Spatial Modelling of the Relationship Between the Characteristics of Vegetation Index, Life Expectancy and Fertility Rate in Banten Province

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Abstract. Rapid urbanization in Banten Province has reduced green open spaces, impacting environmental sustainability and demographic dynamics. This study analyzes the spatial relationship between vegetation index, life expectancy (LE), and total fertility rate (TFR) using Landsat 8 imagery (2020–2024) and demographic data from the Central Bureau of Statistics (BPS). The vegetation index, measured using the Normalized Difference Vegetation Index (NDVI), was examined alongside LE and TFR through Pearson correlation and Moran's I spatial autocorrelation. The results indicate a moderate negative correlation between NDVI and LE ($r = -0.561$, $p < 0.05$) and a strong negative correlation between LE and TFR ($r \approx -0.94$). Urban areas such as Tangerang City and South Tangerang City, despite having low vegetation cover, recorded higher LE due to adequate healthcare access. Conversely, rural areas with greater vegetation tended to have lower LE. Spatial analysis identified urban centers as hotspots with high LE, while rural regions appeared as coldspots. These findings confirm that healthcare access and socioeconomic factors can compensate for limited vegetation, while demographic transitions contribute to fertility decline, ultimately supporting sustainable development in Banten Province.
Keyword: Corelation, Fertility Rate, Life Expectancy, NDVI, Spatial Analys.

1. Introduction

Human quality of life indicators is often measured using several parameters, such as social and economic indicators. However, to determine the quality of life in a country, several indicators need to be measured. According to the Organisation for Economic Co-operation (OECD), there are several indicators for determining quality of life, including income, housing, environment, social stability, health, education, and employment opportunities [1]. However, in practice, there is often a tendency to ignore or minimize the influence of physical environmental factors that can affect the health of individuals and the population as a whole. The physical environment includes various components such as infrastructure, sanitation, and air quality, which can contribute significantly to public health [2].

In the context of regional development, physical environmental factors are increasingly crucial to consider, given that urbanization in Indonesia has been a trend in recent decades. Urbanization has occurred alongside rapid economic growth, infrastructure development, and increased employment opportunities, especially in large cities such as Banten Province. Based on data from the Central Statistics Agency , the percentage of the urban population in Indonesia is projected to reach 66.6% by 2035 [3]. This rapid urbanization is driven by the hope for a better quality of life and easier access to education, health services, and other public facilities [4].

In relation to quality of life, life expectancy is an important indicator because it reflects the average number of years a person can expect to live from birth. Life expectancy can be used to evaluate the government's performance in improving the welfare and health of the community. In 2024, the Central Statistics Agency Indonesia recorded that the average life expectancy of the population in Indonesia increased from 72.13 years in 2023 to 72.39 years [5]. An increase in life expectancy is usually in line with improved access to health services, nutrition, and environmental quality. Life expectancy correlates with the geographical conditions of a region. This is the case in China, where Shanghai, located in the east, has a high life expectancy of 82.55 period, while Tibet, located in western China, has an average of 72.90 period [6]. Tibet's geographical conditions, namely its high altitude, result in thin air supply, while the extreme climate during winter can increase the risk of health problems. In addition, the hilly geographical conditions cause the people living in Tibet to be isolated. This is in contrast to the geographical conditions in Shanghai, which is a lowland area with a flatter terrain that is easier to navigate for mobilization. This situation is supported by research conducted in rural areas of the United States, where the terrain is steep, making mobilization difficult. Socioeconomic conditions contribute to remote areas consistently having lower life expectancy rates compared to communities living in coastal areas [7].

However, the increase in life expectancy is also closely related to other population dynamics, namely the Fertility Rate (TFR). The Total Fertility Rate (TFR) is defined as the number of live births of males and females per 1000 women who live to the end of their reproductive period or during their fertile period [8]. In Indonesia, the TFR trend shows a downward trend in line with socio-economic changes, increased female participation in education and the workforce, and easier access to reproductive health services [9]. A decline in fertility rates usually implies a demographic transition, where a society experiences a shift from high birth and death rates to lower rates, which ultimately leads to an increase in life expectancy.

Research shows that regions with high life expectancy generally have low TFR, due to shifts in lifestyle, urbanization, and increased awareness of family health. This finding is validated by research analyzing the relationship between TFR and LE, which shows a very strong negative correlation with a value of r = -0.86. When compared with several other parameters, they also have a very strong negative correlation with TFR. The correlation with the average years of schooling is r = -0.82 and the Human Development Index is r = -0.88 [10]. Regions with high HDI are mostly found in urban areas with high life expectancy and average years of schooling. Meanwhile, the fertility rate is low. Thus, the phenomenon of urbanization not only impacts demographic structure through declining fertility rates and increased life expectancy, but also poses new challenges related to urban environmental sustainability [11].

Urbanization not only affects the demographic structure, but also has an impact on social, economic, and environmental aspects. Rapid and poorly planned urban growth often has a negative impact on urban ecosystems. One of the main problems that arises is environmental degradation. Urbanization contributes significantly to the decline of green open spaces, which are crucial for the sustainability of urban ecosystems [12]. The conversion of land into built-up areas often sacrifices green areas that previously functioned as urban natural buffers.

Beyond the physical environment, recent research shows that vegetation and green spaces in urban areas significantly influence public health and various quality-of-life indicators. Vegetation is not only an aesthetic element of cities but also plays a vital role in regulating temperature, reducing air pollution, and improving psychosocial well-being [13]. Furthermore, the availability of green spaces in urban areas has been shown to contribute significantly to increased life expectancy. A study in the Netherlands showed that a one standard deviation increase in the percentage of green space was associated with a 0.1-year increase in life expectancy, while the quality of green space had an even greater impact of approximately 0.3 years [14].

In addition to direct health benefits, the existence of green space is also associated with reduced stress and increased community spirit. Previous studies have shown that good quality green space can reduce stress levels among urban residents by up to 20%, as well as increase feelings of security and

social cohesion, which have a positive impact on the general welfare of the community [15]. Although previous studies have examined the relationship between socioeconomic factors and fertility, as well as the role of green open spaces in urban environmental quality, studies that specifically link physical environmental factors such as vegetation with demographic indicators, namely Life Expectancy (LE) and Total Fertility Rate (TFR), are still limited. Most previous studies tend to be descriptive and do not take into account spatial variations between regions.

Spatial modelling is an important tool for understanding the distribution of vegetation indices and how they affect important indicators such as life expectancy and fertility rates. The use of Geographic Information System (GIS) technology, remote sensing, and spatial analysis can map vegetation distribution and show the spatial correlation between vegetation and health indicators, as well as the correlation with socio-economic aspects of society. Previous research conducted in China's Belt and Road region has indeed shown a positive correlation between ecological environmental quality and life expectancy, and emphasized the existence of a time lag effect [16]. However, this research only focused on life expectancy indicators, while the relationship with TFR has not been widely studied.

This study fills that gap by examining the relationship between vegetation, LE, and TFR. However, this study has limitations in terms of detailed mobility data. Due to the lack of such data, this study focuses more on spatial analysis between NDVI, LE, and TFR. By linking TFR, this study is expected to contribute to a more comprehensive understanding of how vegetation affects life expectancy, as well as fertility dynamics in urban areas. Thus, spatial modeling between vegetation, LE, and TFR not only contributes to understanding demographic dynamics in Banten Province but also emphasizes the importance of integrating ecological aspects into public health studies. By examining this relationship spatially, this study is expected to serve as a policy recommendation, thereby supporting policy-making that is more oriented towards sustainability and public health [17].

2. Research Method

2.1. Area Study

This research was conducted in Banten Province, Indonesia. Its capital is Serang City and it has 8 regencies/cities. Banten is bordered by the Java Sea and the Thousand Islands in the north, DKI Jakarta and West Java in the east, West Java again and the Indian Ocean in the south, and the Sunda Strait and Lampung in the west. The province of Banten is part of the Greater Jakarta area, which has a high level of economic activity and population growth. High population growth has led to increasing levels of development, accompanied by problems arising from this, such as environmental degradation, declining public health, and so on. These conditions led to the selection of Banten Province for further research using spatial modelling to determine the relationship between vegetation conditions and the social conditions of the local community.

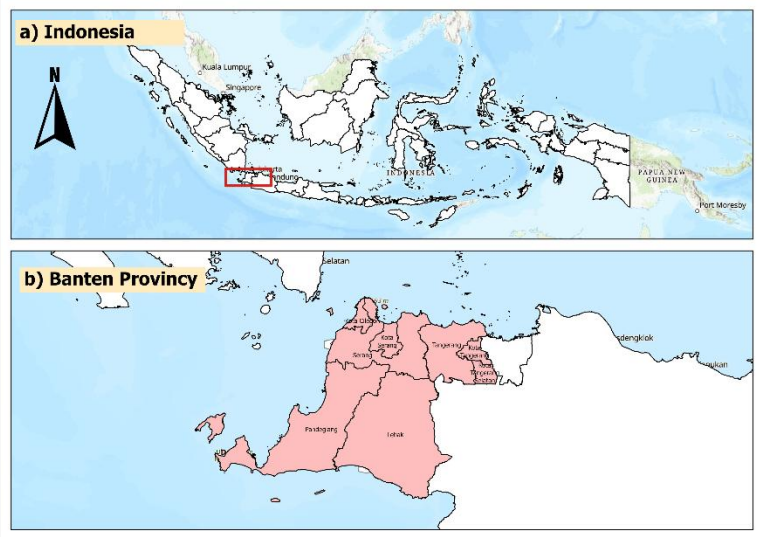

Figure 49. Area study

2.2. Data Analysis Techniques

Modelling the relationship between vegetation indices, life expectancy, and birth rates was conducted by integrating remote sensing data and Geographic Information Systems (GIS). Vegetation indices were obtained from the processing of the Normalized Difference Vegetation Index (NDVI) using Landsat 8 imagery. Vegetation indices were used to observe vegetation conditions over a specific period of time. The NDVI map has values ranging from -1 to 1. If the value is close to -1 in an area, it indicates that the area has very low greenery or even no vegetation. Meanwhile, a value close to 1 indicates an area with very high greenery [18]. The NDVI map was obtained using the near infrared (NIR) and red bands using the following formula.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

The NDVI processing period is from 2020 to 2024 to observe changes in vegetation conditions, which will later be linked to life expectancy and fertility rates. NDVI processing produces five classes of vegetation conditions, ranging from very low to very high. The next step is to process tabular data on life expectancy and fertility rates. Both data sets are integrated with administrative boundary data to produce data on life expectancy and fertility rates by district/city.

The known NDVI data was tested using Pearson's correlation or product moment correlation with life expectancy, then life expectancy with total fertility rate. This correlation test was conducted to determine the level of correlation between each variable in this study, which is expressed by the correlation coefficient (r). The results of the correlation can be positive, which means that the two variables have a significant relationship. In a scatter plot, this is symbolized by a trend line that slopes upward from left to right. There is also a negative correlation, indicating that an increase in one variable causes a decrease in another variable. In a scatter plot, this is symbolized by a trend line that slopes downward from left to right [19]. In addition, there is a principle that applies to making decisions between the two variables by considering the following principles:

a. The correlation is proven if the significance value is <0.05;
b. The correlation is not proven if the significance value is >0.05.

Table 25. Level of Correlation Between Variables (r)

Coefficient Interval	Level of Relationship
0.00-0.199	Very Weak
0.20-0.399	Weak
0.40-0.599	Moderate
0.60-0.79	Strong

Coefficient Interval	Level of Relationship
0.80-1.0	Very Strong

Source: [20]

To determine the relationship between environmental indices and life expectancy and fertility rates, Moran's I index is processed. Moran's I index is a spatial autocorrelation tool that can measure the similarity of values from nearby locations that tend to cluster together. The values of the Moran's I index range from -1 to 1. If the autocorrelation value is positive, the proximity between locations is closer. Meanwhile, if the autocorrelation value is negative, it indicates a pattern of proximity that tends to be unsystematic [21]. The results of Moran's I Index autocorrelation can also produce random patterns, which indicate the absence of spatial autocorrelation. The processing of Moran's I Index will produce an analysis of the relationship between vegetation index, life expectancy, and fertility rates. The correlation results will be further analyzed by linking them to the amount of health infrastructure. The correlation results between the environmental index and life expectancy will be proven with data on the amount of health infrastructure, as infrastructure plays a large and important role in social and health fields.

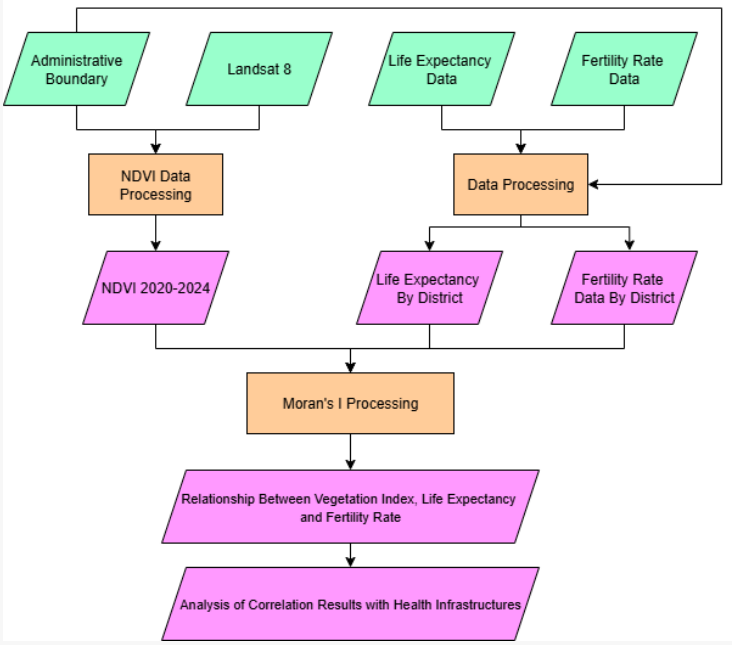

Figure 50. Flowchart

3. Result and Discussion

The Normalized Difference Vegetation Index (NDVI) map for Banten Province in 2020-2024 is divided into five classifications. These classifications start from non-vegetated land (-1 – 0.267156), very low greenness (0.267156 – 0.457131), low greenness (0.457131 – 0.619966), moderate greenness (0.619966 – 0.755663), and high greenness (0.755663 – 1). The classification is shown in Figure 3 for the NDVI map of Banten Province in 2024. Meanwhile, the NDVI map of Banten Province for 2020-2023 is shown in Figure 4.

The distribution for the moderate greenness and high greenness classes is concentrated in the central to southern parts of Banten Province, which are under the administration of Lebak and Pandeglang. Meanwhile, the low greenness to non-vegetated land classes are more widely distributed in the northern part of Banten Province, which is under the administration of Tangerang City, South Tangerang City, Tangerang Regency, Cilegon City, Serang Regency, and Serang City. These areas are buffer zones for the capital city, which is part of the Jabodetabek agglomeration in the west. Meanwhile, the eastern part is mostly used for industry and mining. Table 2 below shows the NDVI area in each regency/city, divided into five classes from 2020 to 2024.

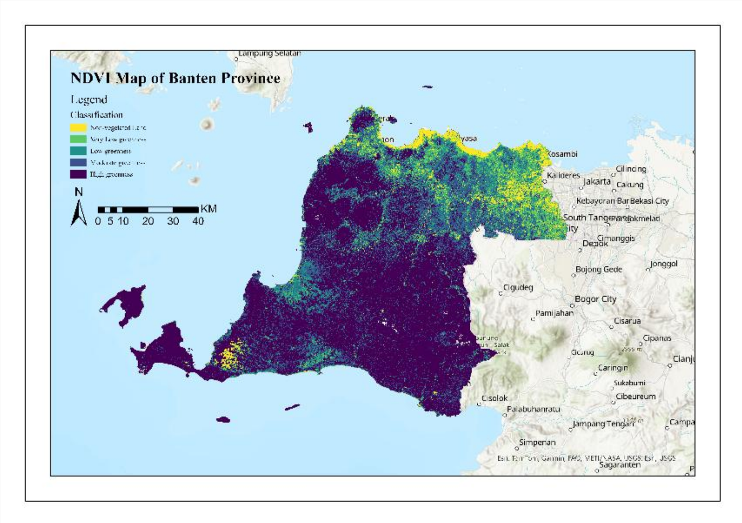

Figure 51. NDVI Map of Banten Province in 2024

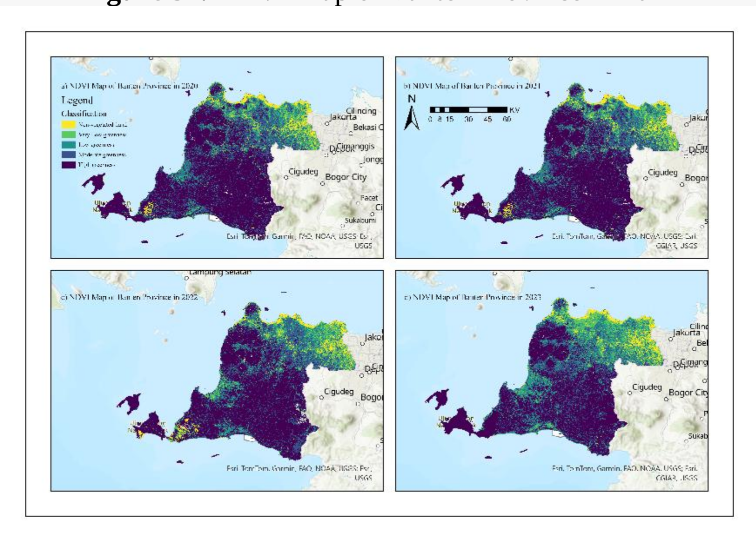

Figure 52. NDVI Map of Banten Province a) 2020 b)2021 c)2022 d)2023

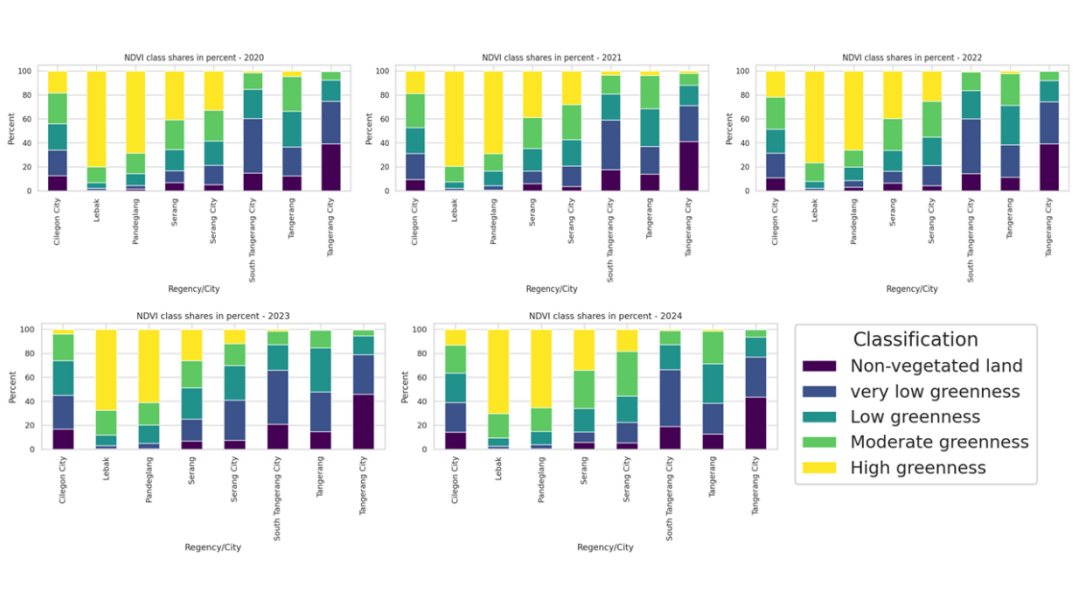

Figure 53. Percentage of NDVI Area in Banten Province 2020-2024
Source: Author's Analysis (2025)

The distribution of the greenness index, which is often measured using NDVI (Normalized Difference Vegetation Index), shows the level of vegetation health in an area. Ecologically, healthy vegetation plays a vital role in producing oxygen through photosynthesis, which has a positive impact on air quality and the human respiratory system. Thus, good vegetation conditions should correlate positively with human health. The model results between NDVI and LE in Banten Province show a negative correlation with a moderate level of relationship (r = -0.562). This figure means that areas with high vegetation have lower life expectancy rates. This situation occurs due to other factors that influence the level of life expectancy.. The areas with the highest levels of vegetation health are mostly located in Lebak District (438 people/km^2) and Pandeglang (478 people/km^2), which are characterized by relatively low population density and minimal built-up land [22]. Although the dominance of vegetation in these two regions ensures good oxygen quality, these natural geographical conditions actually result in limited infrastructure, including health facilities such as hospitals and community health centers. This limited access makes public services, especially medical care, slower and less optimal. As a result, local communities often have to travel long distances to other districts/cities to obtain adequate services. This situation highlights the importance of equitable infrastructure development balanced with environmental conservation considerations so that all aspects can function optimally without compromising others [23].

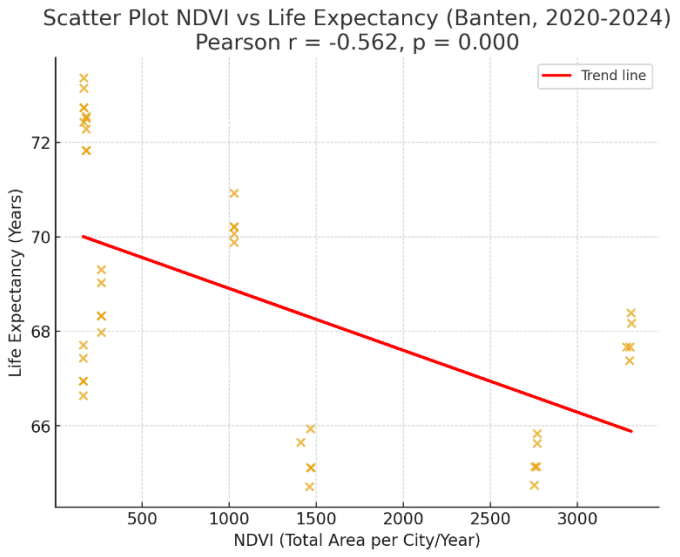

Figure 54. Graph scatter plot correlation test

Table 2 above and Table 3 below show that areas with high life expectancy actually have low to very low vegetation conditions. Figure 6 shows that the distribution of life expectancy points is scattered above the trend line, while districts/cities with a fairly wide distribution of high vegetation have low life expectancy and are scattered below the trend line. This occurs in urban areas with high life expectancy rates, largely due to infrastructure development and easy access to health facilities. However, vegetation health can still be said to be indirectly related to life expectancy. The function of vegetation as a carbon sink and oxygen producer will be disrupted if its quantity is low and its condition is poor. This condition can result in unhealthy air quality. This phenomenon makes it one of the climate parameters that can be felt immediately or only after a long period of time. According to data from the World Health Organization (WHO), poor air quality has caused 7 million deaths worldwide each year. If this continues, the death rate will continue to increase and affect the life expectancy of a region [24].

Table 26. Life Expectancy by District/City

City	Life Expectancy per Year				
	2020	2021	2022	2023	2024
Pandeglang	65.135	64.75	65.135	65.63	65.84
Lebak	67.675	67.385	67.675	68.18	68.39
Tangerang	70.22	69.885	70.22	70.7	70.925
Serang	65.115	64.715	65.115	65.65	65.945
Tangerang City	71.83	72.55	71.83	72.285	72.51
Cilegon City	66.95	66.645	66.95	67.44	67.71
Serang City	68.335	67.985	68.335	69.035	69.31
South Tangerang City	72.735	72.43	72.735	73.155	73.365

Source: [25]

The availability of more health facilities serves to provide wider access to health services for the community. So when they are sick, they will go to health facilities to regain their health. The closer the distance to health facilities, the lower the risk of death. The availability of more health facilities aims to provide broader access to health services for the community. So, when they are sick, they will go to health facilities to recover their health. The closer the distance to health facilities, the lower the risk of death. Based on data released by the Central Statistics Agency, in 2022 Banten had 101 general hospitals, 25 specialized hospitals, 68 inpatient health centers, 179 non-inpatient health centers, 1,557 primary clinics, and 15,153 integrated health service posts spread across 8 regencies/cities. The table shows that Tangerang City, South Tangerang City, and Tangerang have the highest number of general

and specialized hospitals in Banten Province. This has resulted in a relatively high life expectancy in these three areas. Although some areas have more health facilities than these three areas, their life expectancy is still lower. Improvements in public health status are influenced by the adequacy of medical equipment and health personnel. Complete equipment enables doctors to contribute better care to speed up recovery and reduce patient mortality rates. In addition, optimal service can be achieved with a larger number of health personnel, with an ideal standard of one doctor per thousand inhabitants.

Table 27. Number of Health Facilities in Banten Province in 2022

Regency/City	General hospitals	Specialized hospitals	Inpatient health centers	Non-inpatient health centers	Primary clinics	Pos-yandu
Pandeglang	4	1	21	22	26	1832
Lebak	4	0	15	16	67	3062
Tangerang	22	5	0	9	539	3677
Serang	6	0	7	37	109	2444
Tangerang City	28	6	9	22	200	1539
Cilegon City	5	1	9	27	46	557
Serang City	10	2	7	9	109	790
South Tangerang City	22	10	0	37	461	1252
Banten	101	25	68	179	1557	15153

Source: [26]

This is proven by several studies, including that neonatal children living within a 1 km radius have a 7.7% risk, those within a 2 km radius have a 16.3% risk, and those within a 3 km and 5 km radius have a 25% risk of death [27]. In addition to proximity to health facilities, the number of health workers needs to be considered. An increase in healthcare personnel will contribute to an increase in life expectancy and, of course, improve the quality of life for the community [28].

The analysis did not stop at Pearson's correlation analysis, the researchers also conducted an autocorrelation analysis between neighbouring regions or Moran's I for life expectancy. This analysis found that there were two regions in Banten Province that had a positive (high-high) correlation, symbolized by the colour red in Figure 7. These regions were Tangerang City and South Tangerang City. These two cities have the highest life expectancy in Banten Province, namely South Tangerang with 73.365 years in 2024 as the city with the longest life expectancy, and in second place is Tangerang City with a life expectancy in 2024 of 72.51. Because it is a high-high region, it can also be called a hotspot region. Meanwhile, the area with a low-low cluster, symbolized by the colour blue, is Serang Regency. As a low-low area, it can also be referred to as a coldspot. The Moran's I obtained in this analysis is 0.661, indicating positive autocorrelation, which is also shown in Figure 7.

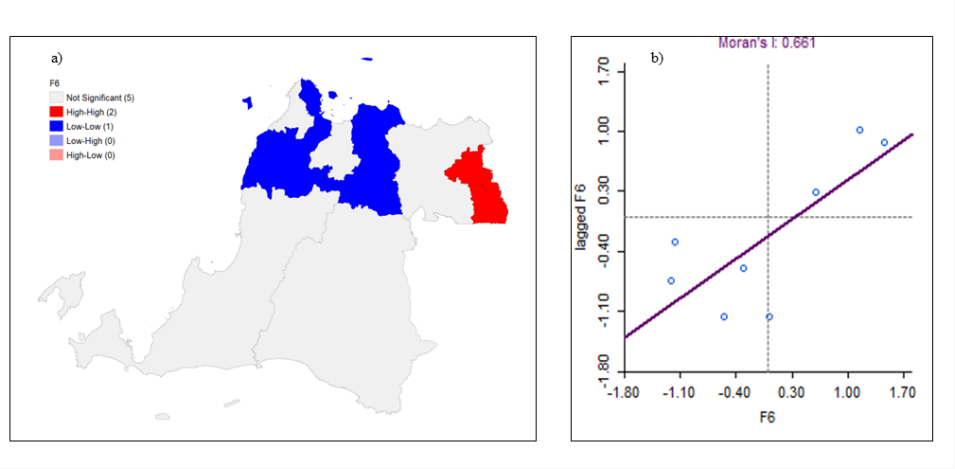

Figure 55. a) Map of Life Expectancy Clusters in Banten Province and b) Scatter Plot of Life Expectancy in Banten Province

Next, life expectancy data for the period 2020-2024 was tested using Pearson's correlation coefficient with the total birth rate in Banten Province in 2020. The correlation value between the two parameters ranged between -0.94 and -0.95, and the p-value between 0.001 and 0.000. Based on these values, the two variables have a very strong negative significance. This can be seen in Figure 8, where the regression line slopes downward from left to right, and the distribution of points is still scattered within the confidence interval. Therefore, the higher the life expectancy, the lower the total fertility rate in a region. This indicates that the region has a better quality of life in terms of education, economy, health, and so on. This phenomenon can be found in regions with advanced economic conditions. This is also in line with the author's analysis above regarding easy access to health services, which is one of the factors that can contribute to a person's life expectancy. This situation has caused a demographic transition in the world. Other factors include an increase in per capita income, an increase in human needs, a decrease in gender inequality, and demands for security at age [25], [29].

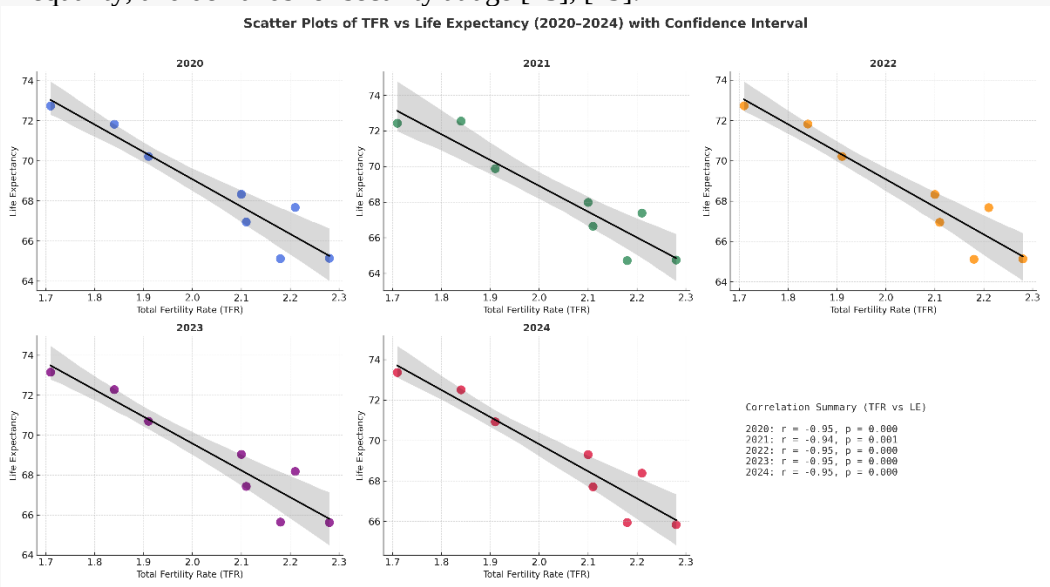

Figure 56. Scatter Plots Between TFR 2020 and Life Expectancy Figures for 2024 in Banten Province

Behind all this, longer life expectancy has caused people to delay having children, which has affected the TFR. As a result, women tend to become pregnant at a relatively older age. Consequently, when childbirth occurs at an older age, the mother's life expectancy decreases by 0.555 years [30]. The areas in Banten with low TFR and high life expectancy are Tangerang City and South Tangerang City. They have TFR and life expectancy rates of 2.1 and 72.51 years and 1.71 and 73.365 years, respectively.

4. Conclusion

Based on the results of the study, there is a significant negative relationship between the vegetation index (NDVI) and life expectancy in Banten Province, with a Pearson correlation value of -0.562 and a significance value (p) of 0.000. These results indicate that the higher the NDVI value of an area, the lower the life expectancy tends to be. This condition can be attributed to the characteristics of areas with high vegetation levels, such as Lebak and Pandeglang Regencies, which generally have low population densities and limited access to health facilities. Conversely, urban areas with relatively low vegetation levels, such as Tangerang City and South Tangerang City, show higher life expectancy due to the availability of adequate health facilities and services. However, these results contradict general ecological conditions, given that healthy vegetation plays an important role in producing oxygen and generally correlates positively with human health. Based on data from the Central Statistics Agency in 2022, Banten Province has a number of health services spread across eight regencies/cities. Areas such as Tangerang City, South Tangerang City, and Tangerang Regency are recorded as having better health facilities, contributing to the high life expectancy in these areas. Spatial analysis using Moran's I shows the existence of hotspot clusters in Tangerang City and South Tangerang City as areas with high life expectancy, while areas such as Serang Regency are identified as coldspots with low life expectancy. In addition, a very strong negative relationship was found between life expectancy and total fertility rate (TFR), with correlation values ranging from -0.94 to -0.95. This indicates that improvements in quality of life and community welfare contribute to a decline in birth rates. Indirectly, the vegetation index also affects life expectancy in the long term. Although areas with low vegetation may show high life expectancy due to health facilities, environmental conditions, particularly air quality, tend to deteriorate over time. Therefore, vegetation continues to play an important role as an ecological factor that supports improvements in the quality of life and health of the community.

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