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Original Article

Drought in West Sumbawa: Non-Structural Mitigation Efforts Through Mapping and Policy Recommendations

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ABSTRACT
This study aims to map the level of drought across sub-districts in West Sumbawa Regency. The research was conducted through several stages, including preparation, collection of both primary and secondary data, data processing, data analysis, and the development of a comprehensive assessment. The primary data required include the Normalized Difference Vegetation Index (NDVI) map, Normalized Difference Water Index (NDWI) map, Land Surface Temperature (LST) map, average Rainfall map, hydrogeological map, and land use map. The drought level mapping in West Sumbawa Regency was carried out using an overlay technique involving six parameters through remote sensing, which was subsequently processed using ArcGIS software. The results indicate that high to very high drought levels occur in Pototano, Brang Rea, and Jereweh sub-districts. The spatial distribution of drought levels can be utilized to establish priority areas, particularly Pototano, Sekongkang, and Jereweh sub-districts, in decision-making processes as part of drought disaster mitigation efforts and as an early warning measure to prevent more severe future impacts.

KEYWORDS
Drought; mapping; mitigation

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INTRODUCTION

Drought is a natural disaster closely linked to the hydrological functions of a region, characterized primarily by an increased demand for water and a decrease in water availability within a specific area over a certain period (Adam & Rudiarto, 2017). This understanding is supported by findings that droughts are primarily caused by a lack of water supply from clean water sources (Selvia et al., 2024). Four other factors influencing drought levels include physical environmental aspects such as surface temperature, Rainfall, land use, and slope gradient (Febriyanti, 2021). Drought is considered a complex and recurrent hazard

(Nuraimmatul & Buchori, 2019). The level of vulnerability is a key starting point and a crucial aspect in disaster risk assessment for a given area (Wibowo & Rahman, 2021). Regional vulnerability to drought is often associated with global climate change issues, which contribute to increasingly unpredictable weather patterns (Hidayanti & Suryanto, 2015). If prolonged, such conditions can significantly disrupt the activities of all living organisms (Sukmono et al., 2018). In Indonesia, drought disasters can hinder the agricultural sector and, in turn, impact the national economy (Mujtahiddin, 2014). Additionally, drought poses a threat to the daily water needs of communities and can harm the surrounding natural environment (Wardani & Nafiah, 2022). Furthermore, droughts may affect ecological, cultural, social, and even political conditions (Mathbout et al., 2018). The severity and frequency of drought events vary according to geographical location (Mohammed & Schloz, 2017).

According to the National Disaster Management Agency (BNPB), between January 1 and May 31, 2023, there were 1,675 hydrometeorological disaster events in Indonesia. Of these, more than 90% were wet hydrometeorological disasters, while approximately 7% were dry hydrometeorological disasters. West Nusa Tenggara (NTB) is one of the provinces frequently affected by natural disasters. BNPB recorded 71 disaster events in NTB in 2017, including floods (41), whirlwinds (14), droughts (9), landslides (6), and forest and land fires (1) (BNPB, 2018). In 2021, the Regional Disaster Management Agency (BPBD) of NTB reported that drought affected 151,444 households, threatening clean water availability and agricultural activities across nearly all districts and municipalities in the province, including West Sumbawa Regency. Furthermore, West Sumbawa Regency encompasses two strategic zones, including the Poto Tano–Alas–Utan agribusiness strategic area, which emphasizes fisheries, agro-industry, and tourism as leading sectors. According to BPBD disaster records in 2023, drought affected 11 villages across the sub-districts of Poto Tano, Seteluk, Taliwang, and Brang Rea. Therefore, it is imperative to implement adaptation and mitigation efforts to build community resilience, particularly in the agricultural sector and in ensuring access to clean water (Lon, 2015).

In recent years, during the dry season in West Sumbawa Regency, communities have increasingly reported water shortages in their areas. This has impacted daily activities, such as crop failure due to dried-out rice fields, disruption of the local water utility (PDAM), dust pollution from unpaved roads, and other related issues. Drought conditions have also consistently triggered forest and land fires, with one to three incidents reported annually during the dry season in West Sumbawa. Given these drought-related challenges, there is a pressing need for initial mitigation measures, such as vulnerability assessments based on accurate data and information, to help safeguard the basic needs and well-being of local communities (Prabowo, 2016). The results of such assessments are expected to assist both the public and local governments in identifying areas at risk of drought as a basis for developing drought disaster management strategies (Hastuti et al., 2017). The spatial assessment of drought levels in West Sumbawa Regency may serve as a fundamental reference for stakeholders in spatial planning, land use management, and the formulation of adaptation and mitigation strategies against drought disasters.

The lack of studies concerning drought vulnerability mapping is one of the key factors that hinders effective drought resolution. Thus, knowledge of drought-prone areas is essential for preventing the broader impacts of drought disasters. This research aims to identify the drought levels across West Sumbawa Regency, thereby providing a reference for planning and managing drought disaster responses in the region.

LITERATURE REVIEW

Drought in an area is caused by several factors. Studies related to drought in previous studies in the Inner Mongolia Region stated that the causes of drought include Rainfall, temperature, evapotranspiration potential, soil type and characteristics, land use, altitude and topography as well as climate variability and ENSO phenomena (Yang *et al*., 2021). In other regions such as China, it is known that the dominant factors in studies on drought using seasonal data from 1979-2018 include climate change factors, Rainfall, evapotranspiration and other meteorological factors (Wan *et al.,* 2023). Several studies on drought in Indonesia are known to come not only from meteorological factors, but also hydrological factors that are closely related to climate change (Sipayung *et al*., 2019)

Based on the causative factors, drought conditions are classified into 3 types, including meteorological drought, agricultural drought and hydrological drought. (a) Meteorological droughts are caused by weather and climate change factors such as a decrease in Rainfall over a certain period of time within a region (Inarossy et al., 2019). (b) Hydrological drought is caused by the availability of surface water and groundwater that cannot meet the demand for water in an area (Saidah et al., 2017). (c) Agricultural drought is caused by a decrease in soil moisture and a reduction in soil moisture levels so that plants on agricultural lands accompany the stress of water shortage. This causes impacts such as reduced agricultural production to crop failure These three types of drought have a multiplied impact, so they are often referred to as socioeconomic droughts. Less water availability will result in decreased agricultural production, increased demand for clean water, resulting in economic and social problems. The technology that can map the distribution of drought locations in an area is through the Geographic Information System (GIS) approach which uses remote sensing data. Remote sensing data is in the form of satellite imagery that is processed to evaluate drought conditions spatially.

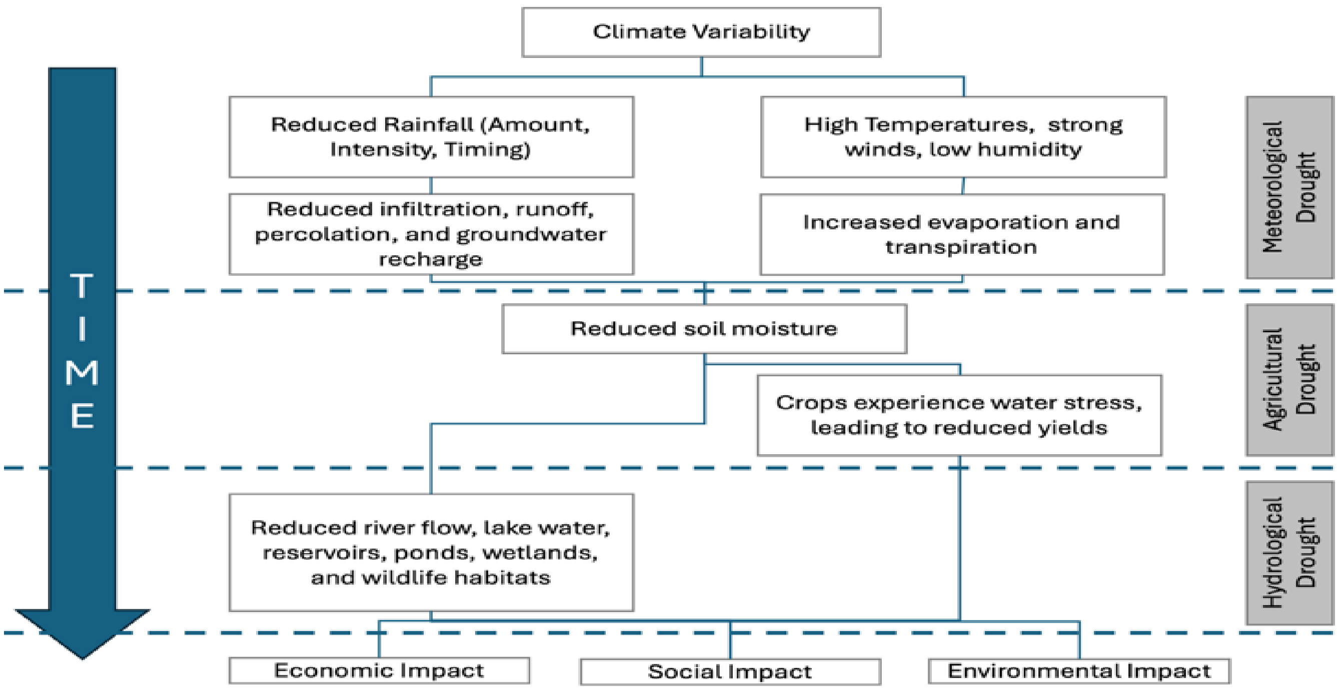

Figure 1. Drought Classification
Source: Hatmoko & Adidarma, 2014

METHOD

Research Location

This research is located in West Sumbawa Regency, as one of the nine districts/cities in the West Nusa Tenggara Province located at the western end of Sumbawa Island at the position 080 29' LS - 90 05' LS and 116042' - 117005' BT. Map of research location can be seen in figure 2. Based on Law Number 30 of 2003 concerning the Establishment of West Sumbawa Regency in West Nusa Tenggara Province is approximately 184,902 Ha (one hundred and eighty-four thousand Nine hundred and two hectares). West Sumbawa Regency consists of 8 sub-districts including: Sekongkang, Jerewh, Maluk, Taliwang, Brang Ene, Brang Rea, Seteluk and Poto Tano Districts. The sub-district with the largest area is in Jereweh District.

Research Procedure

This research consists of several stages, including 1) preparation stages; 2) the implementation stage and 3) the final stage. The preparation stage is carried out in the form of identification and formulation of problems to study the issues that occur in West Sumbawa Regency so that the goal is formulated to conduct a spatial analysis of the level of drought. Furthermore, in the preparation stage, a literature study was also carried out on the level of drought to capture some information about the definition of drought, classification or type of drought to methods in mapping drought. Then it was continued with the collection of data in the form of secondary data obtained from various related agencies and also primary data in the form of field observations and conducting *ground checks* for the accuracy of mapping (Rahman, 2024) drought in West Sumbawa Regency.

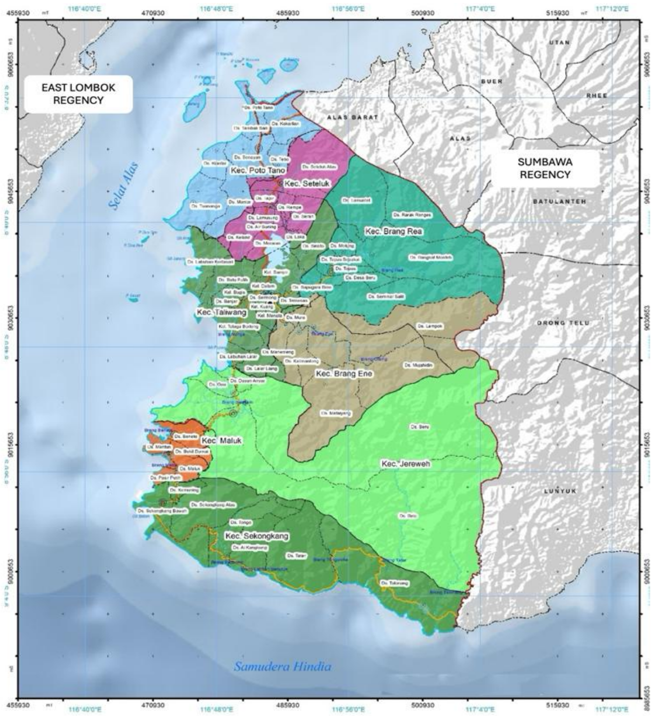

Figure 2. Research Location of West Sumbawa Regency

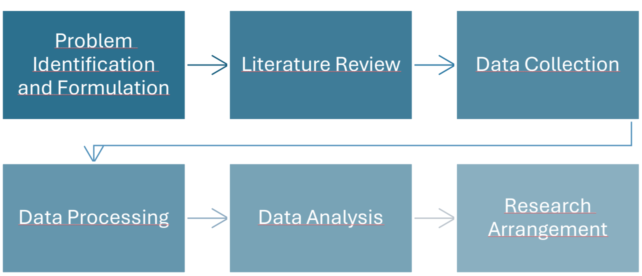

Figure 3. Research Stages

The second stage is the implementation stage, which consists of processing secondary data and primary data that has been obtained. Then it was followed by conducting image analysis (image transformation, overlay and scoring) using the Geographic Information System (GIS). The overlay process in mapping aims to combine the spatial elements contained in each parameter (Sianturi, 2023). Furthermore, the final stage is carried out by compiling various information obtained from the mapping results and describing the existing conditions regarding drought in West Sumbawa Regency.

Data Collection Instruments

The data needed in this study consists of primary and secondary data. Primary data was obtained through interviews with several related agencies and *ground checks* (field observations) as part of the satellite image data validation process. Secondary data consists of Landsat 8 Oil satellite imagery, mapping data (land use, soil surface temperature, Rainfall and hydrogeology) and secondary data from the following agencies:

1. Regional Disaster Management Agency (BPBD): Data on drought disaster events, drought-affected villages and district disaster risk data
2. Public Works and Spatial Planning Office: water discharge data, surface water sources, raw water potential
3. Environment Agency: Deforestation and land cover change data and strategic environmental assessment documents
4. Agriculture Office: data on agricultural production trends in the period 2013-2023

Data Analysis

The research method in the mapping of the level of drought in West Sumbawa Regency uses a descriptive research approach that explains the level of drought which is then associated with several secondary data so that it can present a more comprehensive discussion of the drought in the West Sumbawa Regency area. The data analysis technique used is spatial analysis consisting of remote sensing analysis and geographic information system analysis. Remote sensing technology and Geographic Information Systems (GIS) can provide convenience for users (researchers) to conduct analysis with a high level of accuracy to provide information spatially, especially in disaster management (Ballo, 2023).

Table 1. Parameters in Regional Drought Rate Mapping

No	Parameter	Class	Shoes	Reference
1	NDVI	Non-Vegetated Land	5	Perdana *et al.*, 2022
		Very Low Greenness	4	
		Low Greenness	3	
		Medium Greenery	2	
		High Greenery	1	
2	NDWI	Non-Badan Air	5	Perdana *et al.*, 2022
		Medium Wetness	3	
		High Wetness	1	
3	LST	47-51	5	Du *et al.*, 2017
		32-36	4	
		37-41	3	
		32-36	2	
		26-31	1	
4	Land Use	Open Land, Built Land (Settlements)	4	Raharjo *et al.*, 2021
		Dryland Farming,	3	
		Rice Fields	2	

No	Parameter	Class	Shoes	Reference
		Check		
		Forests,		
		Plantations, Ponds		
		Water Body		
5	Rainfall	<1,500	4	Aripbilah &
		1.500-2.000	3	Suprapto,
		2.000-2.500	2	2021
6	Hydrogeology	Rare Groundwater	4	Pranata &
		Small-Medium Productivity	3	Aji, 2021
		Medium-High Productivity	2	
		High Productivity	1	

The six parameters are presented in Table 1. Furthermore, it will be overlaid to obtain an overview of the drought level of the West Sumbawa Regency area. The mapping of the drought level uses scoring and weighting. The scoring on each parameter illustrates the level of interconnectedness, proximity and also the impact caused to the level of drought in the region (Fattah & Widyasamratri, 2024). Here's the weighting formula of several parameters:

a. Drought Levels = 0,17 NDVI + 0,17 NDWI + 0,17 LST + 0,17 Land Use + 0,17 Rainfall + 0,17 Hydrogeology ....(1)

After the weighting results are known, then the determination of the drought class or classification is carried out using the interval formula as follows:

b. Interval = (maximum value-minimum value)/ many classes.. (2)

RESULTS AND DISCUSSIONS

The water sources used in West Sumbawa Regency are varied, consisting of surface water sources, groundwater and sea waters. Surface water sources are rivers, lakes and reservoirs. Rivers in West Sumbawa Regency are included in the Sumbawa River Area Unit (SWS). In SWS Sumbawa in West Sumbawa Regency there are several Sub-Units of River Areas (SSWS), namely SSWS Jereweh and SSWS Rea. West Sumbawa Regency is divided into four watersheds, namely the Beh watershed, the Kereweh watershed, the Rea watershed, and the Rhee watershed. Each watershed has a distribution of water sources used for irrigation of rice fields and for household drinking water sources.

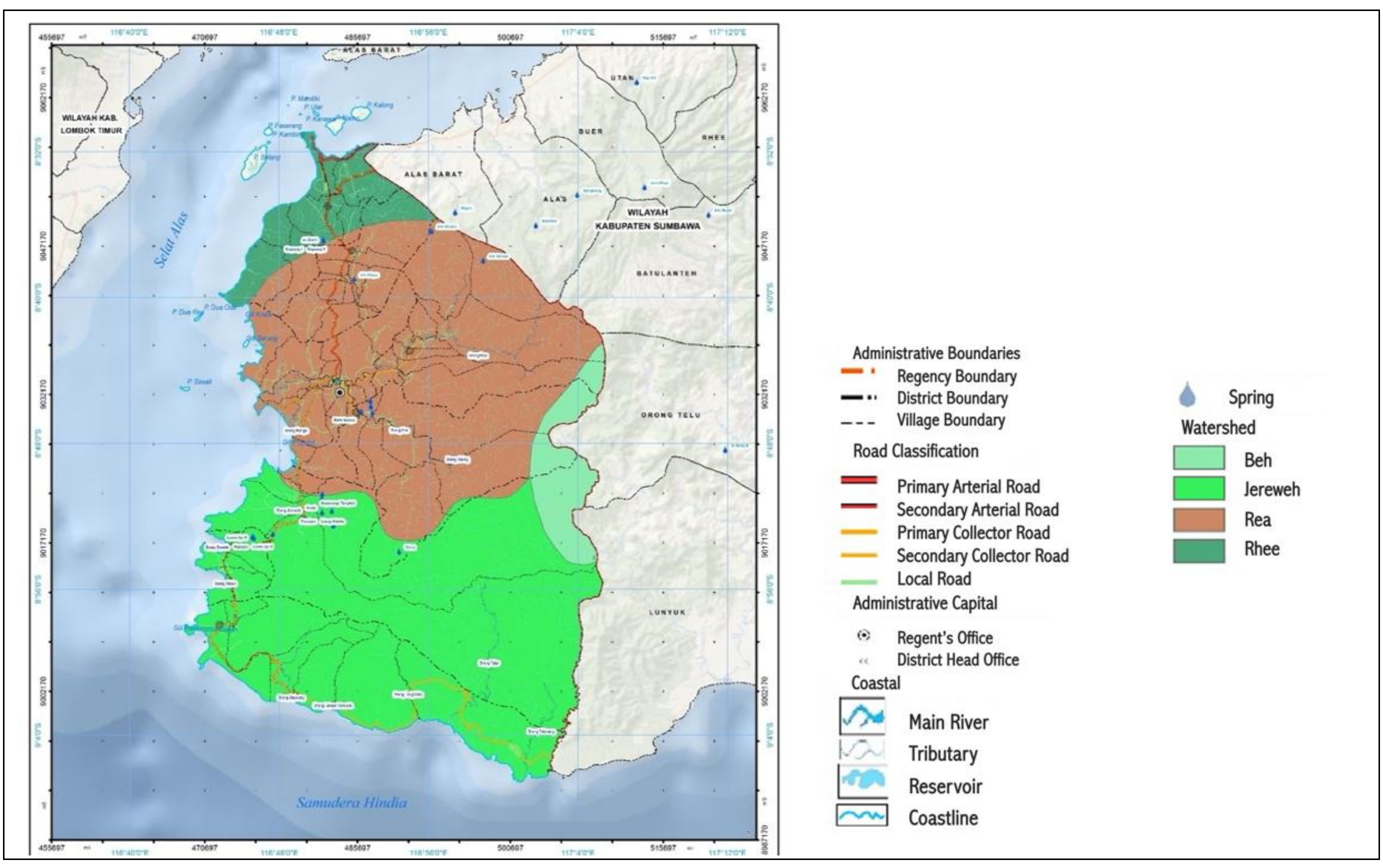

Figure 4. Hydrological Map of West Sumbawa Regency

The air temperature in the West Sumbawa Regency area varies between 21°–35°C with a relative humidity level of ±76%. The West Sumbawa region has a tropical climate with a wet and dry tropical climate type (Aw) which has two seasons, namely the rainy season and the dry season. The dry season in the West Sumbawa region takes place in the months of April-October with the driest month being August. Meanwhile, the rainy season usually occurs in the months of November–March with the wettest month being January with monthly Rainfall of more than 250 mm per month.

Vegetation Index (NDVI)

The most widely used Vegetation Index is the NDVI *(Normalized Difference Vegetation Index)* method, which is by transforming the image and spectral sharpening of various different types of vegetation surfaces will be able to reflect different types of light waves (Saputra, 2023).

West Sumbawa Regency is dominated by the high greenery class with an area of 149,790.57 hectares or 85% of the total area, while the class with the lowest area is the non-vegetated land class with an area of 1499.54 hectares or only 1% of the total area. NDVI with high greenery dominates because land use in the West Sumbawa Regency area is mostly forests, plantations, rice fields, and fields.

Table 2. Vegetation Index (NDVI)

Class	Category	Broad (hectares)	%
1	Unvegetated Land	1499,54	1%
2	Very Low Greenness	2218,74	1%
3	Low Greenness	8068,19	5%
4	Medium Greenery	13797,73	8%
5	High Greenery	149790,57	85%

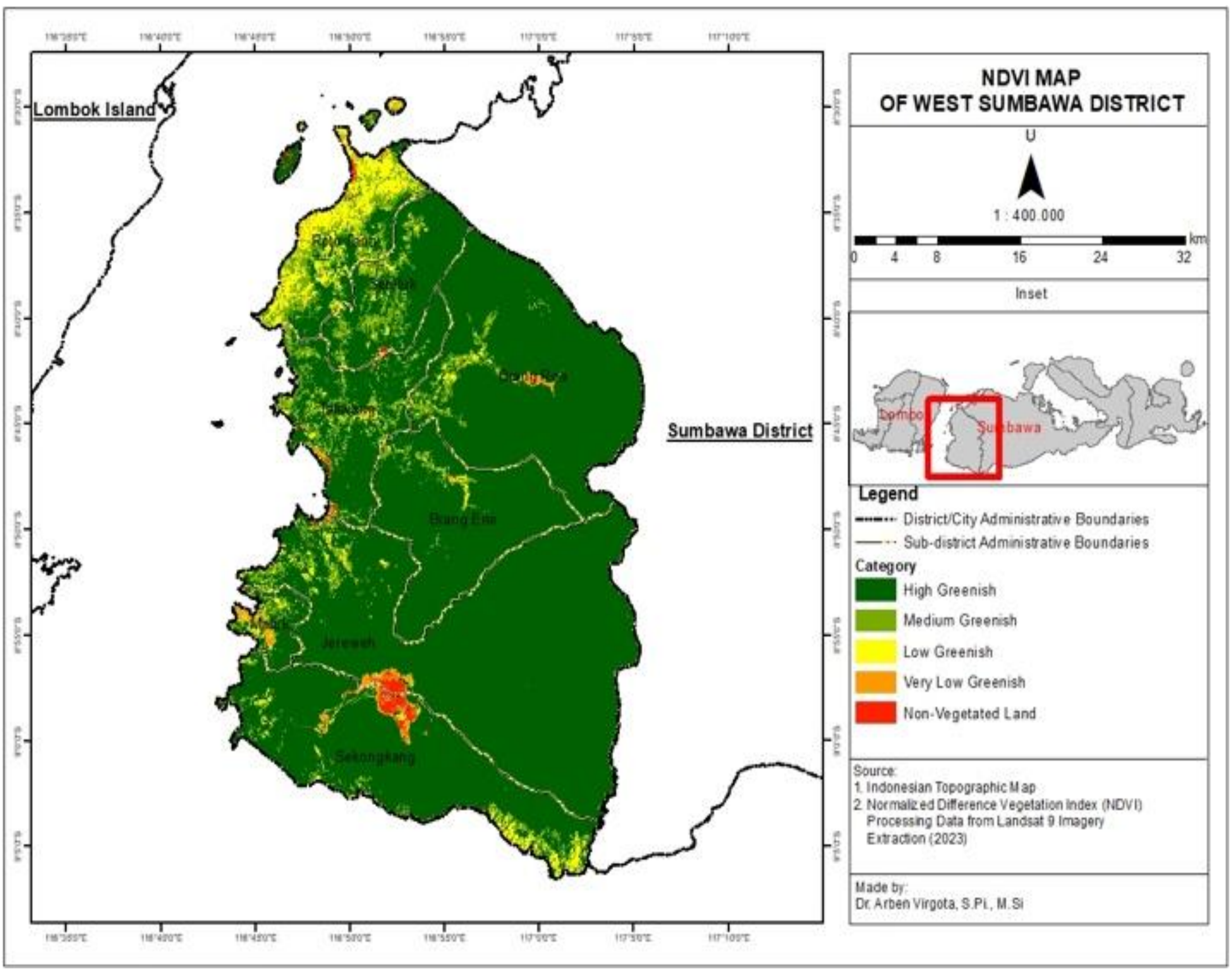

Figure 5. NDVI Parameter Map in West Sumbawa Regency (KSB)

Wetness Index

West Sumbawa Regency is mostly dominated by the High Wetness class with an area of 96,726.49 hectares or 55% of the total area and the class that has the lowest area is the Non-Water Body class, which is only 27,399.48 or 16% of the total area. High NDWI values are mostly identified in the eastern part of the region with land cover in the form of forests and plantations.

Table 3. Vegetation Index (NDVI)

Class	Category	Area (Hectares)	%
1	Non Water	27.399,48	16%
2	Medium Wetness	51.240,24	29%
3	High Wetness	96.726,49	55%

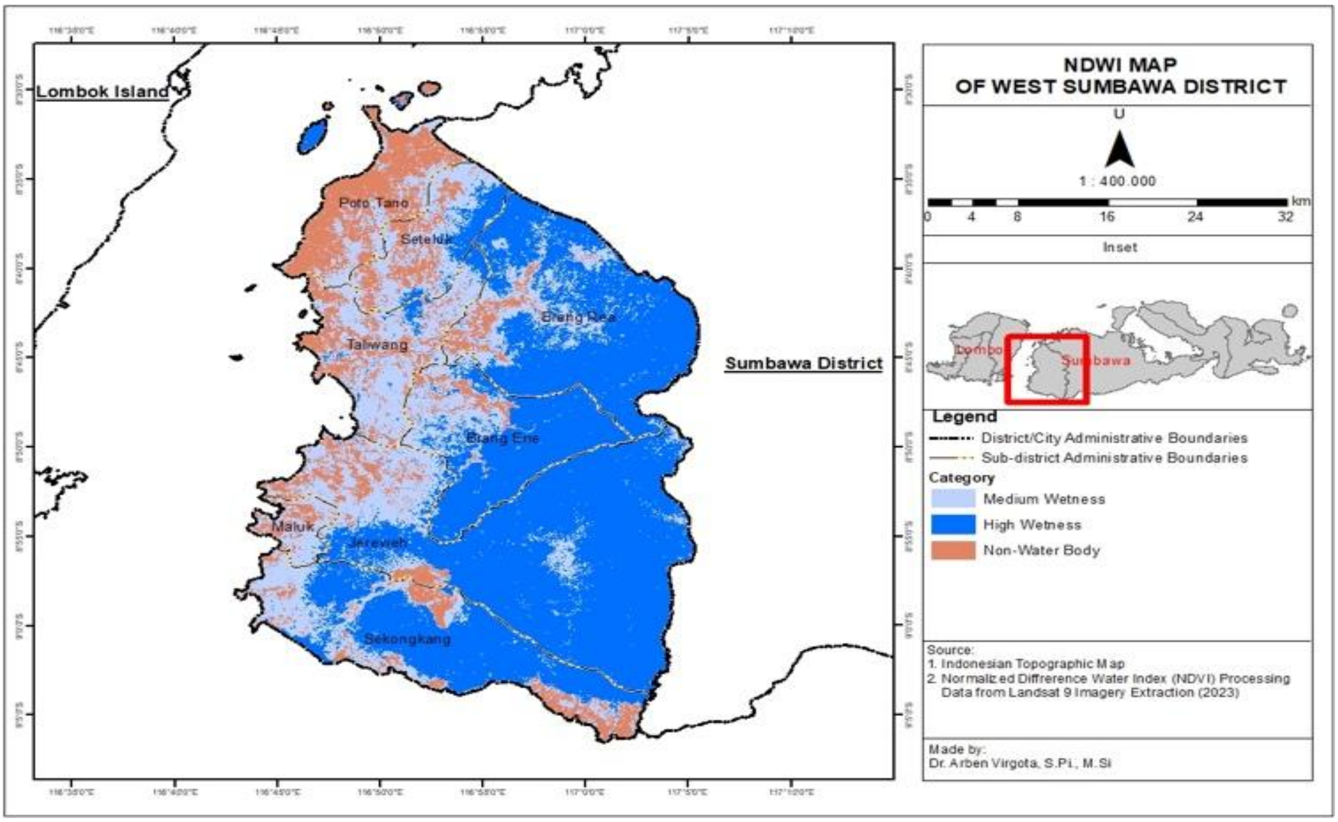

Figure 6. NDWI Parameter Map in West Sumbawa Regency (KSB)

Land Surface Temperature (LST)

The temperature class of 26°C - 31°C dominated most of the research area with an area of 113,028.94 hectares or 64% of the total area and the class with the lowest area was the temperature class of 47°C - 51°C with an area of 239.94 hectares or only 0.1% of the total area of West Sumbawa Regency.

Table 4. LST Parameters

Class	Temperature	Area (Hectares)	%
1	26˚C - 31˚C	113.028,94	64%
2	32˚C - 36˚C	36.336,04	21%
3	37˚C - 41˚C	19.497,66	11%
4	42˚C - 46˚C	6.279,56	4%
5	47˚C - 51˚C	239,94	0,1%

From the table 2, it can be seen that the temperature class of 26°C - 31°C dominates most of the research area with an area of 113,028.94 hectares or 64% of the total area and the class with the lowest area is the temperature class of 47°C - 51°C with an area of 239.94 hectares or only 0.1% of the total area. The highest surface temperature class was identified in the northwest part of West Sumbawa Regency such as Poto Tano District, and its surroundings. The surface temperature results from image processing certainly need to be compared with the surface temperature in the field. From 20 test points of soil surface temperature samples using a soil temperature thermometer, a comparison of the temperature of the image processing results and the temperature in the field was obtained as in the table below

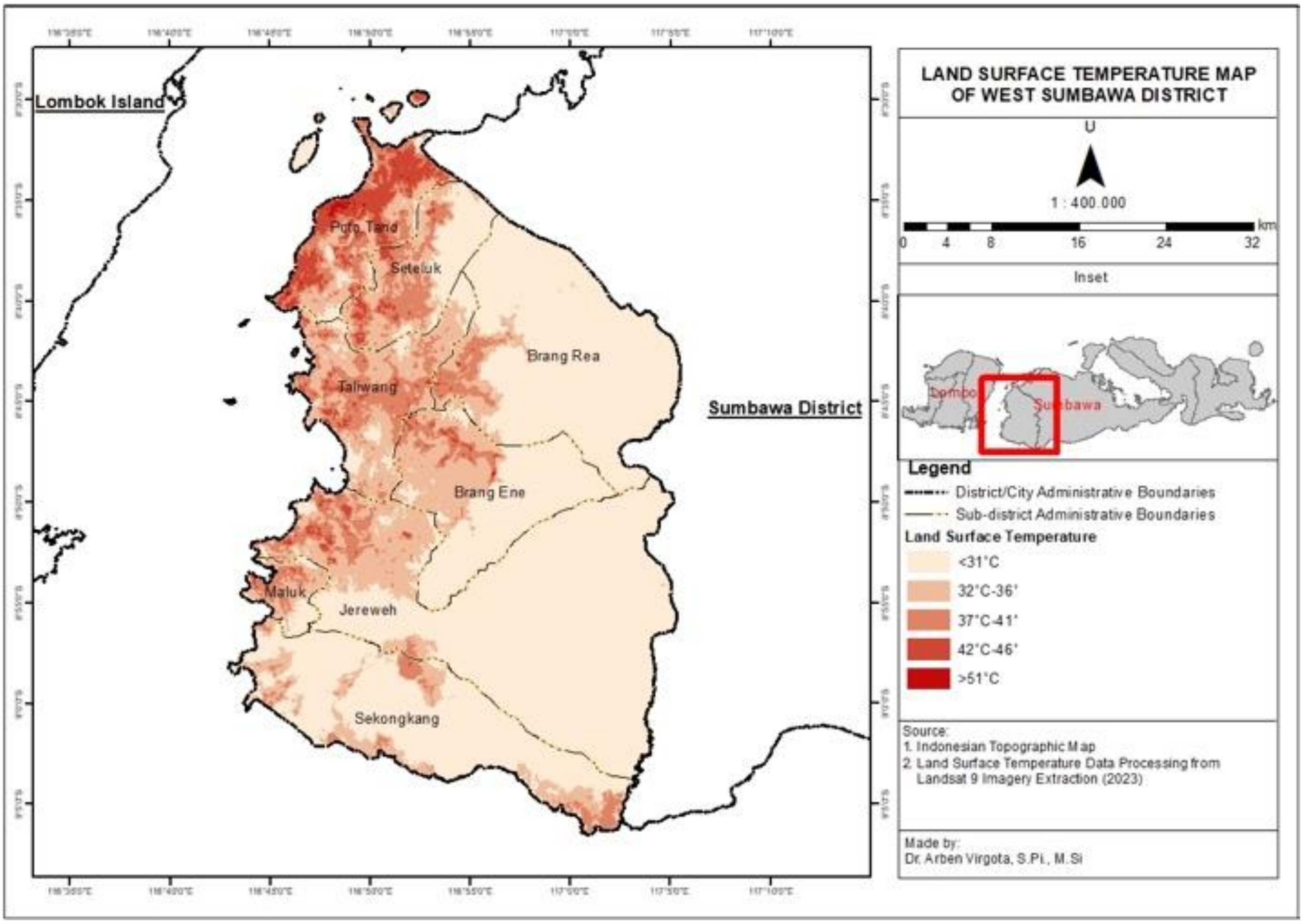

Figure 7. Map of ESG Parameters in West Sumbawa Regency (KSB)

Land Use Parameters

Land use changes are a parameter that is often used in relation to the reduction of environmental carrying capacity because it can be a causative factor for other environmental problems (Haryanti *et al.*, 2019). The land use used in this study is from the input of RBI map data on a scale of 1:25,000 downloaded on the tanahair.indonesia.go.id website which is then corrected with the latest Landsat imagery.

Table 5. Land Use Index

Class	Land Use	Area (Hectares)	Percentage (%)
1	Open Land, Built-up Area (Residential)	687.06	0.39%
2	Dryland Agriculture, Mixed Farming, Rice Fields	12,520.15	7%
3	Shrubland	47,413.05	27%
4	Forest, Plantation, Fishpond	112,502.78	65%
5	Water Bodies	2,232.95	1%

This land use data is then grouped into 5 classification classes according to Fersely (2007) in Jamil (2013) according to the level of influence on drought which can be seen in Table 6. West Sumbawa Regency is dominated by land use class in the form of Forests and Plantations, which covers an area of 112,502.78 hectares or 65% of the total area. Meanwhile, the lowest land use class is in the form of Open Land, Built Land (Settlement) which is only 687.06 hectares or 0.39% of the total area.

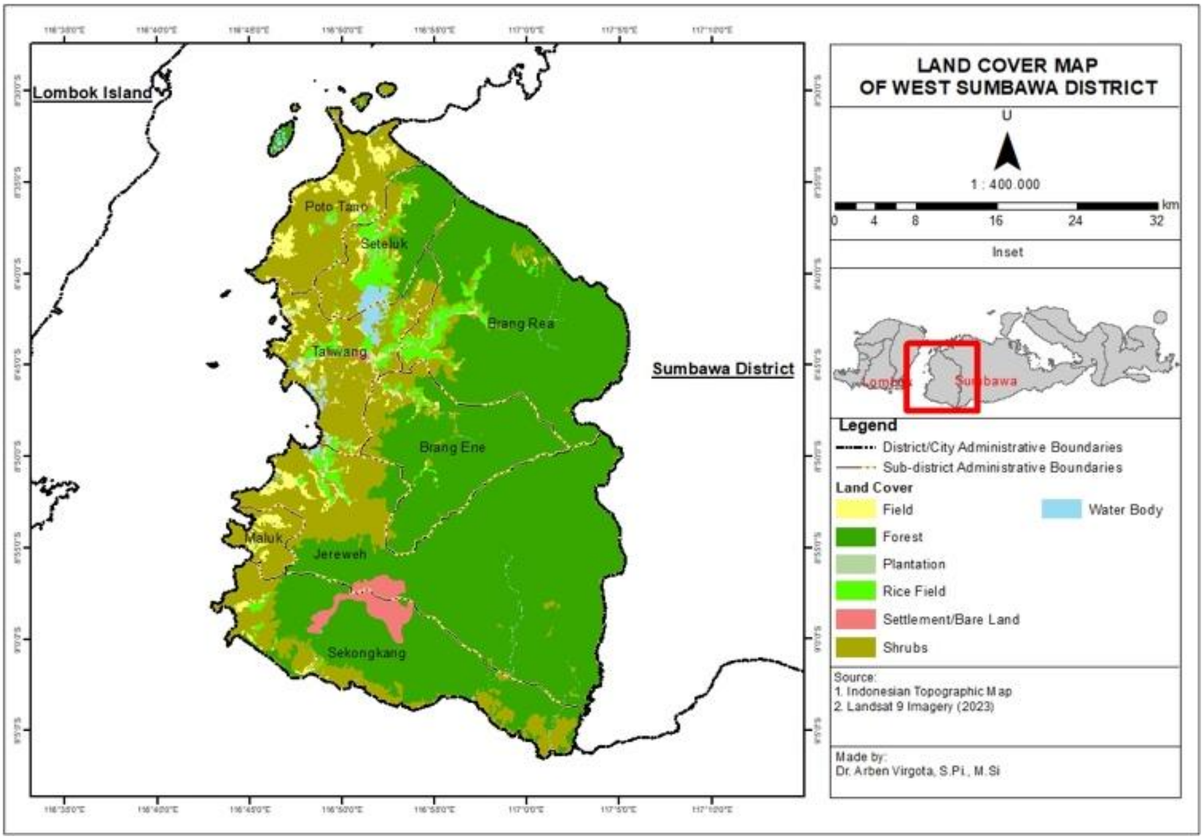

Figure 8. Map of Land Use Parameters in West Sumbawa Regency (KSB)

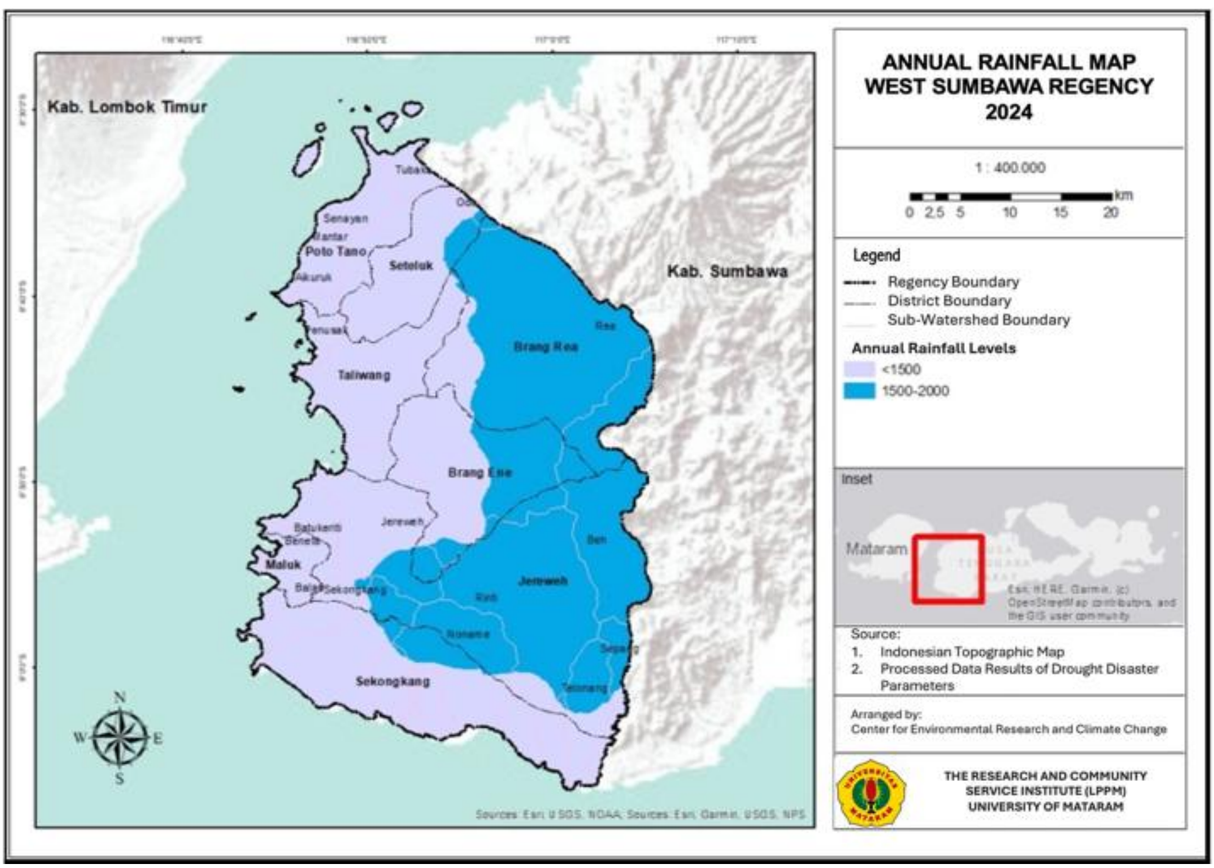

Figure 9. Map of Rainfall Parameters in West Sumbawa Regency (KSB)

Rainfall Parameters

Most of the area of West Sumbawa Regency is dominated by Rainfall <1500 mm/year with a percentage of 55%. Rainfall with a range of 2000 - 2500 is not found in West Sumbawa Regency.

Table 6. Rainfall Index

Class	Rainfall	Area (Hectares)	%
1	<1500	95.614,04	55%
2	1500 – 2000	79.747,55	45%
3	2000 – 2500	0	0%

Based on Figure 9, the Rainfall level <1,500 mm/year is shown in light purple and is located on the east side of the West Sumbawa Regency area and is a coastal area. Rainfall, which tends to be low, is one of the factors that trigger regional drought, both drought on agricultural land and drought in meeting domestic and non-domestic water needs.

Hydrogeological Parameters

From the hydrogeological data of West Sumbawa Regency, half of the area of West Sumbawa Regency is dominated by small to medium productive aquifer types, which reach 87417.51 hectares or 50%, then the Rare Groundwater Area is 57834.49 hectares 33%.

Table 7. Hydrogeological Index

Class	Aquifer Type	Area (Hectares)	Percentage (%)
1	Low Groundwater Availability Area	57,834.49	33%
2	Low to Moderate Productivity	87,417.51	50%
3	Moderate to High Productivity	28,095.01	16%
4	High Productivity	2,072.14	1%

According to (Putranto, 2020), an overview of the hydrogeological conditions of the region can determine the aspects of water quality and quantity in the Groundwater Basin (CAT) unit. Based on Figure 10, it is known that the hydrogeological distribution map in West Sumbawa Regency is known, where there are areas with red color that indicate that the area is in the category of rare groundwater. The distribution of rare groundwater is spread across parts of Brang Rea, Brang Ene, Jereweh and Sekongkang Districts. Meanwhile, the coastal area bordering the sea (the eastern side of the KSB Regency area) is dominated by small-medium production.

Drought Disaster Vulnerabiliti in West Sumbawa

Based on the image transformation that produces several maps such as NDVI, NDWI, LST, parameter maps, Rainfall, land use and hydrogeology, then overlay analysis is carried out using ArcGis software using the intersect method. The overlay is based on the weighting score in Table 1. The overlays and scoring resulted in a classification of drought levels in West Sumbawa Regency with class 1 (very low), class 2 (low), class 3 (medium), class 4 (high) and class 5 (very high). In Table 8, it explains the results of the calculation of the area in West Sumbara Regency based on the level of drought based on the results of overlay analysis. The table shows that the majority of areas in West Sumbawa Regency are in the very low drought category with a proportion of 49% of the total KSB area. Meanwhile, the high level of drought is 10% and the drought is very high with a proportion of 3% of the total area or 4,688.85 ha.

Table 8. Distribution of areas based on the Level of Drought Disaster Vulnerability in West Sumbawa Regency

Categories Drought	Luas	%
Very Low	85.251,08	49%
Low	39.731,73	23%
Moderate	27.466,09	16%
High	18.057,65	10%
Very High	4.688,85	3%

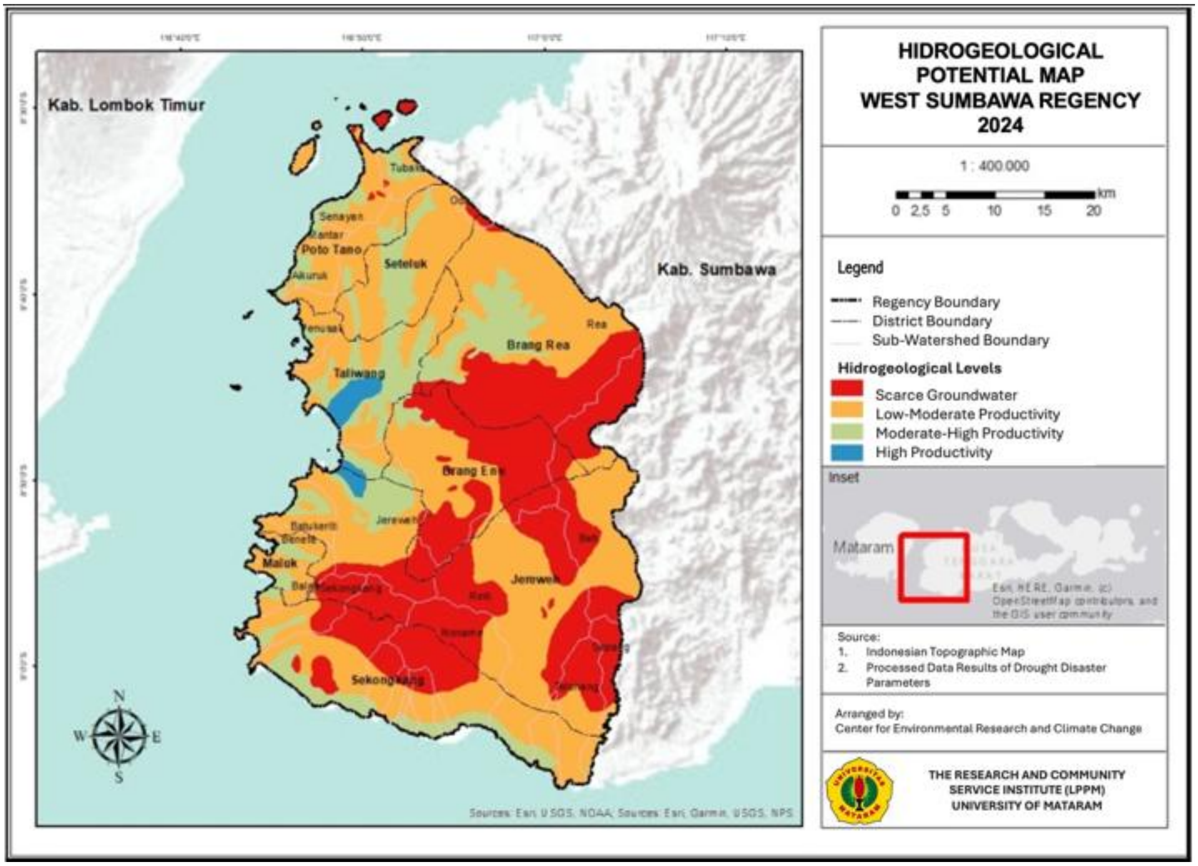

Figure 10. Hydrogeological Parameter Map in West Sumbawa Regency (KSB)

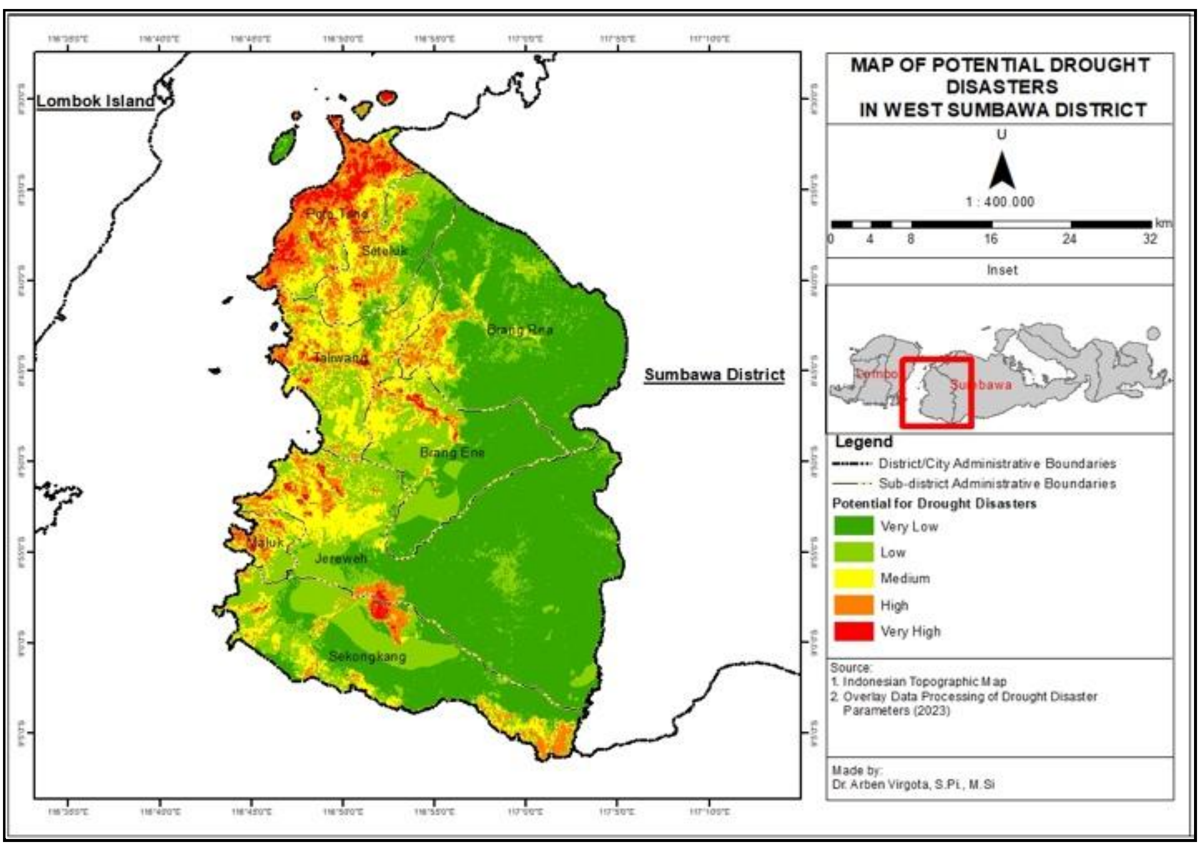

Figure 11. Drought Level Map in West Sumbawa Regency (KSB)

When observed in Figure 11, there are 5 categories of drought from the very low to very high range. More than half of the eastern KSB region is blue, indicating a "very low" level of drought vulnerability. The Very Low Category is spread mostly in Brang Rea, Brang Ene, Jereweh and Sekongkang Districts. Meanwhile, the red color on the map shows that the level of drought vulnerability is "very high" in the northern part of the KSB area which is included in Poto Tano District with a proportion of 23% of the total area of the sub-district, while 43% of the Poto Tano area is in the "high" category.

When studied in the context of population density, the sub-district with a high level of drought is in Pototano District which is a coastal area with a population density level of 0.50 people/ha. Population density and also public service facilities cause the demand for water for domestic and non-domestic to be higher. The condition of Pototano District with a high and also very high level of drought is supported by high soil surface temperature and also low Rainfall, making this area vulnerable to drought disasters.

Based on the map of land use distribution in West Sumbawa Regency, the majority of high and very high levels of drought occur in the use of agricultural areas, food crops and plantation areas. Drought disasters that have occurred in the last five years due to uncertain weather have caused a decrease in agricultural production of food crops. Based on the trend for 5 years (2019-2023), there has been a decline in rice and corn production. In rice commodities, in 2019 with a production of 104,757.21 tons to 90,693.62 tons in 2023. Including for corn commodities, production decreased from 103,417 tons to 80,742.72 tons. The most significant decline in rice production occurred in Maluk District, Sekongkang District, Brang Rea District and Poto Tano District. This sub-district has a tendency to be vulnerable to drought, especially Poto Tano with a "very high" drought rate. It is possible that there is a correlation between the level of regional drought and crop production, although there are certainly many other factors that affect the level of drought.

CONCLUSION

Based on the results of the overlay of the NDVI, NDWI, LST, Rainfall, land use and hydrogeology parameter maps, a drought level map was produced which shows that the majority of areas in West Sumbawa Regency are in the very low drought category with a proportion of 49% of the total KSB area. Meanwhile, the high level of drought is 10% and the drought is very high with a proportion of 3% of the total area or 4,688.85 ha. High to very high drought was detected in Pototano District and in the border between Sekongkang and Jereweh Districts. Drought in Pototano District occurs in the use of agricultural land, food crops and plantations. Meanwhile, in Sekongkang and Jereweh Districts, high and very high levels of drought occur in the use of built land such as settlements and public service facilities. This condition is the basic information for decision-making for the handling of drought disasters in West Sumbawa Regency, it is necessary to separate between drought management on agricultural land and drought in the context of meeting daily clean water needs for domestic and non-domestic residents. The distribution of drought level maps can be used to determine priorities related to Pototano District and also Sekongkang District and Jereweh District as the top priorities in decision-making.

The limitation of this study is to describe the area based on the conditions of drought level spatially. In addition, the scale of mapping the level of drought is carried out within the scope of the Regency area. Therefore, the recommendation of this study is that it is necessary to add ground checks in locations with different levels of drought by taking direct measurements in the field related to soil surface temperature, humidity, and land cover. Regional drought studies will be richer in information if they are added to socioeconomic aspects or associated with government efforts to adapt and prepare for the mitigation of drought disasters.

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Conflict of interest: The author has no competing interests to declare that are relevant to the content of this article.

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