Sumatra Journal of Disaster, Geography and Geography Education, December, 2021. Vol.5, No. 2, pp. 107-114
Disaster, Geography, Geography Education http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

THE DIFFERENCE OF LANDSLIDE-PRONE AREAS BETWEEN HEURISTIC AND STATISTICAL METHODS IN LIMA PULUH KOTA REGENCY

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*Corresponding Author, Received: Sept 12, 2021. Revised: Oct 19, 2021. Accepted: Dec 3, 2021

ABSTRACT: Measurement of landslide area can be done by heuristic, statistical or deterministic methods. This article will discuss the differences between the results of the two approaches, heuristic method and the statistical method at a scale of 1: 50,000 in Lima Puluh Kota Regency as one of the regencies in West Sumatera Province that often experiences landslides. The heuristic method is measured based on the rules outlined in the Indonesian disaster risk book (RBI) issued by the National Disaster Management Agency, while the statistical method uses the bivariate WoE (Weight of Evidence) method with the variables used as determinants of landslide occurrence. The results of this study indicate that the use of heuristic methods and statistical methods shows different results in several areas regarding the high and low probability of landslide events.

Keywords: Landslide, Heuristic, Statistics

1. INTRODUCTION

Landslides in Lima Puluh Kota Regency occur almost every year. In 2016 there were 25 cases of landslides that caused damage to roads, agricultural land, and residents' houses. Then in 2017 there were 10 cases of landslides, in 2018 there were 22 cases of landslides and in 2019 there were 11 cases of landslides. Measurement of landslide area usually uses heuristic methods on a small scale, statistical methods on a medium scale and deterministic methods on a large scale. Mapping of landslide areas can be small, with a scale of 1:100,000 and above, usually using the heuristic method, a scale of 1:50,000 to 1:25,000 using statistical methods and scales below 1:10,000 using deterministic methods. The heuristic approach is used on small-scale maps such as that done by Stanley and Kirschbaum which estimates the geographic distribution of landslide activity at the continental and global scale, due to the absence of previous data [1]. According to Strauch (2019), a new approach to mapping landslide hazard by combining the possibility of landslides from statistical data approaches and physical models of landslides, using physical data and landslide events calculated based on frequency ratio (FR) [2]. While in China, the data in the government for landslides available for a scale of 1:100,000, so for the community level a map of vulnerability and disaster risk is developed at a scale of 1:10,000 by applying the probability [3].

Variables used in mapping using heuristic methods very greatly from one study to others, for example, slopes, faults, geology, forest loss, and road networks [2], some use cumulative daily rainfall for 3 consecutive days, slope, geology, the presence of faults/escarpments, and soil depth in addition to management factors such as land use, infrastructure, and settlement density [4]. Experts who use this method, the conventional weighting procedure, combine it with artificial neural network procedure and fuzzy set based procedure to get the weighted value [5]. There are also experts who combine it with the qualitative method [6].

An example that uses statistical methods to determine landslide-prone areas is in the Uatzau basin in Northwestern Ethiopia which uses 6 variables consisting of lithology, land use/cover, distance to stream, slope gradient, slope aspect, and slope curvature using 514 landslide points [7] and also adds in addition to these factors with topographic Wetness

Index (TWI), Stream Power Index (SPI), proximity to road [8]. As in the heuristic method, in the statistical method, experts also combine it with other methods in making decisions to determine landslide hazard maps, for example with expert consultation [9].

Generally, disaster hazard maps at the regency scale in Indonesia use the heuristic method with the procedures obtained from the Indonesian Disaster Risk book issued by the National Board for Disaster Management [10]. Based on the theory, the use of this method is not appropriate because it is presented on a scale of 50,000, so the more suitable is the statistical method. Regional Spatial Plan (RTRW) both at national, provincial, regency and city scales contained the landslide susceptibility map which become a reference for controlling the use of space in development.

The landslide hazard map helps spatial planning to determine areas that cannot be built, as done in Tawangmangu sub-district, Central Java Province, Indonesia which uses 6 parameters, namely slope, lithology, soil depth, texture, permeability, and land use with the weighted-score method [11].

Because it is a reference for the use and control of spatial development, it is necessary to use the appropriate methods to represent landslide hazard locations in regional planning documents. The Research objectives of this study is to compare the results of landslide hazard mapping using heuristics and statistical methods with the case Lima Puluh Kota Regency.

2. METHODS

This study aims to compare the results of landslide hazard maps based on the analysis of heuristic methods and statistical methods. The heuristic method is based on the result index of the weighted score method [12] while the statistical method uses the bivariate WoE method. The research location is in the Lima Puluh Kota Regency as shown in Figure 1.

Fig. 1. The research area

The heuristic method uses variables from the Indonesian Disaster Risk book (RBI), each method is explained as follows

Heuristic method : weighted score

$$\mathbf{I} = \sum_{i=1}^{n} xi\, wi$$

I = landslide susceptibility index
xi = score at each location according to the variable class
wi = variable weight

Statistical method : bivariate WoE (Weight of Evidence)

$$\mathrm{Wij}^{+} = \mathrm{Log\,e}\frac{\mathrm{P(B/S)}}{\mathrm{P(B/\bar{S})}}$$

$$\mathrm{Wij}^{-} = \mathrm{Log\,e}\frac{\mathrm{P(\bar{B}/S)}}{\mathrm{P(\bar{B}/\bar{S})}}$$

Where:
W_{ij}^{-} = The negatif weights of evidence of the j^{th}parameter class of i^{th} landslide
W_{ij}^{+} = The positif weights of evidence of the j^{th}parameter class of i^{th} landslide
B = presence of the landslide evidential feature
P = Probability
$\bar{B}$ = The total area on the map where the evidential feature is absent
S = The number of landslide belonging in the evidential feature
$\bar{S}$ = The number of landslide not belonging in the evidential feature
Cij = Wij^{+}- Wij^{-}
Cij = contrast

When C > 1, A class of parameters has a greater predictive and value is approximately 2 is very significant. When the Area Under Curve (AUC) which measures the reliability of association of the parameters to landslides occurrence. A model validation by comparing the susceptibility measurement of the training sets that were used. The AUC value of the factors prediction of landslides is 0.6 to 1. A factor regards as most predictive to the landslides analysis when its value is closer to 1. If AUC are: < 0.6 as a poor model, 0.7-0.8 as a medium or reasonable model, 0.8-0.9 as a good model, 0.9 very good model. The research flow chart for both methods can be seen in Figures 2 and 3.

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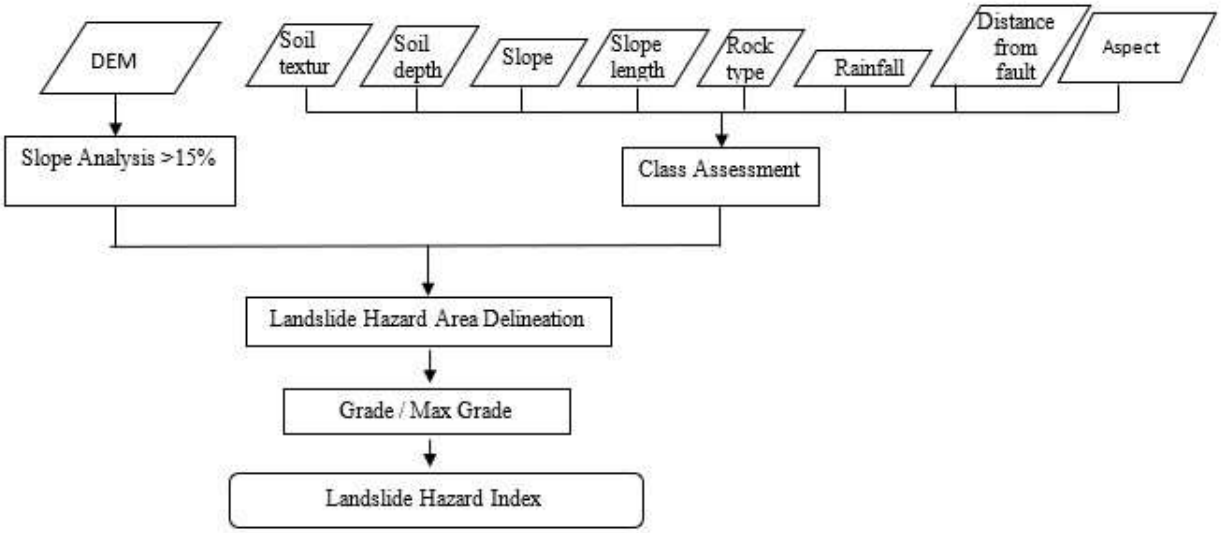

Fig. 2. Flow Chart of Heuristic Method

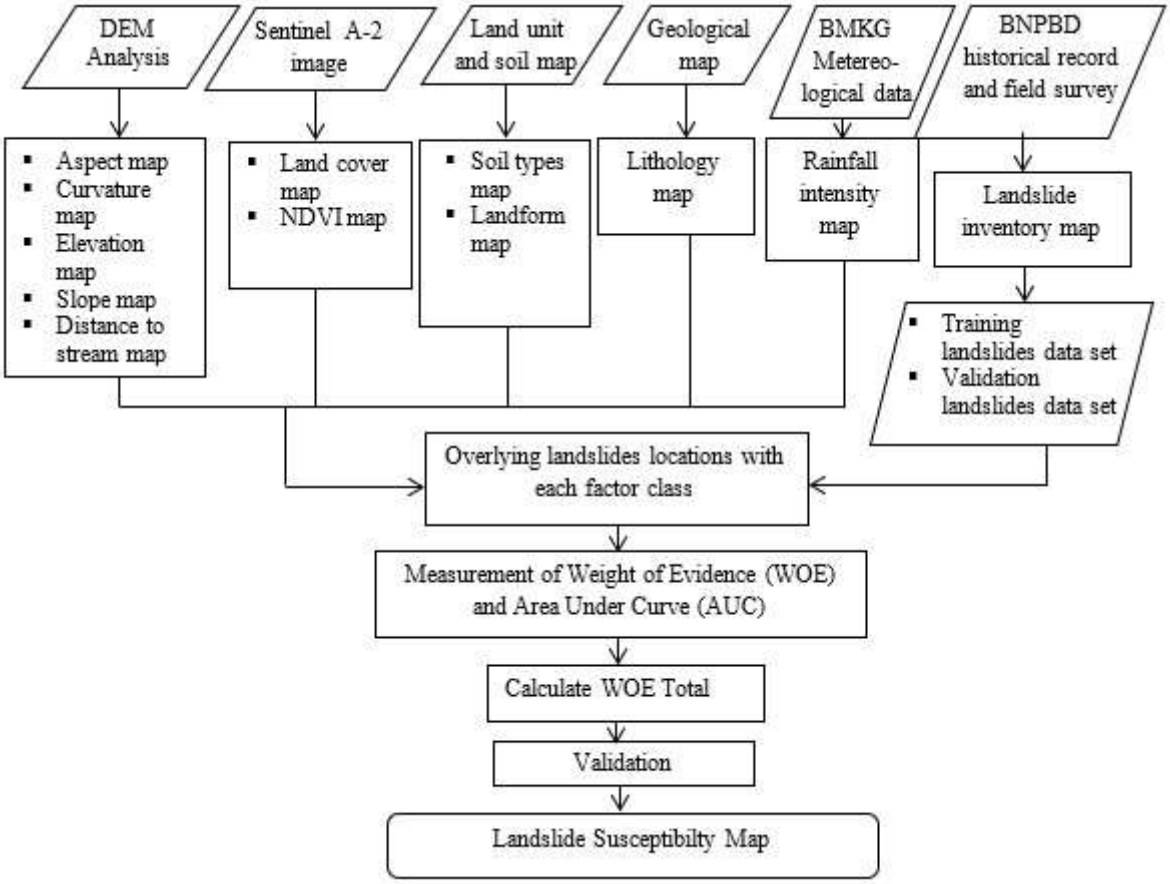

Fig. 3. Flow Chart of the Bivariate Method

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3. RESULTS AND DISCUSSION

3.1. Analysis based on heuristic method

The heuristic method based on the Indonesian Disaster Risk book issued by BNPB [10] considers the determinants of landslide-prone areas such as slopes of more than 15%, soil texture, soil depth, slope length, rock type, rainfall, distance from faults and slope direction. aspects). The variable is based on the score and weight of each variable characteristic and then overlay on the ArcGIS 10.4 to obtain an area (polygon) with a certain value. This value is classified into very low landslide class with an area of 101,022.74 ha, low 69,120.40 ha, moderate 65,794.20 ha, high 54,744.68 ha and very high 26,907.02 ha. (table 1). The table shows the distribution of landslide hazard for each district. Suliki District is the area with the lowest vulnerability while the highest vulnerability is in Bukit Barisan District and Kapur Sembilan District. The results of the analysis are displayed in the form of a landslide hazard map as shown in Figure 4.

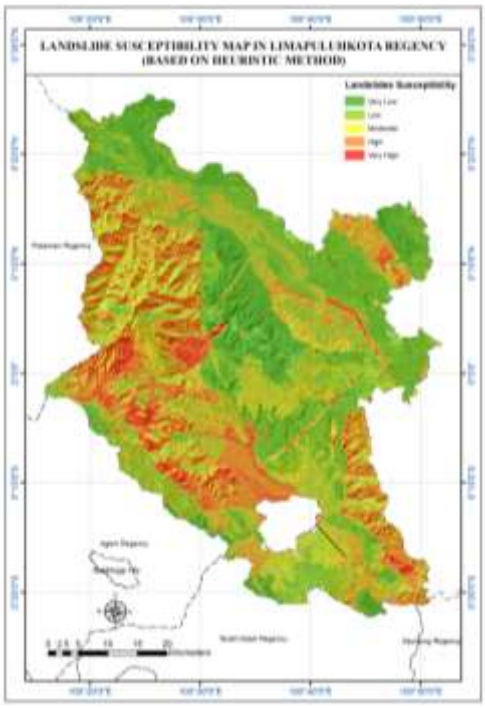

Fig. 4. Landslide Susceptibility Map Based on Heuristic Method

Table 1. Landslide Area Based on Heuristic Method in Lima Puluh Kota Regency (ha)

No.	District	Very Low	Low	Moderate	High	Very High
1	Akabiluru	2913.30	2364.32	2239.89	2337.82	1231.90
2	Bukit Barisan	6022.33	5903.05	6939.24	8407.64	5991.75
3	Guguak	245.91	1367.37	2009.70	3717.84	2073.34
4	Gunung Omeh	1943.40	2451.21	3275.62	3494.88	3420.21
5	Harau	8180.58	7007.74	8378.31	5162.47	1702.07
6	Kapur Sembilan	27494.07	19226.23	16867.08	13771.75	5712.42
7	Lareh Sago Halaban	3847.39	4952.65	5165.14	5631.11	2083.76
8	Luak	601.09	2282.62	1198.37	433.76	33.15
9	Mungka	3995.90	3177.98	4147.79	2252.30	843.80
10	Pangkalan Koto Baru	39748.76	16450.59	12587.72	7052.38	2250.38
11	Payakumbuh	1478.81	1153.56	1360.43	1643.24	1260.57
12	Situjuah Limo Nagari	2275.34	91.07	1623.13	838.76	151.83
13	Suliki	2275.87	2692.02	1.79	0.73	151.83
	Total	101022.74	69120.40	65794.20	54744.68	26907.02

3.2. Analysis based on statistical method

To perform statistical analysis, data on landslide events is needed. In this study, data on landslide events was obtained from the Lima Puluh Kota Regional Disaster Management Agency (BPBD) Regency and from the results of a field survey. There are 149 points of landslides for the last 5 years. The data is divided into data for train, data for compiling the model 60%

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or 89 Landslide points and data to test the model validation (test data) are 60 landslide points (40%) as shown in Figure 5. The validation value is obtained from AUC = 0.787 which indicates that the model is classified as good, which can be used to determine landslide susceptibility maps. From the results of the analysis based on statistical methods, maps and tables of the landslide area area for each district are obtained as shown in Table 2 and figure 6.

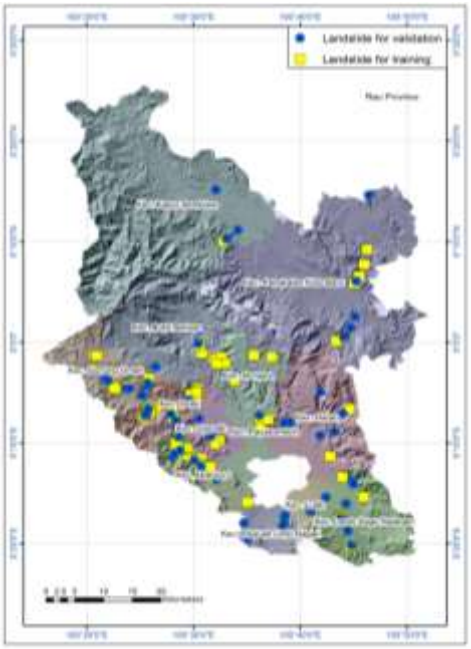

Fig. 5. Landslide point location

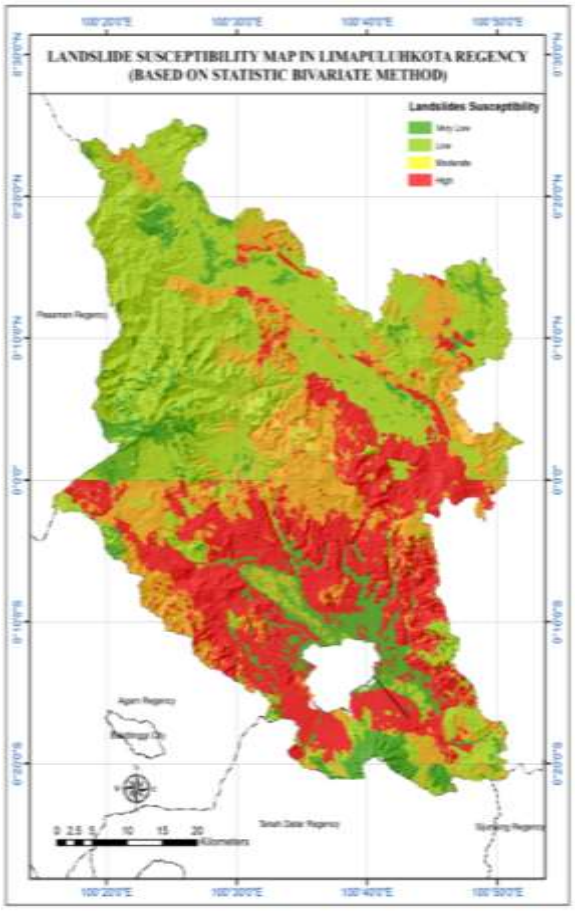

Fig. 6. Landslide susceptibility map based on Statistic method

Table 2. Landslide Area Based Statistics Method in Lima Puluh Kota Regency

No.	District	Very Low	Low	Moderate	High
1	Akabiluru	729.01	638.19	1257.84	8308.35
2	Bukit Barisan	3299.99	17688.58	7618.49	4656.94
3	Guguak	1567.42	704.72	1198.15	5943.87
4	Gunung Omeh	1788.06	2752.23	5086.90	4958.13
5	Harau	6066.29	2395.65	3869.60	18099.63
6	Kapur Sembilan	8610.37	61516.44	10661.07	2283.66
7	Lareh Sago Halaban	4747.55	7319.99	3492.72	6119.78
8	Luak	1381.67	574.99	132.53	2459.80
9	Mungka	1346.73	803.64	4996.89	7270.52
10	Pangkalan Koto Baru	3137.15	34418.27	21758.96	18775.44
11	Payakumbuh	2274.85	400.57	369.54	3851.66
12	Situjuah Limo Nagari	1861.36	1447.60	762.71	3601.20
13	Suliki	587.89	1189.44	4101.80	6307.08
	Total	37398.35	131850.30	65307.19	92636.07

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3.3. Comparison of disaster-prone mapping results based on the two methods

Many experts say that the heuristic method is a qualitative method, while the statistical method is mentioned as a quantitative method. The comparison of the results of the two methods is also carried out by Erener who compares the weighting method with the regression method with ordinary logistic regression (OLR) [13].

In Lima Puluh Kota Regency, the two methods produce different hazard maps, especially in the very low, low and very high categories. The very low category is wider in the heuristic method and conversely the low category is wider in the statistical method. Likewise, the high vulnerability category is broader in statistical methods, as shown in table 3 .

Table 3. Comparison of susceptibility categories on heuristic methods and statistical methods in Lima Puluh Kota Regency

No.	Category	Heuristic Method	Statistic Method	Difference
1	Very Low	101022.74	37398.35	63624.39
2	Low	69120.40	131850.30	-62729.90
3	Moderate	65794.20	65307.19	487.01
4	High	81651.70	92636.07	-10984.37

These differences will be clearer if they are depicted on a map of different levels of vulnerability as shown in Figure 7.

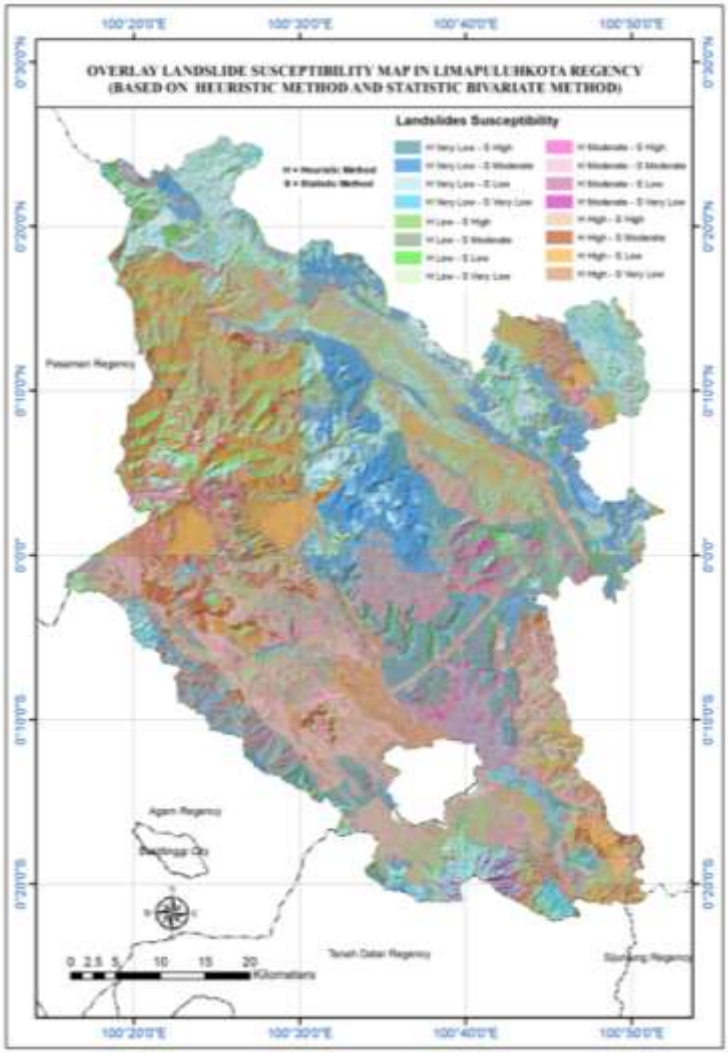

Fig. 7. Differences in the level of susceptibility of heuristic methods and statistical methods

Research in Wahig-Inabanga Watershed, Bohol, Philippines which compared these two methods showed more than 75% accuracy for the logistic regression method, while the heuristic method did not show its accuracy [14]. There are also experts who compare the three methods, namely the heuristic, statistical and data driven methods, showing that the last 2 methods (statistics and data driven) have more objective results [15]. The result of this study shows that statistical method more appropriate according to landslide event.

4. CONCLUSION

Data on landslide events is not always well available in every regency in Sumatera, especially related to the coordinates of landslide points. This makes it impossible to use statistical methods, so that landslide hazard maps in the regency are mostly based on the results of the heuristic methods approach. The landslide susceptibility map is an important map to be informed in regional spatial planning (RTRW). RTRW uses scale 1:50,000. On this scale the statistical approach is more recommended than the heuristic approach.

5. ACKNOWLEDGEMENTS

The author would like to thank Lembaga Penelitian dan Pengabdian Masyarakat (Research Institutions and Community Service) Universitas Negeri Padang for funding this work with a contract number : 969/UN35.13/LT/2021.

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