International Journal of Multidisciplinary and Current Educational Research (IJMCER)
ISSN: 2581-7027 ||Volume|| 4 ||Issue|| 6 ||Pages 46-54 ||2022||

Mapping of Drought Vulnerability in the Saba Watershed based on AHP-GIS

[1,] I Gusti Agung Putu Eryani, [2,] Made Widya Jayantari
[1,] Civil Engineering Department, Warmadewa University, Terompong Street No.24, Denpasar, Bali, 80239
[2,] Civil Engineering Department, Udayana University, Kampus Unud Jimbaran Street, Badung, Bali, 80361

ABSTRACT : Water availability is currently declining in the Buleleng Regency's Saba watershed. The Saba watershed, on the other hand, is widely used for raw water and irrigation water. Determining the impact of climate change on the level of drought vulnerability and mapping drought vulnerability in the Saba watershed are therefore necessary. This can then be used as a reference in developing sustainable water resource management patterns for the Saba watershed. This research begins with the preparation of data for each parameter of drought vulnerability estimation. The parameters used are five, namely average annual rainfall (mm/year), temperature (^{o}C), soil type, land use, and elevation. Each parameter is divided into five classes and given a score for each class. A review of the literature was conducted to determine the level of influence of these parameters on drought vulnerability. The level of drought vulnerability for each condition was examined in four different scenarios. Using the mean annual rainfall and mean temperature in scenario 1, the minimum annual rainfall and maximum temperature in scenario 2, the minimum annual rainfall and mean temperature in scenario 3, and the mean annual rainfall and maximum temperature in scenario 4. Based on the analysis, it can be seen that the Saba Watershed will become more vulnerable to drought if rainfall decreases and temperatures rise.

KEYWORDS: Drought, Vulnerability Watershed, AHP-GIS.

I. INTRODUCTION

A watershed is a naturally occurring water system component that is created when water passes through a river and its tributaries. The watershed is divided into three sections: upstream, middle, and downstream [1]. Due to various issues with watershed management, including deforestation, silting of river flows, landslides, erosion, and changes in land use that have an impact on changes to critical land, watershed performance is currently beginning to deteriorate [2]. Hydrological disasters like floods in the rainy season and drought in the dry season may become more frequent as a result of changes to critical land [3]–[5].

Droughts are climatic disasters that occur on a global scale, with varying frequency and intensity. Droughts have a significant impact on water availability as well as agricultural, economic, environmental, and socio-economic activities. The drought poses a threat to regional food, ecological, and economic security in particular. Due to climate change and an increase in the demand for water for human activities, drought occurrences and the severity of these effects will, as predicted, be greater in the upcoming years [6][7][8].Water discharge tends to be reduced in almost every irrigation area before the rainy season ends, which is an indication that watersheds have sustained significant damage. The Saba watershed is located in Buleleng Regency. There is a risk of drought in the Saba watershed, which is currently used for raw water and irrigation needs, as a result of the agricultural and irrigated land there and the continued rise in water demand brought on by the population growth.Effective drought management can reduce the overall effects of droughts on people, the economy, and the environment. Effective drought management includes the creation and prompt application of drought mitigation strategies. Planning and implementing drought strategies require spatial information about the causes of droughts, vulnerable areas, and levels of vulnerability. A framework for locating, processing, and analyzing pertinent factors that because drought is provided by drought vulnerability mapping.Determining the impact of climate change on the level of drought vulnerability and mapping drought vulnerability in the Saba watershed are therefore necessary. This can then be used as a reference in developing sustainable water resource management patterns for the Saba watershed.

II. RESEARCH METHODS

Study Area : The Saba Watershed is located in the northern part of Bali Province, precisely at the geographical coordinates of 114^{o} 55' 13.08" and 115^{o} 7' 7.68" East Longitude and 8^{o} 10' 50.16" and 8^{o} 20' 5.64" South Latitude, as shown in Figure 1. The Saba watershed area includes five sub-districts consisting of 30 villages located within the administrative areas of Buleleng Regency (78% of the total area) and Tabanan Regency (22% of the total area) [9].

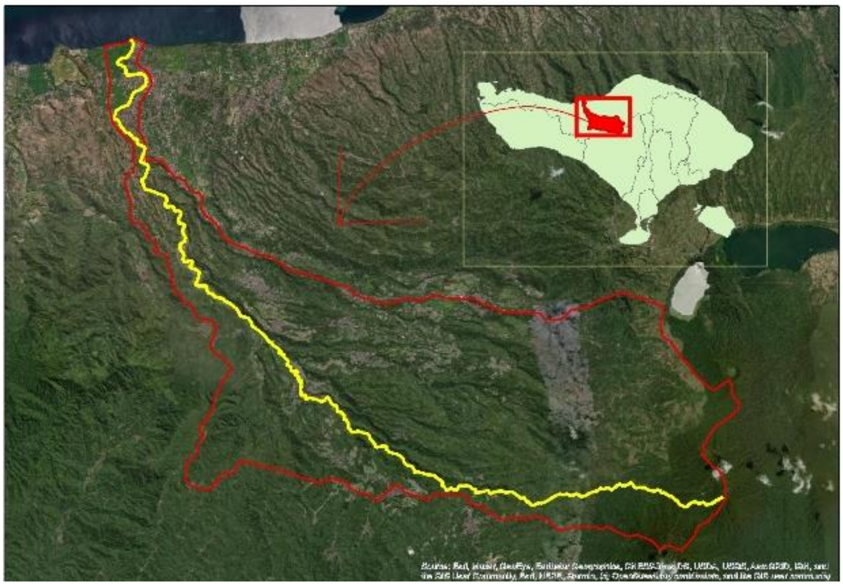

Figure 1. Saba Watershed

Research Data : Digital maps of watershed boundaries, the Saba River network, and land use that were obtained from the Bali-Penida BWS were used as secondary data in this study. Elevation data generated from the Digital Elevation Model or DEM data obtained from DEMNAS (https://tanahair.indonesia.go.id/demnas/#/). For analysis of rainfall and temperature data obtained from NASA POWER (https://power.larc.nasa.gov/data-access-viewer/), in the form of daily rainfall from 2001-2020, and monthly temperatures from 2001-2020. For the digital map of soil types, obtained from the digitization of the Bali soil type map by the Center for Environmental Research Udayana University.

Data Analysis Methods : This research begins with the preparation of data for each parameter of drought vulnerability estimation. The parameters used are five, namely average annual rainfall (mm/year), temperature (^oC), soil type, land use, and elevation. Each parameter is divided into five classes and given a score for each class. A review of the literature was conducted to determine the level of influence of these parameters on drought vulnerability. Then, from the literature review, the relationship of each parameter with the AHP analysis was compiled. In this AHP analysis, it is also ensured that the relationship between each parameter is consistent. After getting the weights, the weights are entered into a digital map and overlaid. After being overlaid, the score of each parameter is multiplied by its weight, and then the drought vulnerability value in the Saba watershed will be obtained. The flowchart of the research can be seen in Figure 2 and the score of each parameter can be seen in Table 1.

Table 1. Score of Each Parameter

Parameter	Class	Score
Annual Rainfall (mm/year)	<1000	10
	1000-1500	8
	1500-2000	6
	2000-2500	4
	>2500	2
Temperature (^{o}C)	28.5 - 29.2	10
	27.9 - 28.5	8
	27.2 - 27.9	6

	26.5 - 27.2	4
	25.8 - 26.5	2
Land Use	Irrigation	10
	Dryland Mixed Farming	8
	Settlement	6
	Bush/Open Land	4
	Water Body and Nature Conservation	2
Soil Type	Alluvial, Planosol, Hydromorph	10
	Latosol	8
	Timberland, Mediterranean	6
	Andosol, Lateritic, Grumosol, Podzol	4
	Regosol, Lithosol, Organosol, Renzina	2
Elevation (m)	1785.8 - 2233	10
	1338.6 - 1785.8	8
	891.4 - 1338.6	6
	444.2 - 891.4	4
	0 - 444.2	2

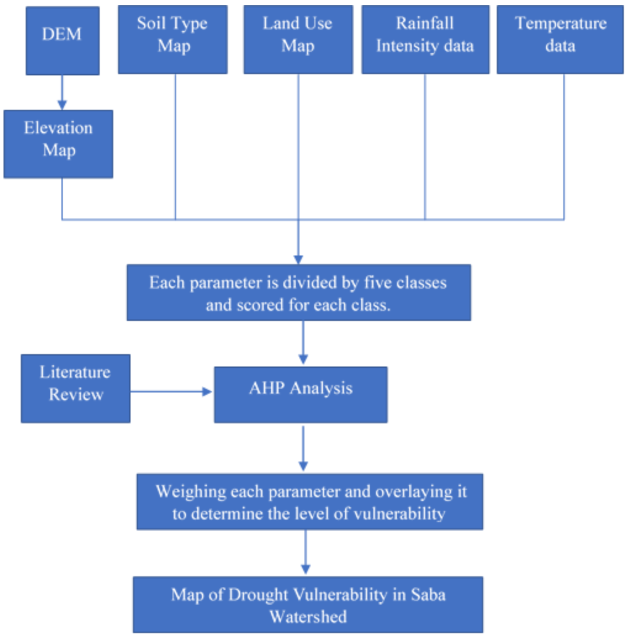

Figure 2. Flowchart of the Research

III. RESULT AND DISCUSSION

Annual Rainfall : Rainfall is one of the variables that can be used to forecast the occurrence of drought [7], [10], [11]. The lower the rainfall, the greater the potential for drought. For this annual rainfall parameter, it is divided into five classes: rainfall less than 1000 mm/year is given a score of 10, rainfall between 1000 and 1500 mm/year is given a score of 8, rainfall between 1500 and 2000 mm/year is given a score of 6, rainfall between 2000 and 2500 mm/year is given a score of 4, and more than 2500 mm/year is given a score of 2. According to daily rainfall data from 2001 to 2020, the average annual rainfall value in the Saba watershed is approximately 1730.57 mm/year, with a minimum annual rainfall value of 1240.69 mm/year and a maximum annual rainfall value of 3264.82 mm/year. The Saba watershed's annual rainfall varies from 2001 to 2020, with the largest variations occurring between the years 2010 and 2011 (a difference of 1024.52 mm/year), and 2011 and 2012 (a difference of -1818.57 mm/year). The annual rainfall data can be seen in Table 2 and the difference can be seen in Figure 3.

Table 2. Annual Rainfall in Saba Watershed

Year	Annual Rainfall (mm/year)	Year	Annual Rainfall (mm/year)	Year	Annual Rainfall (mm/year)	Year	Annual Rainfall (mm/year)
2001	1544.20	2006	1347.67	2011	3264.82	2016	2130.90
2002	1240.69	2007	1294.49	2012	1446.25	2017	2438.82
2003	1429.69	2008	1421.78	2013	2075.00	2018	1759.56
2004	1335.88	2009	1287.77	2014	1284.91	2019	1590.92
2005	1455.90	2010	2240.30	2015	1681.32	2020	2340.53
Min (mm/year)					**1240.69**		
Max (mm/year)					**3264.82**		
Average (mm/year)					**1730.57**		

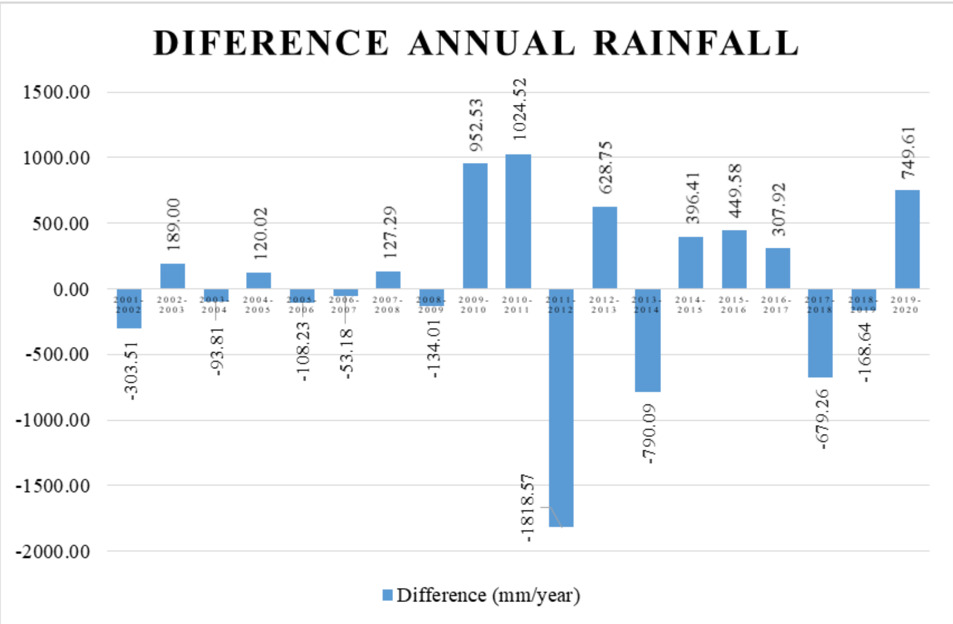

Figure 3. The trend of difference of annual rainfall from 2001-2020

Annual Average Temperature : Another factor that can be used to forecast the occurrence of drought is temperature [6], [12]. The evaporation process is accelerated by temperature, which can lead to faster water loss and dryness. The five classes of temperature parameters are as follows: temperatures between 25.8 ^{o}C and 26.5 ^{o}C get a score of 2, temperatures between 26.5 ^{o}C and 27.2 ^{o}C get a score of 4, temperatures between 27.2 ^{o}C and 28.5 ^{o}C get a score of 8, and temperatures between 28.5 ^{o}C and 29.2 ^{o}C get a score of 10. Temperature data from 2001 to 2020 show that the Saba watershed's average temperature is approximately 27.58 ^{o}C, with minimum and maximum values of 25.83 ^{o}C and 29.22 ^{o}C.

Land Use of Saba Watershed : According to Figure 4, the land use in the Saba Watershed consists of Dryland Forest with an area of 10.49 km^2 (8.1%), Settlement with an area of 5.71 km^2 (4.4%), Agriculture Land with an area of 93.33 km^2 (72.3%), and an irrigation area of 19.54 km^2 (15.1%). If not properly managed, the high demand for irrigation and agricultural water may result in sustained droughts.

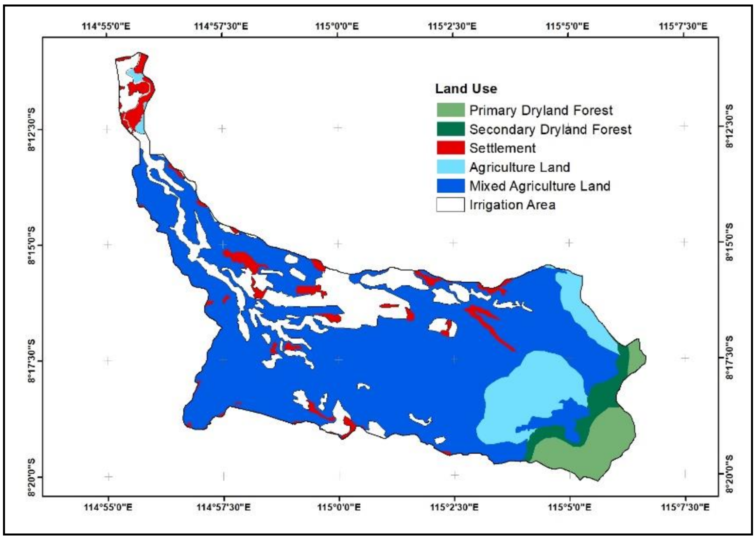

Figure 4. Land Use of Saba Watershed

Soil Type of Saba Watershed : According to Figure 5, the Latosol Yellowish Brown soil type dominates the Saba watershed with an area of 36.89 km^2 (28.15%). The soil types in the Saba watershed also include Brown Latosol and Litosol, which cover an area of 24.89 km^2 (19.00%), Gray Regosol, which covers 6.49 km^2 (4.95%), Andosol Gray Brown, which covers 30.50 km^2 (23.28%), and Reddish Brown Latosol and Litosol, which covers 32.27 km^2 (24.63%).

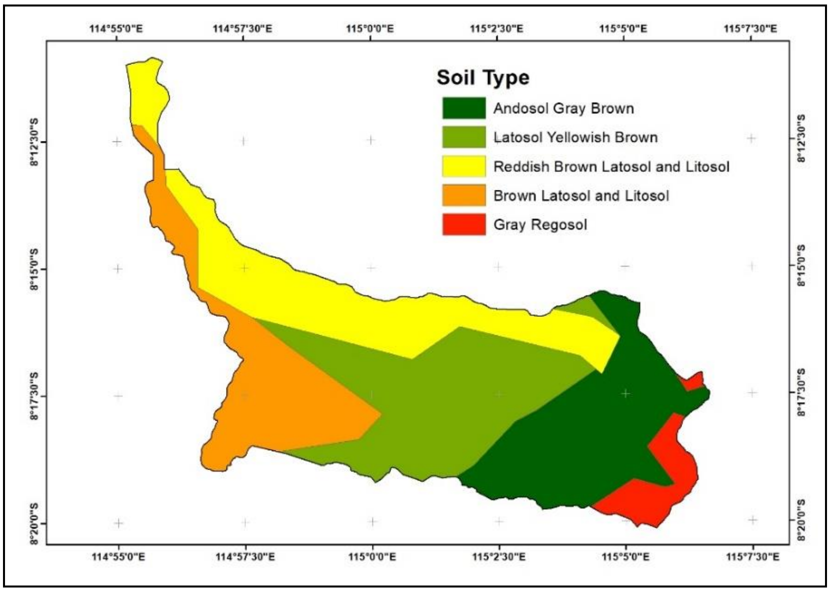

Figure 5. Soil Type of Saba Watershed

Topography of Saba Watershed : According to Figure 6, Saba watershed elevation dominant area ranging from 444.2 to 891.4 m with the area of 48.46 km^2 (37.49%). Other areas have elevations that range from 0 to 444.2 meters in an area of 44.46 km2 (34.40%), from 891.4 to 1338.6 meters in an area of 23.26 km^2 (18.0%), from 1338.6 to 1785.8 meters in an area of 11.26 km^2 (8.51%), and from 1785.8 to 2233 meters in an area of 1.82 km^2 (1.41%).

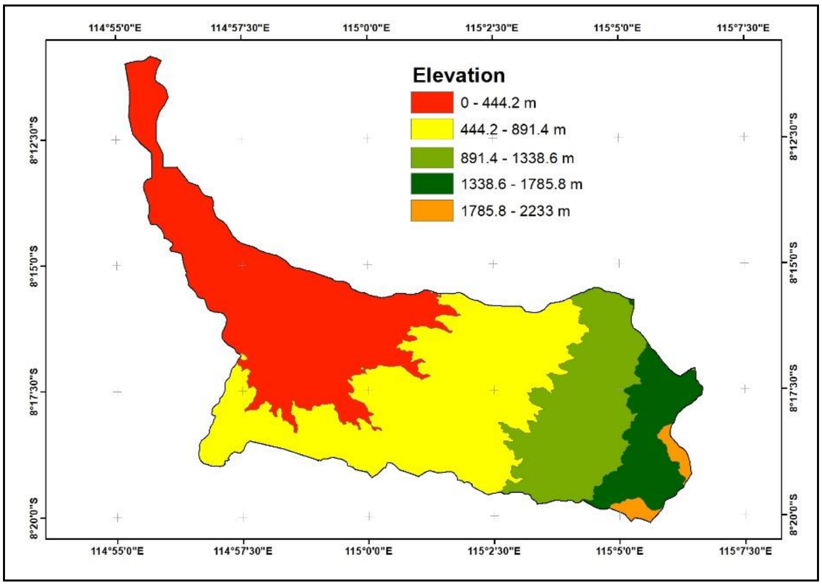

Figure 6. Topography of Saba Watershed

AHP Analysis : AHP analysis was performed by comparing each parameter with the weight of each. The relationship of each parameter can be seen in Table 3.

Table 3. Drought Parameter's Relationship

Indicator	Annual Rainfall (mm/year)	Temperature (°C)	Land Use	Soil Type	Elevation (m)
Annual Rainfall (mm/year)	1.00	1.00	3.00	3.00	5.00
Temperature (°C)	1.00	1.00	3.00	3.00	5.00
Land Use	0.33	0.33	1.00	1.00	3.00
Soil Type	0.33	0.33	1.00	1.00	3.00
Elevation (m)	0.20	0.20	0.33	0.33	1.00

Table 4. Drought Parameter's Weight

No	Parameter	Weight
1	Annual Rainfall (mm/year)	0.34
2	Temperature (°C)	0.34
3	Land Use	0.13
4	Soil Type	0.13
5	Elevation (m)	0.06
		1.00

AHP theory states that an indicator is consistent if the consistency ratio (CR) value is less than 0.1. In accordance with the results analysis, the CR value for the five parameters was 0.02, indicating consistency.

Drought Vulnerability Map of Saba Watershed : The level of drought vulnerability for each condition was examined in four different scenarios. Using the mean annual rainfall and mean temperature in scenario 1, the minimum annual rainfall and maximum temperature in scenario 2, the mean annual rainfall and maximum temperature in scenario 4, and the minimum annual rainfall and mean temperature in scenario 3. The drought vulnerability map for each scenario is shown in Figure 7–10. The percentage area of each level of drought vulnerability is also shown in Figure 11-14.In scenario 1, which assumes average rainfall and average temperature, the Saba watershed is 31% moderately vulnerable to drought and 69% highly vulnerable; if rainfall decreases and temperatures rise, these vulnerabilities rise to 69% very high and 31% high. Based on this, it can be seen that the Saba watershed will become more vulnerable to drought if rainfall decreases and temperatures rise.

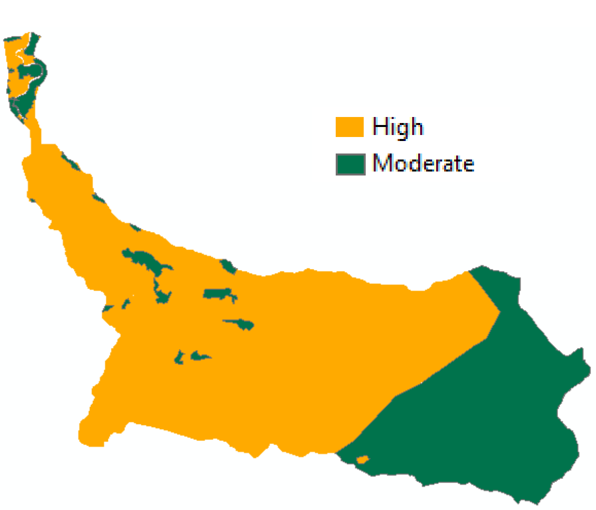

Figure 7. Drought Vulnerability Map Scenario 1

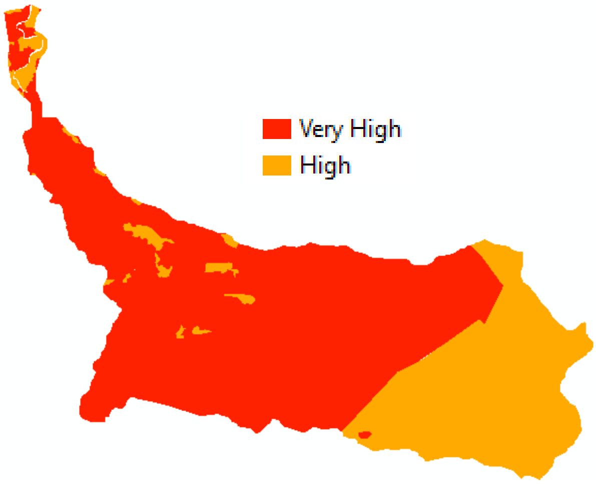

Figure 8. Drought Vulnerability Map Scenario 2

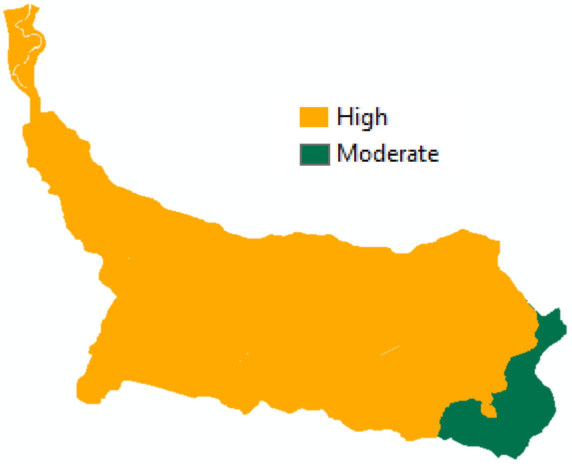

Figure 9. Drought Vulnerability Map Scenario 3

Figure 10. Drought Vulnerability Map Scenario 4

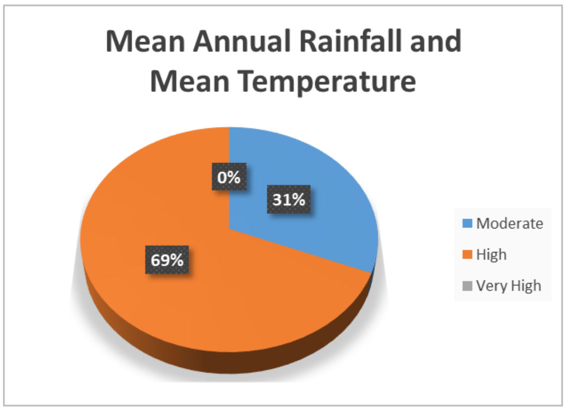

Figure 11. Drought Vulnerability Percentage Area of Scenario 1

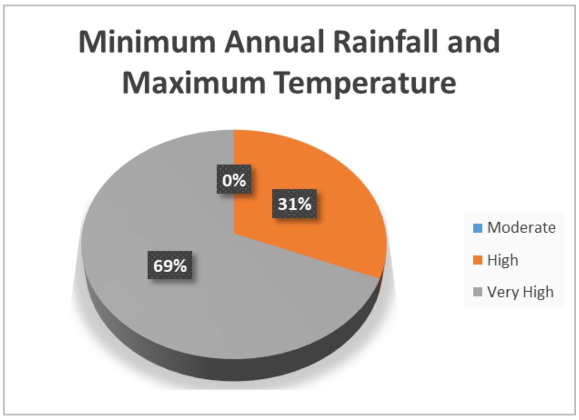

Figure 12. Minimum Annual Rainfall and Maximum Temperature

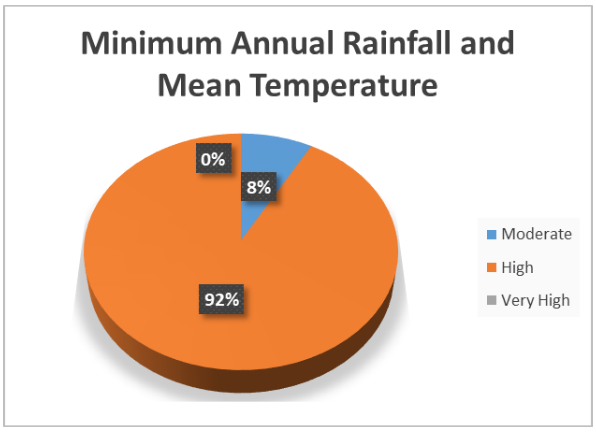

Figure 13. Minimum Annual Rainfall and Mean Temperature

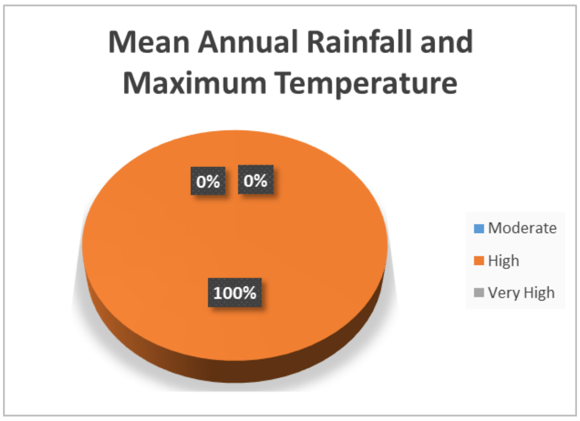

Figure 14. Mean Annual Rainfall and Maximum Temperature

.

IV. CONCLUSION

According to the result analysis it can be concluded several things as follows.

1. According to daily rainfall data from 2001 to 2020, the average annual rainfall value in the Saba watershed is approximately 1730.57 mm/year, with a minimum annual rainfall value of 1240.69 mm/year and a maximum annual rainfall value of 3264.82 mm/year
2. Temperature data from 2001 to 2020 show that the Saba watershed's average temperature is approximately 27.58 ^{o}C, with minimum and maximum values of 25.83 ^{o}C and 29.22 ^{o}C.
3. The land use in the Saba Watershed consists of Dryland Forest with an area of 10.49 km^2 (8.1%), Settlement with an area of 5.71 km^2 (4.4%), Agriculture Land with an area of 93.33 km^2 (72.3%), and an irrigation area of 19.54 km^2 (15.1%).
4. The Latosol Yellowish Brown soil type dominates the Saba watershed with an area of 36.89 km^2 (28.15%).
5. Saba watershed elevation dominant area ranging from 444.2 to 891.4 m with the area of 48.46 km^2 (37.49%)
6. It can be seen that the Saba watershed will become more vulnerable to drought if rainfall decreases and temperatures rise

REFERENCES

[1] Eryani I G A P and Jayantari M W, 2019 Water conservation model in Ayung river estuary based on ecotourism Water conservation model in Ayung river estuary based on ecotourism *J. Phys. Conf. Ser. Pap.* **1402**.

[2] Jayantari M W Wardoyo W and Maulana M A, 2019 Satellite data use in the WEAP Model as an evaluation of Water Availability in Unda River Basin *IOP Conf. Ser. Earth Environ. Sci.* **389**, 1.

[3] Hutauruk R C Alfiandy S Nainggolan H A and Raharjo M H F Y, 2020 GIS-based Flood Vulnerability Mapping Using Overlay Method in Central Sulawesi *Forum Geogr.* **34**, 2 p. 136–145.

[4] Giri S Lathrop R G and Obropta C C, 2020 Climate change vulnerability assessment and adaptation strategies through best management practices *J. Hydrol.* **580** p. 124311.

[5] Daba M H Bazi Z and Belay A, 2018 Effects of Climate Change on Soil and Water Resources: A Review *J. Environ. Earth Sci.* **8**, 7.

[6] Schilling J Hertig E Tramblay Y and Scheffran J, 2020 Climate change vulnerability, water resources and social implications in North Africa *Reg. Environ. Chang.* **20**, 1.

[7] Hoque M Pradhan B Ahmed N and Alamri A, 2021 Drought vulnerability assessment using geospatial techniques in Southern Queensland, Australia *Sensors* **21**, 20 p. 13–15.

[8] Kalura P Pandey A Chowdary V M and Raju P V., 2021 Assessment of Hydrological Drought Vulnerability using Geospatial Techniques in the Tons River Basin, India *J. Indian Soc. Remote Sens.* **49**, 11 p. 2623–2637.

[9] Setiawan B I Saptomo S K Chadirin Y Arif C Budiasa I W and Sutoyo, 2016 *A bit of the Saba Watershed, Buleleng* Bogor.

[10] Sivakumar V L Radha Krishnappa R and Nallanathel M, 2020 Drought vulnerability assessment and

mapping using Multi-Criteria decision making (MCDM) and application of Analytic Hierarchy process (AHP) for Namakkal District, Tamilnadu, India *Mater. Today Proc.* **43**, xxxx p. 1592–1599.
[11] Zagade N D and Umrikar B N, 2021 Drought severity modeling of upper Bhima river basin, western India, using GIS–AHP tools for effective mitigation and resource management *Nat. Hazards* **105**, 2 p. 1165–1188.
[12] Hettiarachchi S Wasko C and Sharma A, 2017 Increase in urban flood risk resulting from climate change – The role of storm temporal patterns *Hydrol. Earth Syst. Sci. Discuss.* p. 1–28.