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Measuring The Impact of Special Economic Zone (SEZ) Arun Lhokseumawe on the Sustainability of its Peripheral Area

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The impact of special economic zones (SEZ) on the sustainability of their peripheral areas is rarely measured and discussed. This research was conducted to determine the sustainability level of the Arun Lhokseumawe SEZ generated to its surrounding area before and after the exhaustion of its natural gas resources. The statistical matching method and the Moran index used for the analysis involved 14 sustainability variables representing social, economic, and environmental dimensions. The method used includes building the sustainability index using village level data, statistical matching to find evidence of impact, and determination of the Moran index to describe its spatial patterns. Additionally, the index was used to describe the policy implication based on the current SEZ sustainability level. The results show that there is no upward trend in the sustainability index after three years of operation, except for an increase in the SEZ (inside) in 2018 which then declines again in 2021. This figure is lower than before natural gas depletion. It was found that, in 2008, the spatial pattern of the high sustainability index mainly spread to areas outside the Arun Lhokseumawe industrial area. Meanwhile, in 2021, the spatial pattern of a high sustainability index clustered near the Arun Lhokseumawe special economic zone.

Keywords: special economic zones, statistical matching, Moran index, sustainability index.

Introduction

The natural gas production in the Province of Aceh, Indonesia, including the Arun Lhokseumawe oil and gas industrial area experienced a decline in 2000 and fully stopped in 2014. This subsequently affected the social, economic, and environmental development in Aceh Province because the oil and gas industry, its derivatives, and processing partners have become the main trade sector since the 1990s (Hasyim et al., 2010). As evident to that, Aceh province's Trade Balance in 2000 was 1.7 billion USD and reached the highest value in 2005 of 2 billion USD, but then experienced a steep drop reaching the lowest value of –0.023 billion USD in 2015 and rose again slowly starting in 2016 (Central Bureau of Statistics Republic of Indonesia, 2021). It was also observed that the human development index (HDI) of North Aceh regency and city declined in 2010 reaching 63.56% and 71.55% and rose gradually afterward and reached 69.33% and 77.31% in 2020 (Central Bureau of Statistics Republic of Indonesia, 2021).

One of the efforts made by the Indonesian government to mitigate the decline of the developmental pace in Aceh was the establishment of the Arun Lhokseumawe special economic zone (SEZ) in an industrial area located in Aceh regency and Lhokseumawe city. This was conducted to resuscitate and sustain industrial and economic progress in the area (Department of Industry, Trade and Trade, Government of Aceh, 2016). The SEZ are areas with certain boundaries developed due to their geoeconomic and geostrategic advantages and provided with special facilities and incentives to attract investment. Although it is often discussed that the SEZ has proved to have a positive impact on its surrounding economic performance and may be used as a catalyst for industrialization and economic transformation (Frick and Rodríguez-Pose, 2019; Zeng, 2021), research on the performance of sustainability in and around a SEZ is rarely conducted or discussed.

Sustainability is a political process of linking values with rights, welfare, and abilities, both between and across generations (Sachs, 2015). The optimization of the benefits associated with certain resources for developmental purposes is known as the sustainable development process and conceptually as a progressive transformation of the social, economic, and political structures (Supriatna, 2021). Other research also suggests that sustainable development includes three simultaneous and important dimensions which are the social, environmental, and economic dimensions (Luukkanen et al., 2019; Mensah, 2019). Based on the above arguments, we will focus our study on three dimensions of sustainability, i.e., social, environmental, and economic dimensions.

The available secondary data do not always produce normal and homogeneous data which can then be analyzed and concluded. With reference to the greatest impact of SEZs up to a radius of 10–20 km (Frick and Rodríguez-Pose, 2019) and the large number of villages within that radius and the uniqueness that accompanies it, an appropriate method is needed to measure and analyze sustainable development in the area around this SEZ. Furthermore, the Moran global and local indices were used to determine the pattern used by the Arun Lhokseumawe SEZ to influence sustainable development and its dimensions. These two methods were applied because they are statistically suitable and the SEZ formation has geoeconomic and geostrategic advantages (Iskandar, 2021), which are in line with the first law of geography (Tobler, 2004) that everything is related, but things that are closer together are more related than things further away.

The aim of this research is the determination of sustainability using such an index for the external environment of the Arun Lhokseumawe SEZ using the statistical matching and the Moran index methods as part of the basic strategy to manage the special economic zones and as an effort to revitalize the industrial area which has declined due to the depletion of raw materials and auxiliary materials sources.

Methods

Research location

Arun Lhokseumawe SEZ is in North Aceh Regency and Lhokseumawe City, Aceh Province, and the analysis unit is all buffer villages located 10 km from the SEZ while those at 20 km were applied as the control. It is important to note that 269 villages were used as a buffer while 398 were applied as control, thereby, leading to a total of 667 villages in Bireuen and North Aceh Regencies as well as Lhoksuemawe City. North Aceh is geographically located at 95°52'–97°31' East Longitude and 4°46'–5°18' North Latitude, Lhokseumawe city is between 4˚–5˚ North Latitude and 96°–97° East Longitude, and Bireuen Regency is at 4° 54'–5°21' North Latitude (LU) and 96°20'– 97°21' East Longitude (BT).

Research step

The steps taken in this research include a) the development of the sustainability index (SI) at the village scale using indicators or variables from the village PODES data, followed by b) a comparative analysis of the LSDI of villages inside and outside the Arun Lhokseumawe SEZ buffer area using statistical matching to determine the impact of the Arun Lhokseumawe SEZ on its peripheral area with the village level analysis unit, and lastly c) analysis of the distribution patterns and LSDI trends inside and outside the Arun Lhokseumawe SEZ buffer area using the Moran and the local indicator of spatial association (LISA) indices.

Data collection technique and dimension determination

The main data that constructed our sustainability index come from PODES data, obtained from the Indonesian Central Statistics Agency (BPS) with a focus on numeric and categorical data. PODES or Village Potential Statistic is a survey-based data that BPS collected and covered various subjects including regional development and social issues (Central Bureau of Statistics Republic of Indonesia, 2021). PODES data obtained from 2008–2021 that are available at the village level enable us to measure sustainability at the lowest administrative unit where regional policies were often directed. A total of 14 variables were used to represent the three dimensions of sustainability such that 4 were used to represent the environmental aspect, 6 were for the social, and 4 were for the economic aspect as indicated in *Table 1*.

Table 1. *PODES data used as indicators and sustainability dimensions*

No	PODES indicator	Type	Sustainability dimension
1	The main source of income for most villagers	Categorical	Economy
2	Number of families using PLN electricity	Numeric	Economy
3	Number of slum locations	Numeric	Social
4	Number of landslides	Numeric	Environment
5	Number of flood events in 2020	Numeric	Environment
6	Number of educational facilities	Numeric	Social
7	Number of health facilities	Numeric	Social
8	Source of drinking water	Categorical	Environment
9	Number of mosques	Numeric	Social
10	Widest road surface type	Categorical	Economy
11	Number of industries or Micro Small and Medium Enterprises (MSMEs)	Numeric	Economy
12	Number of conflicts	Numeric	Social
13	Number of people with malnutrition in the last three years	Numeric	Social
14	Percentage of forest cover loss area by the village area	Numeric	Environment

The sustainability index calculation

The formation of the SI requires (1) the normalization of the minimum and maximum variable data to equate their values with a range of 0–1 using formula following the *"min-max method"* (OECD et al., 2008) (a), (2) aggregation of data on each dimension of sustainable development using formula (b), and (3) the final aggregation of the dimensions of social, economic, and environmental sustainable development to the sustainability index using formula (c).

$$Normalization = \frac{(variable\ value - minimum\ value)}{(maximum\ value - minimum\ value)} \quad (1)$$

$$SI\ Dimension\ k = \left(\frac{\sum_{k=1}^{N} Norm_i}{N}\right), k = 1, \ldots K \quad (2)$$

Where: $Norm_i$ – the results obtained from normalizing the variable value into the 0 – 1 range; N – number of variables defining dimensions (social, environmental, economic).

$$SI = \left(\frac{\sum_{k=1}^{N} Dimension_k}{N}\right), k = 1, \ldots K \quad (1)$$

Where: $Dimension_k$ – the kth dimension of the three development dimensions (social, economic, environmental); N – number of sustainable development dimensions (social, environmental, economic).

Table 2 shows the direction of the contribution of each variable toward sustainable development such that a negative value indicates that the variable has a greater contribution to the sustainable development index and vice versa.

Statistical matching

The statistical matching method could reduce research bias through the comparison of the treatment and control units with the same observed characteristics by identifying covariates/confounding variables and through estimation of standardized mean difference (SMD) and variance ratios (VR) in statistical matching. It is a method normally used in non-experimental research to often evaluate the impact of the object under research by comparing the treatment unit and control unit without random elements. It is important to note that non-experimental research does not manipulate independent variables nor randomly assigns research participants to a certain condition.

Table 2. *Dimensions of sustainable development and village potential variable mapping*

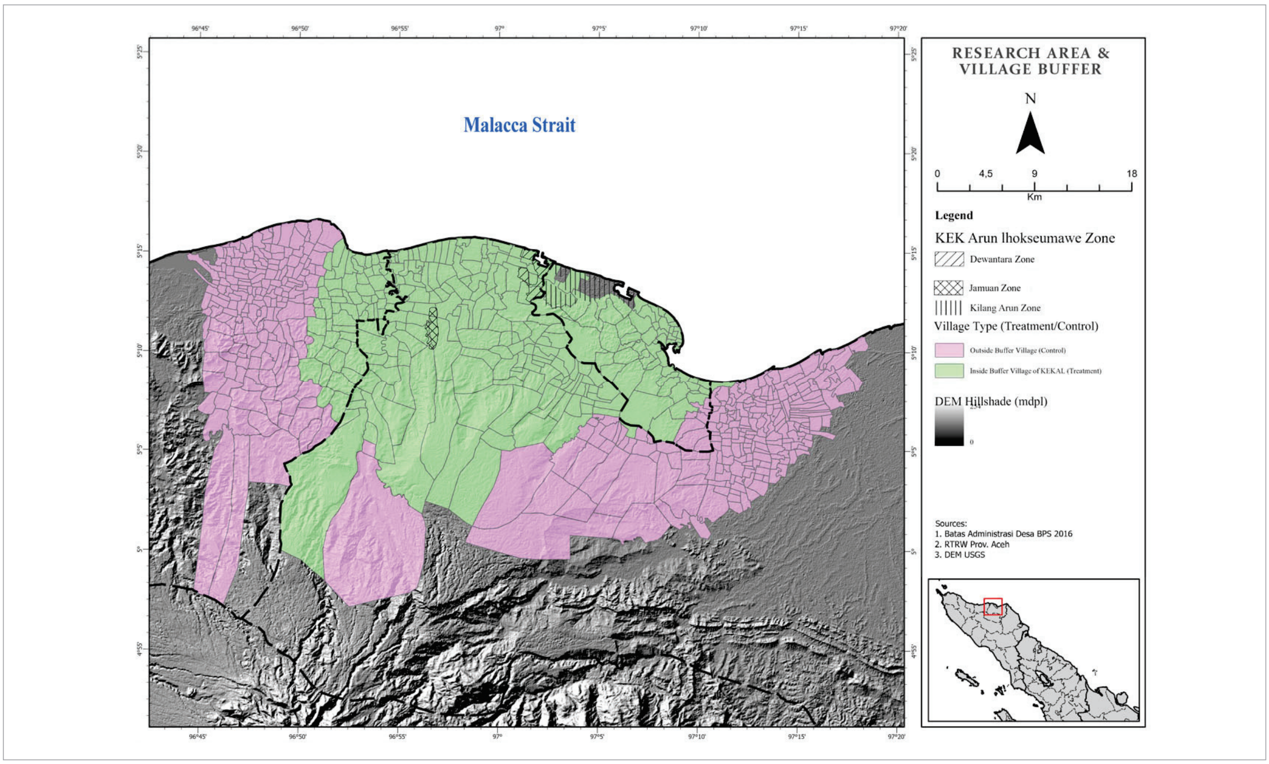
No	Dimensions of sustainable development	Variable	Description	Direction
1	Environmental dimension	X4	Total landslide occurrence	–1
2		X5	Total flood occurrence	–1
3		X8	Drinking water source	1
4		X14	FC loss in proportion of total village area	–1
5	Social dimension	X3	Total family in slum area	–1
6		X6	Total educational facility	1
7		X7	Total health facility	1
8		X9	Total mosque	1
9		X12	Total conflict occurred	–1
10		X13	Total malnutrition incidence	–1
11	Economy dimension	X1	Main income source	1
12		X2	Total household using electricity	1
13		X10	Main road type	–1
14		X11	Total small industries (UMKM)	1

The existence of the Arun Lhokseumawe SEZ has a positive impact on the economic performance, both internally and externally for the SEZ area itself and surrounding areas such as the villages, but the effect is limited to the area and exhibits a strong distance decay effect such that the influences were observed to be decreasing continuously up to 50 km. This means that the area closest to the zone is likely to benefit from its economic dynamism and this indicates a strong distance decay effect. This research examines the impact of the Arun Lhokseumawe SEZ on the sustainability of its peripheral areas. A previous study showed that the social, economic, and environmental impacts of a SEZ reaches a radius of 50 km from the area and decreases as the distance increases (Frick and Rodríguez-Pose, 2019) and differs by local context. Thus, we believe that it is more measurable within a 10–20 km radius of a spillover effect in our research area, and we used that value as a buffer zone of the SEZ indicating inside and outside of the SEZ buffer zone. Therefore, the villages within a 10 km radius were used in this research as the SEZ buffer zone while those located within a 20 km radius were applied as the control zone or the area out of buffer. We assumed that the spillover effect is strongest within a 10 km radius of the zone and rapidly decreases afterward.

Measuring the influence of the Arun Lhokseumawe special economic zone on the surrounding areas is done by calculating the sustainability index in the area around the Arun Lhokseumawe SEZ using village level administrative boundaries. The sustainability index which is a statistical indicator that provides information can simultaneously simplify the process of analyzing the phenomenon that the author is researching (Saric et al., 2013). We acknowledge another index that contributes to measuring sustainable development that was also recently published in Indonesia, named the local sustainability development index (LSDI) (Lubis et al., 2021), yet our index calculation was more likely to follow the better life index (BLI) from OECD (Greco et al., 2020) using the same data as LSDI, which is PODES data.

Proximity or buffer analysis was used to determine the villages located 0–10 km and 10–20 km away from the Arun Lhokseumawe SEZ. This was used to define (a) 259 villages located 0–10 km from the SEZ as the treatment unit and (b) 398 villages within 10–20 km as the control unit as indicated in *Fig. 1.*

Fig. 1. *Research locations with the control and treatment units*



Confounding variables

Confounding variables usually interfere with the influence or relationship between the independent and dependent variables (Notoatmodjo, 2012). They were selected in this research based on the relationship between the performance of village sustainable development and the Arun Lhokseumawe SEZ existence. Therefore, three themes of confounding variables were selected in line with the sustainable development dimensions and general factors inhibiting economic activity, and these include (1) accessibility with 5 confounding variables, (2) socio-economic conditions with 1, and (3) environmental conditions with 1 variable. Their definitions and data sources are presented in *Table 3.*

The data on these confounding variables were used to generate the main table per village which consists of the characteristics of the 7 confounding variables associated with the SI for each village. The table was subsequently processed into R software with RStudio for statistical matching using the "MatchIt" package (Ho et al., 2011).

The Moran index

The distribution pattern and the sustainability index (SI) trend inside and outside the Arun Lhokseumawe SEZ buffer area were determined using the Moran index which was divided into two including the local Moran index and the global Moran index (Anselin, 1995). The global Moran index calculates the spatial autocorrelation of research variables, in this case SI, in the research area. This spatial autocorrelation describes the strength of object relationships relative to their distance such that the objects close together have a higher relationship strength or correlation than those far away. This means that the global Moran I determines the distribution type of SI globally in the research year. Meanwhile, the local Moran I was applied to determine the local patterns and distributions in the research area and each village. The difference from the global Moran is that the calculation of I (Moran index) only produces one I value that defines the entire research area and another for each village which is subsequently compared with the correlation analysis.

The Moran index defines "neighbors" or the level they are applied to the weighting matrix. Meanwhile, the Rook adjacency method is normally used to define the weighting matrix with the neighbors. ArcGIS Pro software version 2.8 was used to calculate the Moran I in this research.

It is important to note that a global Moran value close to 0 indicates a random object in the research area, those close to –1 indicate the object's perfect dispersion in the research area, and those close to 1 show a perfectly clustered object. Meanwhile, the local Moran index value ranges from –1 to 1, and $I < 0$ represents a negative spatial autocorrelation while $I > 0$ indicates a positive spatial autocorrelation, which means they both characterize the existence of a spatial correlation or autocorrelation (Getis and Ord, 1992).

Table 3. *Selected confounding variables between the local sustainable development index and the presence of SEZ*

No	Confounding variables	Abbreviation	Source
Accessibility			
1	Mean distance to large cities	AVG_DIS	Geospatial Information Agency
2	Total distance of arterial roads	TOT_ROADS	Geospatial Information Agency
3	Mean elevation	AVG_ELEV	Digital Elevation Model USGS
4	Mean slope	AVG_SLP	Digital Elevation Model USGS
5	Mean human population density	AVG_POPDEN	SEDAC CIESIN
Village socioeconomic			
6	Night-time lights	AVG_NTL	EOG DATA MINE
Environmental quality			
7	% Forest cover in 2000	AVF_FORCVR	Hansen et al., 2013

Results and Discussion

Standardized mean difference (SMD) and variance ratios (VR)

The similarity of the data distribution was measured using the statistical matching method for the control and treatment units through the standardized mean difference (SMD) and variance ratios (VR), and their results are presented in *Fig. 2.* By using VR, the data are said to be good if the variance value of the confounding variable of each control and treatment unit is at a difference value of 0.20 down relative to the value of 1. In VR, a value of 1 indicates the similarity of the variance of the confounding variable data. Meanwhile, SMD and VR results were plotted using R and R Studio. R is a statistical computing and graphics program and RStudio is a programming language for statistical computing and graphics.

The visual interpretation is indicated through the boxplot in *Fig. 3*. below to compare the data distribution.

The match results using the statistical matching method showed that 57 pairs of villages, which is a total of 114 villages, have the same confounding covariate/ variable characteristics as indicated by the SMD and VR values in *Fig. 4.* These villages were observed to spread to Bireuen District at a radius of 20 km from the Arun Lhokseumawe SEZ.

Fig. 2. *Standardized mean difference and variance ratios for the control and treatment units*

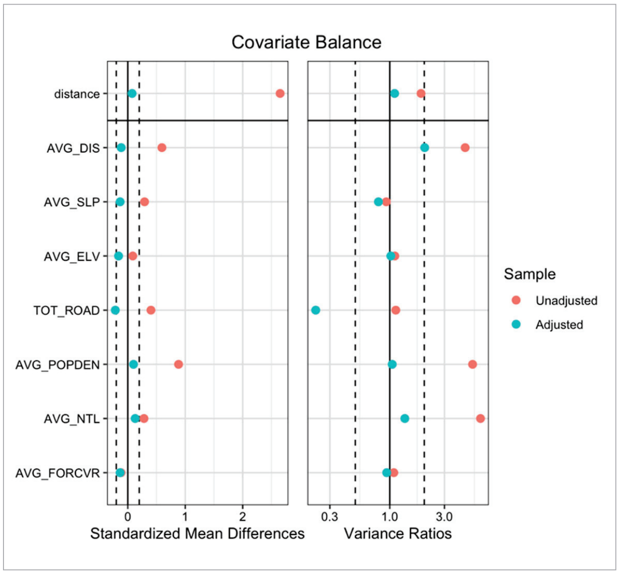


Fig. 4. *Distribution of villages based on statistical matching*

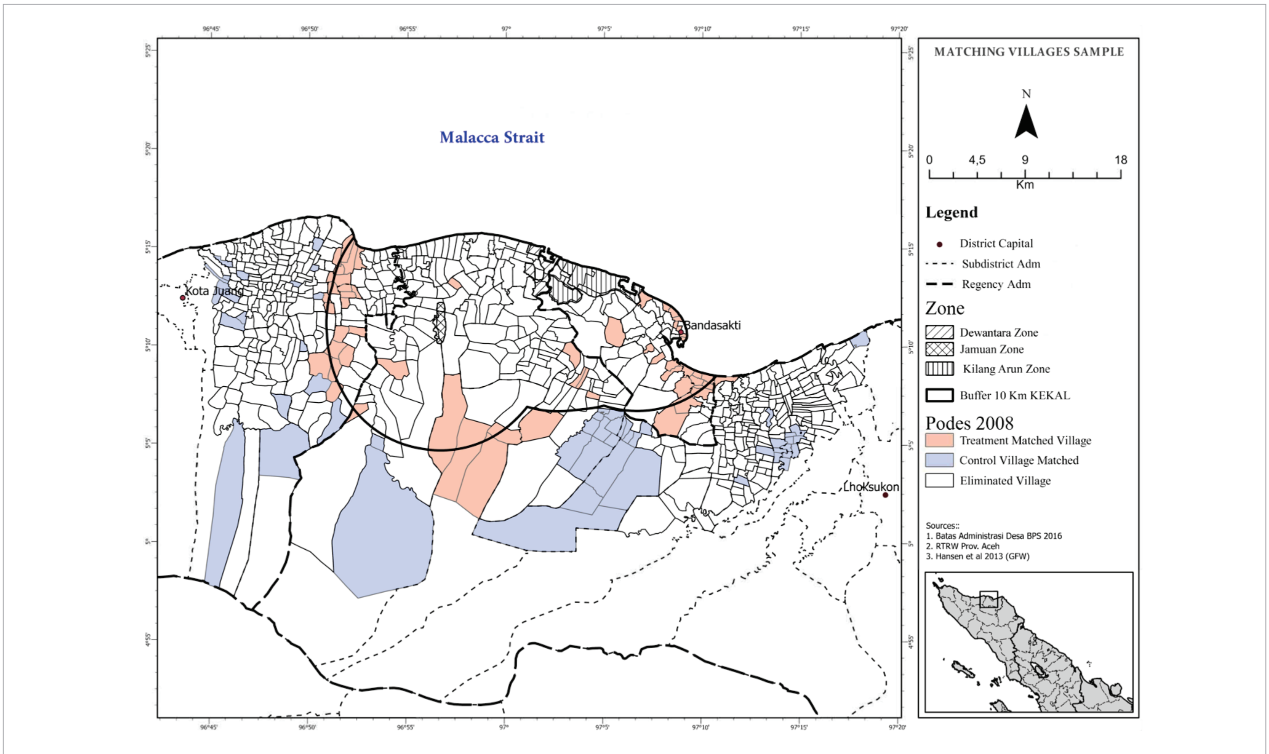
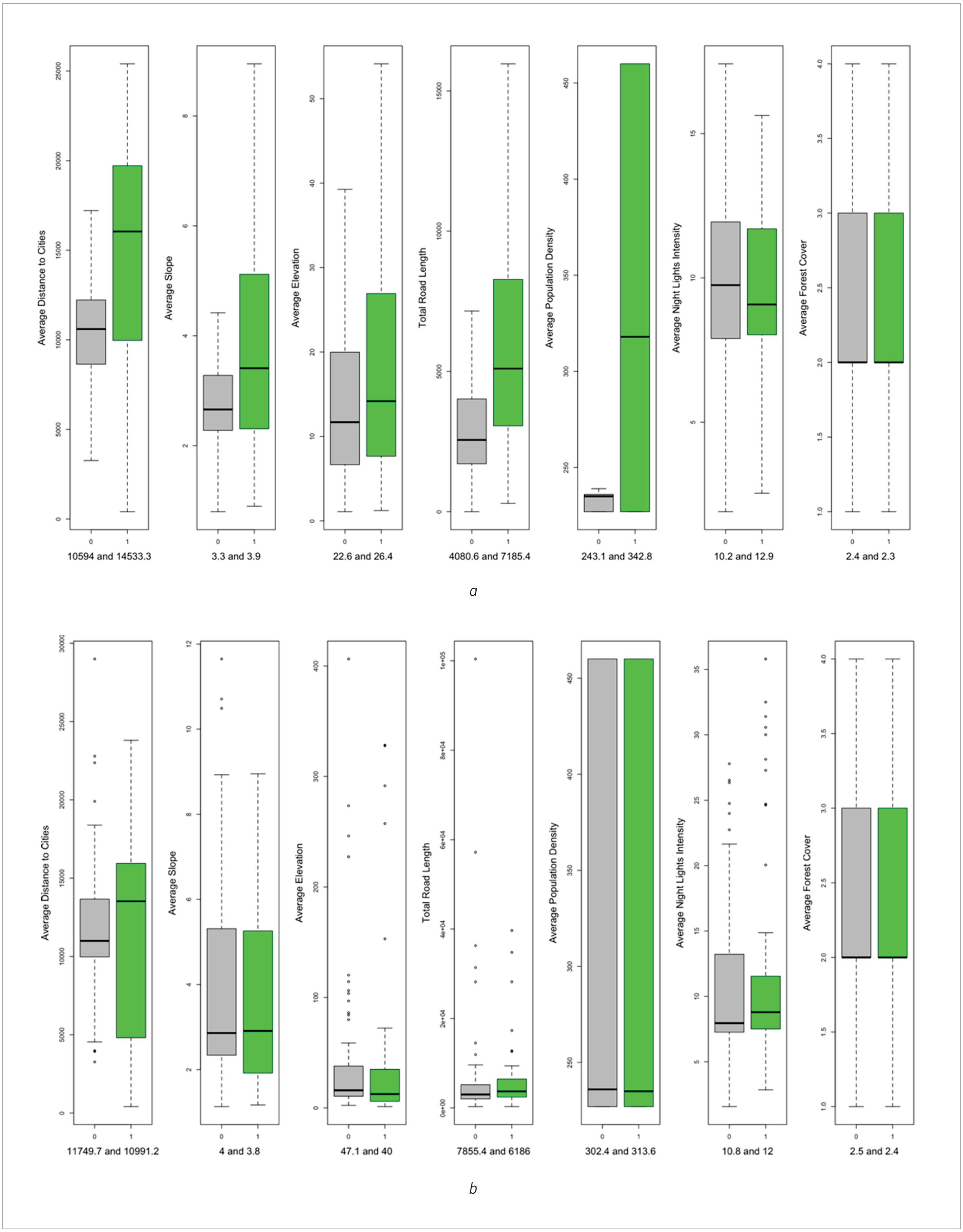


Fig. 3. *Boxplot distribution and average data before (a) and after (b) statistical matching for confounding variables*

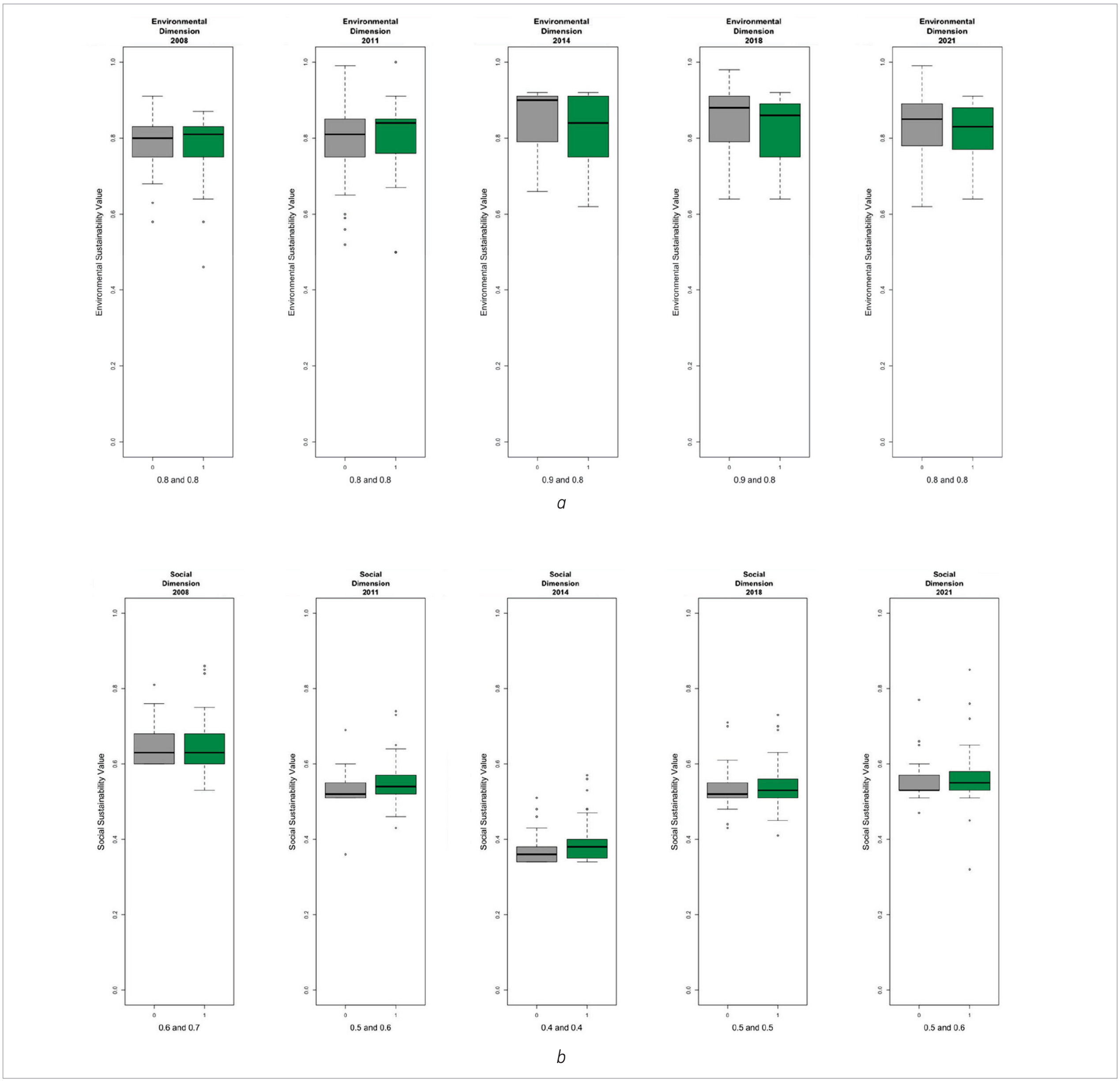


Sustainability of the environmental dimension

The statistical matching result for the environmental dimension sustainability presented in *Fig. 5a* showed that there was a relatively high sustainability index, both inside (treatment unit, colored green) and outside (control unit, gray) the Arun Lhokseumawe SEZ in 2008, 2011, 2014, 2018, and 2021.

The cessation of some industries was observed to have increased the environmental sustainability value in this region. The establishment of the SEZ in 2018 was discovered to have led to a decrease in the environmental sustainability inside and outside the area. However, in reality, the average value of environmental sustainability is still high (0.8 inside and outside) and above the environmental conditions in 2008 and is expected to be continuously maintained by the developmental activities of the SEZ in the area. Sustainability development can be measured using three criteria which include 1) no wastage of natural resources, 2) no pollution and other environmental impacts, and 3) conduct

Fig. 5. *Boxplot statistical matching results of the environmental dimension sustainability (a) and statistical matching results of the social dimension sustainability (b)*



of activities to increase useful or replaceable resources (Salim, 1990). In the current condition, only the second criterion appears to be fulfilled while the first and third have not been implemented. This means that the high value of environmental sustainability around the Arun Lhokseumawe SEZ is largely due to the inoperability of several industries and the lack of development activities in the area.

Sustainability of the social dimension

The results of statistical matching for the sustainability of the social dimension presented in *Fig. 5b* showed that the reduction and exhaustion of gas production had a significant impact on the social dimension of the Arun Lhokseumawe SEZ area.

It was discovered that there was a continuous decline of social variables in the area from 2008 to 2014 (from 0.6 to 0.4 in the outside area and 0.7 to 0.4 in the inside area). Then it started to increase again in 2018 and in 2021 it will remain at 0.5 (outside area) and 0.6 (inside area). This means that the SEZ has a positive impact on external environment as indicated by the increase in the social sustainability value even though it is only three years old. This is, however, different from previous research that the SEZs in the Southeast Asia region only influenced the economic sector without any wider social and environmental impact (Nash, 2017). The finding is in line with the results of the SEZ that in Poland increased the overall economic and social development and noted that the specific attributes of the province or region studied were important factors (Ambroziak and Hartwell, 2018). It is important to note that the Arun Lhokseumawe SEZ is an industrial area that has been existing since the 1980s and inhabiting people expecting to obtain economic and social benefits from the industry.

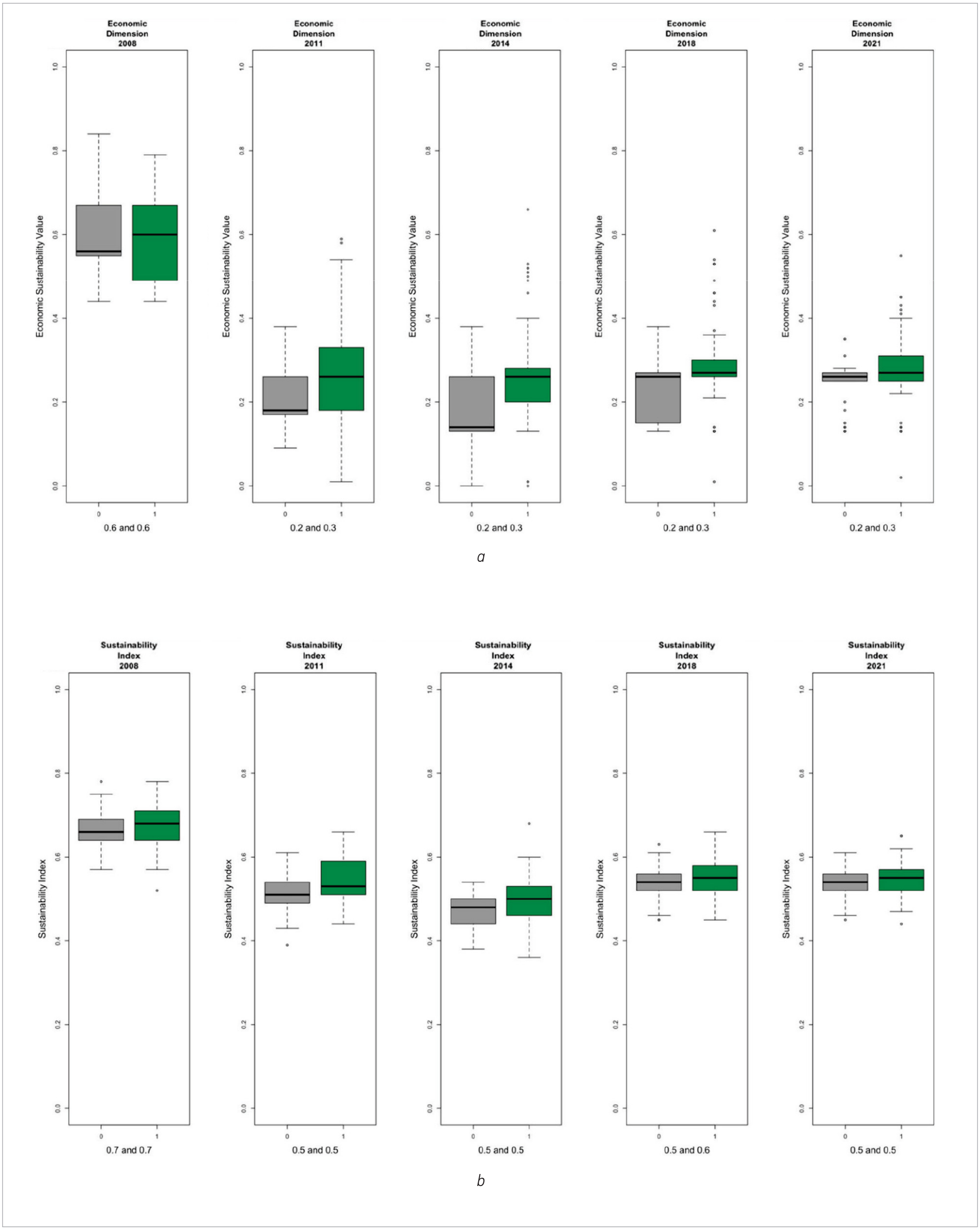
Sustainability of the economic dimension

The statistical matching results of the economic dimension sustainability, presented in *Fig. 6a*, indicate a drastic decline from 2008 to 2011. The products and exports of natural gas and its by-products fell sharply in 2008 and this continuously declined the Aceh economy up to when the natural gas products were declared exhausted in 2014. The value of the economic dimension sustainability remained at 0.2 (outside area) and 0.3 (inside area) until 2021, although regasification efforts were carried out in 2015 and continued with the establishment of the Arun Lhokseumawe SEZ in 2018. A bigger strategy is needed to match the recorded sustainability value for the economic dimension in the 1980s. Previous research suggests that industrial transformation is needed to sustain economic growth when comparative advantage fades and this can be in the form of the diversification of raw materials and products (Sun and Liao, 2021). This is observed to have been implemented by the industries in the Arun Lhokseumawe SEZ such as the regasification of liquefied natural gas into the gas by Perta Arun Gas (PAG) Ltd which is directed at obtaining new raw materials from other places and fulfilling the energy needs for the industry in this region. Another example is the establishment of an NPK compound fertilizer factory to replace urea fertilizer production to reduce the need for natural gas, ensure the importation of other raw materials from other places, and ascertain that production provides good value for the industry. However, at the beginning of 2023, Indonesian Government planned to develop a green industries cluster within the area to promote sustainable energy and develop green and blue ammonia (KataData, 2023).

Sustainability index analysis

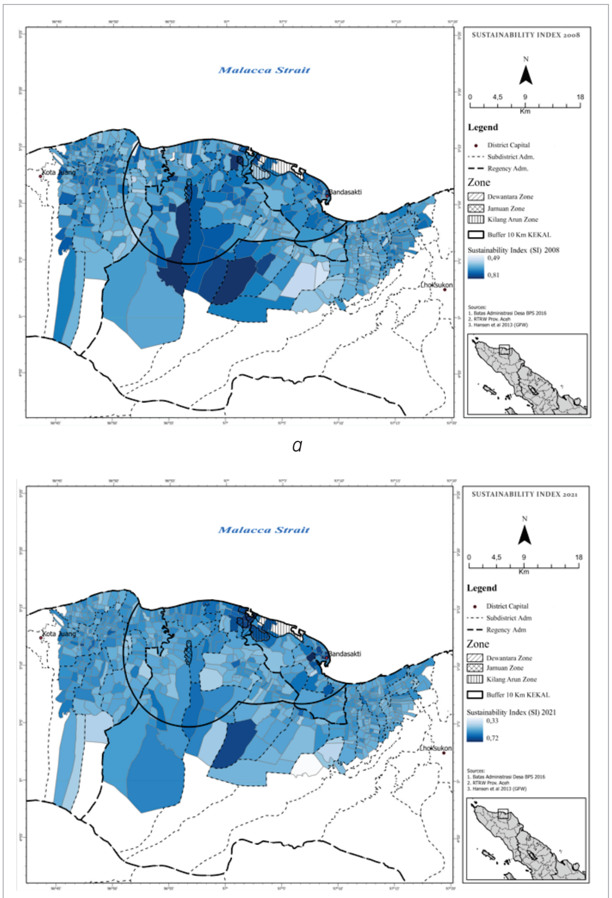
The statistical matching results for the sustainability index, presented in *Fig. 6b*, show that the three dimensions including the social, environmental, and economic aspects appear to have decreased (2008 to 2014) due to the reduction in natural gas production. They were observed to be increasing gradually after the industry started operating through the implementation of a new strategy which involved regasification liquefied natural gas obtained from Tangguh LNG (Bintuni Bay, West Papua), Donggi Sonoro LNG (Banggai, Central Sulawesi) and Badak LNG (Bontang, East Kalimantan). The external sustainability index value of the Arun Lhokseumawe SEZ area is expected to continue increasing with the simultaneous increase in the sustainability of the environmental, social, and economic dimensions. However, the concepts of sustainability and sustainable development are technically not the same (Ozili, 2022). Sustainability is the driving force, agenda, strategy, and guiding principle that coordinates all development aspects intending to achieve sustainable development. Meanwhile, sustainable development is achieved when sustainability is prioritized on the road to development. This means that the realization of sustainable development requires conceptualizing sustainability strategies from the start.

Fig. 6. *Boxplot statistical matching results of the economic dimension sustainability (a) and statistical matching results for sustainability index (b)*



The sustainability index of the area within a radius of 10–20 km from the Arun Lhokseumawe SEZ mapped in *Fig. 7* was observed to be high in 2008 but later decreased while there was relatively no change or expansion in 2021. The decline was indicated around the Aceh Kraft Paper (AKP) industry which stopped operating in 2007 due to gas shortages and the conflict by the Free Aceh Movement.

Fig. 7. *Sustainability index map for (a) 2008 and (b) 2021*

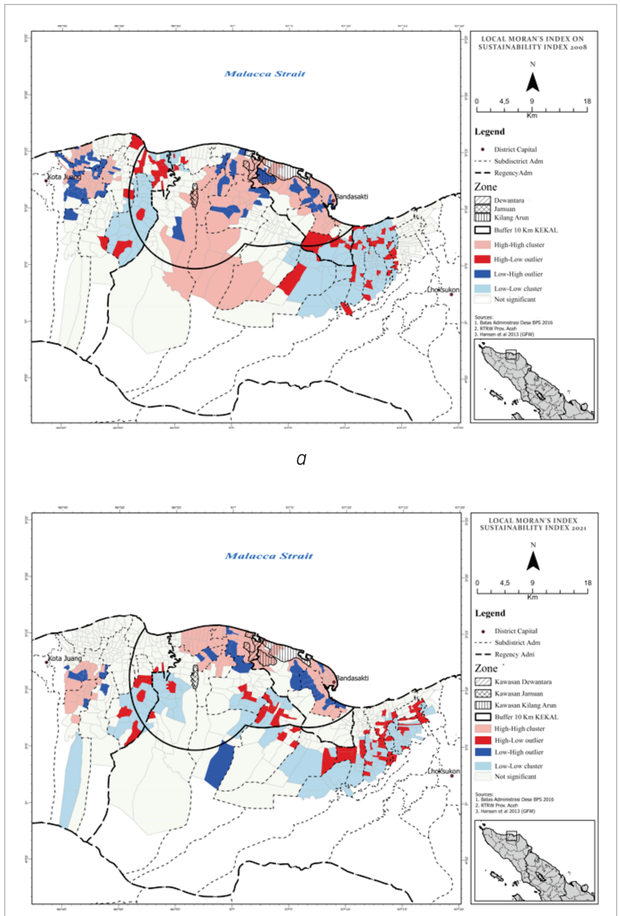


a

b

The Moran index distribution showed that the sustainability index values in clusters HH (high-high) to LL (low-low) measured in 2008 decreased towards 2021 and the HH cluster shifted to the Arun Lhokseumawe SEZ. It was observed that the existence of the Kertas Kraft Aceh / Aceh Kraft Paper (KKA) factory is quite significant to the sustainability index of villages in the Arun Lhokseumawe SEZ area, and its extinction made the surrounding villages that initially had a high value to have none. This means that the SEZ is the hope for the growth and development of the area to have better economic, social, and environmental development.

Fig. 8. *Sustainability index in Moran's index distribution map for 2008 (a) and 2021 (b)*



a

b

Policy implication based on current SEZ sustainability level

The policy that must be taken related to the current level of SEZ sustainability is to develop a better and more targeted management strategy. Therefore, it is necessary to develop a strategy so that SEZs can take place according to targets so that the static and dynamic benefits of SEZs and their sustainability can be realized (Zeng, 2016). To realize sustainable development, it is necessary to implement SDG policies that involve the central and local governments and make the government an important actor to prioritize and adapt the SDGs to national conditions, enable policy coherence and inter-sectoral linkages, and implement integrated action plans. This work can only really begin with a high level of political commitment to the SDGs (Allen et al., 2018).

Conclusions

The statistical matching method is used for the analysis of SEZ sustainability which is formed based on an overview of geoeconomic and geostrategic advantages and involves data on many villages that are within a certain radius of the SEZ. In addition, this method is also used to determine the effect of the amount of gas production on the social dimension with the result that the decrease in the amount has a significant impact on the social dimension of the SEZ area of Arun Lhokseumawe. The SEZ is a hope for regional growth and development to have better economic, social and environmental development. This method shows that Arun Lhokseumawe SEZ has an impact on several sustainability variables, but its existence for the last 3 years has not shown significant changes to the external environment within a 10–20 km radius. The changes that occurred during the three years of Arun Lhokseumawe existence were the environmental sustainability index being the highest score, followed by the social and economic sustainability index. The external sustainability index did not experience much increase, and the increase occurred in the internal sustainability index.

The high value of the sustainability index for the environmental dimension is allegedly solely due to the absence of re-operational activities or the development of new industries in the SEZ. The significant reduction in the sustainability index in non-operating industrial areas such as the Aceh Kraft Paper Factory shows that the industry is the spirit of sustainable development in this region. Therefore, this concept needs to be applied in the Arun Lhokseumawe SEZ to achieve sustainable development targets in this region.

The distribution of the Moran index shows that the value of the regularity index in the HH to LL clusters measured in 2008 decreased towards 2021 and the HH cluster shifted to KEK Arun Lhokseumawe. The existence of the Aceh Kraft Paper (KKA) factory is quite significant for the sustainability index of villages in the SEZ area of Arun Lhokseumawe, and its extinction has made the surrounding villages, which were originally of high value, not have any added value. This means that the SEZ is a hope for regional growth and development to have better economic, social and environmental development.

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