needs, the longerthe drought duration and the greater drought intensity.

Cabbage is considered the most suitable cropof the five analysed crop, for urban agriculture because it has the lowest drought characteristics in terms of duration and intensity.

Urban agriculture can actually be done for all types of crops, but if the plant has large water needs and the catchment area cannot fulfil it, then another water source is needed and must be reconsidered for its economic aspects.

REFERENCES

Adidarma, W. K.2015.Model PendukungPenanggulanganKekeringanBerbasis Disaster Risk Management. Bandung: Pustaka Jaya.

Adidarma, W. K. &Putuhena, W.M.2013. PerubahanCiriKekeringanPertanian di PulauJawa. Bandung: Kolokium Hasil Penelitian 2012.

FAO (Food and Agriculture Organization). 1986. Irrigation Water Needs. Rome: FAO.

FAO (Food and Agriculture Organization). 2014. Growing Greener Cities in Latin America and the Caribebean. Rome: FAO.

FAO (Food and Agriculture Organization). 2017. Food for the Cities. Rome: FAO.

Hore, S.K., Werne, M. &Maskey, S. 2019. Effectiveness of Drought Indicators in Characterizing Past Drought in the North-Western Part of Bangladesh. Dhaka: International Conference on Water and Environmental Engineering (iCwee2019) 19-22 Jan 2019 Bangladesh

Gibbs, W.J. &Maher, J.V. 1967. Rainfall Deciles as Drought Indicators. Melbourne: Bureau of Meteorology Bulletin No. 48.

USAID (United States Agency International Development). 2017. LaporanPenilaianKetangguhan Kota Kendari. Kendari: USAID.

Syahrial, A. 2017. AnalisisKekeringanMenggunakanMetode Theory of Run di DAS Krueng Aceh. Jurnal Teknik Sipil Vol. 24 No.2 Agustus 2017 Halaman 167 – 172.

WFP (World Food Programme) Indonesia. 2017. Bulletin PemantauanKetahananPangan Indonesia FokusKhususTrenKonsumsi dan ProduksiBuah dan Sayur. Jakarta: WFP Indonesia.

WMO (World Meteorological Organization). 2016. Handbook of Drought Indicators and Indices. Geneva: WMO.