International Journal of GEOMATE, April, 2024 Vol.26, Issue 116, pp.64-71
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2024.116.4353
Geotechnique, Construction Materials and Environment

THE MOUNT MARAPI ERUPTION DISASTER EVACUATION PATH MODEL USING A LOCAL WISDOM APPROACH

*Endah Purwaningsih[1], Siti Ainim Liusti[2], Eva Purnamasari[3], Risky Ramadhan[1], Aulia Fajrin Ramadhani Nasution[4]

[1]Department of Geography, Universitas Negeri Padang, Indonesia;
[2]Department of Indonesian and Regional Languages and Literature, Universitas Negeri Padang, Indonesia;
[3]Study Program of Remote Sensing and Geographic Information System, Universitas Negeri Padang, Indonesia;
[4]Bachelor Program of Geography, Department of Geography, Universitas Negeri Padang, Indonesia

*Corresponding Author, Received: 28 Dec. 2023, Revised: 02 Feb. 2024, Accepted: 09 Feb. 2024

ABSTRACT: This research focuses on the slopes of an active volcano, seeing its importance in studying disaster mitigation, especially evacuation routes, to minimize fatality during a volcanic eruption. Determining evacuation routes using local wisdom is used as a guide for communities around the mountain slopes to safeguard themselves in the event of a mountain eruption. This research aims to model an eruption disaster evaluation pathway using a local wisdom approach. This research employs a mixed-method approach, combining quantitative and qualitative methods to process and analyze relevant variables. The ultimate output is a map illustrating volcanic disaster evacuation routes. For vulnerability analysis related to volcanic disasters, this research uses quantitative methods with the Maximum Entropy algorithm. The research identifies slope as the environmental variable with the highest gain when used in isolation, suggesting its significant informational value. The modeling used was in the 12th iteration of 25 model test replications, with AUC training data reaching a value of 0.877 and AUC test data of 0.932, indicating highly effective modeling results. In addition, the local wisdom from the community plays a crucial role in recognizing impending eruption signs, with an emphasis on observing natural symptoms in the surrounding environment. The people of Nagari Batu Palano do not have specific social traditions related to volcanic eruptions. Instead, their primary response involves surrendering to God and seeking a safe place if an eruption occurs. In relation to saltwater pools, there is a need for further studies to establish the reliability of the information produced.

Keywords: Eruption disaster, Evacuation routes, Local wisdom, Maximum entropy

1. INTRODUCTION

Indonesia is one of the ring of fire zones because the country has several active volcanoes spread across its territory. At some point, an active volcano will release its materials, this event is usually called an eruption or volcanic eruption. The resulting consequences often involve substantial losses, both in terms of materials and human lives. [1,2]. There are 127 volcanoes in Indonesia; thus, eruptions are not new disasters in Indonesia [3,4]. Apart from fertile agricultural land, beautiful views, and large geothermal potential, the negative impact is the occurrence of various geological disasters such as earthquakes, tsunamis, volcanic eruptions, and landslides. The consequences of geological disasters cause horrific fatality, social and economic losses, and environmental damage [5,6].

The various natural disasters that hit Indonesia require the community to be ready, responsive, and alert [7,8]. Establishing a secure living environment for individuals in disaster-prone regions poses a significant challenge for the Indonesian government and society [9-12]. Enhancing volcanic disaster management programs, monitoring and communication systems, and community preparedness planning are fundamental steps in mitigating disaster risks [13,14]. Knowledge regarding disaster mitigation and adaptation models for disasters has actually been passed down from generation to generation by ancestors who had previously studied the characteristics of mountains [15,16].

Generally, this past knowledge is passed on by oral traditions and expressed in customary laws, rules, norms, traditional rules, and local wisdom. Local wisdom is also interpreted as certain principles and methods that are adhered to, understood, and applied by local communities in their interaction with the environment. These principles are then transformed into a system of local customary values and norms. Thus, local wisdom is traditional views and knowledge serving as a behavior reference and has been practiced for generations to address the needs and challenges within community life. Local wisdom has functional and meaningful roles in society both in preserving natural and human resources, maintaining customs and culture, and contributing to the life of the community.

Mount Marapi is one of the active mountains in West Sumatra Province, Indonesia, with the potential eruption at any moment. Nagari Batu Palano is located on the slopes of the mountain and is a location to be discussed with the surrounding community regarding local wisdom in determining evacuation routes. The local community certainly has its ways of mitigating disasters or identifying signs of an impending volcanic eruption. These communal discussions contribute crucial information for determining evacuation routes that are believed to be safer and more efficient by the local populations. These people around the mountain slopes have more environmental awareness and firsthand experience with past eruptions, making them able to identify signs of impending eruptions and act accordingly. Determining evacuation routes using local wisdom is used as a guide for future generations, offering a sustainable approach to facing potential volcanic eruptions.

Determining evacuation routes using local wisdom is studied in more depth with the results of modeling using software. These two results were seen to see whether there is a match between the discussion and the modeling results. Evacuation route modeling in this research uses various secondary data which includes several parameters used. The rapid development of remote sensing technology and geographic information systems (GIS) can be utilized to optimize evacuation routes for volcanic eruptions [17], [18], [19], [20]. Mapping which road sections are suitable as evacuation routes will later become a priority for the government to manage or optimize repairs and maintenance. Handling evacuation routes is fundamental because it is the route for residents to get to temporary shelters when Mount Merapi erupts. The assessment of the feasibility of these evacuation routes will serve as an important factor in minimizing the likelihood of casualties.

In this research, the identification of evacuation routes goes beyond the utilization of remote sensing data and the GIS approach, but it also incorporates insights gained from focus group discussions (FGD) from the local wisdom of the community around Mount Marapi, West Sumatra. Based on the results of the FGD, researchers analyzed the data processing result using various variables from remote sensing data and the GIS approach. Unlike previous studies on evacuation routes, this research integrates local wisdom-based evacuation routes. This local wisdom approach serves as reinforcing data in assessing the results of path modeling using software. Therefore, this research is expected to produce accurate climbing routes because it comes from the knowledge possessed by the people around the mountain slopes. In other words, this article seeks to discuss a lot of parameters in modeling evacuation routes, modeling route results, and approaches to evacuation routes based on the local wisdom of the surrounding community.

2. RESEARCH SIGNIFICANCE

Most research on modeling evacuation routes for volcanic eruptions is limited to using physical variables without connecting them to the local wisdom of the local community. Thus, the novelty of this research emphasizes local wisdom-based evacuation routes. In addition, this research seeks to dig up information on signs of impending eruption disasters within the research area. The local wisdom approach will be linked to the modeling results, whether the results of the modeling are in accordance with the local wisdom of the local community in the study area. There has been no research on determining evacuation routes for eruption disasters using a local wisdom approach, especially in this research area. Researchers are very enthusiastic about conducting this research, aspiring for its outcomes to prove beneficial for communities residing around the mountain slopes in the event of a potential eruption disaster. The findings of this research are not only valuable for the local communities residing around the mountain slopes but are also useful for relevant government agencies involved in disaster mitigation. For this reason, this research is closely linked to the environmental conditions in the study area, given its location on the slopes of an active mountain.

3. METHODS

This research method consists of the research location, parameters for modeling evacuation routes for eruption disasters, and local wisdom regarding eruption disasters.

3.1 Research Site

Mount Marapi (Indonesian: *Gunung Marapi*, Minangkabau: *Gunuang Marap*i) stands as a complex volcano in West Sumatra, Indonesia. As the most active volcano in Sumatra, its name translates to "Fire Mountain". With an elevation of 2,891 meters (9,465.2 ft), Mount Marapi holds prominence in the landscape of West Sumatra. Several large and small cities are located around this mountain, including Bukittinggi, Padang Panjang, and Batusangkar. This research was carried out in the villages surrounding Mount Marapi. However, this research focuses on Batu Palano village since it has the main climbing route to Mount Marapi. Batu Palano is one of the villages in the Sungai Pua sub-district, Agam Regency, West Sumatra Province. It is located at the foot of Mount Marapi, making the soil very fertile. The majority of the people are farmers (secondary crops). The area is 2.96 square kilometers or 7.83% of the area of Sungai Pua District. This village is 3 kilometers away from the sub-district capital, 90 kilometers from the district capital, and 100 kilometers from the provincial capital.

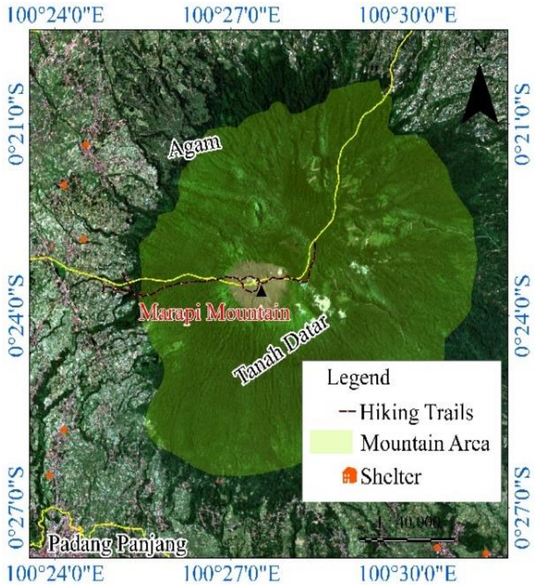

Fig.1 Research Site

3.2 Types and Data of Research

This research uses a mixed-method approach combining quantitative and qualitative methods in processing and analyzing each variable, which then resulted in a map of volcanic disaster evacuation routes. Quantitative methods were used to develop and model maps mathematically based on variables relating to the phenomenon to be researched, while qualitative methods were used to study phenomena by explaining them in more depth ways by collecting data from reliable information sources, such as the relative location of the surrounding areas through FGD.

3.3 Evacuation Route Modelling

Vulnerability analysis for volcanic disasters uses quantitative methods with the Maximum Entropy algorithm, also known as Maxent, which is a method for modeling potential in identifying sample distributions [21,23]. The Maxent selector works by taking a list of sample locations as input, which is called presence-only (PO) or presence data, as well as various data on relative environmental variables in the research area landscape. Maxent will extract a sample location in the research area that contrasts with the location where it is located, which will then produce analytical data that comes from a combination of the two types of input data and will show which variables have the most influence on the distribution prediction results that are produced relatively specifically, in which its existence depends on finding its location. Therefore, maximum entropy distribution is widely used in various problems, such as wind engineering [24], hydrology [25], and geotechnical engineering [26]. Hence, the use of maximum entropy is very suitable to be used in this research for modeling evacuation routes purposes, done by paying attention to wind direction. It is undeniably an excellent method to address challenging issues [27].

4. RESULT AND DISCUSSION

This research produces evacuation route and wind direction modeling from several variables used. Apart from that, this research discusses the relationship between the modeling results and discussion results with communities around the mountain using a local wisdom approach.

4.1 Parameters for Modelling

The parameters used for modeling the evacuation route for the eruption disaster on Mount Marapi include crater distance [Fig.8], elevation [Fig.9], hot spring distance [Fig.10], land cover [Fig.11], river distance [Fig.12], and slope [Fig.13]. These parameters can be used to determine shelters around mountain slopes. Table 1 provides estimates of the relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, for each environmental variable, in turn, the values of that variable on training presence and background data are randomly permuted.

The environmental variable with the highest gain when used in isolation is a slope, which, therefore, appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is the slope, which, therefore, appears to have the most information that isn't present in the other variables [28-30,32].

These curves illustrate the impact of each environmental variable on Maxent prediction and the predicted probability of presence changes when each environmental variable is adjusted while keeping all other environmental variables at their average sample value. It is important to note that these curves can be hard to interpret if you have strongly correlated variables, as the model may depend on the correlations in ways that are not evident in the curves. In other words, the curves show the marginal effect of changing exactly one variable, whereas the model may take advantage of sets of variables changing together. These visualizations reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other related variables.

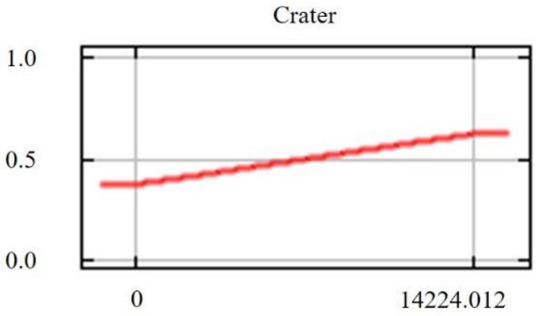

Fig.2 Crater distance parameter curve

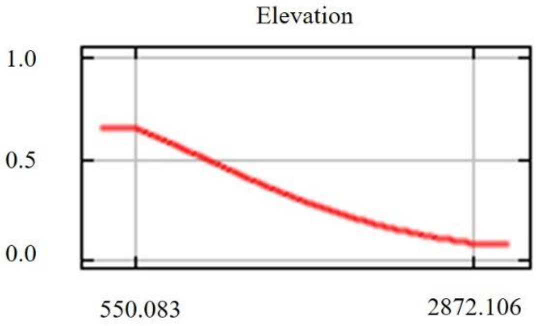

Fig.3 Elevation parameter curve

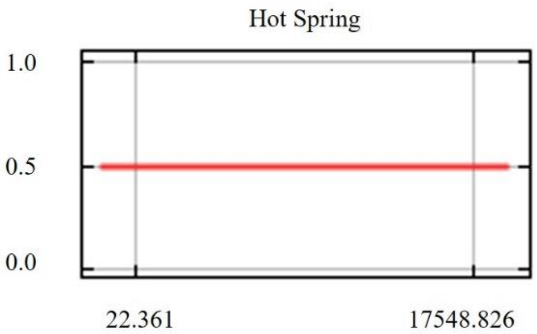

Fig.4 Hot spring parameter curve

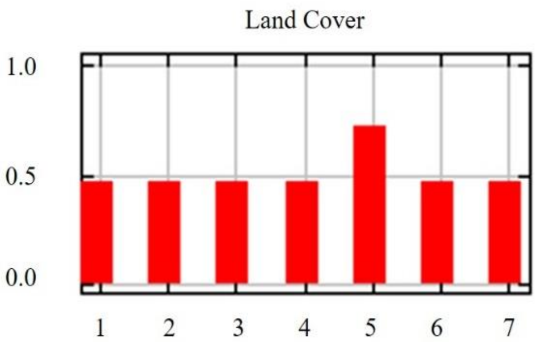

Fig.5 Land cover parameter graph

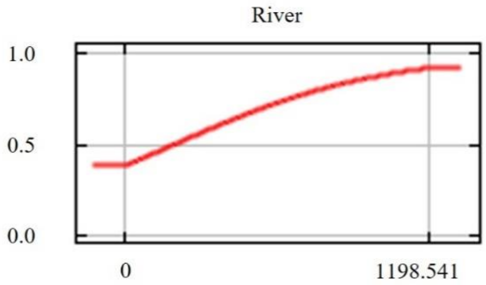

Fig.6 River distance parameter curve

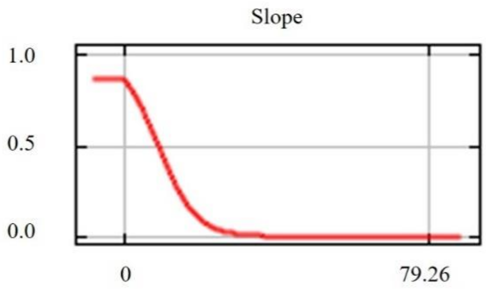

Fig.7 Slope parameter curve

The omission rate is calculated both on the training presence records, and (if test data are used) on the test records. The omission rate should be close to the predicted omission, because of the definition of the cumulative threshold. This implies that the maximum achievable AUC is less than 1. If test data is drawn from the Maxent distribution itself, then the maximum possible test AUC would be 0.829 rather than 1; in practice the test AUC may exceed this bound. The modeling used was in the 12th iteration of 25 model test replications, with AUC training data reaching a value of 0.877 and AUC test data at 0.932, which means the modeling results were very good (Fig.14).

If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area.

Table 1 Variable contribution

Variable	Percent contribution	Permutation importance
Slope	65.6	84.2
Land Cover	33.6	14.2
River	0.9	1.5
Hot Spring	0	0
Elevation	0	0
Crater	0	0

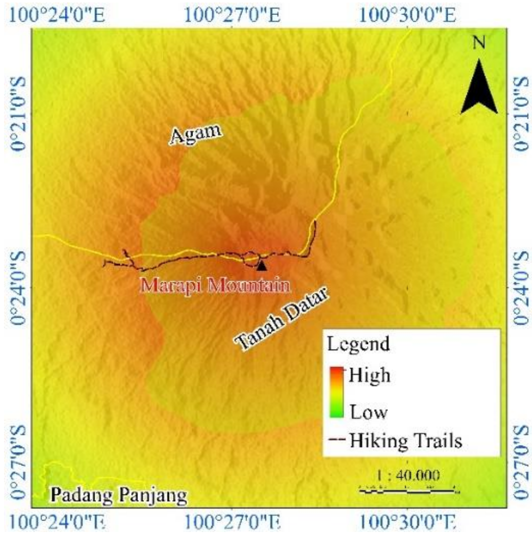

Fig.8 Crater distance

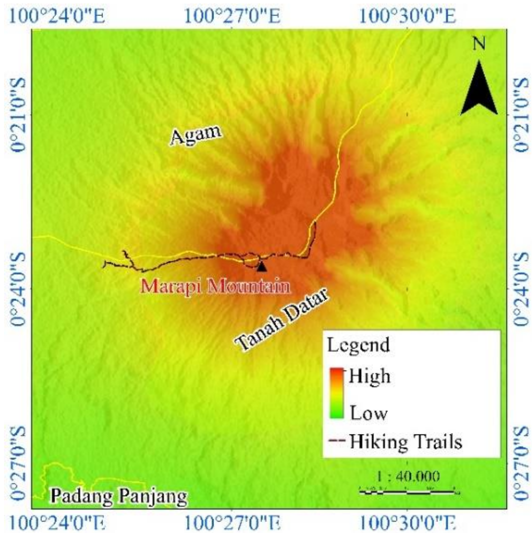

Fig.9 Elevation

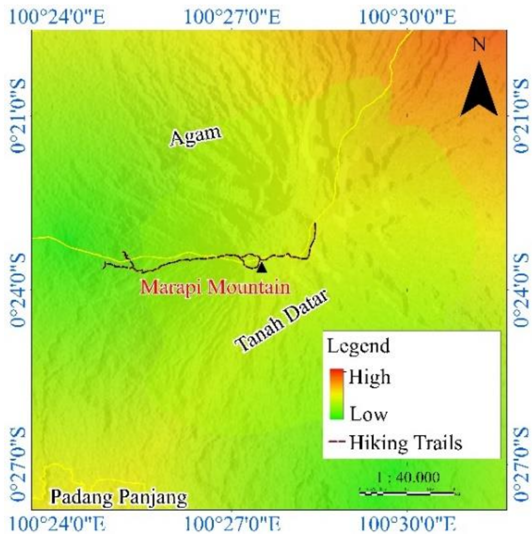

Fig.10 Hot spring distance

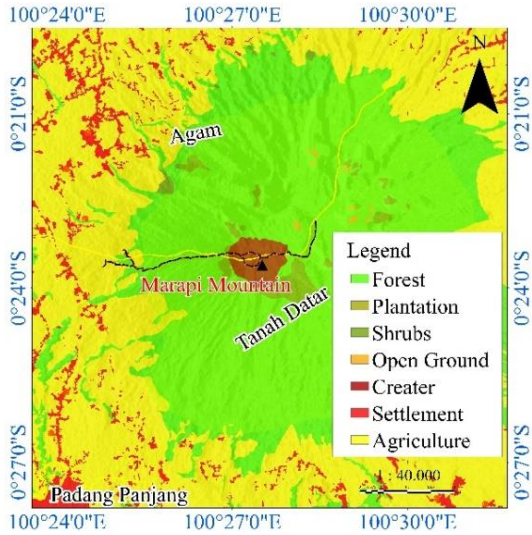

Fig.11 Land cover

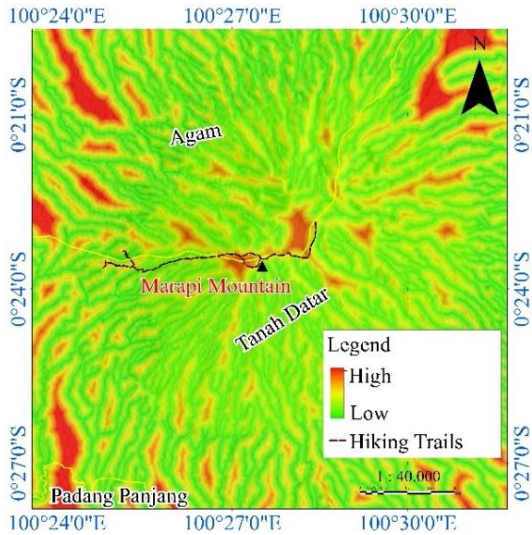

Fig.12 River distance

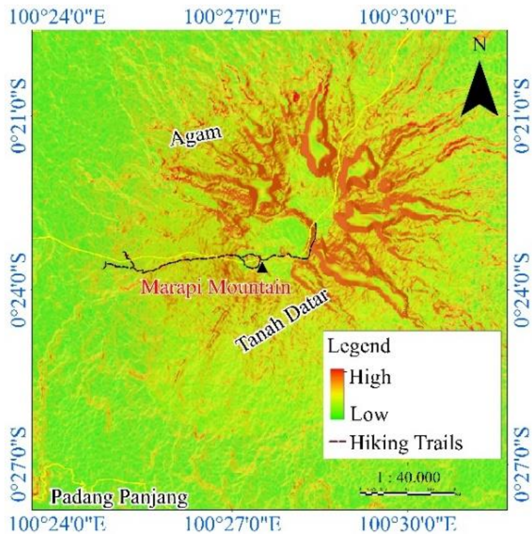

Fig.13 Slope

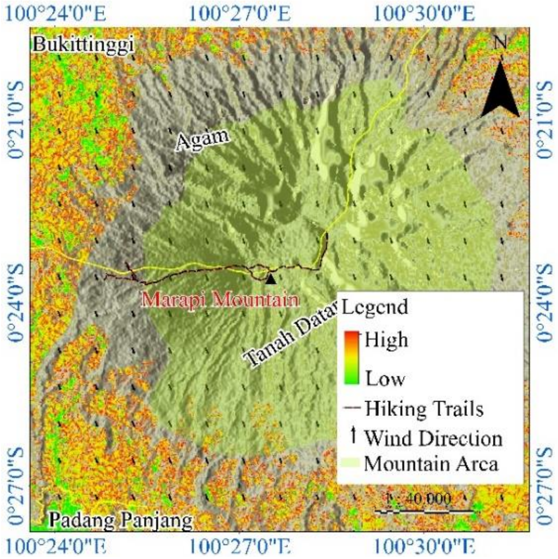

Fig. 14 Evacuation route modeling

4.2 Local Wisdom Regarding Eruption Disasters

An early warning system is a series of systems to notify about the occurrence of natural events, which can be in the form of disasters or other natural signs. Providing early warnings to the public involves conveying information in easily understandable language. In critical situations, this information delivery is typically executed through means such as sirens, gongs, and so on.

In addition to the early warning system, there are designated assembly points and open areas near the organization's environmental centers, which serve as a meeting point for residents during an eruption. These locations facilitate evacuation to safer places, namely a temporary refuge. Sports fields are commonly used as gathering points, while a few open areas, such as village office yards, schools, places of worship, or shelters, also allow for evacuation activities.

Over the last two to four years, the eruptions have not impacted Nagari Batu Palano in terms of ashfall. Wind direction and the contour of Mount Marapi's peak influence this, aligning with the slope modeling results. Based on Figure 13, Nagari Batu Palano tends to be medium to flat, marked in yellow and green. The steep grade slopes are marked in red on the north and west sides of Batu Palano. Therefore, the variables used in this research are pertinent to identify the impact of the eruption of Mount Marapi.

Based on the results of focus group discussions with the surrounding community, Nagari Batu Palano has never experienced an eruption but has been affected by dust due to wind direction. This is in accordance with the modeling results in Figure 14, which shows that the wind direction is not towards Nagari Batu Palano. The wind direction is more towards Nagari Batusangkar. This is in accordance with the local community's explanation that the impact of eruptions often occurs in the Nagari Batusangkar area. Hence, in this case the relationship between local community exposure in terms of local wisdom is in accordance with the results of the modeling that has been carried out. In the picture, the climbing route in Nagari Batu Palano serves as an evacuation route, also known as the "proclaimer road". Apart from that, climbers of Mount Marapi usually choose the Batu Palano route, which has been designated by local agencies as the official climbing route.

The local wisdom guides the community in observing natural symptoms in the surrounding environment, such as the condition of the water from "Tabek Aia Asin," which is the local language of the saltwater pools. If the pool starts to become cloudy, this is a sign that the sulfur levels in the pool are increasing. This is in accordance with the results of lab tests from field samples, when the sulfur content is erupting, the levels are high. This event is a natural phenomenon felt by the surrounding community. This is equivalent to research conducted by [31] that local residents have long inherited danger knowledge embedded in oral traditions about haunted places. Seeing these natural signs, the local community immediately evacuated to save themselves, but in the end, the impact did not occur in Nagari Batu Palano.

The people of Nagari Batu Palano do not have social traditions like Javanese people do, namely, *Slametan* or sending prayers to ancestors who have died at certain times. The people of Batu Palano tend to look only at natural phenomena to find out the signs of an eruption, showing their attitude of not believing in mystical things. They believe that whatever happens is God's destiny. The majority of the people of Nagari Batu Palano are Muslim, so according to their belief, all days are the same and there are no good days or bad days. Their job is simply to surrender to God and try to find a safe place to stay safe if an eruption occurs.

5. CONCLUSIONS

In conclusion, the modeling of evacuation routes for the Mount Marapi eruption disaster is in accordance with the insights gained from focus group discussions with local communities. The utilization of Maxent software has proven to be an effective tool for modeling this evacuation route. The findings also produce a commendable model that can serve as a reference to determine shelters and make evacuation route signs on-site. The incorporation of local wisdom from the community marking the signs of an impending eruption is to look for natural symptoms in the surrounding environment. The people of Nagari Batu Palano do not have social traditions, their only job is to surrender to God and try to find a safe place to stay safe if an eruption occurs.

6. ACKNOWLEDGMENTS

This research was funded by the 2023 *Penelitian Dasar* (Fundamental Research) Grant scheme provided by the Institute for Research and Community Service, Universitas Negeri Padang (contract number 1294/UN35.15/LT/2023). The authors would like to express gratitude to (1) the Department of Geography, Faculty of Social Science, Universitas Negeri Padang for their assistance in research facilities and equipment, (2) West Sumatra Natural Resources Conservation Center for granting field work permits, (3) Zaki Mubarok, Defi Afriyanti, Adek Andreas, and Nagari Batu Palano Community for their invaluable assistance during the field works.

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