Measuring Urban and Regional Sustainability Performance in Java: A Comparison Study Between 6 Metropolitan Areas

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Abstract. Java is widely known as the economic center of as well as the most populous (main) island in Indonesia. Rapid urbanization process and economic development in Java are mostly concentrated in six major metropolitan areas (MA): "Jabodetabek" (Jakarta MA), "Bandung Raya" (Bandung MA), "Kedungsempur" (Semarang MA), "Kartamantul" (Jogjakarta MA), "Gerbangkertosusila" (Surabaya MA), and "Solo Raya" (Surakarta MA). Due to its extensive development progress over the past decades, Java is now facing environmental crisis and declining carrying capacity. This paper aims to measure urban and regional sustainability in these metropolitan areas in particular and in all regencies/municipalities in Java more generally by drawing on the so-called Regional Sustainability Index (RSI). The results show that every regency/municipality in Java has diverse regional development condition and sustainability performance. In addition to this, most of the localities (regencies/municipalities) being part of the metropolitan areas have a relatively better economic, social, and environmental condition than that of other localities.

Keywords: metropolitan region, Regional Sustainability Index, sustainable development, urban resilience

1. Introduction

The continuing urbanization and overall growth of the world's population is projected to add 2.5 billion people to the urban population by 2050, with nearly 90% of the increase will be concentrated in Asia and Africa. At the same time, the proportion of the world's population living in urban areas is expected to increase, reaching 66% by 2050 [1]. World Bank [2] reported that Indonesia has the third-largest amount of urban land in East Asia, after China and Japan. Between 2000 and 2010, the amount of urban land in Indonesia increased from about 8,900 to about 10,000 km^2, or about 1.1% each year. It is the largest increase in terms of the absolute amount of urban land after China. In recent years, Indonesia has made notable progress in economic growth and development. This development progress has been

followed by rapid urbanization that has transformed some Indonesian cities into metropolitan areas (MAs). As a home to more than 260 million people in 2017, which is equivalent to around 3.5% of the total world population, Indonesia is the fourth most populous nation in the world after China, India and the United States. However, 60% of Indonesia's total population lives on the island of Java.

Covering 7% of Indonesia's total land area, Java is also the country's economic center. About 59% of Indonesia's total GDP was contributed by this island alone [3]. This condition reflects the country's regional development inequality that tends to spatially privilege Java. In particular, the economic development in Java is greatly centered in six major metropolitan areas, i.e., (1) "Jabodetabek" (Greater Jakarta), (2) "Bandung Raya (BMA)", (3) "Kedungsempur" (Semarang MA), (4) "Kartamantul" (Yogyakarta MA), (5) "Gerbangkertosusila" (Surabaya MA), and (6) "Solo Raya" (Surakarta MA). The rapid urbanization process in Indonesia in general, and in these large urban agglomerations in particular, has, however, failed to fully promote the nation's economic growth. For every 1% of urbanization, Indonesia achieved only 2% GDP growth. In contrast, for the same percentage of urbanization, China gained 6% GDP growth, while Vietnam and Thailand gained 8% and 10% respectively [4]. It has been argued that Indonesia has failed to fully utilize its urbanization potential given the fact that most of the nation's cities suffer from 'diseconomies of scale', such as severe traffic congestion, pollution and disaster risks, leading to high cost [4].

The rapid urbanization process of these metropolitan areas has also had a number of negative externalities, such as increasing land-use conversion, rising regional economic disparity, and increasing slum areas. In addition to these, it has also caused different forms of negative impacts, such as environmental degradation (water, water and soil pollution), anthropogenic disasters, increasing unemployment, criminality, etc. As some have studied, Java is encountering environmentally overshoot and, therefore, declining carrying capacity caused by these extensive urban development processes [3, 5, 6]. In general, as Samad [7] points out, Java appears to be highly urbanized.

As the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities, particularly in the lower-middle-income countries where the pace of urbanization is fastest [1]. From a policy perspective, there is a need to address these challenges in the context of the Indonesian government's wider agenda for sustainable urban development. In particular, there is a need to address this sustainable urban development with a more comprehensive approach, comprising (at least) three basic aspects of development: economic development, social transition, and environmental preservation [8].

The assessment of sustainable development needs to be figured as the measurement of sustainability. Measurement issues are of current concern to organizations faced with the task of promoting sustainability [9]. In order to achieve this goal, it is necessary to set a limited number of easily understandable indicators [10]. There are few studies of sustainable development measures in Indonesia but still focused on partial dimension. Against this backdrop, this paper aims to measure urban and regional sustainability in Java. Although a number of studies have been conducted to measure sustainable urban and regional development in Indonesia, their focus tends to be partial. To this end, the objectives of this study are three-fold: (1) measuring sustainability performance by developing Regional Sustainability Index (RSI) for all regencies (*kabupaten*) and *municipalities* (*kota*) in Java by incorporating three dimensions of sustainable development; (2) identifying the spatial distribution pattern of RSI; and (3) producing a cluster map by combining RSI value of each dimension for comparing sustainability performance between 6 metropolitan areas. Identifying the relationship or spatial association of RSI is also important since there is a spatial interdependency between locations at the regencies/municipalities level: the sustainability performance in a particular location is affected by the sustainability condition in its surrounding areas [5, 11, 12].

2. Study Area

This study focuses on six metropolitan areas located in Java Island: (1) "Jabodetabek" (Greater Jakarta), (2) "Bandung Raya (BMA)", (3) "Kedungsempur" (Semarang MA), (4) "Kartamantul" (Yogyakarta MA), (5) "Gerbangkertosusila" (Surabaya MA), and (6) "Solo Raya" (Surakarta MA) (Figure 1). "Jabodetabek" (Greater Jakarta) encompasses different localities from three provinces: Special Capital Region of Jakarta; Bogor Regency, Bogor Municipality, Depok Municipality, Bekasi Regency, and Bekasi Municipality (West Java Province); and Tangerang Regency, Tangerang Municipality, and South Tangerang Municipality (Banten Province). "Bandung Raya (BMA)" is located in West Java Province, consisting of Bandung Municipality, Bandung Regency, Cimahi Municipality, and West Bandung Regency. "Kedungsempur" (Semarang MA) and "Solo Raya" (Surakarta MA) are both located in Central Java Province. "Kedungsempur" (Semarang MA) consists of Semarang Municipality, Semarang Regency, Salatiga Municipality, Kendal Regency, Grobogan Regency, and Demak Regency, while "Solo Raya" (Surakarta MA) consists of Surakarta Municipality, Sukoharjo Regency, and Klaten Regency. "Kartamantul" (Yogyakarta MA) is located in The Special Region of Yogyakarta, consisting of Yogyakarta Municipality, Sleman Regency, and Bantul Regency. "Gerbangkertosusila" (Surabaya MA) is located in East Java Province, comprising Surabaya Municipality, Gresik Regency, Bangkalan Regency, Mojokerto Municipality, Mojokerto Regency, Sidoarjo Regency, and Lamongan Regency.

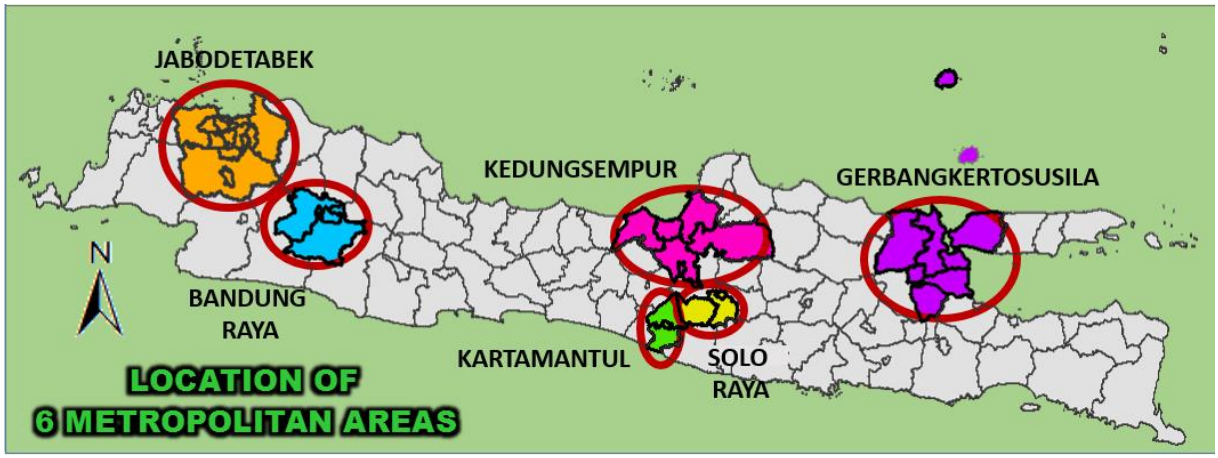

Figure 1. The administration map of Java and the location of 6 metropolitan areas.

Table 1. Population, population density, GDP per capita, total area and built up area of six metropolitan areas in Java.

Metropolitan Areas	Population (person)	Population Density (person/ha)	GDP per capita (Rp/capita)	Total Area (ha)	Built Up* (%)
Jabodetabek	32,050,022	11,128	86,298,232	680,107	32.2
Bandung Raya	8,231,580	8,054	31,175,688	324,290	12.5
Kedungsempur	6,297,440	1,992	31,087,440	552,959	15.4
Kartamantul	2,551,696	5,549	31,457,522	113,090	42.6
Gerbangkertosusila	9,570,370	3,052	49,006,508	643,508	14.4
Solo Raya	2,535,240	5,085	33,340,892	126,945	30.2

Source: BPS (2015); * based on LANDSAT imagery analysis in 2015.

3. Material and Methods

In this research, we used Regional Sustainability Index (RSI) to measure sustainable urban and regional development in Java. RSI was developed based on 30 variables (indicators) which are grouped into three aspects: economy, social, and environment (Table 2). RSI was later refined by employing Factor Analysis (FA) to select the most notable variables/indicators. Factor Analysis (FA) is a statistical method

used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors.

The FA model used in this study can be written as follows:

$$RSI_{ki} = \sum_{m=1}^{nk} E_{km} . S_{kmi} \quad (1)$$

Where: *RSIki* = RSI for *k*-th dimension on *i*-th region; *k* = Dimension (*k*=1: economy; *k*=2: social; *k*=3: environment); *Ekm* = Eigenvalue for *k*-th dimension on *m*-th factor; S_{kmi} = Factor score for *k*-th dimension, *m*-th factor on *i*-th region; *i* = 1, 2, 3,…, n. To standardize RSI value (RSI_{ki} *(std)*) in scale 0-100, we used this formulation:

$$RSI_{ki}(std) = \left(RSI_{ki} - RSI_{ki}(min)\right) * \frac{100}{RSI_{ki}(max) - RSI_{ki}(\min)} \quad (2)$$

Table 2. List of variables of RSI.

Code	Variables
ECONOMY (K=1)	
V1	Percentage of households working in the agricultural sector (%)
V2	Percentage of households using electricity (%)
V3	Number of industries per 1,000 population
V4	Number of markets, minimarkets, shops per 1,000 population
V5	Number of hotels, hostels, motels, and inns per 1,000 population
V6	Distance to the closest bank (km)
V7	Distance to the closest market (km)
V8	Distance to the closest central business district (CBD) (km)
V9	Local infrastructure index (scalogram index)
V10	Percentage of secondary and tertiary sectors to the total GDP (%)
SOCIAL (k=2)	
V11	Number of formal education facilities (kindergarten to university) per 1,000 population
V12	Number of health facilities (hospitals, clinics, health centers, doctors, pharmacies) per 1,000 population
V13	Number of people suffering from malnutrition per 1,000 population
V14	Number of mortalities per 1,000 population
V15	Number of toddler death per 1,000 population
V16	Number of maternal mortalities per 1,000 population
V17	Number of incidents on fight of citizen
V18	Distance to the closest entertainment venue/facility (pub, cinema) (km)
V19	Distance to the closest health facility (hospital, clinic, health center, pharmacyi) (km)
V20	Distance to the closest formal education facility (kindergarten to university) (km)
ENVIRONMENT (k=3)	
V21	Number of drought events
V22	Number of flood events
V23	Number of landslide events
V24	Percentage of households living along the river (riparian area) (%)
V25	Percentage of households living in the slum area (%)
V26	Number of people suffering from malaria per 1,000 population
V27	Number of people suffering from respiratory tract infection per 1,000 population
V28	Number of people suffering from diarrhea and vomit per 1,000 population
V29	Percentage of villages having water pollution (%)
V30	Land conversion from agricultural land (excluding rice field) to non-agricultural land (ha)

4. Result and Discussion

In this research, we have developed an index to measure sustainable development in six metropolitan areas in Java, especially at the local/regional (regency and municipality) level, what we call Regional Sustainability Index (RSI). As previously mentioned, RSI incorporate three dimensions of sustainable development: economy (RSI1), social (RSI2), and environment (RSI3). FA selected 3 factors from 10 variables, representing RSI for economic dimension (RSI1) (Table 3). Based on factor loading's values, factor 1 is represented by number of hotels, hostels, motels, and inns per 1,000 population (V5), distance to the closest market (km) (V7), and distance to the closest central business district (CBD) (km) (V8). Factor 2 is represented by percentage of households working in the agricultural sector (%) (V1), number of industries per 1,000 population (V3), and percentage of secondary and tertiary sectors to the total GDP (%) (V10). Meanwhile, factor 3 is represented by number of markets, minimarkets, shops per 1,000 population (V4) and percentage of secondary and tertiary sectors to the total GDP (%) (V10). Those selected variables show the number of economic facilities and the accessibility to some economic facilities.

Table 3. Factor loading of economic factor analysis.

Var	Factor 1	Factor 2	Factor 3
v1	0.165033	0.904042 *	-0.221368
v2	-0.596446	0.105146	0.073465
v3	-0.131164	0.792183 *	0.244567
v4	0.096432	0.201057	0.805175*
v5	0.837193 *	-0.027018	0.344766
v6	0.549577	0.350765	-0.371425
v7	0.921388 *	0.225799	0.015265
v8	0.869052 *	0.399473	-0.070176
v9	-0.071847	-0.415397	0.802143*
v10	-0.418639	-0.774806 *	0.170363
Expl.Var	3.197044	2.603535	1.696956
Prp.Totl	0.319704	0.260354	0.169696
Eigenvalue	4.084226	2.005660	1.407649
% Total	40.84226	20.05660	14.07649
Cumulative	40.84226	60.89886	74.97536

***Note**: *statistically significant at p-value < 0.05*

For social aspect, FA also determined 3 factors from 10 variables, representing RSI (Table 4). Factor 1 is represented by number of formal education facilities (kindergarten to university) per 1,000 population (V11), number of health facilities (hospitals, clinics, health centers, doctors, pharmacies) per 1,000 population (V12) and number of mortalities per 1,000 population (V14). Factor 2 is represented by distance to the closest entertainment venue/facility (pub, cinema) (km) (V18) and distance to the closest formal education facility (kindergarten to university) (km) (V20). Factor 3 is represented by number of toddler death per 1,000 population (V15) and number of maternal mortalities per 1,000 population (V16). Those selected variables show the number of social facilities, the accessibility to some economic facilities, and the mortality number.

Table 4. Factor loading of social factor analysis.

Var	Factor1	Factor2	Factor3
v11	0.726354 *	0.371780	0.221500
v12	0.821569 *	0.066994	-0.156241
v13	0.530708	-0.267099	0.300621
v14	0.787044 *	-0.138404	0.137266
v15	0.257099	0.356478	0.734619 *
v16	-0.209509	0.126617	0.837715 *
v17	-0.598692	0.013811	0.170940
v18	0.351432	0.764732 *	0.191357
v19	-0.461371	0.614201	0.215848
v20	-0.111941	0.800246 *	0.103253
Expl.Var	2.920981	1.978956	1.547209
Prp.Totl	0.292098	0.197896	0.154721
Eigenvalue	2.960130	2.468106	1.018910
% Total	29.60130	24.68106	10.18910
Cumulative	29.60130	54.28236	64.47146

***Note**: *statistically significant at p-value < 0.05*

For environmental aspects, FA determined 3 factors from 10 variables representing RSI (Table 5). Factor 1 is represented by number of drought events (V21), number of landslide events (V23), and land conversion from agricultural land (excluding rice field) to non-agricultural land (ha) (V30). Factor 2 is represented by number of people suffering from respiratory tract infection per 1,000 population (V27) and number of people suffering from diarrhea and vomit per 1,000 population (V28). Factor 3 is represented by percentage of household living in the slum area (%) (V25) and percentage of villages having water pollution (%) (V29). Factor 4 is represented by percentage of household living along the river (riparian area) (%) (V24).

Table 5. Factor loading of environmental factor analysis.

Var	Factor1	Factor2	Factor3	Factor4
v21	0.868307 *	-0.040054	0.071197	0.048939
v22	0.256014	0.234663	-0.202508	0.637185
v23	0.743643 *	-0.103515	-0.345148	0.026163
v24	0.036264	-0.096486	0.146728	0.875606 *
v25	-0.037500	-0.085608	0.781960 *	0.125450
v26	0.204599	0.192639	-0.445757	0.035215
v27	-0.058516	0.853259*	-0.138051	0.006816
v28	-0.034029	0.881633*	0.053082	0.057222
v29	0.269336	0.191123	0.800071 *	-0.118310
v30	0.791999 *	0.031279	0.141854	0.230191
Expl.Var	2.121475	1.663968	1.679006	1.263055
Prp.Totl	0.212147	0.166397	0.167901	0.126306
Eigenvalue	2.285663	1.768900	1.591348	1.081593
% Total	22.85663	17.68900	15.91348	10.81593
Cumulative	22.85663	40.54563	56.45911	67.27504

***Note**: *statistically significant at p-value < 0.05*

Figure 2 represents the spatial distribution of values for each RSI (RSI_1, RSI_2 and RSI_3). The color gradation indicates the value of RSI: the darker the color of certain locality (regency/municipality), the higher its sustainability performance. Figure 2 (a) shows that regencies/municipalities in Java are dominated by moderate until high value of RSI_1. Higher value of the RSI_1 is concentrated in metropolitan areas: "Jabodetabek" (Greater Jakarta), "Bandung Raya (BMA)", "Gerbangkertosusila" (Surabaya MA), and "Solo Raya" (Surakarta MA). This condition implies that those four metropolitan areas have better economic performance vis-a-vis other regencies and municipalities in Java. On the other hand, RSI_2 (Figure 2 (b)) shows different situation. Most of the regencies and municipalities are dominated by low until moderate value. Meanwhile, Figure 2 (c) exhibits that regencies and municipalities in Java are mostly dominated by very low until low value for RSI_3. Only a small number of regencies and municipalities have moderate value. At the provincial level, West Java Province is dominated by very low value of RSI_3, while Central Java Province, Special Region of Yogyakarta and East Java Provinces are dominated by low value of RSI_3.

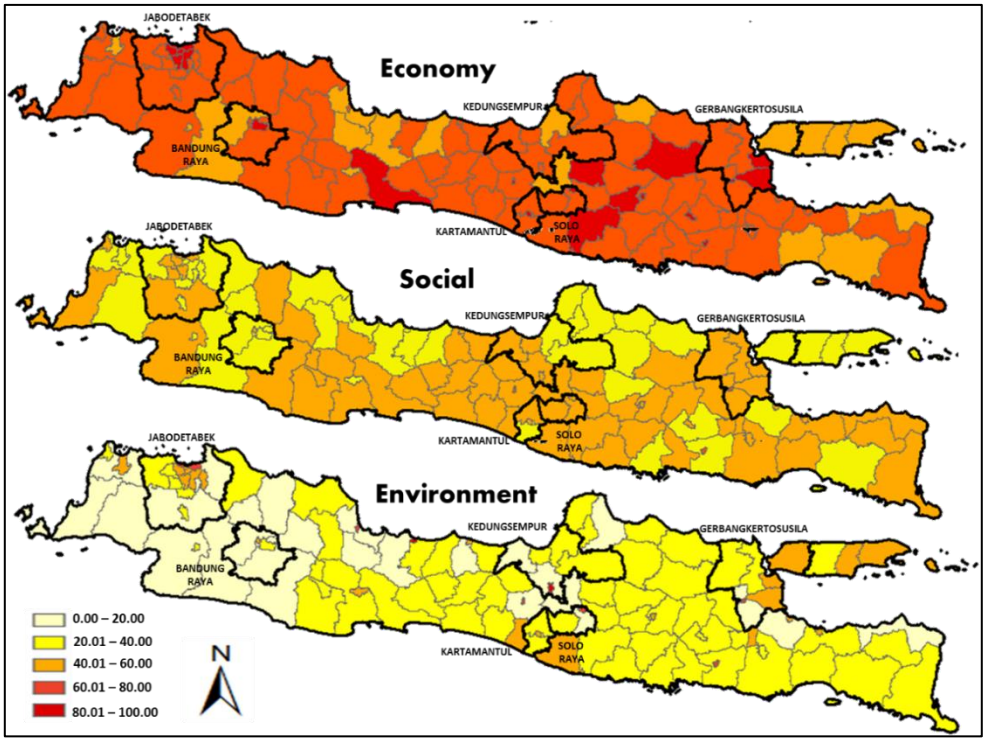

Figure 2. (a) Regional Economy Index (RSI_1); (b) Regional Social Index (RSI_2); (c) Regional Environmental Index (RSI_3).

Table 6. Minimum, maximum and average value of economic, social and environmental sustainability index in six metropolitan areas of Java.

Kawasan Metropolitan	Local Sustainability Index								
	Economy			Social			Environmental		
	min	max	average	min	Max	average	min	Max	Average
Jabodetabek	60.48	153.93	80.43	32.03	55.55	42.12	18.85	66.36	39.5
Bandung Raya	55.15	89.75	69.75	37.39	41.42	39.19	5.07	52.85	27.01
Kedungsepur	58.52	74.88	66.52	33.48	49.66	42.07	5.72	88.52	33.47
Kartamantul	68.07	107.88	82.75	39.97	56.04	47.84	27.29	40.83	34.32
Gerbang Kertosusila	46.95	85.52	74.82	30.15	60.84	44.42	7.31	74.61	41.28
Solo Raya	65.82	103.87	78.85	44.16	56.28	48.34	19.17	72.54	41.27

Comparing the local sustainability index for each dimension, it can be seen that the Jabodetabek metropolitan area has the highest economic sustainability index, while the highest social and environmental sustainability index is shown by the metropolitan areas of Gerbang Kertosusila and Kedungsempur (see Table 6). Furthermore, based on Figure 3, it can be gleaned that in general, the state of sustainability of regencies/municipalities within the metropolitan areas in Java are relatively better compared to those of non-metropolitan areas.

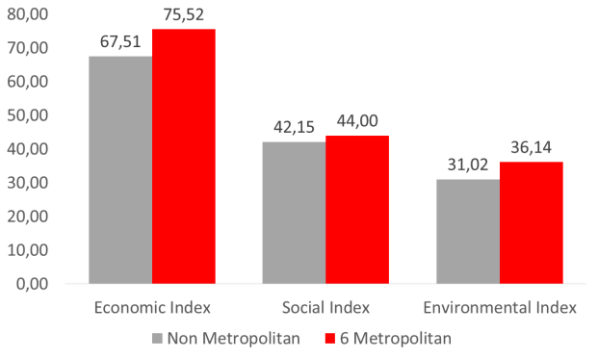

Figure 3. Comparison of sustainability performance between metropolitan and non metropolitan areas.

The final output of this study is to produce a cluster map of regencies and municipalities based on their regional sustainability index value (RSI_1, RSI_2, and RSI_3). There are 27 groups/typologies that were derived by combining the value of RSI for all three dimensions (Figure 4). Based on our analysis, there are only 8 typologies produced by this clustering analysis. The distribution of regencies/municipalities for each cluster can be seen in Figure 5.

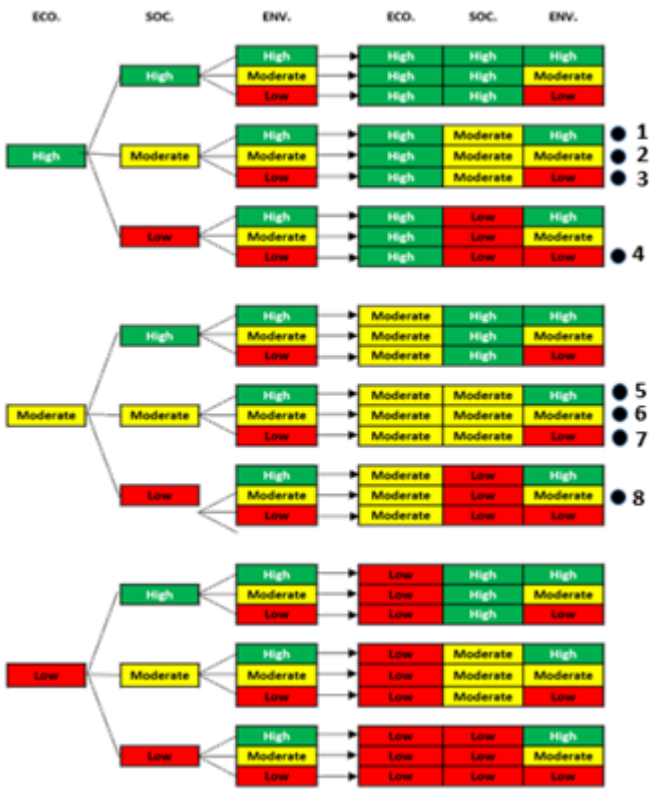

Figure 4. Combination of Typologies Based on RSI_1 (Economy), RSI_2 (Social), and RSI_3 (Environmental) Index Value.

The principal of clustering analysis is minimizing varians within group and maximizing varians between group. It means that there is a distinction between groups/clusters; however, each group/cluster shows the similarity within the members. Based on the cluster analysis (Figure 5), there is no regency/municipality that has high value of RSI for all dimensions. Based on the analysis, cluster 7 (moderate value in economic and social aspects and low value in environmental aspect) has the most members, comprising 46 regencies and municipalities in total (39%). Regencies and municipalities in Cluster 7 are scattered across the island of Java.

The second largest cluster is cluster 2, consistsing of 25 members in total (21.2%). Cluster 2 is characterized by high value of economy, moderate value of social and environmental index. Members of cluster 2 are also scattered across different regions in Java and are especially concentrated in 5 metropolitan areas, i.e., "Jabodetabek" (Greater Jakarta), "Bandung Raya (BMA)", "Gerbangkertosusila" (Surabaya MA), "Kedungsempur" (Semarang MA) and "Kartamantul" (Yogyakarta MA). A similar condition is also exhibited by cluster 3. This cluster consists of 16 regencies and municipalities in total.

In general, regencies and municipalities in cluster 2 and cluster 3 display strong economic performance, while their environmental dimension shows the opposite. Whereas, sustainability indicators reflect the reproducibility of the way a given society utilizes its environment [13]. Conceptually, as Kates et al. [14] put forward, one of the successes of sustainable development lies on its ability to serve as a grand compromise between those who are principally concerned with nature and environment, those who value economic development, and those who are dedicated to improving the human condition.

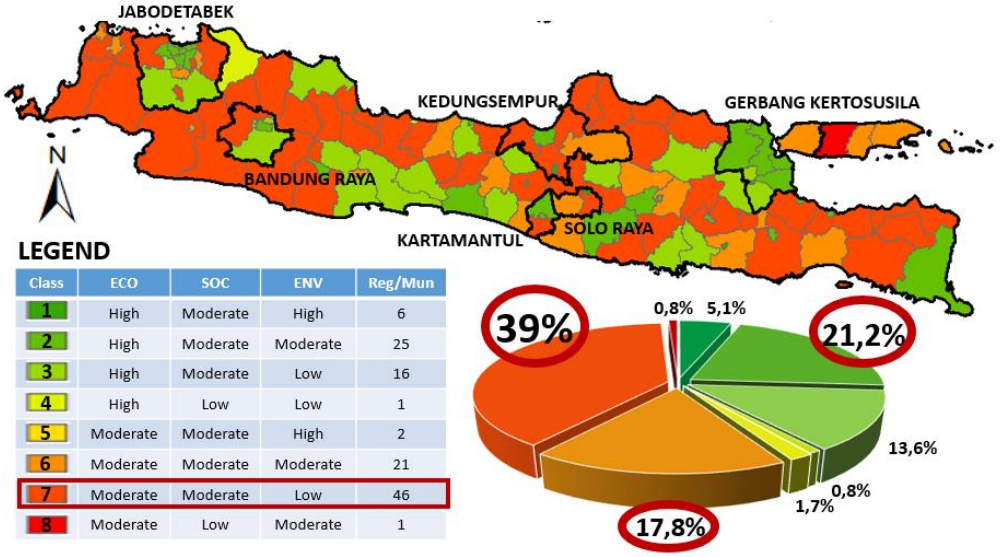

Figure 5. Cluster Map based on RSI_1 (Economy), RSI_2 (Social), and RSI_3 (Environmental) Index Value.

5. Conclusionsion

RSI is a new approach for assessing economic, social, and environmental conditions at the urban and regional level. Such an approach is expected to gauge urban (and regional) development in a more comprehensive manner as it aims to integrate the main dimensions of sustainability. As discussed above, every regency/municipality in Java is experiencing diverse sustainability performances. Most of the localities that are part of the metropolitan areas have a relatively better economic, social, and environmental condition vis-a-vis those located outside these metropolises. Based on the spatial distribution map of RSI1, RSI2 and RSI3, there is no regency/municipality in Java that has high value of RSI for all dimensions. Instead, most of these localities have moderate and low value of RSI.

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