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Sustainable development in Sumatra Island: Spatial distribution and its implications

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ABSTRACT

This study aims to examine the implementation of sustainable development on Sumatra Island and its spatial distribution, assessed from economic, social, and environmental dimensions. Data analysis was conducted using a composite index method, which comprises various unitless indicators or sub-indicators. Furthermore, Geographic Information System (GIS) techniques were applied to identify the spatial distribution of sustainable development. For the economic dimension, indicators include Gross Regional Domestic Product (GRDP) per capita and the open unemployment rate. The social dimension was analyzed using the Human Development Index (HDI), school participation rates, life expectancy at birth, and poverty rates. Meanwhile, the environmental dimension utilized indicators such as the environmental quality index, air quality index, water quality index, and land cover quality index. Based on the composite index analysis of sustainable development in Sumatra from 2016 to 2020, the results indicate that regional development, in the short term, can be classified as moderately sustainable. Spatially, the sustainable development index values ranged from 50.01 to 75.00, which falls into the moderately sustainable category.

Keywords: Sustainable Development, Economic Aspect, Social Aspect, Environmental Aspect, Composite Index, GIS.

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1. INTRODUCTION

Sustainable development refers to development that aims to meet current needs without compromising the ability of future generations to meet their own needs (Muktianto & Diartho, 2018). It is a progression toward fulfilling present-day needs without sacrificing the capabilities of future generations (WCED, 1987 as cited in Maryunani, 2018). The contemporary development paradigm emphasizes the pursuit of balanced development through three interrelated dimensions: equity (distributional fairness), growth efficiency, and sustainability (Erlinda, 2016). The Sustainable Development Goals (SDGs) are a global agenda designed to ensure the continuous improvement of societal welfare through sustained economic growth, social inclusion, and environmental protection. They also aim to promote justice and good governance to secure quality of life for current and future generations. The SDGs are underpinned by three core pillars: (1) the social pillar, focusing on human development within social systems; (2) the economic pillar, emphasizing inclusive and sustainable economic growth; and (3) the environmental pillar, including the preservation of biodiversity (Murniningtyas & Alisjahbana, 2018).

In accordance with the Presidential Regulation on Sustainable Development Goals, all provinces within the Unitary State of the Republic of Indonesia are required to implement Presidential Regulation No. 59 concerning the SDGs. This regulation aims to reduce inter-provincial, urban–rural disparities and ensure that all Indonesians benefit from national development. However, the complexity of developmental challenges in Indonesia such as the trade-offs of high economic growth, persistent social inequality, and environmental degradation continues to pose obstacles to achieving sustainable development. Java and Sumatra are the two islands with the highest contributions to Gross Regional Domestic Product (GRDP) and the Human Development Index (HDI) compared to other islands in the archipelago. Significant disparities in GRDP contributions and HDI levels are evident across different islands. Notably, although Java reports the highest GRDP contribution, it simultaneously records the lowest Environmental Quality Index (IKLH) among all islands. This reveals a discrepancy between Indonesia's economic achievements and the broader objectives of sustainable development, as progress continues to be concentrated in the economic domain, often unevenly distributed.

Between 2013 and 2018, nearly all provinces in Sumatra experienced steady growth in constant-price GRDP, with the exception of Riau. This trend reflects a positive trajectory in economic development. However, during the same period, several provinces with high GRDP growth namely North Sumatra, West Sumatra, South Sumatra, and Lampung—also recorded an increase in the extent of degraded (critical) land. Critical land refers to areas that have lost their vegetative cover and can no longer function effectively in terms of water retention, erosion control, nutrient cycling, microclimate regulation, and carbon sequestration (Ministry of Forestry, 2011). This situation demonstrates that stable economic growth does not necessarily align with environmental sustainability. In addition to economic growth, a comparative assessment of social and environmental aspects specifically HDI and IKLH offers further insights. The HDI is a composite index that measures key dimensions of human development, including health (measured by life expectancy), education (measured by years of schooling), and standard of living (measured by per capita income). Meanwhile, the Environmental Quality Index (IKLH) is the result of a collaboration between the Ministry of Environment and the Danish International Development Agency (DANIDA). It integrates environmental indicators developed by Statistics Indonesia (BPS) and Virginia Commonwealth University (VCU), focusing on river water quality, air quality, and forest cover (MZP, 2011). From 2018 to 2020, the province ranked highest in environmental quality did not hold a top position in human development, suggesting a gap in synergy between the environmental and social dimensions.

These findings reinforce the importance of building the three pillars of sustainable development economic, social, and environmental in a balanced and integrative manner. Strategic efforts must be directed at strengthening each pillar from a multi-dimensional perspective. For instance, improving human resource quality is crucial for developing a productive economic workforce capable of generating high value-added goods, which, in turn, contributes to increases in GDP and per capita income.

2. RESEARCH METHODS

The research employed a quantitative descriptive design, utilizing secondary data obtained from Statistics Indonesia (Badan Pusat Statistik/BPS), the Ministry of Environment and Forestry (KLHK), as well as relevant academic journals and previous research findings. The study was conducted in Indonesia over the period 2016–2020, with a specific focus on Sumatra Island as the research site. The data analysis utilized the Composite Index of Sustainable Regional Development (Indeks Pembangunan Wilayah Berkelanjutan/IPB) and employed the Geographic Information System (GIS) method through the ArcGIS software application.

3. RESULT & DISCUSSION

3.1. Analysis Results of the Composite Index for Sustainable Regional Development (IPB)

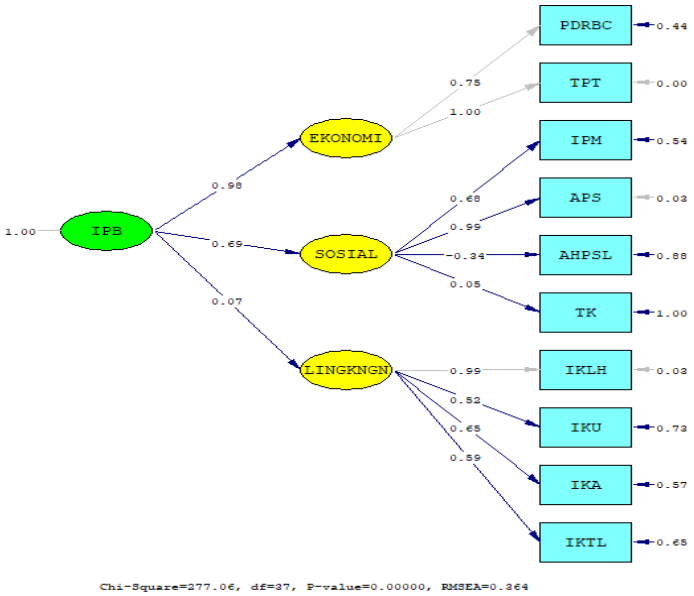

Figure 1. Path Diagram of Loading Factor Values

Based on the results of the loading factor analysis, it can be concluded that the value of each indicator for the latent economic variable is 0.98, while the value for the GRDP per capita (PDRBC) variable is 0.75 and the Open Unemployment Rate (TPT) is 1.00. The social latent variable has a loading factor value of 0.69, while the Human Development Index (HDI) is 0.68, the School Participation Rate (APS) is 0.99, Life Expectancy at Birth (AHPSL) is 0.44, and the Poverty Rate (TK) is 0.05. The environmental latent variable has a loading factor of 0.07, while the Environmental Quality Index (IKLH) is 0.99, the Air Quality Index (IKU) is 0.82, the Water Quality Index (IKA) is 0.65, and the Land Cover Quality Index (IKTL) is 0.59.

Table 1. Weights and Threshold Values for Normalization

Variable	Variable Name	Weight	Unit	Min	Max
GRDP per capita	PDRBC	0.43	Rupiah	21,039.84	85,012.58
Open Unemployment Rate	TPT	0.57	Percent	0	100
Human Development Index	IPM	0.33	Index	0	100
School Participation Rate	APS	0.48	Percent	0	100
Life Expectancy at Birth	AHPSL	0.17	Index	0	100
Poverty Rate	TK	0.02	Percent	0	100

Variable	Variable Name	Weight	Unit	Min	Max
Environmental Quality Index	IKLH	0.36	Index	0	100
Air Quality Index	IKU	0.19	Index	0	100
Water Quality Index	IKA	0.24	Index	0	100
Land Cover Quality Index	IKTL	0.21	Index	0	100

Source: Processed by the researchers (2022)

The economic development index is obtained by summing the normalized data of GRDP per capita, multiplied by its loading factor of 0.43, with the normalized data of the Open Unemployment Rate (TPT), multiplied by its loading factor of 0.57. This aggregate summation yields the value of the economic development index.

Table 2. Economic Development Index

Province	2016	2017	2018	2019	2020
Aceh	53.89	54.82	55.39	56.04	55.92
North Sumatra	61.63	62.64	63.60	64.56	63.23
West Sumatra	58.89	59.38	60.11	60.92	59.57
Riau	86.06	86.86	87.00	88.31	90.93
Jambi	65.94	66.75	67.64	68.65	68.13
South Sumatra	62.38	63.25	64.39	65.23	64.80
Bengkulu	55.12	55.35	56.07	56.80	56.07
Lampung	57.41	58.28	59.20	59.98	58.17
Bangka Belitung	64.32	64.18	64.84	65.80	64.27
Riau Islands	92.45	92.38	92.86	93.12	94.11
Sumatra (Average)	65.81	66.39	67.11	67.94	67.52

Source: Processed by the researchers (2022)

Based on the Economic Development Index, it can be concluded that the Riau Islands Province recorded the highest economic development index among all other provinces, reaching 94.11 percent in the year 2020.

Table 3. Social Development Index

Province	2016	2017	2018	2019	2020
Aceh	62.63	65.95	70.38	73.59	72.76
North Sumatra	55.04	58.09	62.12	63.86	63.58
West Sumatra	72.43	74.82	77.17	80.13	78.62
Riau	44.04	48.50	53.06	54.38	51.97
Jambi	27.67	29.31	32.83	34.76	35.02
South Sumatra	22.75	26.22	29.90	32.98	33.28
Bengkulu	56.10	60.23	63.62	64.82	64.50
Lampung	17.92	22.11	27.36	29.00	28.50
Bangka Belitung	18.32	21.61	24.61	27.79	26.68
Riau Islands	80.49	84.18	88.22	90.71	91.83
Sumatra (Average)	45.74	49.10	52.93	55.20	54.68

Source: Processed by the researchers (2022)

Based on the data, the value of the Social Development Index is obtained by summing the following components: Social Development Index = (Normalized HDI × 0.33) + (Normalized School Participation Rate [APS] × 0.48) + (Normalized Life Expectancy at Birth [AHPSL] × 0.17) + (Poverty Rate [TK] × 0.02). The Riau Islands Province recorded the highest social development index among all provinces, reaching 91.83 percent in 2020. In contrast, Bangka Belitung Islands Province had the lowest social development index, at only 26.68 percent in 2020.

Table 4. Environmental Development Index

Province	2016	2017	2018	2019	2020
Aceh	78.15	74.24	86.12	90.18	81.49
North Sumatra	63.58	54.49	64.58	49.60	44.24
West Sumatra	34.80	36.87	60.25	88.66	63.77
Riau	15.08	26.77	61.71	61.26	44.85
Jambi	42.19	48.84	51.50	68.06	59.39
South Sumatra	61.80	57.25	63.23	60.17	41.87
Bengkulu	84.71	71.46	66.54	77.46	50.17
Lampung	45.71	37.70	36.78	37.33	30.78
Bangka Belitung	69.91	55.97	60.44	59.41	51.91
Riau Islands	73.56	64.45	66.96	55.77	56.94
Sumatra (Average)	56.95	52.80	61.81	64.79	52.54

Source: Processed by the researchers (2022)

Based on the data, the value of the Sustainable Regional Development Index in Sumatra Island increased from 2016 to 2019. However, in 2020, the index experienced a decline from 62.72 percent in 2019 to 61.78 percent in 2020. Changes in the Economic Development Index during the 2016–2020 period showed that almost all provinces in Sumatra experienced an increase, except for the Bangka Belitung Islands Province, which recorded a decrease. The Riau Province demonstrated the most significant increase among all provinces, with a change of 4.88 points. In terms of the Social Development Index, all provinces in Sumatra recorded an increase from 2016 to 2020. The Riau Islands Province showed the highest increase in this dimension, with a gain of 11.34 points. In contrast to the other dimensions, the Environmental Development Index in Sumatra displayed varied trends, with the majority of provinces experiencing a decline. The provinces of North Sumatra, South Sumatra, Bengkulu, Lampung, Bangka Belitung Islands, and Riau Islands all showed decreasing environmental development performance. Positive changes, however, occurred in the provinces of Riau, West Sumatra, Jambi, and Aceh.

The changes in the overall sustainable development index across Sumatra Island from 2016 to 2020 indicate positive progress in all provinces. The province with the largest increase in the composite development index was Riau, with a gain of 7.09 points, while the smallest increase was observed in Bengkulu, with only 2.51 points. In terms of the final value of the composite sustainable development index (IPB) in 2020, the Riau Islands Province had the highest IPB score, reaching 91.71, while the lowest score was recorded in Lampung Province, at 45.21.

3.2. GIS Analysis

Based on the analysis of the sustainable development index, this study classifies the IPB values into five levels: a value of 0.00–25.00 falls into the poor category (not sustainable), a value of 25.01–50.00 falls into the low category (less sustainable), a value of 50.01–75.00 falls into the moderate category (moderately sustainable), and a value of 75.01–100.00 falls into the good category (highly sustainable). To illustrate the overview and mapping of the spatial distribution of sustainable development

achievements across Sumatra Island, this study uses ArcGIS analysis. Based on the IPB level criteria, the spatial distribution of sustainable development achievements as shown in Figure 4.6 indicates changes in sustainable development performance from 2016 to 2020. Dark blue represents the symbol for the good category (highly sustainable), Light blue represents the symbol for the moderate category (moderately sustainable), Dark green represents the symbol for the poor category (not sustainable), and Light green represents the symbol for the low category (less sustainable).

In 2016, there were four provinces classified as less sustainable, namely Jambi, South Sumatra, Lampung, and Bangka Belitung Islands. However, by 2020, only two provinces remained in the less sustainable category, namely Lampung and Bangka Belitung Islands. Meanwhile, in 2016, there were five provinces in the moderately sustainable category: Aceh, North Sumatra, West Sumatra, Riau, and Bengkulu. However, in 2020, this changed to six provinces in the moderately sustainable category. The good (highly sustainable) category in 2016 only included one province, namely the Riau Islands Province, but in 2020, this changed to include both the Riau Islands and Riau provinces. Sustainable development achievements in Sumatra Island from 2016 to 2020 showed improvement, although still within the same category, which is moderately sustainable.

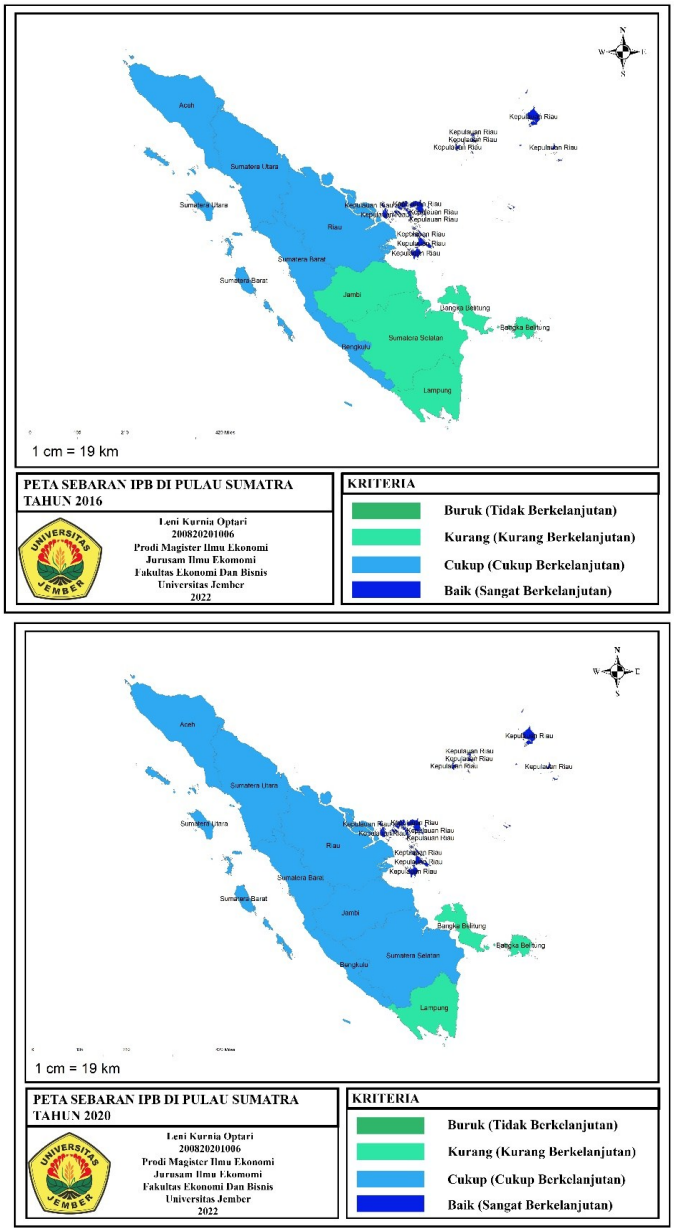

Figure 2. Spatial Distribution of the Sustainable Development Index in Sumatra Island by Province, 2020

3.3. Discussion

Based on the results of the Composite Index of Sustainable Regional Development, the study shows that provinces with abundant natural resources such as Riau and Riau Islands demonstrate very high economic achievements. Riau Province recorded the highest economic development index compared to other provinces. This phenomenon indicates that Riau is a fast-growing region, with high economic growth and per capita income compared to other provinces on Sumatra Island. Riau showed the highest index change, with an increase of 4.88 points compared to other provinces. Referring to the contributing indicators, the increase in Riau's economic development index is attributed to the rise in its GRDP per capita, which increased from 70,569.36 in 2016 to 76,882.94 in 2020. This growth was supported by Riau's economic growth rate, which increased annually from 2016 to 2020—starting at 92.45 in 2016, slightly decreasing to 92.38 in 2017, but rising again to 92.86 in 2018, 93.12 in 2019, and 94.11 in 2020. This phenomenon aligns with the findings of Oxtavianus (2014) in the study "Sustainable Development and Its Relationship with Social Capital in Indonesia", which explained that changes in the economic development index in West Papua were due to an increase in GRDP per capita in that region. Additionally, the open unemployment rate in Riau decreased from 7.43% in 2016 to 6.32% in 2020.

In contrast, Bangka Belitung Islands Province experienced a decline in its economic development index due to a rise in the open unemployment rate, which increased from 2.60% in 2016 to 5.25% in 2020. This is consistent with previous research by Liska (2020) in the study "The Influence of Regional Minimum Wage and Population on the Unemployment Rate in Lampung Province", which noted that the economic index in Bangka Belitung decreased due to a significant rise in unemployment. That research showed that in 2018, the province had the lowest unemployment rate in 7th position, at 3.35%. In the social dimension, the period between 2016 and 2020 shows that all provinces in Sumatra experienced an increase. The Riau Islands Province recorded the highest change, with an increase of 11.34 points. This growth was due to improvements in the Human Development Index (HDI), school participation rate, and life expectancy at birth. These findings are consistent with Devina's (2020) research titled "Implementation of Sustainable Regional Development in Java Island (GIS Approach)", which states that the significant increase in the social development index in DKI Jakarta was driven by improvements in its human development indicators.

Unlike the other dimensions, the environmental development index in Sumatra showed mixed results, with most provinces experiencing declines. This suggests that development activities may have had a negative impact on the environment. Provinces such as North Sumatra, South Sumatra, Bengkulu, Lampung, Bangka Belitung Islands, and Riau Islands experienced a decline in environmental development performance. Upon examining the contributing indicators, this negative trend is attributed to decreases in the Environmental Quality Index (IKLH), Air Quality Index (IKU), Water Quality Index (IKA), and Land Cover Quality Index (IKTL) in these provinces. This observation is also in line with the findings of Oxtavianus (2014), who noted that Lampung Province experienced a negative shift in its environmental development index due to a decline in its environmental quality indicators. Meanwhile, positive changes were observed in the provinces of Riau, West Sumatra, Jambi, and Aceh. Changes in the economic, social, and environmental aspects ultimately affect the achievements in sustainable regional development. Based on the analysis of the Composite Sustainable Regional Development Index across Sumatra from 2016 to 2020, all provinces showed positive change. The province with the highest increase in the sustainable development index was Riau. This improvement was driven by increases across all three dimensions, particularly in the economic and environmental aspects, which were notably higher than those in other provinces.

However, Riau's environmental development index showed fluctuations from 2016 to 2020. In 2016, the index stood at 15.08, increasing sharply to 61.71 in 2018, but then declining significantly to 44.85 in 2020. This indicates that the high environmental development achievement in Riau may not reflect an actually good environmental condition in 2020, but rather a peak performance in 2017 that raised the overall score. Looking at the values of the sustainable development index (IPB), the Riau Islands Province recorded the highest score. This was influenced by strong economic and social development

performance in the region. However, the environmental index in Riau Islands was low and even showed negative growth.

The development in Sumatra remains dominated by economic and social progress, while environmental development continues to be neglected. In connection with the Kuznets Hypothesis, this suggests that sustainable development in Sumatra has not yet reached a turning point where economic growth reduces inequality and environmental degradation. This is further supported by the findings of Akhmad Fauzi and Alex Oxtavianus (2014) in their study "Measuring Sustainable Development in Indonesia", which explained that the use of a sustainable development index has not yet demonstrated optimal achievements across all dimensions economic, social, and environmental. The confirmatory factor analysis also indicates that the environmental aspect has a negative loading factor value, signaling its weaker contribution relative to the other dimensions. Environmental issues remain dominant, particularly as a result of development itself. Therefore, the environmental dimension requires special attention from the government. Environmental degradation caused by economic growth should not become a major obstacle to regional development progress. Although the environmental development index has decreased, the Sustainable Development Index has increased due to improvements in the economic and social dimensions from 2016 to 2020. This suggests that the Sustainable Regional Development Index functions as a linear composite of economic, social, and environmental variables, and when the environmental variable declines, it may be offset by increases in the economic and social variables (Oxtavianus, 2014).

4. CONCLUSION

Based on the findings and data analysis, several conclusions can be drawn. The results of the sustainable regional development index indicate a significant improvement in the economic dimension, a modest improvement in the social dimension, and a decline in the environmental dimension. This suggests that economic and social development have not been aligned with environmental progress, as evidenced by the negative loading factor value associated with the environmental aspect. Furthermore, the spatial distribution analysis of sustainable regional development using the GIS method reveals that, during the 2016 to 2020 period, all provinces on Sumatra Island experienced improvement. Among them, the Riau Islands Province showed the highest increase in the index, with a change of 11.34 points. However, certain aspects of this study highlight a lack of attention toward environmental development. The achievement of environmental development in Indonesia has shown a declining trend. Therefore, the government must take more serious action in promoting environmentally focused development. Preventing environmental degradation, restoring damaged ecosystems, and ensuring the availability of high-quality environmental data are essential policy measures that can be implemented within the environmental dimension.

Ethical approval

Not Applicable.

Informed consent statement

Not Applicable.

Authors' contributions

Leni Kurnia Optari conceptualized the research framework and led the data collection process. Al Bina was responsible for data analysis and interpretation, All authors reviewed and approved the final manuscript.

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Statement of Disclosure

The authors declare no conflicts of interest.

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