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THE INFLUENCE OF SPRAWL DEVELOPMENT, INCOME, AND INFRASTRUCTURE ON ENERGY CONSUMPTION IN CENTRAL JAVA PROVINCE, INDONESIA

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Abstract: *Energy consumption is influenced by many factors. Sprawl development is often alleged as on of its driving factors. Other factors like the increase of community welfare and the improvement of regional infrastructures are often indicated to trigger energy consumotion. This study is aimed at investigating the influence of sprawl development and other relevant factors on the energy consumption in Central Java Province, Indonesia. Other variables denoted to influence energy consumption used in this study are road density, people's income represented by local Gross Domestic Product (GDP) per capita, and GDP growth rate. The observed energy is limited on vehicle fuels. After investigating the significance of correlations among variables, a multiple regression model is employed. By eliminating GDP per capita because of its multicollinearity with other dependent variables, the development formula shows that fuel consumption is generated by 47.84 of sprawling index, added by 17.26 of road ratio and 17.5 of GDP growth rata, and reduced by a constant of 26.18. These measurements are expected to be useful for urban and regional managers in developing their region, especially in estimating the fuels' consumption considering the determined regional policies.*

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1. INTRODUCTION

It is well acknowledged that to achieve the equity of intra- and inter-generational by exploiting the resources without compromising the rights of the future generations is the main goal of sustainable development (WCED, 1987). Efficiency, sustainability, and equity are the problems regarding land management issues in facing population growth and economic intensity (Munashinge, 1994; Sugiri, Buchori, & Ma'rif, 2015). Sustainable development is the framework on how the community should define a long term perspective of resource exploitation (Amir, Ghapar, Jamal, & Najiah, 2015). It aims at achieving economic resilience and ability to contribute to regional development and suitable environmental management (Omer, 2008).

In term of regional development, balancing among economic, social, and environmental aspects should get attention. It is difficult to gain sustainable development when, for example, the conflict between economic growth and environmental concerns in a region is so prominent. On the one hand, economic development can bring to social welfare situation, but on the other hand, it can endanger environmental sustainability. In this regard, how to efficiently use natural resources is therefore important, particularly on maintaining the sustainability of regional development (Rehman & Rashid, 2017).

One of natural resources being important to drive the wheel of economic development is energy. Unfortunately, most energy used in under-developed and developing countries where access to renewable energy is a serious constrain is un-renewable energy (Rehman & Rashid, 2017). The relationship between urban form and energy consumption was actively studied during the early 1970s, when concerns about the security of the energy supply gave rise to a wave of research aimed at evaluating the efficiency of the current state of energy consumption

(Safirova, Houde, & Harrington, 2007). The previous research confirmed that population growth and land use become important factors influencing the usage of energy (Kenworthy & Newman, 1990; Lion & Moavenzadeh, 2015; Yongling, 2011)

As the centre of population, economy, culture and political power, mega-cities takes the role on becoming the source of energy consumption, resource depletion, and pollution (Alam, Murad, Noman, & Ozturk, 2016; Amri, 2017; Gaspar, Marques, & Fuinhas, 2017). According to Lion and Moavenzadeh (2015), urban sprawl is a major source of energy inefficiency, not only does it lead to more vehicle-miles travels, more fuel consumption, more air pollution, but also to inefficiencies in infrastructure provision. They believe that the increase in both energy services and materials de-densification is affected by the extents of residential and commercial districts. It was revealed that sprawl development has used five times more pipe and wire, five times as much heating and cooling energy, twice as many building materials, three times more automobiles, and causes four times as much driving. Besides, it also consumes 35 times as much land, and requires 15 times as much pavement as compact urban living (see Lion & Moavenzadeh, 2015).

Improvement in energy efficiency is an important key to take towards sustainable development, especially in under-developed and developing countries. They should take care of their growing demand for energy and attempt to find best solutions for decreasing their demand of energy and increasing their efficiency (Lion & Moavenzadeh, 2015). Unfortunately, many cases of metropolitan regions in Indonesia show the tendency of unsustainability in energy consumption (Buchori & Sugiri, 2016; Buchori, Sugiri, Hadi, Wadley, & Liu, 2015; Buchori, Sugiri, Maryono, & Pramitasari, 2017; Sugiri, Buchori, & Soetomo, 2011). A previous study in Semarang Metropolitan region, the heart of Central Java Province, shows inefficient use of energy for transportation in conducting spatial interactions among locations (Buchori et al., 2015; Sugiri & Buchori, 2016). Regarding those facts, it is interesting to investigate the factors influencing energy consumption in Central Java Province. The investigation is concerned on observing empirical evidences about the relationship between fuel consumption and other aspects. The results are expected to be useful for urban and regional managers in arranging scenarios of regional development and estimating fuels' consumption in the following years.

Many studies in urban and regional planning reveal that urbanization and metropolitan development have become an interesting issue (Jiang, Ma, Qu, Zhang, & Zhou, 2016). The phenomenon of urbanization frequently occurs in developing countries where the people living in ruralized areas intend to move to big cities, aiming at getting better economic opportunities and improving their quality of life (Soh, 2012; Wu & Zhang, 2012). The rapid growth of urbanization has resulted a diverse landscape with urban and rural land uses (Tsuchiya, Hara, & Thaitakoo, 2015). It represents a trend of demographic change leading to a worldwide land use change (Grimm, Grove, Pickett, & Redman, 2008), covering urban and rural areas in the context of rural-urban relationships (Lambin et al., 2001).

Urbanization is considered as a social process in which the rural society turns into an urban characterized society indicated by the rapid population growth and the expansion of economic activities (Soh, 2012; Wu & Zhang, 2012), particularly in metropolitan areas (Jiang et al., 2016). Regarding this situation, the issue of urban sprawl has also become an interesting topic for being further studied (Altieri et al., 2014; Jiang et al., 2016; Mosammam, Nia, Khani, Teymouri, & Kazemi, 2016; Sun, Wu, Lv, Yao, & Wei, 2012; Zeng, Liu, Stein, & Jiao, 2015). The term of urban sprawl is often used to describe low-density urban areas in suburban areas (Zeng et al., 2015), or inefficient urban development in rural areas (Altieri et al., 2014).

Several studies have attempted to characterize the compactness of urbanization by measuring spatial characteristics of a certain area, associated and compared with the metropolitan area (Burchell et al., 1998; Hasse & Lathrop, 2003). Although it grows to be highly multi-dimensional and dynamic, urban sprawl can be measured in various dimensions, such as fragmentation, cohesiveness, and spatial configuration (Lv, Dai, & Sun, 2012; Seto & Fragkias, 2005; Zeng et al., 2015). If uncontrolled, urbanization and urban sprawl will not only cause a shift of socio-economic but also ecological and environmental aspects. This can certainly affect significantly the environmental quality (Wu & Zhang, 2012). Therefore, monitoring the pattern of urban growth and its changes is important to reduce unintended ecological consequences in the future (Sun et al., 2012).

Some studies have resulted that city's density affects the level of energy use. A study by Steemers (2003), for example, shows that a high level of urban density of Hong Kong City has a lower level of demand for transport energy per capita than that of Houston City having a lower level of urban density. It corresponds to the study of Su

(2011) representing that in U.S urban areas, households with higher freeway densities, higher levels of congestion, or lower population densities use more gasoline. Furthermore, Shammin, Herendeen, Hanson, & Wilson, (2010) argue that the use of energy per household in low-populated areas (less than 125,000) is 19% more intensive than that in densely populated areas (more than 4 million). They also state that the households in rural areas consume more intensive energy, that is, 17% more comparing to those in urban areas.

Not only in terms of density, changes in urban structures can lead to changes in energy consumption (Mindali, Raveh, & Salomon, 2004). In the sprawl process, commercial land use tends to follow the sprawl pattern along the main road (Jiang et al., 2016). The unplanned and sprawl city is often considered as the cause of inefficiency in energy consumption. The people living in a sprawl residential areas have been forced to become a commuter, which in turn require more energy consumption for transportation (Kenworthy & Newman, 1990).

Located on the fringe areas of the city, people living in the sprawl area requires a longer travel time to reach the city centre. It increases the risk of traffic jam, and certainly impacts to the energy consumption (Bhatta, 2010). The increase of urban density is expected to lead to a decrease in energy consumption (Mindali et al., 2004). Therefore, a compact area consumes less energy for transportation. Reducing the usage of cars is able to contribute to the annual energy saving (Shammin et al., 2010). Accordingly, some aspects can be determined to influence the fuel consumption, that is, urban sprawl (Hamidi, Ewing, Preuss, & Dodds, 2015; Karathodorou, Graham, & Noland, 2010; Mindali et al., 2004), length of travel (Kouris, 1984; Noland, 2000; Su, 2011), and people's welfare and income (Alam et al., 2016; Antonakakis, Chatziantoniou, & Filis, 2017; Ramanathan, 2006; Zaman & Moemen, 2017). Therefore, the study aims to measure the influence of those aspects on energy consumption. Furthermore, those aspects are adjusted as the variables observed in this study, that were derived into four quantifiable variables, namely: (1) sprawl index representing urban sprawl level; (2) road density indicating the length of trips that the community can do; (3) GDP per capita and (4) GDP growth rate indicating the level of people's welfare and income.

2. DATA AND METHODS

2.1. Data

This study is mainly based on secondary data. The data are the most actual data that can be obtained during the research period, considering that data availability is still often encountered in developing countries, including Indonesia. The analysis unit is regency/city, the second level of administrative subdivision in Indonesia under provincial level. A city is attributed to the second administrative subdivision having more significant urban activities. If the urban and rural activities are relatively equal, the it is set as a regency. According data availability, fuel consumption (2014), Gross Domestic Product (GDP) (2010 and 2014), Length of Road System (2014), and population (2010, 2014, and 2015) data by regency/city in Central Java Province were obtained from the Statistic Office of Central Java Province.

To develop the built-up area maps, a 741-band combination of Landsat TM7 for the year of 1990 and 2011 was used. The administrative map representing Central Java Province by regency/city and the road map representing the main roads in Central Java Province were digitized from the base map provided by the Geospatial Information Agency (*Badan Informasi Geospasial*/BIG) of Indonesia on the scale of 1:25.000.

2.2. Methods

This study involves three stages of analysis, that is, (1) to identify the spatial distribution of fuel consumption per capita, sprawl index, road density, GDP per capita, and GDP-growth rate, detailed by regency/city in Central Java Province, (2) to analyse the relationship between the fuel consumption per capita as the dependent variable (Y) and the four independent variables (X), and (3) to develop a regression formula that can explain the behaviour of the determined dependent variable in terms of the independent variables.

Sprawl index is the ratio between the growth rate of population and that of built-up areas during a certain period. The higher the value of the index, the better and more compact the regency/city. If the index less than 1, it means that the regency/city tends to be a non-compact regency/city. Otherwise, if it exceeds 1.00, the regency/city tends to be compact.

The growth rate of population is based on the population by regency/city in 2010 and 2015, while growth rate of built-up areas is based on the built-up maps in 1990 and 2011. To compute this, the first stage is to define the shift of build-up areas. For this a 741-band combination of Landsat TM7 for the year of 1990 and 2011 was interpreted using a simple unsupervised classification technique of satellite image processing. A manual digitation technique was further done in this process using ArcGIS tools. The map of built-up area by regency/city was developed by superimposing the built-up area with the regency/city administrative map. The next stage is to compute the growth rate of built-up areas using the rate formula of exponential growth.

The road density map is total length of the roads (2014) divided by the area of regency/city. GDP-growth is the rate of GDP during a certain period. It is the difference between GDP in the year of 2014 and 2013, divided by the GDP in the year of 2013. Meanwhile, the average of people's income is indicated by the GDP per capita, computed by diving the GDP with the population by regency/city.

The correlations between the dependent and independent variables is based on the Pearson correlation test (R^2). The multiple linear regression analysis is employed to develop the regression formula, so that the behaviour of the dependent variable (Y) in terms of the independent variables (X) can be drawn. The results of correlation analysis and the regression formula are then further discussed to answer the research question.

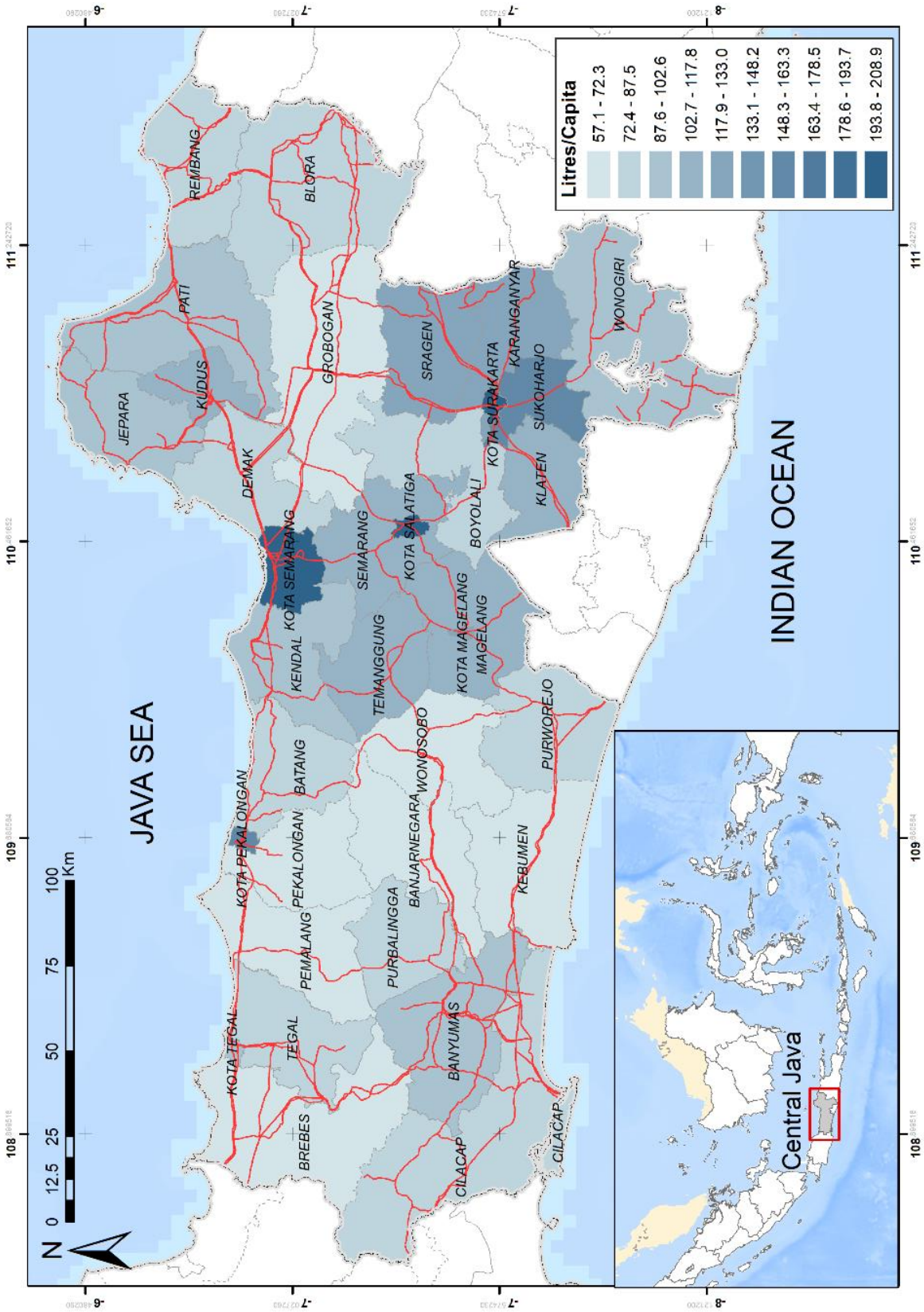
3. RESULTS AND DISCUSSION

3.1. Fuel Consumption per Capita in 2014

Figure 1 represents the fuel consumption per capita detailed by regency/city of the Central Java Province. Some regencies/cities of growth pole centres seem to have higher fuel consumption per capita than other regencies. Semarang and Surakarta, two big cities, which is the centre of the growth triangle corridor often known as Joglosemar (an acronym of Yogyakarta, Solo or Surakarta, and Semarang), consume much higher fuel per capita than other districts. Pekalongan City as a hub city along the corridor of Jakarta-Semarang also consumes higher fuel per capita than others. The regencies of Brebes, Pemalang, Grobogan, Banjarnegara, and Kebumen have lower consumption of fuel per capita than other regions. As for Grobogan Regency, its location being stuck in the middle on the east-northern side of Central Java Province has lower fuel consumption per capita comparing to its surrounding regencies.

The regencies located close to the pole cities, that is, Wonogiri, Karanganyar, Sragen, and Klaten surrounding Surakarta City and Demak and Kendal being close to Semarang City, seem to have a higher level of fuel consumption per capita than others. Besides, the regencies located on the triangle corridors of Joglosemar also consume more fuel per capita. In the corridor of Semarang-Solo, a part of Joglosemar triangle development corridors, the highest fuel consumption rate per capita is accounted for Salatiga City, which is almost the same as that of Semarang and Surakarta.

Generally, regencies/cities located on the north coastal Java (Pantai Utara Jawa/Pantura) main road, except for Brebes and Pemalang regencies, consume prominent level of fuel per capita. However, the regencies located on the central part of Central Java Province, stretching from the northern to southern parts, that is, Pemalang, Pekalongan, Banjarnegara, and Kebumen, have relatively low average fuel consumption per capita than their surroundings.

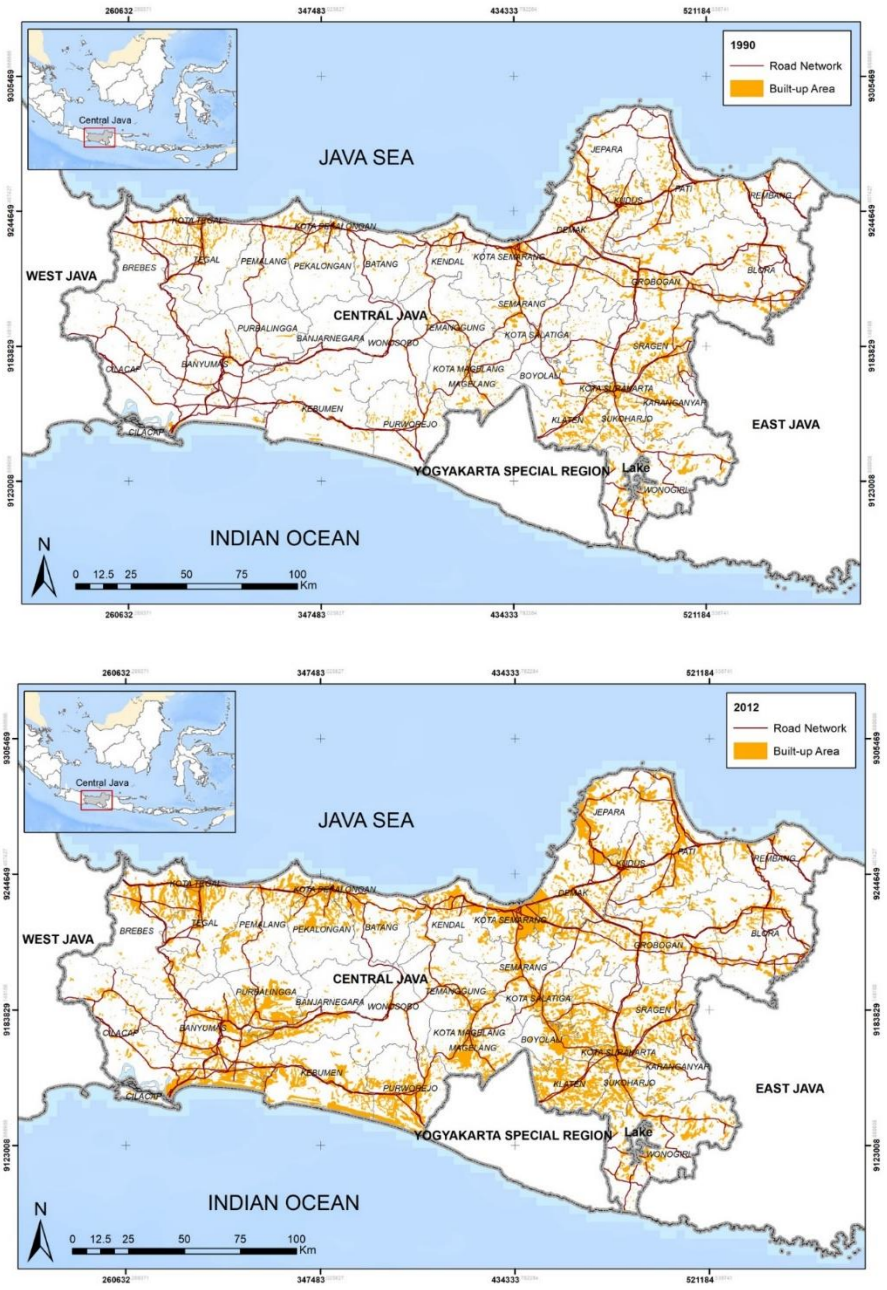


Source: analysed from the data Statistic Office of Central Java Province, 2016

Figure 1. Fuel consumption per capita by regency/city of Central Java Province in 2014

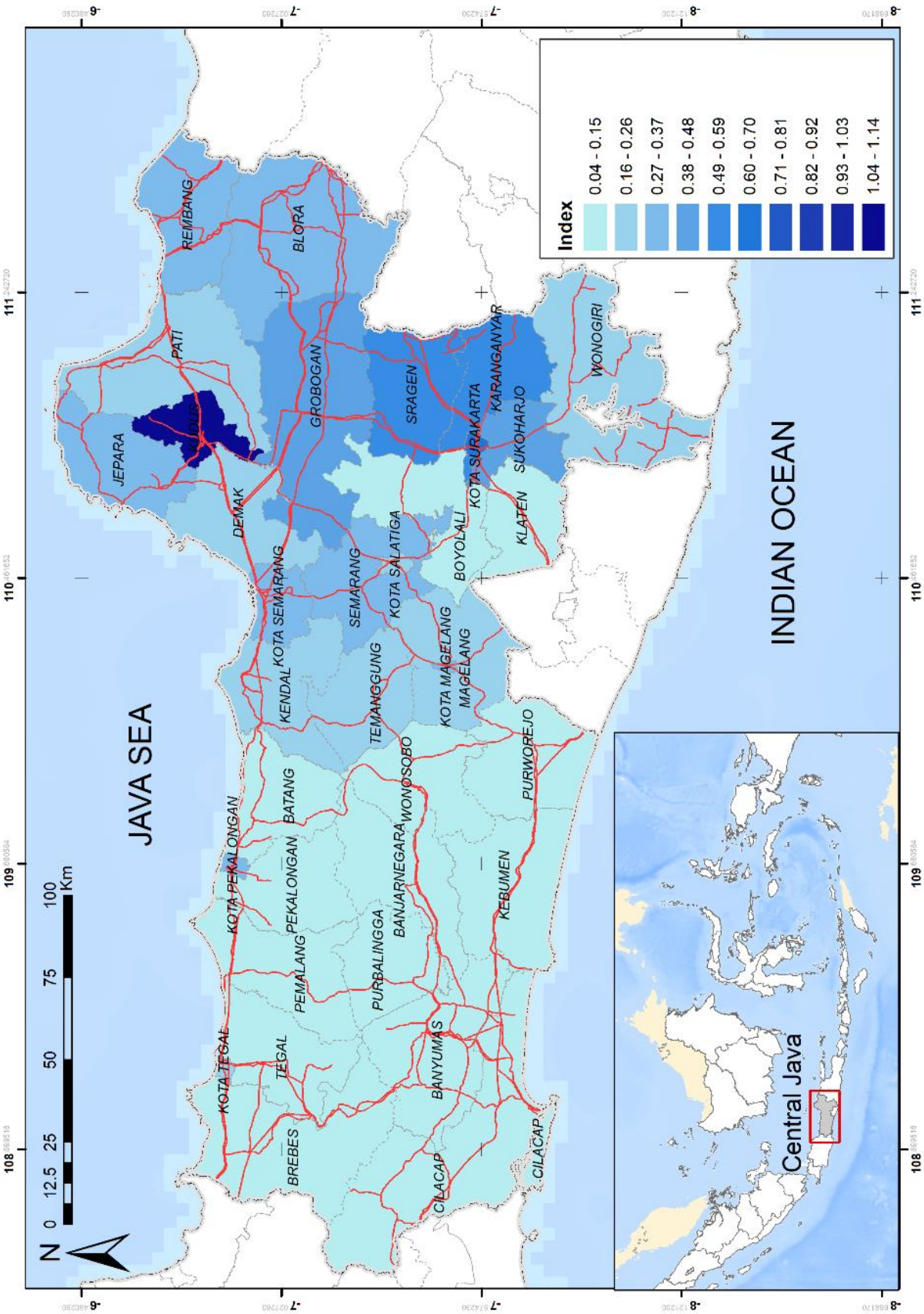
3.2. Sprawl Index

Sprawl index is defined as ratio of the rate of population size to built-up areas. Figure 2 shows the distribution of built-up areas of Central Java Province for the years of 1990 and 2011, detailed by regency/city. Those maps were developed using an unsupervised classification technique of Landsat TM7. By comparing those maps, a significant growth of built-up areas spreading in the whole region can be identified. It mainly appears along the main roads, that is, the north coast road of Java connecting Jakarta, Semarang, and Surabaya, the south coast road of Java connecting Bandung and Yogyakarta, and the roads connecting triangle development corridors of Joglosemar (an acronym of Yogyakarta, Surakarta, and Semarang). A significant growth in the central part of the province appears in the corridor connecting Purwakerto and Temanggung. However, the growth in Purwokerto and its surroundings looks more rapidly.



Source: refined from Buchori et al. (2017)

Figure 2. Built-up areas of Central Java Province in 1990 (top) and 2011 (bottom)



Source: analysed from the data Statistic Office of Central Java Province, 2016

Figure 3. Sprawl Index by Regency/City in Central Java Province

Figure 3 shows the map of sprawl index by regency/city of the Central Java. It shows that sprawl phenomenon appears in the whole region. The strong tendency of non-compact development looks in Kudus Regency. However, the development in the Joglosemar triangle corridors and their surrounding regions on the eastern part of Central Java looks more compact than other regions on the western part.

3.3. Road Density by Regency or City in 2014

Road density represents the level of mobility of a region. Figure 4 shows the map of road density by regency/city in Central Java. It represents that the road density of cities (Semarang, Salatiga, Surakarta, Magelang, and Pekalongan, Tegal) is higher than that of regencies. However, some regencies that capital city is a growth pole like Banyumas, Kudus, and Wonosobo also have a higher road density. The higher value of road density in Purworejo, Kendal, Klaten, Sragen, and Karanganyar seems to be affected by its proximity location to the Central Java's big cities. They also belong to the metropolitan regions of Central Java, that is, Kedungsepur (an acronym of Kendal, Demak, Ungaran, Semarang, Purwodadi) and Subosukowonosraten (an acronym of Surakarta, Boyolali, Sukoharjo, Karanganyar, Wonogiri, Sragen, and Klaten).

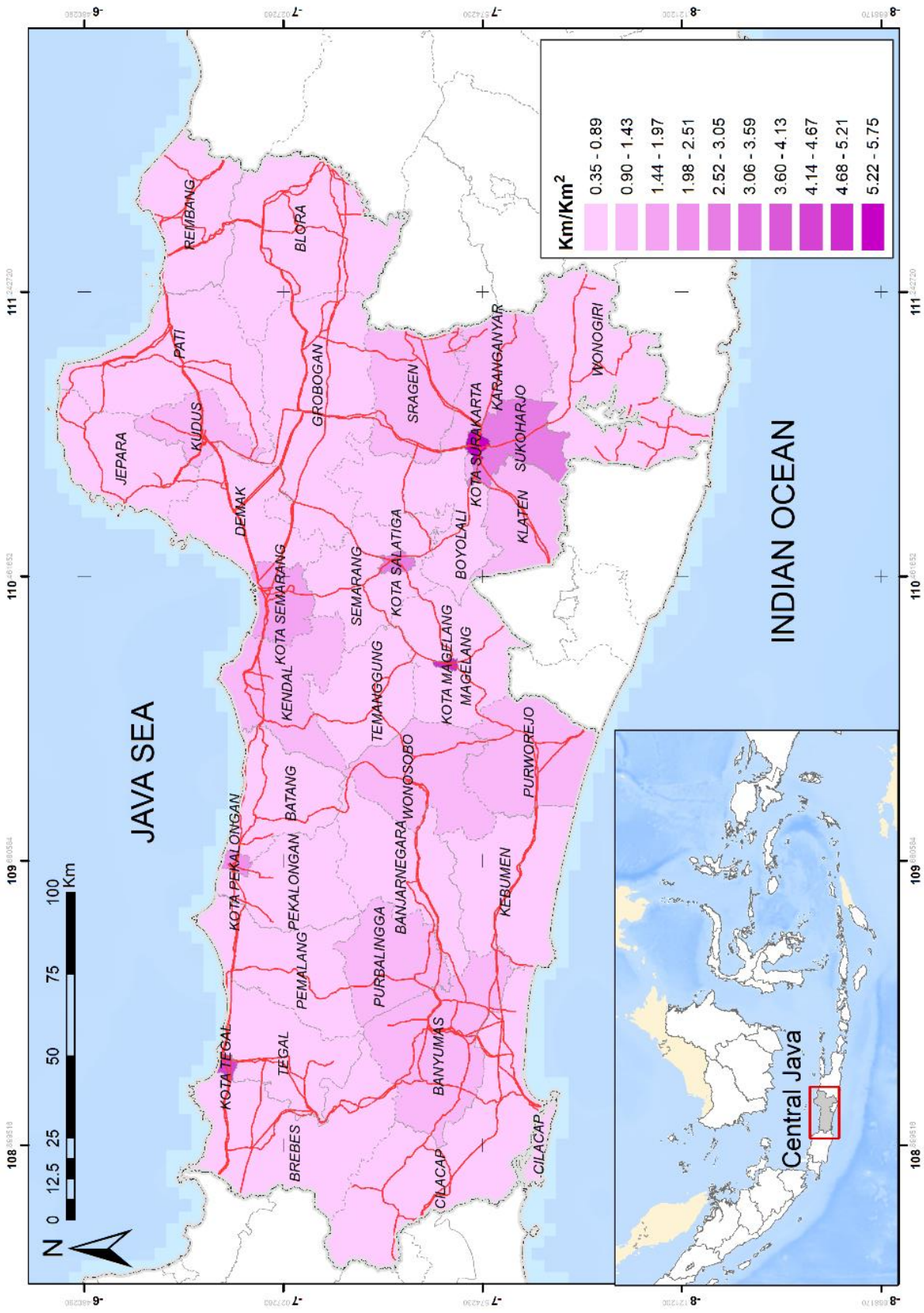
3.4. GDP per Capita in 2014

The welfare level of a community is often associated with the level of their energy consumption. In this study, the variable of welfare level of the community is represented by two indicators, namely GDP per capita and GDP growth rate. Figure 5 shows the spatial distribution of GDP per capita, detailed by regency/city of Central Java Province in 2014. Semarang, City, Kudus, and Cilacap Regency are the biggest three regions in terms of GDP per capita. However, it is interesting that Kudus Regency is the highest because usually, the highest level of income per capita is the capital city of the province. A cigarette factory (named PT Djarum) located in Kudus Regency is alleged to be the largest contributor of GDP to this regency. Semarang City as the capital city is on the second position next to Kudus Regency.

The five regencies with the lowest level of GDP per capita are, respectively, Pemalang, Grobogan, Kebumen, Demak, and Banjarnegara. It interesting that Pemalang and Demak located in Pantura road have low GDP per capita. Similarly, Kebumen District is located in the main road of southern coastal Java. Grobogan with its pinched position and lack of access is reasonable if it has a low level of GDP per capita. Similarly, Banjarnegara is located in the central part of Central Java Province, but not in a strong regional trade route.

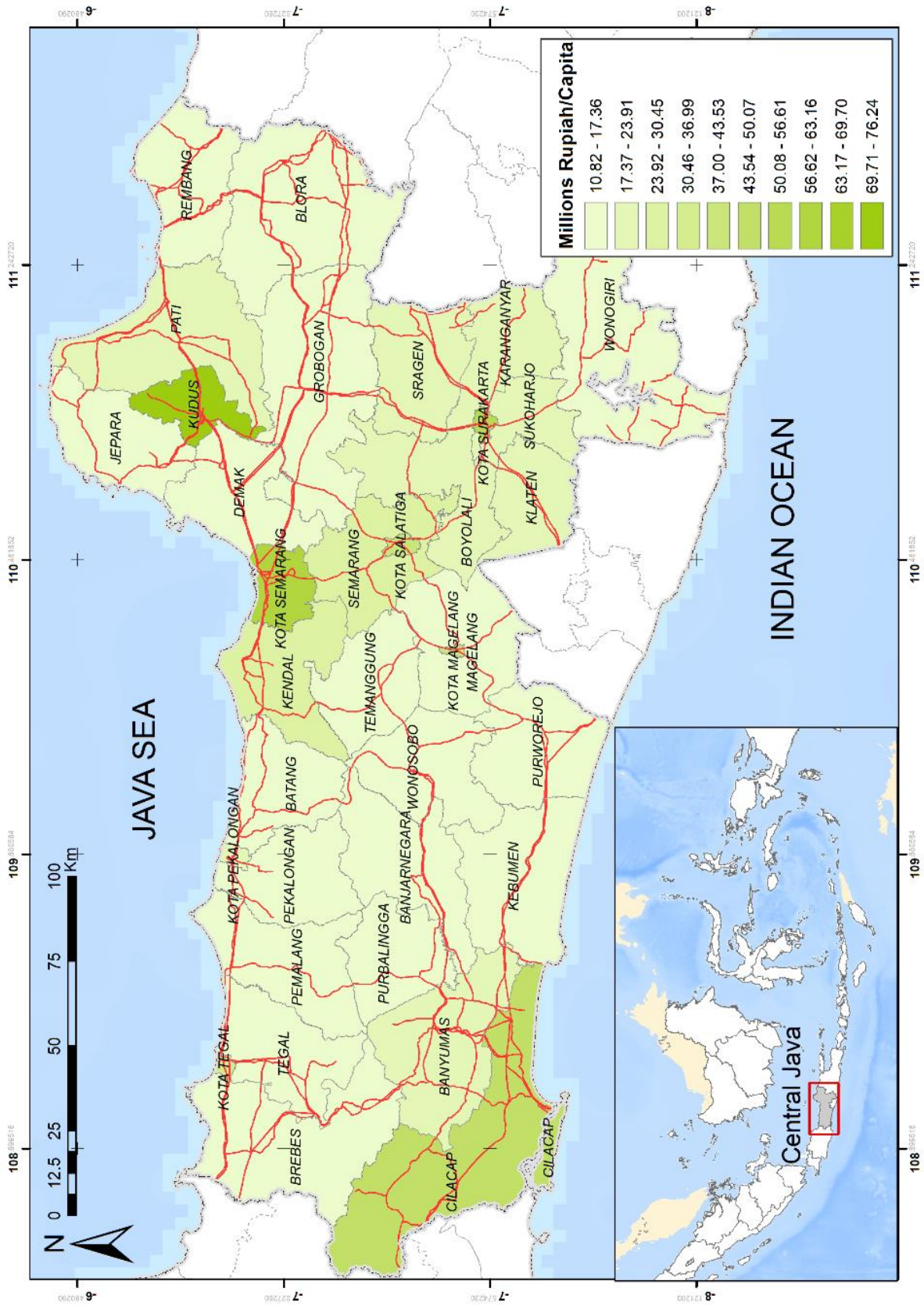
3.5. GDP Growth Rate (2013-2014)

Figure 6 shows the spatial distribution of GDP growth rate by regency/city in Central Java Province. The regencies/cities located on the Joglosemar triangle development area grows more rapidly than others. Similarly, the GDP growth rate of the regencies/cities located on the western side of the province which stretches from north to south, namely Tegal City, Tegal Regency, Brebes, and Banyumas, is relatively high. However, Banyumas Regency has the highest rate and seems to be the growth pole city of the main road of south coastal Java. An interesting fact is found in the Kudus Regency. Although its GDP per capita is the highest in the province, its GDP growth rate is quite low comparing to others.



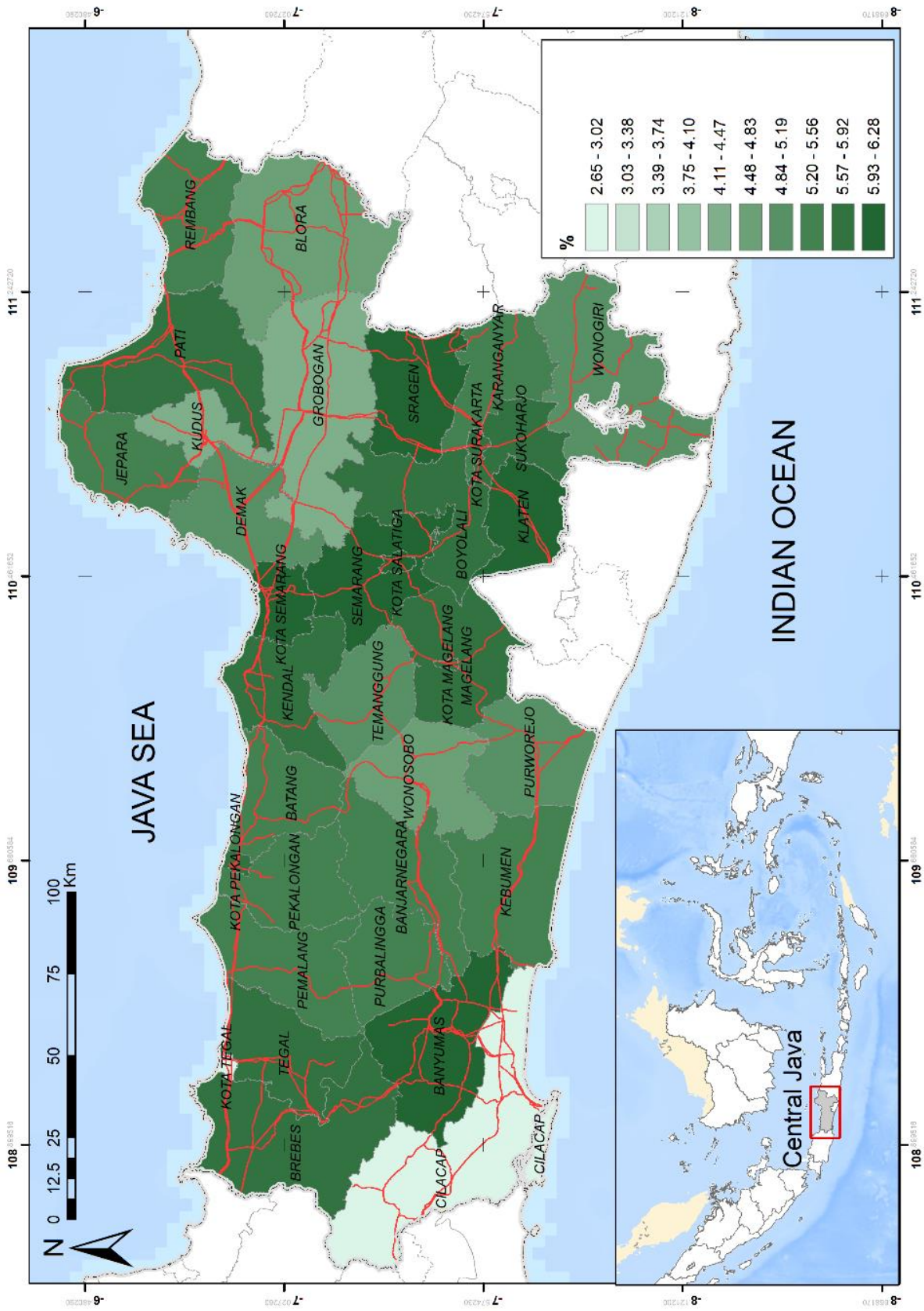
Source: analysed from the data Statistic Office of Central Java Province, 2016

Figure 4. Road Density by Regency/City in Central Java Province



Source: analysed from Statistic Office of Central Java Province, 2016

Figure 5. GDP per Capita by Regency/City in Central Java Province in 2014



Source: analysed from Statistic Office of Central Java Province, 2016

Figure 6. GDP Growth Rate by Regency/City in Central Java Province

3.6. Correlation Analysis and Regression Formula

Correlation analysis is applied to determine the level of relationship between two variables. Table 1 shows that the correlation between fuel consumption with sprawl index, road density, GDP per capita, and GDP growth rate are 0.014, 0.000, 0.000, and 0.037, respectively. If the significance value less than 0.005, it means that a correlation between variables exists. In this case, the variable of fuel consumption per capita as a dependent variable has a correlation with the four independent variables defined. The smaller the value of significance the greater the level of correlation. Thus, the dependent variable with the highest value of correlation is GDP growth rate, while the lowest is sprawl index and GDP per capita.

Furthermore, the coefficient of determination is used to analyse the effect of independent variables to the dependent variable. The result shows that the R square value is 0.698 (69.8%). It indicates that all independent variables (sprawl index, road density, GDP per capita, and GDP growth rate) have simultaneously affected about 69.8% on the dependent variable (fuel consumption). Meanwhile, the rest (30.2%) is influenced by other factors.

Table 1. Correlation among variables

		Fuel Consumption	Sprawl Index	Road Density	GDP per Capita	GDP Growth Rate
Fuel Consumption	Pearson Correlation	1	.411*	.649**	.641**	.353*
	Sig. (2-tailed)		.014	.000	.000	.037
	N	35	35	35	35	35
Sprawl Index	Pearson Correlation	.411*	1	.287	.610**	-.028
	Sig. (2-tailed)	.014		.095	.000	.871
	N	35	35	35	35	35
Road Density	Pearson Correlation	.649**	.287	1	.519**	-.009
	Sig. (2-tailed)	.000	.095		.001	.961
	N	35	35	35	35	35
GDP per Capita	Pearson Correlation	.641**	.610**	.519**	1	-.158
	Sig. (2-tailed)	.000	.000	.001		.363
	N	35	35	35	35	35
GDP Growth Rate	Pearson Correlation	.353*	-.028	-.009	-.158	1
	Sig. (2-tailed)	.037	.871	.961	.363	
	N	35	35	35	35	

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

Table 2. Coefficients of Regression

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-26.180	29.538		-.886	.382
Sprawl Index	47.842	21.939	.255	2.181	.037
Road Density	17.216	3.477	.579	4.951	.000
GDP Growth Rate	17.495	5.366	.366	3.260	.003

Dependent Variable: Fuel Consumption

The next stage is to develop the multiple regression formula. As shown in Table 1, the independent variable of GDP per capita has a significant correlation with other three independent variables. While among the variables of sprawl index, road density, and GDP growth rate, a correlation does not occur. To avoid a multicollinearity among independent variables, the variable of GDP per capita is eliminated from the formula. Therefore, the final formula is: Y = -26.180 + (47.842X1) + (17.216X2) + (17.495X4), where Y = fuel consumption, X1 = sprawl index, X2 = road density, and X4 = GDP growth rate (see Table 2). The equation implies that an addition of 0.1 index sprawl will result in an increase of 4.78 litres in fuel consumption per capita, an addition of 0.1 road density will add 1.72 litres of fuel consumption per capita, and an addition of 0.1 GDP growth rate will increase 1.75 litres of fuel consumption per capita.

3.7. Discussion

The spatial distribution of fuel consumption's level per capita in Central Java generally suits to the spatial pattern of GDP per capita and road density. Higher fuel consumption occurs in the sprawl areas along the main road of North Java Coastal Areas. However, it is quite different from the study of Shammin et al. (2010) stating that households in rural areas consume more energy than those in more urbanized areas. The difference could be instigated from the use of fuel as the only indicator of energy, so that the comparison is not "apple to apple". In term of inefficiency of energy consumption for transportation in sprawl areas, the result of this study confirms that of some previous studies (Kenworthy & Newman, 1990; Mindali et al., 2004; Su, 2011).

High correlation among fuel consumption per capita, road density, and sprawl index represent an inefficiency of fuel consumption in the sprawl areas and in the areas with high road density. Whether inefficiency affected by higher freeway density as shown in the study of Su (2011) also occurs in Central Java has not been yet clarified because the data unit of this study is based on regency/city. To verify this question, further investigation using more detail data unit is therefore required.

Furthermore, the analysis shows weak correlation between road density and GDP growth rate. It implies that developing a proper strategy for road development network is important for local governments. The strategy of increasing regional accessibility should be directed to support the system of local collection and distribution of the region. Doing so is expected to have a direct impact on improving the welfare of community, which in this study is represented by the variable of GDP growth. In this Central Java case, road development without proper strategy will just imply to the increase of fuel consumption without positive impacts to the people's welfare.

The positive correlation between sprawl index and GDP per capita shows that the expansion of land uses for non-agricultural activities may instantly increase the people's income in a shorten period. However, it will potentially bring negative impacts in the longer period, which in this case is represented by the negative correlation between sprawl index and GDP growth. Urban and regional managers, particularly in developing proper strategies that can control the widespread development of sprawling suburbs, should consider these facts.

GDP per capita in big cities tends to be higher than that of other regencies. In other words, the economic level of urban areas is higher than other regions. However, the highest GDP per capita occurs in Kudus Regency, not in Semarang City that is also the capital city of the province. However, its GDP growth rate is lower than other regencies/cities. It means that GDP per capita is not always linearly correlated to its growth rate. Considering that GDP growth is often used as an indicator of new jobs available, the local government should anticipate this issue, although it's GDP per capita is relatively high.

Among variables, road density is the most influenced variable to energy consumption per capita, followed by GDP per capita, sprawl index, and GDP growth rate, respectively. Availability of road and better people's income spur the people to travel, which in turn increases the fuel consumption. Urban sprawl also potentially increases the length of trips, which in turn also increases the fuel consumption. These facts confirm the previous studies (for instances: Jiang et al., 2016; Kenworthy & Newman, 1990; Steemers, 2003) showing that a compact city is more efficient in term of energy consumption. It implies that some strategies for minimizing sprawl through, for examples, controlling the land use change for housing in the peri urban areas, developing zoning regulation for urban and peri urban areas, giving incentive for compact development, etc., could be adjusted as proper instruments in controlling fuel consumption.

4. CONCLUSION

This study concludes that fuel consumption is influenced by the determined independent variables, that is, sprawl index, road density, and GDP growth rate. This finding confirms the previous studies perceiving that spatial distribution of fuel consumption per capita follows the pattern of the people's incomes and road density. Besides, the level of sprawl also potentially increases the level of fuel consumption. The concentration of high consumption exists in the capital city of the province and other cities that serve as a growth pole for their hinterland areas. This pattern follows the pattern of the community welfare, represented in this study by GDP per capita.

In term of sprawl level, most regencies/cities of Central Java Province tend to be sprawl. However, the regencies/cities located on the eastern side of the province tend to be more sprawl than those on the eastern side. Furthermore, it was revealed that in term of road density, the value of road density of the big cities and the regencies in their surroundings seems to be higher than others. The results of this study indicate a relatively similar pattern among fuel consumption, sprawl index, road density, and GDP per capita. However, only GDP growth rate do have a little different pattern of spatial distribution.

This study still leaves some unanswered questions. For this, an outlook for further studies, such as minimizing the unit of analysis, adding such variables as availability of public transportation, availability of urban and regional facilities, using more detailed level of land use, etc., are recommended. With these advanced studies, the influence of various urban and regional variables to the level of fuel consumption can be better understood. In turn, proper policies relating to regional planning and development can be drawn. Besides, the results will also beneficial for other regions having the same characteristics as Central Java Province.

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