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Mapping the Potential Development of Soybean Crops Based on Growing Degree Days

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Abstract

The main factors affecting crop growth and yield are soil, climate, and crops. The influence of clime is more than soil on crop growth under certain conditions. The evidence is that some cover vegetation growth conditions are much different even though they grow on the same land. In each distinct place, the harvest time of one type of crops is not the same. One crucial factor that affects this is the daily growth rate or the degree of Growing Degree Days (GDD). Know parameters such as soil type, slope, land use, rainfall, and GDD temperature by using geographic information systems in determining the suitability of agricultural commodity development areas. The study aims to determine the suitability of soybean cropland in West Sumatra based on GDD value. Conducting land suitability analysis using the GDD method through several stages, namely, the classification of soybean land suitability parameters, making a map of soybean crop land suitability in physical characteristics, classifying the GDD value of soybean crops for the West Sumatra region, and making a soybean cropland suitability map based on GDD value. The potential land for soybean cultivation in West Sumatra based on land suitability class, physical characteristics, and GDD value is 267,539.09 hectares in class S1 (very suitable) and an area of 1,612,438.84 hectares in class S2 (appropriate enough). The most optimal planting time for soybean cultivation is in August. Lima Puluh Kota Regency, Pasaman Regency, Sijunjung Regency, and Solok Regency have land suitable for soybean cultivation with more than 200 thousand hectares of areas and are in areas with growing degree days suitable for soybean growth.

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1. Introduction

West Sumatra Province is one of the centers of food production in Indonesia. Based on data from the Central Statistics Agency, West Sumatra is contributing the most to reach 6.38% in 2020 in the agricultural sector with food crop sub-sectors that include rice and crop commodities (corn, soybeans, peanuts, green beans, cassava, and sweet potatoes). Primary agricultural business is one of the main activities of the horticultural and plantation food crop agricultural subsector, which are the six

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commodities (Food Crops, Horticulture and Plantation Office of West Sumatra Province, 2020). Soybeans are one of the six crop commodities. Increasing population growth and also public awareness of food nutrition have led to an increase in the need for soybean commodity consumption. This growth exceeds the soybean production in the country, so it is necessary to import soybeans to cover the increasing demand for soybeans.

Soybean self-sufficiency is still not achieved due to the rate of soybean import value, which has reached an average of 200% in the last 52 years based on FAO data, while domestic soybean only can produce as much as 65.61% of domestic consumption. Therefore, to meet the needs of domestic soybean consumption without dependence on imports and the production of other regions, it is necessary to increase soybean production in West Sumatra.

The main factors that establish crop growth and yield are soil, climate, and crops. Evaluate the suitability of physical land with matching and scoring methods to determine the suitability of crops to grow and develop in an area. Requires conformity research with further evaluation levels to obtain more optimal results (Naibaho et al., 2018).

The type of vegetation that grows in an area can be identified based on climate features. The influence of climate on crop growth is more than that of soil under certain conditions. The proof is that in cover vegetation, the growth is much different despite planting it in the same soil. Therefore, it requires detailed climate data from several decades with monthly averages and distribution throughout the year (Setiawan, 2009). Dynamically simulating crop growth and development by knowing the components of rainfall, maximum temperature, minimum temperature, and solar radiation highly affect crop growth (Setiawan, 2009).

Temperature affects root growth, nutrient absorption, water absorption, and photosynthesis. The energy and temperature received by crops affect the growth rate of crops. Growth analysis is one way to study crop growth by knowing how crops respond to their environment.

The harvest time of one type of crop is not the same in different places. One crucial factor that affects this is the daily growth rate or Growing Degree Days. The concept of Growing Degree Days is to accumulate the difference in average daily air temperature with the base temperature of crops from the beginning of growth to harvest which is characterized by the achievement of the cumulative value of heat degrees needed at the end of the crop development phase or at the time of harvesting.

Growing Degree Days can be used to deal with climate change. Therefore, growth testing is needed and determining the degree of growth or degree days of each phase of crop growth based on heat accumulation, Growing Degree Days so that it can be used as a reference for farmers in determining planting periods. Knowing parameters such as soil type, slope, land use, rainfall, and GDD temperature using geographic information systems can be a reference to determine the regional

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suitability for agricultural commodity development. The study aims to determine the suitability of soybean cropland in the West Sumatra region based on the value of Growing Degree Days spatially and temporally.

2. Research Methods

2.1. Research Location

The research was conducted in West Sumatra Province. Carry out processing, data analysis, and mapping processes in the Agricultural Engineering Study Program, Faculty of Agricultural Technology, Andalas University, Padang.

2.2. Data Collection

The materials needed in this research process are:

1. As secondary data, the Climatology (daily rainfall and temperature) of the West Sumatra region for 30 years (1990-2020) is used for land suitability analysis and value calculation and GDD mapping. The data is obtained from the website power.larc.nasa.gov
2. The administrative map of the West Sumatra region is used to determine the limits of research obtained from the tanahair.indonesia.go.id website.
3. Using the slope map of the West Sumatra region for the land suitability analysis process obtained from processing digital elevation model data from the tanahair.indonesia.go.id website.
4. The soil texture map of the West Sumatra region is used for the land suitability analysis process obtained from the Indonesia-geospasial.com website.
5. The land use map of West Sumatra is used for the land suitability analysis process obtained from the tanahair.indonesia.go.id website.
6. The pH map of the West Sumatra region is used for the land suitability analysis process obtained from the tanahair.indonesia.go.id website.
7. The rainfall distribution map is used for land suitability analysis obtained from image data processing for the West Sumatra region (1990-2020).
8. The spatial pattern map of West Sumatra is used land suitability analysis to determine the types of areas that can be planted with soybeans obtained from secondary data processing.

2.3. Data Processing

Land suitability analysis using the Growing Degree Days (GDD) method is carried out through several stages, namely land suitability analysis based on physical land characteristics, making physical land suitability maps, soybean land suitability analysis based on Growing Degree Days (GDD) for West Sumatra Province, and making Growing Degree Days (GDD) maps for West Sumatra Province.

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2.3.1. Analysis of Land Sustaibility of Soybeans Crops based on Physical Land Characteristics

The matching method is used to analyze. Match the growing requirements of soybean crops with land characteristics until the results of a classification in each unit of land are obtained. The land characteristics used in this classification process consist of slopes, land use, annual rainfall, soil texture, and pH. The results of land classification are divided into several land suitability classes, namely very suitable (S1), appropriate (S2), less suited (S3), and unsuitable (N). Land characteristic scores based on the level of land suitability for soybeans are in Table 1 (BBSDLP, 2011) .

Table 1. Land Characteristics Score based on the level of Soybean Land Suitability.

No	Land Characteristic	Land Characteristic Conditions	Score
1	Slope (%)	<3	4 (S1)
		3 – 8	3 (S2)
		>8 – 15	2 (S3)
		>15	1 (N)
2	Land Use	Moor	4 (S1)
		Rice field	3 (S2)
		Plantation	2 (S3)
		-	1 (N)
3	Annual Rainfall (mm/year)	1,200 – 1,500	4 (S1)
		1,000 – <1,200	3 (S2)
		>1,500 – 1,900 and 800 - <1,000	2 (S3)
		>1,900 – 2,300 and <800; >2,300	1 (N)
4	Land Texture	Smooth, slightly smooth, medium	4 (S1)
		Smooth, slightly smooth, medium	3 (S2)
		Rather rough	2 (S3)
		Rough	1 (N)
5	pH Land	5.5 – 7.5	4 (S1)
		5.0 – 5.5	3 (S2)
		7.5 – 8.0	2 (S3)
		<5.0; >8.0	1 (N)

The score for each land characteristic is given according to the level of suitability for plant growth requirements. Land characteristics that are very suitable for growing soybeans will be given a score of 4 (S1) and conversely if land characteristics do not match the conditions for growing soybeans they will be given a score of 1 (N). The parameters are put together using an overlay way. The value of

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each level of land suitability needs to be known to obtain the range of values of each land suitability class. Evenly weighting each parameter assumed that all parameters have the same level of influence on land suitability (Killa, 2020). Land classification is carried out in equation (1) (Ekaputra, 2022). The calculation of the scoring value is in Table 2.

$$X = \sqrt[n]{B/A} \quad (1)$$

Information: X: Interval variable, n: Number of class intervals, B: Maximum scoring value, A: Minimum scoring value

Table 2. Land Suitability Geometry Intervals

Classification	Formula	Information
S1	Ax^3 - Ax^4	Very Suitable
S2	Ax^2 - Ax^3	Appropriate Enough
S3	Ax - Ax^2	Marginal Fit
N	A - Ax	Unsuitable

The process of making a land suitability map of soybean crops in the West Sumatra region based on land characteristics is as follows:

1. Ensure the coordinates of the map coordinate project become WGS1984 on GCS (Geographic Coordinate System).
2. Enter the data needed to create maps for physical land suitability analysis into the ArcMap application.
3. Make administrative maps, slopes, land use, rainfall distribution, texture, soil pH, and spatial patterns in the West Sumatra region. Create a rainfall distribution map using Thiessen's Polygon method.
4. Ensure the completeness of the attribute data of each parameter.
5. The overlay stage is to combine the maps that have been created. Select the intersect tool, insert the maps, and save the file in shapefile format.
6. Reconfirm the attribute data in the overlay results by opening the attribute table.
7. Add a new column using the add field in the attribute data table to populate the total score and land suitability class.
8. Sorting and processing attribute data using Excel to obtain total values and classification of land suitability classes.
9. Fill in the table of total land suitability grades and classes.
10. Add color to each classification of overlay activity results.

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11. A map output with different colors is obtained. Each color determines the level of physical suitability of the soybean field.
12. Cut the land suitability map with the spatial pattern map.
13. A land suitability map that has been cut with a spatial pattern map is obtained as the final result.

2.3.2. Soybean Land Suitability Analysis Based on Growing Degree Days (GDD)

In a year, the soybean can crop as many as four times because soybean crops have a planting age of 75-95 days. Calculate the GDD value at each planting start which is 12 scenarios, in a year to determine the appropriate planting time. The data needed in the Growing Degree Days (GDD) analysis is secondary data in the form of daily temperature data in the West Sumatra region from 1990 – 2020. The temperature data was obtained from the power.larc.nasa.go website using observation points following the number of BMKG stations in West Sumatera, which is as many as 45 observation posts.

Process temperature data to determine the average minimum and maximum values for 1990-2020, then calculate the GDD value using equation (2) to get a representative GDD value for one year. The accumulated GDD value is then compared with the reference GDD value for soybean crops that can grow well (based on the literature) so that the category for each observation point is categorized as suitable and not suitable. The spatial determination of the GDD area is carried out using the isolines method. Each map produced in this study represents one cropping scenario (12 scenarios).

$$\text{Growing Degree Days (°C)} = \sum\left[\left(\frac{T_{max}+T_{min}}{2}\right) - T_{base}\right] \quad (2)$$

Information: Tbase: Base temperature that crops can pass through (10°C), Tmax: Daily maximum temperature (°C), Tmin: Daily minimum temperature (°C)

With the lowering of temperature, the rate of metabolic processes slows steadily and eventually stops under extreme stress (Taiz and Zeiger, 2002). The base temperature value of soybean crops is 10°C (Kumar et al., 2008).

Making a soybean cropland suitability map based on GDD is as follows:

1. Ensure the coordinates of the projected coordinates become WGS1984 on GCS (Geographic Coordinate System)
2. Add an administrative map of West Sumatra
3. Adding GDD data that has been processed using Excel, which has been equipped with coordinates (x, y) for each observation point
4. Mapping using the isolines method
5. The results are obtained as a classification map of the GDD accumulation value per planting time scenario (12 scenarios).

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2.4. Data Analysis

Identification of suitable areas for soybean cultivation based on GDD values is obtained after do analyzed the suitability of soybean crops based on physical land characteristics and combining with the results of GGD analysis based on planting time scenarios (Figure 1).

2.5. Output

The output of this study is a map of the suitability of soybean crops in West Sumatra based on GDD spatially and temporally based on planting time scenarios. Use GDD-based land suitability maps as a reference for soybean crop development in the West Sumatra region.

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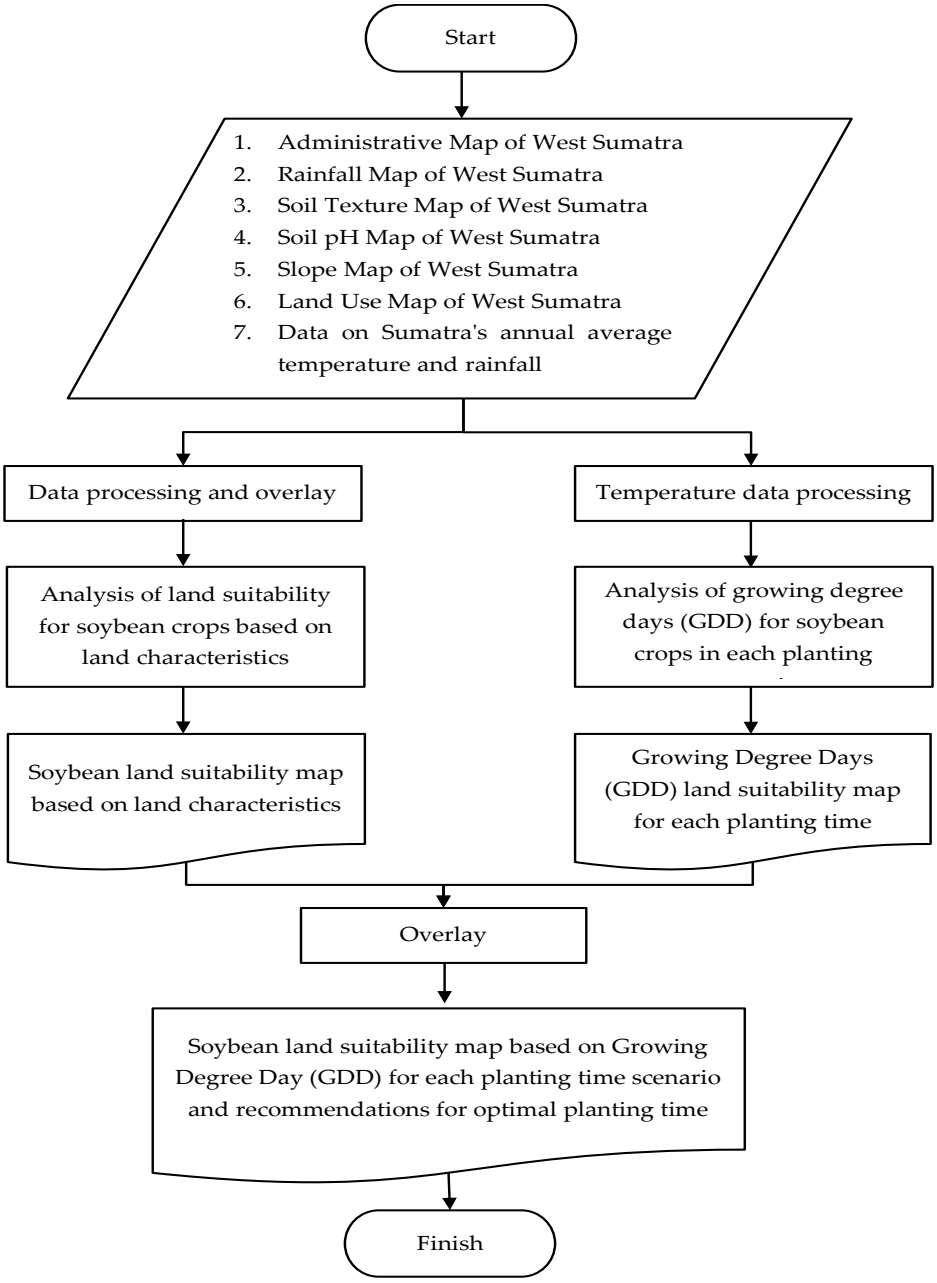

Figure 1. Soybean Land Suitability Analysis Workflow Based on GDD

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3. Result and Discussion

3.1 Research Site Overview

The location of West Sumatra is 0° 54' North Latitude - 30° 30' South Latitude and 980° 36' - 1010° 53' East Longitude. West Sumatra Province has 19 total regencies and cities consisting of 12 regencies and seven cities. The study was conducted in 18 (regencies/cities) without Mentawai Islands Regency. The total area of West Sumatra without the Mentawai Islands Regency studied is 3,600,154 hectares.

West Sumatra Province is a tropical climate region traversed by the equator with equatorial rainfall patterns characterized by two peaks of the rainy season within one year. West Sumatra is located on the west coast of the central part of the island of Sumatra. It is formed by the Barisan Mountains, so it has a volcanic plateau. The geographical condition of West Sumatra Province provides natural wealth in the form of fertile land. It is very beneficial for the agricultural process. The West Sumatra region has an enormous role in farming activities and is one of the food-producing centers in Indonesia.

3.2 Classification of Soybean Land Suitability Parameters in West Sumatra Region

3.2.1. Slopes

The slope is one of the factors that must be considered in land suitability. The risk of erosion and surface flow increases on steeper and longer slopes. Land with slopes of >15% with high rainfall is more at risk of landslides (Andrian et al., 2014). Slope parameters were divided into four classes with different levels ranging from very suitable to unsuitable for the growth of soybean crops. Land slopes in the West Sumatra region are in Table 3.

Table 3. Classification of Land Slopes in the West Sumatra Region

Slope	Class	Area (Ha)	Percentage (%)
0 % - 8 %	S1	953.055,05	26,47
8 % - 14 %	S2	574.415,97	15,96
15 % - 25 %	S3	691.401,33	19,20
>25 %	N	1.381.281,65	38,37
Total		3.600.154	100

Based on Table 3, a land classification with several levels of slopes in West Sumatra was obtained. The West Sumatra region is chiefly included in the land suitability category N (unsuitable), which is as much as 38.37% of the total area and has slopes of >25% or very steep. West Sumatra is an area traversed by the Barisan Mountains. There are many hilly and mountainous areas, so many lands have high slopes enough. A very steep field has a high risk of erosion and surface flow, increasing landslides and loss of soil fertility due to surface runoff.

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3.2.2. Land Use

Land use indicates the use of land carried out in a particular area. Land use data was used to determine the potential of land to support agricultural cultivation activities and assist in processing and planning land use. The classification of West Sumatra land use classes based on soybean cropland suitability requirements in Table 4.

Table 4. Land Use Classification of West Sumatra Region

Land Use	Class	Area (Ha)	Percentage (%)
Moor	S1	1.297.980,31	36,05
Rice Field	S2	256.121,24	7,11
Plantation	S3	1.348.731,46	37,46
Other land uses	N	697.320,99	19,37
Total		**3.600.154**	**100**

Based on Table 4 of land use in West Sumatra, it is known that most of the land in West Sumatra is dominated by plantation and moor land use. Moorland is a type of dry land used for annual crops. Upland is a group in suitability class S1 for soybean crops. Rice fields are in the S2 suitability group because if the fields are not planted with rice, they can be used for cultivating seasonal crops. The plantation is in the S3 class category. Other land uses include Primary Dry Land Forest, Swamp, Shrub/Shrub, Secondary Mangrove Forest, Primary Swamp Forest, Secondary Swamp Forest, Settlements, Mining, Water Bodies. Other land uses are included in class N because they cannot be cultivated on soybean agricultural land.

3.2.3. Rainfall

Data on the distribution of annual average rainfall for the West Sumatra region was obtained by processing the data using the thiessen method. Rainfall data is obtained from the power.larc.nasa.gov website using the coordinates of 45 observation points according to the number of existing West Sumatra rainfall observation posts based on PSDA data. The classification of rainfall classes based on soybean land suitability requirements is presented in Table 5.

Table 5. Classification of Average Annual Rainfall of West Sumatra Region

Annual Rainfall (mm/year)	Class	Area (Ha)	Percentage (%)
>1.900 – 2.300	S3	210.804,10	5,86
>2.300	N	3.389.349,90	94,14
Total		**3.600.154**	**100**

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It can be seen that the average yield of annual rainfall in West Sumatra in 1990-2020 is high, so there are only two classes of soybean land suitability based on rainfall parameters, namely S3 and N, based on Table 5.

3.2.4. Soil Texture

The texture is one of the physical properties of soil that affects the growth of a crop. Soils with fine texture have a fine particle size, while soils with texture have larger particle sizes, like gravel. Clayey soil texture has a smaller volume weight than soil with a sandy texture. The density of high soil volumes will increase soil density, disturbing aeration, and drainage. It makes root growth disturbed. The better the soil texture, the better the soil is used as agricultural land. That is because the soil is easily penetrated by water and crop roots (Bintoro et al., 2017). Soil texture in the West Sumatra region is divided into several classifications in Table 6.

Table 6. Soil Texture Classification of West Sumatra Region

Texture	Class	Area	Percentage (%)
Smooth, Rather Smooth, Medium	S1	3.092.718,58	85,91
Rather Rough	S3	367.620,81	10,21
Rough	N	139.814,61	3,88
Total		**3.600.154**	**100**

It can be seen that 85.91%, or almost the entire area of West Sumatra, has a good soil texture for soybean growth, according to Table 6. Soil with a coarse texture will have more rock and sand content. The lack of ability to retain water and store organic substances needed by crops makes fertility levels low. This condition is not good and will inhibit the growth of soybean crops.

3.2.5. Soil pH

The level of acidity or soil pH is one of the chemical properties of the soil that affects crop growth. The pH value affects crop nitrogen levels, nitrogen, and phosphorus uptake (Lubis et al., 2015). Nitrogen and phosphorus are essential elements that have an important role in photosynthesis and crop root development. The level of acidity can be controlled by adding certain substances to the soil to neutralize the soil pH. The soil pH in the West Sumatra region is in Table 7.

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Table 7. Soil pH Classification of West Sumatra Region

Soil pH	Class	Area	Percentage (%)
5,5 - 7,5	S1	369.584,27	10,27
5,0 - 5,5 7,5 - 8,0	S2	483.438,46	13,43
< 5,0 ; > 8,0	S3	2.747.131,27	76,31
Total		**3.600.154**	**100**

Based on Table 7, it is known that most of the land in West Sumatra, which is 2,747,131.27 hectares, which is 76.31% of the total area of West Sumatra, has an extreme soil pH, which is too acidic and too alkaline. Too acidic or too alkaline soil will interfere with crop growth and development.

3.3 Land Suitability Classification of Soybean Crops in West Sumatra Based on Physical Characteristics

Land suitability is an indicator that provides information about the ability or suitability of land to grow a crop. The suitability of soybean land was obtained by comparing several land parameters against the growing requirements of soybean crops. The classification of West Sumatra land based on suitability classes for soybean crops is presented in Figure 2. Based on the analysis of the suitability of soybean crops physically that has been carried out, the results were obtained as in Table 8.

Table 8. Land Suitability of Soybean Crops in West Sumatra Based on Physical Characteristics

Class	Information	Area (Ha)	Percentage (%)
S1	Very Suitable	557.791,66	15,49
S2	Appropriate Enough	2.313.796,44	64,27
S3	Marginal Fit	47.480	1,32
N	Unsuitable	681.085,90	18,92
Total		**3.600.154**	**100**

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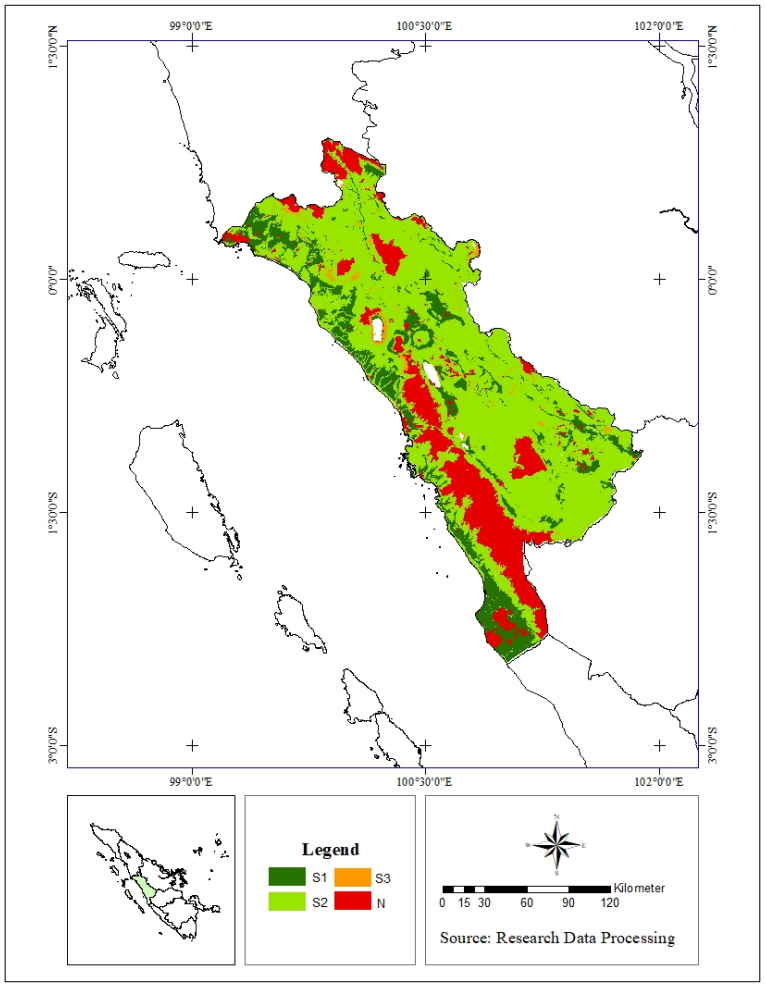

Figure 2. Map of Land Suitability of Soybean Crops in West Sumatra Based on Physical Characteristic

Based on the result analysis presented in Table 8, it is known that West Sumatra has the largest S2 area compared to the other three land suitability classes. West Sumatra has S2 class land covering an area of 2,313,796.44 hectares, which is 64.27% of the total area of West Sumatra. The S2 class land that dominates West Sumatra shows the high potential of land for soybean cultivation.

Land that is suitable for processing and being used as a place for soybean cultivation is S1 and S2 land. S1 class land (very suitable) is the most suitable land condition for planting soybean crops because it meets the requirements for growing soybean crops. S2 class land (appropriate) is adequately good land and has the potential to be processed and improved again into optimal land for soybean plant growth.

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S3 class land (according to marginal) has the smallest percentage among all existing classes, which is 1.32%, with an area of 47,480 hectares, while class N (non-suitable) land has an area of 681,085.90 hectares with a percentage of 18.92%. S3 class land indicates that land has too low a potential to be planted with soybeans due to more dominant limiting factors. As S2 class land, S3 class land can still be improved using convinced treatments, but it is arduous and requires costly effort. Class N is a land that is not suitable for soybean cultivation due to limiting factors that are very dominant and difficult to overcome.

The limiting factor for soybean growth is a parameter whose value is not following the conditions for growing soybean crops. The first parameter is the slope. Land with a high slope is a limiting factor in soybean growth because of the risk of causing soil damage. This very steep land is quite difficult to handle, if only with the help of makeshift equipment. The way that can be done to hold land with a high slope is by carrying out minimum tillage and planting based on contour lines (Mujiyo et al., 2021). Minimum tillage includes soil and water conservation activities to minimize soil loss due to erosion on sloping land. Land damage due to corrosion can also be avoided by making terracing (Haryadi et al., 2019). Terraces are mechanical soil and water conservation by reducing slope length and reducing slope by making land terraced (Pramudo et al., 2016).

Land use in West Sumatra that is suitable and has potential for soybean cultivation is dry land agriculture as much as 12.22% with an area of 443,643.75 hectares, dry land agriculture mixed with shrubs as much as 16.66% with an area of 604,455.86 hectares, rice fields as much as 7.11% with an area of 258,177.68 hectares, shrubs/thickets as much as 6.41% with an area of 232,668.86 hectares and swamp shrubs as much as 0.76% with an area of 27,633.53 hectares. This result shows that the total land area that has the potential to be planted with soybeans in the West Sumatra region is as much as 43.16% of the total area of West Sumatra.

Rainfall data shows that the average value of rain per year (1990-2020) in the West Sumatra region is most classified as enormous for the annual rainfall needs of soybean crops. This can be seen in the rainfall data table where 94.14% of the total area of West Sumatra has rainfall of more than 2,300 mm/year which is very unsuitable for soybean growth, and only 5.86% of the total area of West Sumatra has rainfall that is classified as marginal for soybean growth. Rainfall parameters cannot be controlled by humans, so it needs good water handling and management to deal with it so that land can be cultivated to remain planted with soybeans. The way that can be done to deal with rainfall patterns for agricultural land is by adjusting planting times and applying irrigation technology (Surmaini et al., 2017).

Soil texture is one of the characteristics of soil in terms of physical that is difficult to control or strive to meet the requirements for growing soybean crops. Soil texture is influenced by geographical location, natural phenomena and takes a long time to be changed. West Sumatra land based on soil

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texture parameters. Most of it has the potential to be planted with soybeans. This can be seen from the research results that only 14.1% of the total area of West Sumatra has a slightly coarse to coarse texture, which is unsuitable for soybean growth.

Soil parameters from a chemical perspective are also used as limitations to determining the land suitability for soybean growth. The chemical properties of the soil analyzed are soil pH. Based on the results of the study, the soil pH value of the West Sumatra region has a very suitable grade of 9.1% and is appropriate for as much as 17.1% of the total area based on soybean growing requirements. The rest is marginal-grade land against soybean growing conditions which is 73.8% of the sum area. Liming with the proper dosage, method, time, and conditions is widely known to increase soil and crop productivity (Maulana et al., 2020).

3.4 Classification of Growing Degree Days (GDD) Value of Soybean Crops in the West Sumatra Region

The GDD value is obtained from processing temperature data using equation (1) obtained through the power.larc.nasa.gov site using the coordinates of 45 rainfall posts in West Sumatra based on PSDA data. These coordinates are used to obtain temperature data representing all regions in West Sumatra. The average GDD value each month from the year (1990-2020) is used to determine the number of GDD values in a single cropping scenario.

Based on the results of interviews with farmers in the field, it is known that soybeans have a planting age of 4 months from the beginning of planting to the time of harvest. The GDD value for one planting scenario is obtained by adding up the GDD value according to the soybean planting age, which is 4 months. Every month from January to December is the start of the growing season. So, there are 12 accumulated GDD values in one year that represent each of the planting scenarios.

The optimal GDD value for soybean crop growth is 1680-1800 (Atman & Hosen, 2008). Inquiry into the value of growing degree days was carried out using the ArcMap software from ArcGis 10.8. The results of the analysis of the Growing Degree Days values are presented in Table 9.

Analysis of the value of Growing Degree Days resulted in 2 class categories. They are appropriate and inappropriate. The appropriate class is an area with accumulated GDD values that are included in the optimal GDD value range for soybean growth, and the inappropriate group is an area with accumulated GDD values outside the optimal GDD value range for soybean crops. The optimal GDD value for soybean crops is 1680 – 1800 (Atman & Hosen, 2008).

The best scenario chosen is the widest distribution of appropriate GDD accumulation. The scenario with the spacious distribution area of GDD accumulation is scenario VIII, with the beginning of the growing season in August and harvest time expected in November. The GDD distribution area, according to scenario VIII, is the widest, namely 2,492,362.92.

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Table 9. Classification of Soybean Growing Degree Days for the West Sumatra Region

Scenario	Month	GDD	Distribution Area GDD (Ha)	
			Suitable	Unsuitable
I	January - April	1524,34 - 2019,28	2.472.448,82	1.127.705,18
II	February - Mei	1544,62 - 2041,26	2.310.909,62	1.289.244,38
III	March - June	1558,22 - 2065,03	2.107.757,50	1.492.396,50
IV	April - July	1547,29 - 2057,10	2.475.715,80	1.124.438,20
V	Mei - August	1552,61 - 2065,36	2.261.442,83	1.338.711,17
VI	June - September	1531,89 - 2026,83	2.378.909,38	1.221.244,62
VII	July - October	1548,95 - 2023,22	2.475.715,80	1.124.438,20
VIII	August - November	1542,19 - 1994,11	2.492.362,92	1.107.791,08
IX	September - December	1528,75 - 1980,30	2.328.086,06	1.272.067,94
X	October - January	1529,19 - 1996,85	2.413.713,08	1.186.440,92
XI	November - February	1498,53 - 1976,69	1.922.130,71	1.678.023,29
XII	December – March	1516,22 - 2013,73	2.244.139,91	1.356.014,09

3.5 Classification of Land Suitability for Soybean Crops in The West Sumatra Region Based on the Accumulated Value of Growing Degree Days (GDD)

Analysis of land suitability for soybean crops based on soybean growing conditions alone is not enough to determine the suitability level of land for soybean growth. Land which very suitable (S1) and appropriate enough (S2) land characteristics still have the possibility of being less than optimal for crop growth due to the influence of environmental factors. Further analysis of land characteristics with environmental factors of an area to be planted with agricultural commodities is needed. One of the environmental factors that has a great influence on the process of soybean growth and development is temperature.

Analysis of soybean land suitability based on GDD values is only focused on S1 and S2 class areas that have GDD following the optimal GDD value range according to Atman & Hosen (2008), which is 1680-1800. After obtaining the best scenario based on the GDD value analysis, then overlaid with the results of the land suitability analysis based on growing requirements to get the area of class S1 and S2 that has optimal GDD for soybean growth. The results of land suitability analysis for soybean crops in the West Sumatra region based on the best scenario Growing Degree Days (scenario VIII) are presented in Table 10 and spatially in Figure 3.

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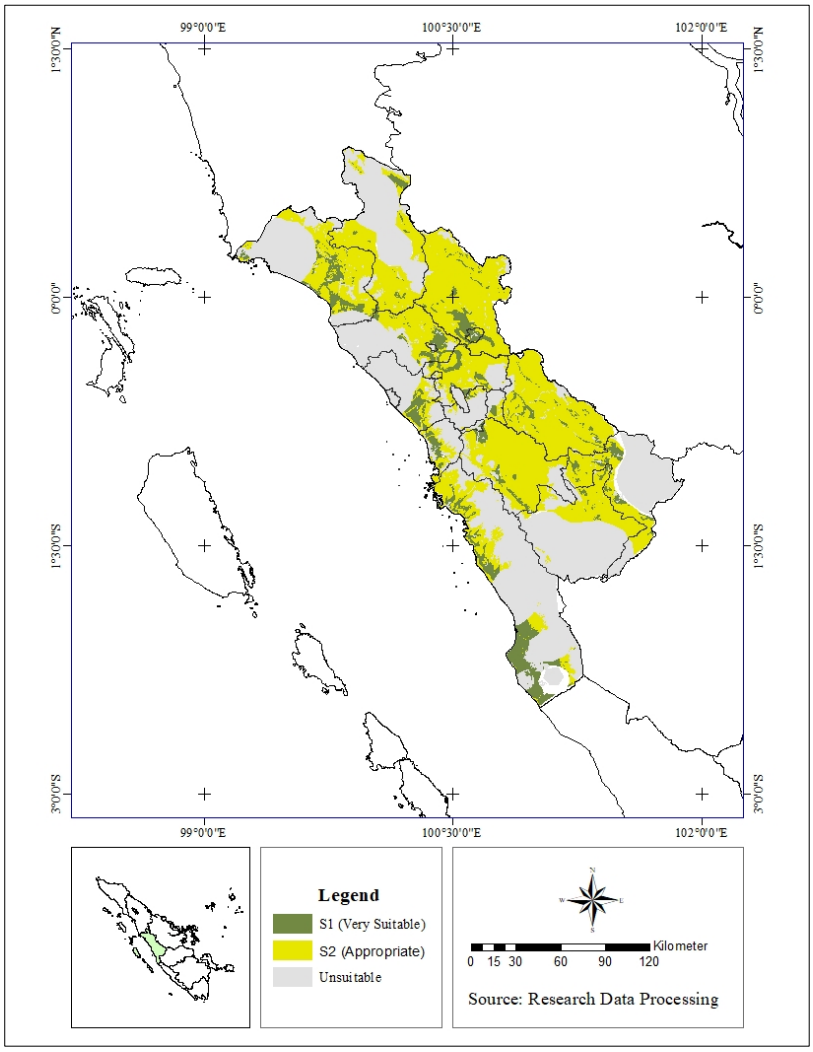

Figure 2. Map of Land Suitability of Soybean Crops in West Sumatra Region Based on the Value of Growing Degree Days in Planting Scenario VIII

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Table 10. Soybean Land Suitability in the West Sumatra Region Based on the Accumulated Value of Growing Degree Days Scenario VIII

Regency/City	Area (Ha)		
	S1	S2	Total
Agam	20.149,96	76.355,22	96.505,18
Bukittinggi	431,05	665,73	1.096,77
Dharmasraya	17.997,71	87.393,21	105.390,92
Kota Pariaman	-	-	-
Kota Solok	2.745,48	1.602,42	4.347,90
Lima Puluh Kota	27.659,80	283.015,76	310.675,56
Padang	11.094,88	20.001,51	31.096,39
Padang Panjang	185,04	1.957,33	2.142,37
Padang Pariaman	16.088,21	21.081,43	37.169,64
Pasaman	14.102,65	198.345,83	212.448,48
Pasaman Barat	18.272,49	98.730,20	117.002,69
Payakumbuh	5.051,06	2.340,23	7.391,29
Pesisir Selatan	63.131,57	81.370,45	144.502,02
Sawahlunto	5.265,93	16.168,09	21.434,02
Sijunjung	17.565,17	268.057,84	285.623,01
Solok	22.972,22	230.019,53	252.991,75
Solok Selatan	7.447,53	127.685,56	135.133,10
Tanah Datar	17.378,34	97.648,50	115.026,84
Total	267.539,09	1.612.438,84	1.879.977,93

Table 10 shows the area whose characteristics follow the growing requirements of soybean crops and are located in areas with appropriate GDD accumulation values. The yield of potential S1 and S2 areas for soybean cultivation based on the accumulated value of Growing Degree Days is smaller because not all fields are suitable based on the optimal GDD value for soybean growth. Class S1 and S2 areas, located in inappropriate GDD accumulation, are not optimal for soybean growth. Based on the analysis presented in Table 10, it is known that four regencies/cities in West Sumatra have an optimal area for soybean growth of more than 200,000 hectares they are Lima Puluh Kota, Pasaman, Sijunjung, and Solok. Based on data on the average soybean harvest area of each district/city in West Sumatra, these areas include areas with an average harvest area that is greater than other districts/cities.

Based on the analysis results, West Sumatra is a potential area for soybean cultivation. There are many obstacles in the field when harvesting soybeans, including the expensive price of soybean seeds, quite high maintenance and harvest costs. Soybean crops are very susceptible to attack by pests which

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cause black spots on the soybean fruit. This condition is closely related to the weather, so it requires quite high maintenance costs. To reduce this, it is necessary to carry out further research for areas in classes 1 and 2 by paying attention to local weather characteristics.

4. Conclusion

Based on the research that has been done, it was found that the Potential land for soybean cultivation is in West Sumatra based on the GDD-based land suitability class, covering an area of 267.539,09 hectares in class S1 (very suitable) and covering an area of 1.612.438,84 hectares in class S2 (appropriate enough).

The most optimal planting time for soybean cultivation is in August, and the estimated harvest time is in November.

Lima Puluh Kota Regency, Pasaman Regency, Sijunjung Regency, and Solok Regency have land suitable for soybean cultivation with an area of more than 200 thousand hectares and are located in areas with Growing Degree Days that are suitable for soybean growth.

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