Geographic information system-based spatial analysis of population distribution in Banten province - Indonesia

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Abstract. Population distribution is one of the of disaster vulnerability parameters needed in a disaster risk assessment. The analysis approaches to determine the spatial population distribution can use many methodological alternatives. The general approach used in Indonesia is based on the results of a survey or census, where the number of population density is distributed evenly within the administrative borders. Another approach using Random Regression Tree model-based Forest Mapping is used by Worldpop. Both methodologies have their respective advantages and disadvantages. This study was conducted by combining these two methods where some data and parameters are added as driving factors on the scale spatial resolution analysis (grid size) 0.000833333 decimal degrees (approximately 100 m in the equatorial region) for a case study in Banten Province. Data processing is performed by raster analysis approach and GIS. The results are more affordable, meet cost requirements, and can be utilized to calculate the level of disaster risk in the area.

1 Introduction

In order to conduct a disaster assessment, spatial distribution data that illustrates the distributions of the human population are needed. In disaster management context, population distribution is significant to estimate the element of the risk to reduce the incident of fatalities [1]. The accurate population information can be achieved by considering the estimated Indonesia population for next 10 years since 2010, which more than 50% of the growth will be absorbed into urban areas. The easily-updatable population data for research and others are requested. This request can be satisfied by the use of remote sensing and other geospatial data sets to refine estimation of population data. But, a new approach is needed to achieve accurate spatial population distributions.

In general, the population is provided in the form of statistical tables and presented spatially in a reference map. The spatial presentation also commonly referred to as mapping choropleth. The disadvantage of this method is that this method can't describe in detail the occupied area. In fact, the population distribution through choropleth mapping does not represent actual population distribution [1]. For the disaster risk analysis purposes, this method is less feasible to be used, especially to describe the populations exposure.

In order to have population data in more detail, some scholars such as [2] and [3] have employed a dasymetric mapping method. The Dasymetric mapping is one area-

based thematic mapping method that produces more detailed spatial information [4]. Dasymetric mapping has an advantage in generating more realistic spatial population distribution compared to choropleth mapping.

Dasymetric mapping has been well developed along with the development of spatial technology. One of the spatial data were freely available to be used is data from WorldPop, especially for the region of Indonesia. The WorldPop data are generated using *random* regression tree model-based *forest* mapping along with various assumed variables which effect the population density pattern. The predicted value is then used as a surface weight values to redistribute *dasymetric* population density per grid up to villages level. The WorldPop spatial resolution data is 0.000833333 decimal degrees (approximately 100 m in the equatorial region).

In particular cases in Indonesia, the WorldPop data has some disadvantages. First example, the IndoPop population (Indonesia Population data produced by WorldPop) data in 2015 is overestimate compared to the Indonesia Statistical Agency (BPS) at the Provincial level. Second, the distribution of population density values is not only in residential areas but also outside the areas. Then the IndoPop data quality is necessary to be improved.

This research introduces a new method to improve population distribution data by combining the two earlier mentioned methods for more reliable population data as well as its accuracy.

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2 Material and method

2.1. Data

The data used in the form of spatial data consists of:

Table 1. Data types

No.	Data Type	Forms Data
1.	Village Administration Boundaries	Vector (Polygon)
2.	Indonesian Population Distribution (IndoPop)	Raster
3.	Residential Distribution	Vector (Polygon)
4.	Amount of Population (Village level)	Tabular

The official source data are available on the internet. The village-level boundary data and the population data are obtained from BPS. The IndoPop data is available online and the residential distribution is extracted from 1:25.000 topography map which is also freely available (tanahair.indonesia.go.id) which can be opened through ArcGIS - ArcMap program.

2.2 Methodology

The methods used in this study are data pre-processing, improving IndoPop data, and spatial distribution of the population.

2.2.1 Data pre-processing

This step aim to prepare the initial data for a further analysis. Since the data is run in a raster environment, the data must be common in the format, cell size, and coordinate system. All data must use a *Mercator* projection such as *WGS_1984_World_Mercator* or *Universal Transverse Mercator* (UTM). The transformation of the coordinate system can be done using *ArcToolbox - Projections and Transformations - Project* (for vector data) or *ArcToolbox - Projections and Transformations - Raster - Raster Project*.

2.2.2 Improving IndoPop data

Since the data have inaccurate estimated population and distribution, it is necessary to improve the IndoPop data. The basic concept of this step is to distribute the population only in the settlement area. This step can be run through the following procedures:

- *Indo Pop* Data include *polygon settlement*, the *number of residents*, the *administrative borders of the village* and *study area* are called through the *Add Data On the Toolbar*.

- Ensure that the data *polygon settlement* is distributed for all administrative boundaries of the village.
- Change the grid size (*pixel/cell*) of *Indo Pop* to 100 with *Resample* tools. Use resample technique "BILINEAR".
- Overlay the *polygon boundary settlement* and *study area* data with *Union* tools.
- Add a column (*field*) with the attribute of *Short Integer*.
- Please rate 1 for the residential attribute and give 0 for the non-residential attribute.
- Convert to raster polygon overlay by using *Polygon to Raster* tools and set the size of the *cell* to 100 (uniformity with *IndoPop* data).
- Get *Indo Pop* pieces of data based on study area boundaries using tools *Extract by Mask* or *Clip Raster*.
- Use the *Raster Calculator* tool to perform the data *Indo Pop* settlement based on data from existing polygons by using the syntax:

Con ("raster_A" = 1, "raster_B", "raster_A")

Where "raster_A" is settlement raster; and "raster_B" is *IndoPop* raster.

- The result of these steps is an improved *IndoPop* data.

2.2.3 Spatial distribution of population

This step deals with the population size. The population data from the *IndoPop* will be adjusted according to the BPS data. In this case, the spatial data distribution will be updated based on BPS in 2015. The procedure can be done by following scheme:

- Use the tools *Zonal Statistics* to count the number of inhabitant village of the *Indo Pop* data. Select the type of statistics *SUM* to obtain the number of residents in each village based on administrative boundary data.
- Convert polygon administrative boundaries of the village into raster data based on the number of people by using the tools *Polygon to Raster*. Set the size of the *cell* to 100 (uniformity with *IndoPop* data).
- Use the *Raster Calculator* tool to redistribute the value of the total population based on data *Indo Pop* improvement and the existing population in 2015 by using the formula:

$$P = \frac{p_i}{\sum_{j=1}^k p_j} x p_j \quad (1)$$

where *P* is the number of people per grid; *p_i* is the number of people form *WorldPop* data *i*; *p_j* is the number of people form BPS by village data *j*, and *j* is the village.

3 Results and discussion

3.1 Administrative-based of population distribution

The map shows the population distribution of Banten Province in village-level basis. Each color in the map represents the total population of the villages. In general, the north parts of the area are denser than the south one.

Fig 1. Population distribution in administrative bases

3.2 Random regression tree model-based forest mapping

The map (Fig 2) illustrates the population distribution in the study area generated through the Random Regression Tree model-based Forest Mapping method. Generally, this map displays the same population distribution as the previous map in which the population concentrates in the northern part of the study area.

3.3 Final results

The map shows the population distribution of Banten region modeled through the combination between the administrative-based mapping method and the Random Regression Tree model-based Forest Mapping method. It shows the population distribution pattern agree with the administrative and WorldPop map.

Fig 2. Population distribution is generated from the Random Regression Tree model-base Forest Mapping

Fig 3. Population distribution produced by the combination method.

Even though the three maps show the similar population distribution pattern, each map actually has the different accuracy. For instance, in the first map (Fig.1) the amount of population is distributed evenly in administrative bases. The map is also able to distinguish the number of people live in the area. However, this choropleth map is insufficient to show the population distribution precisely since the people are not distributed evenly but concentrated in settlement areas.

Figure 2 displays the population proportionally based on the land use classification. It addresses the issue of population unevenness. However, when it comes to the population calculation, it may overestimates or underestimates the amount of population (see Table 1). The combination of administrative-based and the Random Regression Tree model-base Forest Mapping does not only deal with the distribution issues but also provides more reliable amount of population compared to the statistics data.

Table 1 shows an underestimate of the total population using WorldPop data. One of the possible reasons is the Random Regression Tree model-base Forest Mapping utilizes a medium-resolution satellite imagery to identify the human presence. As a result, some settlement areas may not be captured, especially for one that smaller than image spatial resolution. In contrast, the combined method uses a settlement dataset derived from the topographic map (1: 25,000) is more detail. Therefore, it can distribute the population data precisely within the settlement area.

In order to illustrate the population distribution data effects the disaster risk assessment, the analysis results of three different methods are compared each other. Figure shows the study area overlayed by flood hazard map. From the figure the number of flood exposure can be estimated as displayed in Table 2.

Table 2. Estimated potential populations expose for flood hazard class based on two different data

No	Distric Name	BantenPop		WorldPop		Total of BantenPop	Total of WorldPop
		Moderat	High	Moderat	High		
1	Pandeglang	206.180	24.608	183.745	43.361	230.788	227.106
2	Lebak	141.125	7.966	101.682	10.736	149.091	112.418
3	Tangerang	1.749.230	380.673	1.321.600	471.573	2.129.903	1.793.173
4	Serang	451.491	169.370	459.641	319.704	620.861	779.345
5	Tangerang City	1.286.770	71.314	1.170.786	75.074	1.358.084	1.245.860
6	Cilegon	147.503	26.621	119.811	28.402	174.124	148.213
7	Serang City	305.084	54.731	183.605	52.373	359.815	235.978
8	South Tangerang	200.052	3.184	172.566	3.313	203.236	175.879
	Grand TOTAL	4.487.435	738.467	3.713.436	1.004.536	5.225.902	4.717.972

Fig 4. Flood hazard map (inarisk.bnpb.go.id)

Compared to the BantenPop, which uses the combination method, the *choropleth* mapping method is overestimated but the WorldPop data (Random Regression Tree model-base Forest Mapping method) is underestimated. Disaster risk analysis requires an accurate data and information as it will affect the disaster management plan. The overestimate calculation will result in more resource needs such as logistics, housing, and sanitation. On the other hand, an underestimate calculation may result in a lack of resource in case of disaster.

The method used in this study shows the possibility to adjust the WorldPop before it is used. It also provides an updating and distribution mechanism for the census data which usually exists in administrative format.

Although the developed method is able to provide more reliable distribution and population information, this method has some limitations. Firstly, since this method relies on WorldPop data, all data need to be adjusted accordingly to the WorldPop data structure especially the cell size (approximately 100 x 100 m). There may be some distortions if one intends to use this method in a finer pixel resolution. Therefore, it requires

further study to examine the significance of this issue as well as some possible solutions. Secondly, this method also depends on the quality of input data.

Table 3. Amount of population in the comparison between WorldPop, BantenPop (combined method), and statistics data.

No	Distric Name	WorldPop	BantenPop	Statistics Data
1	Pandeglang	1.157.849	1.194.547	1.194.547
2	Lebak	1.270.450	1.263.211	1.263.211
3	Tangerang	3.321.367	3.453.444	3.453.444
4	Serang	1.579.502	1.472.883	1.472.883
5	Tangerang City	2.064.925	2.046.998	2.046.998
6	Cilegon	425.577	412.058	412.058
7	Serang City	499.372	643.135	643.135
8	South Tangerang City	1.491.431	1.543.143	1.543.143
	Grand TOTAL	11.810.473	12.029.419	12.029.419

4 Conclusions

Disaster risk analysis requires accurate population distribution data to calculate the vulnerability. The combined methods of administrative-based and the Random Regression Tree model-base Forest Mapping can be an excellent alternative to overcome the population data.

GIS is an effective tool to deal with spatial data. Therefore, it can play a greater role in disaster management practices.

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