International Journal on
Advanced Science
Engineering
Information Technology

Vol.8 (2018) No. 6
ISSN: 2088-5334

Evaluation of Drought Vulnerability on Watersheds in West Sumatera Province by Using Cropwat-8 and GIS

Darwizal Daoed[#], Bujang Rusman[*], Bambang Istijono[#], Abdul Hakam[#], and Masril Syukur[#]

[#]*Civil Engineering Department, Andalas University, Padang, Indonesia*
E-mail: darwizaldaoed@ft.unand.ac.id; bistijono1452@yahoo.co.id; ahakam2008@yahoo.com; symasril@gmail.com

[*]*Agriculture Department, Andalas University, Padang, Indonesia*
E-mail: bujang rusman@yahoo.com

***Abstract*—Differences in temperature, duration of irradiation, wind speed, watershed shape, slope, and rainfall are the factors that determine the amount of evaporation and discharge flow also characterizing of the watershed. As noted, the difference between the maximum and minimum temperatures is over6^{o}C and the dry season happens mostly from May to October in West Sumatra Province each year. It, of course,will affect the magnitude of potential evapotranspiration and the minimum water flow that tend to decrease. Therefore, a particular evaluation of the impact of drought or susceptibility to water potential of the watersheds in the Areas of Akuaman River of West Sumatra should be undertaken. The methods used were the standard of Ministry of Forestry of Indonesia-the Agency for Research and Development of Forestry and the Center for Research and Development of Conservation and Rehabilitation 2012 and Arc-GIS-10.3 software to determine the index of vulnerability to drought and Cropwat-8to calculate evapotranspiration by Penman-Monteith method. The evaluation results show evapotranspiration value was 5.32 mm / day, 161.7 mm / month and the category of susceptibility tended to be medium and somewhat vulnerable. A review of the aspect of service levels of the use of water and minimum specific discharge is seen that in small watersheds $(A \leq 100\ km^2)$ is more susceptible to get drought than larger basins. It is therefore suggested to stakeholders to consider the possibilities for watershed integration as a solution to improve water supply for irrigation.**

***Keywords*— characteristics; drought vulnerability; watersheds; GIS.**

I. INTRODUCTION

Evaluation of watershed characteristics against drought is one of the indicators to determine the basin typology[1]. It also shows the possible water that can be provided by the watershed and drought vulnerability [2],[3],. The level of water drought the potential of the watershed is affected by several parameters: annual rainfall, annual evapotranspiration, the number of dry months for a year, geological factors and water use index as well as specific minimum water discharge. For instance, the result of the evaluation of potential water vulnerability in Tuntang Hulu Basin in Java Island≤ 3.0 [4]. In China that has smaller rainfall and lower temperature in the subtropical area provides very different evapotranspiration values, 0.4- 6.9 mm/day. In addition, the maximum values occurred in the summer season (May, June,and July).

Delay of planting time or shifting cropping patterns leads to an increase in the required water[5]. One of the factors that cause increased water demand is a potential evapotranspiration problem[6]. In addition, with the increasing population, industry, agriculture and plantation factors will also increase water demand[7],[8].

Based on aspects of the plant, the lack of water can disrupt the process of photosynthesis, although the different type of the plant will give various water stress[9]. However, the response does not occur vastly because there are other parameters, such as soil humidity, the plant adaptation, topography or slope.

The global climate change phenomenon makes unpredictable events occur, such as a rainstorm, flood and dry season, rainy season, up and down the temperature of seawater, evaporation, etc., that is often called El Nino or La Nina. They are two different events, in which El Nino more tends to give an impact in the dry season or decrease the rainfall, while La Nina tends to occur in wet season or increase the rainfall[10]. El Nino ever occurred in 1997 and 2015 through countries in Southeast Asia including Indonesia. The impact in Indonesia could be felt in the entire territories of Indonesia, including Sumatera that is in the west. The result of the topography of West Sumatera on the lack of water shows El Nino in 2015 really endanger not only farmers but also other aspects which need river water discharge[11].

Since the influence of climate change is the tremendous unusually dry season, thus it needs to be studied in order to anticipate the adverse impact that can occur later.One of them is a drought that will have an impact on yields and region [3],[12]. Therefore, the engineering in improving the water demand need to be done. One of the attempts is to do a study about the characteristics of the watershed on drought or water potential in Akuaman river, West Sumatera by using natural and management parameters approach.

A. Watershed Characteristics

Characterization can be defined as an activity or character formation process, whereas characteristic is a distinctive quality.Hence, the characteristics of the watershed are typical features of the watershed which are characterized by several parameters: morphometry, topography, soil, geology, vegetation, land use, hydrology, climatology, and humans. In order to obtain the characteristics of a watershed or a sub-watershed,it is required away or procedure that is arranged in a formula as a basis for carrying out the whole character formation process of the watershed[1].

B. Drought Vulnerability Analysis Model

Drought susceptibility analysis models or water potentials are analyzed from watershed parameters: water use index, geological conditions, rainfall in dry and rainy seasons, evapotranspiration and specific flow rate. The following schematic analysis of drought vulnerability is illustrated in figure 1,Model analysis of vulnerability to drought.

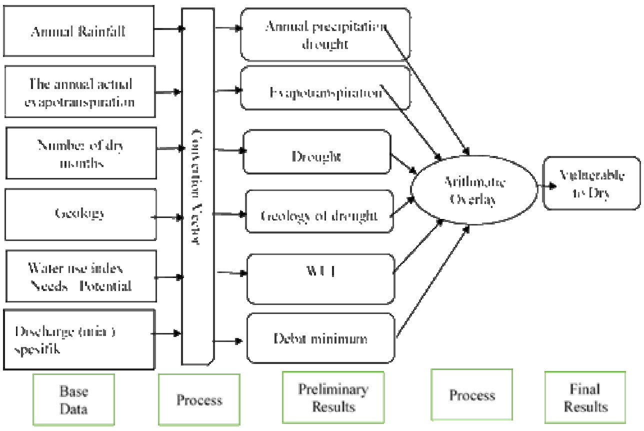

Fig. 1 Model analysis of vulnerability to drought [1]

The determination of drought formulation and water potential is based on natural parameters such as: (1) annual rainfall, (2) annual actual evapotranspiration, (3) dry months, (4) geology, and parameters related to management aspects: (5) water requirements (water use index), and (6) annual specific minimum discharges.

There are two parameters in the management aspect, namely the water usage index (WUI) and minimum water discharge specific. WUI is the ratio of the water requirement $(m^3/s)$to the potential of the watershed (m^3/s). The specific minimum discharge is the minimum water flow (m^3/s)divided by the area of the catchment area(km^2).

C. Formulation of Drought Vulnerability

In determining the level of susceptibility to drought, the qualitative to quantitative approach is done by converting the weighting of each parameter. The weighting is adjusted to the magnitude of their respective effects on the drought [1]. The weight of each parameter is obtained as the table I Formulation of Drought Vulnerability below:

TABLE I
FORMULATION OF DROUGHT VULNERABILITY [1]

No.	Parameter	Weight (%)
A.	Nature (60%)	
a.	Annual precipitation (mm)	20
b.	Annual evapotranspiration (mm)	17.5
c.	Number of dry months	12.5
d.	Geological factors	10
B.	Management (40%)	
a.	Water requirements (Water Usage Index)	25
b.	The minimum specific discharge	15

Furthermore, total natural parameters are summed with total management parameters or:

$$IN = IK_A + IK_B \tag{1}$$

IN = value of drought vulnerability
IK_A = valunerability index of nature
IK_B = valunerability index ofmanagement

D. Potential Evapotranspiration (ETo)

In determining the value of susceptibility to drought, the rate is by annual evapotranspiration (mm). The Penman equation has derived this formula since 1965, and the equation undergoes a change which is a collaboration, now, called the Penman-Monteith equation, which can be expressed as the daily value of evaporation as follows:

$$ET_o = \frac{\Delta(R_n - G) + \left[86{,}400 \frac{\rho_a C_p \left(e_s^o - e_a\right)}{r_{av}}\right]}{\Delta + \gamma\left(1 + \frac{r_s}{r_{av}}\right)} \tag{2}$$

The above equation is then updated and recommended by FAO[13], [14]into the Penman-Monteith FAO-56 equation, which simplifies the above equation by utilizing some fixed parameters assumed for reference cropped grasses. It is assumed that the definition for a reference plant is a hypothetical reference plant with a plant height that is 0.12 m, a fixed surface resistance, that is 70 sm-1 and an albedo value (i.e., light section reflected by the leaf surface) that is 0.23[15], the new equation is:

$$ET_o = \frac{0{,}408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0{,}34\, u_2)} \tag{3}$$

where :
ET_o = reference evapotranspiration rate (mm/day)
T = mean air temperature(°C)
u_2 = wind speed (m/s), and
R_n and G terminologies are stated in (MJm^2/h)

E. *Classification of Drought Vulnerability Level*

Drought is classified into five (5) categories in which each category is scored from 1 to 5. The value of the interval of each group is derived from the difference of highest score with the lowest score divided by the number of many categories[16]. In the table, the following classification of typology or vulnerability of drought shows the values of the interval of each group.

TABLE II
CLASSIFICATION OF TYPOLOGY OR VULNERABILITY OF DROUGHT [16]

Category	**Interval values (*IN*)**	**Level of vulnerability**
Very high	$IN \geq 4.2$	Very vulnerability
High	$3.4 \leq IN < 4.2$	Vulnerability
Average	$2.6 \leq IN < 3.4$	Medium
Low	$1.8 \leq IN < 2.6$	Rather
Very Low	$IN < 1.8$	Not vulnerable

II. MATERIAL AND METHOD

A. *Area of Study and Climatology*

The study was done in the river area that is in West Sumatera Province – Indonesia. West Sumatera Province is an area in the west of Sumatera which has really steep to sloping topography . The hills expand from the north to the south and make it divided into two parts, namely East and West. This region also has a bumpy area in the headwater and flat in the seashore area. Hence, the watersheds are formed with various areas.

This region has 29 watersheds and sub-watersheds dominantly drain the water from East to West. The watersheds relatively have oval and parallel shape [17]. Climatologically, this area has a reasonably high rainfall that is more than 3500 mm / year, monthly rainfall more than 250 mm/month and the number of the rainy days over 130 days in a year [16]. The rainy season occurs between November to April and the dry season between May to October with temperatures between $(21 - 33)°C$.

The data used were the observation of rainfall from 1970 to 2014 and the evapotranspiration from 2005 to 2014. From this study, it is expected that it is an input for the decision maker in managing and improving the use of water.

B. *Classification of Drought Vulnerability*

In this study, the determination of the classification of drought susceptibility was done by qualitative approaches such as watershed shape was changed to quantitative by giving weight and score of each parameter. For rainfall, the annual average from 1970 to 2014was used. Monthly data were from 2005 - 2014. The value of susceptibility index was obtained from the number of fundamental parameters with management after multiplying with the weights. The weight was determined from the results of previous research, and it can be a standard for Forestry Ministry of Indonesia-the Agency for Research and Development of Forestry and the Center for Research and Development of Conservation and Rehabilitation 2012. Furthermore, the drought vulnerability index was calculated, and its classification was based on Table II, Classification of typology or vulnerability of drought. All calculations used Arc-GIS -10.3 software by the base map from Geospatial Information Agency of Indonesia and to determine the magnitude of evapotranspiration or evapotranspiration was performed by using Penman-Monteith method which was processed by using the Cropwat-8 software. Moreover, to get an overview of the future, simulations will be conducted in 2024 and 2034.

III. RESULT AND DISCUSSION

Annual daily rainfall data were obtained from 10 rainfall observation stations in West Sumatera. The maximum annual daily rainfall of all observation stations was obtained more than$3,500\ mm/year$, and monthly it was over$250\ mm/month$. Also, the number of rainy days was over $120\ days$. This area has no monthly rainfall which is smaller than$100\ mm/month$ during one year of the observation. This means that this watershed does not have the dry month required for two months in a year.

A. *Potential evapotranspiration (ETo)*

From the temperature data, it was obtained that the average of the difference between a maximum and minimum temperature as $6\ °C$,and humidity was relatively high that the average was 97% and radiation time was approximately 12 hours in a day.The output of Cropwat software gave the average of ET_0value $5.32\ mm/day$ converted to monthly $161.7\ mm/month$. It is evident that evaporation is quite high, with the average in a year was $1940.6\ mm/year$. The complete detail can be seen in tableIII Result of evapotranspiration calculation (ET_0) with Cropwat – 8.

TABLE III
THE RESULT OF EVAPOTRANSPIRATION CALCULATION (ETO) WITH CROPWAT -8

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	22,8	29,8	98	5	12,0	27,2	5,45
February	22,8	25,6	97	5	12,0	28,1	5,25
March	25	30	97	5	12,0	28,4	5,77
April	24,4	30	97	5	12,0	27,5	5,59
May	24,9	30	97	4	12,0	26	5,27
June	24,5	29,7	97	4	12,0	25	5,03
July	21,7	29,6	96	5	12,0	25,4	4,90
August	21,6	29,4	97	4	12,0	26,7	5,12
September	21,8	29,6	97	4	12,0	27,9	5,50
October	21,8	26	97	4	12,0	28	5,21
November	21,7	31	97	5	12,0	27,3	5,38
December	21,9	30,9	97	5	12,0	26,8	5,33
Total							
Average	22,9	29,3	97,0	5	12,0	27,0	5,32

B. *Drought Vulnerability*

The drought vulnerability review was conducted in seven watersheds consisting of 3 large basins and 4 small basins, in which the wide of a small watershed was assumed smaller than $(100\ km^2)$. The assessment is based on Formulation of drought vulnerability, where the influence of natural parameter is 60%, and the influence of management is 40%.

From the calculation of the annual rainfall was obtained that the average of the rainfall in almost all places was $3500\ mm/year$, it means the vulnerability score was 1, the average of evapotranspiration was $5.32\ mm/day$.

Furthermore, the number of dry months almost never happened.It means that it was never dry for more than two months. Meanwhile, the geological values were varied which the magnitude was different for each watershed. In general, the geological data obtained are seen in .

From the geological map, the layer is dominantly formed by several types of stone, namely granite, andesite, and alluvium. The granite looks dark blue that is almost found along the seashore. To get the value of geology parameter is by calculating the percentage of the area of stone which is in the watershed, then it is turned into a value or score.

The calculations from the management aspect or the obtained water usage, the water use index and specific minimum water discharge were varied for each watershed which show the value of water use index in 2014, and it is estimated for 2024 and 2034 (10 years periods) by estimating the growth of the local population. The improvements in water use for households, offices, and industries need to be taken into account, whereas water needs for irrigation are considered fixed. In the table-IV, it can be seen the potency and demand of each watershed. The table-V Water usage index and figure 3, Map of water use index at a watershed – West Sumatra Province, show that the category value of each watershed ranging from deep (green color), average (yellow color) and very high (red color). The scale was gained by comparing the demand and the potency.

TABLE IV
POTENTIAL AND DEMAND OF WATER EACH WATERSHED

No.	Watersheds	Potential (m^3/s)	Demand (m^3/s) 2014	2024	2034
1	Antokan	27.67	14.41	14.54	14.57
2	Kuranji	8.77	4.65	6.06	6.48
3	Anai	28.75	9.52	9.63	9.66
4	Tiku	4.59	3.40	3.45	3.46
5	Gasan Gadang	0.34	1.53	1.54	1.54
6	Manggung	1.39	0.73	0.77	0.78
7	Sirah	0.57	0.94	0.94	1.02
8	Ulakan Tapakis	3.35	9.26	9.28	9.29

TABEL V
WATER USAGE INDEX

No.	Watersheds	Water Usage Index 2014	2024	2034	Category of value
1	Antokan	0.521	0.525	0.526	medium
2	Kuranji	0.530	0.690	0.739	medium
3	Anai	0.331	0.335	0.336	low
4	Tiku	0.739	0.751	0.753	medium
5	Gasan Gadang	4.500	4.524	4.529	very high
6	Manggung	0.521	0.551	0.558	medium
7	Sirah	1.650	1.650	1.789	very high
8	Ulakan Tapakis	2.762	2.768	2.770	very high

For specific minimum water discharge seen in table-VI, it shows that almost all watersheds gave a smaller value than $0.01\ (m^3/s/km^2)$. It explains that the value category for the specific (minimum) discharge is very high. It is pointed by red color in figure4.

TABLE VI
SPECIFIC MINIMUM WATER DISCHARGE

No .	Watersheds	Q specific-Min ($m^3/s/km^2$)	Category of value Paimin 2012	Kori 1976
1	Antokan	0.0052	very high	bad
2	Kuranji	0.0009	very high	bad
3	Anai	0.0022	very high	bad
4	Tiku	0.0035	very high	bad
5	Gasan Gadang	0.0004	very high	bad
6	Manggung	0.0022	very high	bad
7	Sirah	0.0013	very high	bad
8	Ulakan Tapakis	0.0011	very high	bad

The drought susceptibility value was obtained from the multiplication of each parameter by weight, and the total value was derived from the subtotal of natural values and management. In the table-VII Drought, the vulnerability index shows that the vulnerability value of each watershed was varied ranging from 2.53 to 3.28.

TABLE VII
DROUGHT VULNERABILITY INDEX

No.	Watersheds	Drought Vulnerability Index 2014	2024	2034	Level of vulnerability
1	Antokan	2.78	2.78	2.78	Medium
2	Kuranji	2.78	2.78	2.78	Medium
3	Anai	2.53	2.53	2.53	Rather
4	Tiku	3.03	3.03	3.03	Medium
5	Gasan Gadang	3.28	3.28	3.28	Medium
6	Manggung	2.78	2.78	2.78	Medium
7	Sirah	3.28	3.28	3.28	Medium
8	Ulakan Tapakis	3.28	3.28	3.28	Medium

C. Discussion

From the result of the evapotranspiration calculation, it looks quite high, $ET_0 = 5.32\ mm/day$ and monthly rainfall $167.2\ mm/month$. The research in the sub-tropical area (China) was the only 0.4-6.8 mm/day. The evapotranspiration is $2.6\ mm/day\ or\ 80\ mm/month$[18]. The research result in West Bangkala area of Jeneponto Regency is only 118.5 mm/month; this value was more significant [5]. It means the factor of evapotranspiration was getting more significant. It can be caused by a large number of the rainfall, the speed of the wind and longer radiation.

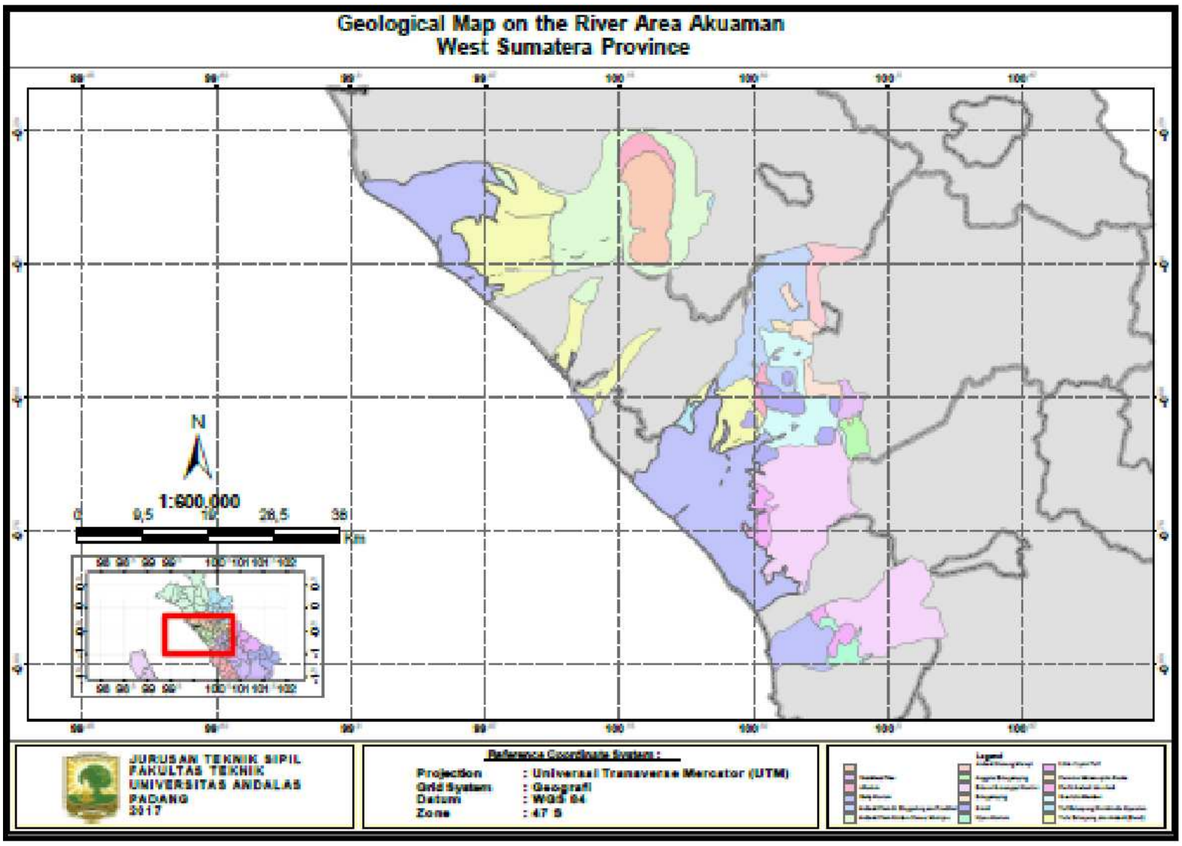

Fig. 2 Geological map of the river area Akuaman

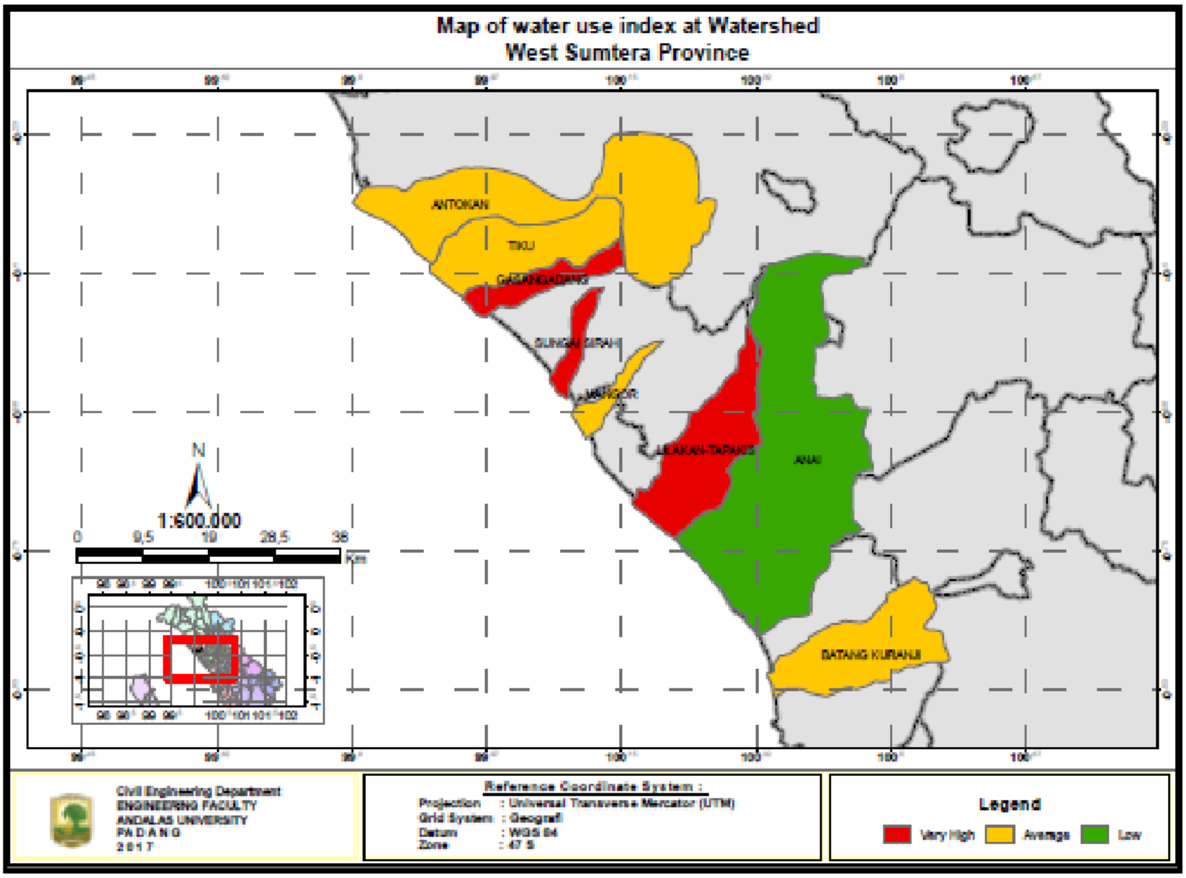

Fig. 3 Map of water use index at a watershed – West Sumatra Province

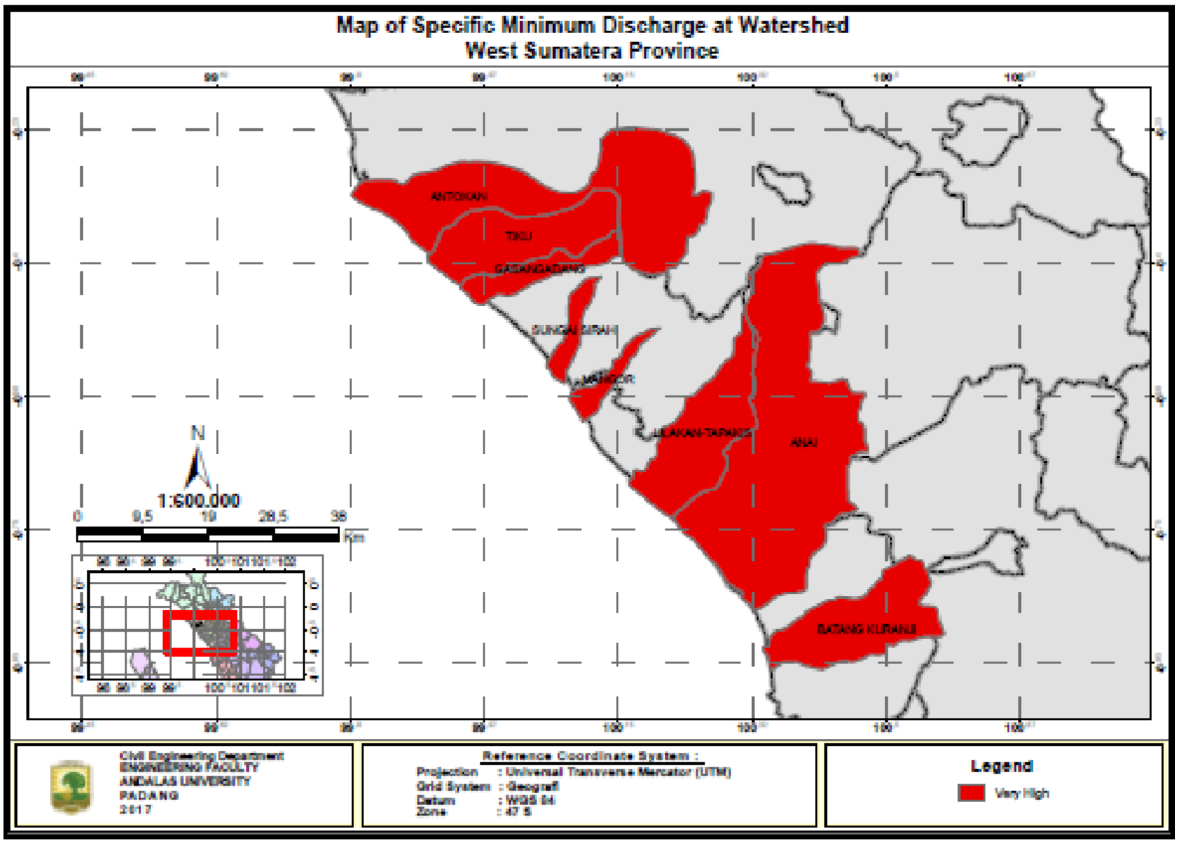

Fig. 4 Map of specific minimum discharge at watershed West Sumatra Province

The result of the water usage index shows that the ratio of the need for the water potential has the value smaller than one. It means that the watershed is able to fulfill its needs. In Table V Water usage index and figure 3Map of water use index at a watershed – West Sumatra Province, it shows that the large watersheds: Anai, Antokan, Kuranji dan Tiku were still able to fulfill the water demand. Meanwhile, the small watersheds: Gasan Gadang, Sirah dan Ulakan Tapakis were relatively unable to meet the water demand, except Manggung (Mangor) watershed. It can be seen from the value of water usage index bigger than one. Especially in Gasan Gadang watershed, it was susceptible to the drought.

When it is seen from the estimation results for 10 (ten) and 20 (twenty) years ahead, the index of water use is not very significant to give an effect on the vulnerability. The numbers of the drought vulnerability are between2.53 to 3.28. Although, the increase in irrigated rice fields has been raised (10%) ten per cent.

In contrast,as viewed from specific minimum discharge inTable VI that was obtained, almost all show a minimal value $(Q_s < 0.01\ m^3/s/km^2)$. It means this parameter gives a very high score, that is 5, and it is very susceptible to drought and considers that this condition is terrible. Especially for the small watersheds, namely Gasan Gadang basin obtained specific minimum water discharge,$Q_s = 0.0004\ (m^3/s/km^2)$.

Overall the degree of susceptibility to drought at the table-VII and figure 5 look almost level of similar for all watersheds, which is medium, except Anai watershed is slightly vulnerable. Figure 5 shows with an average category for the yellow colour and low for the green colour. So, it can be stated that the watershed in the river 'Akuaman' area was still considered quite good.

Also, after the estimation for the year 2024 and the year 2034,the condition of the watersheds still at the same level (medium). This is likely due to the increase in the population that occurs below 10%, and the pace of growth is also small. As a result, the increase in the water demand does not affect the water use index significantly in which the increase in water demand is between$(0.07 - 0.22\ m^3/s)$ in the period of 10 years.

IV. Conclusion

From the results and the discussion above it can be concluded: In Akuaman watershed, the level of drought susceptibility is generally still moderate with interval values (2.6-3.4), except Anai watershed which has the low category. For the small area of small watersheds, there is a tendency to provide the water use index values that are greater than the broad area of watersheds. Specific minimum water discharge on all watersheds is minimal. Thus it indicates a very-high value category that will contribute to increasing the higher value of drought vulnerability. The estimation of drought vulnerability until 2034 for all watersheds is still relatively similar to the previous year.

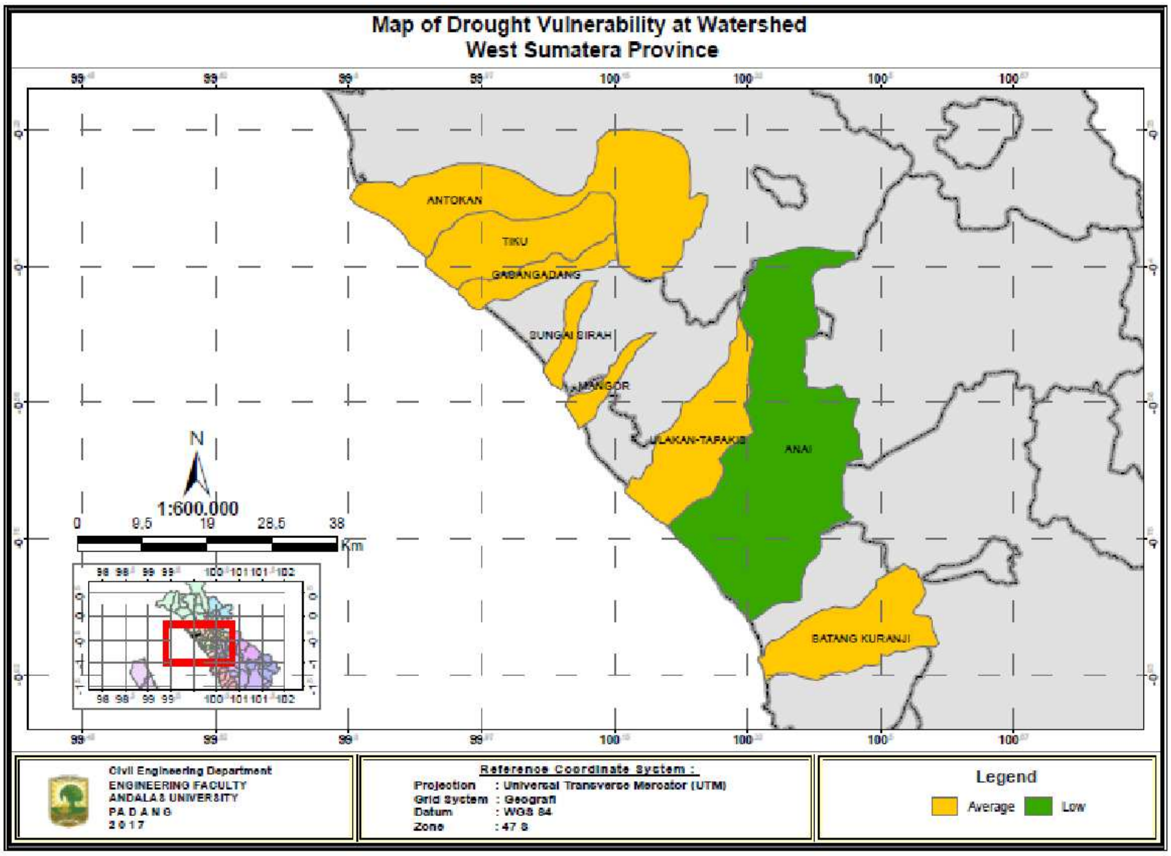

Fig. 5 Map of drought vulnerability at a watershed – West Sumatra

ACKNOWLEDGEMENTS

This research is funded by Andalas University through a grant from the Faculty of Engineering publication - Andalas University No. 024/UN.16.09. D/PL/2017 and I would like to thank the Vice Dean-1, Dean and the Rector for their help.

REFERENCES

[1]. Paimin, I.B.P., Purwanto, Dewi Retna I., *Watershed Management Planning System* (*Sistem Perencanaan Pengelolaan Daerah Aliran Sungai)*. Vol. -. 2013, Bogor Indonesia: Pusat Penelitian dan Pengembangan Konservasi dan Rehabilitasi (P3KR). 100.

[2]. Wu, Huo, Hui Qian, Jie Chen, Chenchen Huo, *Assessment of agricultural drought vulnerability in the Guanzhong Plain, China.* Water resources management, 2017. 31(5): p. 1557-1574.

[3]. Kamali, B., Abbaspour, Anthony Lehmann, Bernhard Wehrli, Hong Yang, *Spatial assessment of maize physical drought vulnerability in Sub-Saharan Africa: Linking drought exposure with crop failure.* Environmental Research Letters, 2018.

[4]. Paimin, P., Murtiono, U. H., Wuryanta, A., *Integrated Watershed Management Planning as a Base for Increasing Food Security in the Tuntang Watershed* (*Perencanaan Pengelolaan DAS Terpadu Sebagai Basis Peningkatan Ketahanan Pangan di DAS Tuntang)*. 2011, BPTKPDAS Bogor, Indonesia.

[5]. Sahindomi Bana, S.P., Ariffin, Soemarno *Evaluation Crop Water Requirement on the Dryland at the West Bangkala Sub District of Jeneponto Regency* International Journal of Ecosystem 2013.: p. 7.

[6]. Ministry, P.W., *Irrigation Planning Criteria Standards*, in *KP-01*, D.G.o.W. Resources, Editor. 2010, -: Jakarta.

[7]. Nurhamidah, N., Rusman, B., & Istijono, B. (2018). A Raster-based model for flood inundation mapping on delta lowland. In MATEC Web of Conferences (Vol. 229, p. 03012). EDP Sciences.

[8]. Rusman, B., Agustian, Aprisal, Syafrimen Yasin, *Andisols Water Retention Under Peasant Oil Palm Plantation.* International Journal on Advanced Science, Engineering and Information Technology, 2018. 8(1): p. 280-284.

[9]. Nasiri Mehdi, Davoud Zarehaghi, and M.R. Neyshabouri, *Some Weeds Community Percent in Response to Pumice Application on Soil under Water Stress Conditions* IJASEIT, 2016. 6 No. 2(-): p. 6.

[10]. Fitria Welly and M.S. Pratama, *The effect of1997 El Nino and 1999 La Nina Phenomena on Rainfall in Biak.* Jurnal Metorologi Geofisika, 2013. 14 No. 2: p. 10.

[11]. Herdianto Revalin, Elvi Roza Syofyan, Suhendrik Hanwar, Bambang Istijono, - Dalrino., *The Investigation of 1997 and 2015 El Nino Events in West Sumatera, Indonesia* IJASEIT, 2017. 7 No. 2(El Nino): p. 6.

[12]. Ahmadalipour, A. and H. Moradkhani, *Multi-dimensional assessment of drought vulnerability in Africa: 1960–2100.* Science of The Total Environment, 2018. 644: p. 520-535.

[13]. Allen, R.G., Luis S. Pereira, Dirk Raes, Martin Smith, *Corp evapotranspiration : guidelines for computing crop water requirements Food and Agriculture Organization of the United Nations, Rome.* 1998.

[14]. Valiantzas, J.D., *Simplified forms for the standardized FAO-56 Penman–Monteith reference evapotranspiration using limited weather data.* Journal of Hydrology, 2013. 505: p. 13-23.

[15]. Allen, R.G., et al., *A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method.* Agricultural Water Management, 2006. 81(1-2): p. 1-22.

[16]. Daoed Darwizal, Bambang Istijono, and A. Hakam., *Predictions of Vulnerability Flood and Flood Prone Areas in Watershed West Sumatra Province using Arc-GIS and Category Value.* International Journal of Earth Sciences and Engineering, 2016. 09 SPL No 03(3rd International Conference on Earth Sciences and Engineering (ICEE 2016) 17th-18th June, 2016): p. 274-279.

[17]. Daoed Darwizal, Bambang Istijono, and A. Hakam. *Integration of Small Watersheds to Meet Water Needs Using Supplemental Channels*(*Integrasi Daerah Aliran Sungai Kecil untuk Memenuhi Kebutuhan Air Menggunakan Saluran Suplesi)* in Pertemuan Ilmiah Tahunan HATHI 31. 2014. Padang: HATHI Pusat.

[18]. Hussein I. Ahmed, J.L., *Evaluating Reference Crop Evapotranspiration (ETo) in the Centre of Guanzhong Basin — Case of Xingping & Wugong, Shaanxi, China.* Engineering Scientific Research, 2013. 5(Crop Evapotranspiration): p. 9.