Pollution Analysis in Rural Areas in Indonesia Using the Multiple Correspondence Analysis (MCA) Method

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Abstract

Regional development is a driving force in advancing a country. In its application, it often causes a number of negative impacts, one of which is pollution. The pollution that is formed will vary in depth if it is broken down according to the distribution medium. This study measures the depth of pollution measured by index using the Multiple Correspondence Analysis (MCA) method. The data used in this study includes village data from the 2018 Podes data collection. The results of this study indicate that the soil pollution index is the index that plays the most important role in the formation of the pollution index in general. The range of the index formed was -10.02 to 0.37. Efforts from the government and local communities are needed, to anticipate the bad impacts that can be caused in order to preserve nature.

Keywords: Development, Multiple correspondence analysis (MCA), pollution

1. Introduction

Development is an important aspect of the country's goals. The state is asked to fulfill a number of aspects for the welfare of society. However, the existence of development often creates a number of problems in terms of the environment and public health (S. Chen, 2015; Landrigan, 2017; Li et al., 2014; H. Wang & Wheeler, 2003). Pollution problems can be exposed to water, soil and air media.

Pollution is a big problem in many countries (Desaigues et al., 2011; Islam et al., 2015; Siddharthan et al., 2018). However, on the other hand, the country must continue to carry out development. This phenomenon becomes two blades, on the one hand it will have a positive impact, but on the other hand it has a bad impact. Therefore, there are often differences of opinion between observers who are struggling for the sector they are engaged in.

Based on information from the Ministry of Health of the Republic of Indonesia, the times have led to an increase in industrial and transportation activities. This triggers air pollution (air pollution) which has an impact on health, especially in industrial areas and big cities. Air pollution has an impact on health including respiratory disorders, heart disease, cancer of various organs of the body, reproductive disorders and hypertension (high blood pressure). (Curtis et al., 2006; Schraufnagel et al., 2019). Some of the most common types of air pollution are Carbon Monoxide (CO), Nitrogen Oxide (NO2), Sulfur Oxide (SOx), Photochemical Oxide and Particles. Sources of air pollution can be classified into stationary sources and mobile sources. Silent sources consist of industry, power plants and households. Meanwhile, the movable sources are motor vehicle activities and sea transportation. Air pollution does not only exist outside, it turns out indoors, such as in homes, offices and other closed rooms, it can also experience air pollution. Air pollution that occurs indoors is caused by the use of cigarettes, glues, paints, and materials that contain chemicals. This can also occur due to unclean room conditions, such as mattresses that are rarely cleaned so that when you sleep the dirt is inhaled and enters the respiratory tract. (Simandjuntak, 2013; Sudrajad, 2006).

In Indonesia, there have been many standard measures for calculating pollution levels (Rahim & Soeprobowati, 2019; Suriadikusumah et al., 2020; Tanjung & Hamuna, 2019). In the area of the national capital, the air quality index has been calculated. This condition is intended as an early warning for policy makers when a threshold has been reached. The calculated index is often associated with several variables to measure the level of influence and the relationship between variables (Nurbiantara, 2010; Suryanto, 2012).

Pollution based indices are often calculated on the air aspect (Swamee & Tyagi, 1999; X.-K. Wang & Lu, 2006). Even though the pollution that arises can be interrelated between various media (water, land, and air). Therefore it is necessary to calculate an index that can calculate the aggregate for all factors as a pollution medium.

2. Methodology

The index calculation in this study refers to the results of the research conducted by Yokota dkk (2017) using the Multiple Correspondence Analysis (MCA) method. This method has been used to measure an index based on categorical data (Abdi & Valentin, 2007; Asselin & Anh, 2008; Rodrigues et al., 2016). In the calculation process, there are a number of K variables, and each variable has a level of Jk and the number of Jk is equal to J. In addition there are as many as I observations. The I x J matrix is denoted by X. Establishing a correspondence analysis on the indicator matrix will produce two sets of factor scores: one for rows and one for columns. These factor scores are generally scaled such that the variance equals the corresponding eigenvalues.

The total value of the matrix of the arrangement is denoted by N, and the first step of the analysis is to calculate the probability matrix Z = N-1X. We denote r the vector of the total row Z, (i.e., r = Z1, where 1 is the corresponding vector of 1) and c is the vector of the total column. The notation Dc = diag {c} and Dr = diag {r}. The factor score is obtained from the decomposition of a single value in the following equation:

$$D_r^{-\frac{1}{2}}(Z - rc^T)D_c^{-\frac{1}{2}} = P\Delta Q^T$$

(Δ is a diagonal matrix of single values, and Λ=Δ2 is a matrix of eigenvalues). The row and column factor scores (respectively) are obtained by means of the following equation:

$$F = D_r^{-\frac{1}{2}} P\Delta \qquad G = D_c^{-\frac{1}{2}} Q\Delta$$

Distance squared ($\chi 2$) of rows and columns can be denoted in the following equation:

$$d_r = \text{diag}\{FF^T\} \qquad d_c = \text{diag}\{GG^T\}$$

This study uses data from the results of the 2018 Village Potential data collection which includes 30 variables and 75,436 villages. The results of the Podes data collection were in the form of answer choices from village officials regarding the existence of detailed pollution events. Villages that are affected by certain conditions will be given the code "1", while the code "0" for the opposite condition.

3. Results and Discussion

Based on table 1, it is known that villages that have a negative index in developing areas as a percentage tend to have relatively high numbers when compared to other categories. Negative conditions indicate that the village is experiencing pollution. Where the more negative the index value is, the deeper the pollution that occurs in an area. This can be due to the fact that the development process in developing villages tends to be higher. The impact of development will have an impact on environmental pollution. This phenomenon is in line with previous research (Bruce et al., 2000; B. H. Chen et al., 1990; Wheeler, 2001).

When viewed in detail, the air pollution index is an index that has a percentage when compared to other types of pollution. This phenomenon is due to the fact that the air medium is sensitive to the main source of pollution. The conditions are in accordance with previous research on the role of air media in pollution (Beelen et al., 2014). For example, noise due to factory activity. Commonly, pollution will arise in water media due to the presence of liquid waste resulting from production activities. However, without realizing it, the noise generated from production activities can also trigger air pollution. This condition will disturb the hearing of the local community, and the extreme condition will disturb the sense of hearing. So that this activity will trigger pollution that can be spread by various media. This condition

is in accordance with the results of previous research (Arnold et al., 2016; Gulas et al., 2017).

Table 1. Index Distribution by Village Development Category in 2018

Index		Development Category			Total
		Underdeveloped	Developing	Developed	
Pollution Index					
Negatif	Abs.	2,211	14,156	1,625	17,992
	%	*2.93*	*18.77*	*2.15*	*23.85*
Positif	Abs.	12,252	41,219	3,973	57,444
	%	*16.24*	*54.64*	*5.27*	*76.15*
Water Pollution Index					
Negatif	Abs.	1,886	11,425	1,295	14,606
	%	*2.50*	*15.15*	*1.72*	*19.36*
Positif	Abs.	12,577	43,950	4,303	60,830
	%	*16.67*	*58.26*	*5.70*	*80.64*
Soil Pollution Index					
Negatif	Abs.	1,975	11,657	1,330	14,962
	%	*2.62*	*15.45*	*1.76*	*19.83*
Positif	Abs.	12,488	43,718	4,268	60,474
	%	*16.55*	*57.95*	*5.66*	*80.17*
Air Pollution Index					
Negatif	Abs.	2,284	14,766	1,712	18,762
	%	*3.03*	*19.57*	*2.27*	*24.87*
Positif	Abs.	12,179	40,609	3,886	56,674
	%	*16.14*	*53.83*	*5.15*	*75.13*

Indonesia is an archipelago, where each island has unique characteristics. If classified based on the large islands in Indonesia, in general, the negative pollution index is mostly found in villages on the island of Java. This result is in line with previous research which states that Java Island is the island with the highest pollution index (Kusminingrum & Gunawan, 2008; Yuwono et al., 2021). Meanwhile, the smallest negative pollution index was in the islands of Bali, Nusa Tenggara, Maluku and Papua. This phenomenon is in accordance with the conditions of development in Indonesia, because Java Island is the center of Indonesian government and economy. Islands located in the eastern region of Indonesia tend to have a relatively small pollution index, this result is consistent with previous research (Hamuna & Tanjung, 2020; Thahir & Lagoa, 2018). The interaction between sectors in the city center will tend to be larger and more dynamic. This will cause a number of negative effects, one of which is pollution. However, on the other hand, the city center will benefit from various

conveniences, such as public facilities and access to jobs (Pradhan & Van Soest, 1995; Tahmasbi et al., 2019).

Table 2. Index Distribution by Island in 2018

Indekx		Islands						Total
		1	2	3	4	5	6	
Pollution Index								
Negatif	Abs	5,612	6,694	579	2,856	1,534	717	17,992
	%	*7.44*	*8.87*	*0.77*	*3.79*	*2.03*	*0.95*	*23.85*
Positif	Abs	17,629	15,778	4,100	3,768	7,270	8,899	57,444
	%	*23.37*	*20.92*	*5.44*	*4.99*	*9.64*	*11.80*	*76.15*
Water Pollution Index								
Negatif	Abs	4,496	5,192	434	2,624	1,197	663	14,606
	%	*5.96*	*6.88*	*0.58*	*3.48*	*1.59*	*0.88*	*19.36*
Positif	Abs	18,745	17,280	4,245	4,000	7,607	8,953	60,830
	%	*24.85*	*22.91*	*5.63*	*5.30*	*10.08*	*11.87*	*80.64*
Soil Pollution Index								
Negatif	Abs	4,610	5,334	452	2,678	1,238	650	14,962
	%	*6.11*	*7.07*	*0.60*	*3.55*	*1.64*	*0.86*	*19.83*
Positif	Abs	18,631	17,138	4,227	3,946	7,566	8,966	60,474
	%	*24.70*	*22.72*	*5.60*	*5.23*	*10.03*	*11.89*	*80.17*
Air Pollution Index								
Negatif	Abs	5,963	6,910	653	2,933	1,582	721	18,762
	%	*7.90*	*9.16*	*0.87*	*3.89*	*2.10*	*0.96*	*24.87*
Positif	Abs	17,278	15,562	4,026	3,691	7,222	8,895	56,674
	%	*22.90*	*20.63*	*5.34*	*4.89*	*9.57*	*11.79*	*75.13*

Notes :
1. Sumatera
2. Jawa
3. Bali dan Nusa Tenggara
4. Kalimantan
5. Sulawesi
6. Maluku dan Papua

If broken down based on the type of index, all types of indexes confirm that Java Island is an island that has a negative pollution index number in its rural areas. This phenomenon is in accordance with several previous studies which stated that, in areas that tend to be advanced, the level of pollution tends to be high. This phenomenon is in line with previous studies that analyzed the level of pollution in developed regions (Kumar et al., 2015; Mayer, 1999; Pospelov et al., 2019).

Pollution will get worse when the pollution source area interacts with the surrounding area. This interaction will cause bad conditions in the surrounding area. In the case of transporting waste

from the DKI Jakarta area through Bekasi, the Provincial Government does not hesitate to spend a number of funds as compensation for the pollution that can be caused when garbage crosses residential areas. (Ishar et al., 2017).

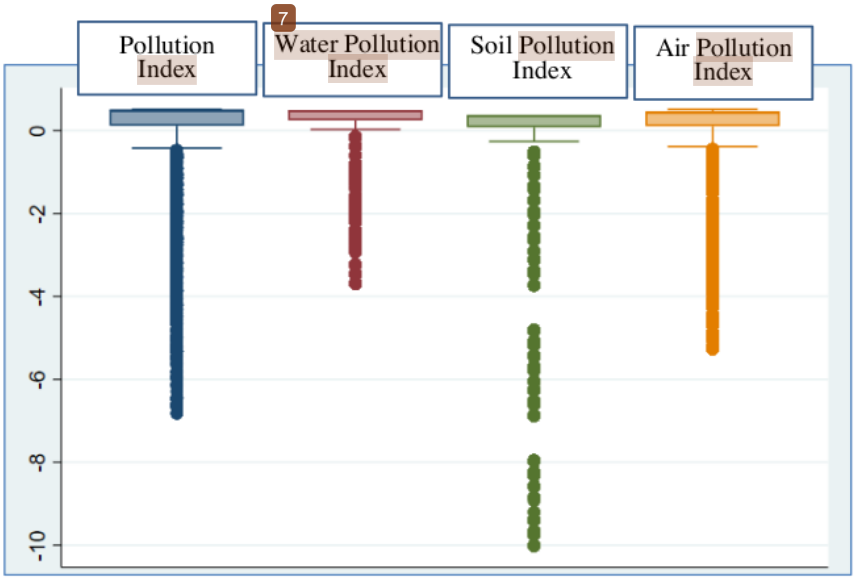

Figure 1. Pollution Index by Type

When viewed from the distribution range, the largest range occurs in the soil pollution index. While the lowest index range occurs in the water pollution index. All pollution will have a negative impact on human life. However, there is severity when viewed from the index formed. The results of the index calculation are in accordance with the phenomena that occur. Soil conditions in urban areas tend to be difficult to plant various types of plants. This is different with land in rural areas, which tends to be easier. Conditions are in accordance with the results of research that has been done before (Cachada et al., 2018). This phenomenon can be caused by the nutrients present. As a result of air pollution, nutrients will be reduced, thereby inhibiting the rate of plant growth and reproduction. This condition is in line with research conducted by Wasis (2013) dan Zulfiah serta Aisyah (2016), which states that plant growth is strongly influenced by nutrients in the soil.

Water pollution in developed areas tends to be higher than in disadvantaged areas. Underdeveloped areas still make use of springs. However, over time the number of springs in Indonesia has decreased (Hamidiana et al., 2016). The amount of water pollution in developed areas has caused a number of polemics. On the one hand, water is a basic household need. On the other hand, when the water is polluted, the household must sacrifice time, energy, or money to get hygienic water. In areas that tend to be developed, residents have subscribed to water that is managed by the private sector and the government. However, this solution will affect the

proportion of household expenditure. It is known that rural areas are very vulnerable to poverty. Based on BPS data, the number of rural poor households in Indonesia is around 26 million people. A solution is needed from the central and local governments to deal with problems related to basic household needs, because this can cause other problems in the community.

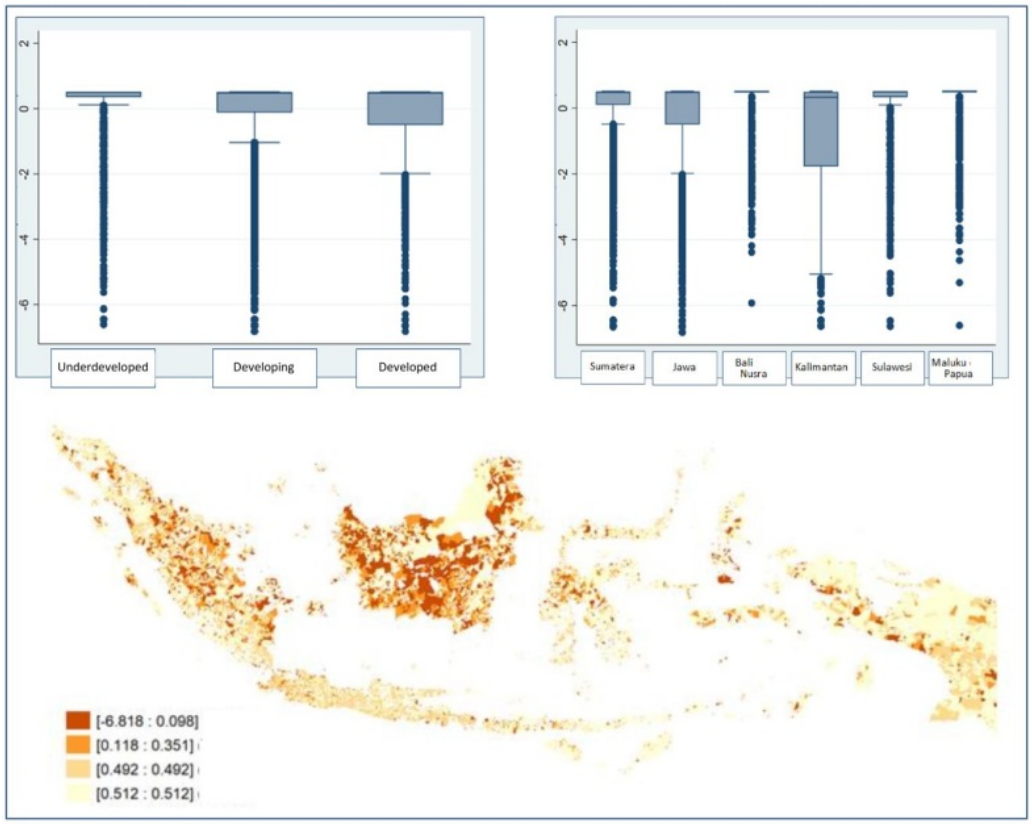

Figure 2. Pollution Index

In general, the severity of the pollution index is in the village which has an independent category. When viewed during the last 1 year, Java and Kalimantan were the islands with the largest index severity. The island of Borneo is the lung of Indonesia. The abundance of forests and good natural ecosystems often supply oxygen for Indonesia and the surrounding countries. However, based on the established index, Kalimantan Island is experiencing a quite deep level of severity, compared to other islands. This condition informs that, Kalimantan Island has experienced a sharp increase in pollution. This result is in line with previous research related to pollution in Kalimantan Island (Albertus & Zalukhu, 2019; Nisa & Arthani, 2011).

On the islands of Sulawesi, Maluku and Papua, the resulting index tends to be good. Islands in eastern Indonesia tend not to be explored, so the pollution they cause is still not visible (Hanim & Noorman, 2018; Yanuarti, 2016). It takes the participation of the community and government to jointly prevent pollution that can occur. Vertical and horizontal government coordination also needs attention, so that the resulting objectives do not have a negative impact on other sectors. Solutions that can be made through early communication on a program, by involving various parties and also accommodating the submitted input.

The water pollution index severity is in the independent and developing village category. When viewed during the last 1 year, Kalimantan Island is the island with the largest index of severity. This condition informs that the island of Kalimantan has experienced a sharp increase in water pollution over the past year. People in Kalimantan Island feel that things are changing in the quality of their environment, so that the index that is formed is getting deeper. On the islands of Sumatra, Java and Sulawesi, the resulting index tends to be good.

The river is a characteristic that cannot be separated from the island of Borneo. Water in rivers is generally collected from precipitation, such as rain, springs, underground runoff and in certain countries also from melting ice or snow. In this era of globalization, a lot of pollution occurs in rivers due to human negligence who do not protect the environment. Another problem that often arises is the increasing quantity of water that is no longer able to meet the needs and the decreasing quality of water for domestic needs. This phenomenon results in a demand condition that is not proportional to supply, resulting in something to be sacrificed if there is no technology to fulfill water resources. The sacrifices could be money to pay or public health problems at stake (Gurjar et al., 2010; Lee et al., 2014; Mallongi et al., 2020).

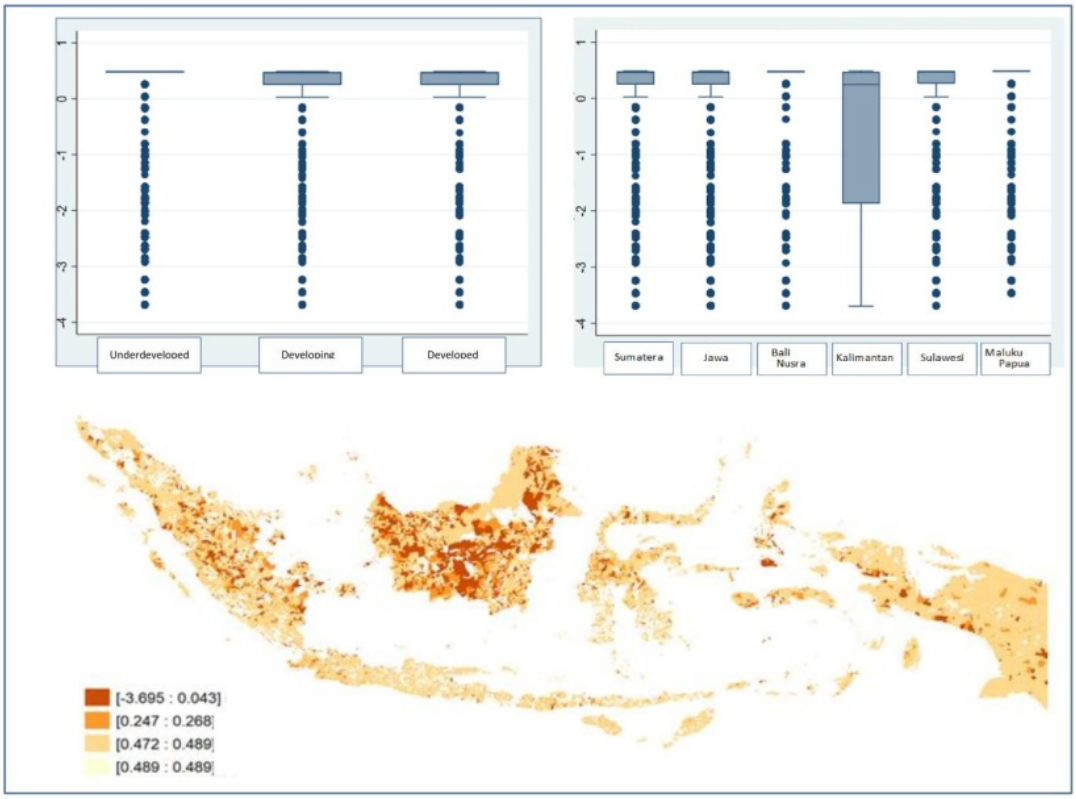

Figure 3. Distribution of Water Pollution Index

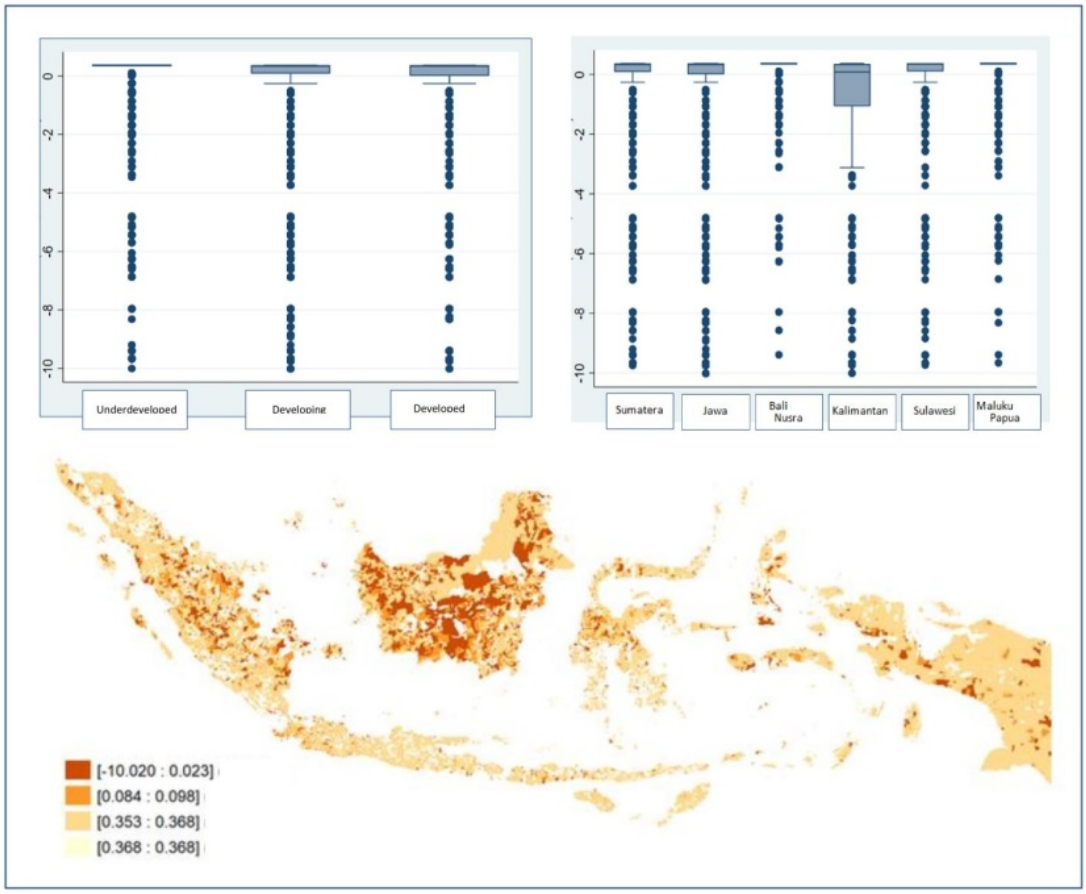

Figure 4. Distribution of Soil Pollution Index

The soil pollution index severity is in the village which has an independent category. When viewed during the last 1 year, Kalimantan Island is the island that has the greatest severity index. This condition informs that, Kalimantan Island has experienced a sharp increase in pollution. People in Kalimantan Island feel that things have changed in the quality of their environment, so that the index formed is getting more negative. On the islands of Sumatra, Java and Sulawesi, the resulting index tends to be good.

On the island of Kalimantan there are many peat forests. Draining and decomposing the peat can cause the peat soil to become thinner. Several cases of peatland damage have occurred in the Kalimantan region. The area is now abandoned acid sulphate land and a source of environmental pollution for the surrounding area (Noor, 2001; Sabiham et al., 2012; Widyati, 2011). When the soil is polluted it will be difficult to use for development based on the natural sector.

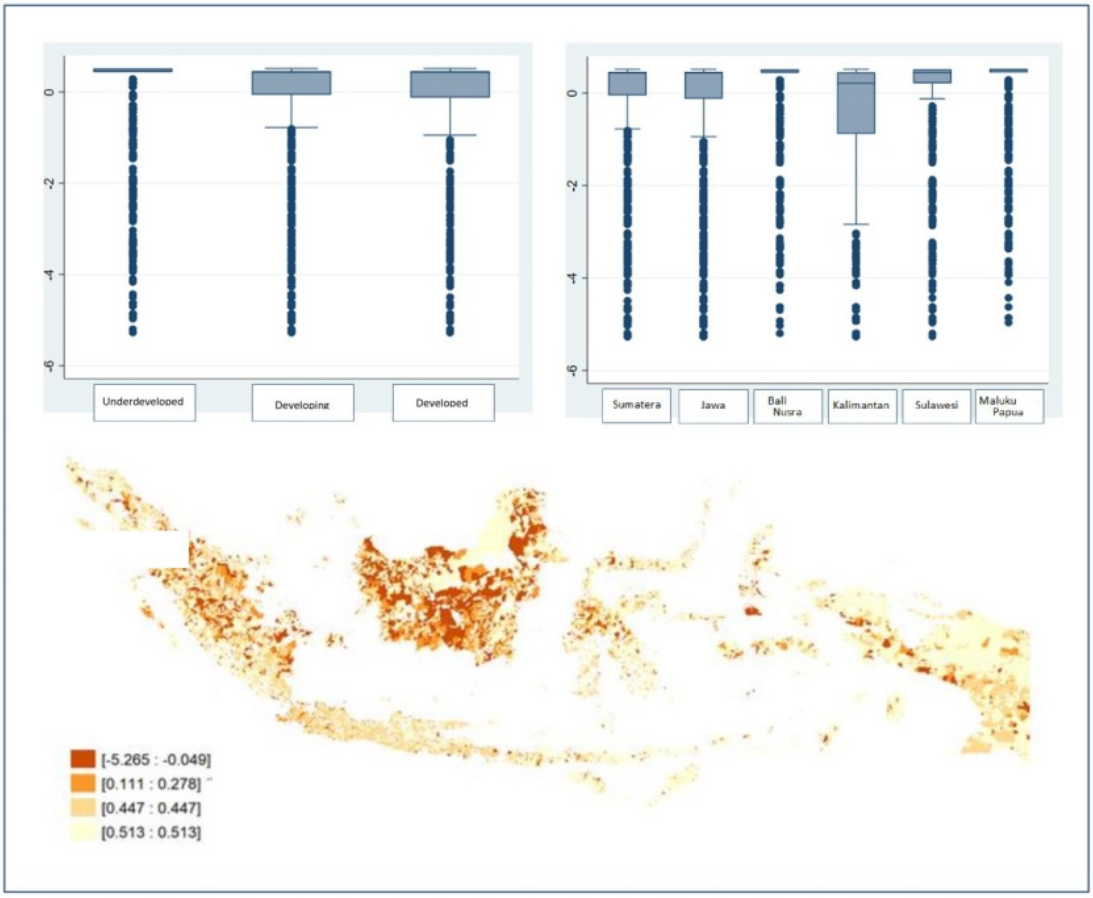

Figure 5. Distribution of Air Pollution Index

The air pollution index severity is in the independent village category. When viewed during the last 1 year, Kalimantan Island is the island that has the greatest severity index. This condition informs that, Kalimantan Island has experienced a sharp increase in pollution. People in Kalimantan Island feel that things have changed in the quality of their environment, so that the index formed is getting more negative. On the islands of Sumatra, Java and Sulawesi, the resulting index tends to be good.

Forest and land fires that occurred in the Kalimantan Region have had very serious impacts on local communities. The smoke that arises and forest and land fires will look like clouds that are grayish-white, brown and even blackish and the darker the smoke color will show the concentration of contaminants (SO2, NO2, 03, CO and PM10). The impact and the smog can cause losses in various fields such as health which can cause various diseases including ARI, bronchitis, pneumonia, asthma, and even eye irritation. The haze will also affect the disruption of

air, land and sea transportation services as well as decrease business activities, tourism and also disrupt the teaching and learning process for school students. In addition, the smog will also disrupt relations between countries such as Malaysia, Singapore and Brunei Darussalam, because they are exposed to the haze and forest and land fires that have occurred in Indonesia and especially those that occurred on the island of Kalimantan.

4. Conclusion

Pollution that occurs in the community needs to be the attention of the government and the people who live in the area. In the short term, the negative effects are not visible yet, but the bad effects will form on future generations. The distribution of the pollution index formed indicates that soil pollution is the most significant aspect in the formation of the overall pollution index. Participation from the central and local governments is needed to regulate regulations, in order to sustain the nature of the environment which can be disrupted due to the negative impacts of development.

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