Geomedia

Majalah Ilmiah dan Informasi Kegeografian

Geomedia Vol. 22 No. 1 Tahun 2024 | 95 – 103

https://journal.uny.ac.id/index.php/geomedia/index

Pemodelan spasial prediksi curah hujan melalui metode *inverse distance weighting* (IDW) di wilayah Sumatera Barat tahun 2026

Rizkia Zulal Karimah[a, 1*], Zein Zidan Azzahmi[a, 2*], Arif Dwi Prasetya[a, 3*], Arin Nanda Dila Apsari[a, 4], Faithfulloh Fatah[a, 5], Khafidh Nur Aziz[b, 6]

[a] Prodi Pendidikan Geografi, Universitas Negeri Yogyakarta, DI Yogyakarta, Indonesia
[b] Prodi Pendidikan Fisika, Universitas Negeri Yogyakarta, DI Yogyakarta, Indonesia
[1] rizkia7249fis.2021@student.uny.ac.id*; zeinzidan.2021@student.uny.ac.id*; arifdwi.2021@student.uny.ac.id*; arinnanda.2021@student.uny.ac.id; faithfullohfatah.2022@student.uny.ac.id; khafidh.na@uny.ac.id
*korespondensi penulis

Informasi artikel

Sejarah artikel
Diterima :
Revisi :
Dipublikasikan :

Kata kunci:
Curah Hujan
Interpolasi IDW
Proyeksi CH
Bencana Hidrometeorologi
Mitigasi

A B S T R A K

Sumatera Barat memiliki tipe curah hujan (CH) ekuatorial yang dipengaruhi oleh keberadaan angin monsun barat laut dan tenggara. Berdasarkan data intensitas CH tahunan pada tahun 2019 dan 2022, diketahui bahwa wilayah Sumatera Barat memiliki distribusi kelas CH yang variatif dengan kelas sedang hingga ekstrim. Tujuan dari penelitian ini yaitu untuk mengetahui proyeksi intensitas hujan tahunan pada tahun 2026 di Sumatera Barat, dengan menggunakan metode interpolasi *Inverse Distance Weighting* (IDW) untuk menganalisis distribusi spasialnya (wilayah). Hasil dari proyeksi intesitas CH tahunan pada tahun 2026 ini menunjukkan tingkatan distribusi curah hujan yang tergolong sangat tinggi. Sehingga, berpotensi menimbulkan bencana hidrometeorologi seperti banjir, banjir bandang, dan tanah longsor di Sumatera Barat.

Keywords:
Rainfall (CH)
IDW Interpolation
CH Projection
Hydrometeorological Disasters
Mitigation

A B S T R A C T

West Sumatra has an equatorial type of rainfall (CH) influenced by the presence of northwest and southeast monsoon winds. Based on annual CH intensity data in 2019 and 2022, it is known that the West Sumatra region has a varied distribution of CH classes with moderate to extreme classes. The purpose of this study is to determine the projection of annual rain intensity in 2026 in West Sumatra, using the Inverse Distance Weighting (IDW) interpolation method to analyze its spatial distribution (region). The results of the projection of annual CH intensity in 2026 show a level of rainfall distribution that is classified as very high. Thus, it can potentially cause hydrometeorological disasters such as floods, flash floods, and landslides in West Sumatra.

Introduction

West Sumatra Province is one of the provinces on the island of Sumatra which has an area of about 42,297.30 km² or equivalent to 2.21% of the Republic of Indonesia with a population as of June 2022 of 5,640,629 people (BPS West Sumatra, 2023). West Sumatra Province is one of the provinces that is very interesting to study in the aspect of hydrometeorological phenomena. This is due to extreme weather phenomena that have become a common phenomenon in West Sumatra, Indonesia. According to Amindoni & Adzkia (2021), the increasing trend of hydrometeorological disasters such as floods, landslides, and flash floods are caused by the climate crisis, which is exacerbated by human activities. The situation is exacerbated by the La Nina phenomenon and other atmospheric phenomena such as air convergence and air mass deceleration that result in the formation of Cumulonimbus clouds (rain clouds). BMKG West Sumatra reported that the peak of the rainy season in the province occurred in January, resulting in more extreme rainfall (CH). This situation has led to a series of natural disasters that killed 213 people, injured 12,000, and displaced nearly two million people as reported in BBC News Indonesia (2021).

Rain is one of the weather elements that often occurs in tropical areas, especially in Indonesia, where rain with very heavy intensity (extreme) can have a significant impact on human life (Hadiansyah et al., 2018). The phenomenon of extreme rain that occurs in the West Sumatra region has an equatorial rain pattern. The equatorial rain pattern has a bimodial monthly rain distribution or has two peaks of the rainy season and almost throughout the year the region will experience a continuous rainy season. On an annual time scale, the distribution of CH in Indonesia, especially West Sumatra, moves in line with the maximum seasonal temperature zone, so that rainfall in the region will experience an increase in intensity every year. Extreme rainfall generally has the lowest rainfall intensity of 100 mm/day or 20 mm/hour (Sofan, 2013). Table 1 is data on rainfall intensity (CH) in West Sumatra Province in 2019, which was obtained from five BMKG CH measurement stations spread across West Sumatra Province:

Table 1. Rainfall Intensity (CH) in West Sumatra Province

Rainfall Station	**2019 (mm/year)**
Minangkabau	2.781,00
Sumatera Barat	4. 071,70
Global	2.981,50
Teluk Bayur	2.640,50
Padang Panjang	3.011,40

Source: BMKG (2023)

Based on the annual rainfall data table in 2019, it is known that the highest CH measurement results are the results of CH measurements at the West Sumatra station. The phenomenon of positive sea surface temperature anomalies in the Indian Ocean to the west and negative sea surface temperature anomalies occurs west of Sumatra Island, resulting in increased rainfall in coastal areas known as the Indian Ocean Dipole Mode (IOD) (Supriyadi et al., 2017). High rainfall can cause several losses to the environment and humans caused by natural disasters. Two of the natural disasters caused by high rainfall in West Sumatra are floods and landslides. BMKG West Sumatra mentioned that convergence is one of the causes of high rainfall, potentially causing floods and landslides as reported by (Kantara-News, 2023).

Extreme rains in West Sumatra have significantly impacted the lives of people in the area such as the economy and health. Floods and landslides have caused damage to infrastructure, homes, and crops, resulting in economic losses. The situation has also affected community development and well-being, with many people suffering from water-borne diseases and respiratory illnesses. Based on the Indonesian Disaster Risk Index in 2022, West Sumatra Province has a high disaster risk class with a value of 144.39, while Padang Pariaman Regency is in the high-risk index class with a value of 156.73 (Padang Pariaman District Government, 2023).

As an area with a high level of disaster threat and risk, the people of West Sumatra province expect that preventive efforts can be made to reduce the impact of extreme rains in the region. The government has undertaken the construction of flood control infrastructure, such as dams and embankments, and the implementation of early warning systems to inform the public of impending disasters. The government has also launched campaigns to raise awareness about the importance of disaster preparedness and the need to reduce greenhouse gas emissions to mitigate the impacts of climate change. The significant impact of extreme weather, especially extreme rainfall in West Sumatra, has greatly affected the lives of people in the region. This situation is exacerbated by the climate crisis, which is caused by human activities. To reduce the impact of extreme weather, the government has implemented various developments, including the development of flood control infrastructure and the implementation of early warning systems. However, more needs to be done to address the root of the problem, such as reducing greenhouse gas emissions and promoting sustainable development practices.

Another effort that is an anticipatory step in dealing with hydrometeorological disasters is to conduct rainfall projections. Rainfall projections are carried out with certain methods that can describe future rainfall trend data. Rainfall projection data can be utilized as a reference in policy making in environmental issues, especially regarding hydrometeorological disaster mitigation. One method that can be used to project rainfall is spatial modeling with the Inverse Distance Weighting (IDW) method. The IDW method is a type of interpolation that predicts the value of unknown points based on the value of known points around them. The IDW method assumes that points located closer to the estimated point will have more influence than points that are far away (Sari et al., 2021). Spatial modeling of rainfall using the IDW method will provide rainfall projection data that can be known for spatial distribution and pattern. This can be implemented in West Sumatra as a variation of rainfall projection methods in the region.

Methode

1. Rainfall Intensity (CH)

Rain is one of the most common and familiar forms of precipitation in Indonesia. In meteorology, the term rain is limited to drops of water that fall from clouds and have a diameter of at least 0.5 millimeters, the majority of which come from nimbostratus or cumulonimbus clouds (Lutgens & Tarbuck, 2016). Rainfall in various parts of Indonesia has different intensities, which can be influenced by regional topography, air temperature, air mass, and air pressure. Extreme rainfall can affect human activities both economic, social, and health. In addition, extreme CH can pose a threat of disaster for the community such as floods, flash floods to landslides. To minimize the impact of extreme CH, it is necessary to map areas that have extreme CH intensity, so that subsequently several preventive efforts can be made by the government, the community, and related parties in dealing with disasters that occur. In this research, the study area to be studied is West Sumatra Province which is located at 0°54" LU-30°30" LS and 98°36"-101°53" East. The rainfall intensity data used in this study is secondary data obtained from BMKG based on the results of CH measurements in West Sumatra Province in 2019 through measurement stations spread across West Sumatra, including Minangkabau Meteorological Station (Kab. Padang Pariaman), Sicincin Climatology Station (Kab. Padang Pariaman), Bukit Koto Tabang Global Atmospheric Monitoring Station (Kab. Agam), Teluk Bayur Meteorological Station, and Padang Panjang Geophysical Station. The following is an administrative map of West Sumatra Province:

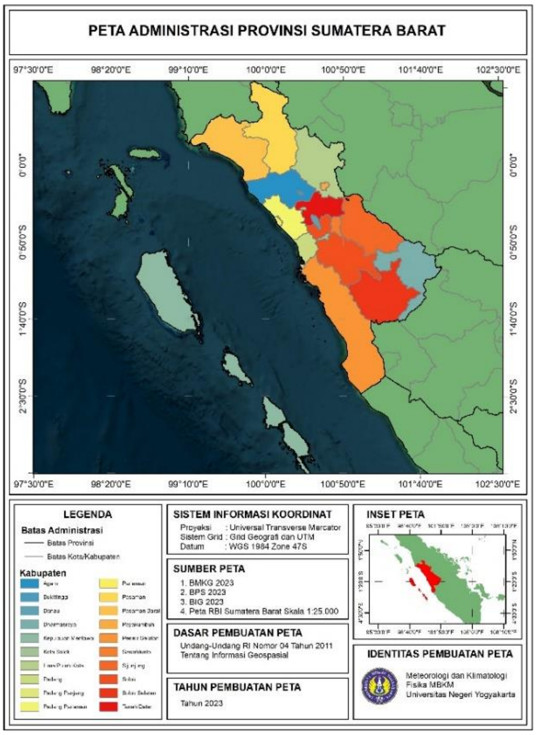

Figure 1. Administrative Map of West Sumatra Province

2. GIS-assisted extreme CH assessment

CH assessment indicators are carried out in this study, based on time series theory so that modeling can be carried out. Time series modeling of time-delayed events is formulated to understand the mechanism of event generation, forecasting, or prediction of future events and also for optimal event control (Wahyudi, 2022). ArcGIS, ESRI, and Microsoft Excel programs were used during the data input, analysis, and mapping process. The base map (shapefile) of the administrative area of West Sumatra Province was obtainedthrough https://tanahair.indonesia.go.id/ provided by the Indonesian Geospatial Information Agency (BIG Indonesia). The 2019 CH intensity data in one year was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG), and then processed with the Inverse Distance Weighting (IDW) interpolation method to determine the spatial distribution of the area of each CH intensity value.

Table 2. Rainfall in West Sumatra 2019

Rainfall Station	CH in 2019 (mm/year)
Minangkabau	2.781,0
Sumbar	4.071,7
Global Bukit Koto Tabang	2.981,5
Teluk Bayur	2.640,5
Padang Panjang	3.011,4

Source: BMKG (2023)

3. GIS mapping procedures

The Inverse Distance Weighting (IDW) method was performed using the Spatial Analyst Extension of ArcGIS 10.8. The 2019 rainfall intensity (CH) data file in the form of CSV (Comma delimited) was exported in the ArcGis 10.8 application. The CH intensity data was then converted into shapefiles in the form of points. The excess data collected for each parameter from the CH measurement points was used in the calculation of each interpolated cell or grid. The quantity classification and classification of rainfall (CH) will be based on the spatial distribution of CH on the map legend according to the data range of each parameter.

4. IDW Interpolation

Inverse Distance Weighting (IDW) interpolation is an interpolation technique that is widely used in the process of mapping spatial variables. The IDW method is a precise and convex interpolation method, so it is only suitable for continuous spatial variation models (Khouni et al., 2021). This method is often used in exploration activities, because the calculation process is simpler and easier for new users to understand, compared to the Kriging or Spline methods. The IDW method assumes that objects that are close to each other have more similar predicted values compared to objects that are far apart. The basic principle of IDW interpolation in this study is to use a weighted linear combination of points in the rainfall data. This method relies on two types of methods, namely statistical and mathematical, to create surfaces and calculate predictions of unmeasured points (Khouni et al., 2021). The main factor that can affect the accuracy of IDW interpolation is the value of the power parameter p (Burrough and McDonnell, 1998). The general equation used for IDW (Equation 1) is :

$$Z_0 = \frac{\sum_{i=1}^{N} z_i \cdot d_i^{-n}}{\sum_{i=1}^{N} d_i^{-n}}$$

Description:

Z0 = Estimated value of variable z at point , or interpolated value from grid nodes

Zi = Sample value of point I, or neighboring data point

di = Distance from the sample point to the estimation point, or the distance between the grid node and the data point

N = Robustness coefficient or distance-based value

n = Total number of predictions for each validation case

Results and discussion

1. General condition of rainfall in West Sumatra

West Sumatra is one of the regions in Indonesia that has high rainfall. The rainfall pattern in West Sumatra generally shows an equatorial type characterized by two rain peaks during the year (Hadiansyah et al., 2018). The equatorial rainfall pattern in West Sumatra is characterized by a bimodal monthly rainfall distribution and almost all year round can be included in the rainy season criteria. The peak of equatorial rainfall usually occurs one month after the sun is right on the equator, which is around March/April and October/November (Apriyana & Kailaku, 2015). This can be the cause of higher annual rainfall in the West Sumatra region than in other regions. Such conditions are also exacerbated by the presence of various hydrometeorological phenomena such as the IODM (Indian Ocean Dipole Mode) in the Indian Ocean, Kelvin Waves, and the Madden Julian Oscillation. The IODM during its negative phase can increase rainfall in the Sumatra region including West Sumatra due to the warming of the Indian Ocean sea surface temperature around Sumatra which causes the growth of many rain clouds. Kelvin wave itself is a tropical weather system that moves east along the equatorial wave path, organizes convection flow, affects equatorial rainfall variability in maritime areas, and affects precipitation with extremes (Senior et al., 2023). Madden Julian Oscillation (MJO) which can increase rainfall in West Sumatra is when phase III usually occurs in the Eastern Indian Ocean including the West coast of Sumatra.

Data from BMKG shows rainfall data at several rain stations in West Sumatra in 2019 and 2022 as follows:

Table 3. Annual rainfall data at several rain stations in West Sumatra in 2019 and 2022

No.	Rainfall Station	Annual Rainfall (mm/year)	
		2019	2022
1.	Minangkabau	2.781,0	4.171,5
2.	Sumatera Barat	4.071,7	6.107,6
3.	Global Bukit Koto Tabang	2.981,5	4.472,3
4.	Teluk Bayur	2.640,5	3.960,8
5.	Padang Panjang	3.011,4	4.517,1

Source: BMKG (2023)

Rainfall data for 2019 and 2022 were selected as observation years and resulted in varied rainfall with moderate to extreme classes. The 2019 rainfall data has a moderate to extreme rainfall class because it has a range of rainfall above 2,500 to above 4,000 mm/year. Meanwhile, the 2022 rainfall data has a very high to extreme rainfall class because it has a range of above 3,500 to above 4,000 mm/year (Baharudin, 2014). This moderate to extreme rainfall can affect the increase of hydrometeorological disasters both in terms of intensity of occurrence and risk.

2. Projected Rainfall and Distribution in 2026

The rainfall projection process in the West Sumatra region is carried out with rainfall data in 2019 and 2022 to obtain rainfall data in 2026 which is four years from the last year of observation. The distribution of rainfall is done by interpolating the Inverse Distance Weighting method. The following is the projection of rainfall in 2026 in West Sumatra from the 2019 and 2022 data presented in Table 4:

Table 4. Projected rainfall in West Sumatra in 2026

No.	Rainfall Station	Annual Rainfall (mm/year)		
		2019	2022	2026
1.	Minangkabau	2.781,0	4.171,5	5562
2.	Sumbar	4.071,7	6.107,6	8143,4
3.	Global Bukit Koto Tabang	2.981,5	4.472,3	5963
4.	Teluk Bayur	2.640,5	3.960,8	5281
5.	Padang Panjang	3.011,4	4.517,1	6022,8

Source: Primary data

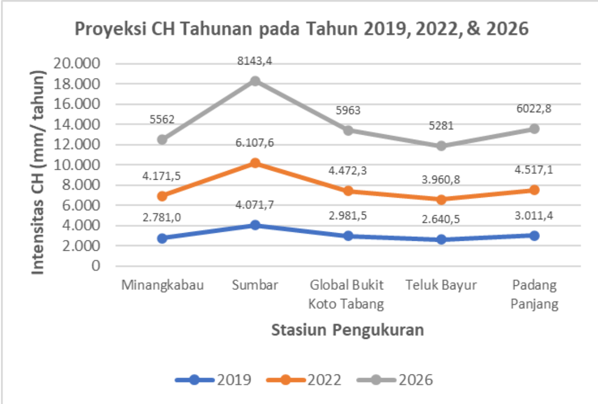

Figure 2. Graph of rainfall projections in West Sumatra in 2026
(Source: Primary data)

Projections of rainfall in 2026 listed in table 4.2 and graph 4.1 at each rain station in West Sumatra resulted in the highest annual rainfall projection data occurring at the West Sumatra Rain Station with an annual rainfall projection value of 8,143.4 mm/year which can be categorized as an extreme class in the rainfall category according to Baharudin (2014). Meanwhile, the lowest annual rainfall projection data occurs at the Teluk Bayur Rain Station with a projected rainfall of 5,281 mm/year. Despite being the lowest value, the projected rainfall value is still categorized into the extreme rainfall class according to Bahaudin (2014) because it has a rainfall range value of more than 4,000 mm/year. Based on graph 4.1, rainfall from 2019, 2022, and 2026 experienced a significant upward trend. Meanwhile, the distribution of rainfall projections in the West Sumatra region in 2026 is interpolated with the Inverse Distance Weighting method depicted in the following map:

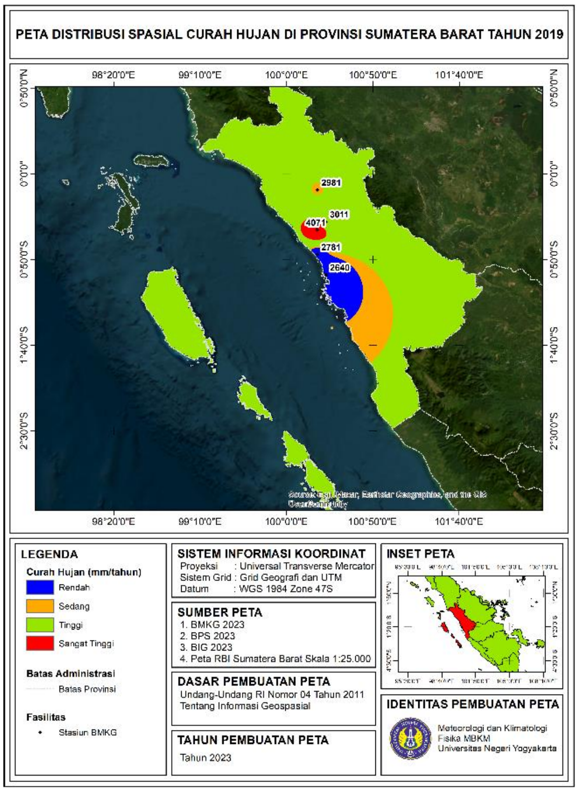

Figure 3. Distribution of rainfall in 2019 in West Sumatra with IDW interpolation. (Source: Primary data)

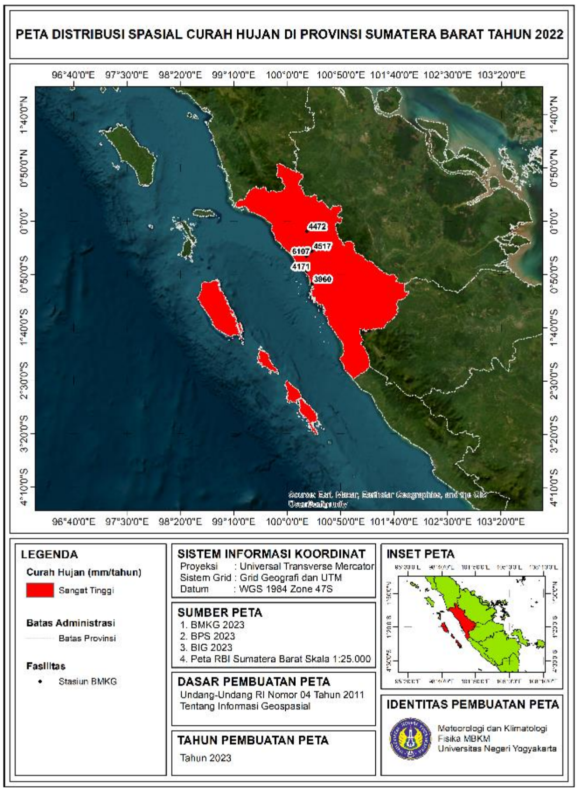

Figure 4. Distribution of rainfall in 2022 in West Sumatra with IDW interpolation. (Source: Primary data)

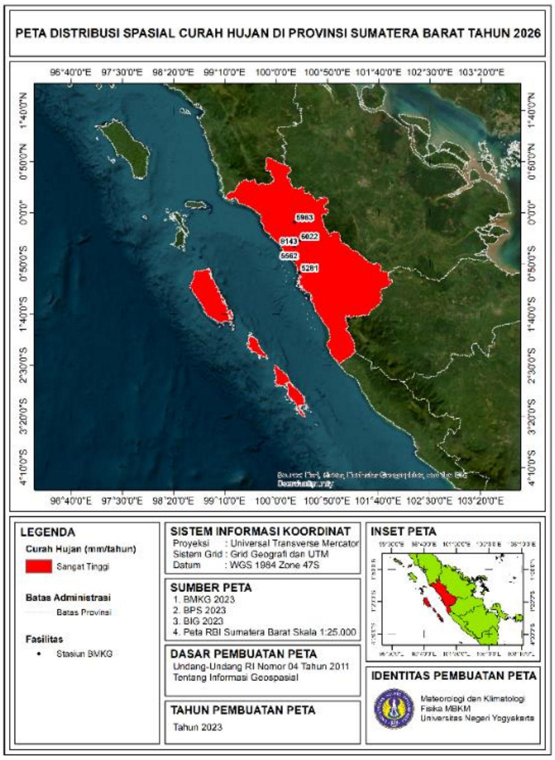

Figure 5. Distribution of rainfall in 2026 in West Sumatra with IDW interpolation. (Source: Primary data)

The interpolation process is carried out to determine the value of rainfall in areas where the rainfall value is unknown based on rainfall station points that are known to have rainfall values. The distribution of annual rainfall in 2019 in West Sumatra is dominated by rainfall of 3011 mm/year which is classified as high rainfall. Rainfall with this value is symbolized by the green color that dominates the West Sumatra region in addition to other colors. Meanwhile, the distribution of rainfall in 2022 and 2026 has a similar pattern with very high intensity rainfall evenly distributed throughout West Sumatra. This can be seen from the red color that dominates the entire West Sumatra region.

3. Implications and Mitigation Measures

Climate change can lead to accelerated erosion and surface water flow, drought, excess water, and subsequent flooding and landslides (Utami, 2019). Rainfall is one of the weather and climate parameters. Very high (extreme) rainfall (CH) can cause various hydrometeorological disasters such as floods, flash floods, and landslides (including mass wasting). The potential for floods and landslides is directly proportional and correlated. According to Estiningtyas et al. (2009), the distribution pattern of extreme rainfall that can cause flooding is dominated by rainfall with intensity >300-400 mm/month, although some areas have lower extreme rainfall limits. Flood events that occur are caused by the potential for high rainfall with a daily to monthly period.

Flash floods are flood disasters that occur in a shorter time than floods in general but with higher flow rates (Sene, 2013). Flash floods can be caused by CH intensity factors and disturbances in waterways such as blockage of river flow by garbage or suspended sediments. High water discharge and fast water flow coupled with the presence of accumulated suspended sediments in the water flow, can cause damage to infrastructure and buildings and can cause high casualties. According to Zain et al. (2021), the socioeconomic impacts arising from flash floods are massive and rapid damage, and property losses, especially to damaged infrastructure and residential buildings, requiring high rehabilitation costs.

In addition to floods and flash floods, landslides can also occur due to the high intensity of CH, especially if the soil texture conditions are clay or loam. Landslides can be defined as the movement of large masses of soil as a result of unstable soil conditions. According to Haribualan et al. (2019), factors that influence landslide vulnerability include natural factors (accumulation of daily rainfall, land slope, geology/rock, presence of faults, presence of impermeable aquiclude layer, and presence of groundwater above the aquiclude layer) and social factors (land use change, settlement, and infrastructure development). Increasing hydrometeorological disasters can exacerbate social and economic damage (Azizah et al., 2022).

Based on the results of the analysis obtained, it is known that the projected annual CH in 2022, and 2026 in West Sumatra Province has an intensity that is included in the very high classification, which ranges from 3500-4000 mm / rainy year (based on the Decree of the Minister of Forestry No. 837 / KPTS /UM / 11/1980 and No. 683 / KPTS /UM / 1981). The very high intensity of rain in West Sumatra raises the potential for high hydrometeorological disasters as well. According to (Hermawan & Lestari, 2007), rainfall in West Sumatra is generally dominated by the accumulation of annual rainfall which is also supported by the northwest monsoon (November-March) and southeast monsoon (May-September). Mitigation is a series of efforts made to reduce losses caused by disasters. Therefore, mitigation efforts for floods, flash floods, and landslides need to be well-planned by the government, community, and related stakeholders in West Sumatra. One form of mitigation effort is to establish and organize institutions to reduce the impact caused by floods (Putri et al., 2023). The Regional Disaster Management Agency (BPBD) of West Sumatra Province has formed Nagari/Kelurahan-based Disaster Awareness Groups (KSB) in all districts in West Sumatra since 2014 (Falah & Savitri, 2016). In addition, cited by Vinolia (2018), hydrometeorological disaster mitigation efforts in West Sumatra that can be carried out include watershed improvement from upstream to downstream, increasing the capacity and adaptation of communities living in floodplain areas, improving river boundaries as protected areas, flood early warning systems that can reach the community, and improving licensing governance by the government and regulation of laws and regulations.

Conclusion

West Sumatra (Sumbar) is one of the regions in Indonesia that has high rainfall, with an equatorial type characterized by two rain peaks in one year. Rainfall data in 2019 and 2022 were selected as observation years because they have varied rainfall distribution with moderate to extreme classes, which were then carried out IDW modeling. The results of the 2026 rainfall projection are known to be 8,143.4 mm/year which can be categorized in the extreme class. This extreme CH projection is evenly distributed throughout West Sumatra without exception. This can be seen from the red color that dominates throughout West Sumatra on the 2026 rainfall distribution map (Figure 4.3). Very high (extreme) rainfall (CH) can cause various hydrometeorological disasters such as floods, flash floods, and landslides. The BPBD of West Sumatra Province has established a Nagari/Kelurahan-based Disaster Awareness Group (KSB) in all districts in West Sumatra since 2014. Hydrometeorological disaster mitigation efforts that can be done are a watershed improvement from upstream to downstream, increasing the capacity and adaptation of communities living in disaster-prone areas, improving river boundaries, and early warning systems, and improving licensing governance by the government and regulation of laws and regulations.

Acknowledgement

The author would like to thank Mr. Khafidh Nur Aziz, S.Si., M.Sc. as the supervisor of the meteorology-climatology project, and various parties who have helped in the process of preparing this article. In the future, we hope that the topics in this article can be further developed by future researchers.

Reference

Amindoni, A. & Adzkia, A. (2021) Banjir dan bencana beruntun di tengah cuaca ekstrem, 'Menurut pemerintah itu anomali cuaca, kami menyebutnya krisis iklim'. *BBC News*. Retrieved from https://www.bbc.com/indonesia/indonesia-56007558

Apriyana, Y., & Kailaku, T. E. (2015). Variabilitas iklim dan dinamika waktu tanam padi di wilayah pola hujan monsunal dan equatorial. *Pros Sem Nas Masy Biodiv Indon, 1*(372), 366-372. http://dx.doi.org/10.13057/psnmbi/m010233

Azizah, M., Subiyanto, A., Triutomo, S., & Wahyuni, D. (2022). Pengaruh perubahan iklim terhadap bencana hidrometeorologi di Kecamatan Cisarua-Kabupaten Bogor. *PENDIPA Journal of Science Education, 6*(2), 541-546. https://doi.org/10.33369/pendipa.6.2.541-546

Badan Pusat Statistik Provinsi Sumatera Barat. (2023). *Provinsi Sumatera Barat Dalam Angka 2023*. Buku diakses pada tanggal 23 November 2023 pukul 17.17 WIB melalui https://sumbar.bps.go.id/publication/2023/02/28/873d22882726e76b9d86b105/provinsi-sumatera-barat-dalam-angka-2023.html

Baharudin, N. A. (2014). Analisis evaluasi fungsi kawasan dengan kondisi lahan existing dan rencana tata ruang wilayah (studi kasus: Kabupaten Sleman, Daerah Istimewa Yogyakarta. *Doctoral Dissertation*. ITN Malang). ITN Malang Repository,. Diakses dari https://eprints.itn.ac.id/1495/ tanggal 30 November 2023.

Burrough, P.A., McDonnell, R.A. (1998). Creating continuous surfaces from point data. In: Burrough, P.A., Goodchild, M.F., McDonnell, R.A., Switzer, P., Worboys, M. (Eds.), *Principles of Geographic Information Systems*. Oxford University Press, Oxford, UK.

Estiningtyas, W., Boer, R., & Buono, A. (2009). Analysis of relationship between rainfall and flood as well as drought events on area with rice farming system in West Java Province. *Journal Agromet, 23*(1), 11-19. https://journal.ipb.ac.id/index.php/agromet/article/view/3522/2413

Falah, F. & Savitri, E. (2016). Pemberdayaan masyarakat dalam mitigasi banjir bandang di Sumatera Barat. *Prosiding Seminar Nasional Geografi UMS 2016 : Upaya Pengurangan Risiko Bencana Terkait Perubahan Iklim,* 612-625. https://publikasiilmiah.ums.ac.id/handle/11617/8529

Hadiansyah, R., Indranata, A. L., Silitonga, A. K., & Winarso, P. A. (2018). Kajian kondisi atmosfer saat kejadian hujan ekstrem di Padang Sumatera Barat (studi kasus tanggal 14 Februari 2018). *Prosiding SNFA (Seminar Nasional Fisika Dan Aplikasinya), 3*, 246-257. https://doi.org/10.20961/prosidingsnfa.v3i0.28556

Haribulan, R., Gosal, P. H., & Karongkong, H. H. (2019). Kajian kerentanan fisik bencana longsor di Kecamatan Tomohon Utara. *Jurnal Spasial, 6*(3), 714-724. https://doi.org/10.35793/sp.v6i3.26015

Hermawan, E. & Lestari, S. (2007). Analisis variabilitas curah hujan di Sumatera Barat dan Selatan dikaitkan dengan kejadian *Dipole Mode*. *Jurnal LAPAN, 4*(2), 91-106. https://jurnal.lapan.go.id/index.php/jurnal_sains/article/view/666

Kantara News.com. (2023). Intensitas curah hujan di Sumatera Barat. *Berita* diakses pada tanggal

23 November 2023 pukul 19.28 WIB. Retrived from https://www.antaranews.com/berita/3634761/bmkg-jelaskan-penyebab-tingginya-intensitas-curah-hujan-di-sumbar#mobile-nav

Lutgens, F. K. & Tarbuck, E. J. (2016). *The atmosphere : An introduction to meteorology (13ed.).* Pearson Education, Inc.

Menteri Pertanian. (1981). *Surat Keputusan Menteri Pertanian No. 683/KPTS/UM/8/1981 tentang Kriteria dan Tata Cara Penetapan Hutan Produksi.* Jakarta. https://bphn.go.id/data/documents/96pdsulsel009.doc

Pemerintah Kabupaten Padang Pariaman., (2023). Padang Pariaman dukung pelaksanaan IDRIP Sebagai upaya pembentukan masyarakat siaga bencana. *Berita Daerah* diakses pada tanggal 20 November 2023 pukul 17.00 melalui https://padangpariamankab.go.id/blog/berita_tampil/22716

Putri, S. E., Frinaldi, A., Rembrandt, Lanin, D., Umar, G., & Gusman, M. (2023). Kota Padang: Identifikasi potensi bencana banjir dan upaya mitigasi. *Jurnal Ilmiah Multidisiplin Nusantara, 1*(3), 116-122. https://doi.org/10.59435/jimnu.v1i3.56

Sari, M., Cahyaningtyas, C., & Prasetyo, S. Y. J. (2021). Analisis daerah rawan longsor di Kabupaten Brebes memanfaatkan citra Landsat 8 dengan metode Inverse Distance Weighted (IDW). JIFOTECH (Journal of Information Technology), 1(2), 1-6. https://dx.doi.org/10.46229/jifotech.v1i2.276

Sene, K. (2013). *Flash flood, forecasting and warning.* Springer. https://link.springer.com/book/10.1007/978-94-007-5164-4

Senior, N. V., Matthews, A. J., Webber, B. G., Webster, S., Jones, R. W., Permana, D. S., ... & Fadila, R. (2023). Extreme precipitation at Padang, Sumatra triggered by convectively coupled Kelvin waves. *Quarterly Journal of the Royal Meteorological Society, 149*(755), 2281-2300. https://doi.org/10.1002/qj.4506

Sofan, P. (2013). Karakteristik pola curah hujan di wilayah Indonesia berdasarkan data satelit TRMM (1998-2011). *Bunga Rampai Penginderaan Jauh Indonesia 2013*, 1-21. https://karya.brin.go.id/id/eprint/14079/

Supriyadi, S., Hidayati, R., Hidayat, R., & Sopaheluwakan, A. (2017). Mapping extreme rain conditions in Sumatra by influence global conditions. *IOP Conf. Series: Earth and Environmental Science, 58*, 1-10. https://iopscience.iop.org/article/10.1088/1755-1315/58/1/012041

Utami, N. D. (2019). Kajian dampak perubahan iklim terhadap degradasi tanah. *Jurnal Alami, 3*(2), 122–131. https://www.semanticscholar.org/paper/KAJIAN-DAMPAK-PERUBAHAN-IKLIM-TERHADAP-DEGRADASI-Utami/a2b835e2983cf9872681e3cdae60804d725423a8

Vinolia. (2018). Banjir dan longsor terjang Sumatera Barat: Berikut masukan upaya pencegahan. *Mongabay : Situs Berita Lingkungan* diakses pada 1 Desember 2023 pukul 14.00 melalui https://www.mongabay.co.id/2018/11/06/banjir-dan-longsor-terjang-sumatera-barat-berikut-masukan-upaya-pencegahan/

Wahyudi, D. (2022). Peramalan curah hujan dengan metode seasonal autoregressive integrated moving average (sarima) (studi kasus: kota bengkulu). *Skripsi*. Yogyakarta: Universitas Islam Indonesia. https://dspace.uii.ac.id/handle/123456789/42749

Zain, A., Legono, D., Rahardjo, A. P., Jayadi, R. (2021). Review on co-factors triggering flash flood occurrences in Indonesian small catchments. *ICWRDEP 2021 : Conf. Series: Earth and Environmental Science, 930*, 1-9. https://iopscience.iop.org/article/10.1088/1755-1315/930/1/012087