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Climate Suitability Analysis of Robusta Coffee and Its Projections in South Sumatera Province

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ABSTRACT

Climate suitability will support the growth of a plant such as Robusta coffee. This study aims to analyze the suitability of the Robusta coffee plant climate and its projection in South Sumatra. Climate suitability is assessed based on the weighting of air temperature, rainfall, number of dry months, altitude, soil texture, and slopes. This study used observation data on rainfall and air temperature at 48 rain post points in the Robusta coffee farming area. The projection uses scenarios shared socioeconomic pathways (SSP) 2-4.5 and 5-8.5 of the MIROC6 model with three projection periods of 2021-2030, 2031-2040, and 2041-2050. The results showed that baseline period 35% of the area as a very suitable class and 65% in fairly suitable class. Based on the projected results of scenario SSP2-4.5 period 1 to 3 have the same percentage of area, that is 91% in very suitable class and 9% in fairly suitable class. The projected results of the scenario SSP5-8.5 show an improvement but not better than scenario SSP2-4.5. The percentage of area very suitable class for periods 1 to 3 of 89%, 50%, and 85% respectively.

1. INTRODUCTION

Coffee is a prominent plantation commodity whose products are now favored by various groups. Coffee contributes to Indonesia's economy as an export commodity generating foreign exchange (BPS, 2022). As a tropical region, Indonesia is one of the world's largest coffee producers. South Sumatra Province is the largest coffee producer in Indonesia, with a production strength of 932 kg/ha and a plantation area of 267,800 ha. The coffee production in this province reached 212,274 tons or 27% of Indonesia's total coffee production in 2021 (BPS, 2022). South Sumatra Province has 12 regencies/cities with coffee planting areas that are mainly smallholder plantations, and the coffee grown is of the Robusta variety (Irmeilyana *et al*., 2019).

It is projected that by 2050, Indonesia will experience changes in climate patterns with rising air temperatures and changing rainfall patterns, both in intensity and frequency (Sarvina, 2019). Air temperature and rainfall are climatic factors that determine the success of crop production (Arifianto & Koesmaryono, 2016). These two climatic elements can directly affect the productivity of Robusta coffee plants (Angka, 2021). Non-ideal temperatures for coffee plants can lead to the emergence of diseases and pests that previously attacked plants at lower altitudes (Widayat *et al*., 2015). Reduced coffee production due to pests and diseases is triggered by climatic factors (Avelino *et al*., 2015). Research on climate projections with various models and scenarios needs to be continually developed to obtain quantitative data on the climate's impact on future fruit and vegetable crops (Sarvina, 2019).

Several studies on climate forecasting in the agricultural sector have proven to yield good results. For instance, Gunda *et al*. (2017) conducted research on seasonal food crops. Simulations showed that farmers using seasonal forecasts had more crop diversity and increased average farm income. The increase in income was more pronounced in drier climate scenarios, where farmers preferred to plant onions. This analysis highlights that programs promoting the production of specific crops can ensure short-term food security. Sarvina's (2019) research on fruit and vegetable crops in tropical regions regarding the impact of climate change and adaptation strategies showed that climate change affects the quantity and quality of fruit and vegetable production, increases pest and disease attacks, leads to the emergence of new pests, and causes crop failures due to extreme weather.

Climate scenario projections can depict climatic conditions affecting the future suitability of Robusta coffee plants. The latest climate projection scenario from IPCC AR6, namely Shared Socioeconomic Pathways (SSP), is an improvement over previous scenarios. The SSP scenarios present several fundamental factors such as population, technology, and economic growth that can lead to different emissions and global warming impacts in the future, even without climate policies (Hausfather, 2018). The SSP2-4.5 scenario describes a world with social, economic, and technological trends not far from the present, with a radiative forcing limit 4.5 W/m^2. The SSP5-8.5 scenario describes a world with high fossil fuel use mitigation, resulting in a radiative forcing limit of 8.5 W/m^2 (Riahi *et al*., 2017).

Suitable climate and land conditions will support the growth and development of a crop. Climate conditions are a crucial factor that must be given primary attention because they play a significant role in determining the success of coffee planting in a region (Supriadi, 2014). Assessing the suitability of weather and climate elements for a crop using simulation models can be employed to ensure the optimal growth of the crop (Ferdiansyah *et al*., 2020). Land suitability assessment is conducted to obtain information on the capabilities and constraints of a land (Ramamurthy *et al*., 2020). This is important to know to reduce the risk of damage that can occur to agricultural yields. Based on these considerations, this study aims to analyze the climate suitability for Robusta coffee plants in the coffee farming centers of South Sumatra Province and its future projections based on the SSP2-4.5 and SSP5-8.5 scenarios.

2. MATERIALS AND METHODS

This research included 10 key Robusta coffee-producing cities/regencies in South Sumatra Province, such as Lahat, Empat Lawang, Musi Rawas, Ogan Komering Ulu, East Ogan Komering Ulu, South Ogan Komering Ulu, North Musi Rawas, Muara Enim, Lubuk Linggau City, and Pagar Alam. The data used consisted of observed rainfall, observed temperature from reference stations, and reanalysis temperature from Era5-Land. Reanalysis temperature was used as the representative temperature value for each rainfall station. Reanalysis temperature resulted from atmospheric condition analysis derived from historical meteorological and oceanographic data processing using the latest forecast models and assimilation techniques. Before using reanalysis temperature data, performance testing against observed temperatures at reference stations was conducted.

The SSP2-4.5 and SSP5-8.5 scenario model data included parameters for rainfall and air temperature with the MIROC6 model output from the Global Climate Model (GCM) with an initial resolution of 1.4° x 1.4° in netCDF (nc) format during the baseline period of 2005-2014. Before extraction, the projection data underwent downscaling or the process of reducing the spatial resolution from global climate data to a higher local resolution. The spatial resolution was reduced to 0.04° x 0.04°. The projection periods were divided into three: 2021-2030, 2031-2040, and 2041-2050.

The physical land parameters included elevation, slope, and soil texture. Elevation data at 48 rainfall station points in the key areas were obtained from the Class 1 Climatology Station in Palembang. Soil texture data for South Sumatra Province were obtained based on soil type classification from the Food and Agriculture Organization (FAO) Digital Soil Map of the World. Slope or land gradient data for South Sumatra Province were obtained from the Shuttle Radar Topography Mission (SRTM). These data were collected for each of the 48 rainfall station points in the study area, with the Palembang Climatology Station as the reference station.

There were gaps in the observed rainfall data for the period 2005-2014 from several rainfall stations. Therefore, missing data were filled using the normal ratio method formulated by Wei and McGuiness in 1973 (Fadholi, 2013) as presented in equation (1).

$$X_{test} = \frac{1}{n}\left(\frac{Y_{test}}{Y_{base,1}} X_{base,1} + \frac{Y_{test}}{Y_{base,2}} X_{base,2} + \frac{Y_{test}}{Y_{base,3}} X_{base,3} + \cdots + \frac{Y_{test}}{Y_{base,n}} X_{base,n}\right) \quad (1)$$

where X_{test} is the estimated rainfall value at the tested rainfall station (mm), Y_{test} is the normal monthly rainfall value at the tested rainfall station (mm), $Y_{base,1}$ is the normal monthly rainfall value at the nearest rainfall station (mm), $X_{base,1}$ is the rainfall value at the nearest rainfall station (mm), and n is total number of nearest rainfall stations used.

Reanalysis temperature data and the extracted model data cannot be used directly; observational data correction is required first due to significant bias. Statistical bias correction is a step to eliminate bias in the data, thus making predictions more accurate and reducing the bias level (Dippe *et al*., 2019). The air temperature correction value was calculated using equation (2) (Weiland *et al*., 2010).

$$T_{model\_kor} = T_{model} + (\overline{T}_{obs} - \overline{T}_{model}) \tag{2}$$

where T_{model_kor} is the monthly model air temperature value after correction (□), T_{model} is the monthly model air temperature value before correction (□), $\overline{T}_{obs}$ is the monthly average air temperature during the baseline observation data period (□), and $\overline{T}_{model}$ is the monthly average air temperature during the baseline model data period (□)

Rainfall data correction was calculated using equation (3) (Lenderink *et al*., 2007).

$$CH_{model\_kor} = CH_{model} \times \frac{\overline{CH}_{obs}}{\overline{CH}_{model}} \tag{3}$$

where CH_{model_kor} is the monthly model rainfall value after correction (mm), CH_{model} is the monthly model rainfall value before correction (mm), $\overline{CH}_{obs}$ is the monthly average rainfall during the baseline observation data period (mm), and $\overline{CH}_{model}$ is the monthly average rainfall during the baseline model data period (mm)

The validation stage was conducted to assess the bias magnitude of the model data. RMSE (Root Mean Square Error) calculation was performed to evaluate the model by assessing the accuracy level of the model's predictions. The lower the RMSE value, the more optimal the model data was for use, and vice versa.

Climate suitability weighting (Table 1) refered to the classification of suitability parameters developed by Djaenudin *et al*. (2011). For altitude parameters, the classification was based on suitability parameters from the Puslitkoka (Coffee and Cocoa Research Center) (Menteri Pertanian, 2014). The calculation of the number of dry months was performed using the Schmidt and Ferguson climate classification. A dry month is defined as a month with rainfall <60 mm. Weighting was calculated based on the value of each suitability parameter. The suitability classes were divided into S1 (highly suitable), S2 (fairly suitable), S3 (marginally suitable), and N (not suitable).

Table 1. Weighting of climate suitability for Robusta coffee

Note	Parameter	Weighting Value			
		4	3	2	1
A	Average air temperature (°C)	25 – 28	20 – 25	–	< 20
			28 – 32	32 – 35	> 35
B	Annual rainfall (mm)	1.500 – 2.500	–	1.250 – 1.500	< 1.250
			2.500 – 3.000	3.000 – 4.000	> 4.000
C	Number of dry months	1 – 2	2 – 3	3 – 4	> 4
					< 1
D	Altitude (m above sea level)	300-500	100-300	0-100	>700
			500-600	600-700	
E	Slope (%)	<8	8 – 16	16 – 30	>30
F	Soil texture	fine, slightly fine, medium	–	very fine, slightly coarse	coarse

Source: (Djaenudin *et al*., 2011; Menteri Pertanian, 2014)

Growth requirements are elements that must be met for plants to grow well. The growth requirements for coffee plants consist of climate and land parameters. Climate parameters included rainfall, temperature, the number of dry months, and altitude. Land parameters included soil type, slope, soil depth, and soil chemical properties. Climate suitability in this study was assessed based on the weighting of air temperature, rainfall, number of dry months, altitude, soil texture, and slope parameters. According to Djaenudin *et al*. (2011) and the Coffee and Cocoa Research

Center (2014), Robusta coffee grows in climates with temperatures ranging from 20-28°C at altitudes of 100-600 meters above sea level. The optimal rainfall ranges from 1,500-2,500 mm per year with 1-3 dry months. The land conditions supporting Robusta coffee growth include slopes of 0-18% with fine to medium texture.

Based on the subsequent weighting parameter values, the final score is calculated by summing the values of the suitability elements. The final score is used to determine the suitability class. Then, the class interval calculation is performed to determine the boundary values for each suitability class. From the class interval calculation, the classification of weighting values is obtained as shown in Table 2.

Table 2. Classification of weighting values

Weighting Value	Suitability Class	Description
20 – 24	S1	Highly Suitable
15 – 19	S2	Fairly suitable
10 – 14	S3	Marginally Suitable
6 – 9	N	Not Suitable

The suitability class is determined by the range of values in the weighting value classification table (Table 2). Analysis is conducted on the results of maps created with spatial mapping applications. Then, interpolation is performed on the final scores obtained at each point using the inverse distance weighted (IDW) method. Maps are created based on the baseline period (2005-2014) and projection periods (2021-2030), (2031-2040), and (2041-2050).

3. RESULTS AND DISCUSSION

3.1. Reanalysis Temperature Data Correction

The reanalysis air temperature data correction graph at the reference station is shown in Figure 1. After correction, the reanalysis air temperature data exhibits a pattern that more closely matches the observations with fewer data outliers. Validation results show that the RMSE (Root Mean Square Error) of the reanalysis air temperature data decreases after correction. However, the reduction in RMSE for the reanalysis air temperature data after correction is not very significant because the data before correction already had a low or good RMSE. Additionally, before correction, the reanalysis air temperature data had a pattern that followed the observational values, although it was underestimated. Due to the limited availability of observational air temperature data in the observation area, especially at each rainfall station, uncorrected reanalysis air temperature data will be used for further processing.

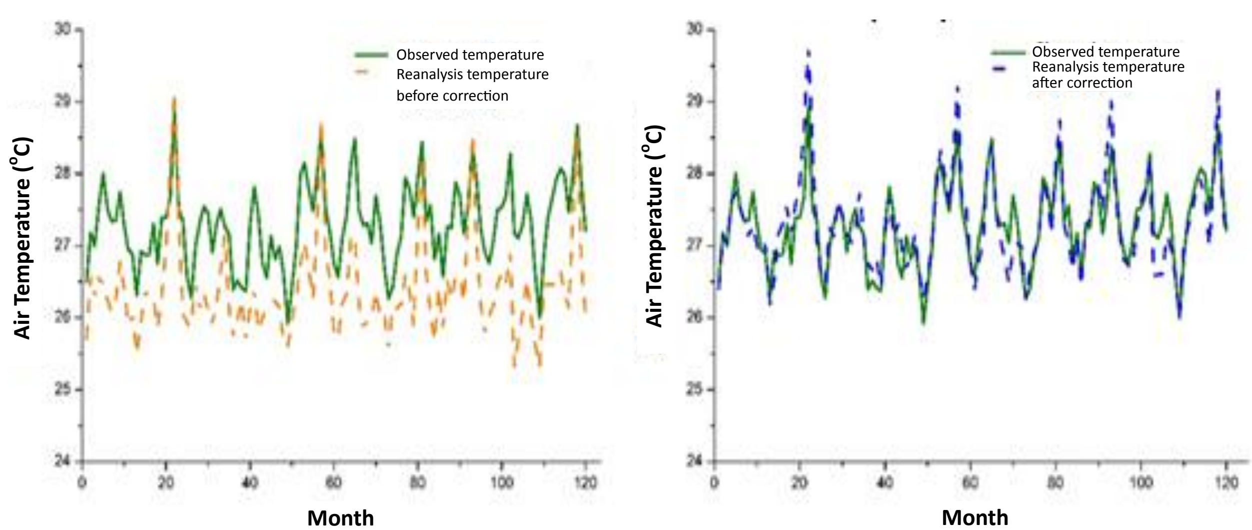

Figure 1. Reanalysis temperature data correction graph.

3.2. Correction of Model Parameters for Air Temperature and Rainfall

The correction graph for SSP2-4.5 and SSP5-8.5 model data for rainfall and air temperature parameters at the Palembang Climatology Station is shown in Figure 2. The model data, after correction, shows improved values. The uncorrected model data for rainfall and air temperature parameters had patterns that did not follow the observational values, resulting in data outliers. For the rainfall parameter model, the pattern after correction aligns more closely with the observational pattern, as indicated by the blue scatter points. Similarly, the air temperature parameter model, although showing higher values than estimates, aligns better with observations, as indicated by the blue dashed line. The validation results of the model data show that the overall RMSE values improve after correction. Data correction is performed on the model data for each rainfall station point. The corrected model data for air temperature and rainfall is then used for simulating climate suitability parameters.

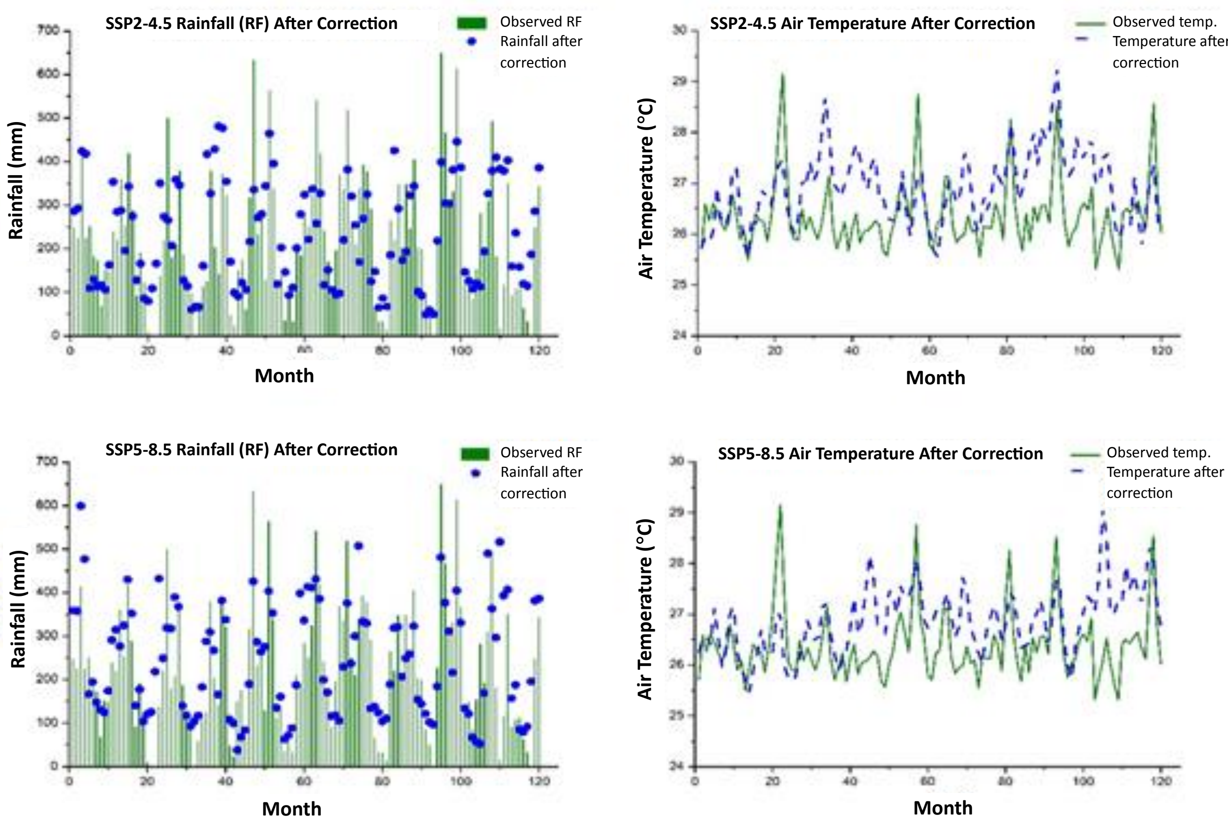

Figure 2. Correction graph for SSP2-4.5 and SSP5-8.5 model rainfall and air temperature data.

3.3. Results of Air Temperature and Rainfall Simulation

The simulation results for air temperature and rainfall parameters indicate a change in patterns. There is an increase in values for each period for both parameters. The average air temperature values from November to January and June to July tend to be low. Air temperature increases from February to March and August to October. The simulation results for rainfall parameters show that high rainfall often occurs from December to February, followed by a decrease until mid-year. From June to August, rainfall values generally decrease and then increase again towards the end of the year. The results from 19 GCM models on average indicate that by 2050, northern regions of Indonesia such as Sumatra will experience temperature rises and changes in rainfall patterns (Syakir & Surmaini, 2017). Total reduction in rainfall and increased variation in rainfall can decrease production yields (Chengappa & Devika, 2016). Low rainfall of less than 2,000mm/year can cause coffee plants to experience water stress or water deficiency conditions over time (Leo *et al*., 2023). Furthermore, monthly rainfall values are used to calculate the number of dry months.

The projection results for the number of dry months in the baseline period are dominated by 0 dry months or no dry months. This occurs because in the baseline period, rainfall in the central region is fairly evenly distributed each month. The projection results for projection period 1 show an increase in the number of dry months, dominated by 1 dry month. In period 2, based on scenario SSP2-4.5, it is dominated by 1 dry month. In scenario SSP5-8.5, there is a decrease in the number of dry months, with this period having the fewest dry months with 0. Period 3 is dominated by 1 dry month. The number of dry months considered suitable for Robusta coffee growth is 1-3 months (Djaenudin *et al*., 2011). These results align with the analysis by Kusumo & Septiadi (2016), where from 2011-2040, the South Sumatra region is projected to have more wet months based on scenarios RCP4.5 and RCP8.5.

3.4. Physical Land Suitability

Based on data from Class 1 Climatology Stations in Palembang with elevations ranging from 0-100 and 600-700 meters above sea level. Soil texture data for South Sumatra Province was obtained based on the soil type classification from the Food and Agriculture Organization (FAO) The Digital Soil Map of The World. The following is the grouping of soil texture classes used based on land evaluation guidelines and techniques by Djaenudin (2011). Mapping of soil texture in South Sumatra Province is shown in (Figure 3) and the mapping results of slope class classification in South Sumatra Province are shown in Figure 4. Soil texture is classified into 6 class as the following:

* Coarse (k): Sand, sandy loam
* Moderately coarse (ak): Sandy clay loam
* Medium (s): Very fine sandy clay, loam, silty loam, silty
* Moderately fine (ah): Clayey loam, sandy clay loam, silty clay loam
* Fine (h): Sandy clay, clay, silty clay
* Very fine (sh): Clay (2:1 clay mineral type)

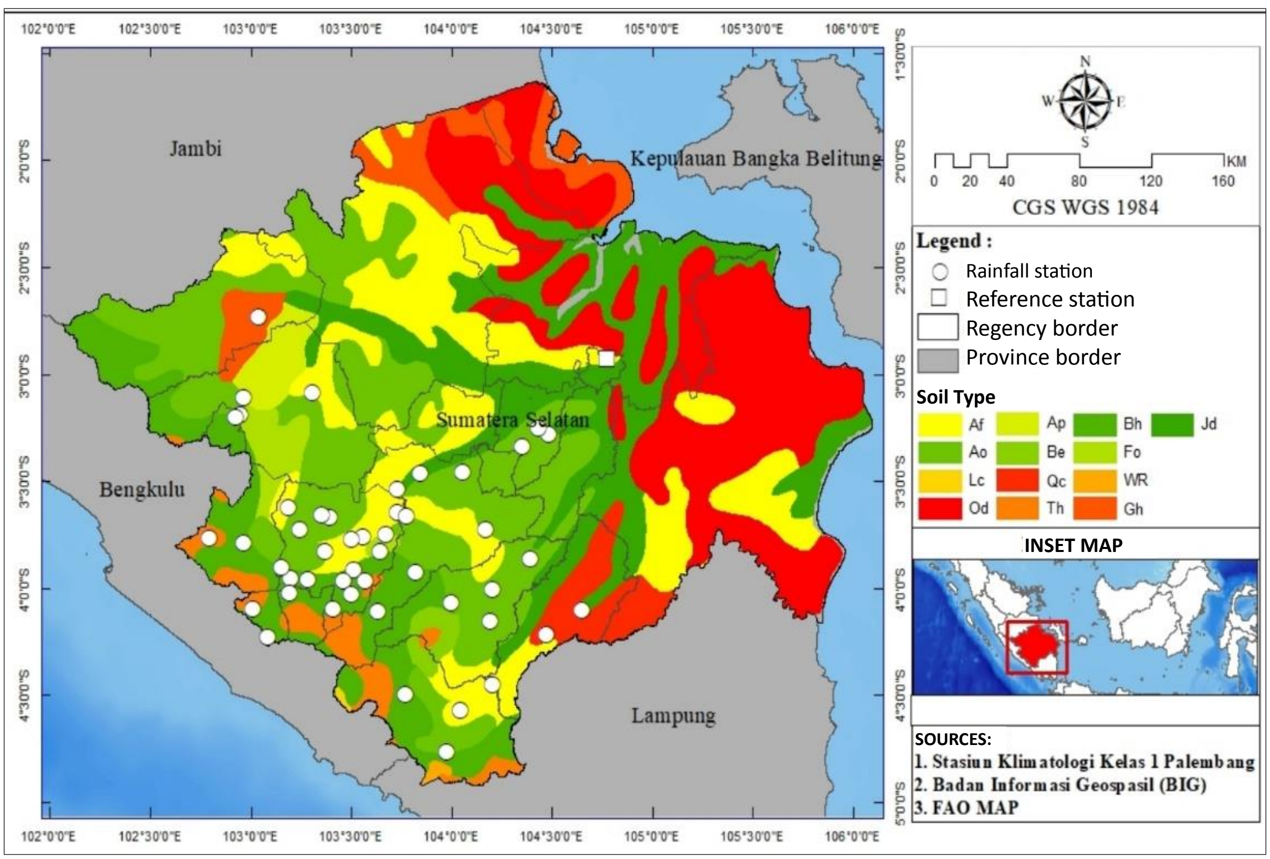

Figure 3. Soil texture map of South Sumatra Province.

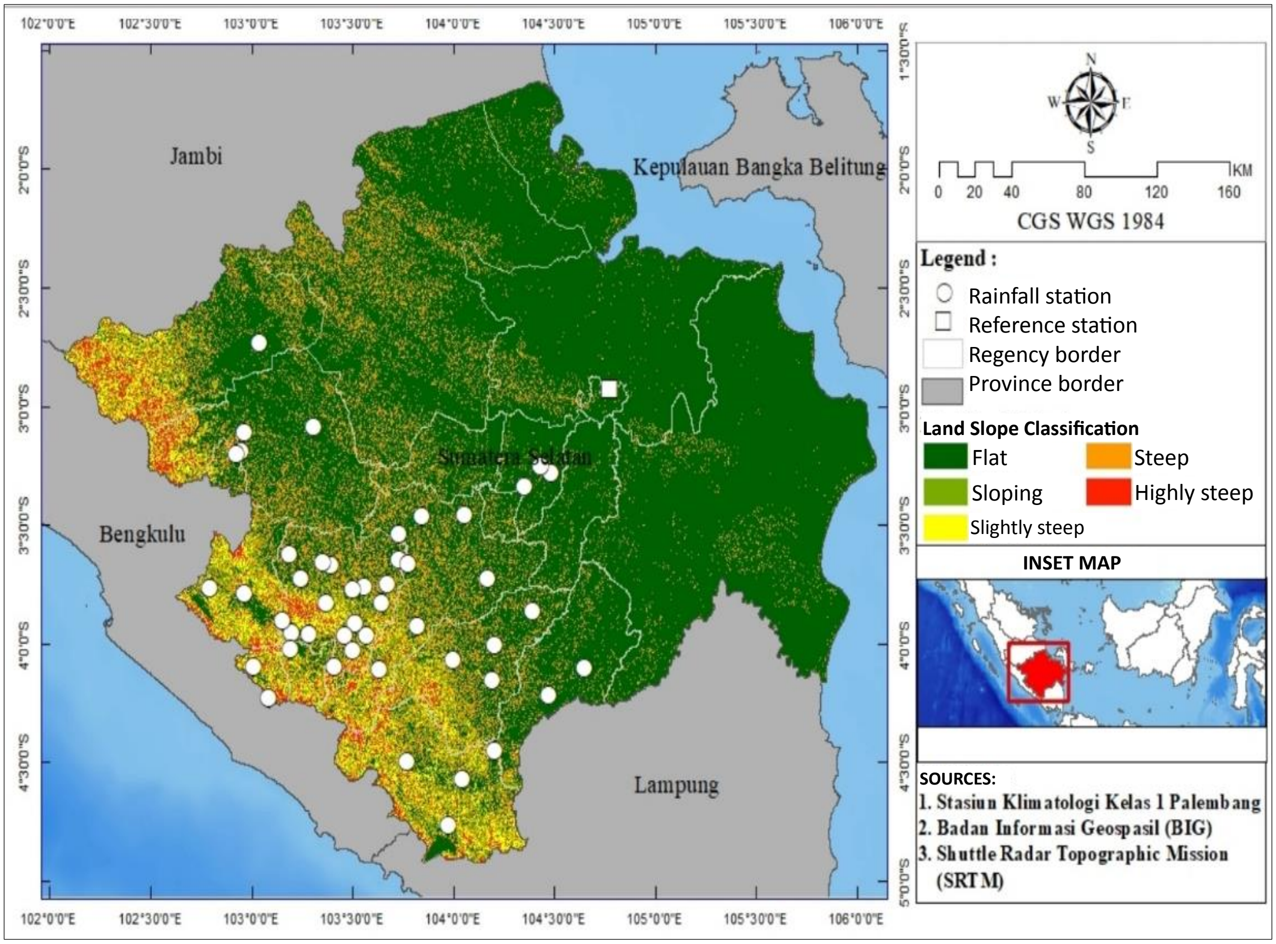

Figure 4. Map of slope classification classes in South Sumatra Province.

Soil texture mapping in South Sumatra Province shows that the soil types contained in the central area include ferric acrisols, dystric fluvisols, dystric histosols, humic gleysols, orthic acrisols, cambic arenosols, humic cambisols, and orthic ferralsols. These soil types indicate that the central area is generally formed from clay and sandy clay soils, which fall into the medium and moderately fine texture categories. Slope or terrain inclination data for South Sumatra Province uses Digital Elevation Model (DEM) data obtained from the Shuttle Radar Topography Mission (SRTM).

Slope inclination affects agricultural management, water management, soil erosion, and land productivity. From the mapping results, it can be seen that the coffee central areas have higher slope values. Coffee central areas are located in highlands generally consisting of hills and mountains with varying slope levels. Generally, points around rainfall stations in the central area have very suitable slope values, less than 8% (flat). Such land conditions are highly suitable for Robusta coffee farming. Points with the highest slope values are found at the rainfall station point of Tanjung Sakti Pumi in Lahat Regency, with values ranging from 25-45% (steep). The slope suitable for Robusta coffee plants ranges from 0-16% (flat to gently sloping) (Djaenudin *et al*., 2011).

3.5. Climate Suitability Distribution for Robusta Coffee Baseline Period

During the baseline period, the distribution of classifications is predominantly suitable for the central coffee-growing areas of South Sumatra Province (Figure 5). Areas classified as highly suitable include North Musi Rawas and Musi Rawas Districts, parts of Lahat and Empat Lawang Districts, parts of Muara Enim District, South OKU, and East OKU. During this period, there are areas classified as marginally suitable in Pagar Alam City, but the area is not significantly large.

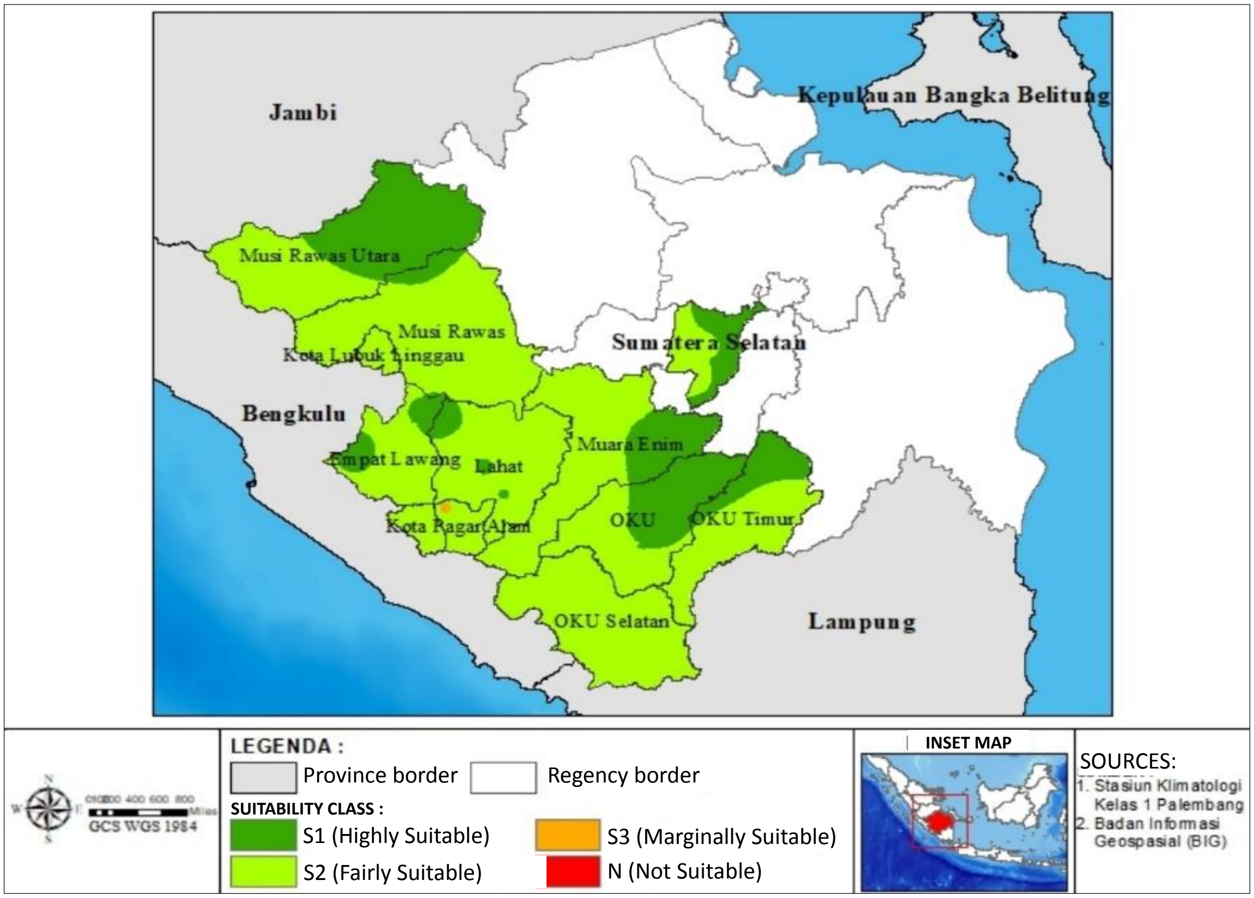

Figure 5. Map of climate suitability for Robusta coffee baseline period (2005 – 2014).

The calculation of the area and percentage of climate suitability for Robusta coffee during the baseline period is shown in (Table 3). The calculation results for the baseline period's suitability area show that the fairly suitable class dominates in all central city/district areas, covering about 65% or 2,452,993 hectares. South Ogan Komering Ulu District has the largest area with highly suitable class, covering 86% of its area or about 378,602 hectares. This is followed by Musi Rawas District with an area of 342,475 hectares or 58% of its area. South OKU District is the area with the largest coffee farming area with 65,205 farmers, followed by Empat Lawang and Lahat Districts (Ditjenbun, 2018).

Table 3. Area and percentage of suitability for baseline period

No.	District/City	Area (ha)	Highly Suitable (S1)		Fairly suitable (S2)		Marginally Suitable (S3)	
			(ha)	(%)	(ha)	(%)	(ha)	(%)
1	North Musi Rawas	594,556	342,475	58	252,081	42	0	0
2	Kota Lubuk Linggau	37,737	0	0	37,737	100	0	0
3	Musi Rawas	611,473	37,777	6	573,696	94	0	0
4	Empat Lawang	231,206	55,402	24	175,805	76	0	0
5	Lahat	423,555	33,518	8	390,037	92	0	0
6	Pagar Alam City	64,313	0	0	64,167	99.995	329	0.005
7	South OKU	437,689	378,602	86	59,087	14	0	0
8	East OKU	339,350	104,032	31	235,318	69	0	0
9	OKU	376,992	183,631	49	193,362	51	0	0
10	Muara Enim	675,342	203,784	30	471,559	70	0	0
	Total	3,792,213	1,339,221	35	2,452,993	64.995	329	0.005

3.6. Climate Suitability Distribution for Robusta Coffee Projection Period 1

Based on the results of climate suitability mapping for projection period 1 (Figure 6), the central region consists of highly suitable and fairly suitable classification classes. Both SSP 2-4.5 and SSP 5-8.5 scenarios predominantly result in highly suitable classification classes in most cities/districts in the central region. Areas classified as fairly suitable include parts of Musi Rawas Regency, parts of Muara Enim Regency, and Pagar Alam City. According to the percentage calculation of suitability area for projection period 1 (Table 4), the central region experiences an increase in the area of highly suitable suitability from the baseline period. Under the SSP 2-4.5 scenario, 91% or an area of 3,462,117 ha of the central region falls into the highly suitable class. Cities/districts where the entire area is classified as highly suitable include North Musi Rawas Regency, Empat Lawang, Lahat, Ogan Komering Ulu, Ogan Komering Ulu Selatan, Ogan Komering Ulu Timur, and Pagar Alam City. Under the SSP5-8.5 scenario, there is an expansion of highly suitable area by 89% or an area of 3,383,287 ha from the baseline period.

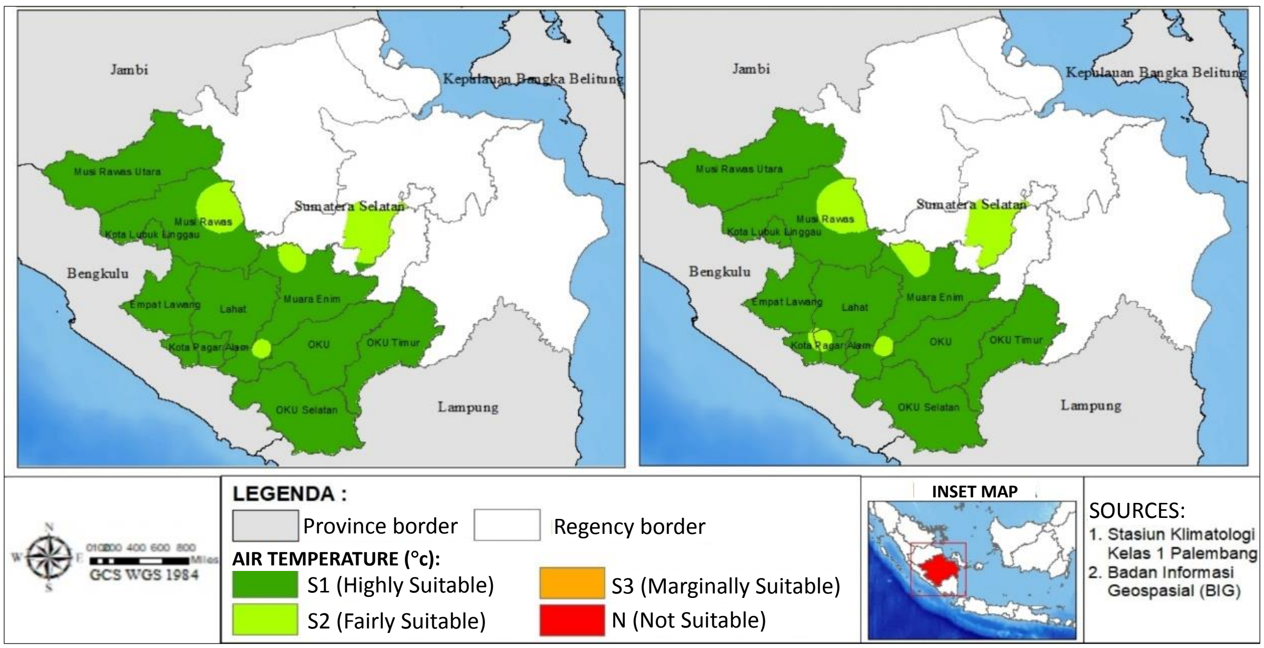

Figure 6. Climate suitability map for Robusta coffee cultivation period projection 1 (2021–2030): SSP2-4.5 (left), SSP5-8.5 (right)

Table 4. Area and percentage of suitability area for projection period 1

No,	City/District	Area (ha)	Percentage (%) Highly Suitable			Percentage (%) Fairly suitable		
			Baseline	SSP 2-4,5	SSP 5-8,5	Baseline	SSP 2-4,5	SSP 5-8,5
1	North Musi Rawas	594,556	58	100	100	42	0	0
2	Kota Lubuk Linggau	37,737	0	100	100	100	0	0
3	Musi Rawas	611,473	6	81	77	94	19	23
4	Empat Lawang	231,206	24	100	99.95	76	0	0.05
5	Lahat	423,555	8	100	98	92	0	2
6	Pagar Alam City	64,313	0	100	67	100	0	33
7	South OKU	437,689	86	100	100	14	0	0
8	East OKU	339,350	31	100	100	69	0	0
9	OKU	376,992	49	100	100	51	0	0
10	Muara Enim	675,342	30	69	65	70	31	35
	Total	3,792,213	35	91	89	65	9	11

3.7. Climate Suitability Distribution for Robusta Coffee Projection Period 2

Based on the results of climate suitability mapping for projection period 2 (Figure 7), there is a decrease in suitability classes in several parts of the region compared to projection period 1. Under the SSP 2-4.5 scenario, most of the area is still dominated by highly suitable classes. Some areas fall into the fairly suitable classification, such as parts of Musi Rawas Regency, Empat Lawang, the area between Lahat and Pagar Alam City, and some parts of Muara Enim Regency. The SSP 5-8.5 scenario shows a decrease in suitability classes from S1 to S2 in various areas. Areas classified as fairly suitable include Pagar Alam City, Lubuk Linggau City, Lahat Regency, Musi Rawas Regency, parts of North Musi Rawas, Muara Enim Regency, OKU Regency, East OKU Regency, and South OKU Regency. Period 2 under the SSP 5-8.5 scenario represents the period with the greatest decrease. Looking at the weighting data for this period, there is an increase in rainfall at several points, resulting in a decrease in the number of dry months. According to the calculation of suitability area for projection period 2 (Table 5), there is a decrease in the percentage of land area in projection period 2 for both scenarios. Under the SSP 2-4.5 scenario, the highly suitable category has the same percentage area as the previous period, which is 91%, but there is a slight decrease in the area to 3,460,724 ha. Under the SSP 5-8.5 scenario, the largest decrease occurs in Pagar Alam City, where 31% of its area, or 19,571 ha, falls into the fairly suitable class (S2). In period 2 under the SSP 5-8.5 scenario, there is a decrease in the highly suitable suitability class to 50%, or 1,888,320 ha. The fairly suitable suitability class increases to 50%, or 1,888,137 ha, from the previous projection period. This scenario represents the worst-case scenario if it occurs in the central region.

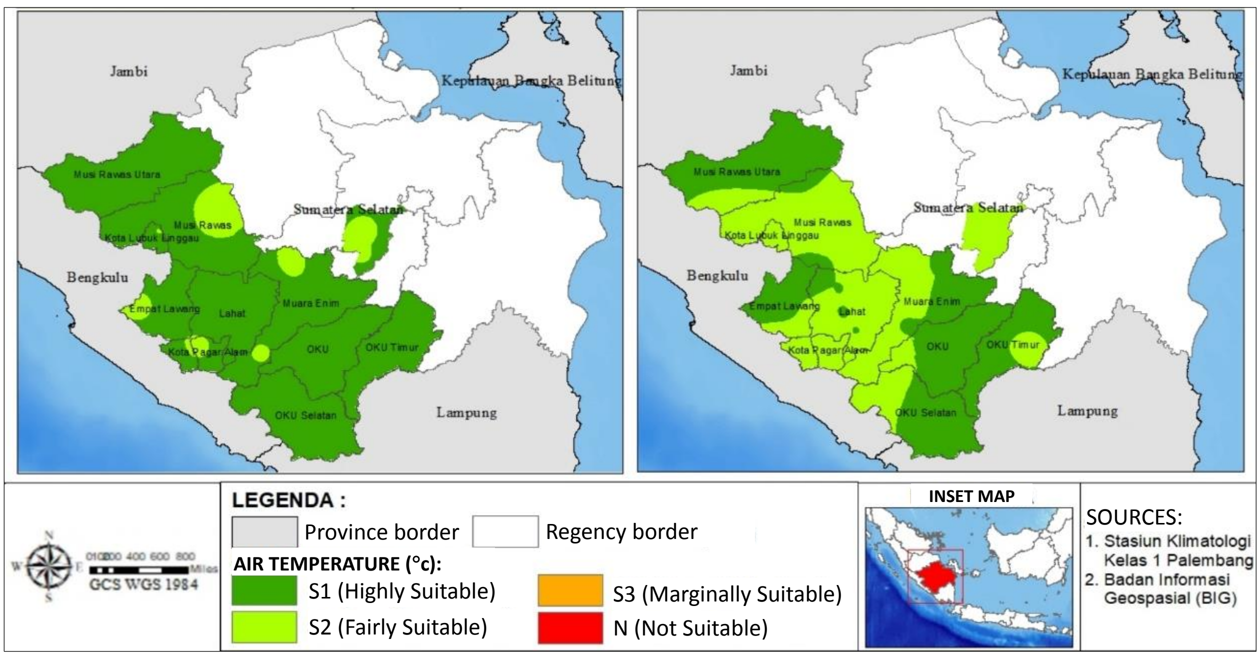

Figure 7. Climate suitability map for Robusta coffee cultivation period projection 2 (2031–2040): SSP2-4.5 (left), SSP5-8.5 (right)

Table 5. Area and percentage of suitability area for projection period 2

No,	City/District	Area (ha)	Percentage (%) Highly Suitable			Percentage (%) Fairly suitable		
			Baseline	SSP 2-4,5	SSP 5-8,5	Baseline	SSP 2-4,5	SSP 5-8,5
1	North Musi Rawas	594,556	58	100	85	42	0	15
2	Kota Lubuk Linggau	37,737	0	96	0	100	3	100
3	Musi Rawas	611,473	6	78	11	94	22	89
4	Empat Lawang	231,206	24	86	73	76	14	27
5	Lahat	423,555	8	98	12	92	2	88
6	Pagar Alam City	64,313	0	69	0	100	31	100
7	South OKU	437,689	86	100	68	14	0	32
8	East OKU	339,350	31	100	81	69	0	19
9	OKU	376,992	49	100	87	51	0	13
10	Muara Enim	675,342	30	80	30	70	20	70
	Total	3,792,213	35	91	50	65	9	50

3.8. Climate Suitability Distribution for Robusta Coffee Projection Period 3

Based on the results of climate suitability mapping for projection period 3 (Figure 8), the projections show an increase in highly suitable classes compared to the previous period. Under the SSP 2-4.5 scenario, most of the area is still dominated by highly suitable classes. Some areas fall into the fairly suitable classification, such as parts of Musi Rawas, Lahat, and Muara Enim Regencies. In the SSP 5-8.5 scenario, there is an increase in suitability classes from S2 to S1 compared to the previous period. Areas classified as fairly suitable include Lubuk Linggau City, some parts of Muara Enim and Musi Rawas Regencies. The calculation of the area and percentage of Robusta coffee climate suitability for the baseline period is displayed in Table 6. Under the SSP 2-4.5 scenario, the highly suitable class still dominates at 91%, covering 3,453,046 ha. With the SSP 5-8.5 scenario, there is an increase in highly suitable classes dominating the central region at 85%, covering 3,214,152 ha. Fairly suitable suitability class (S2) is found in some parts of the central region with a total area of 569,720 ha, including Lubuk Linggau City, some parts of Musi Rawas Regency, North Musi Rawas, and Muara Enim Regency.

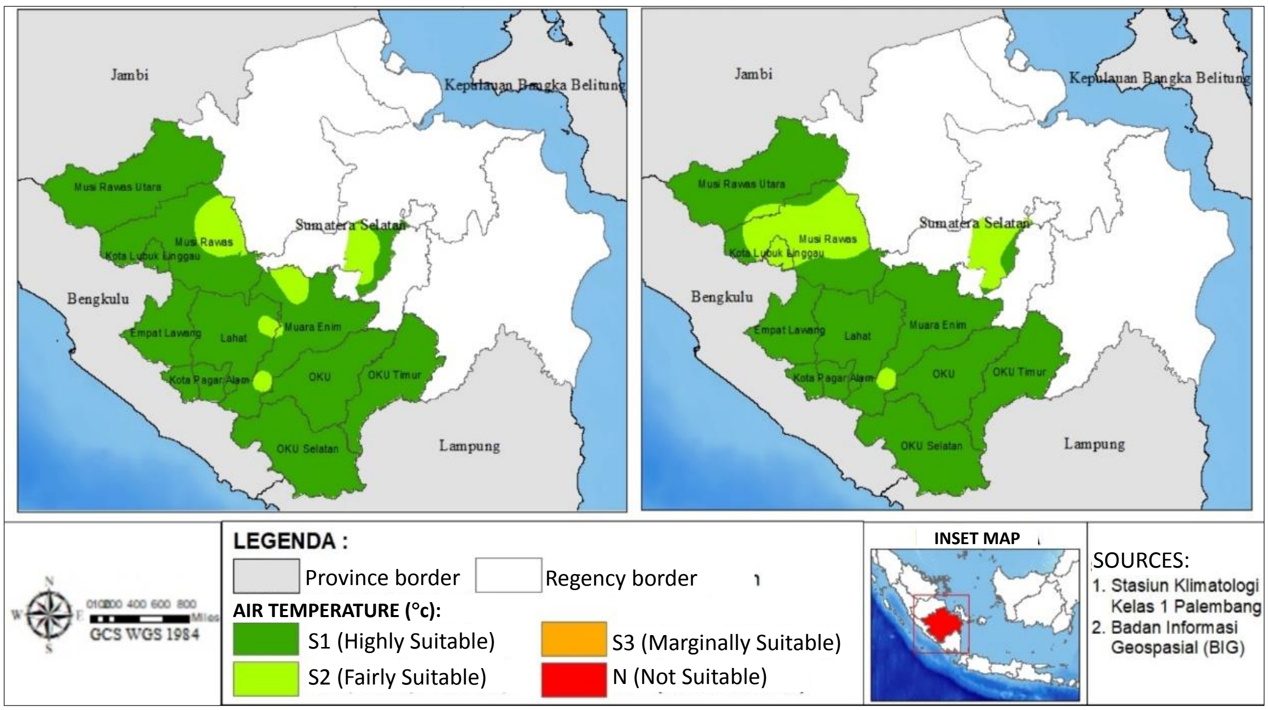

Figure 8. Climate suitability map for Robusta coffee cultivation period projection 3 (2041 – 2050): SSP2-4.5 (left), SSP5-8.5 (right)

Table 6. Area and percentage of suitability area for projection period 3

No,	City/District	Area (ha)	Percentage (%) Highly Suitable			Percentage (%) Fairly suitable		
			Baseline	SSP 2-4,5	SSP 5-8,5	Baseline	SSP 2-4,5	SSP 5-8,5
1	North Musi Rawas	594,556	58	100	97	42	0	3
2	Kota Lubuk Linggau	37,737	0	100	2	100	0	98
3	Musi Rawas	611,473	6	76	40	94	23	60
4	Empat Lawang	231,206	24	100	100	76	0	0
5	Lahat	423,555	8	96	100	92	4	0
6	Pagar Alam City	64,313	0	100	100	100	0	0
7	South OKU	437,689	86	100	100	14	0	0
8	East OKU	339,350	31	100	100	69	0	0
9	OKU	376,992	49	100	100	51	0	0
10	Muara Enim	675,342	30	74	78	70	26	22
	Total	3,792,213	35	91	85	65	9	15

Direct climate pattern changes can directly affect the suitability of Robusta coffee plants. This study is relevant to the research by Arifianto & Ismail (2023), which states that changes in coffee plant suitability can occur due to changes in climate parameters such as rainfall patterns and air temperature. The projection with the SSP 5-8.5 scenario in period 2 (2031-2040) becomes the period with the worst impact, causing 50% of the central region to fall into fairly suitable suitability. However, considering only the six weighting aspects in this study based on the SSP 2-4.5 and SSP 5-8.5 scenarios, Robusta coffee plants have the potential to continue to be developed in the coffee center region of South Sumatra Province, as it is still dominated by highly suitable and fairly suitable categories.

4. CONCLUSION

The distribution of climate suitability for Robusta coffee plants during the baseline period (2005-2014) was predominantly characterized by fairly suitable suitability class (S2), covering 65% of the land area. The areas dominated by this suitability class include Musi Rawas Regency, Empat Lawang, Lahat, East Ogan Komering Ulu, Ogan Komering Ulu, Muara Enim, Lubuk Linggau City, and Pagar Alam City. Under the SSP 2-4.5 scenario for projection periods 1 through 3, the highly suitable suitability class (S1) predominates, increasing to 91%. Cities/districts where the entire area falls into the highly suitable suitability class (S1) for all three projection periods include North Musi Rawas Regency, South Ogan Komering Ulu, East Ogan Komering Ulu, and Ogan Komering Ulu Regency. Under the SSP 5-8.5 scenario, the highly suitable suitability class (S1) predominates in projection periods 1 and 3, with respective land area percentages of 89% and 85%. Cities/districts where the entire area falls into the highly suitable suitability class (S1) include South Ogan Komering Ulu, East Ogan Komering Ulu, and Ogan Komering Ulu Regency. However, in projection period 2, the highly suitable classification (S1) decreases to 50% across all cities/districts.

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