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Settlement Patterns of the Population Use the Average Nearest Neighbor Method

Tika Widayanti*[1], Tiyas Yulita[2]

*[1]Department of Geomatics Engineering, Institut Teknologi Sumatera, Lampung, Indonesia
[2]Department of Cyber Security, Politeknik Siber dan Sandi Negara, Bogor, Indonesia
tikawidayanti@gt.itera.ac.id[1]

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ABSTRACT

This study utilizes the Average Nearest Neighbor (ANN) method to analyze settlement patterns based on population density data across 15 regencies and cities in Lampung Province, Indonesia. ANN is a spatial statistical technique used to determine spatial distribution patterns by calculating the average distance between points, the number of points, and the area of the region. The analysis involved computing the ANN index and z-scores for each regency and city. The results, as shown in the analysis, indicate that the ANN index values are below one, ranging from 0.114 to 0.769, and the z-scores are negative, ranging from -146.719 to -13.235. These findings suggest that the settlement patterns across all studied areas in Lampung Province exhibit a clustered pattern. This implies that densely populated areas do not significantly influence the settlement patterns of less densely populated regions. The study concludes that the population density pattern in Lampung Province is predominantly clustered, reflecting a tendency for settlements to be concentrated in specific areas rather than dispersed.

Keywords: Average Nearest Neighbor, Clustered Patterns, Population Density, Settlement Patterns, Spatial Analysis.

I. INTRODUCTION

Spatial statistics methods can be used to analyze geographic data across various fields, including environmental science, epidemiology, economic geography, urban planning, and social sciences. Examples of spatial statistics applications include mapping population density, cluster analysis, spatial interpolation, spatial pattern analysis, and spatial modeling. In spatial analysis, there is a method called spatial pattern and spatial autocorrelation. Spatial Pattern refers to the arrangement of objects or phenomena on the Earth's surface.

One commonly used spatial pattern analysis is the Average Nearest Neighbor (ANN), which focuses on

the distance parameter of the nearest neighbors. ANN is one of the oldest techniques for detecting spatial clustering, using the ANN ratio index [1]. This index is influenced by distance, the number of location points, and the area of a region, and the ANN results can form three clustering patterns: clustered, random, and dispersed.

Spatial data research using ANN has been extensively conducted, including forming the spatial distribution of dengue fever cases in Kuala Lumpur by combining Geographic Information System (GIS) and ANN [2], crime modeling using ANN, hotspot analysis, least absolute shrinkage and selection operator (LASSO), and binary logistic regression [3], hotspot analysis of forest fires [4], mapping crime in Ghana using ANN [5], identifying archaeological sites by combining ANN and Kernel Density (KD) [6]. Additionally, there is research on the capabilities of ANN and Ripley's K Function in regional clustering [7] and land distribution and development for a shipping center using ANN in Poland [8].

The ANN method has been widely used for various spatial data clustering problems. Therefore, this study applies the method to settlement data, specifically using residential data from Lampung Province, Indonesia. The results of this research are expected to be beneficial for various stakeholders and useful for regional development, ultimately creating a better living environment.

II. METHODS AND MATERIAL

A. Average Nearest Neighbor (ANN)

The Average Nearest Neighbor (ANN) is a method used in geography to determine settlement distribution patterns. ANN is capable of explaining the spatial distribution of location points by calculating the distance, the number of location points, and the area of the region. The result of the ANN analysis is an index ranging from 0 to 2.15. If the index is less than 1, the pattern is said to be clustered. If the index is greater than 1, the pattern is considered dispersed. The formulation for the Average Nearest Neighbor (ANN) is as follows:

$$ANN\ (R) = \frac{\overline{D}_0}{\overline{D}_E}$$

$\overline{D}_0$ is average distance between each feature and its nearest neighbor, and $\overline{D}_E$ is the expected average distance in a random pattern. The calculation for $\overline{D}_0$ is:

$$\overline{D}_0 = \frac{\sum_{i=1}^{n} d_i}{n}$$

and the expected average distance $\overline{D}_E$ is:

$$\overline{D}_E = \frac{1}{2\sqrt{p}},$$

p is the point density in square kilometers, calculated as:

$$p = \frac{n}{|A|}$$

n is the number of features, and $|A|$is the area of the region. The z-score statistic can be obtained using the following formula:

$$z = \frac{\overline{D}_0 - \overline{D}_E}{\sigma_{\overline{D}_E}}$$

These formulas allow the ANN method to quantify the spatial distribution pattern by comparing the observed nearest neighbor distances with those expected under a random distribution, and $\sigma_{\overline{D}_E}$is the standard error of the average nearest neighbor distance under complete spatial randomness (CSR), given by the following equation:

$$\sigma_{\overline{D}_E} = \frac{0{,}26136}{\sqrt{n\rho}}$$

Here, n is the number of features, and ρ\rhoρ is the point density. The interpretation of the z-score is as follows: a negative z-score indicates that the data is

clustered, while a positive z-score suggests that the data is dispersed [7].

B. Data

The research location is Lampung Province, located on the island of Sumatra, Indonesia. Lampung Province has a population of 9,419.58 thousand people and an area of 33,575.41 km². The data used in this study are residential density data, including information from 15 regencies/cities within Lampung Province. Map of Lampung Province is given by Figure 1.

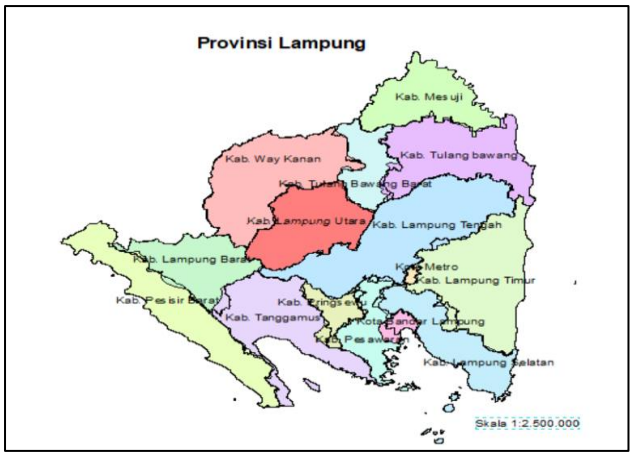

Figure 1. Map of Lampung Province

III. RESULTS AND DISCUSSION

An example of a population density map for one of the regencies in Lampung Province, specifically Lampung Barat in Figure 2, and Pesawaran in Figure 3. The red markers or dots represent the locations of settlements.

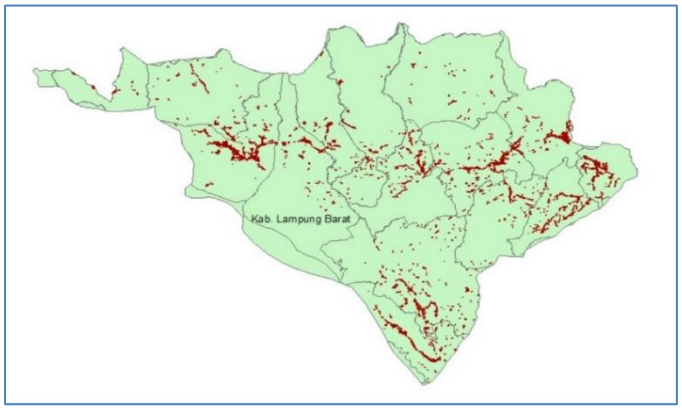

Figure 2. Settlement Patterns of Lampung Barat Regency

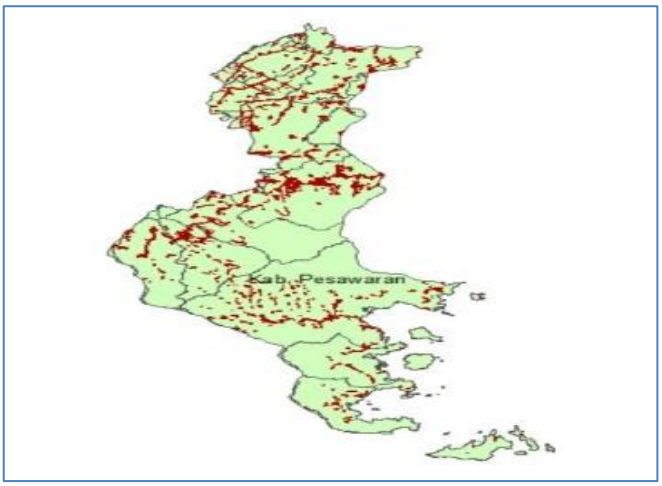

Figure 3. Settlement Patterns of Pesawaran Regency

The ANN analysis was conducted using population density data from 15 regencies and cities in Lampung Province. The basic concept of ANN involves considering the number of points, distance, and area. As example, the results from the ANN calculation in Bandar Lampung is illustrated in Figure 4, and the ANN analysis results of all cities and regencies in Lampung Province is presented in Table 1.

From Table 1 above, it is observed that the results of the analysis using the ANN method show index values below one, ranging from 0.114890 to 0.769887, and the z-score values are negative, ranging from -146.719866 to -13.235968. This indicates that the settlement pattern of the population in all regencies and cities in Lampung Province is clustered, meaning there is no influence between densely populated and sparsely populated areas regarding settlement patterns.

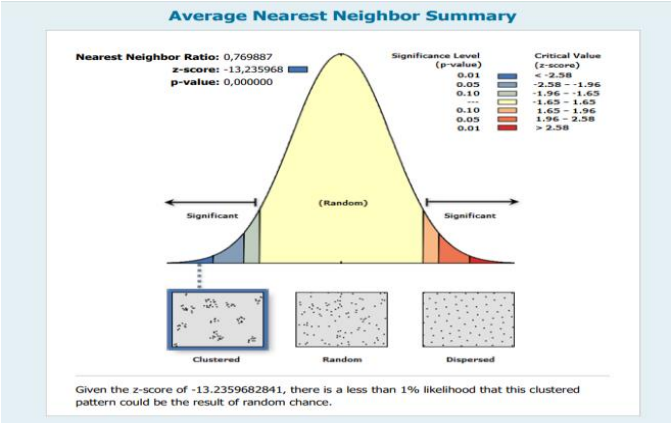

Figure 4. ANN Calculation Results for Bandar Lampung City

Lampung has varied topography, including mountainous regions, lowlands, and coastal areas. Typically, settlements tend to develop in flatter and more accessible areas, such as lowlands and along riverbanks. These regions are more conducive to agricultural activities and provide access to necessary resources.

TABLE 1.
AVERAGE NEAREST NEIGHBOR ANALYSIS RESULTS

No.	City/Regency	Index	z-Score	*p*-Value	Pattern
1	Bandar Lampun	0,769	-13,235	0,000	*Clustered*
2	Lampung Barat	0,325	-144,838	0,000	*Clustered*
3	Lampung Selata	0,135	-146,719	0,000	*Clustered*
4	Lampung Tenga	0,154	-77,824	0,000	*Clustered*
5	Lampung Timu	0,172	-122,436	0,000	*Clustered*
6	Lampung Utara	0,134	-26,905	0,000	*Clustered*
7	Mesuji	0,164	-113,575	0,000	*Clustered*
8	Metro	0,347	-42,437	0,000	*Clustered*
9	Pesawaran	0,114	-56,566	0,000	*Clustered*
10	Pesisir Barat	0,214	-101,499	0,000	*Clustered*
11	Pringsewu	0,199	-42,365	0,000	*Clustered*
12	Tanggamus	0,197	-123,558	0,000	*Clustered*
13	Tulang Bawang Barat	0,135	-55,890	0,000	*Clustered*
14	Tulang Bawang	0,130	-58,644	0,000	*Clustered*
15	Way Kanan	0,191	-115,421	0,000	*Clustered*

Most of Lampung's population works in agriculture, including palm oil, rubber, and coffee plantations. Consequently, settlements are often centered around agricultural areas to facilitate access to farmland and supporting infrastructure. Regions with significant agricultural activities include Central Lampung, East Lampung, Mesuji, and Way Kanan.

In addition to agricultural areas, regions where settlements cluster include those near economic centers, such as markets and trade hubs. In Lampung, major cities like Bandar Lampung and Kotabumi serve as economic and public service centers, attracting residents to live in these areas. Transportation infrastructure such as roads and bridges affects settlement distribution. Areas with good access and adequate infrastructure often experience denser settlement. Overall, this clustered pattern occurs because settlements tend to develop in strategic locations that support key economic activities, such as agriculture, and take advantage of favorable geographic conditions for daily life.

IV.CONCLUSION

From the discussion results, it can be concluded that using the ANN method shows that the population density pattern in the 15 regencies/cities of Lampung

Province, Indonesia, is clustered. Settlement density is concentrated in urban centers, infrastructure areas, and agricultural regions.

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