Determining the Spatial Connectivity of Surabaya's Peri-urban Area towards Urban Rural Linkage Framework Based on Population Movement Relation

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Determining the Spatial Connectivity of Surabaya’s Peri-urban Area towards Urban Rural Linkage Framework Based on Population Movement Relation

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Abstract. The rapid development and becoming the most dominant growing center at East Java Province, Surabaya City is affected by its periphery areas. This fact is shown by the core area act as an economic center and the periphery act as a settlement support, resulting in urban area widening, known as peri-urban area. This also indicate a domination of periphery area movement toward the core area in the form of people’s flow or population movement. However, the result of the observation shows a tendency of peri-urban problem occurrences such as traffic jam, flood, and slum area. Thus, it is necessary to determine its connectivity between the core area and its support area in urban-rural linkage framework for the aim of having a formulated anticipation effort to face those problems in the future. The analysis was done by quantitative and qualitative approach resulting Normalized Difference Built-Up Index (NDBI) of the year 2002 until 2018 which the conversion reach out 43.95% of non-built-up area to build up area due of the urban area widening. Also, the spatial interaction from the Gravity Model shows the strongest interaction force occurred at Sidoarjo Regency’s districts which directly adjacent with Surabaya City. It can be concluded that the peri-urban area at southern Surabaya have a significant urban rural linkage interaction strength from the population movement. This imply that prioritizing the infrastructure development is a step forward to solve the occurred problems. With a hope by understanding these facts will encourage the government to formulate the sectoral policies.

Keywords: Urban rural linkage, periphery, spatial interaction

1. Introduction

Limitation of land which isn’t consistent with the needs of its inhabitants result in change of rural area around it slowly changing into urban area. This phenomenon is called urban sprawl where the physical appearance of area out of the city become less of rural [1]. This area has a characteristic of high population growth and density, its predominantly non-agricultural sector, and the awareness of the population as a city dweller in the area [2]. Differences in the availability of resources as a form of fulfillment of human needs in each region led to inter-regional interaction to obtain needs that are not available in the region. Relationship in the fulfillment of life needs to form economic relationships that can be seen in the process of demand and supply.

Gerbangkertasusila region is a separate administrative area but has close physical, economic, and social connections. The linkage of economic and social activities in the area caused the urban sprawl in Surabaya [3]. One of the city that affected the most from the activity of Surabaya City is Sidoarjo Regency. From the growth of population, the increasing of density area, and the change of land to non-agriculture in some districts in Sidoarjo Regency, the regency experienced urban sprawl from Surabaya City. Waru and Taman Districts which directly adjacent with Surabaya experienced faster population growth than other districts in Sidoarjo [4]. The population of Waru district is the highest, which is...
11.38% of the total population of Sidoarjo Regency, while the second is Taman district that reaches 10.79%. High population growth also began to occur in Sukodono, Gedangan, and Candi districts which located near Waru and Taman districts. The density of the population of Sidoarjo Regency in 2015 reached 3,026 people/km², while in Taman and Waru districts, the density reached 7,168 people/km² and 7,734 people/km². Apart from the population side, an indication of the formation of peri-urban characteristics due to urban sprawl is also seen from land use. In 2015, there is a lot of diversion of agricultural land function in Sidoarjo regency into residential and industrial land, 5,3 thousand hectares of paddy fields have diverted function. Waru, Taman, and Gedangan sub-districts have large and medium scale industries of about 42% of the total industries located in Sidoarjo Regency [4]. From the data explained, Sidoarjo regency is experiencing urban sprawl from Surabaya City. In this research, the physical appearance of urban sprawl is seen with remote-sensing from landsat data to acquire its built-up area from year 2002 and 2018. The built-up area that formed is connected to the area interaction forces with gravitational analysis.

The objectives of this research were, 1) to see the pattern of urban sprawl in Sidoarjo Regency with normalized difference built-up index (NDBI) method by using Landsat satellite image year 2002 and year 2017 with the help of GIS, and 2) to study the characteristics of regional linkage formed in built-up area result from NDBI and gravitational force. After mentioning the backgrounds of this research, data and methods used in this research are described in the chapter 2. In the chapter 3, the results of built-up area pattern from year 2002 and year 2018 of Sidoarjo Regency and population from each district in Sidoarjo Regency are given. In the chapter 3, we also discuss about the characteristic that formed from result of NDBI and gravitational forces analysis. Finally, in the chapter 4, we conclude our findings resulted in this research.

2. Data and Method

2.1. Study Site

As the main characteristic of land use pattern in Sidoarjo regency, agricultural land constitutes the majority of land, occupying 36.2% of total land area. Approximately 17.5% of the land is built land, covering residential areas, commercial areas, industrial estates and other urban uses (see Figure 1).

![Figure 1. Administration Area of Sidoarjo Regency](image)

Based on data obtained from the Central Bureau of Statistics (BPS) of Sidoarjo Regency, the population of Sidoarjo Regency in 2017 (Table 1) amounted to 2,223,002 inhabitants. In 2017, the most populous sub-district is Waru Sub-district with 242,004 inhabitants. While the District Jabon has a population of at least 61,015 people.
Table 1. Total Population Per District in Sidoarjo Regency

| No | District   | Population |
|----|------------|------------|
| 1  | Sidoarjo   | 225,046    |
| 2  | Buduran    | 104,039    |
| 3  | Candi      | 161,952    |
| 4  | Porong     | 88,191     |
| 5  | Krembung   | 73,800     |
| 6  | Tulangan   | 102,328    |
| 7  | Tanggulangin| 107,127    |
| 8  | Jabon      | 61,015     |
| 9  | Krian      | 134,923    |
| 10 | Balongbendo| 78,803     |
| 11 | Wonoayu    | 87,032     |
| 12 | Tarik      | 70,939     |
| 13 | Prambon    | 83,324     |
| 14 | Taman      | 233,458    |
| 15 | Waru       | 242,004    |
| 16 | Gedangan   | 133,379    |
| 17 | Sedati     | 108,214    |
| 18 | Sukodono   | 127,428    |
|    | Total      | 2,223,002  |

The fluctuation of population that occurs in Sidoarjo Regency has been major attribute to urban sprawl. The flow of people from Surabaya City who moves to Sidoarjo as the effect of lack of land contributes to the changes of physical appearance of rural to urban. The graph in Figure 2 shows the population growth rate of Sidoarjo Regency from 2002 to 2007.

Figure 2. In this population graph of Sidoarjo Regency, it can be seen that the highest population growth is on District Sukodono while the lowest growth is on Jabon District.

2.2. NDBI

Landsat imagery was used to delimitate built-up. Images were selected according to age from the earliest and latest available imagery, using satellite pictures with clear skies. Images were selected to reflect urban growth trends for the 2002 and the 2018.

\[
\text{NDBI} = \frac{\text{Band 5} - \text{band 4}}{\text{band 5} + \text{band 4}} \quad (1)
\]
The derived NDBI image was then recoded to create a binary image. The standardized differentiation of Band 5 and Band 4 will result in close to 0 for woodland and farmland pixels, negative for waterbodies, but positive values for built-up pixels, enabling the latter to be separated from the remaining covers.

2.3. Gravity Model

The method of analysis used to calculate the magnitude of inter-regional spatial interaction using gravity theory method. Gravity Theory measures the strength of interaction between two different regions can be measured by taking into account the population factor and the distance between the two regions. To measure the strength of inter-regional interactions, the following formulations are used.

$$A_{ij} = k \frac{P_i P_j}{d_{ij}^2}$$  \hspace{1cm} (2)

- \(A_{ij}\) = interaction forces between area A and B
- \(k\) = constant number, 1
- \(P_i\) = total population area A
- \(P_j\) = total population area B
- \(d_{ij}\) = distance area A and B

From the general formulation of gravity method in regional interaction analysis, it is adopted new formulation from Vaz, E., & Nijkamp, P., [5] research, where the mass is not population but mass is likened to changes of population in an area with acceleration from built-up changes (a) which is the urban sprawl that happened in that area.

$$F = k \frac{m_1 m_2}{r_{12}^2}$$  \hspace{1cm} (3)

Mass from the initial formulation is likened as change of population in a city with the acceleration of built-up changes [5]. With that assumptions, \(F_p\) is population changes in the area, and \(a\) is changes of built-up area.

$$m = \frac{F_p}{a}$$  \hspace{1cm} (4)

Keterangan:
- \(F\) = interaction forces with Surabaya
- \(F_p\) = changes of population
- \(a\) = changes of built-up area
- \(m_1\) = mass of urban sprawl area 1
- \(m_2\) = mass of urban sprawl Surabaya
- \(r_{12}\) = distance of area 1 and Surabaya
- \(k\) = constant
3. Result and Discussion

3.1. NDBI

![Figure 3. NDBI result of Sidoarjo Regency in year 2002 and 2017](image)

From the result of raster calculation of the landsat maps, it is found built-up area index of the area as it seen in Figure 3. Table 2 below show the built-up index of each districts in Sidoarjo. The changes of built-up area in each district will be use to determine the force of interaction in each districts with gravity model.

| No | Kecamatan | Built Up Area |
|----|-----------|---------------|
|    |           | 2002 (pixel)  | 2017 (pixel) |
| 1  | Jabon     | 5737          | 13833        |
| 2  | Tarik     | 9073          | 10342        |
| 3  | Krembung  | 9402          | 20557        |
| 4  | Balongbendo | 5635        | 6423         |
| 5  | Porong    | 7804          | 8789         |
| 6  | Prambon   | 4790          | 9151         |
| 7  | Tanggulangin | 7977        | 13035        |
| 8  | Tulangan  | 13465         | 28563        |
| 9  | Wonoayu   | 8721          | 20714        |
| 10 | Candi     | 7751          | 23608        |
| 11 | Buduran   | 6244          | 9277         |
| 12 | Krian     | 14189         | 19060        |
| 13 | Sedati    | 4458          | 8455         |
| 14 | Sidoarjo  | 15544         | 29882        |
| 15 | Sukodono  | 9758          | 19882        |
| 16 | Gedangan  | 4396          | 5119         |
| 17 | Taman     | 6137          | 11126        |
| 18 | Waru      | 5125          | 7087         |
3.2. **Gravity Model**

The method of analysis used to calculate the magnitude of inter-regional spatial interaction using gravity theory method. Gravity Theory measures the strength of interaction between two different regions can be measured by taking into account the population factor and the distance between the two regions. To measure the strength of inter-regional interactions, by using the formulation as mentioned above, which result shown in Table 3.

### Table 3. Results of Interaction Analysis of Sidoarjo’s districts to Surabaya City

| No | Kecamatan       | Built Up Area (pixel) | a       | F population 2002 | F population 2017 | Fp = Fp_a | r12 | F = k (m1,m2) / r12 | m1 = 8,086478867 |
|----|-----------------|-----------------------|---------|-------------------|-------------------|-----------|-----|---------------------|------------------|
| 1  | Jabon           | 5737                  | 13833   | 8096              | 47683             | 61015     | 0.1532 | 0.01372 | 0.01372 | 0.01372 |
| 2  | Tarik           | 9073                  | 10342   | 1269              | 53645             | 70939     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 3  | Krembung        | 9402                  | 20557   | 11155             | 53039             | 73800     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 4  | Balongbendo     | 5635                  | 6423    | 788               | 57357             | 78803     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 5  | Porong          | 7804                  | 8789    | 985               | 69337             | 88191     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 6  | Prambon         | 4790                  | 9151    | 4361              | 60924             | 83324     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 7  | Tanggulangin    | 7977                  | 13035   | 5058              | 64288             | 107127    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 8  | Tulangan        | 13465                 | 28563   | 15098             | 67308             | 102328    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 9  | Wonoayu         | 8721                  | 20714   | 11993             | 61666             | 87032     | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 10 | Candi           | 7751                  | 23608   | 15857             | 92897             | 161952    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 11 | Buduran         | 6244                  | 9277    | 3033              | 65164             | 104039    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 12 | Krian           | 14189                 | 19060   | 4871              | 88572             | 134923    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 13 | Sedati          | 4458                  | 8455    | 3997              | 67469             | 108214    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 14 | Sidoarjo        | 15544                 | 29882   | 14338             | 146615            | 225046    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 15 | Sukodono        | 9758                  | 19882   | 10124             | 66430             | 127428    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 16 | Gedangan        | 4396                  | 5119    | 723               | 106630            | 133379    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 17 | Taman           | 6137                  | 11126   | 4989              | 176704            | 233458    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |
| 18 | Waru            | 5125                  | 7087    | 1962              | 210426            | 242004    | 0.1532 | 0.12456 | 0.12456 | 0.12456 |

* m1 = 8,086478867

The results of these calculations can be seen that each districts have different interactions values. Then the interaction value is classified into 5 classes from highest to lowest.

### Table 4. Interaction Classification of Sidoarjo districts to Surabaya City

| Class | Districts                                                                 |
|-------|---------------------------------------------------------------------------|
| I     | District Gedangan                                                         |
| II    | District Waru                                                            |
| III   | -                                                                         |
| IV    | District Taman                                                           |
| V     | District Sukodono, Jabon, Tarik, Krembung, Balongbendo, Porong, Prambon, Tanggulangin, Tulangan, Wonoayu, Candi, Buduran, Krian, Sedati, dan Sidoarjo |

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Based on the Table 4 and Figure 4 above, it can be seen the interaction to Surabaya City, the strongest based on gravity analysis is District Gedangan, then the second strongest is District Waru. While the weakest interaction is District Sukodono, Jabon, Tarik, Krembun, Balongbendo, Porong, Prambon, Tanguengin, Tulangan, Wonoayu, Candi, Buduran, Krian, Sedati, dan Sidoarjo. The results of this gravity’s interaction analysis is the districts that have closer proximity to the city of Surabaya have a stronger urban character than the district further from Surabaya. It also can be seen that the urban sprawl happening in Kabupaten Sidoarjo starting to shift from District Waru and District Taman to District Gedangan.

4. Conclusion

From the analysis above, it can be concluded that peri-urban area in southern Surabaya is a part of Sidoarjo Regency’s District, with Normalized Difference Built-Up Index (NDBI) of the year 2002 until 2017 resulting a conversion value reach out 43.95% of non-built-up area to build up area due of the urban area widening. A significant urban rural linkage interaction strength occurred from the population movement that resulted by the gravity model, is in Sidoarjo regency’s District around the border area of Surabaya City which are Gedangan District and Waru District.

5. References

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