Analysis of the distribution and the impact of drought on agricultural land in Sekotong District, West Lombok

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Abstract. The existence of the El Nino phenomenon has an environmental impact, it causes low rainfall in the southern hemisphere, like Indonesia. Drought caused by El Nino is distributed throughout Indonesia, including Lombok Island. Sekotong District has an area surrounded by karst landforms and beaches. Karst areas cannot store groundwater so droughts often occur. Low rainfall and low water availability cause agricultural land to dry out so it cannot fill agricultural needs. This study aims to map the distribution of land affected by drought due to El Nino and its impact on agriculture in Sekotong District. The analysis of this study uses the Normalized Difference Drought Index (NDDI) analysis for the distribution of land drought and by conducting purposive interviews with farmers in Sekotong District. The results are the area of land drought class of around 2754.81 hectares without water shortage; 11,727.46 hectares in normal conditions; 11,715.31 hectares mild drought; 5313.1 hectares moderate drought; 1,606.62 hectares severe drought; and 1,144.57 hectares very severe drought. The impacts of this land drought include 1) Crop failure in rice commodities; 2) Agricultural land crops are substituted with peanuts and corn; 3) Agricultural land is not utilized at all because there is no water available.

1 Introduction

El Nino is a climate anomaly phenomenon that has occurred recently. The El Nino phenomenon is the opposite of La Nina where its influence is related to rainfall in an area [1]. El Nino brings drought to the affected areas, while La Nina has an impact on high rainfall. Indonesia is one of the countries affected by the El Nino phenomenon. The El Nino phenomenon is usually marked by a shift in warm circulation in Indonesian waters to the east (Central Pacific) which is accompanied by a shift in the location of the formation of rain clouds in the Indonesian region to the east, that is in the Central Pacific Ocean [2]. The movement of the rain-forming clouds results in low rainfall occurring continuously or even no rainfall falling accompanied by high air temperatures. With this event occurring for a long

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time, it results in a prolonged drought which is commonly referred to as the El Nino phenomenon [3]. Land drought conditions are conditions where the availability of water cannot supply all of the needs for life such as social, economic, agricultural, livestock and living things in the surrounding environment [4-5]. Drought is a disaster where the dry month period is longer than the wet month in previous conditions [6]. This land drought has a major impact on the social, economic, and environmental aspects of the affected community [7-8].

As a tropical country with highly fertile soil, the majority of the population works as farmers. The agriculture that is developed is mostly food crops that are consumed every day. The sustainability of agriculture in Indonesia is greatly influenced by the availability of groundwater because in agricultural cultivation, water is an important factor for plant growth [9]. One of the small islands in Indonesia is Lombok Island which is located in the West Nusa Tenggara Province. This island is located in the eastern part of Indonesia which has a climate type classification with low rainfall, namely less than 1,000 mm/year [10] so that the West Nusa Tenggara area is included in the dry land area [11]. The limited water for agricultural cultivation in this area is an important issue to be solved so that local food security is maintained. Food security is an important point in sustainable development which in this case affects various aspects [12].

One of the areas on Lombok Island, namely Sekotong District, which is the research location, has an area surrounded by karst landforms and beaches in the south (Figure 1). Karst landforms or commonly called solutional landforms are landforms formed due to the dissolution process of limestone. The movement of water in this area is very limited due to massive rocks that are difficult for water to penetrate. Karst areas cannot store water well so that droughts often occur. Coupled with being surrounded by beaches, this area tends to have low rainfall even under normal conditions. It is known that the average monthly rainfall in 2021 was recorded at 132 mm/month [13].

Fig 1. Morphology of Sekotong District

Low rainfall caused by the El Nino phenomenon has an impact on agricultural land. Agricultural land areas always require water availability to meet the water needs of cultivated plants [14-15]. Low rainfall results in land drought [16], especially agricultural and livestock cultivation land because the availability of groundwater is unable to meet the needs of agriculture and livestock [17]. Especially in terms of water availability, rice plants are plants that really need the availability of water. Continuous drought conditions can disrupt local and national food security [18].

Agricultural land in Sekotong District is quite extensive. Based on BPS data in 2021, Sekotong District has an agricultural land area of around 12,425.8 hectares. Agricultural land in this district is dominated by rice plants that can only be planted during the rainy season. When the dry season occurs, it is usually replaced with other commodities such as corn, beans, soybeans and others or agricultural crops that do not require much water. Based on the El Nino phenomenon that occurred in 2023, this research activity aims to map the

distribution of land affected by drought due to El Nino and its impact on agriculture in Sekotong District.

2 Research method

This research was conducted in Sekotong District, West Lombok Regency, which was conducted in June-July 2024. This study used spatial analysis and qualitative descriptive analysis. Spatial analysis was used to create and present the results of land drought in Sekotong District, while descriptive analysis was used to analyze the impact of land drought on agricultural land. The analysis to determine the distribution of drought was carried out using the Normalized Difference Drought Index NDDI analysis [19] which combines Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) data obtained from satellite imagery. The data obtained from the image are the vegetation density index and its development (NDVI) and the vegetation moisture index (NDWI) [20]. These two indexes can be used to measure drought in an area. The Normalized Difference Vegetation Index (NDVI) is an index that measures the development and density of vegetation, which has a range of values from −1 to 1 [21]. Negative values indicate water or clouds, positive values approaching zero indicate land without vegetation and positive values greater than 0.6 to 1 indicate vegetation density. To calculate NDVI can be done with the following formula:

$$NDVI = \frac{\rho NIR - \rho RED}{\rho NIR + \rho RED} \quad \text{(i)}$$

Description:
ρNIR is the near infrared wavelength (channel 2) and ρRED is the red wavelength (channel 1).
Normalized Difference Water Index (NDWI) is an index for measuring leaf water content and is also used to detect and monitor vegetation moisture [22]. NDWI in its calculation is influenced by plant dehydration so it is considered a better indicator for drought monitoring than NDVI [23]. The NDWI range value is also the same as NDVI, namely a range of values from -0.1 to 1.0, but for vegetation values are in the range of -0.1 to 0.4. To calculate the NDWI value, you can use the following formula:

$$NDWI = \frac{\rho NIR - \rho SWIR}{\rho NIR + \rho SWIR} \quad \text{(ii)}$$

ρNIR is the near infrared wavelength (channel 2) and ρSWIR is the mid infrared wavelength (channel 6).
Furthermore, to calculate the Normalized Difference Drought Index, it can be found from the following formula:

$$NDDI = \frac{NDVI - NDWI}{NDVI + NDWI} \quad \text{(iii)}$$

From the equation above, the Normalized Difference Drought Index (NDDI) can be obtained which can be used as a reference to determine the distribution and extent of drought in the area. After obtaining the results of the Normalized Difference Drought Index (NDDI) and creating spatial information, it is then continued with an analysis of the impact of drought on agricultural land owned by farmers in the Sekotong area.
In this study, the impact of drought was carried out using qualitative descriptive analysis [24]. The data collection method was carried out using the interview method with farmers in Sekotong District. The sampling technique for communities considered to be affected by drought was carried out using purposive sampling where interview samples were carried out on farmers in Sekotong District by taking a sample of 5-7 farmers in each village. Sekotong

District has 9 villages and with this purposive sampling method, 70 interview samples were obtained with farmers.

3 Result and discussion

This research on the analysis of the distribution of land drought and its impact on agricultural land was conducted in Sekotong District using NDDI (Normalized Difference Drought Index) analysis, namely using parameters of water availability and vegetation density. This study uses Landsat 9 for image data before being analyzed and made into NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Drought Index) maps, after which the NDDI (Normalized Difference Drought Index) map can be made based on the results of vegetation density and water availability maps. In addition, this study also uses interviews with farmers in Sekotong District to obtain data related to the impact of land drought in Sekotong District.

3. 1 Land drought distribution

Land drought occurs due to various factors. Land drought in Sekotong District in 2023 until now is part of the impact of the El Nino phenomenon. Sekotong District, which is generally located on the coast and has a karst morphology, has a low water availability which is common. However, with the El Nino phenomenon, the impact of drought is getting worse, resulting in crop failure on agricultural land. To determine the distribution of land drought that occurs in Sekotong District, this study uses Landsat 9 imagery as data used to determine vegetation density and groundwater availability. By knowing the water availability index and vegetation density, from the two image analyses, the land drought index in Sekotong District is known with a distribution per village.

3. 1. 1 NDVI (Normalized Difference Vegetation Index)

Vegetation density index is an index obtained through data from the reflection of light waves on the earth's surface. The numbers obtained from calculating this index indicate the photosynthetic activity and density of vegetation on the earth's surface. The higher the NDVI (Normalized Difference Vegetation Index) value, the green colour and dense the vegetation in an area will be. NDVI (Normalized Difference Vegetation Index) is one of the indices used to measure land drought which is analyzed by taking Landsat satellite imagery data. From the results of data taken from Landsat imagery, vegetation density shows that vegetation density ranges from no vegetation being recorded to very high vegetation density. In 2023 until now, the El Nino phenomenon is still ongoing, so this has reduced the availability of water in the soil so that much vegetation dies and land cannot be planted. The Normalized Difference Vegetation Index analysis process uses bands 4 and 5 to obtain the sharpness of Landsat imagery. The image below is an NDVI (Normalized Difference Vegetation Index) image of Sekotong District taken in mid-May 2024.

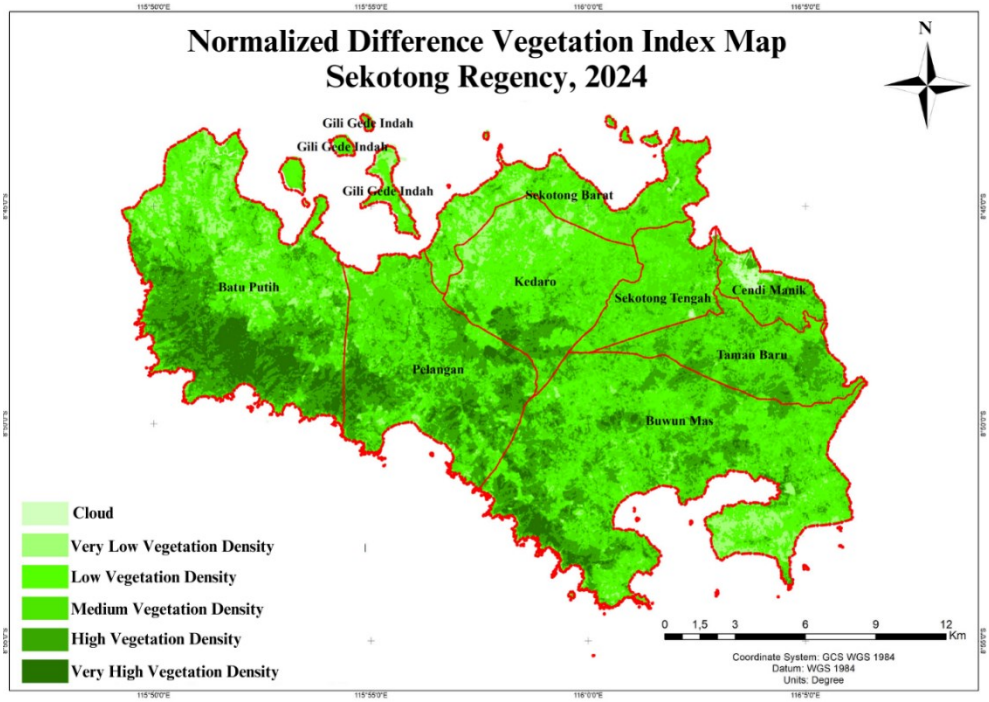

Fig 2. Normalized Difference Vegetation Index Map

The results of Landsat 9 imagery for vegetation density index analysis in Sekotong District show that vegetation density is dominated by medium, low, high, very low, very high vegetation density and cloud/non-vegetation appearance with areas of 11,343.1 hectares, 10,527 hectares, 7,519.9 hectares, 2,494.1 hectares, 2,021.1 hectares, and 222.2 hectares, respectively. The area of vegetation density is balanced with the average rainfall in Sekotong District which was only around 132 mm/month in 2021 [13] before the El Nino phenomenon occurred. The vegetation density depicted on the map shows that the villages in the southern part have quite dense vegetation, while the villages in the northern part tend to be more sparse. Sekotong District, based on regional conditions, tends to be dry due to low rainfall. On the other hand, agricultural activities still dominate the community's livelihoods. In detail and completely based on the village administrative area, the following is table 1 of the area of vegetation density index results in Sekotong District.

Table 1. NDVI (*Normalized Difference Vegetation Index)* area

Village	Cloud	Very Low	Low	Medium	High	Very High	Total
Batu Putih	40	852,5	2149,2	1570,7	2029,2	1108,5	7710,1
Buwun Mas	52,6	557	2900,5	3526,2	2261,6	387,9	9633,2
Cendi Manik	72,7	73,7	193,5	451,9	129,9	2,2	851,2
Gili Gede Indah	9,3	70,4	206,6	70	2,7	0	349,7
Kedaro	10,3	385,9	1761,9	912,4	486,5	87,8	3634,5
Pelangan	15,4	140,9	931,7	1829,5	1737,8	410,1	5050
Sekotong Barat	17,8	384,8	1353,1	685,2	64,6	1,1	2488,8
Sekotong Tengah	4,1	23	668,2	983,9	96,1	0,7	1771,9
Taman Baru	0	5,9	362,3	1313,3	711,5	22,8	2415,8

Source: Data Analysis, 2024

3. 1.2 NDWI (Normalized Difference Water Index)

The soil water availability index can be determined through image analysis. Based on the results of Landsat 9 image analysis, it is known that the distribution of water availability is in line with the vegetation density index that has been discussed previously. With a composite of bands 5 and 6 from Landsat 9 imagery, the groundwater availability index in Sekotong District was detected in the southern villages (Batu Putih Village, Pelangan Village, Buwun Mas Village, and Taman Baru Village) where water availability is still quite abundant compared to the villages in the northern area of Sekotong District. The following is an image of the NDWI map for Sekotong District.

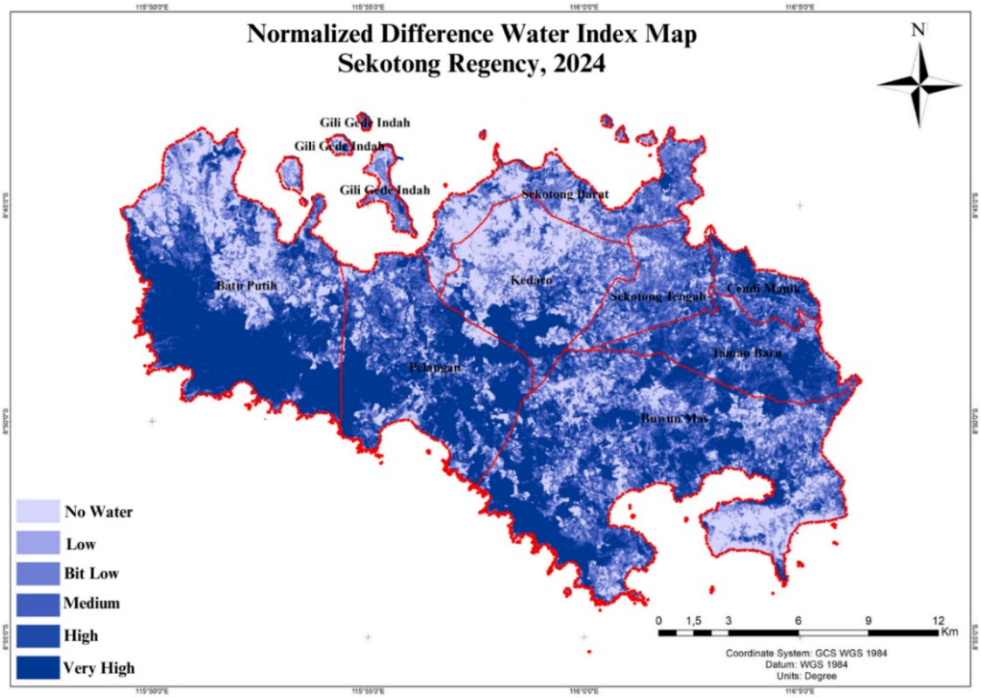

Fig 3. Normalized Difference Water Index Map

From the results of the NDWI mapping of Sekotong District, the area of the water availability index in each village can be seen. Based on the results of the mapping of the distribution of water availability in Sekotong District, it is dominated by Buwun Mas Village with an area of 8255.9 hectares, then Batu Putih Village and Pelangan Village with an area of 6276.4 hectares and 4614.2 hectares respectively. For details of each village can be seen in table 2 below:

Table 2. NDWI (*Normalized Difference Drought Index)* area

Village	No Water Available	Low	Bit Low	Medium	High	Very High	Total
Batu Putih	1473,6	806	859,7	729,8	728,2	3152,7	6276,4
Buwun Mas	1430,2	1236,6	1747,7	1532,4	1331	2408,2	8255,9
Cendi Manik	32,7	62,5	191,4	238,1	186	213,1	891,1
Gili Gede Indah	73,6	81,6	128,1	43,5	17,3	14,8	285,3
Kedaro	1271,2	636,3	612,4	359,7	231,9	533,1	2373,4
Pelangan	451,3	342,6	643,6	802,1	789,9	2036	4614,2
Sekotong Barat	728,5	443,8	713,1	394	136,9	90,3	1778,1
Sekotong Tengah	205,9	275,9	541,5	440,8	220,9	90,8	1569,9
Taman Baru	99,2	159,1	356,5	537,7	617	646,4	2316,7

Source: Data Analysis, 2024

3. 1. 3 Normalized Difference Drought Index (NDDI)

The distribution of land drought in Sekotong District was carried out using the Normalized Difference Drought Index (NDDI) analysis, the result of the Normalized Difference Vegetation Index (NDVI) analysis with the Normalized Difference Water Index NDWI using Landsat 9. Image data collection was carried out in May 2024. Based on this analysis, the distribution of land drought was obtained as shown in the following map:

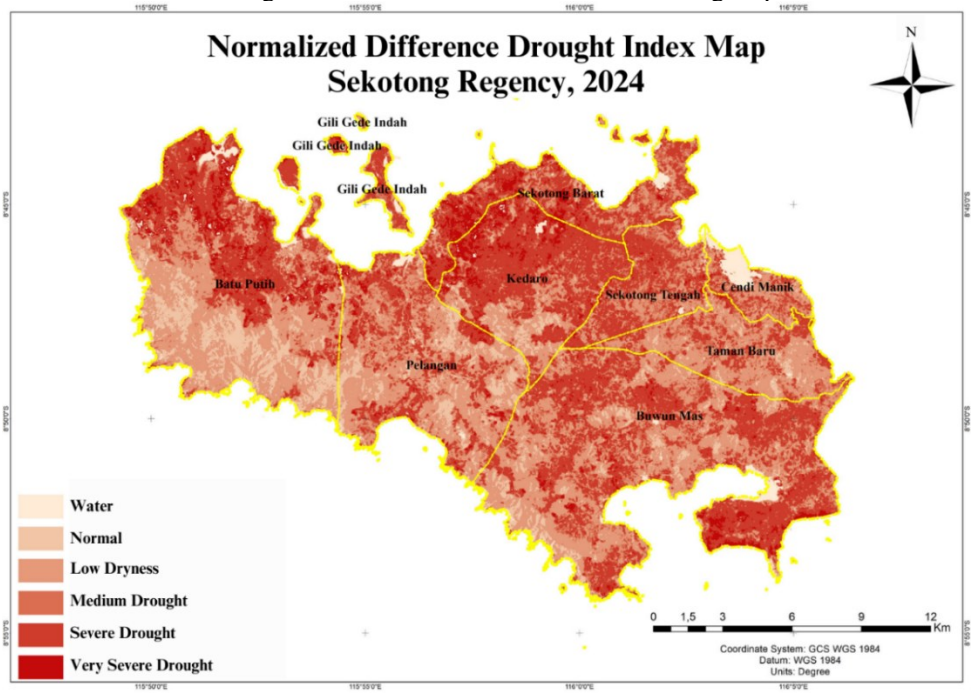

Fig 4. Normalized Difference Drought Index Map

Based on the results of land drought mapping in Sekotong District, it can be seen that several villages are experiencing drought to severe drought conditions. The worst land drought is in the northern part of Sekotong, including Sekotong Tengah Village, Kedaro Village, Sekotong Barat Village, Gili Gede Village, Batu Putih Village and the northern part

of Buwun Mas Village. Meanwhile, some of Taman Baru Village, Pelangan Village, Buwun Mas Village, and Batu Putih Village are still not experiencing drought. Land drought in each village with the worst conditions includes Sekotong Tengah Village reaching 97% of its area experiencing drought; Sekotong Barat Village 95%; Taman Baru Village 94%; Kedaro Village 94%; Buwun Mas Village 91%, Gili Gede Indah Village 88%; Pelangan Village 85%; Batu Putih Village 81% and Cendi Manik Village 76%. Details of the area of villages experiencing land drought can be seen in table 3 below:

Tabel 3. Normalized Difference Drought Index (NDDI) area

Village	Water	Normal	Low Dryness	Medium	Severe Drought	Very Severe Drought	Total	% Drought
Batu Putih	279,5	1192,5	2838,5	755,4	2174,4	509,8	6278,1	81
Buwun Mas	274,4	537,2	3418,9	1616,7	3550	288,8	8874,4	91
Cendi Manik	194,3	23,6	315,3	203	182,8	4,7	705,8	76
Gili Gede Indah	30,7	9,2	41,6	78,5	185,8	13,1	319	88
Kedaro	25,7	182,6	677,3	420,7	1981,5	356,9	3436,4	94
Pelangan	100,6	628,2	2356,8	759,9	1107,2	112,9	4336,8	85
Sekotong Barat	86,6	26,3	374,8	509,6	1225,2	284	2393,6	95
Sekotong Tengah	17,5	21	417,2	481	815,8	23,3	1737,3	97
Taman Baru	4,2	133,4	1285,9	487,6	491,9	12,8	2278,2	94
Total	1013,5	2754,0	11726,0	5312,0	11715,0	1606,3	13321,0	

Source: Data Analysis, 2024

3. 2 Impact of Land Drought

As a sub-district which is a karst area, drought is an unavoidable disaster coupled with the presence of El Nino. Karst areas are very prone to drought, even without the El Nino phenomenon, this area remains dry throughout the year. The condition of land drought in karst areas is influenced by the hydrological pattern of the area. Karst areas are areas formed from limestone, gypsum, dolomite and other rocks that are easily dissolved [25]. Groundwater in karst areas cannot be absorbed but flows through underground flows [26]. Rainwater that falls in karst areas cannot be accommodated in groundwater, but enters the surface through cracks in impermeable limestone rocks and flows in the water flow below following the cracks in the rocks that form the karst morphology [27]. This is what causes the absence of underground water reserves in karst areas.

The morphology of the southern Sekotong area is a hilly karst area with a lower population density compared to the villages in the northern part of Sekotong District which have a more declivous. This environmental condition is one of the factors in population density in Sekotong District. The gentle area in the northern part of Sekotong makes the population density higher than in the southern area. The increasing number of residents means that the need for water is increasing, in this case resulting in the availability of water for various needs also becoming increasingly limited. The use of water for daily needs including cooking, bathing, drinking and needs in their agricultural land is obtained from rain that is collected in underground water reserves. With various activities carried out by the community, the increasing number of residents who need more water availability. This is

what causes the northern part of Sekotong District to experience more land drought compared to the villages in the South Sekotong area. The population density level in Sekotong District can be seen in the following table 4:

Table 4. Population density of Sekotong district

Village	Population Density
Batu Putih	157
Buwun Mas	271
Cendi Manik	145
Gili Gede Indah	433
Kedaro	873
Pelangan	126
Sekotong Barat	216
Sekotong Tengah	281
Taman Baru	116

Source: BPS Sekotong District, 2023

In addition, villages that are included in small islands such as Gili Gede Village, Gili Layar and Gili Asahan which are part of Batu Putih Village in the use of water for their daily needs use gallon water taken from the mainland/main island. This is because the water sources on these small islands are affected by seawater intrusion which results in very high salt levels so that they cannot be used for food and drink needs. The condition of the village which is entirely in the coastal area with sandy soil and high salt levels so that the small islands in Sekotong District do not have agricultural land. To meet their daily food needs, people take staple foods from the mainland.

Land drought in Sekotong District has occurred since 2023 and will continue until 2024. This land drought has had a significant impact on agricultural land in the district, with a total agricultural land area of 3040.73 hectares [28]. Agricultural land in Sekotong District is mostly rain-fed land and some use non-technical irrigation. Most farmers who cultivate food crops rely on rain or rain-fed rice fields. Meanwhile, with the presence of El Nino, farmers feel a major impact, especially on the availability of groundwater, which results in rice fields not being able to be planted with food crops, resulting in crop failure, especially in rice and corn food crops, so farmers make substitutions in cultivated commodities.

3. 2. 1 Water Availability

Low rainfall due to the El Nino phenomenon results in very low water availability on agricultural land. In addition, as a dry land area, water availability in Sekotong District is low and cannot meet the water needs of agricultural land [29-30]. Most farmers use rain-fed rice fields so that rainfall greatly determines their cultivation activities. This low rainfall causes significant losses to farmers so that plants begin to die and result in crop failure. [31] Nurseto, 2017 in his research stated that in the dry season, agricultural land experiences drought and causes food commodities to die due to the lack of water availability, conversely during the rainy season the condition of agricultural land becomes flooded. Therefore, farming communities work together to build dams that can accommodate and store water. Meanwhile, research by [32] Sukarman et al, 2022 showed that reduced water availability resulted in decreased palm oil productivity in several types of soil. This shows that water availability is very important in the sustainability of agricultural cultivation activities in various places. Based on the results of interviews with farmers in research activities on the impact of land drought due to the El Nino phenomenon, namely water availability. The need for water to meet the daily lives of the people of Sekotong District is quite difficult to meet. Moreover,

the fulfillment of water on agricultural land is very difficult to obtain. In the results of the NDWI (Normalized Difference Water Index) map of Sekotong District, Batu Putih Village is the village with the least water availability.

Fig 5. River for irrigation

3. 2. 2 Crop Failure

Based on the results of interviews with farmers in Sekotong District, the most detrimental impact on farmers in Sekotong District is crop failure. Most farmers in Sekotong District cultivate food crops such as rice and corn. These two food crops have always been used as the main crops by farmers so far, but in 2023, rice and corn food crops experienced crop failure due to land drought and water sources around them also experienced drought so that they could not meet the water needs of agricultural land. Food crop cultivation activities experienced crop failure in 2023 to 2024, this resulted in farmers not daring to take risks to cultivate food crops such as rice and corn that they usually plant. As a step to continue to earn income from agricultural land, most farmers changed their cultivated commodities. The cultivated commodities are selected and adjusted to the availability of water, so farmers try to cultivate plants that do not require a lot of water in these cultivation activities.

3. 2. 3 Agricultural Commodities

The main agricultural commodities in Sekotong District are food crops in the form of rice and corn. These two commodities are staple food crops consumed by the community in Sekotong District. These plants can grow in various types of land in Sekotong District provided that groundwater is available for the growth and development of these plants. In [33] Trinugroho's research, 2024, rainfed rice fields experienced difficulties in cultivating rice plants during the dry season. Rice plants that lack water will experience stress during the growth period, so that rice plants cannot grow and can result in crop failure. [34] Novia, 2021 in his research stated that the failure of the rice harvest in Banyumas was widespread due to drought in agricultural land. The El Nino phenomenon that occurred in Sekotong District had an impact on the low rainfall that fell, resulting in insufficient water availability. Groundwater that could not meet the water needs of rice and corn plants resulted in failure in 2023. With this failure, farmers were reluctant to cultivate rice and corn considering the almost non-existent rainfall. Therefore, in order to continue to utilize their land, farmers continued to carry out cultivation activities. However, the cultivated plants that were usually cultivated were replaced with other plants that were quite adaptive to the little groundwater.

Fig 6. Secondary crops

4 Summary

The distribution of land drought in Sekotong District occurs in almost all villages. The villages experiencing drought from the widest to the narrowest include Sekotong Tengah Village 97% of the area experiencing drought, Sekotong Barat Village 95%, Taman Baru Village 94%, Kedaro Village 94%, Buwun Mas Village 91%, Gili Gede Indah Village 88%, Pelangan Village 85%, Batu Putih Village 81%, Cendi Manik Village 76%. The impact of land drought in Sekotong District is almost evenly distributed, namely the availability of water becomes scarce, crop failures to the replacement of agricultural commodities.

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