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Statistical Assessment of Human Development Index Variations and Their Correlates: A Case Study of Aceh Province, Indonesia

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Abstract

The Human Development Index (HDI) provides a holistic measure of human development in a country or locality. This study aims to identify factors correlated with changes in the Human Development Index and analyze changes in the distribution of the Human Development Index in Aceh Province from 2012 to 2022. Apart from the Human Development Index as the variable used in this study, five variables are used in this study as indicators: Life Expectancy, Gross Regional Domestic Product (GRDP), Per Capita Expenditure, Average Years of Schooling, and Expected Years of Schooling as socioeconomic factors. This research uses an ecological study design. Data was sourced from the "Aceh in Figures" report by the Central Bureau of Statistics of Aceh Province. The statistical methods used were descriptive statistics, the Shapiro-Wilk test for normality, the Spearman test for correlation analysis, the Wilcoxon one-sample test for data distribution, and the Kruskal-Wallis test to compare distributions. Based on the correlation analysis, the study revealed that the five socioeconomic variables tested showed a significant positive correlation with changes in the HDI in Aceh Province (p -value < 0.05). In addition, the difference analysis showed a significantly different distribution of HDI across the years studied (p -value < 0.05), with a pattern of increasing HDI observed from the beginning to the end of the study period. The recommended based on finding of the study is policymakers and stakeholders focus on strategies that enhance the positive correlates identified. Finally, these results provide important and structured insights into the role of factors in HDI change.

Introduction

The study on Human Development Index (HDI) is very important as it provides an understanding of the population's quality of life and changes in well-being [1]. HDI is a crucial indicator in monitoring the progress of a country or region. The HDI is a comprehensive indicator used to measure human development progress in a particular country or region. Through HDI analysis, we can also compare well-being between countries or regions, providing essential insights for cross-border comparisons [2–4]. HDI study results also play a role in planning and policymaking, helping governments determine development priorities, resource allocation, and more effective strategy changes [5,6]. The HDI is essential to understanding, monitoring, and improving the population's quality of life and informing more effective development policies [7].

The HDI incorporates three main dimensions: health as measured by life expectancy, education as measured by expected years of schooling and average years of schooling, and living standards as determined by Gross Regional Domestic Product (GRDP) per capita and Per capita

expenditure [8]. Health, education, and living standards are considered socioeconomic factors. These factors are crucial to a person's or a population's socioeconomic well-being [9,10]. They are often used to assess and measure the overall socioeconomic status and development of individuals, communities, or nations. The HDI also linked with various aspects of a nation's progress, including energy consumption, corporate development, cryptocurrency adoption, and overall economic growth. A higher HDI often correlates with increased energy usage, reflecting a society's advanced infrastructure and technological capabilities [11–14]. Additionally, a nation's ability to manage and recover from natural disasters, as well as the quality of its democratic processes, significantly influence its HDI [15,16].

In Aceh Province, one of 38 provinces in Indonesia, there is a need to understand how various socioeconomic factors affect the HDI in Aceh [17]. The study helps the government and local stakeholders identify districts requiring special attention and appropriate resource allocation. With this understanding, more targeted development strategies can be designed to improve the quality of life of Acehnese residents. In addition, this research provides a solid scientific foundation for evidence-based policymaking, assisting the government and relevant organizations in making better decisions to improve human development in Aceh.

Various previous studies have investigated the factors that influence HDI. For example, The study found that life expectancy has a significant positive correlation with HDI in several provinces in Central Sulawesi Province [18]. Meanwhile, another study found that GRDP does not impact HDI in certain regions [19] but on education and health [20,21]. On the other hand, a prior study states that per capita expenditure has a direct impact on the quality of life of individuals, which ultimately affects HDI [22].

Although many studies have been conducted on HDI in various regions in Indonesia, very few focus on Aceh Province, especially those that look at the correlation between socioeconomic factors and HDI at the district/city level over the past 11 years. This study is one of the first attempts to comprehensively combine correlation and difference analyses to explore the socioeconomic factors associated with HDI in Aceh Province. The aim of this study is to identify socioeconomic factors that are correlated with changes in HDI and to analyse changes in the distribution of the HDI in Aceh Province over the period 2012 to 2022. Through this research, it is hoped to provide a deeper understanding of the socioeconomic factors contributing to the development of HDI in Aceh Province as well as identify areas that require special interventions in an effort to improve the quality of life of its community.

Materials and Methods

Study Design

This study adopted an ecological study design, with 23 districts/cities in Aceh Province being the object of study. An ecological approach was used to analyze the correlation between the HDI and socioeconomic factors indicators in a broad geographical context.

Variables

Apart from the HDI as the variable used in this study, the variables used in this study as indicators are Life Expectancy, GRDP, Per Capita Expenditure, Average Years of Schooling, and Expected Years of Schooling as socioeconomic factors.

Data sources

The data on each variable in this study is sourced from the Aceh in Figure report from 2012-2022 issued by the Statistics of Aceh Province [17].

Statistical Methods

To analyze the data, the study calculated descriptive statistics such as minimum, mean, and maximum values. In addition, the study also calculated the standard deviation to measure data distribution. This analysis of descriptive statistics helps identify patterns, trends, and important statistics in the data, providing a snapshot of the distribution of the data [23–25]. At the inferential statistics stage, the study conducted a normality test using the Shapiro-Wilk test. The Shapiro-Wilk test tends to be more sensitive to deviations from normality, especially in the tails of the distribution. This makes it a good choice when you are concerned about detecting departures from normality, even with a relatively small sample size [26]. The purpose of testing for data normality in statistics is to check whether the data follows a normal distribution [27–30]. In the Shapiro-Wilk normality test, the null hypothesis (H_0) is that the data follows a normal distribution, and the alternative hypothesis (H_1) is that the data does not follow a normal distribution. The analysis is important because many statistical methods assume a normal distribution [31,32], so analysis results are more accurate if this assumption is met. In addition, normality testing helps identify outliers that may affect the analysis results and allows the researcher to choose the most appropriate statistical method [33,34]. This, in turn, increases confidence in the conclusions and makes interpretation of the results easier [35,36].

The Pearson test or Spearman test was used to assess the correlation between the HDI and the socioeconomic indicators used in this study, depending on the results of the normality distribution found in the data. The purpose of the correlation test in statistics is to evaluate the relationship between two or more variables [37–39]. The null hypothesis (H_0) of the Spearman rank correlation test is that there is no monotonic relationship between the two variables in the population, while the alternative hypothesis (H_1) posits that there is a monotonic relationship between the variables. Correlation tests are used to measure the extent to which changes in one variable are related to changes in another variable. It helps us understand whether there is a positive correlation (when one variable goes up, the other also goes up), a negative correlation (when one variable goes up, the other goes down), or no correlation at all. Correlation tests provide important insights in data analysis, allowing us to identify relationships that may exist between the variables, which in turn can help in decision-making, planning, or further research [40,41].

To analyse the distribution of the HDI for 2012–2022 and for 2022 separately, the study used the Wilcoxon one-sample test to determine the middle position in the distribution. To see if there is a difference in the centredness of the data in the comparison of the distributions for each year, the study will use the Analysis of Variance (ANOVA) test or the Kruskal-Wallis test, depending on the results of the normality test on the data. The purpose of a difference test in statistics is to determine whether there are significant differences between two or more groups or conditions [42]. Difference tests are used to test whether these differences arise randomly or reflect real differences in the population. For the Analysis of Variance (ANOVA), the null hypothesis (H_0) states that there are no significant differences among the group means, while the alternative hypothesis (H_1) asserts that at least one group mean is different. In the Kruskal-Wallis test, H_0 posits that the distribution of a continuous variable is the same across multiple independent groups, and H_1 suggests that there is a significant difference in the distribution of the variable across the groups.

This helps the researcher or data analyst in understanding whether actions or changes in certain variables have a significant impact and also helps in making decisions based on strong statistical evidence [43]. The software used in data analysis is R version 4.3.1. The use of this software makes it possible to conduct precise and comprehensive statistical analyses in accordance with the research objectives.

Results and Discussion

The Results section should systematically present the study's findings, employing a logical structure and utilizing tables and figures to enhance result visualization. Findings should be articulated clearly and accurately, complemented by appropriate statistical analyses. Moreover,

this section should offer an interpretation of the results, elucidating how they address the research questions or bolster the hypotheses. It should also engage in a comparative analysis with preceding studies and contemplate the ramifications of these findings. Additionally, the section should conscientiously acknowledge any limitations in the study and propose avenues for future research. Subheadings may be employed to enhance organization and coherence. In sum, the Results section should offer a concise and precise account of experimental outcomes, their interpretations, and the resultant conclusions.

Analysis of Descriptive Statistics

Descriptive statistical analysis is an important first step in this study to describe the basic characteristics of the data that has been collected. In this section, the study will present the main findings of the descriptive analysis, which provides a strong understanding of the variability and trends in the data. The study discusses the results of the descriptive statistical analysis for each variable used in this study. The results provide insight into the extent to which these variables vary among the studied districts in Aceh Province.

Table 1. Descriptive statistical analysis of each variable.

No	Variables	Min / Max	Mean	Std. Dev.
1	HDI*	59.76 / 86.28	69.62	4.961
2	Life Expectancy**	62.83 / 71.87	67.90	2.272
3	GRDP***	335526 / 18,151,766	4,777,899	3,834,523
4	Per capita expenditure ^s	10.43 / 25,917.00	9,028.02	2,314.296
5	Average Years of Schooling ^{ss}	6.53 / 813.00	12.20	50.562
6	Expected Years of Schooling ^{sss}	11.69 / 17.81	14.08	0.973

*unit : Index, **unit : Years, ***unit : rupiah, ^sunit : rupiah per person, ^{ss}unit : years, ^{sss}unit : years

Table 1 presents the descriptive analysis of several variables included in this study. The HDI's observed values range from 59.76 to 86.28, with an average of about 69.62. In this context, an HDI of 69.62 suggests that, on average, the regions or entities represented in the dataset have a level of human development in Aceh around this value. The average Life Expectancy is 67.90 years, with data variations from 62.83 to 71.87 years. Meanwhile, GRDP shows significant variation, ranging from 335,526 to 18,151,766, with the average reaching 477,789. The average per capita expenditure is 9,028, with data ranging from 10,43 to 25,917. Average Years of Schooling shows an average education duration of 8.82 years, with a wide range of data from 6.53 to 813.00 years. Finally, the Expected Years of Schooling has an average of 14.08 years, with minimum and maximum values ranging from 11.69 to 17.81 years. From the data, it can be seen that there is significant variation in several variables, particularly GRDP and Average Years of Schooling.

Analysis of Inferential Statistics

The study highlights the findings of the Shapiro-Wilk normality test applied to the data. The results of this test determine whether or not the data follows a normal distribution, which will influence the selection of appropriate inferential statistical methods. Table 2 provides comprehensive information regarding the results of the data normality test analysis on the variables used. Based on the Shapiro-Wilk test, only the HDI data distribution follows a normal distribution pattern with a p-value of 0.152. Meanwhile, other variables such as Life Expectancy, GRDP, Expenditure per capita, Average Years of Schooling, and Expected Years of Schooling show abnormal distributions. Because all independent variables show abnormal distribution, a Spearman correlation test is conducted to determine what socioeconomic factors are related to HDI.

Then, the results of the Spearman Test showed a significant correlation between HDI and socioeconomic factors (p-value <0.000). There is a strong positive correlation between HDI and

Life Expectancy ($r=0.823$), Per Capita Expenditure ($r=0.897$), Average Years of Schooling ($r=0.881$), and Expected Years of Schooling ($r=0.671$). Meanwhile, GRDP shows a weaker positive correlation with HDI, with a correlation coefficient of $r=0.217$. A visualization of the correlation analysis can be seen in Figure 1, 2, 3, 4, and 5.

Table 2. Normality and correlation test.

Variables	Shapiro Wilk test		Spearman Test	
	z	p-value	r	p-value
HDI	1.135	0.152	-	-
Life Expectancy	1.839	0.002	0.823	0.000
GRDP	2.036	0.001	0.217	0.001
Per capita expenditure	2.041	0.000	0.897	0.000
Average Years of Schooling	7.786	0.000	0.881	0.000
Expected Years of Schooling	1.506	0.021	0.671	0.000



Figure 1. Correlation plots for life expectancy to HDI.

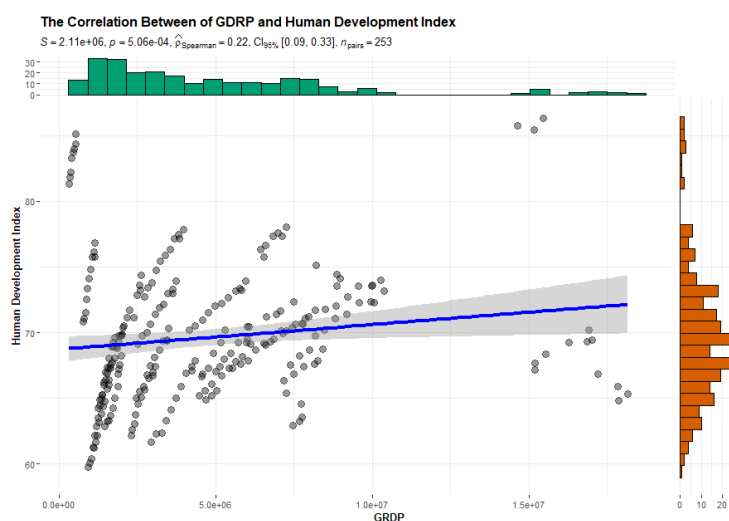


Figure 2. Correlation plots for GRDP to HDI.

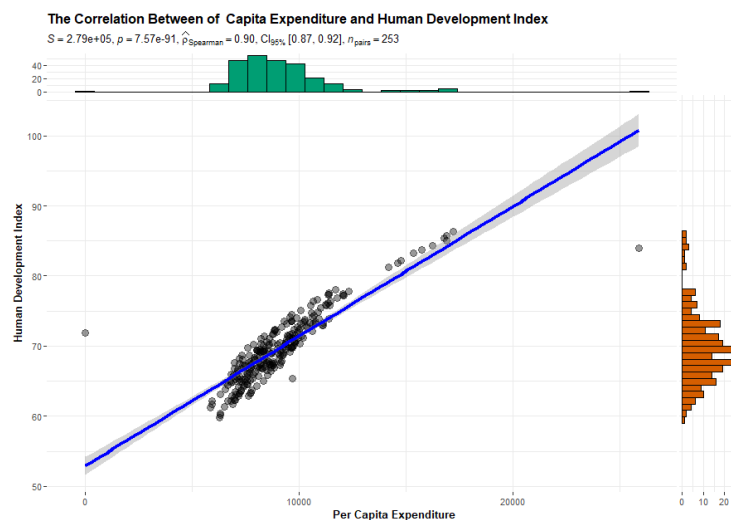


Figure 3. Correlation plots for per capita expenditure to HDI.



Figure 4. Correlation plots for the average years of schooling to HDI.

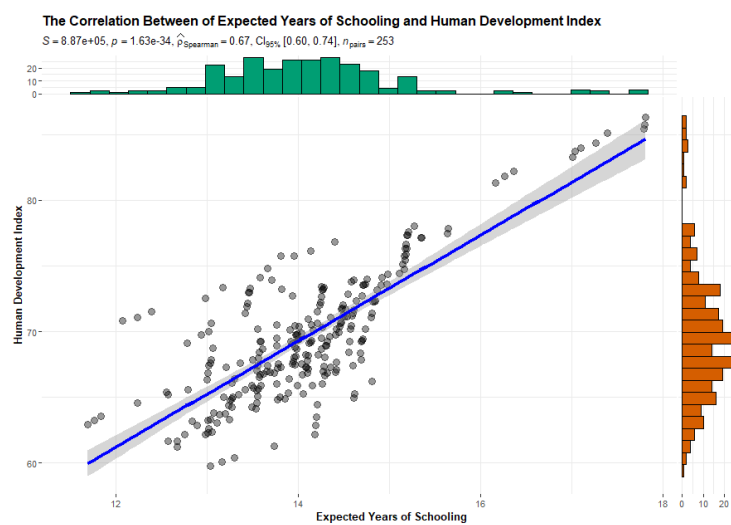


Figure 5. Correlation plots for the expected years of Schooling to HDI.

Figure 1 shows a strong positive relationship between Life Expectancy and HDI. With a Spearman correlation coefficient of 0.82, the two variables show a significant relationship, reinforced by the very small p-value ($p\text{-value} < 0.05$), signalling that the relationship is highly statistically significant. The distribution of the data shows that most regions in the sample have HDI in the range of 70-75 and Life Expectancy close to 70 years. Figure 2 displays the relationship between GRDP and HDI. Although the blue line indicates a positive relationship, the Spearman correlation coefficient of 0.22 indicates that this relationship is relatively weak. However, with a p-value of 0.001, this relationship is still statistically significant. From the distribution of the data, most regions in the data have HDI in the range of 70-80. As for GRDP, most of the data ranges in the lower values, but there are some outliers with very high GRDP.

Furthermore, Figure 3 shows the relationship between Per Capita Expenditure and HDI. With a Spearman correlation coefficient of 0.90, the relationship between these two variables is solid and positive. The very small p-value ($p\text{-value} < 0.05$) indicates this relationship is statistically significant. The data shows that the HDI also tends to increase as per capita expenditure increases. Most regions in the sample have HDI in the range of 70-90 and per capita expenditure in the lower range, but there are some outliers with higher per capita expenditure. Then, Figure 4 shows the relationship between Average Years of Education and HDI. With a Spearman correlation coefficient of 0.89, the relationship between these two variables is very strong and positive. The p-value, which is almost close to zero ($p\text{-value} < 0.05$) confirms that this relationship is statistically significant. This suggests that as the average years of education increase, the HDI tends to increase. Most of the data shows that regions with average years of education in the range of 8-12 years have HDIs between 70 and 90.

Figure 5 illustrates the relationship between Years of Education Expected and the HDI. The Spearman correlation coefficient of 0.67 indicates a moderately strong positive relationship between the two variables. The very low p-value ($p\text{-value} < 0.05$) confirms that this relationship is statistically significant. This indicates that regions with higher expected years of education tend to have higher HDI scores. Nonetheless, the relationship between these two variables does not seem as strong as in the previous figure on average years of education. In the next analysis, the study explains the findings from analyzing the distribution of HDI over 2012-2022 and focuses on 2022. This will help us understand the changes over time in HDI and the position of the center of the distribution in the last year of the study.

Life Expectancy, GRDP, Per capita Expenditure, Average Years of Schooling, and Expected Years of Schooling are social and economic indicators that are widely recognized to have a significant correlation with HDI. The results of this study confirm this relationship, which has been previously proven through previous studies [8,44], emphasizing the importance of these variables in the measurement and understanding of human development [45].

Life expectancy has long been an important indicator in assessing a population's quality of life and well-being. An increase in life expectancy tends to be positively correlated with an increase in HDI, reflecting improved health, medical services, and better living conditions [46]. GRDP is an important measure of a region's economic activity [47]. An increase in GRDP often increases per capita income and the availability of resources for investment in basic services such as education and health, which contribute to improvements in HDI. Per capita expenditure is an economic indicator that reflects the average income of individuals within a region. Higher per capita expenditure often correlates with better quality of life and better access to education and health services.

Average Years of Schooling and Expected Years of Schooling are education indicators that reflect the level of education within a region. Higher education correlates positively with an increase in HDI, as education is critical to improving individual capabilities and access to better economic opportunities [48].

Previous studies in various places have also investigated similar relationships. The results of these studies consistently show that there is a positive relationship between Life Expectancy, GRDP, Per capita Expenditure, Average Years of Schooling, and Expected Years of Schooling and the HDI in some countries [49–51]. These findings reinforce that sustainable human development does not rely on just one variable but results from a balance of these factors. Therefore, effective development policies should consider and promote improvements in all these variables to achieve sustainable social and economic progress.

Figure 7 illustrates the distribution of the HDI across different regions in Aceh over the period 2012-2022. With a median HDI of 68.41, marked by the blue vertical line, this reflects that most regions in Aceh have relatively similar levels of human development. The Wilcoxon test results, with a V-value of 276.00 and a very low p-value (p-value < 0.005), indicate significant differences in the distribution of HDI between regions.

Further, Figure 8 depicts the distribution of the HDI across different regions in Aceh for the year 2022. With a median HDI of 70.43, marked by the blue vertical line, this reflects that most regions in Aceh have relatively similar levels of human development. The Wilcoxon test results, with a V-value of 276.00 and a very low p-value ($p\text{-value} < 0.00$), indicate significant differences in the distribution of HDI between regions. Banda Aceh, as the province's capital city, shows the highest HDI score, close to 90. This indicates that Banda Aceh has better access to education, health, and living standards compared to the rest of Aceh. Meanwhile, several other areas, such as Lhokseumawe, Langsa, and Sabang, show HDI scores above the median but still below Banda Aceh. This suggests that while these areas have made progress in human development, there is still room for improvement. On the other hand, there are regions such as Aceh Tenggara, Aceh Timur, and Gayo Lues that have HDI scores below the median. This indicates that these areas may face certain challenges in improving the quality of life of their people, perhaps related to inadequate access to education or health facilities.

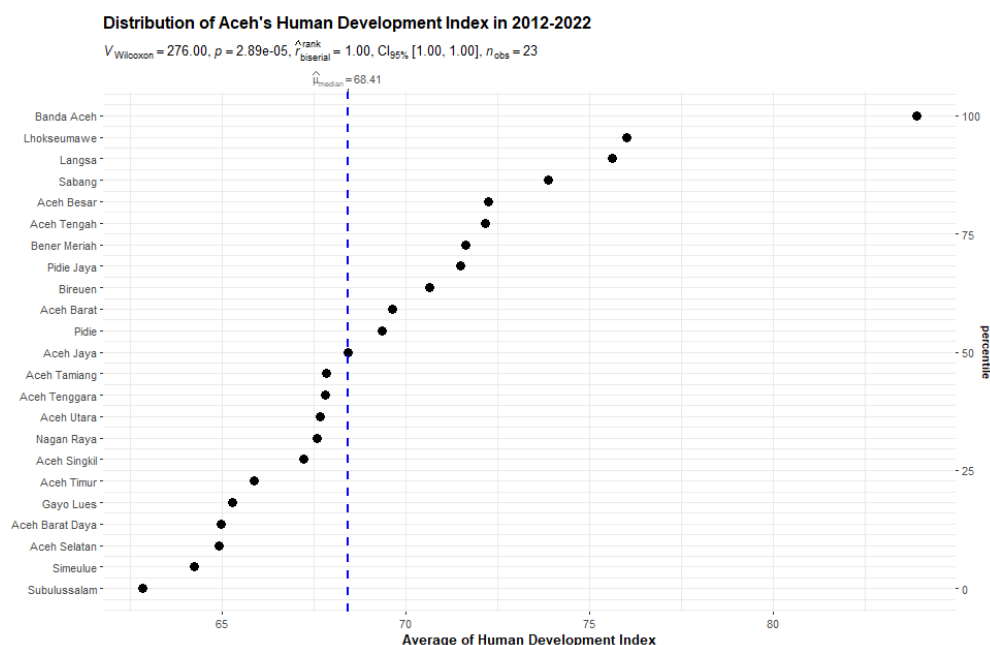


Figure 7. Distribution of Aceh's HDI in 2012-2022.

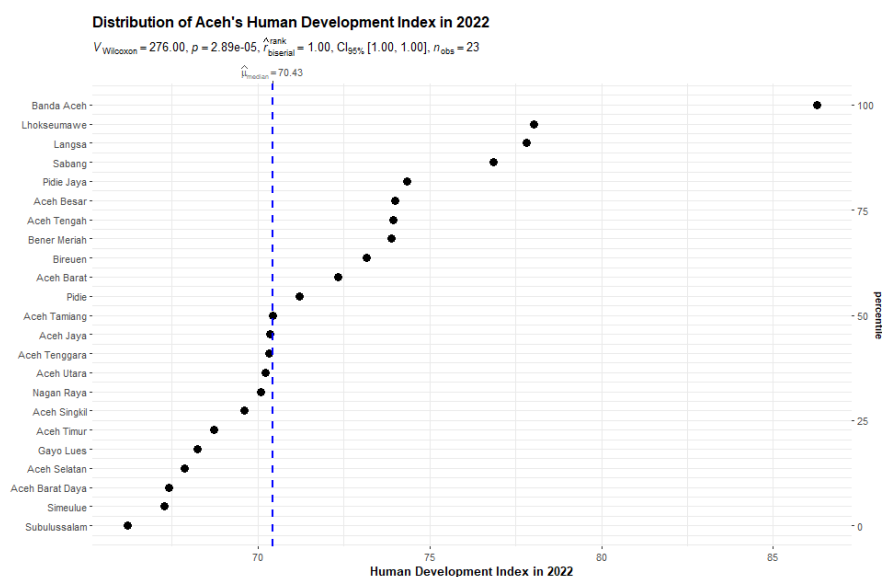


Figure 8. Distribution of Aceh's HDI in 2022.

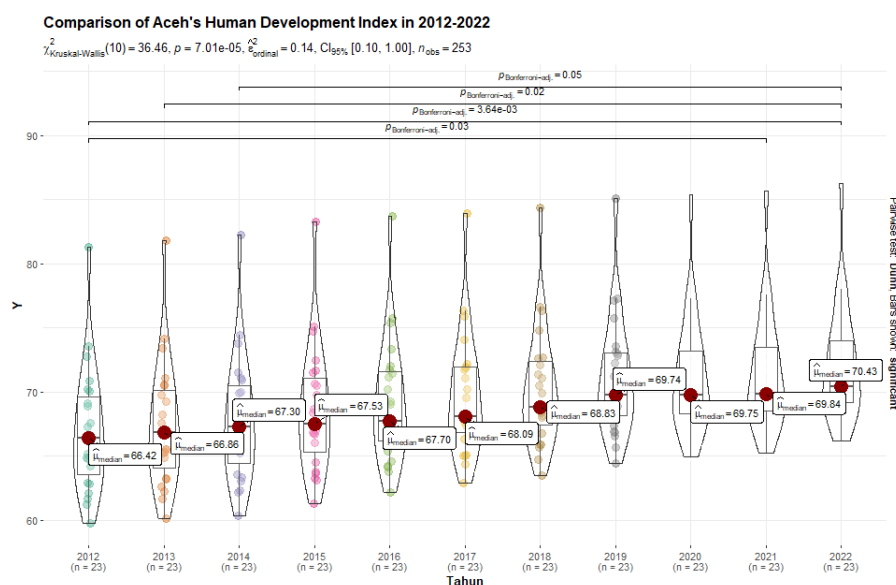


Figure 9. Comparison of Aceh's Human Index Development in 2012-2022.

Figure 9. shows a comparison of Aceh's HDI from 2012 to 2022. Each point in the figure represents an individual observation, while the diamond shape illustrates the distribution of observations, with the red line signifying the median of each year. Furthermore, in 2012, Aceh's HDI had a median of 66.42. Throughout the following years, there was a gradual increase in the median HDI, indicating an improvement in the quality of life and development in Aceh. 2015 and 2016 saw slight fluctuations, with median HDIs of 67.70 and 67.53, respectively. There was a significant spike in 2020, with the median HDI reaching 69.74. In the last year shown, 2022, Aceh's HDI reached its highest level with a median of 70.43. Overall, this figure shows that over the 11 years, there was a positive increase in the HDI in Aceh, signaling significant growth and development in aspects of the quality of life of the Acehnese people. In the last analysis stage, we ran the Shapiro-Wilk test to evaluate the normality of the distribution of the HDI variable over various years. An interesting result of this test is that the HDI distribution from 2012 to 2018 is shown to follow a normal distribution (with a p-value > 0.05), but in contrast, the HDI distribution from 2019 to 2022 shows abnormalities (with a p-value < 0.05). This

highlights an interesting dynamic in our data, with some years showing different HDI value distribution patterns.

Table 3. Normality and comparability tests for the HDI.

Years	Shapiro-Wilk Test		Kruskal-Wallis Test		
	W	p-value	χ^2	p-value	95% CI
2012	0.931	0.117			
2013	0.929	0.109			
2014	0.932	0.121			
2015	0.925	0.087			
2016	0.919	0.064			
2017	0.918	0.061	36.46	0.00	0.10 – 1.00
2018	0.915	0.054			
2019	0.912	0.046			
2020	0.900	0.025			
2021	0.892	0.017			
2022	0.889	0.015			

Furthermore, based on Table 3. It is found that there is a significant difference in the distribution of the variables we studied for each year. This result is found based on the low p-value (p-value < 0.05), which is also accompanied by a 95% confidence interval that ranges from 0.10 to 1.00. These significant differences in HDI from year to year illustrate a noteworthy dynamic in human development in the observed region [52]. The social, economic, or policy factors that may have influenced HDI appear to have changed over time [53]. This highlights the need for further studies to understand what underlies these changes and the efforts that may be needed to improve the level of human development in the future.

In addition, these findings have important implications for policy planning and decision-making. Understanding the differences in HDI between specific years provides a solid basis for identifying areas that may require more attention in terms of social and economic development. With this understanding, strategic efforts can be made to improve the population's quality of life in the various years observed [54].

Furthermore, this study has several areas for improvement. The analysis period was limited, variables were incomplete, correlation analyses were conducted without consideration of cause and effect, and no post hoc tests were conducted regarding differences in HDI distribution over the study period. Awareness of these weaknesses is essential for improvement in future research.

Conclusions

This research provides an in-depth understanding of the positive correlation between the HDI and some key social and economic indicators, including Life Expectancy, Gross Regional GRDP, Expenditure Per Capita, Average Years of Schooling, and Expected Years of Schooling in several districts/cities in Aceh Province over the period 2012-2022.

Based on the findings of the study, it is recommended that policymakers and stakeholders focus on strategies that enhance the positive correlates identified, namely Life Expectancy, GRDP, Per Capita Expenditure, Average Years of Schooling, and Expected Years of Schooling. Initiatives aimed at improving healthcare, economic development, education, and individual well-being can contribute to overall human development. Additionally, as the study reveals a positive trend in HDI over the years, it is crucial to sustain and further amplify efforts that have led to this improvement. Monitoring and adapting policies based on ongoing socioeconomic changes can ensure continued progress in enhancing the quality of life and overall development in Aceh Province.

Furthermore, the study found significant differences in the distribution of HDI for each of the years we compared. The results of this distribution analysis reveal that there is a structured upward trend in addition to differences in distribution between years. This indicates that, overall, the distribution of HDI in Aceh Province tends to increase over time.

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Ethical Clearance: Not applicable

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available on Aceh in Figure from 2012-2022.

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Conflicts of Interest: All the authors declare no conflicts of interest.

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