International Journal Of Humanities Education And Social Sciences ***(IJHESS)*** *E-ISSN:* **2808-1765**
Volume 3, Number 5, April 2024, *Page. 2741 – 2749*
Email : editorijhess@gmail.com

Projection Of Climate Suitability For Mangosteen Based OnClimate Change Scenarios In West Sumatra To Support National Resilience

Eka Alfred Sagala[1], Ernalem Bangun[2] , Adi Subiyanto[3], Presly Panusunan Simanjuntak[4]
[1,2,3] Disaster Management Study Program, Faculty of National Security, Indonesian Defense University
[4] Bangka Belitung Climatology Station, Central Bangka, Indonesia

*Corresponding Author
Email: alfredsagala92@gmail.com

Abstract

The West Sumatra Provincial Government began to improve the development of the plantation sector of mangosteen, because the mangosteen plant became a superior commodity in the Province of West Sumatra. In this regard, it is important to know the climate suitability of the mangosteen plant and its projections, which will be used to take development planning steps in the appropriate area and support the increase in exports of mangosteen plants in West Sumatra Province to support national resilience in the face of climate change. The data used were monthly rainfall observation data and monthly air temperature for the period 2006-2015 at 46 rain posts in West Sumatra Province. The Minangkabau Meteorological Station is used as a reference station for monthly air temperatures estimation in 45 other rain posts which were calculated using the Braak method. Besides, land physical data such as soil texture and slope were used in each district in West Sumatra Province. Projected data used the Representative Concentration Pathways (RCP) 4.5 scenario model for monthly air temperature and monthly rainfall from the Model for Interdisciplinary Research on Climate (MIROC5) model with resolutions up to 20 x 20 km in the period 2006-2040. The projection data was divided into the baseline period for 2006-2015 and the projection period of 2031-2040. The climate suitability period was made for the present period 2006-2015 and the future projections for the period 2031- 2040. The results showed that the area of West Sumatra Province for the Very Appropriate category (S1) wasdecreasing in the projection period of 2031-2040 compared to the 2006-2015 baseline period. This can be seen in the projection period of the Very Appropriate category (S1), the area was reduced to 2,584,234 ha (72%) while in the baseline period the Very Corresponding category (S1) reached 2,811,321 ha (78%).

***Keywords**: Climate Suitability, Mangosteen Plants, Projections, Rcp 4.5, National Resilience*

INTRODUCTION

Mangosteen is an export commodity that is very in demand in the international market. There are 23 countries where mangosteen exports from Indonesia are recorded, where China is the largest mangosteen export destination, namely 6,227,740 kg reaching US$ 10,650,339. (Ministry of Agriculture, 2020). When viewed from the needs of export destination countries, Indonesia has the opportunity to increase mangosteen exports. This has made the government make efforts to increase mangosteen exports, including conducting exhibitions and trade missions to several export destination countries, empowering farmer group associations and facilitating mangosteen entrepreneurs.

The mangosteen plant, which is Indonesia's flagship fruit, is the most exported fruit, one of which is West Sumatra Province. Since 1999 until now, mangosteen farming and trade in West Sumatra has grown rapidly. Almost all districts and cities in West Sumatra Province cultivate mangosteen plants. (Irfan, Z, 2005)

Agam Regency is the largest producer of mangosteen commodities in West Sumatra Province (BPS, 2018). This is supported by the potential of its natural resources which are suitable for several fruit commodities including mangosteen. (Juniarti, 2008).

Finding the right and optimal location for a plant is very important in order to reduce the adverse effects caused by the environment. Mangosteen plants are very sensitive to air temperature where hot air temperatures can cause leaves to fall off due to unbalanced evaporation and water availability (Hapsari, et al, 2020).

Climate suitability for mangosteen plants is needed to know the climatic conditions that are very suitable to be quite suitable and less suitable to be unsuitable (Sari, et al., 2020). This information can be utilized optimally, which by paying attention to this information, is able to provide scientific support for the climatic suitability of mangosteen plants.

National resilience is a concept that includes the regulation and implementation of welfare, prosperity, and defense and security in national life. The impacts of climate change are manifested in the disruption of the socio-economic aspects of society, especially in terms of livelihoods. Communities that depend on agriculture, farming and fishing are significantly affected by climate change (Subiyanto, 2022). Climate change in the future can change the structure and weatherability of the soil, so mapping is necessary. This is expected to provide an overview so as to increase the productivity of mangosteen plants and prevent crop failure in West Sumatra in the future.

To see the picture of future climate change related to the climate suitability of mangosteen plants, we can use *Representative Concentration Pathways* (RCP). Scenarios are based on research with four climate modeling equated with carbon gas concentrations, namely RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. The use of scenarios is not to predict thefuture but to better understand uncertainties and alternative futures (Intergovernmental Panel on Climate Change, 2014).

This study uses the RCP 4.5 scenario with the *Model for Interdisciplinary Researchon Climate* (MIROC5) output of the *Global Climate Model* (GCM) which is global projection data and released by the Modeling Center in Japan. The advantage is that the resolution reaches 20 x 20 km and is *downscaled* by the BMKG Climate Change Center (PIPER). Then for the advantages of the RCP 4.5 scenario, namely in accordance with the current situation where there is a policy to limit greenhouse gas emissions through the Kyoto Protocol (Barung, 2017).

This study aims to analyze the distribution of mangosteen plant climate suitability areas in the baseline period of 2006-2015 and to determine changes in the distribution of mangosteen plant climate suitability areas based on the RCP 4.5 scenario in 2031-2040 against the baseline period in West Sumatra Province.

RESEARCH METHODS

Research Area

Geographically, West Sumatra Province is located at 0° 54' North latitude and 3° 30' South latitude and 98° 36' and - 101° 53' East longitude. West Sumatra province occupies the west coast of central Sumatra, the Bukit Barisan plateau to the east, and a number of offshore islands such as the Mentawai Islands. From north to south, the province covers an area of 42,297.30 km², equivalent to 2.17% of Indonesia.

Research Tools

The tools or software used in this research include:

1. A number processing application used to process station data, rainfall posts and projection data.
2. The Grid Analysis and Display System (GrADS) software to extract RCP 4.5 scenario data in netCDF format into numerical data. GrADS is software recommended by the World Meteorological Organization (WMO) to describe meteorological parameters in spatial form and if we pay attention to international meteorological journals, most of theimages displayed are processed using GrADS software (Makmur, 2008). GrADS can display data with 4 dimensions: longitude, latitude, altitude (level), and time.

International Journal Of Humanities Education And Social Sciences ***(IJHESS)*** *E-ISSN:* **2808-1765**
Volume 3, Number 5, April 2024, *Page. 2741 – 2749*
Email : editorijhess@gmail.com

3. Spatial mapping software, QGIS Version 2.18, was used for spatial mapping of climate and physical land suitability.
4. The R-Console software was used to extract slope data from the *Shuttle Radar* Topography Mission (SRTM).

Research Data

The research data used in this study include:

1. Monthly Rainfall and Air Temperature Data

   The data used in this study are observational data from observations of Climatology Stations, Meteorological Stations and rain posts spread across West Sumatra Province. The observation data is monthly rainfall at 46 rain post points for the period 2006-2015 which is used as a baseline and to correct the model data. The air temperature data used is monthly air temperature from Minangkabau Meteorological Station as a reference station.
2. Soil Texture and Elevation Data

Figure 1. Elevation Map of West Sumatra Province

   Soil texture data for each district in West Sumatra Province is taken from the book Utilization of Water Resources (Pawitan, et al., 1996). Data on altitude at 46 rain stations in West Sumatra Province will be used to estimate monthly air temperature at rain stations in the study area that do not have air temperature.
3. Land Slope Data

Figure 2. Land Slope Map of West Sumatra Province

Slope data for each district in West Sumatra Province derived from the Shuttle Radar Topography Mission (SRTM).

Calculation of Average Monthly Rainfall and Air Temperature

Rainfall data obtained from the BMKG station is monthly rainfall data at 46 rainpoints spread across West Sumatra Province, while monthly air temperature is obtained from the

Minangkabau Meteorological Station which is used for estimating air temperature at 45 other rainpoints. In this study, the rainfall and air temperature data used is the average monthly rainfall data and the average monthly air temperature with the period 2006-2015. For the calculation of the average can be **Equation 1** (Walpole, 1995):

$$\bar{X} = \frac{1}{n}\sum_{i-1}^{n} X_i \qquad (1)$$

$\bar{X}$: Average Count
n : Amount of data
X_i : Data (i) ; i= 1,2,3,…

The formula is used to calculate the average monthly rainfall and average monthly air temperature from the RCP 4.5 scenario projection model data after being extracted and corrected.

Estimation of Monthly Average Air Temperature Based on Altitude

Most of the rain posts in West Sumatra Province only conduct rainfall observations, so they do not have air temperature data. Some areas where air temperature data is not available can be estimated based on the height of the place from sea level. The estimation of air temperature is calculated from the interpolation of the altitude of the place using the *Lapse Rate* theory, where every 100 m increase there is a decrease in average air temperature by 0.6˚C. The estimation can be calculated using **Equation 2** by Braak as follows:

$$Th = Th_0 - (0.6\ x\ h\ x\ 0.01) \qquad (2)$$

Th : Estimated Temperature (° C)
Th_0 : Reference Station Temperature (° C)
h : Height Difference between Rain Post and Reference Station (masl)

RCP 4.5 Scenario Model Data Extraction

The RCP 4.5 scenario projection model data obtained from PIPER BMKG consists of monthly rainfall and monthly air temperature data with the extension format .netCDF (.nc). Before processing, the data must be extracted first using GrADS *software* whose extraction must use a *script* with the extension format (.gs).

RCP 4.5 Scenario Model Data Extraction

The RCP 4.5 scenario projection model data correction needs to be done to equalizethe values and changes in rainfall and air temperature between the RCP 4.5 scenario modeland its observation values. The correction can be calculated based on the differencebetween observation data and model data that have the same period. Corrected rainfall is calculated based on **Equation 3** (Weiland, et al, 2010) as follows:

$$CH_{model\_kor} = CH_{mod}\ x\ \frac{{}^{*}CH_{mod}}{CH_{obs}} \qquad (3)$$

CH_{model_kor} : model-corrected monthly rainfall
CH_{mod} : modeled rainfall before correction
CH_{obs} : average rainfall of the baseline period of observation data
$*\ CH_{mod}$ verage rainfall of the baseline period of the modeldata

As for the correction of air temperature data, it is calculated based on **Equation 4** below:

$$T_{model\_ko} = T_{mod} + \bar{T}_{obs} + \bar{T}_{mod} \quad (4)$$

T_{model_kor} : model-corrected monthly air temperature
T_{mod} : model air temperature before correction

T_{obs} : average air temperature of the baseline period of observation data

T_{mod} : average air temperature of the baseline period of themodel data

After making corrections, it is necessary to validate to see how much bias (*error*) between uncorrected model data and corrected model data with observations using the same year period, namely the 2006-2015 period. This process is applied by looking at the *Root Mean Square Error* (RMSE) value to determine how much *error the* model data used is, the smaller the RMSE value, the better the performance of a model to be used in the next process. **Equation 5** to calculate the RMSE value:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}|e_i|^2}{n}} \quad (4)$$

e_i : bias/ *error*

$i=1$: Amount of data

Table 1. Weighting of Climate and Land Suitability for Mangosteen Crops

Ket	Land Characteristics	Weight Value			
		4	3	2	1
A	Air Temperature (˚C)	20-23	23-30	30-40	>40
			18-20	15-18	<15
B	Rain (mm)	1250-1750	1750-2000	2000-2500	>2500
			1000-1250	750-1000	<750
C	Soil Texture	Very Fine, Fine, Somewhat Fine	Medium	omewhat Coarse	Rough
D	Slope (%)	<8	8-15	15-40	>40
E	Height (m)	<600	600-800	800-1000	>1000

Weighting

In this study, the determination of land suitability of mangosteen plants was carried out with a weighting system of climatic elements and physical conditions of mangosteen plant land. Determination of the weighting of climate suitability of mangosteen plants can be seen in Table 1. Then the value of all weights is summed up from each element to get the level of climatic suitability of mangosteen plants with **Equation 6.**

Final Score = (A+ B + C + D + E) (6)

The final score to determine the classification of climatic suitability of mangosteen plants, which is divided into 4 categories, namely Very Suitable (S1), Moderately Suitable (S2), Marginal Suitable (S3) and Unsuitable (N), can be seen in Table 2.

Table 2. Classification of the number of weight values

l Weighted Value	iitabilityLevel	Description
16-20	S1	Very suitable
11-15	S2	Suitability
6-10	S3	Marginal Fit
<6	N	Not suitable

RESULT AND DISCUSSION

1. Distribution of Climate Suitability for Mangosteen Crops in the Baseline Period 2006-2015

Figure 3 is a map of the climatic suitability of mangosteen plants in the baseline conditions for the 2006-2015 period in West Sumatra Province.

Figure 3. Climate Suitability Map for Mangosteen Crops Baseline Period 2006-2015 West Sumatra Province

The entire area of West Sumatra Province is categorized as Suitable (S) for planting mangosteen plants. The suitability is divided into the categories of Very Suitable (S1) and Quite Suitable (S2). In the figure, it can be seen that most of the areas in West Sumatra Province

Table 3. Classification of Number of Weighted Values

NO	DISTRICT/CITY	KAB/KOTA AREA (ha)	VERY SUITABLE (S1)			MODERATELY SUITABLE (S2)		
			AREA (ha)	%	SECTION	KAB/ CITY (ha))	%	SECTION
1	AGAM	180.430	96.374	53	WEST PART	84.056	47	EAST
2	DHARMASRAYA	296.113	296.113	100	WHOLE PART	0	0	
3	FIFTY CITIES	357.114	242.524	68	LARGE SHARE	114.590	32	WEST, SOUTH
4	PADANG PARIAMAN	133.351	128.338	96	LARGE SHARE	5.013	4	EAST
5	PASAMAN	394.763	340.532	86	LARGE SHARE	54.231	14	WEST, SOUTHEAST
6	WEST PASAMAN	388.777	371.703	96	LARGE SHARE	17.074	4	EAST
7	SOUTH COAST	574.989	551.314	96	LARGE SHARE	23.675	4	NORTHEAST, EAST
8	SIJUNJUNG	313.040	164.942	53	SOUTH PART	148.098	47	NORTH
9	SOLOK	373.800	183.672	49	NORTH	190.128	51	SOUTH PART
10	SOUTH SOLOK	334.620	246.491	74	LARGE SHARE	88.129	26	THWESTERN PART
11	GROUND LAND	133.610	81.412	61	LARGE SHARE	52.198	39	NORTHWEST, EAST
12	BUKITTINGGI	2.524	0	0		2.524	100	WHOLE PART
13	PADANG	69.366	68.001	98	LARGE SHARE	1.365	2	EAST
14	PADANG PANJANG	2.300	0	0		2.300	100	WHOLE PART
15	PARIAMAN	6.613	6.613	100	WHOLE PART	0	0	

16	PAYAKUMBUH	8.522	6.845	80	LARGE SHARE	1.677	20	SOUTHEAST
17	SAWAHLUNTO	23.193	19.294	83	LARGE SHARE	3.899	17	EAST
18	SOLOK	7.129	7.129	100	WHOLE PART	0	0	
	AMOUNT	**3.600.254**	**2.811.321**	**78**		**788.933**	**22**	

categorized as Very Suitable (S1), which is marked in green on the map. Regencies whose entire area is categorized as Very Suitable (S1) include Dharmasraya Regency, Pariaman City and Solok City. Areas categorized as Moderately Suitable (S2) are marked in yellow on the map. Furthermore, districts whose entire area is categorized as Moderately Suitable (S2) include Bukittinggi City and Padang Panjang City. Then, the calculation of the area and percentage of climatic suitability of mangosteen plants per district in West Sumatra Province was carried out.

The calculation results in Table 3 show that the Very Suitable (S1) category covers more than half of West Sumatra Province for mangosteen cultivation with a land area of around 2,811,321 ha (78%). Then, the Moderately Suitable (S2) category is about 788,933 ha (22%). Some districts / cities whose entire area is categorized as Very Suitable (S1) for mangosteen cultivation are in Dharmasraya Regency with a land area of 296,113 ha (100%), Pariaman City which has a land area of 6,613 ha (100%), and Solok City whose land area is around 7,129 ha (100%). Then, for districts/cities whose entire area is categorized as Moderately Suitable (S2), there are Bukittinggi City with a land area of 2,524 ha (100%) and Padang Panjang City which has a land area of around 2,300 ha (100%).

Table 4. Classification of Number of Weighted Values

NO	DISTRICT/CITY	KAB/KOTA AREA (ha)	VERY SUITABLE (S1)			MODERATELY SUITABLE (S2)		
			AREA (ha)	%	SECTION	KAB/CITY (ha))	%	SECTION
1	AGAM	180.430	96.374	53	WEST PART	84.056	47	EAST
2	DHARMASRAYA	296.113	296.113	100	WHOLE PART	0	0	
3	FIFTY CITIES	357.114	242.524	68	LARGE SHARE	114.590	32	WEST, SOUTH
4	PADANG PARIAMAN	133.351	128.338	96	LARGE SHARE	5.013	4	EAST
5	PASAMAN	394.763	340.532	86	LARGE SHARE	54.231	14	WEST, SOUTHEAST
6	WEST PASAMAN	388.777	371.703	96	LARGE SHARE	17.074	4	EAST
7	SOUTH COAST	574.989	505.967	88	LARGE SHARE	69.022	12	NORTHEAST, EAST
8	SIJUNJUNG	313.040	164.942	53	SOUTH PART	148.098	47	NORTH
9	SOLOK	373.800	181.779	49	NORTH	192.021	51	SOUTH PART
10	SOUTH SOLOK	334.620	66.668	20	EAST	267.952	80	LARGE SHARE
11	GROUND LAND	133.610	81.412	61	LARGE SHARE	52.198	39	NORTHWEST, EAST
12	BUKITTINGGI	2.524	0	0		2.524	100	WHOLE PART
13	PADANG	69.366	68.001	98	LARGE SHARE	1.365	2	EAST
14	PADANG PANJANG	2.300	0	0		2.300	100	WHOLE PART
15	PARIAMAN	6.613	6.613	100	WHOLE PART	0	0	
16	PAYAKUMBUH	8.522	6.845	80	LARGE SHARE	1.677	20	SOUTHEAST
17	SAWAHLUNTO	23.193	19.294	83	LARGE SHARE	3.899	17	EAST
18	SOLOK	7.129	7.129	100	WHOLE PART	0	0	
	AMOUNT	**3.600.254**	**2.584.234**	**72**		**1.016.020**	**28**	

2. Distribution of Climate Suitability for Mangosteen Crops for Projection Period2031-2040

Figure 4 is a map of the climate suitability of mangosteen plants in the projection period 2031-2040 in West Sumatra Province.

Figure 4. Climate Suitability Map for Mangosteen Crops Projected Period 2031-2040 West SumatraProvince

It can be seen in Figure 4 that all areas of West Sumatra Province are categorized asSuitable (S) for planting mangosteen plants. In the projection period 2031-2040 there is an increase in the area of land in the category of Moderately Suitable (S2) occurs in South Solok Regency, South Pesisir Regency and Solok Regency. Furthermore, the calculation ofthe area and percentage of climate suitability of mangosteen plants per district in West Sumatra Province is presented in Table 5.

The calculation results show that in the projection period 2031-2040 compared to the baseline period, it can be seen that in several districts there was a reduction in the area of the Highly Suitable category (S1) to the Moderately Suitable category (S2) in the areas of South Solok Regency, South Pesisir Regency and Solok Regency.

CONCLUSION

Based on the results of the research that has been done, it can be concluded that the distribution of climatic suitability of mangosteen plants in West Sumatra Province in the baseline period 2006-2015 shows the category of Very Suitable (S1) by 78% and the category of Moderately Suitable (S2) around 22%. Based on the projection data for the period 2031-2040 when compared to the baseline period 2006-2015, the distribution of climatic suitability of mangosteen plants in West Sumatra Province for areas that are Very Suitable (S1) is reduced to Moderately Suitable (S2).

The Very Suitable (S1) category area of about 78% in the baseline period changed to 72% in the projection period, a change of 6% of the total area of West Sumatra Province. This is because the RCP 4.5 scenario projection data produces an increase in annual rainfall or annual air temperature which affects the weighting of mangosteen plants.

REFERENCES

C. Braak, *The Climate of The Netherlands Indies*. Batavia :Javasche Boekhandel & Drukkerij, 1928.

C. J. Willmott and K. Matsuura, “Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance,” *Clim Res*, vol. 30, no. 1, pp. 79–82, 2005, [Online]. Available: http://www.jstor.org/stable/24869236

D. Hapsari, R. Poerwanto, S. Didy, E. Santosa, and D. Matra, “Perubahan Morfofisiologi Bibit Manggis (Garcinia mangostana L.) terhadap Pemberian Polietilena Glikol (PEG,” *Jurnal Hortikultura Indonesia*, vol. 11, pp. 1–12, Apr. 2020, doi: 10.29244/jhi.11.1.1-12.

D. P. Sari, R. Novia, and Juniarti, “Kesesuaian Lahan untuk Tanaman Manggis dan Potensi Pengembangannya di Kecamatan Pauh Kota Padang,” *Jurnal Ilmu Tanah dan Lingkungan*, vol. 22, no. 2, pp. 89–94, Oct. 2020, doi: 10.29244/jitl.22.2.89-94.

E. Makmur, *Panduan Grads untuk Pemula*. Jakarta: Pusat Klimatologi Dan Kualitas Udara BMKG, 2008.

F. C. Weiland, L. P. H. van Beek, J. C. J. Kwadijk, and M. F. P. Bierkens, “The ability of a GCM-forced hydrological model to reproduce global discharge variability,” *Hydrol Earth Syst Sci*, vol. 14, no. 8, pp. 1595–1621, 2010, doi: 10.5194/hess-14-1595-2010.

F. M. Barung, “Proyeksi Kesesuain Agroklimat Tanaman Padi Berdasarkan Skenario Representative Concentration Pathways (RCP) 4.5 dan RCP 8.5 di Propinsi Jawa TImur,” 2017.

H. Pawitan, J. S. Baharsjah, R. Boer, I. Amien, and B. D. Dasanto, “Keseimbangan Air Hidrologi Wilayah Indonesia Menurut Kabupaten,” Bogor, 1996.

Intergovernmental Panel on Climate Change, *Climate Change 2013 – The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 2014. doi: DOI: 10.1017/CBO9781107415324.

J. Juniarti, Y. Yulnafatmawita, and S. Isminingsih, “Evaluasi Kesesuaian Lahan dan Potensi Produksi Tanaman Manggis (Garcinia mangostana L.) di 50 Kab Kota,” *Jurnal Solum*, vol. 5, p. 14, Jan. 2008, doi: 10.25077/js.5.1.14-22.2008.

Kementerian Pertanian, “Outlook Komoditas Pertanian Hortikultura Manggis Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal Kementerian Pertanian 2020,” Jakarta, Aug. 2020.

R. E. Walpole, *Pengantar Statistika*, 3rd ed. Jakarta: PT Gramedia Pustaka Utama, 1995.

Subiyanto, Adi. *Ketahanan Nasional Dan Resiliensi Iklim*. Penerbit Qiara Media, 2022.

Z. Irfan, “Profil Usahatani Manggis Pada Tiga Daerah Sentra Produksi Di Sumatera Barat,” in *Seminar Nasional Hortikultura*, Balai Pengkajian Teknologi Pertanian Sumatera Bara, 2005, pp. 86–104.