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Predictive Mapping of Hydrometeorological Disaster Prone Areas in Central Kalimantan

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Abstract: Disaster is an event or a series of events that threatens and disrupts people's lives and livelihoods, caused by natural and/or non-natural factors and human factors, resulting in human casualties, environmental damage, property losses, and psychological impacts. Hydrometeorological disasters are events related to water, atmosphere, and oceans. It is recorded that hydrometeorological disasters occurring in Indonesia reach 86%, including floods, tornadoes, landslides, forest and land fires, and droughts. Specifically, in Central Kalimantan Province, forest and land fires and floods are frequent disasters. Both fall into the category of hydrometeorological disasters, closely related to the climate in Central Kalimantan. In this study, the prediction of rainfall, temperature, and humidity values in Central Kalimantan Province was calculated using the Auto-Regressive Integrated Moving Average method at 5 stations in the province. Subsequently, the prediction analysis of flood events was carried out using the machine learning random forest method based on the rainfall data, temperature, humidity, and event data. According to the calculation results, flood disasters are not predicted to affect almost all areas of Central Kalimantan Province. However, by the end of 2023, it is anticipated that most areas in the province will still be categorized as experiencing a normal level of drought. Notably, there are two areas that must increase awareness of this drought disaster, namely Pulang Pisau and Sampit, especially in October 2023.

Keywords: Climate; Drought; Flood; Humidity; Hydrometeorology; Rainfall; Temperature

Introduction

A disaster is an event or a series of events that threaten and disrupt people's lives and livelihoods, caused by natural and/or non-natural factors and human actions, resulting in human casualties, environmental damage, property losses, and psychological impacts (Badan Penanggulangan Bencana Daerah, 2021; Eka Putri et al., 2023; Jalaludin, 2023). Hydrometeorological disasters are those related to water, the atmosphere, and oceans (Administrator Portal Informasi Indonesia, 2023). It is recorded that hydrometeorological disasters occurring in Indonesia reach 86%, including floods, tornadoes, landslides, forest and land fires, and droughts, among others (Ferdi et al., 2021; Nugraheni et al., 2022).

The National Disaster Management Agency (BNPB) noted that throughout 2019, there were 3,814 events, with 784 of them being flood disasters spread throughout Indonesia (Badan Nasional Penanggulangan Bencana, 2023). Flooding is one form of disaster in Indonesia that occurs almost every year. In the last 10 years, floods have always occupied the first position of disaster events (Table 1). Even in the *Indonesia Disaster Management Reference Handbook,* the largest flood disaster ever occurred in Indonesia, namely in May-July 2016, floods occurred in South Kalimantan, West Kalimantan, Central Kalimantan,

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Bengkulu, Gorontalo, West Java, Central Java, Bali, East Nusa Tenggara, North Sulawesi, and Papua (Balai Besar Litbang Sumberdaya Lahan Pertanian (BBSDLP), 2013).

Table 1. Disaster Events in Indonesia by Disaster Type in 2020 (Badan Nasional Penanggulangan Bencana, 2020)

Disaster Type	Occurrences
Flooding	6,548
Whirlwind	5,437
Landslides	4,337
Forest and land fires	894
Drought	754
Tidal wave/abrasion	188
Earthquake	159
Volcanic Eruption	106
Tsunami	9
Earthquake and tsunami	2

Especially in Central Kalimantan Province, the disasters that occur most frequently are forest and land fires and floods (Badan Penanggulangan Bencana Daerah, 2021b; Bochenek & Ustrnul, 2022; Fitriyaningsih & Basani, 2019). Both disasters fall into the category of hydrometeorological disasters and are closely related to the climate in Central Kalimantan (Rosyida et al., 2019). As is known, Indonesia has a wet tropical climate with high rainfall. The climatic conditions in Indonesia have quite extreme climate change which includes rainfall, temperature and humidity (Ferdi et al., 2021). In 2021, according to data from the Central Statistics Agency, floods and forest fires emerged as priority disasters requiring attention from the government and the people of Central Kalimantan. Table 2 presents data on disaster events in Central Kalimantan Province (Febriansyah et al., 2020).

Table 2. Occurrence of Disasters in Central Kalimantan Province in 2021 (Badan Penanggulangan Bencana Daerah, 2021)

Disaster Type	Occurrences
Flooding	735
Forest Fire	66
Drought	37
Landslides	24
Whirlwind/Tornado/Typhoon	16
Ocean Tidal Wave	12
Flash Flood	9
No natural disasters	7
Earthquake	0
Tsunami	0

Based on this data, the mitigation and management of hydrometeorological disasters in Central Kalimantan Province must be a top priority, demanding increased attention from both the community and the government (Ardaneswari et al., 2017; Jing et al., 2022; Saranya et al., 2020). One effective approach to mitigate hydrometeorological disasters is to create prediction maps for rainfall, temperature, and humidity in Central Kalimantan Province (Aswin et al., 2018; Fazri et al., 2022). The aim is for these maps to serve as visual references for the occurrence of hydrometeorological disasters, enabling the community and local government to collaborate effectively in preventing larger disasters (Bochenek & Ustrnul, 2022; Maryati, 2018). The urgency of this research is to mitigate hydrometeorological disasters by predicting the possibilities that will occur in Central Kalimantan Province, especially related to climate and weather (Junaidy et al., 2019; Luthfin, 2023; Maryati, 2018).

Method

The research was conducted using data from 5 BMKG stations in Central Kalimantan from June 2022 to July 2023. The methods used as a whole are focused on using the Auto-Regressive Integrated Moving Average (ARIMA) time series prediction method, and using the machine learning prediction method because this method is quite flexible in predicting various types of data to be used as the basis for an event (Bradley et al., 2000; Bustamam et al., 2020; Fitriyaningsih & Basani, 2019; Kaloka et al., 2019; Swasti et al., 2020).

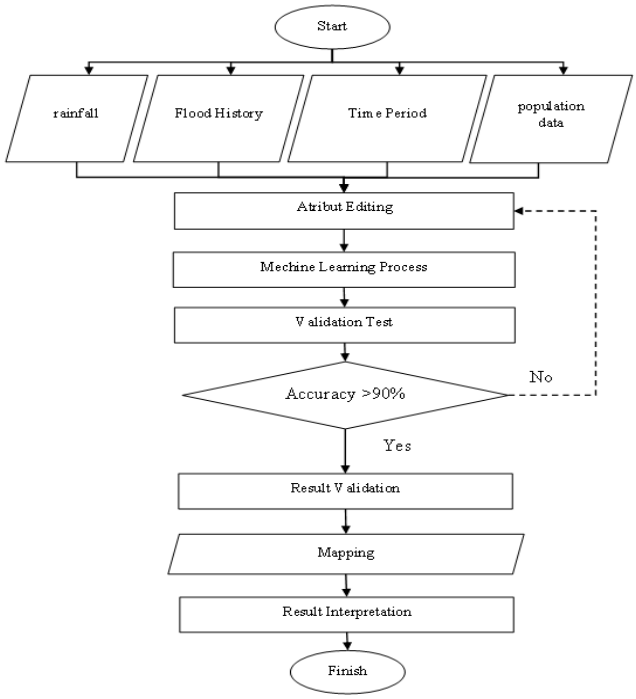

Figure 1. Research flowchart

Figure 1 is a research flow chart, illustrating the research process beginning with a literature review (Bholowalia & Kumar, 2014; Fitriyaningsih et al., 2018; Syakur et al., 2018). Subsequently, data collection is conducted for three variables: rainfall, temperature, and humidity. In the initial stage, data collection includes obtaining latitude, longitude, and elevation data from five stations, as detailed in Table 3 (Wardhana et al., 2022). This information is crucial for mapping as it serves as location points for data collection. Additionally, data on latitude, longitude, and elevation points of districts in Central Kalimantan Province are also needed, as shown in Table 4.

Table 3. Station data in Central Kalimantan Province

Station name	Longitude	Latitude	Elevation
Beringin	114.53	-0.56	42
Tjilik Riwut	113.95	-2.22	27
Sanggu	114.90	-1.67	37
Iskandar	111.66	-2.73	22
H. Asan	112.93	-2.55	3

Table 4. City or District Location Data of Central Kalimantan

City/ District	Longitude	Latitude	Elevation
Pangkalan Bun	111.6322	-2.6854	16
Sampit	112.9494	-2.5389	5
Buntok	114.8387	-1.71761	15
Muara Teweh	114.897	-0.95847	31
Palangka Raya	113.9164	-2.2073	16
Tamiang Layang	115.1694	-2.11727	39
Kuala Kurun	113.8649	-1.09832	166
Kuala Kapuas	114.3859	-3.00841	9
Kasongan	113.3805	-1.9166	32
Nanga Bulik	111.4329	-2.1832	21
Puruk Cahu	114.5696	-0.65064	70
Pulang Pisau	113.8623	-3.1186	6
Kuala Pembuang	112.5465	-3.38264	5
Sukamara	111.2368	-2.6268	22

Result and Discussion

In this study, the prediction of rainfall, temperature, and humidity values in Central Kalimantan Province was calculated using the Auto-Regressive Integrated Moving Average (ARIMA) method at five stations in Central Kalimantan Province (Jiao et al., 2022; Kafi & Abygail Sihombing, 2022; Suhartono et al., 2012). ARIMA is a model used for statistical analysis of time series data. It helps to gain a better insight into the data and predict future trends. In this case, it is like predicting humidity, temperature and rainfall based on a certain time using data from the previous year (Eni & Adeyeye, 2015; Wibawa et al., 2018). The values were then interpolated to obtain rainfall, temperature, and Kalimantan. Predictions for rainfall, temperature, and humidity are conducted only in August, October, and December, with the assumption that the values do not change significantly in October and November. Based on the data and predictions, the rainfall prediction map of Central Kalimantan Province is presented in Figure 2.

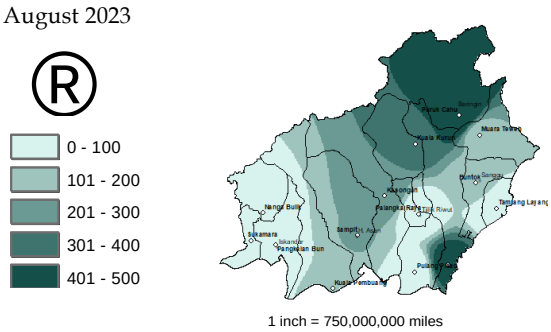

Figure 2. Predicted rainfall in august 2023 in Central Kalimantan Province

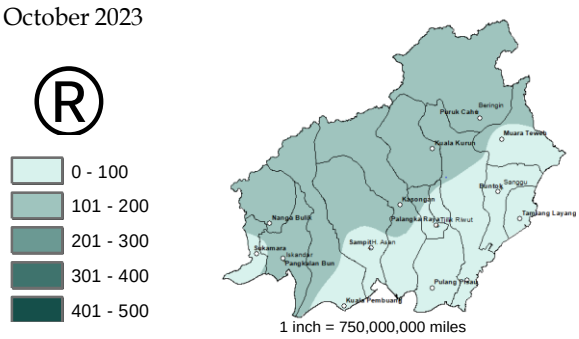

Figure 3. Predicted rainfall in october 2023 in Central Kalimantan Province

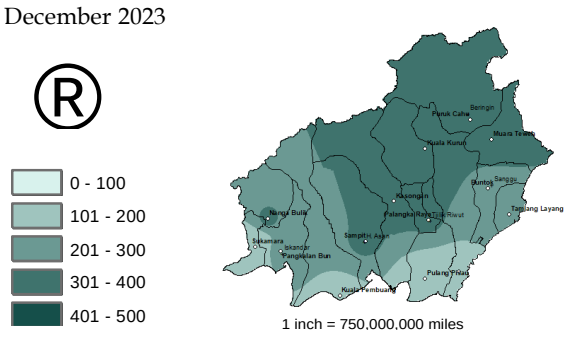

Figure 4. Predicted precipitation in december 2023 in Central Kalimantan Province

According to the categories set by Badan Meteorologi dan Geofisika (BMKG), low rainfall is in the range 0-100mm, medium rainfall is in the range 101-300mm, high rainfall is in the rainfall 301-500mm and very high rainfall is in the range more than 500mm.

Based on the Figures 2, 3, and 4, it is evident that Central Kalimantan Province still has areas with high rainfall, including in the districts of Pulang Pisau, Puruk Cahu, and Kuala Kurun. However, in the areas of Nanga Bulik, Sukamara, Pangkalan Bun, Palangka Raya, and Tamiang Layang, there is an anticipated need to increase awareness due to the low average rainfall (Bochenek & Ustrnul, 2022).

In October, Central Kalimantan Province experienced the lowest average amount of rainfall, with almost every region in Central Kalimantan witnessing a decrease in the average amount of rainfall. During this month, it is expected that the community can be more vigilant against forest and land fires that occur in Central Kalimantan Province (Febrianti et al., 2018; Prihatin, 2022). The details of the prediction of average rainfall are shown in table 5.

Table 5. Predicted Rainfall for Each District of Central Kalimantan Province

City	Predicted Rainfall (mm)			Error
	August	October	December	
Pangkalan Bun	63.2	167.6	272.9	2.54
Sampit	201	90.1	283.1	2.59
Buntok	128	66	259	2.68
Muara Teweh	160	73.1	286	2.84
Palangka Raya	35.8	55	282	3.06
Tamiang Layang	27.3	88.7	265.2	3.34
Kuala Kurun	329	115	331	3.67
Kuala Kapuas	459	49.1	212.4	4.07
Kasongan	268	148.6	301	4.51
Nanga Bulik	72	123	281.8	5.00
Puruk Cahu	634	198.7	312	5.53
Pulang Pisau	19.7	87.7	201.6	6.10
Kuala Pembuang	107.7	84	233.6	3.83
Sukamara	51	63	190.4	4.12

After predicting rainfall, the subsequent predictions involve temperature and humidity with data on the same time scale. The prediction of the average temperature in Central Kalimantan Province is obtained as follows:

Table 6. Temperature Predictions for August, October and December 2023

Station	Temperature (^{0} C)			Error
	August	October	December	
Beringin	28.30	27.67	27.26	0.53
Canggu	27.23	27.22	27.22	0.52
H. Asan	27.67	27.48	27.43	0.53
Iskandar	28.33	27.26	27.55	0.56
Tjilik Riwut	27.17	26.58	27.20	0.665

Based on the results of these calculations, the highest average temperature prediction occurs in October throughout Central Kalimantan Province.

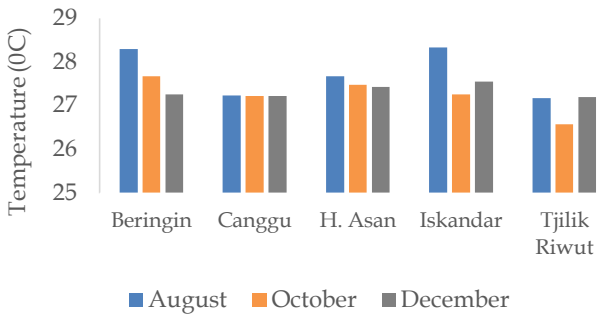

Figure 5. Predicted Average monthly temperature for 5 rainfall stations in Central Kalimantan Province

Table 7. Predicted Humidity in August, October and December 2023 in Central Kalimantan Province

Station	Humidity			Error
	August	October	December	
Beringin	86.15	85.29	85.29	0.85
Canggu	88.51	86.52	84.21	0.86
H. Asan	77.79	75.62	73.45	0.95
Iskandar	77.34	76.68	76.03	0.95
Tjilik Riwut	77.96	77.84	77.71	0.67

Furthermore, based on data on flood events in Central Kalimantan Province from June 2022 to July 2023, no such events were recorded. Subsequently, using the rainfall data, temperature, humidity, and event data, the prediction of flood events was analyzed using the machine learning random forest method (Bustamam et al., 2020; Saranya et al., 2020). One of the weaknesses of this method is that if the variables or data used are small, the splitting process will cause the correlation between trees to be lower, then the flood prediction results are obtained as in table 8.

Table 8. Flood Prediction Results in 2023

City	Flood Event Prediction		
	August	October	December
Pangkalan Bun	No	No	No
Sampit	No	No	No
Buntok	No	No	No
Muara Teweh	No	No	No
Palangka Raya	No	No	No
Tamiang Layang	No	No	No
Kuala Kurun	No	No	No
Kuala Kapuas	No	No	No
Kasongan	No	No	No
Nanga Bulik	No	No	No
Puruk Cahu	No	No	No
Pulang Pisau	No	No	No
Kuala Pembuang	No	No	No
Sukamara	No	No	No

The data is obtained from the classification of temperature, humidity and rainfall variables that occur where rainfall data is classified as follows table 9.

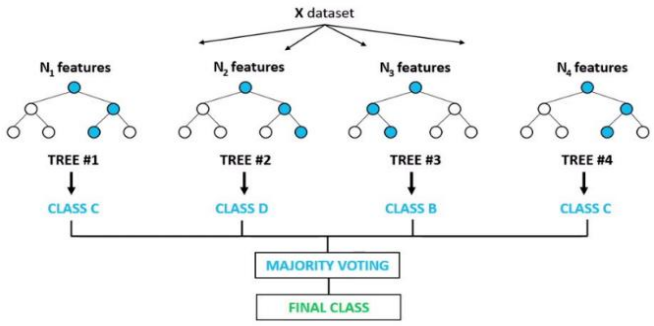

Figure 6. Structure chart of random forest method

Table 9. Classification of Rainfall Indicators

Rainfall (mm)	Category	Point
0-100	Very Low	5
101-150	Low	4
151-300	Intermediate	3
301-500	High	2
>500	Very High	1

For temperature variables, they are classified as follows:

Table 10. Classification of Temperature Indicators

Temperature (°C)	Category	Point
< 17	Very Low	1
18-35	Intermediate	2
>35	High	3

Based on the data in Table 10, it is observed that in 2023, almost all districts in Central Kalimantan Province do not experience flood disasters (Chen et al., 2023). Subsequently, the data is interpolated into a map, resulting in a map depicting the distribution of flood disaster predictions in Central Kalimantan Province for 2023, as shown in figure 7.

Based on the flood disaster prediction data, further analysis was conducted to predict drought disasters, which are common in Central Kalimantan Province alongside floods and often lead to forest and land fires (Bustamam et al., 2020; Jing et al., 2022; Prigel Kaloka et al., 2021). Utilizing the same categories and data, the interpolation results for drought disaster predictions in Central Kalimantan Province are depicted in Figure 8. The drought levels in Figure 8 are classified into five categories: very dry (red color), dry (orange color), normal (yellow color), wet (light green color), and very wet (dark green color).

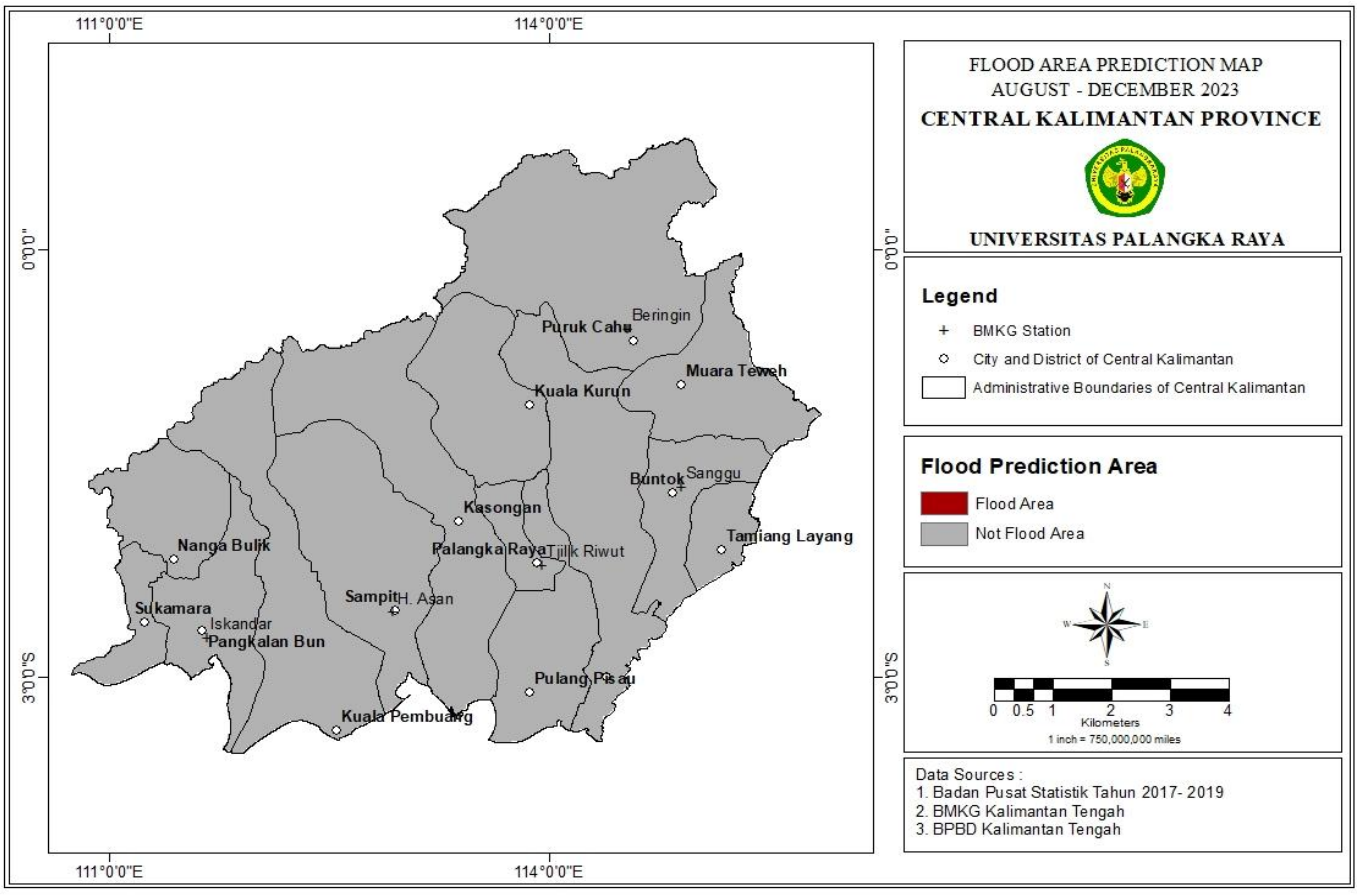

Figure 7. Prediction map of the distribution of flood disasters in Central Kalimantan Province in 2023

According to the map for the year 2023, particularly at the end of the year, it is predicted that most areas in Central Kalimantan Province will be categorized as having a normal level of drought. However, two areas, Pulang Pisau and Sampit, need to increase awareness of the potential drought disaster, especially in October 2023 (Pratiwi et al., 2022; Yusuf et al., 2019).

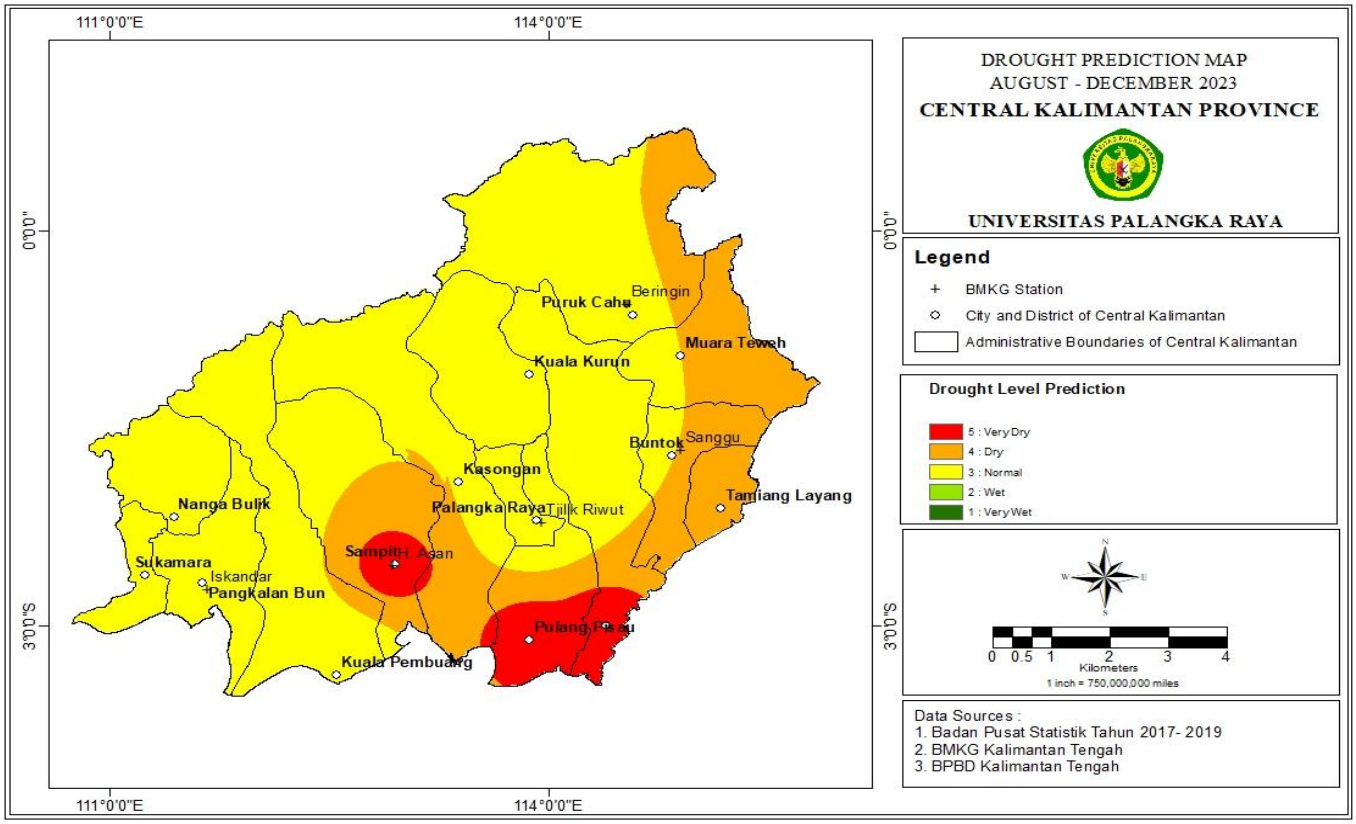

Figure 8. Prediction map of the distribution of drought disasters in Central Kalimantan Province in 2023

Conclusion

Based on rainfall prediction data, it is found that Central Kalimantan Province with high rainfall is in Pulang Pisau, Puruk Cahu and Kuala Kurun districts, but for Nanga Bulik, Sukamara, Pangkalan Bun, Palangka Raya and Tamiang Layang districts are expected to increase vigilance due to low average rainfall. The predicted rainfall will increase in December 2023. In addition to rainfall parameters, prediction calculations were also carried out for temperature and humidity which were then calculated using machine learning and the results showed that in 2023 there would be no floods in all areas of Central Kalimantan but it was necessary to be vigilant, especially in Pulang Pisau and Sampit because the level of land dryness in these areas was high, increasing the risk of forest and land fires.

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Author Contributions
Field data collection, K.A.C; Methodology, I.G.D; data correction, K.A.C; Data processing, T.P.K; Calculation analysis and prediction R.W.W and F.A; mapping I.G.D and D.S.P; disaster analysis I.G.D and D.S.P; writing original drafting, I.G.D and K.A.C. All authors have read and agree to the published version of the manuscript.

Conflicts of Interest
The authors declare no conflict of interest.

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