

## Interregional Disparity and Spatial Autocorrelation of Access to Water and Sanitation in Indonesia

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### *Abstract*

This study investigates the interregional district-level inequalities and the spatial associations of household access to sustainable water and sanitation in Indonesia between 2004 and 2018. The findings show that although the gap in household access to water and sanitation declined over the years, the disparities among districts in Indonesia kept persisting. Related to proliferation, the access in the districts that never separated is higher than in others. Furthermore, this study also confirms the presence of spatial cluster/outlier accesses, although it remains fragile. The majority of districts with high access are clustered in the western part of Indonesia, especially in Java island. At the same time, in the mountainous areas of Papua island and some districts in Sumatera island where forest land has been degraded into plantation and mining areas have relatively low access for years. These left-behind districts need government attention and support to provide more equitable access to water and sanitation for the people.

**Keywords:** water; sanitation; access inequality; spatial analysis; spatial association.

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## I. Introduction

In recent years, collective development goals amongst countries have been introduced. Leaders worldwide have agreed upon agendas in pursuing economic and human developments to achieve human welfare. Their joint initiatives were set up into Millennium Development Goals (MDGs), which were later upgraded to Sustainable Development Goals (SDGs). The updated commitments consist not only of new aims but also several recurring objectives with renewed targets. Ensuring people have access to safe drinking water and sanitation is a repeated development goal.

Globally, the target to halve the proportion of people without sustainable access to water has been met by the end of the MDGs period.<sup>2</sup> However, the improvement was widely ranged across regions. Some have enabled safe drinking water access for almost their entire population, while others could not make substantial improvements. While Oceania did not progress significantly, Eastern and South-Eastern Asia halved the share of people without access to improved drinking water more than its target. Other regions were in between these two extremes.

On the other hand, the target to cut in half population without access to improved sanitation was not achieved globally, although more people were using sanitation in 2015.<sup>3</sup> Only a few regions succeed in halving the population without adequate sanitation. Moreover, the development was greatly varied between regions and countries. Sub-Saharan Africa, Oceania, and Southern Asia were far from reaching their respective targets. At the same time, Latin America, the Caribbean, and South-East Asia were close but missed the goal.

ASEAN Report on MDGs shows a similar result with the worldwide indices (ASEAN, 2017). In Southeast Asia, increasing access to sustainable water<sup>4</sup> Moreover, improved sanitation varies among the countries. Singapore is the only ASEAN member achieving 100% access coverage of safe water and sanitation. On the other hand, Cambodia has the lowest population proportion to the two accesses. At the same time, Indonesia is the second-worst country regarding access to safe water and sanitation.

Similar to the worldwide and regional trends, the access to safe water and sanitation in Indonesia increases but differs among sub-national areas (Afifah et al., 2018; Lewis, 2017). Several studies explained access inequality between the urban and rural areas (Irianti et al., 2016; Patunru, 2015). Others found that the access gap is also evident amongst islands and provinces (Afifah et al., 2018; Irianti et al., 2016). Moreover, Lewis (2017) studied access disparity between different local governments based on the history of their territorial split.

Only a few studies incorporated geographical aspects in the regional access inequality analysis. Therefore, this study examines the interregional gap of the two accesses in Indonesia to enrich the literature regarding access inequality to sustainable water and sanitation. Another contribution of this study is that a constructed balance panel data of 514 districts is employed. Moreover, data filtering is performed to see the influence of the artificial factors in the sampling process and the presence of the regional cyclical shocks on safe water and sanitation access.

In addition to inequality, this study investigates spatial autocorrelation aspects of districts. Global spatial analysis is conducted to find the presence or absence of spatial dependency between districts. Furthermore, local spatial analysis is performed to determine

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<sup>2</sup> Based on The Millenium Development Goals Report 2015, the worldwide population with access to improved drinking water increased from 76% in 1990 to 91% in 2015. In aggregate, both developed and developing regions achieved the target. A total of 147 countries have met the target to halve the population without access to safe water.

<sup>3</sup> The United Nations reported that the share of the population with access to improved sanitation increased from 54% to 68% globally. The developed regions nearly reached the goal, while developing ones were far behind the target. Ninety-five nations succeeded in halving their people without access to improved sanitation.

<sup>4</sup> In this study, sustainable water and safe water are used interchangeably.

the spatial cluster/outlier location. The 15-year period of observation between 2004 and 2018 enables this study to define persistent spatial clusters/outliers for each safe water and sanitation access.

Using Indonesia's district-level data of 15 years observation period, this study aims to explore three research topics including:

1. the trend of district-level regional inequalities in the household access of safe water and sanitation,
2. the presence of the spatial autocorrelations in the household access of safe water and sanitation, and
3. the locations of the four types of spatial clusters: the high/low household access spatial clusters/outliers.

This study contributes to the existing literature on the three issues mentioned above. Moreover, identifying the locations that continue to be left behind helps improve residential welfare and regional development programs. The government of Indonesia may be able to overcome access inequality issues of sustainable water and sanitation access and achieve its goal to provide equal access across the nation with better knowledge and strategy.

The rest of this paper is organized as follows. First, relevant literature regarding inequality and spatial association of sustainable water and sanitation access is reviewed. Second, the data and methodologies used in this study are explained. Third, some results and findings are discussed. Then, the last section highlights significant findings and provides policy implications of this study.

## **II. Literature Review**

### **2.1 Studies in Other Countries**

Despite the progress in achieving universal access to safe water and sanitation, access inequality exists (Deshpande et al., 2020). Several studies proved that water access and its use is higher in high-income than in low-income households (Malakar & Mishra, 2017). Similarly, the UNDP reported that the richest had at least twice as much access to water and sanitation as the poorest (UNDP, 2019). Morales-Novelo et al. (2018) examined the safe water access gap in Mexico City between low- and high-income families. They found that water consumption in the highest income households is substantially more significant than in others. Likewise, Jia et al. (2016) found that areas with high sanitation coverage are where better-off populations resided in Kenya. They further explained that the poorest households have a higher gap than the wealthier ones.

Studies also showed that water and sanitation coverage inequality also occurs in urban areas of developing countries (Adams, 2018; Alankar, 2013; Luby et al., 2018; Saroj, Goli, Rana, & Choudhary, 2020). For example, a study of spatial inequality in India proved that access to water and sanitation is significantly higher in urban areas than in rural areas (Chaudhuri & Roy, 2017). Moreover, literature also has shown that most people with low water and sanitation coverage live in regions with a deficiency of water infrastructure and management; Some of them stay in agricultural areas (Cohen & Sullivan, 2010; Jemmali & Sullivan, 2014; Radosavljevic et al., 2020; Sullivan, 2002).

Several studies investigate the regional pattern of disparity in access to safe water and sanitation. Sinha & Rastogi (2020) confirmed a decline in the disparity of access to improved water worldwide. They also showed that the between-region component of inequalities contributes more to the worldwide access gap. Their regional analysis shows that disparity trends in Central & South America and the Middle East do not follow the global trend and the inequalities in these regions kept increasing. Moreover, they also pointed out that the disparity is relatively more significant in Africa than in other areas.

## 2.2 Studies in Indonesia

Several studies found that Indonesia's disparities in access to sustainable water and improved sanitation are also apparent. Patunru (2015) investigated the dynamics of access to safe water and sanitation in Indonesia. He utilized aggregate provincial data compiled by World Health Organization (WHO) and United Nations Children Fund (UNICEF) for 1990 and 2012. He employed data estimations for 2015 and performed multilevel logistic regression to examine progress in access to water and sanitation. The evidence concluded that an urban neighborhood is better than a rural area.

Afifah et al. (2018) found inequalities between the region regarding household access to improved water and sanitation in Indonesia. They use the 2015 Indonesian Economic Survey (SUSENAS) disaggregated data to examine regional inequalities patterns. Using the mean difference from the mean and weighted index of disparity, they calculated inequalities and found that between and within provinces, disparity varies significantly across regions.

Another study of water access determinants using cross-sectional household-level data from the Indonesia Family Life Survey (IFLS-4) found that interregional inequalities exist (Irianti et al., 2016). Their multivariate regression analysis found that households in urban areas are more likely to have improved water access than rural areas. Moreover, the likelihoods of access to sustainable water were diverse amongst islands.

Lewis (2017) investigated public service delivery improvement upon local government proliferation in Indonesia. Access to safe water and sanitation were included as the variables of interest in their study. Their findings indicate that new district creation negatively influences service access in the short and long run. They also showed a conditional convergence of service delivery amongst all districts. Moreover, they found that newly created districts have lower access to sustainable water and sanitation, but the difference is insignificant.

Based on the related literature review, regional inequalities in access to safe water and sanitation persist despite access development in Indonesia and other nations. Only a few studies examined the spatial association of access inequalities in Indonesia. This study explores the district-level inequality and the spatial association in household access to sustainable water and sanitation to address this gap.

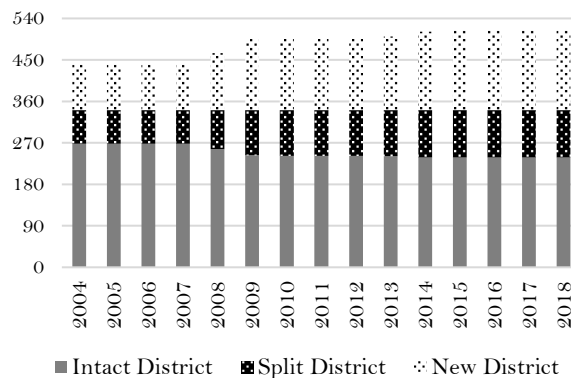
## III. Data and Methodology

### 3.1 Data

This study was used to access safe water and sanitation data to analyze interregional inequalities and spatial autocorrelation at the district level in Indonesia for 2004–2018. This panel data was sourced from World Bank's Indonesia Database for Policy and Economic Research (INDODAPOER). Sustainable water access is defined as the proportion of households with safe water sources from plumbing, drilling wells or pumps, protected wells, and protected springs, including rainwater (Afifah et al., 2018). The second variable is the ratio of households with access to sanitation. The access is specified as the percentage of households using improved sanitation facilities either privately or shared with others (Afifah et al., 2018).<sup>5</sup>

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<sup>5</sup> Based on the definition used by Statistics of Indonesia (BPS), households with access to sustainable water include those that use bottled water or refillable gallon, water that is sold through tanks, and water sourced from unprotected springs for drinking, but use improved water sources for bathing or washing. The facilities include toilets (flush or pour-flush) with septic tanks or wastewater treatment plants.



**Figure 1.** District proliferation: intact, split, and newly created districts in 2004 – 2018<sup>6</sup>

After the 1998 economic crisis, the administrative reforms increased the number of provinces from 33 (2004) to 34 (2014). Simultaneously, the number of the district has been increased from 440 to 514. These changes were due to new districts that were separated from the existing ones (Figure 1). In 2014–2018, INDODAPOER presented the data covering 514 districts while it did not cover as many districts before 2014 as it conducts no data adjustment for these historical changes. This change modifies area unit problems that may deteriorate the consistent spatial data analysis, in which balanced data is needed.

There are several possible methods to solve the problem of missing data. The first measure is to drop all observations with missing values. That is arguably the most straightforward procedure, but it may result in selection bias. The analysis may lead to an invalid conclusion without the information on the newly created districts. Moreover, district creation inevitably modifies the area of split districts. The change in the area of observation may further impede the spatial analysis consistency.

The second method is data aggregation. Aggregating the new districts to the original district gives less information. The new and original districts have different safe water and sanitation provisions and issues for the solutions. Thus, the information at the district level is more valuable and practical in formulating policies that are suitable to the condition of the area to increase access, especially in areas with lower access.

The last possible technique to overcome the issue of missing values is data imputation. Several available imputation methods could be performed for this study. However, interpolating and extrapolating data may result in negative values inconsistent with the variables.<sup>7</sup> An article by Kurniawan et al. (2019) that analyzed the dynamic of socio-economic inequality in Indonesia constructed balanced district-level panel data using the interpolation method. They used the original district data and year for linear interpolation imputation regressors.

This study adopts the data imputation technique by Kurniawan et al. (2019). Data imputation is the more rational response regarding the missing values for this research. Analyzing a balanced dataset consisting of all districts will explain inequality and the spatial

<sup>6</sup> Author's calculation based on Law and Regulation of each district's creation. Intact districts are those that never split. Split indicates the original district that was split-off during the period of observation. New districts are the newly proliferated districts.

<sup>7</sup> It is not rational for a district to have harmful access to either sustainable water or adequate sanitation. The variables are the share of households with access from the total population. Thus, the value is supposed to be between 0% and 100%.

dimension more thoroughly. Moreover, the imputation is unlikely to affect the outcome of inequality and spatial autocorrelation analysis.<sup>8</sup>

Moreover, this study applies the filtering technique to identify the trend components, removing non-trend (=cyclical) components. The reason for applying the filtering procedure is mainly to remove the artificial factors in the sampling process rather than the presence of the regional cyclical shock. The sample survey over a decade cannot avoid the artificial changes due to changes in sampling, survey mode, or other changes in procedures (Morelli & Thompson, 2015). Two filtering techniques of Hodrick-Prescott and Butterworth were applied, and there were no significant differences in the trend component between the two techniques. Thus, only the Hodrick-Prescott filter result is presented since it is widely used in the existing literature.

### 3.2 Summary Statistics

Table 1 summarizes the two variables' statistics between 2004 and 2018 for imputed non-filtered data. In general, more people have access to sustainable water and sanitation by the end of the observation. On average, households with access to sustainable water increased from 41.9% to 67.3%. Similarly, households with access to sanitation rose from 58.9% to 75.5%.

**Table 1.** Summary statistics: non-filtered data

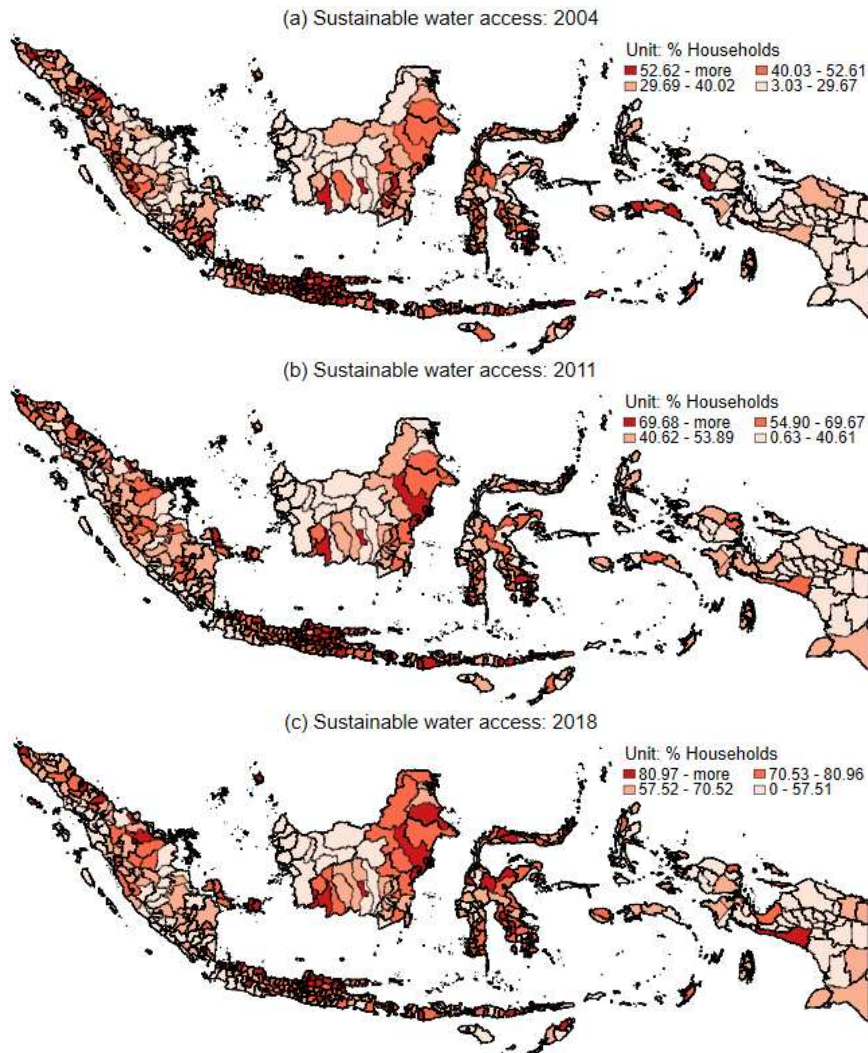
| Variable    | N   | mean   | sd     | min   | max    | cv    | skewness |
|-------------|-----|--------|--------|-------|--------|-------|----------|
| <b>2004</b> |     |        |        |       |        |       |          |
| water       | 514 | 41.943 | 19.231 | 3.03  | 99.460 | 0.459 | 0.430    |
| sanitation  | 514 | 57.896 | 19.536 | 4.582 | 96.550 | 0.337 | -0.140   |
| <b>2011</b> |     |        |        |       |        |       |          |
| water       | 514 | 54.527 | 21.811 | 0.631 | 100    | 0.4   | -0.194   |
| sanitation  | 514 | 60.877 | 17.53  | 2.183 | 96.419 | 0.288 | -0.428   |
| <b>2018</b> |     |        |        |       |        |       |          |
| water       | 514 | 67.271 | 20.352 | 0     | 100    | 0.303 | -0.979   |
| sanitation  | 514 | 75.501 | 14.634 | 3.576 | 98.007 | 0.194 | -1.372   |

The minimum and maximum values illustrate that the accesses are widely ranged between districts. Furthermore, the skewness gives information on data distribution within the observation period. In 2004, the skewness of water access data was positive, indicating a right-skewed data distribution. However, it was left-skewed by the end of observation. On the other hand, the distribution of households' access to sanitation data was skewed to the left from the beginning, and the skewness becomes more negative over time. These patterns occurred in both non-filtered and filtered data.

Figures 2. (a)-(c) depict the spatial distribution of household access to sustainable water. The figures imply that the access is unequal between districts. Most of the high-access

<sup>8</sup> Although these procedures result in few data fluctuations, they will not impair the analysis. The oscillations along the period of observation are relatively modest than extreme. Moreover, they occur not only in new districts but also in intact districts. The possible explanation is that it is due to the artificial factors in the sampling process or regional cyclical shock. Later filtering technique is performed to separate cyclical components from the non-filtered data.

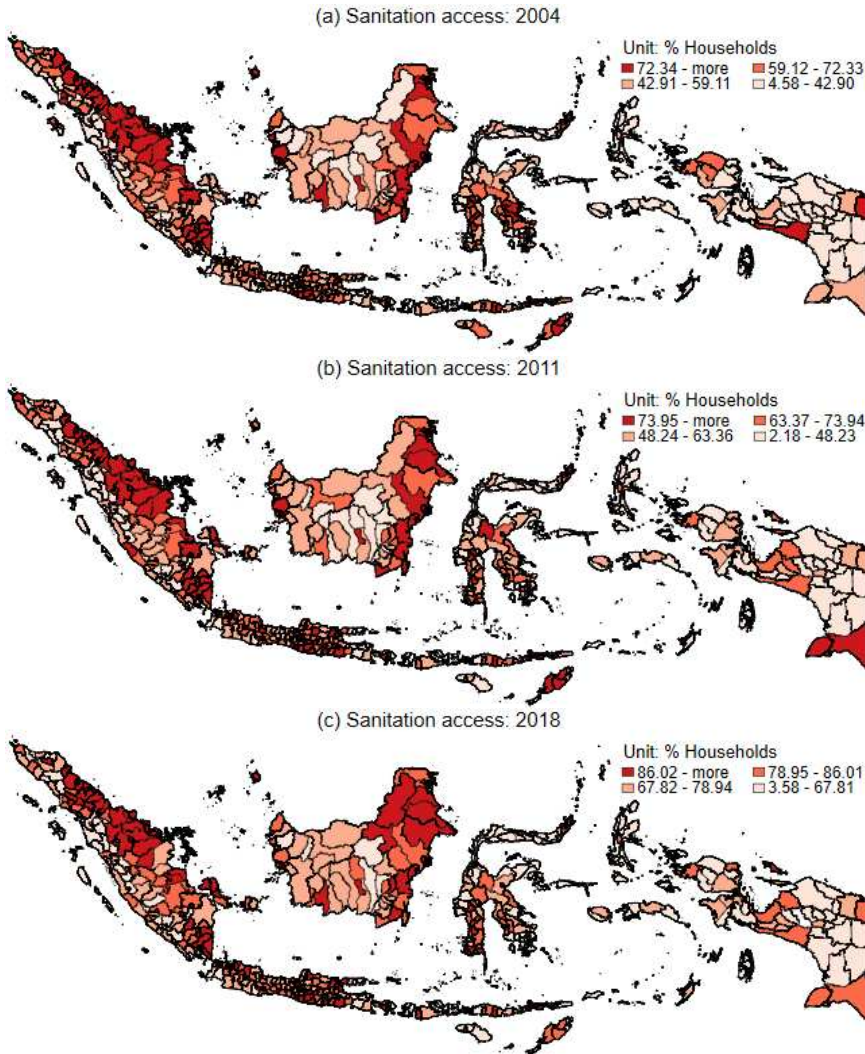
districts are located in the Java-Bali region, where Indonesia's economic activities and population are concentrated. While safe water access in East and North Kalimantan provinces has been better, other parts of Kalimantan are still left behind. Similarly, districts in Sulawesi show noticeable development, except for some in West Sulawesi province. On the other hand, districts in Papua island have been left behind throughout the observation period.



**Figure 2.** (a)-(c) Spatial distribution in water access in 2004, 2011, and 2018

Figures 3. (a)-(c) illustrates the spatial distribution of access to sanitation in Indonesia. Similar to sustainable water access, the figures indicate that the access to sanitation amongst districts is unevenly distributed. High-access districts are clustered in Java-Bali, Sumatra, and the north-eastern part of Kalimantan. In contrast, districts in other parts of Indonesia have relatively lower access.





**Figure 3.** (a)-(c) Spatial distribution in sanitation access in 2004, 2011, and 2018

### 3.3 Methodology

This study employs several methods to calculate the gap in access to sustainable water and sanitation in Indonesia. All inequality measurement indexes satisfy the desirable properties of inequality: anonymity, scale independence, population relative, and Pigou-Dalton transfer principles.

#### 3.3.1 Gini coefficient

The Gini coefficient is used to obtain the relative disparity among all districts in Indonesia. The ratio is calculated for each access to sustainable water (*water*) and sanitation (*sanitation*) for non-filtered and filtered datasets. Gini coefficient,  $G$ , is the Gini ratio of the corresponding  $x_i (x \in \text{water}, \text{sanitation})$ , denotes as:

$$G = \left( \frac{1}{2n^2x} \right) \sum_{i=1}^n \sum_{j=1}^n |x_i - x_j| \quad (1)$$



Where  $n$  is the number of total districts,  $x$  is the average value of each access, and  $i$  ( $j$ ) is district  $i$  ( $j$ ), where  $i \neq j$ . G's ratio ranges from perfect access equality (0) to perfectly unequal access (1). The lower (higher) the index, the more (less) equal the district is.

### 3.3.2 Theil index and its decomposition

Another important inequality measure is the Theil index. In addition to the inequality measure principles. This feature allows decomposition of the overall disparity into within-group and between-group components. This study uses weighted Theil T and L indexes to measure total inequalities and their respective components.

Supposed that population can be grouped into mutually exclusive and completely exhaustive groups, Theil T ( $T$ ), and Theil L ( $L$ ) can be denoted as:

$$T = \sum_{i=1}^n \sum_{j=1}^m \left( \frac{x_{ij}}{x} \right) \ln \left( \frac{x_{ij}/x}{p_{ij}/p} \right)$$

and

$$L = \sum_{i=1}^n \sum_{j=1}^m \left( \frac{p_{ij}}{p} \right) \ln \left( \frac{p_{ij}/p}{x_{ij}/x} \right) \quad (2)$$

Where  $n$  is the number of total districts,  $m$  is the number of district group,  $x_{ij}$  is the corresponding access of district  $i$  in group  $j$  ( $x \in \text{water, sanitation}$ ),  $x$  is average access,  $p_{ij}$  is the population in district  $i$  group  $j$ , and  $p$  is the total population.

Referring to the widely-used income inequality decomposition, then, the indexes for this study can be decomposed into within-group and between-group components with the following equations:

$$T = \sum_{i=1}^n \left( \frac{x_i}{x} \right) T_i + \sum_{i=1}^n \left( \frac{x_i}{x} \right) \ln \left( \frac{x_i/x}{p_i/p} \right) = T_w + T_b$$

and

$$L = \sum_{i=1}^n \left( \frac{p_i}{p} \right) L_i + \sum_{i=1}^n \left( \frac{p_i}{p} \right) \ln \left( \frac{p_i/p}{x_i/x} \right) = L_w + L_b \quad (3)$$

where

$$\begin{aligned} T_j &= \sum_{i=1}^n \left( \frac{x_{ij}}{x_j} \right) \ln \left( \frac{x_{ij}/x_j}{p_{ij}/p_j} \right), \\ L_j &= \sum_{i=1}^n \left( \frac{p_{ij}}{p_j} \right) \ln \left( \frac{p_{ij}/p_j}{x_{ij}/x_j} \right), \end{aligned} \quad (4)$$

$T_j$  is group's  $j$  Theil T index,  $L_j$  is group's  $j$  Theil L index,  $x_j$  is the mean access in group  $j$ , and  $p_j$  is the total population of group  $j$ .  $T_w$  and  $T_b$  are within-group and between-group components of Theil T, while  $L_w$  and  $L_b$  are those of Theil L.

### 3.3.3 Spatial weight matrix

This study also investigates the existence of spatial dependence between districts in Indonesia. Given that there is evidence of the presence of spatial association, the location of spatial cluster/outlier districts of sustainable water and sanitation access is further determined. To do so, first, a spatial weight matrix is constructed.

A spatial weight matrix represents the quantified spatial relationship of the spatial unit. The matrix calculates the degree of spatial proximity among the spatial unit. This study uses row-standardized distance band weight to specify spatial weight matrix,  $w_{ij}$  denotes as

$$w_{ij} = \frac{w_{cij}}{\sum w_{cij}} \quad (5)$$

where  $w_{cij}$  is defined as

$$w_{cij} = \begin{cases} 1 & \text{if } 0 \leq d_{cij} \leq d_{max} \\ 0 & \text{if } d_{cij} > d_{max} \end{cases} \quad (6)$$

### 3.3.4 Global/Local indications of spatial association (GISA/LISA)

Spatial autocorrelation is one of the essential concepts in spatial analysis. It measured the spatial association between values based on their relatively close geographical location. The global indications of spatial association (GISA) indicate the existence of spatial autocorrelation, while the local indications of spatial association (LISA) determine the magnitude and location of spatial association. This study uses the widely used measure to calculate spatial autocorrelation, the global and local Moran's I statistics. GISA and LISA are estimated to have access to sustainable water (*water*) and sanitation (*sanitation*) for each dataset.

The subscript  $i(j)$  denotes district  $i(j)$ , where  $i \neq j$ , and a country consists of  $n$  districts. The Moran's I statistics,  $I$ , is specified as follow:

$$I = \frac{n}{w_0} \sum_i \sum_j \frac{w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{(x_j - \bar{x})^2} \quad (7)$$

Where  $x_i (x \in \text{water, sanitation})$ ,  $\bar{x}$  indicates the mean value of the corresponding variable, and  $w_0$  means the sum of all elements in the spatial weight matrix  $w_{ij}$  defined in equation (5). The summation,  $w_0$ , denotes as

$$w_0 = \sum_i \sum_j w_{ij} \quad (8)$$

The Moran's I statistics,  $I$ , are valued between -1 and 1, which 1 (-1) indicates a strong positive (negative) spatial association.

The local Moran's I statistics,  $I_i$ , denotes as

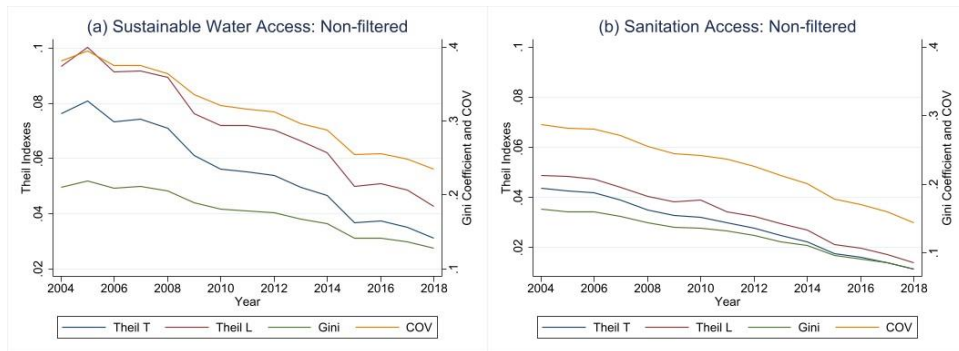
$$I_i = \frac{\sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i \frac{1}{n}(x_i - \bar{x})^2} \quad (9)$$

The Moran's I statistics for LISA are proportional to the corresponding global statistics and decomposed from the statistics. Local Moran's I statistics show the location and the magnitude of spatial association, as developed by Anselin (1995). A positive (negative) value of local Moran's I statistics indicates cluster (outlier).

## IV. Results and Discussion

### 4.1 Interregional Inequality

This section measures the interregional inequality in household access to safe water and sanitation. Figures 4.1(a)-(b) present the four inequality measures, Gini ratio, Theil T and Theil L indexes, and coefficient of variation (COV) for 15 years (2004–2018). The figures show only the non-filtered inequality values as they exhibit the same trend as the filtered ones. Moreover, the figures show that the regional gap of all index measures in both variables declined during the observation period. In addition, the regional disparities of water access show larger values than those of sanitation.



**Figure 4.**(a)-(b) Inequality measures of access to sustainable water and sanitation, 2004–2018

#### 4.1.1 Inequality between regency and city

Subsequently, inequality decomposition analyses by district sub-groups, such as locations (urban/rural), district types of administrative reform (intact, split, and new)<sup>9</sup>, and sub-national regions are performed. The districts are classified into regencies and cities that differ in size, demographic, and economic structures. In general, cities are considered urban areas, while regencies are thought of as rural areas. The differences between the two areas may affect the service delivery provision by each government, resulting in the disparity of access to sustainable water and sanitation for households.

The mean-comparison t-tests between regency and city are presented in Table 2. On average, water and sanitation access were higher than in the regency. The results are statistically significant at a 1% significance level in 2004 and 2018 for non-filtered and filtered data. This is consistent with Irianti et al.'s (2016) study, which found that households in urban areas are more likely to access improved water sources. Moreover, most cities are districts where the province's capital city is situated. The co-existence of sub-national and regional governments in these cities can provide a more developed infrastructure of household services than regencies.

**Table 2.** Mean values and two-sample t-test between regency and city

| Variable / Dataset                 | 2004    |        | 2011    |       | 2018    |        |
|------------------------------------|---------|--------|---------|-------|---------|--------|
|                                    | Regency | City   | Regency | City  | Regency | City   |
| <b>Access to Sustainable Water</b> |         |        |         |       |         |        |
| Non-filtered                       | 37.231  | 61.945 | 48.64   | 79.53 | 62.730  | 86.551 |
| Filtered                           | 37.287  | 62.682 | 49.10   | 76.44 | 61.516  | 89.597 |
| <b>Access to Sanitation</b>        |         |        |         |       |         |        |
| Non-filtered                       | 53.904  | 74.844 | 57.22   | 76.40 | 73.231  | 85.136 |
| Filtered                           | 51.505  | 71.545 | 60.06   | 77.85 | 69.885  | 84.394 |

<sup>9</sup> Indonesia experienced the local government proliferation at the province and district levels associated with the decentralization process. The new local administrative units are separated from the original units in the administrative reforms. Thus, this study categorizes the units into three types: intact, split, and new. Intact is the district that has never been separated. In other words, it has never changed during the observation period. Split is the original/parent district that has experienced separation while a new district is newly created

Table 3 presents the decomposition of Theil indexes for sustainable water and sanitation access between regency-city of non-filtered data and their corresponding Theil index. The within-group component shows a higher proportion than the between-group component in both accesses. However, the contribution decreased along the observation period for both accesses. Moreover, the districts in urban areas were more equal than those in rural areas. The urban sector shows the higher access welfare for all years, and it is more equal than the rural sector.

**Table 3.** Theil decomposition between regency-city and their corresponding Theil index

| District Type                      | Theil T <sup>a</sup> |                  |                  | Theil L <sup>a</sup> |                  |                  |
|------------------------------------|----------------------|------------------|------------------|----------------------|------------------|------------------|
|                                    | 2004                 | 2011             | 2018             | 2004                 | 2011             | 2018             |
| <b>Access to Sustainable Water</b> |                      |                  |                  |                      |                  |                  |
| All districts                      | 0.076                | 0.055            | 0.031            | 0.093                | 0.072            | 0.043            |
| Between-group component            | 0.017<br>(21.86)     | 0.017<br>(30.68) | 0.007<br>(23.70) | 0.015<br>(16.57)     | 0.016<br>(21.97) | 0.007<br>(16.65) |
| Within-group component             | 0.059<br>(78.14)     | 0.038<br>(69.30) | 0.024<br>(76.30) | 0.078<br>(83.42)     | 0.056<br>(78.03) | 0.035<br>(83.35) |
| Regency <sup>b</sup>               | 0.064                | 0.049            | 0.031            | 0.084                | 0.068            | 0.044            |
| City <sup>b</sup>                  | 0.048                | 0.012            | 0.007            | 0.054                | 0.014            | 0.007            |
| <b>Access to Sanitation</b>        |                      |                  |                  |                      |                  |                  |
| All districts                      | 0.044                | 0.030            | 0.011            | 0.049                | 0.034            | 0.014            |
| Between-group component            | 0.008<br>(19.30)     | 0.005<br>(18.26) | 0.001<br>(8.66)  | 0.008<br>(16.36)     | 0.005<br>(15.42) | 0.001<br>(7.02)  |
| Within-group component             | 0.035<br>(80.70)     | 0.025<br>(81.70) | 0.010<br>(91.34) | 0.041<br>(83.64)     | 0.029<br>(84.58) | 0.013<br>(92.90) |
| Regency <sup>b</sup>               | 0.044                | 0.030            | 0.012            | 0.049                | 0.035            | 0.015            |
| City <sup>b</sup>                  | 0.009                | 0.008            | 0.005            | 0.010                | 0.008            | 0.005            |

Notes: <sup>a</sup> value in parentheses are components' share to the total inequality. <sup>b</sup> Corresponding Theil indexes of each group.

#### 4.1.2 Inequality by district type

In this subsection, the mean difference and inequality decomposition between districts experiencing territorial splits are examined. For this analysis, the districts are categorized into three types: intact (never separate/split), split (original/parent district), and new (newly created district). The areas that never split had higher access to sustainable water and sanitation than the separated and created districts. Moreover, accesses in the original district were higher than the newly created ones. ANOVA results show that, on average, all district types did not have the same mean values at a 1% significance level.

Furthermore, Bonferroni multiple-comparison tests show that the means of access were statistically different between the intact and split districts and between intact and new

districts at a 1% significance level in 2004, 2011, and 2018. The mean values of the access were different between split and new districts at a 10% significance level in 2018. This finding is consistent with Lewis (2017), who found that new districts provide lower access to water and sanitation than parent districts, but the result is insignificant.

Table 4 shows the result of Theil decompositions of safe water and sanitation access by district types and their corresponding indexes. Similar to the regency-city decomposition, the within-group component shared a more outstanding contribution to the overall inequality. In addition, the within-group contribution decreases over time in sustainable water access but increases in sanitation access.

The inequalities of water access in intact districts are similar to the parent districts; the two groups are relatively more equal than new districts. In contrast, the newly created area had the highest access inequality. Access disparity among new districts may occur as a result of their separation process. In the short and long run, district creation negatively affects infrastructure access (Lewis, 2017). Due to their establishment, new districts may have low access for several years. However, in this study, not a few values of the new districts are imputed values. Therefore, we cannot overlook that the presence of bias that may affect the lower mean of the access and the higher access gaps.

**Table 4.** Theil decomposition by district type, and their corresponding Theil index

| District Type                      | Theil T <sup>a</sup> |                  |                  | Theil L <sup>a</sup> |                  |                  |
|------------------------------------|----------------------|------------------|------------------|----------------------|------------------|------------------|
|                                    | 2004                 | 2011             | 2018             | 2004                 | 2011             | 2018             |
| <b>Access to Sustainable Water</b> |                      |                  |                  |                      |                  |                  |
| All districts                      | 0.076                | 0.055            | 0.031            | 0.093                | 0.072            | 0.043            |
| Between-group component            | 0.011<br>(13.81)     | 0.007<br>(13.08) | 0.003<br>(8.53)  | 0.011<br>(11.85)     | 0.008<br>(10.54) | 0.003<br>(6.49)  |
| Within-group component             | 0.066<br>(86.19)     | 0.048<br>(86.92) | 0.029<br>(91.47) | 0.082<br>(88.14)     | 0.064<br>(89.45) | 0.040<br>(93.51) |
| Intact <sup>b</sup>                | 0.061                | 0.042            | 0.024            | 0.071                | 0.051            | 0.029            |
| Split <sup>b</sup>                 | 0.069                | 0.043            | 0.022            | 0.090                | 0.050            | 0.026            |
| New <sup>b</sup>                   | 0.103                | 0.105            | 0.071            | 0.136                | 0.164            | 0.123            |
| <b>Access to Sanitation</b>        |                      |                  |                  |                      |                  |                  |
| All districts                      | 0.044                | 0.030            | 0.011            | 0.049                | 0.034            | 0.014            |
| Between-group component            | 0.001<br>(1.67)      | 0.001<br>(3.33)  | 0.000<br>(4.01)  | 0.001<br>(1.52)      | 0.001<br>(2.99)  | 0.000<br>(3.33)  |
| Within-group component             | 0.043<br>(98.32)     | 0.029<br>(96.67) | 0.011<br>(95.96) | 0.048<br>(98.48)     | 0.033<br>(97.01) | 0.013<br>(96.60) |
| Intact <sup>b</sup>                | 0.038                | 0.025            | 0.008            | 0.042                | 0.027            | 0.008            |
| Split <sup>b</sup>                 | 0.050                | 0.034            | 0.013            | 0.055                | 0.038            | 0.014            |
| New <sup>b</sup>                   | 0.061                | 0.051            | 0.028            | 0.072                | 0.061            | 0.040            |

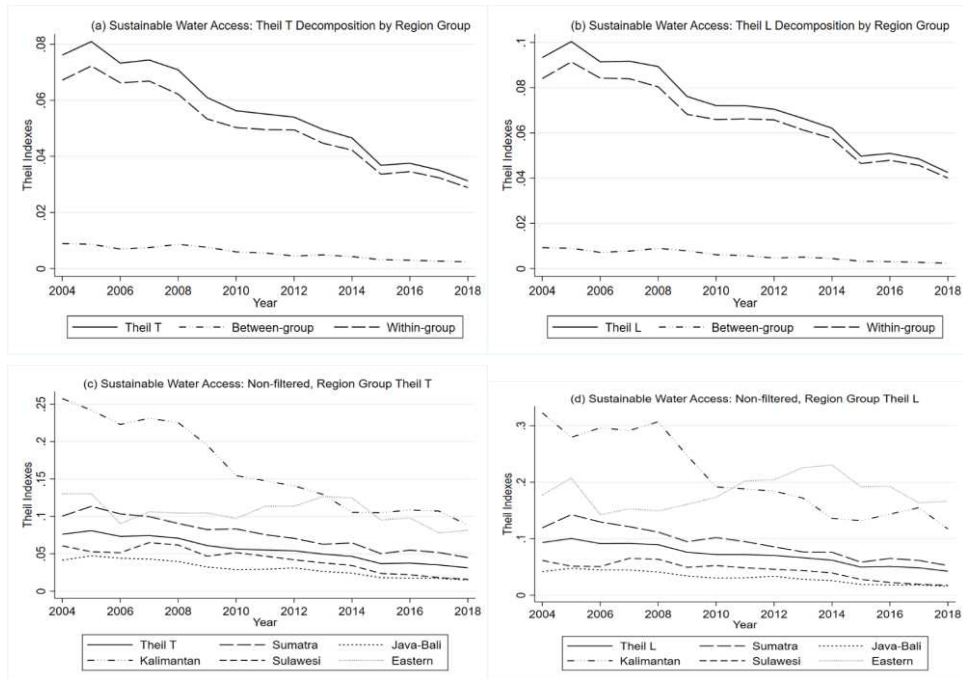
Notes: <sup>a</sup> value in parentheses are components' share to the total inequality. <sup>b</sup> Corresponding Theil indexes of each group.

#### 4.1.3 Inequality by sub-national regions

Regional analysis is conducted to examine the disparity of seven region groups in Indonesia. These regions are categorized according to the main islands. They are Java-Bali,

Sumatra, Kalimantan, Sulawesi, and Eastern<sup>10</sup>. There are several notable discussions from the result. First, the one-way ANOVA rejects that all mean values are the same across sub-region groups at a 1% significance level. Second, the water access in Java-Bali is relatively higher than in other regions, while Eastern has the lowest access. Third, Java-Bali, Sumatra, and Kalimantan have a similarly higher access proportion of sanitation access than other regions in 2018. The Bonferroni test confirmed the aforementioned multiple comparisons in mean values.

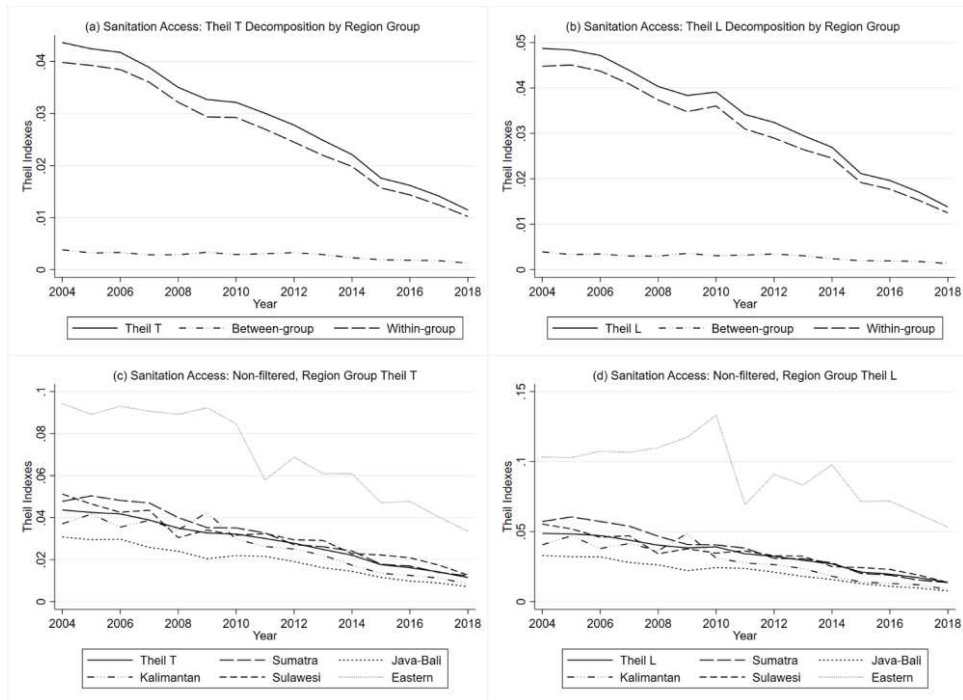
Figures 4.2(a)-(d) show the inequality decomposition of access to sustainable water among regions, and their corresponding index. Similar to other decompositions, the within-group component contributes the most to the overall disparity. Moreover, Eastern and Kalimantan are the regions with the highest inequality, while Java-Bali has the lowest inequality. This finding provides insights to the key research question regarding the location of the spatial cluster.



**Figure 5.** (a)-(d) Theil decomposition of access to sustainable by region group, and their corresponding Theil index

Figures 4.3(a)-(d) display the decomposition of Theil T and L indexes for sanitation access by region. The within-group component contributes the most to the total inequalities in Indonesia. Among all areas, Eastern is the region with the highest inequality in sanitation access. In comparison, Java-Bali is relatively the least unequal. Moreover, the sanitation access disparities in other regions are almost similar to the overall inequality by the end of the observation.

<sup>10</sup> Eastern region consists of districts that belong to West Nusa Tenggara, East Nusa Tenggara, Maluku, North Maluku, Papua, and West Papua provinces.



**Figure 6.** (a)-(d) Theil decomposition of access to sanitation by region group, and their corresponding Theil index

## 4.2 Spatial Autocorrelation

Next, this study examines the presence of spatial autocorrelation and identifies the spatial clusters/outlier districts, using global and local Moran's I. Results are derived based on the non-filtered and filtered values.

### 4.2.1 The existence of spatial association

Table 5 displays the values of global Moran's I statistics and its corresponding p-values of access to sustainable water and sanitation. The values for water access were low positive and increased over time from 0.158 in 2004 to 0.185 in 2018 for non-filtered data. For filtered data, the statistics lay between 0.158 in 2004 and 0.164 in 2018.

Similarly, Moran's I statistics of the household access to sanitation are low positive in all datasets. The values ranged from 0.127 in 2004 to 0.167 in 2018 for non-filtered data and between 0.133 and 0.152 for the filtered ones. The null hypothesis of the absence of spatial autocorrelation was rejected at a 1% significant level, indicating the presence of spatial dependence. The result is consistent for both variables in all datasets along the period of observation.

These findings imply that districts with high (low) access to sustainable water/sanitation tend to be close to each other. Moreover, the trend of spatial autocorrelation of both accesses increased but remained very weak. This result implies that in terms of access to sustainable water and sanitation, the districts have become more dependent by the end of the observation period than initially.



**Table 5.** Global Moran's I statistics

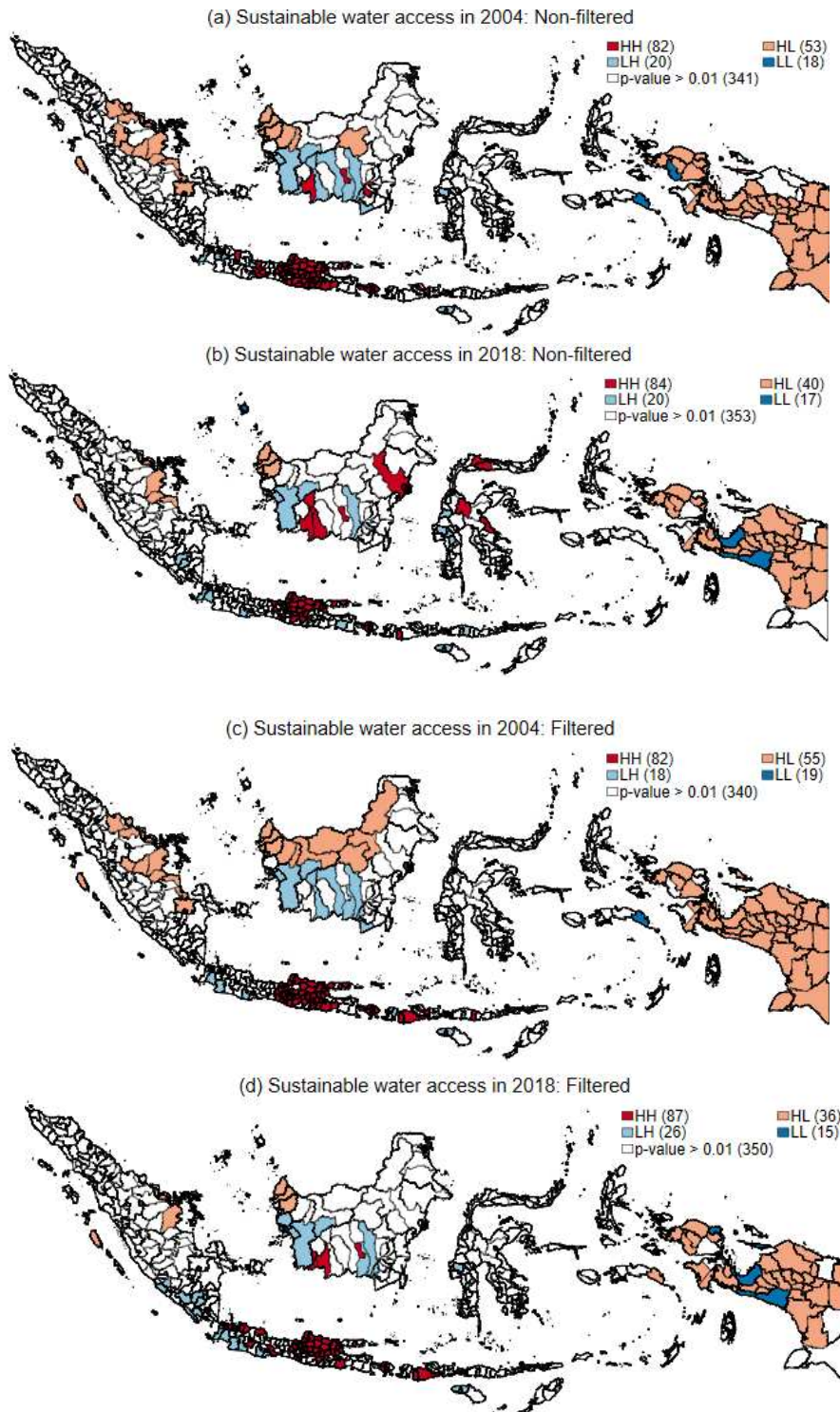
| Year | Access to Sustainable Water |         |           |         | Access to Sanitation |         |           |         |
|------|-----------------------------|---------|-----------|---------|----------------------|---------|-----------|---------|
|      | Non-filtered                |         | Filtered  |         | Non-filtered         |         | Filtered  |         |
|      | Moran's I                   | p-value | Moran's I | p-value | Moran's I            | p-value | Moran's I | p-value |
| 2004 | 0.15783                     | 0.000   | 0.15834   | 0.000   | 0.12658              | 0.000   | 0.13307   | 0.000   |
| 2005 | 0.14665                     | 0.000   | 0.16359   | 0.000   | 0.10452              | 0.000   | 0.13707   | 0.000   |
| 2006 | 0.13163                     | 0.000   | 0.16794   | 0.000   | 0.09728              | 0.000   | 0.14083   | 0.000   |
| 2007 | 0.12902                     | 0.000   | 0.17140   | 0.000   | 0.09867              | 0.000   | 0.14434   | 0.000   |
| 2008 | 0.15242                     | 0.000   | 0.17397   | 0.000   | 0.10246              | 0.000   | 0.14756   | 0.000   |
| 2009 | 0.15779                     | 0.000   | 0.17568   | 0.000   | 0.13456              | 0.000   | 0.15045   | 0.000   |
| 2010 | 0.14174                     | 0.000   | 0.17659   | 0.000   | 0.10605              | 0.000   | 0.15297   | 0.000   |
| 2011 | 0.16663                     | 0.000   | 0.17678   | 0.000   | 0.13467              | 0.000   | 0.15504   | 0.000   |
| 2012 | 0.14176                     | 0.000   | 0.17631   | 0.000   | 0.15380              | 0.000   | 0.15661   | 0.000   |
| 2013 | 0.16123                     | 0.000   | 0.17528   | 0.000   | 0.16611              | 0.000   | 0.15760   | 0.000   |
| 2014 | 0.15487                     | 0.000   | 0.17373   | 0.000   | 0.16786              | 0.000   | 0.15793   | 0.000   |
| 2015 | 0.16807                     | 0.000   | 0.17172   | 0.000   | 0.13445              | 0.000   | 0.15757   | 0.000   |
| 2016 | 0.16062                     | 0.000   | 0.16933   | 0.000   | 0.13033              | 0.000   | 0.15650   | 0.000   |
| 2017 | 0.16700                     | 0.000   | 0.16660   | 0.000   | 0.18082              | 0.000   | 0.15473   | 0.000   |
| 2018 | 0.18520                     | 0.000   | 0.16358   | 0.000   | 0.16749              | 0.000   | 0.15227   | 0.000   |

#### ***4.2.2 Geographic locations of spatial association***

The following analysis identifies the location of spatial high/low household access clusters/outliers of safe water and sanitation, referring to Anselin's (1995) Moran scatterplot. He used two variables, the standardized values of local Moran's I and the spatial lags, to classify all districts into four groups: (I) spatial clusters of high household access, (II) spatial outliers of low household access, (III) spatial clusters of low household access, and (IV) spatial outliers of high household access.

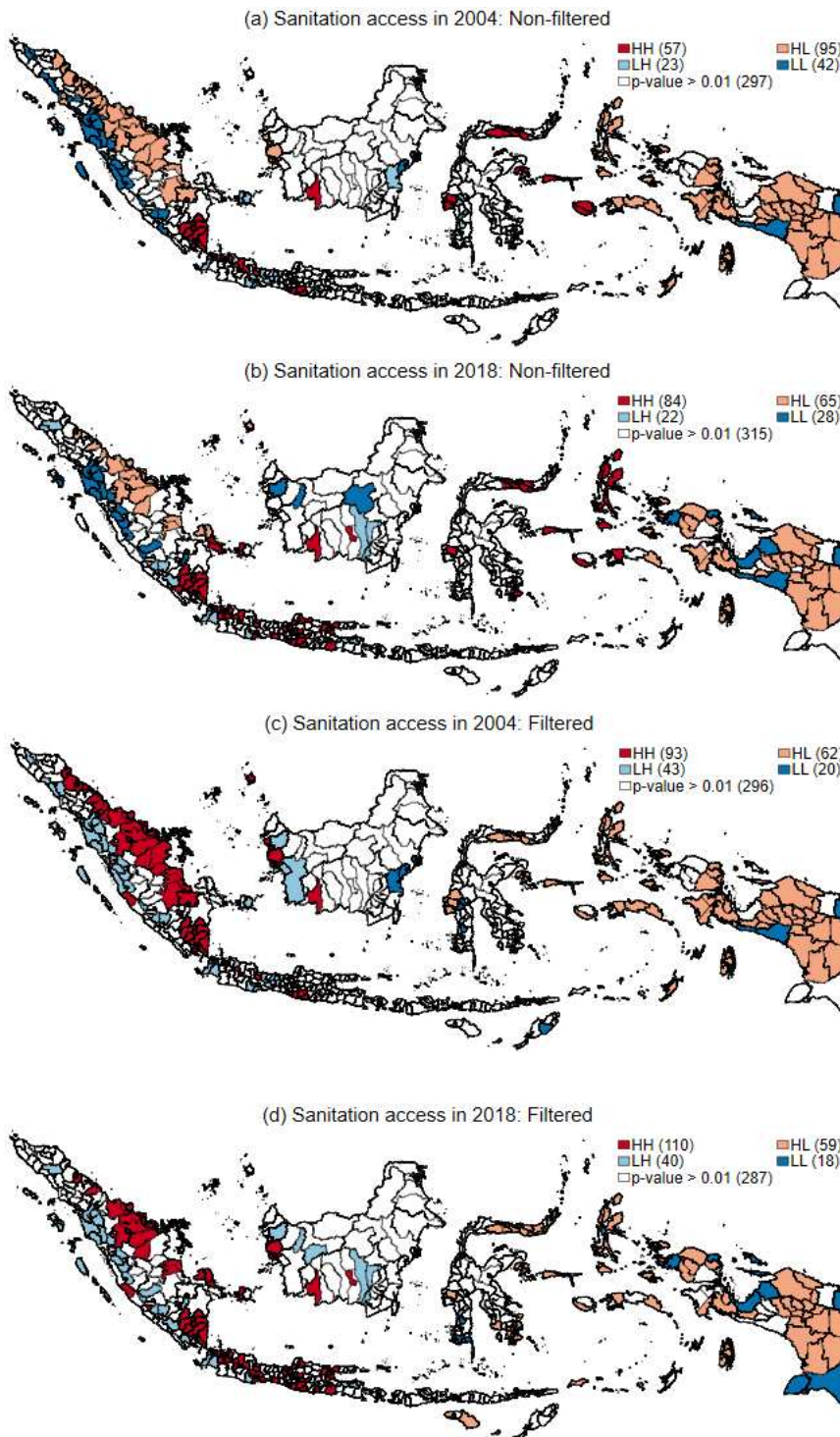
Spatial lags are the weighted values by the access to the neighboring districts. Those values are derived by using the spatial weight matrix. The groups I and III are the local positive spatial association values; that is, they have higher (lower) household access and are surrounded by districts with relatively high (low) household accesses. On the other hand, groups II and IV exhibit negative local spatial association, and the observed values are dissimilar to neighboring districts, and those with similar access levels are located far from each other.

This study refers to groups I through IV using the following four classifications: high-high (HH), low-high (LH), low-low (LL), and high-low (HL). HH and LL are high- and low-access spatial clusters referred to as "hot spots" and "cold spots," respectively. Meanwhile, LH and HL districts are low- and high-access spatial outliers, respectively.



Note: HH:High-access cluster, HL:High-access outlier, LH: Low-access outlier, LL: Low-access cluster

**Figure 7.** (a)–(d) Choropleth map of significant water access cluster/outlier districts



Note: HH:High-access cluster, HL:High-access outlier, LH: Low-access outlier, LL: Low-access cluster

**Figure 8.** (a)-(d) Choropleth map of significant sanitation access cluster/outlier districts

Figures 7. (a)-(d) and 8. (a)-(d) display the choropleth maps of the clusters/outliers in water and sanitation access in 2004 and 2018 for non-filtered and filtered data. The values in the parentheses of map legends in the non-white districts are the number of 1% significant spatial cluster/outlier districts. It is noticeable that there are differences in the location of the significant cluster/outlier districts between non-filtered and filtered maps. This indicates that the regional measurement errors and cyclical shock influenced the districts' spatial association.

Moreover, the comparison allows us to identify the significantly vulnerable districts to the artificial factors sampling process or regional shocks. For instance, Figure 7 (a) shows Kota Waringin Barat regency in North Kalimantan province as a high-access cluster (HH) of sustainable water access in 2004, but it does not appear in Figure 7 (c). This implies that the positive spatial association of Kota Waringin Barat regency was affected by the non-trend components. In 2002, this district was split, and two new districts, Sukamara and Lamandau regencies, were created. The separation was likely to influence spatial association in this area.

The results of geographic spatial autocorrelation led to several other noteworthy findings of safe water access. The statistically significant spatial high-access cluster (HH) districts are concentrated in Java-Bali region. Specifically, most of them are in Central Java, Yogyakarta, and East Java provinces; only a few are located outside Java. The hot spots in Java island are widely known for their relatively high-performance local-owned water companies (PDAM).<sup>11</sup> More than 94% of the PDAM in those provinces are categorized as best-performed by the Ministry of Public Works and Housing.

On the other hand, the significant low-access spatial clusters (LL) of sustainable water are clustered in Sumatra region. Others are spread in Kalimantan, Maluku, and Papua. The cold spots of safe water access are the areas that have experienced high land conversion for the past years. The land was transformed for several purposes, such as palm-oil plantation in Jambi provinces or plantation and mining area in West Sumatra provinces. Land conversion results in the decline of water absorption area, which degrades water source capacity. Protecting water sources is important to ensure water supply for the people living in the area. Paired with climate changes impact, human activities that reduce water supply contribute to water stress situations (Wang et al., 2012).

There are also some outstanding results in the spatial association of sanitation access. First, there were more statistically significant high-access cluster (HH) districts in 2018, indicating a rise in positive spatial correlation. In contrast, the low-access spatial cluster (LL) districts decreased from 53 to 40 by the end of the observation, implying that some districts within the lower access clusters successfully improved the access.

Second, the statistically significant spatial high-access cluster (HH) districts of sanitation access are located in Java-Bali and Sumatra. They are also widely known as high-income areas with high economic activities. The result is consistent with a study by Cameron, Olivia, & Shah (2019), who found that poorer households have inadequate capacity to improve their sanitation. Based on their randomized controlled trials in Indonesia, low-income families are only willing to build sanitation facilities when incentives are provided for them through a community-led total sanitation program.

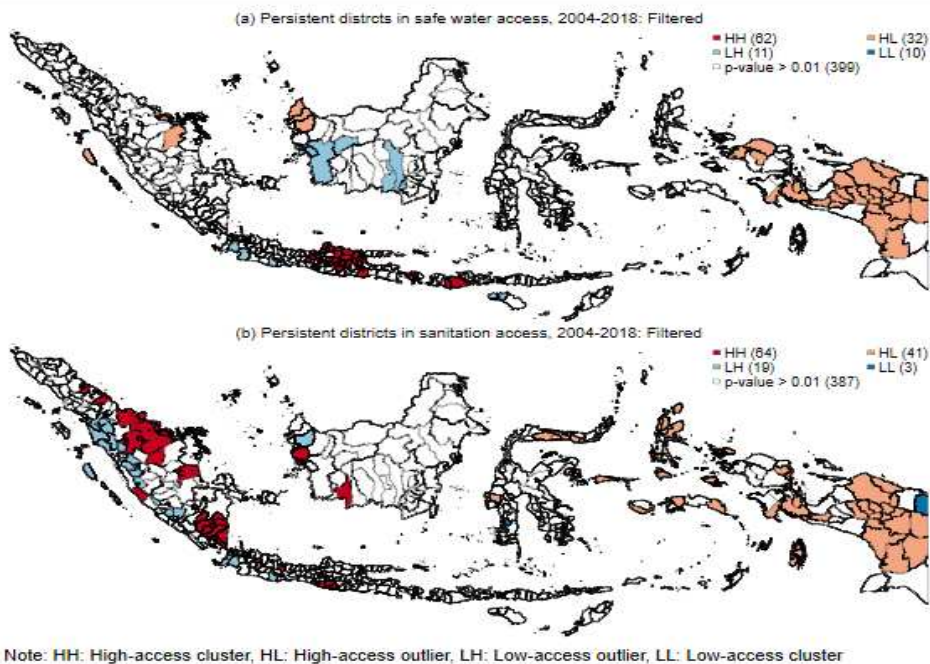
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<sup>11</sup> Ministry of Public Works and Housing together with Financial Development Supervisory Board of Indonesia conduct annual performance evaluation for local-owned water companies (PDAM). The assessment consists of financial, service delivery, operational, and human resource aspects. The result is classified into three categories from the best to the worst: healthy, less healthy, and sick. In 2019, it was reported that 224 out of 380 (58.95%) PDAM were healthy. Java island showed the highest percentage of PDAM with the best performance, 93% (100 from 108). Moreover, the proportion of high-performed PDAM in Central Java, Yogyakarta, and East Java provinces were 97.14%, 100%, and 94.29%, respectively.



Third, similar to the water access, most of the areas in Papua are persistent spatial outliers (HL) of high household access. The general view is that districts in Papua are lagged behind. The low economic growth in these areas may explain the minimal access to both sustainable water and sanitation. Moreover, geographic conditions exacerbate the problem.

Among all districts, some districts remain statistically significant throughout the observation period, invulnerable to the artificial factors from the sampling process and the cyclical shock. This means that several districts appeared as cluster/outlier of the access for all years in the non-filtered dataset. Figures 9 (a)-(b) display these persistent districts.



**Figure 9.** (a)-(b) Choropleth map of persistent districts of water and sanitation access

There are 62 HH, 10 LL, 11 LH, and 32 HL persistent cluster/outlier districts of safe water access invulnerable to the sampling process and the presence of regional shocks for the period of observation. The majority of prolonged hot spots (62 HH) are districts in Central Java and East Java provinces, where many PDAM with high performances existed. Moreover, almost all of these persistent high-access cluster districts are those districts that never split.

In contrast, only a few invulnerable persistent sustainable water access cold spot districts are observed for the period. These low access spatial clusters are mostly located in Sumatra, precisely in West Sumatra province. As mentioned before, in West Sumatra, water absorption areas have been degraded as the change of land function into palm-oil, or rubber plantations increased.

In addition, there are 64 HH, 3 LL, 19 LH, and 41 HL persistent districts invulnerable to the artificial factors sampling process and the presence of regional cyclical shocks for sanitation access. Compared to safe water access, the hot spots of sanitation access are spread across Indonesia. Specifically, these high-access spatial clusters are located in Sumatra, Java-Bali, and Kalimantan. While there are many persistent hot spots, there are only three continuous cold spot districts of sanitation access. Two of these low-access clusters are intact districts in Sulawesi. Another persistent district is a newly created area in Papua.

Another worthy finding from the geographical analysis of persistent districts is that the high-access outliers (HL) for both accesses are mostly concentrated in Papua. To be precise, most of these dual persistent HL districts are the newly created regencies in Papua province. This implies that poor development of access occurs in the districts where administrative reforms took place and it is pervasive. Appendix 4 and 5 report the lists of persistent statistically significant cluster/outlier districts in sustainable water and sanitation access.

## V. Conclusion and Policy Implications

This study investigates the interregional disparity among districts in Indonesia using the data of household access to sustainable water and improved sanitation. The findings show that the access gap declined during the period of observation. On average, access in the cities is significantly higher than in regencies, and these urban areas are more equal than the rural. Evidence of this study also suggests that the average access level in the districts that never separated is significantly higher than other districts for both accesses. In comparison, the districts that are newly created are relatively more unequal than others. Since local governments provide public services, the lower access may be a possible reason for the proliferation. In addition, the regional analysis tells that households in Java-Bali have the highest or at least relatively higher access to safe water and sanitation, and districts in this region are more equal than in other areas. In contrast, Eastern parts of Indonesia have the lowest accesses, and the districts within the region are more unequal than in other areas.

Regardless of the decreasing inequality trend in access to safe water and sanitation, the disparities with the neighboring districts in Indonesia persist. The global spatial analysis indicates the existence of spatial clusters and outliers, although it remains very weak. The local spatial analysis identifies the location difference in the persistent high-access cluster districts (HH) between sustainable water access and sanitation. The formers are mainly located in Java-Bali, while the latter are spread in Java-Bali, Sumatra, and Kalimantan. It is also apparent that several districts in the Eastern region are continual high-access outlier districts in both accesses. The possible explanation for this is that the mountainous areas of Papua island complicate the development of safe water and sanitation facilities. This emphasizes that this factor is an important challenge to increase access to sustainable water and sanitation in that area.

The household access to safe water and sanitation affects productivities in regions through human capital that consists of several factors such as education and health (Headey & Palloni, 2019; Komarulzaman et al., 2017; Luby et al., 2018; Patunru, 2015; Prüss-Ustün et al., 2019). Hence, the government must strive to provide sustainable access to water and sanitation for all.

While some regions have far higher access, other parts of the country have been left behind for an extended period. Within the vast, diverse Indonesian territories, there is no panacea for the issue of access inequality. With the specific ecological conditions, different areas require different treatment. Tailored policies and development plans must be adjusted to the landscape and socio-economic conditions of each particular area.

Spatially augmented policies are more likely to be adequate to achieve universal access to safe water and sanitation. For instance, implementing the community-based program may increase water and sanitation access to low-access areas. Involving citizens in the planning process may give more reliable information regarding their needs. Moreover, it may motivate them to proactively contribute to the efforts in improving access in the area.

The government could prioritize subsidies for water access and sanitation in the Eastern part of Indonesia. This region has many persistent high access outlier districts (HL) in safe water and sanitation. This indicates the persistent large gaps with the neighboring

districts. Assuming that access to safe water and sanitation is one of the major factors in development, those can be a driving force in migration among districts. Public supports are needed in reducing access disparity. Both central and local governments may give financial support either to the local water companies or directly to the communities in order to improve water coverage. Cameron et al. (2019) confirmed that government incentives help low-income households to build improved sanitation facilities. Moreover, specific infrastructure facilities of water and sanitation must be built because mountainous land in Eastern areas is a unique challenge in improving access in the region.

Furthermore, as water access is related to water supply and its source, it is also crucial for the government to ensure the sustainability of water resources. Imposing policies that prevent the decline of the water supply is essential. Preventing more land conversion for commercial/industrial plantation and mining purposes is also important to sustain the water resources and supply in Indonesia. A comprehensive evaluation of the impact of land transformation must be conducted before the government permits land conversion authorization to preserve water absorption areas.

This study has several limitations and could be improved with several possible extensions. First, the constructed dataset from imputed values may cause bias in the examination. Other imputation methods may be conducted to provide a more accurate dataset. Second, analyzing convergence or club-convergence in both accesses may give additional information regarding access inequality. Another possible extension is to examine growth incidence curves to explain sustainable water and sanitation access development in particular areas in Indonesia.

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