Distribution Mapping and Typology of Slum Area Based on Spatial Autocorrelations in Padang City

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Abstract. The high population development of Padang City is faced with limited land for areas and its infrastructure, resulting in a dense and slum-prone environmental condition of the City. The Central Government, together with the Padang City Government, held a program aimed at rehabilitating slum areas with the KOTAKU (Kota Tanpa Kumuh) program. This policy needs to be evaluated with the identity of the distribution and typology of slum areas to see changes in the slum area spatially. This study aims to identify the distribution of slum areas and describe slum areas' typology using spatial autocorrelation in the City of Padang. Based on the survey results, slum areas were identified in 45 (forty-five) well-known subdistrict in 11 districts with a total area of 129.16 hectares of slum areas. There are 8,282 households in slum identified areas in the City of Padang. The spatial typology of slum areas resulted in a p-value of 0.061, a z-score of 1.867, and a moran index of 0.095 with a clustered pattern. The influence of spatial dependence is presented by the distribution of Moran and sub-district in the City of Padang's urban fringe area. This condition is supported by a result of the concentration of activities at the core of the Padang City sub-district, causing it to not develop in the urban fringes area.

1. Introduction

Building cities and areas inclusive, safe, and resilient is the goal of the Sustainable Development Goals (SDGs)\textsuperscript{[1]}. One of the essential points to be achieved in the SDGs is ensuring access to decent, safe, and affordable housing and essential services for all and improving slum areas' quality. The development of the high population rate of Padang City is faced with limited land for areas and infrastructure. An area whose carrying capacity is exceeded results in a densely populated city environment and tends to be a slum. The City of Padang is the capital of West Sumatra Province, which is in the West Coast Region of Sumatra, which has a population in 2018 of 939,112 people\textsuperscript{[2]}. The slum areas in the City of Padang are determined through the Decree of the Mayor of Padang Number 163 of 2014\textsuperscript{[3]}, area of 107.96 ha in 23 sub-district. The Central Government together with the Padang City Government held a program aimed at rehabilitating slum areas with the KOTAKU (Kota Tanpa Kumuh) program and the Padang City Regional Regulation Number 5 of 2018\textsuperscript{[4]}; however, the realization of this policy needs to be evaluated through the distribution and typology of slum areas to determine spatial changes in slum areas so that directions for the utilization of slum areas in Padang City can run effectively and create an inclusive, safe, resilient and sustainable city by 2030.
Tobler [5], In the law of geography, 1 (one) states that everything has a relationship with other things, but those close together have more. Spatial autocorrelation is an analysis to determine the relationship and linkages between observation locations [6]. An indication of a positive value in spatial autocorrelation is a systematic pattern affecting a region. Based on this description, the importance of the research objectives can be formulated as follows: (1) Identifying the distribution of slum areas in the City of Padang. (2) Analyzing the typology of slum areas using spatial autocorrelation.

2. Material and Methods
The research location is the City of Padang, the capital of West Sumatra Province, which is in the West Sumatra Coastal Zone, which directly faces the Mentawai Strait and the Indian Ocean. The area of the City of Padang Perda No. 10 of 2005 concerning the area of Padang City is known to be 1,414.96 Km² [7]. Geographically, Padang City is between 00° 44’ 00” dan 1° 08’ 35” South Latitude and between 100° 05’ 05” dan 100° 34’ 09” East Longitude. Padang City, which stretches from North to South, has 68,126 km of beaches [7].

Figure 1. Research Location

2.1. Distribution Mapping of Slum Area
The data needed from this study is secondary data obtained from KOTAKU Padang as a baseline and a guide in carrying out field surveys. Besides that, data is also needed, such as the head of the family indicated as a slum area, and the distance threshold used for weighting. Slum area location maps were constructed using spatial data and slum location data from KOTAKU and the Decree on the Location of Slum areas in Padang City. The map is added with the attributes of the percentage of slum households for each sub-district.

Slum distribution mapping is carried out after the data collection process is complete. Secondary survey and field data serve as the baseline in making the distribution of areas in the City of Padang. The mapping method is done spatially by utilizing a geographic information system (GIS) application in ArcGIS 10.3 software released by Esri.

Polygon areas are digitized on the screen using the help of supporting tools, namely Google Earth Pro. Google earth is an application that supports medium to high-resolution image input. For the City of Padang, the last data found was on March 7, 2020. Data on slum families from the field survey
The results are inputted into the attribute table in the shapefile data for slum villages in Padang City. The final stage is the process of layout/framing of a 2 (two) dimensional map with a JPEG format with a pixel resolution of 500 dpi.

2.2. Typology Spatial of Slum Area

To see the spatial typology of slum areas that occurred, it was carried out using spatial autocorrelation analysis. Spatial data modeling requires data that is based on location and contains information about that location. The location of the spatial data must be measured to see the spatial impact that occurs. According to Kosfeld[8], Location information can be measured through the relationship between proximity and distance. Besides that, it is essential in spatial analysis is the spatial weight matrix. According to Kosfeld[8], the grid neighborhood can be interpreted in several ways:

2.2.1. Rook Contiguity. The location is determined based on tangent sides, and the angle is not taken into account. The illustration of the rook contiguity is seen in Figure 2, where Units B1, B2, B3, and B4 are neighbors of unit A.

![Figure 2 Rook Contiguity](image)

2.2.2. Queen Contiguity. The area of observation is based on intersecting sides and calculated angles. Illustration of queen contiguity can be seen in Figure 3, where B1, B2, B3, B4, C1, C2, C3, and C4 are neighbors of unit A.

![Figure 3 Queen Contiguity](image)

2.2.3. Bishop Contiguity. The area of observation is based on the calculated angle. The bishop contiguity illustration can be seen in Figure 3, where units C1, C2, C3, and C4 are neighbors of unit A.

![Figure 4 Bishop Contiguity](image)

The next stage of the analysis is the Moran's Index, by analyzing the household's variable proportion in slum areas in each sub-district unit. The following is the formula for Moran's index [9]:

\[
I = \frac{n}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})} \cdot \frac{1}{\sum_{i=1}^{n} (x_i - \bar{x})^2} - 1
\]
\[ I = \frac{n}{S_0} \times \frac{\left( \sum_{i=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x}) \right)}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \]  
(1)

\[ S_0 = \sum_{i=1}^{n} = 1 \sum_{j=1}^{n} = 1 W_{ij} \]  
(2)

With \( w_{ij} \), \( w_{ij} \) as the elements of the spatial weights matrix, \( S_0 = \sum_j \sum_{i} w_{ij} \) as the sum of all the weights, and \( n \) is the number of observations.

Most statistical tests begin by identifying a null hypothesis \[ ^{10} \]. The z-scores and p-values returned by the pattern analysis tools tell you whether you can reject that null hypothesis or not. Often, you will run one of the pattern analysis tools, hoping that the z-score and p-value will indicate that you can reject the null hypothesis because it would indicate that rather than a random pattern, your features (or the values associated with your features) exhibit statistically significant clustering or dispersion. Whenever you see spatial structures such as clustering in the landscape, you see evidence of some underlying spatial processes at work, and as a geographer or GIS analyst, this is often what you are most interested in \[ ^{11} \].

The p-value is a probability. For the pattern analysis tools, it is the probability that some random process created the observed spatial pattern. When the p-value is very small, it means it is doubtful (small probability) that the observed spatial pattern is the result of random processes so that you can reject the null hypothesis.

Z-scores are standard deviations. If, for example, a tool returns a z-score of +2.5, you would say that the result is 2.5 standard deviations. Both z-scores and p-values are associated with the standard normal distribution, as shown below.

| No | Z Score | P-Value | Confidence Level |
|----|---------|---------|------------------|
| 1  | < -1.65 or > +1.65 | <0.10   | 90%              |
| 2  | < -1.96 or > +1.96 | <0.05   | 95%              |
| 3  | < -2.58 or > +2.65 | <0.01   | 99%              |

Therefore, the value generated in calculating the Moran's Index ranges between -1 and 1. This value is denoted by \[ ^{5} \]:

1. \( I_o = -1/(n - 1) \) the spatial distribution of feature values may result from random spatial processes. The observed spatial pattern of feature values could be one of many possible versions of complete spatial randomness (CSR).
2. \( I > I_o \) The spatial distribution of high values and low values in the dataset is more spatially clustered than would be expected if underlying spatial processes were random.
3. \( I < I_o \) The spatial distribution of high values and low values in the dataset is more spatially dispersed than would be expected if underlying spatial processes were random. A dispersed spatial pattern often reflects some competitive process—a feature with a high value repels other features with high values; similarly, a feature with a low value repels other features with low values.

2.3. Moran's Scatterplot

Moran's scatterplot, first described by Anselin \[ ^{9} \], consists of a plot with the spatial variables on the y-axis and the original variables on the x-axis. Then the variable z is determined by the deviation from the mean. With standardized line weights, the proportion of all weights (\( S_0 \)) equals observations (n).

The grouping and distribution pattern between locations is presented with the Moran Scatterplot, which shows the relationship between the observed values at a location and the average observed values of the neighboring locations to the observed location. The scatterplot consists of 4 (four) quadrants, namely \[ ^{10} \]: We refer to these values respectively as high and low, in the limited sense of
higher or lower than average. Similarly, we can classify the spatial lag values above and below the mean as *high* and *low*.

The scatter plot is then easily decomposed into four quadrants. The upper-right quadrant and the lower-left quadrant correspond with *positive* spatial autocorrelation (similar values at neighboring locations). We refer to them as respectively *high-high* and *low-low* spatial autocorrelation. In contrast, the lower-right and upper-left quadrant correspond to *negative* spatial autocorrelation (different values at neighboring locations). We refer to them as respectively *high-low* and *low-high* spatial autocorrelation.

The classification of the spatial autocorrelation into four types begins to make the connection between *global* spatial autocorrelation. However, it is essential to keep in mind that the classification as such does not imply significance.

![Figure 5 Moran’s Scatterplot Quadrant](image)

3. Result and Discussion

3.1. Distributions Mapping of Slum Areas in Padang

The determination of the slum areas' location in the City of Padang is obtained from 45 (forty-five) sub-districts spread over 11 districts. The survey team took the slum areas that are scattered in each Rukun Tetangga/Rukun Warga (RT/RW). This point is the basis for house buildings' arrangement to produce an area of slum areas in each RT/RW. [13]. The following are sub-district identified as slums according to the results of field surveys and data tracing in KOTAKU Padang in 2020:

1. **Bungus Teluk Kabung District**: Sub-District Bungus Barat (347 Household), Bungus Timur (164 Household), Teluk Kabung Selatan (222 Household), Teluk Kabung Tengah (180 Household), dan Teluk Kabung Utara (57 Household).
2. **Koto Tangah District**: Sub-District Balai Gadang (144 Household), Batang Kabung Ganting (135 Household), Batipuh Panjang (126 Household), Dadok Tunggul Itam (73 Household), Koto Panjang Ikur Koto (137 Household), dan Padang Sarai (47 Household).
3. **Kuranji District**: Sub-district Ampang (169 Household), Anudring (228 Household), Kalumbuk (86 Household), Lubuk Lintah (33 Household) dan Pasar Ambacang (112 Household).
4. **Lubuk Begalung District**: Sub-district Banuaran (134 Household), Batung Taba (170 Household), Kampung Jua (193 Household), Koto Baru (123 Household), dan Lubuk Begalung (87 Household).
5. **Lubuk Kilangan District**: Sub-district Bandar Buat (143 Household), Koto Lalang (66 Household), Padang Besi (201 Household), dan Tarantang (25 Household)
6. **Nanggalo District**: Sub-district Kurao Pagang (211 Household), Surau Gadang (100 Household), Tabing Bandar Gadang (161 Household).
7. **Padang Selatan District**: Sub-district Batang Arau (801 Household), Mata Air (370 Household),

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**Kuadran II**

(L-H)

**Kuadran I**

(H-H)

**Kuadran III**

(L-L)

**Kuadran IV**

(H-L)
Pasar Gadang (291 Household), Seberang Padang (316 Household), dan Sebarang Palinggam (283 Household).

8. **Padang Barat District**: Sub-district Flamboyan Baru (161 Household), dan Purus (247 Household).

9. **Padang Timur District**: Sub-district Jati (156 Household), Kubu Marapalam (66 Household), Parak Gadang timur (104 Household), dan Sawahan Timur (109 Household).

10. **Padang Utara District**: Sub-district Alai Parak Kopi (199 Household).

11. **Pauh District**: Sub-district Kampung Dalam (438 Household), Kapalo Koto (207 Household), Piai Tangah (341 Household) dan Pisang (194 Household).

As a result of delineation in 45 (forty-five) urban villages in Padang City, the slum areas' total area is 129.16 hectares. This result was also obtained by the Decree of the Mayor of Padang Number 501 of 2019 concerning slum areas, where the area of the slum areas of Padang City in 2019 is 122.33 hectares. When compared with the Decree of the Mayor of Padang Number 163 of 2014, there was an increase in 21.38 hectares with an area of 107.78 hectares in 2014, but the slum locations that were determined were different from the Decree of 2020. This means the shift of slum areas from the slums according to the criteria for slum housing and slum areas according to the Regulation of the Minister of Public Works and Public Housing Number 14 of 2018 [14]. The figure below shows the distribution of slum areas in Padang City:

In the slum area of Padang City, there are 8,282 households the identified slum area Padang City: Batang Arau Subdistrict, Padang Selatan district, is the largest slum in the household, with 801 households. Tarantang sub-district is the smallest contributor to the slum-identified area, namely 25 households.

![Distribution Mapping of Slum Areas in Subdistrict of the Padang City 2020](image)

**Figure 6** Distribution Mapping of Slum Areas in Subdistrict of the Padang City 2020

3.2. **Typology Spatial of Slum Areas in Padang City**

In this case, Spatial weighting is determined based on the relationship of neighbor (neighborliness) with the concept of spatial provision. This concept calculates the observation location based on the tangent sides. The following shows the histogram and neighborhood map of the sub-districts in the City of Padang:
In general, neighborliness is based on the primary side, not the angle; according to Kosfeld in Wuryandari\cite{15}, spatial weighting matrix W is obtained from a standardized weighting matrix, which gives equal weight to the nearest location and others 0 (zero).

The histogram of the analysis of the proximity of the spatial relationship is a graph that explains the number of sub-district locations that are directly adjacent to the provisions of the proximity of the rook to the observed sub-district. Based on Figure 7, the average sub-district in Padang City has a location boundary (neighbors) of 7 neighbors with a sub-district frequency of 29 sub-district. Sub-district Alai Parak Kopi has the most location boundaries (neighbors) with 11 neighbors, and Sub-district Teluk Kabung Selatan is the sub-district that has the least location boundaries, namely one neighbor. The following is a map of neighboring connectivity in the City of Padang.

![Figure 7 Histogram Connectivity In Padang City](image)

**Figure 7** Histogram Connectivity In Padang City

![Figure 8 Spatial Relationship Rook Contiguity in Padang City](image)

**Figure 8** Spatial Relationship Rook Contiguity in Padang City
3.3. Moran’s Index of Slum Areas in Padang City
The spatial autocorrelation analysis with data on the proportion of slum heads of households in the City of Padang was carried out with the Global Moran’s Index in the Arcgis 10.3 application. Spatial autocorrelation will show attribute values at one location about attribute values at neighboring locations [16]. The spatial autocorrelation report from Arcgis 10.3 software shows that with a p-value of 0.061 and a z-score of 1.867, spatial autocorrelation with a moran’s index of 0.095 is shown in Figure 9.

![Spatial Autocorrelation Report](image)

**Figure 9** Report Moran Index in Padang City

The range value at 0 < I < 1 indicates a positive spatial autocorrelation of the proportion of household slum areas between sub-district in Padang City. The proportion of households of slum areas between sub-district in Padang City is clustered and has content on the location. With a z-score of 1.867, there is a less than 10% chance of a clustered pattern forming due to random changes.

3.4. Moran’s Scatterplot of Slum Area in Padang City
Moran's Scatterplot analysis of the proportion of slum areas households in the City of Padang is processed using Geoda software. The analysis results are mapped in 4 (four) quadrants, as shown in Figure 6. The pattern of the proportion of slum proportions in each subdistrict in 2020 is based on Moran’S Scatterplot; most of them are in quadrant IV (High-Low), as many as 26 subdistricts. There are 23 urban subdistricts in Quadrant III (Low-Low), 11 subdistricts in Quadrant I (High-High), and 0 subdistricts in Quadrant II (Low-High). The results of the Moran's Scatterplot analysis of the proportion of household slum areas between subdistricts in Padang City in 2020 are as follows:

1. Quadrant I (High-High) shows subdistricts with a high proportion of households, namely Batang Arau, Kampung Dalam, Alai Parak Kopi, Anduring, Balai Gadang, Bungus Barat, Mata Air, Piai Tengah, Seberang Padang, Seberang Palinggam, Teluk Kabung Selatan.
2. Quadrant II (Low-High) shows sub-district with a high proportion of households consisting of a high proportion of slum areas.

3. Quadrant III (Low-Low) shows villages that have a low proportion of slum areas by subdistricts that have a low proportion of slum areas, namely Teluk Kabung Utara, Tarantang, Padang Sarai, Lubuk Lintah, Kubu Marapalam, Koto Lalan, Air Pacah, Air Manis, Air Tawar Barat, Air Tawar Timur, Alang Laweh, Andaleh, Baringin, Batu Gadang, Behind the Pondok, Behind Tangsi, Berok Nipah, Bukit Gado-Gado, Bungo Pasang, Bungus Selatan, Cengkeh, Cupak Tangah, and Dadok Tunggul Hitam.

4. Quadrant IV (High-Low) shows sub-districts that have a high proportion of households slum areas by sub-districts that have a low proportion of households slum areas, namely Ampang, Bandar Buat, Banuwan, Batang Kabung Gating, Batipuh Panjang, Batung Taba, Bungus Timur, Flamboyan Baru, Jati, Kalumbuk, Kampung Jua, Kapalo Koto, Koto Baru, Koto Panjang Ikur Koto, Kurao Pagang, Limau Manis, Lubuk Begalung, Padang Besi, Parak Gadang Timur, Pasar Gadang, Pasar Ambacang, Pisang, Purus, Sawahan Timur, Sawah Gadang, Teluk Kabung Barat dan Teluk Kabung Tengah. The following shows the sub-districts in each quadrant based on Moran's Scatterplot:

The spatial influence's influence is presented by the scatterplot moran located in the urban fringes of both the northern, eastern, and southern parts of Padang City. This condition is supported by the centralization of activities in the core sub-districts of Padang City, creating responsibility for the urban fringe or periphery areas.

4. Conclusion
Based on the result and discussion that has been compiled, the conclusions of this study are:

1. Based on the survey results, slum areas in the City of Padang have obtained from 45 (forty-five) well-known sub-districts in 11 districts. As a result of delineation in 45 (forty-five) sub-districts in Padang City, the total area of the slum areas is 129.16 hectares.

2. The results of the spatial autocorrelation report from Arcgis 10.3 software show that with a p-value of 0.061 and a z-score of 1.867, the spatial autocorrelation with the Moran's index is 0.095. The spatial distribution pattern of the proportion of households slum areas between sub-districts in Padang City is clustered and has content on the location. With a z-score of 1.867, there is a less than 10% chance of a clustered pattern forming due to random changes.

3. The analysis results are mapped into 4 (four) quadrants, as shown in Figure 6. The pattern of relating to the proportion of household slum areas in each sub-districts in 2020 is based on
Moran's Scatterplot; most of them are in quadrant IV (High-Low) many as 26 sub-districts. There are 23 sub-districts in Quadrant III (Low-Low), 11 sub-districts in Quadrant I (High-High), and 0 sub-districts in Quadrant II (Low-High).

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