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ANALYSIS OF DROUGHT DISASTER POTENTIAL BASED ON REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM
(Case Study: North Central Timor Regency)

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ABSTRACT: Drought is a natural phenomenon that is a complex and difficult to predict and has the potential to be detrimental to human life, so mitigation efforts need to be made to reduce its impact. To provide information related to drought in North Central Timor District, it is necessary to make efforts to map areas that are vulnerable to drought. Mapping drought potential can be done by utilizing remote sensing data and using Geographic Information Systems (GIS). The aim of this study is to determine the distribution of drought potential in TTU Regency using remote sensing and GIS. The method used is the scoring and overlay method using ArcMap by paying attention to several parameters, such as rainfall, slope, type of soil, and land use. The results of the analysis show that the level of drought in the TTU regency is in the medium to high category, so it is necessary to mitigate drought efforts. Overlay analysis identified low drought class reaching 1,8 km^2 or 0,1%, medium drought with an area of 1696,1 km^2 or 65,4%, high drought class covering an area of 894,9 km^2 or 35%, and very high drought class covering 0,08 km^2 or 0,01% of TTU Regency area.

Keywords: *Drought Potential, Remote Sensing, GIS, North Central Timor Regency*

1. INTRODUCTION

Indonesia has a tropical climate, experiencing both rainy and dry seasons throughout the year. During the dry season, droughts frequently happen due to climate change, leading to a prolonged and intense dry period. Drought is an unpredictable natural disaster that can significantly impact human life. In some areas, drought can disrupt various aspects of life, such as health, agricultural, productivity and the socio-economic activities of the community. Drought, resulting from prolonged periods of insufficient water, is a natural yet complex climatological phenomenon [1]. It impacts numerous societal sectors, including agriculture, ecosystem services, human health, recreation, and water resources, making it the most expensive natural disaster [2].

Droughts can be categorized into four types: meteorological, agricultural, hydrological, and socio-economic [3], [4]. Meteorological drought occurs when there's a deficiency in rainfall compared to typical conditions over an extended duration, whereas agricultural drought results from soil moisture levels dropping below the optimal requirement for rice plants at each growth stage, leading to decreased crop yields. Hydrological drought relates to the decrease in surface and underground water availability due to reduced rainfall, characterized by a significant reduction in surface water flow until it reaches below-normal conditions or cessation of groundwater recharge. In contrast, socio-economic drought relates to the disruption of human activities due to reduced rainfall and water availability.

Several areas in Indonesia often experience meteorological drought. One area that is frequently hit by drought is East Nusa Tenggara. In general, the East Nusa Tenggara region has a predominantly dry climate. Wind flows that carry a lot of water vapor from Asia and the Pacific Ocean reach NTT with reduced water vapor levels, resulting in a lower frequency of rainy days in the region compared to areas adjacent to Asia. This causes NTT to be a relatively dry region with relatively low average rainfall, ranging from 0 to 12 mm in the dry months (May to October) and 50-300 mm in the

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wet months (November to April) [5], [6]. Based on the analysis of rainfall patterns, the East Nusa Tenggara region is classified in the monsoon pattern. This pattern is characterized by the presence of one peak rainfall season occurring in January to February [6].

This short rainy season causes the availability of water in East Nusa Tenggara to be minimal. Various areas often experience water supply shortages during the dry season [7]. The drought's impact is massive, with more than 1 million people in NTT affected [8]. Based on the Decree of the Governor of East Nusa Tenggara Number 172/KEP/HK/2023 on April 26, 2023, concerning the determination of the status of an emergency alert for drought disaster management, one of the districts with a drought disaster emergency is North Central Timor [9]. North Central Timor Regency (TTU) is one of the districts in East Nusa Tenggara that face a high drought risk, with an average annual rainfall from 2018 to 2023 of 1155 mm/year to 1893 mm/year [10], [11]. The Low rain has caused most communities to experience the threat of drought and famine. According to BPS records, in 2022, 743 people were affected and displaced because of the drought.

The phenomenon of drought as part of climate change is difficult to avoid. Therefore, a careful analysis of the level of drought is needed as part of disaster mitigation efforts to reduce the damage it causes [2], [12]. Dealing with drought requires specialized and focused policies because drought is an extraordinary natural phenomenon with various complex aspects that affect several sectors and have long-term impacts on the environment, economy, and society [13].

Lack of rainfall because of weather change is a significant challenge requiring us to have appropriate strategies to mitigate losses. Determining the potential drought might be possible through direct surveys, but this process is time-consuming and costly. Therefore, even though conventional methods have proven accurate, they have yet to be used. Finding a more efficient approach to identifying drought is essential, especially one that can provide continuous precise time mapping. In anticipation of this, the use of remote sensing technology and spatial data analysis through Geographic Information Systems (GIS) becomes very important so that it becomes a reference for policymakers in anticipating the impacts experienced and appropriate disaster management action [2], [14]. Geographic Information Systems (GIS) have the advantage of conducting spatial evaluations, including assessing the possibility of drought in certain areas.

To provide information related to drought disasters in the North Central Timor district, it is necessary to map areas vulnerable to drought. There are four parameters to measure the level of drought vulnerability in an area, namely rainfall, soil type, land use, and slope [15], [16]. Besides using information already available, drought information can also be obtained using remote sensing technology and Geographic Information Systems [17]. GIS can map drought patterns, identify vulnerable areas, and plan appropriate responses by integrating spatial and attribute data. The application of GIS in drought analysis has been proven to provide significant results in drought modeling and mapping. Drought analysis using GIS can successfully develop knowledge for valid and robust drought risk assessments, both globally and regionally while supporting robust drought management practices in vulnerable areas [18]. In addition, the overlay method is one of the relevant analysis approaches, enabling the merging of thematic data layers to produce accurate drought risk maps. Thus, we can better understand the complexity of drought and design more effective mitigation strategies through the combination of theory and methodology.

The purpose of this study is to determine the distribution of drought potential in the North Central Timor Regency based on spatial data produced by GIS and provide recommendations for mitigation to be conducted.

2. METHOD

2.1 Research Time and Location

This research was conducted from March to April 2024. The research location is in the North Central Timor District. The population in this research is the entire sub-district of North Central Timor district, which consists of 24 sub-districts (figure 1).

2.2 Method of Collecting Data

The data collected includes data originating from two main sources: primary and secondary data. The secondary data required includes various thematic maps, such as rainfall maps, soil maps, slope maps, and land use maps. Meanwhile, primary data involves directly checking activities in the field regarding land use patterns related to water sources for agricultural purposes and other human activities [19]. In this context, it is essential to note that drought conditions that disrupt human activities are often considered an indicator of potential land disasters (drought).

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2.3 Data Analysis Methods

Based on the thematic maps that have been collected, further analysis was conducted using Arc Map. Two geographical information system methods will be applied in data analysis, namely scoring and overlay methods. The scoring or assessment method is used to group parameters into several categories, where each category is then given a score or evaluation based on their ability level [20], [21], [22]. Furthermore, it will be overlaid with the soil map, rainfall map, land use or land cover map, and slope map. From the overlay results of various thematic maps, a drought class analysis was carried out based on the weight and score for each predetermined factor. The weights and scores of each influential factor are presented in the following table (Table 1):

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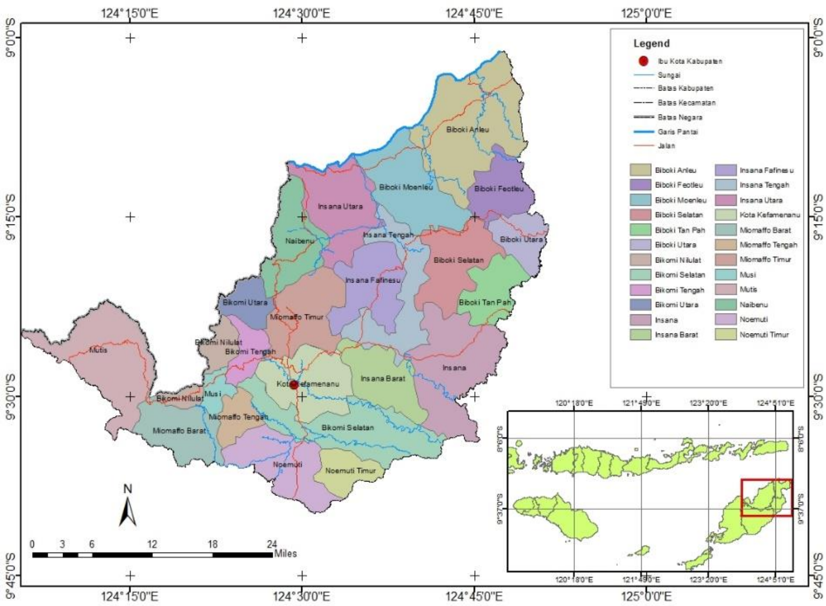

Fig. 1: Map of the Research Location (BPS TTU Regency and Geospatial Information Agency Data, 2024)

Table 1**.** Parameters of Drought Area

NO	Parameters	Class	Score
1	Rainfall	<1000	5
		1000-1500	4
		1500-2000	3
		2000-2500	2
		>2500	1
2	Slope	0%-8%	1
		8%-15%	2
		15%-25%	3
		25-45%	4
		>45%	5
3	Type of Soil	Alluvial, Gley, Planosol, Hydromorph	1
		Andoso, Organosol	2
		Latosol, Grumusol, Podsol	3
		Regosol	4
		Mediteran, Litosol, Renzina	5
4	Land Usage	Protected Forest, Primary Forest	1
		Buffer Forest, Secondary Forest	2
		Garden, Plantation, mixed garden, Shrubs	3
		Rice field, The Moor	4
		Open Ground, Settlement	5

Source: BNPB with modifications (2024)

3. RESULT AND DISCUSSION

3.1 Description of the Research Location

North Central Timor Regency is situated in East Nusa Tenggara Province. Geographically, it lies between 9° 02' 48" to 9° 37' 36" South Latitude and 124° 04' 02" to 124° 46' 00" East Longitude. Similar to other regions in Indonesia, this regency experiences only two seasons: dry and rainy. Typically, the dry season spans from June to September, while the rainy season extends from December to March. Temperatures in North Central Timor Regency vary, but the majority of the region is generally hot.

North Central Timor District has a land area of 2,669 km^2. In 2003, the administrative area of TTU was divided into 24 sub-districts consisting of 182 villages and 11 sub-districts. With an area of 333.08 km^2 (12.48%), the Insana sub-district holds the title of the most significant area, while the Biboki Anleu sub-district comes in second with an area of 206.40 km^2 (7.73%). The City of South Bikomi is the smallest area, at 48.68 km^2 (1.82%). The southern part of the region borders South-Central Timor district, while the northern part is adjacent to Ambenu (Timor Leste) and the Sewu Sea regions. To the west lies Kupang Regency and to the south, Central Timor district. The eastern boundary is shared with Belu and Malacca Regency.

3.2 Analysis of Drought Prone Parameters

3.2.1 Rainfall

Rainfall is one of the main components that determines an area's weather and climate characteristics. It is measured by the volume of water that reaches the surface before undergoing surface flow, evaporation, or absorption by the soil. Processing of rainfall data is obtained from CHIRPS data to see the average annual rainfall. CHRIPS data has been widely used and has a good level of accuracy. Faisol, in his research, said that CHIRPS data has an acceptable level of reliability in providing information about drought [23]. According to the results of the study, CHIRPS data and the SPI approach have the potential to be used in other regions as a means of monitoring agricultural drought. This is particularly beneficial in regions lacking sufficient rainfall data due to the absence of climate stations or rain measurement tools. CHIRPS rainfall data can be utilized to compute the drought index, and the results demonstrate an excellent drought index[24], [25], [26]. CHRIPS data processing, TTU district rainfalls are calculated from January to December 2024 in mm^2 units. The following is a map of rainfall for North Central Timor district:

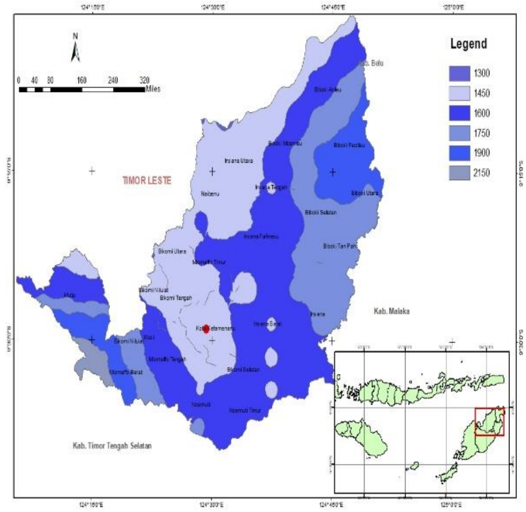

Fig. **2:** Rainfall Map (Source: Map Processing Results in 2024)

Figure 2 shows that the average annual rainfalls with the dominant is 1600 mm/year with a total area of 1037 km^2 or 40% of the North Central Timor Regency area spread over several sub-districts, namely Biboki Anleu, Biboki Moenleu, South Biboki, Insana, West Insana sub-districts, Insana Fafinesu, Central Insana, Central Miomaffo, East Miomaffo, Musi, Mutis, Noemuti, and East Noemuti and the lowest rainfall intensity is below 1300 mm/year with a presentation of 0.11% of the total area. The amount of rainfall can be seen in the following table:

Table 2**:** Classification of Rainfall

NO	Total Rainfall	Score	Area (km^2)	Percentage (%)
1	1450	4	762,8	29,1%
2	1900	3	249,0	9,5 %
3	1600	3	1036,8	39, 5%
4	1300	4	3,1	0,1 %
5	1750	3	533,7	20, 3%
6	2150	2	37,4	1,4 %
	Amount		2622,8	100 %

3.2.2 Slope

The slope is an essential variable in calculating the potential for drought in the North Central Timor Regency. Slope mapping was conducted using DENMAS image data on the website tanahair.indonesia.go.id and then analyzed the slope using Arc Map 10.8. The following is a map of the distribution of slopes in the North Central Timor district:

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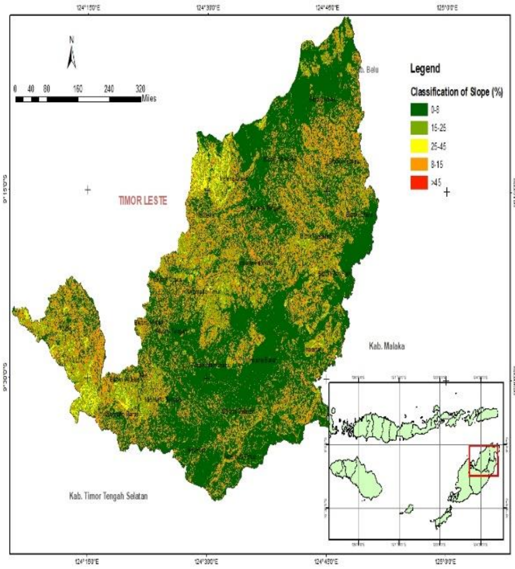

Fig 3**:** Slope Map (Source: Map Processing Results in 2024)

Figure 3 shows the classification of slopes in the North Central Timor district, divided into five class groups: flat, sloping, rather steep, steep, and very steep (Table 2).

Table 3**:** Classification of Slope

NO	Slope (%)	Class	Score	Area (km^2)	Percentage (%)
1	0-8	flat	1	1532,30	58,5 %
2	8-15	Sloping	2	745,29	28,5 %
3	15-25	Rather steep	3	272,07	10,4 %
4	25-45	Steep	4	67,57	2,6 %
5	>45	Very steep	5	2,28	0,1 %
Amount				2619,51	100 %

The slopes of the North Central Timor district are mostly flat topography with slope levels of 0-8% and a percentage of 58.5% or 1532.3 km^2 of the total area. The Areas with a very steep category with a slope of >40% as one of the indicators of drought-prone is 0.1% or 2.28 km^2 of the total area spread across several sub-districts, including Insana Fafinesu, North Insana, East Miomaffo, Mutis, and Naibenu sub-districts. Some of these sub-districts are areas that have the potential for drought because they have very steep topography.

3.2.3 Type of Soil

The type of soil can affect an area's fertility, groundwater absorption capacity, and drought. To obtain the type of soil, researchers used data from the FAO/USESCO Soil Map of the World and analyzed them using Arc Map 10.8. In this research, the TTU district is classified into three types of soil: litosol, Grumosol, and Luvisol.

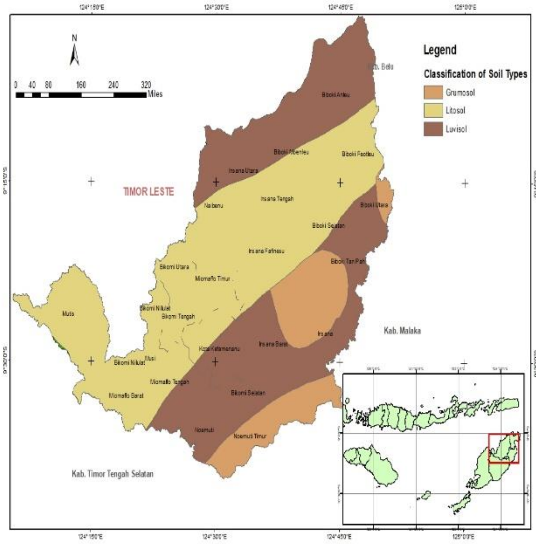

Fig.4**:** Map of Soil (Source: Results of Map Processing in 2024)

Based on the explanation and characteristics of each soil type, it can be concluded that their contribution to drought disasters is significant. The most dominant soil type in the North Central Timor district is litosol soil, with an area of 1264.61 km^2 or 48% of the area. This type of soil significantly impacts the drought in the North Central Timor district because of its rough soil texture. Furthermore, the second largest type of soil is the Luvisol soil type, with an area of 1013 km^2 or 39%, and the Grumosol soil type, with an area of 349 km^2 or 13% of the area. The classification of soil types in the North Central Timor district can be seen in the following table:

Table 4**:** Classification of Soil Types

NO	Type of Soil	Score	Area (km^2)	Percentage (%)
1	Litosol	5	1264,61	48 %
2	Luvisol	3	1013	39 %
3	Grumosol	3	349	13 %
Amount			2626,61	100 %

3.2.4 Land Use

Land use is a significant factor in the risk of drought in an area because the type of land cover can affect its ability to absorb water. Based on data obtained from DEMNAS TTU district, land cover data was obtained, which can be seen on the following map:

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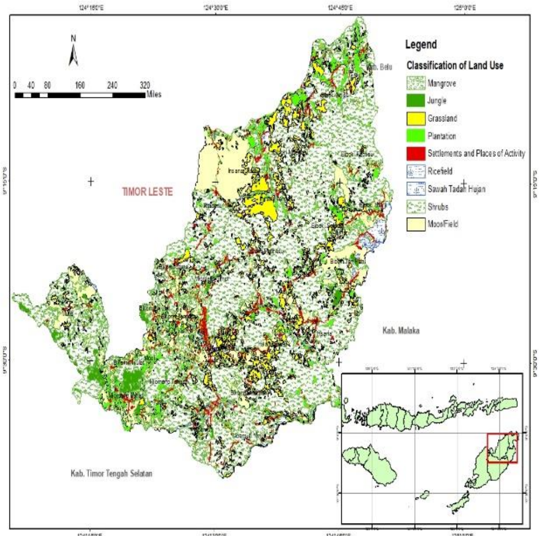

Fig. 5: Map of Land Use (Source: Results of Map Processing in 2024)

Figure 5 shows that the most dominant land use in the North Central Timor district is shrubs, with an area of 1597 km^2 or 60.8% of the total area, while land use as settlements, plantations, and grasslands is classified as very small. The land uses can be seen in the following table:

Table 5**:** Classification of Land Use

No	Use of Land	Score	Area (Km^2)	Percentage (%)
1	Mangrove Forest/Mangrove	1	2,24	0,1 %
2	Jungle	1	481,15	18,3 %
3	Grassland	2	44,24	1,7 %
4	Moor/Field	3	46,06	1,8 %
5	Shrubs	3	1597,8	60,8 %
6	Plantation	3	45,61	1,7 %
7	Ricefield	4	266,81	10,2 %
8	Settlements and Places of Activity	5	112,23	4,3 %
9	Not identified		30,47	1,2 %
	Amount		2626,61	100 %

3.2.5 Analysis of Drought Disaster Potential

The map used as a reference to assess the potential for drought in the North Central Timor District has been given a score for each existing criterion. Then, these maps are overlapped using Arc Map 10.8 software to produce new criteria. These areas could experience drought in the North Central Timor Regency. The following are the results of an overlay of several maps used as a reference in assessing drought potential (figure 6).

Drought mapping in 2023 in North Central Timor District after the analysis process shows that areas with a high level of drought cover 34.5% of the total area of TTU District, while areas with a low level of drought cover 0,1% of the total area. The distribution of TTU district drought-prone classes can be seen in Table 6 below:

Table 6**:** Drought Prone Level of North Central Timor Regency.

No	Districts	Drought Danger Class (Km^2)		
		Medium	High	Very High
1	Biboki Anleu	246,2	49,4	-
2	Biboki Feotleu	55,1	47,9	-
3	Biboki Moenleu	111,1	37,4	-
4	South Biboki	89,0	40,9	-
5	Biboki Tan Pah	67,7	0,6	-
6	North Biboki	59,4	0,5	-
7	Bikomi Nilulat	11,1	28,5	-
8	South Bikomi	121,1	14,7	-
9	Middle Bikomi	5,4	41,4	0,01
10	North Bikomi	3,5	46,1	0,01
11	Insana	252,3	2,2	-
12	West Insana	81,1	11,2	-
13	Insana Fafinesu	44,4	47,8	-
14	Middle Insana	55,5	33,0	-
15	North Insana	62,8	80,6	0,03
16	Kefamenanu City	35,0	35,6	-
17	West Miomaffo	64,6	45,5	-
18	Middle Miomaffo	42,8	20,2	-
19	East Miomaffo	15,5	74,6	0,01
20	Musi	19,0	28,7	-
21	Mutis	57,4	128,4	-
22	Naibenu	18,0	78,2	0,02
23	Noemuti	128,6	0,8	-
24	East Noemuti	50,0	0,7	-
	Amount	1696,1	894,9	0,08

Table 6 shows the dominance of drought potential classes, with the moderate class marked in light green (figure 6), covering 1696,1 km^2 or 65,4% of the total area. The class considered low, indicated by the dark green color (figure 6), has an area of 1,8 km^2 or 0,1% of the total area, while the high class, marked in orange color (figure 6), has an area of 894,9 km^2 or 34,5% of the total area. The very high class only has an area of 0, 08 km^2 of the total area spread across the Central Bikoni sub-district.

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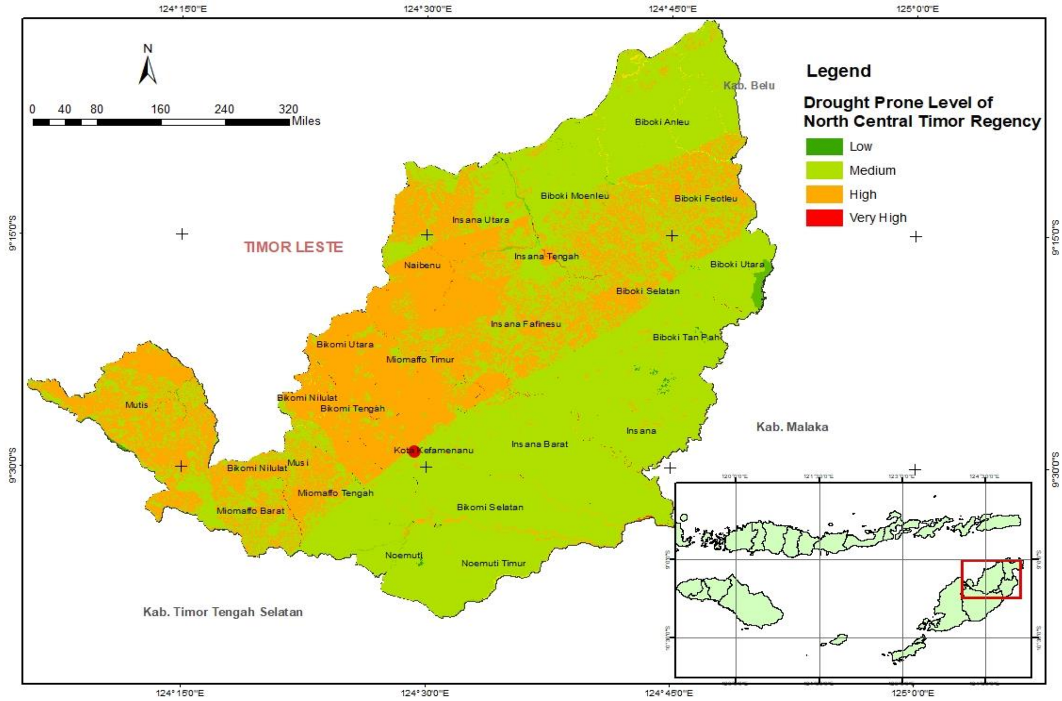

Fig. 6: Drought Prone Map (Source: Results of Map Processing in 2024)

The analysis results show that the low drought class only covers a small part of the area with an area of 1,8 km^2 or 0,1 % of the total area. The distribution of areas in the low category is a small part of the South Biboki sub-district, North Biboki sub-district, and Noemuti sub-district. This area is categorized as low to drought because of the moderate rainfall intensity between 1600-1900 mm/year. The land cover in this area is mostly jungle, with relatively flat to sloping topography. This is in line with research conducted by Lestari et al. which states that the TTU district is an area with a high level of drought disaster prone [11], [27].

The moderate category of drought is spread across almost all sub-districts in North Central Timor Regency, including Biboki Anleu sub-district, Biboki Feotleu sub-district, Biboki Moenleu sub-district, South Biboki sub-district, Biboki Tan Pah sub-district, North Biboki sub-district, South Bikomi sub-district, Insana sub-district, West Insana sub-district, Central Insana sub-district, West Miomaffo sub-district, Central Miomaffo sub-district, Noemuti sub-district and East Noemuti sub-district. The areas with the most significant potential for moderate drought are the Insana sub-district, with an area of 252.31 km^2 or 99% of the total area, and the Anleu sub-district, with a total area of 246.12 km^2 or 83% of the total area. Several factors influence the moderate classification of this region, such as the land cover in the sub-districts, which is predominantly shrubs and fields, giving it a drought influence score of three, and its flat to gently sloping topography. The area receives medium rainfall, with an average annual precipitation of 1600 mm/year.

The high drought class dominates in the central and western regions of North Central Timor district, which consists of several districts, including the Biboki Feotleu sub-district, North Bikomi sub-district, Nilulat sub-district, Insana Fafinesu sub-district, Central Insana sub-district, Central Miomaffo sub-district, East Miomaffo sub-district, and Mutis sub-district. Mutis sub-district has a relatively high potential for drought, with an area of 128 41 km^2 or 55% of the total area. Based on the rainfall distribution, this area has a low rainfall intensity category ranging from 1000 to 1500 mm/year. Most of the slopes in this region fall into the category of topography, which slopes slightly steeply. The area's land use is dominated by meadows and bushes, and the litosol type of land dominates the region. This condition contributes to the low level of soil fertility, making the area less productive for agricultural activities. Moreover, the characteristics of litosol soils that are less water-resistant make the region susceptible to drought. In addition, some of the land covers are rain-fed rice fields and fields with an area of 529 km^2 or 20,2% of the area, so the disaster is not only drought but also has an impact on lack of food needs and famine. Drought also affects the function and benefits of various types of land use. On agricultural land, such as rice fields, fields, and plantations, drought affects plant growth and land productivity. Meanwhile, drought in residential areas contributes to shortages or inadequate water supply for daily use.

The drought class with a very high category of drought only covers a small part of the three sub-districts in the North Central Timor regency, including a small part of the Central Bikomi sub-district, North Insana sub-district, and Naibenu sub-district. These areas need to be taken seriously by the government to minimize the impact of drought disasters during the dry season. Several factors determine these areas are highly prone to drought based on the parameters that have been set. Rainfall has a dominant role in determining the potential for drought in an area. The lower the intensity of rainfall, the greater the potential for drought. Rainfall is classified as low, with an intensity of less than 1500 mm/year. Besides that, the land cover in this region is also dominated by grasslands and fields. The need for forests to store water reserves in this region is the main obstacle to water availability. According to Dewa, in their research, land significantly contributes to the risk of drought in an area because the vegetation that grows on it affects the land's ability to absorb water (Dewa et al., 2023). The type of lithosol soil in this region also influences the relatively high dryness level because of its rough structure. This type of lithosol soil has a rocky and sandy texture with layers that are not too thick, making it challenging to plant. Soils with a sand texture have a limited surface area, making storing or absorbing water and nutrients difficult. In drought, physical characteristics of the soil, such as texture, also play a role in determining the soil's capacity to store water (water holding capacity) [28].

3.3 Field Data Verification

Based on data from the BMKG report, in 2023, 99 villages from 21 sub-districts in North Central Timor district will be experiencing drought, so severe handling is needed. This is in line with the very high demand for clean water in this region, and most of the region is threatened with crop failure. The results of the analysis of drought-prone areas (figure 6) show that regions with moderate to high drought cover most of the areas in the North Central Timor district, with an area of 2591 km^2 or 98% of the area. The results of this analysis follow the facts on the ground and can describe the drought conditions in the North Central Timor district.

3.4 Mitigation Efforts for Drought Disasters

Classifying the level of drought risk in various regions, considering local and national aspects, plays an essential role in understanding the threats faced by local communities and the country. The data produced in the form of maps from such an analysis can support decision-making processes in drought disaster mitigation efforts and policy-making[29]. By understanding the level of drought risk in an area, local governments can develop emergency plans to overcome the impact, such as distributing clean water and food aid. Taking preventative and mitigation measures is essential in areas with moderate to very high disaster risk. Prevention in disaster-prone areas can involve appropriate technology programs. To overcome drought, mitigation includes the construction of water infrastructure, such as wells, large water storage tanks, and reservoirs.

Additionally, measures such as reducing unnecessary water use are implemented. In areas with a very high risk of disaster, replanting trees in springs and water catchment areas and adequate socialization on water use must be carried out as preventive measures. In addition, drought mitigation can include clean water infrastructure development, irrigation improvements, and food assistance for affected communities.

4. CONCLUSION

Using GIS in processing data and analyzing drought potential into a drought-prone map is very helpful for policymakers as a basis for making decisions and mitigation processes to overcome drought in an area. Based on the analysis of drought potential in the North Central Timor district, the drought potential class is divided into four drought classes, namely: low drought class, medium drought class, high drought class, and very high drought class. Areas with low vulnerability class categories are spread over a small part of the North Central Timor district with an area of 1.8 km^2 or 0.1% of its total area. Areas with high drought classes are found in the central and western parts of the North Central Timor regency, including several sub-districts such as Biboki Feotleu, North Bikomi, Nilulat, Insana Fafinesu, Central Insana, Central Miomaffo, East Miomaffo, and Mutis. Mutis sub-district is of particular concern because it has a relatively high level of drought, with the affected area reaching 128.41 km^2 or around 55% of the total area. Drought classes with moderate categories are spread across almost all North Central Timor Regency sub-districts. Several sub-districts with relatively large areas affected include Biboki Anleu, Biboki Feotleu, Biboki Moenleu, South Biboki, Biboki Tan Pah, North Biboki, South Bikomi, Insana, West Insana, Central Insana, West Miomaffo, Central Miomaffo, Noemuti, and East Noemuti. Insane District occupies the largest moderate drought class, reaching 252,31 km^2 or approximately 99% of the total area. The very high drought category only covers a small area of the three sub-districts in TTU Regency, namely Central Bikomi, North Insana, and Naibenu, with an area of 0.1 km^2. These areas require serious attention from the government to minimize the impact of drought disasters during the dry season.

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