GIS-Based Analysis Of Senior And Vocational High School Distribution Patterns In Kepulauan Yapen Regency

Analisis Pola Persebaran Sekolah Menengah Atas Dan Sekolah Menengah Kejuruan Berbasis Sistem Informasi Geografis Di Kabupaten Kepulauan Yapen

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Abstrak

Penelitian ini mengkaji pola persebaran Sekolah Menengah Atas (SMA) dan Sekolah Menengah Kejuruan (SMK) di Kabupaten Kepulauan Yapen dengan menggunakan Sistem Informasi Geografis (SIG). Data lokasi sekolah diperoleh dari Kementerian Pendidikan dan diverifikasi melalui Google Maps, sedangkan peta batas administrasi diambil dari Badan Informasi Geospasial (BIG). Analisis spasial dilakukan di ArcGIS Pro dengan menggunakan metode Average Nearest Neighbor (ANN), Mean Center, Standard Distance, dan Standard Deviational Ellipse. Hasil penelitian menunjukkan bahwa jarak rata-rata terdekat antar sekolah yang teramati lebih kecil dibandingkan jarak harapannya. Nilai rasio yang diperoleh sebesar 0,779877 dengan z-score −1,975184 dan p-value 0,048247, yang berarti pola persebaran sekolah cenderung mengelompok pada tingkat kepercayaan 95%. Persebaran tersebut terutama terkonsentrasi di wilayah pesisir selatan, khususnya di sekitar Serui, sementara wilayah utara dan pulau-pulau kecil memiliki jumlah sekolah yang lebih sedikit dengan jarak antarlokasi yang lebih renggang. Kondisi ini menunjukkan masih terbatasnya akses pendidikan menengah atas bagi masyarakat di wilayah terpencil.

***Keywords*: SIG, pola persebaran, sekolah menengah**

Abstract

This study examines how Senior High Schools (SMA) and Vocational High Schools (SMK) are distributed across Kepulauan Yapen Regency using Geographic Information Systems (GIS). School location data were taken from the Ministry of Education and verified through Google Maps, while administrative maps were obtained from the Geospatial Information Agency (BIG). Spatial analysis was carried out in ArcGIS Pro using the Average Nearest Neighbor (ANN), Mean Center, Standard Distance, and Standard Deviational Ellipse tools. The results show that the observed mean distance between schools is smaller than the expected mean distance, with a nearest-neighbor ratio of 0.779877, a z-score of −1.975184, and a p-value of 0.048247. These figures indicate that the distribution pattern is clustered at the 95% confidence level. The analysis also shows that most schools are concentrated along the southern coastal area, particularly around Serui in Yapen Selatan District, while the northern and outer island areas have fewer facilities and wider spacing between them. This shows that students in remote areas face relatively limited access to upper secondary education.

Kata Kunci : GIS, spatial distribution, high school, Average Nearest Neighbor

INTRODUCTION

Upper secondary education is regarded internationally as a strategic stage for social mobility and human capital competitiveness, as this level influences access to further study pathways and future economic opportunities (Mandahu, 2025; Brodny & Tutak, 2024; Canatay et al., 2025). Developing countries continue to face uneven access due to distance, geographical barriers, island characteristics, and infrastructural limitations, which restrict educational prospects for school-age populations living outside well-served areas (Rodriguez-Segura & Kim, 2021; Guijaro-Garvi et al., 2024; Zickafoose et al., 2024). These disparities are visible in urban zones with concentrated school networks and transportation systems, while peripheral or remote regions face physical and financial burdens that lead to absenteeism and reduced continuation into upper secondary schooling (Petre et al., 2025; Pezzulo et al., 2022; Raj & Sandasagan, 2024). In this global context, Geographic Information Systems are adopted to identify spatial inequality, calculate network-based accessibility, and evaluate school service coverage as an evidence base for planning the distribution of educational facilities (Meena et al., 2022; Yang et al., 2025; Jiang et al., 2024). Spatial assessments show that expanding the number of schools alone is insufficient, as spatial placement determines reachability and influences who can realistically continue to the upper secondary level, including specialized streams such as STEM programs which exhibit better access and quality in more populated and economically supported regions (Hazans et al., 2025; Sajjad et al., 2022; Bruno et al., 2022; Aule et al., 2023). Studies in remote regions further indicate that socioeconomic constraints, geographical isolation, and limited infrastructure restrict participation in schooling and require targeted improvements to educational service delivery in difficult-to-reach territories (Sapiah et al., 2025; Lesnawati et al., 2025). Research also confirms that residential distance to upper secondary schools can function as a practical barrier to entering school-based pathways, particularly for students located far from educational centers, showing that spatial factors shape opportunities to pursue continued education (Benz, 2025).

The distribution of senior and vocational high schools in Indonesia remains concentrated in urban centers and growth corridors, while rural areas, disadvantaged regions, and island territories experience reduced service access due to distance, transport limitations, and geographical barriers that restrict equitable provision of upper secondary education (Putri et al., 2025; Sakti et al., 2022; Ristanto & Gamal, 2023). This inequality is reinforced by travel burdens, difficult topographic conditions, and limited financial capacity, which weaken the continuity of attendance and reduce the likelihood of students reaching upper secondary services, especially in territories located far from educational hubs (Bakari & Sidik, 2025). Government efforts such as zoning and targeted support for 3T areas have been introduced to expand coverage, although the policy framework still relies heavily on administrative boundaries rather than spatial evidence that reflects proximity between schools and settlements (Cahyani et al., 2025; Muhaimin et al., 2022). Geographic Information Systems have begun to be used to evaluate allocation, assess spatial patterns, measure coverage radii according to national standards, and identify the mismatch between facility location and population distribution, although implementation remains uneven and dependent on local data readiness (Hadibasyir et al., 2025). Spatial analyses in several Indonesian regencies demonstrate

clustered patterns around population centers and strategic corridors, while peripheral districts experience greater separation from educational nodes, producing longer travel distances and revealing a distribution that is not proportional to the growth of school-age populations requiring access to upper secondary education (Ruhaimi & Yenny, 2025).

Kepulauan Yapen Regency in Papua presents an insular territorial structure, dispersed settlements across the main island and peripheral coastal clusters, and fragmented terrestrial connectivity disrupted by maritime barriers, resulting in senior high schools (SMA) and vocational high schools (SMK) that are not proportionally accessible despite their administrative presence. Educational facilities at these levels are recorded in regional datasets, yet actual reachability is influenced by maritime travel, discontinuous road corridors, and disconnected settlement chains, producing areas where access is weakened, particularly in communities located away from primary circulation routes and inter-settlement links. The issue in Kepulauan Yapen is not limited to the numerical adequacy of schools but lies in the spatial pattern that fails to align consistently with the distribution of the student-age population, indicating the need for spatial examination rather than administrative listing. Existing records remain predominantly inventory-based and have not been converted into spatial information capable of quantifying nearest-point relationships or evaluating school separation distance, leaving a blind spot in decisions concerning the placement of new schools and adjustments in educational service allocation. No comprehensive study has applied Average Nearest Neighbor (ANN) to assess the spatial distribution of SMA and SMK in Kepulauan Yapen, so the current pattern has not been statistically established as clustered, random, or dispersed, even though ANN values, z-scores, and p-values are required to determine that tendency and understand its implications for coverage. Geographic Information Systems in this context focuses on ANN-based pattern identification, followed by proximity interpretation between school locations and settlement points to indicate zones at risk of under-service and areas where educational access may require structural adjustment.

METHOD

Study Area

The Kepulauan Yapen Regency is situated in Papua Province, Indonesia, covering a terrestrial area of approximately 2,429.03 km² and occupying a position separated from the mainland of Papua within the waters of Cenderawasih Bay at coordinates 2°02'8.42''–1°23'19.55'' S and 134°56'21.708''–137°04'20.592'' E. It is bordered in the east by Mamberamo Raya Regency, in the west by Manokwari Regency of West Papua Province, in the north by Biak Numfor Regency, and in the south by Waropen Regency. The administrative structure consists of three principal islands—Yapen, Kurudu, and Poom—alongside smaller surrounding islands. Physical conditions are dominated by hilly and mountainous terrain, while limited flat and gently sloping areas occur primarily in the eastern and western sectors of Yapen Island. The variation in slope ranges from low-gradient zones near settlement corridors to steeper interior sectors, shaping patterns of accessibility and spatial distribution of inhabited areas without uniformity across the regency.
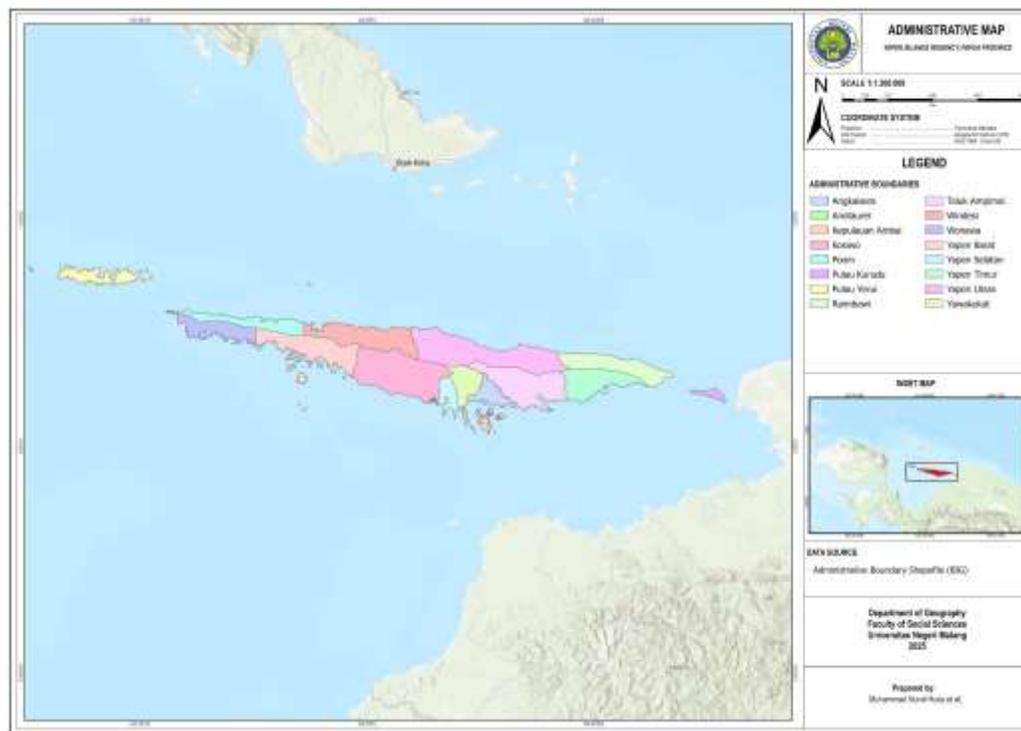
Figure 1. Administrative Map

Data Source

A dataset of senior and vocational high schools was compiled from the Ministry of Education to obtain institutional information, while coordinate points were extracted through direct verification in Google Maps to secure precise spatial references for each location. Administrative boundaries were taken from the Geospatial Information Agency (BIG) to construct the base map required for spatial processing. Data used in this study consists only of school point features and administrative polygons, without supplementary thematic layers, and serves as the primary input for spatial analysis and map production in the subsequent stages of the research.

Table 1. Data and Sources

Data Type	Format	Source	Purpose
Senior and Vocational High Schools	Point Coordinate (.csv/.xlsx)	Ministry of Education and coordinate survey via Google Maps	Spatial analysis and point feature input
Administrative Boundaries	Shapefile (.shp)	Geospatial Information Agency (BIG)	Base map construction for study area

The list of schools below represents SMA and SMK identified in the study area based on the survey process in Google Maps, followed by the inclusion of coordinate points and district information.

Table 2. List of Senior and Vocational High School

School	Coordinate		Sub-District
	X	Y	
SMKN 1 Agribisnis Dan Agroteknologi Serui	136,3305000	-1,8513000	Angkaisera
SMAN Menawi	136,3049800	-1,8603500	Angkaisera
SMAN Kosiwo	136,1088942	-1,8367015	Kosiwo
SMAN Poom	135,7048018	-1,6327947	Poom
SMAN Randawaya	136,5216274	-1,8521620	Teluk Ampimoi
SMKN 2 Kemaritiman Serui	135,8240200	-1,7738560	Yapen Barat
SMAN Marau	135,7374535	-1,6937115	Yapen Barat
SMA Yasuka Ansus	135,8016569	-1,7323860	Yapen Barat
SMKS Muhammadiyah Teknologi dan Rekayasa Serui	136,2343300	-1,8800900	Yapen Selatan
SMKS YPK Teknologi Informasi Dan Komunikasi Serui	136,2379800	-1,8771600	Yapen Selatan
SMA Advent Serui	136,2386000	-1,8803000	Yapen Selatan
SMA Kristen Kasih Bangsa	136,2345800	-1,8600700	Yapen Selatan
SMAN 1 Serui	136,2349800	-1,8760700	Yapen Selatan
SMAN 2 Serui	136,2419855	-1,8679589	Yapen Selatan
SMA Onate Serui	136,2415141	-1,8576098	Yapen Selatan
SMA PGRI Serui	136,2302851	-1,8758201	Yapen Selatan
SMA Yapis Serui	136,2418881	-1,8848371	Yapen Selatan
SMA YPK Penabur Serui	136,2386032	-1,8777442	Yapen Selatan
SMKN 3 Seni Dan Industri Kreatif Serui	136,7581000	-1,8174000	Yapen Timur
SMAN Unggulan Dawai	136,7071000	-1,8136000	Yapen Timur
SMA PGRI Dawai	136,7371000	-1,8143000	Yapen Timur
SMAN Kiriyou	136,2636753	-1,6761153	Yapen Utara

Data Processing

Data processing in ArcGIS Pro begins by importing school coordinate points into a geodatabase, checking spatial duplication through the Find Identical and Delete Identical tools, and projecting all layers into a uniform coordinate system such as UTM Zone 53S to secure spatial consistency. The analysis stage applies several spatial statistical tools to examine the distribution trend of school locations. The Average Nearest Neighbor (ANN) tool calculates the spacing between each point and its nearest neighbor to evaluate the statistical tendency of the distribution. The ANN index is produced through the ratio between the observed mean distance and the expected mean distance for a random pattern, expressed as:

$$ANN = \frac{\overline{D}_{obs}}{\overline{D}_{exp}}$$

$$\overline{D}_{exp} = \frac{0.5}{\sqrt{\frac{n}{A}}}$$

where $\bar{D}_{obs}$ is the mean observed nearest neighbor distance, $\bar{D}_{exp}$ is the expected distance, nnn is the number of points, and AAA is the study area. The Mean Center tool identifies the central point of the spatial distribution using the arithmetic mean of X and Y coordinates:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \ ; \ \bar{Y} = \frac{\sum_{i=1}^{n} Y_i}{n}$$

The Standard Distance tool measures the average spatial spread of the schools around the mean center by calculating a radial distance:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}[(X_i - \bar{X})^2 + (Y_i - \bar{Y})^2]}{n}}$$

The Standard Deviational Ellipse tool assesses the directional trend of the point distribution and the degree of dispersion along the major and minor axes, formulated as:

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n}} \ ; \ \sigma_Y = \sqrt{\frac{\sum_{i=1}^{n}(Y - \bar{Y})^2}{n}}$$

$$\theta = \frac{1}{2} tan^{-1}\left[\frac{2\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sum(X_i - \bar{X})^2 - \sum(Y_i - \bar{Y})^2}\right]$$

ANN provides the statistical tendency of clustering or dispersion, Mean Center locates the central tendency of school distribution, Standard Distance measures the extent of spatial spread around that point, and the ellipse defines orientation and directional bias of the distribution pattern.

RESULT AND DISCUSSION

**Senior and Vocational High School Distribution**

The spatial distribution of senior and vocational high schools in Kepulauan Yapen shows a concentration pattern centered in Yapen Selatan, particularly around Serui as the regency capital, while other districts display more limited institutional presence. The map in Figure 2 illustrates that most points cluster along the southern section of Yapen Island, where settlement intensity and administrative activity are highest, contrasting with the sparse configuration in Poom, Kurudu, Yapen Timur, Angkaisera, and Kosiwo. School locations extend across the main island and smaller adjacent islands, yet the numerical dominance in Yapen Selatan forms a noticeable core area of educational facilities compared to the peripheral districts. The distribution appears aligned with coastal settlement corridors and accessible road segments around Serui, whereas interior and northern sectors show fewer facilities. The table inserted in the methodology section confirms this pattern through coordinate entries that correspond to the visual concentration on the map in Figure 2.

Figure 2. Map of Distribution School

Average Nearest Neighbor (ANN) Result

The Average Nearest Neighbor results indicate that the observed mean distance of 4323.2397 meters is smaller than the expected mean distance of 5543.4885 meters, and the nearest neighbor ratio of 0.779877 confirms that the spacing between points is shorter than what would occur under a random configuration. The z-score of −1.975184 and p-value of 0.048247 show statistical evidence that the pattern does not fall within the range of random distribution and therefore aligns with a clustered spatial form at the 95 percent confidence level. This outcome means the locations tend to group into concentrated zones rather than spread evenly across Kepulauan Yapen, and the point arrangement leans toward spatial proximity instead of separation across the full extent of the regency. The visual distribution in Figure 2 supports this statistical output through the accumulation of schools around Yapen Selatan, specifically Serui, while the remaining districts show fewer points at wider distances. The coordinate entries in the data table reinforce this condition as repeated listings appear in Yapen Selatan and adjacent subdistricts while the northern, eastern, and outlying island sectors contain limited entries and greater spacing. The clustered interpretation in this context indicates that the measured distances between nearest neighbors fall below the threshold of a random pattern and the ratio expresses concentration instead of neutrality in spatial arrangement. The numerical relationship between observed and expected distances situates the result in the clustered category, and the statistical parameters confirm the pattern's deviation from randomness rather than dispersion.
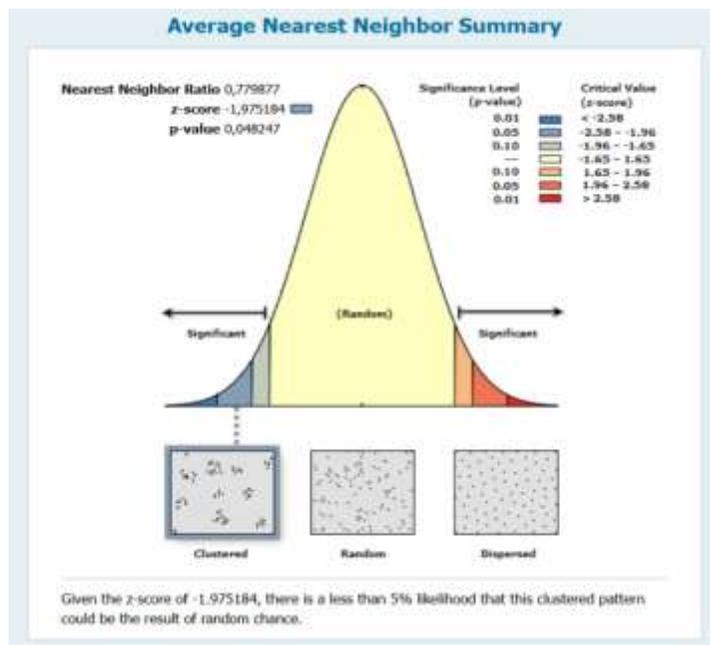
Figure 3. ANN Result

Spatial Centrality and Dispersion Analysis Based on Mean Center, Standard Distance, and Standard Deviational Ellipse

The mean center output places the central point of the distribution in the southern sector of the main island, positioned close to Serui in Yapen Selatan as shown in the Mean Center Map. The location of this point lies slightly offset toward the southeast rather than occupying a midpoint between the western and eastern districts, and it aligns more closely with the cluster of schools around the administrative hub. The spatial position of this mean center corresponds to the highest concentration of coordinate entries in the dataset and reflects the numerical weight of schools located around Serui, Yapen Selatan, and nearby subdistricts such as Anotaurei, Kosiwo, and Teluk Ampimoi. The map shows that this point does not approach northern or inland districts, and the centrality remains situated near the coastline where the majority of educational facilities appear.

Figure 4. Mean Center Map

The standard distance result forms a circular radius around the mean center, covering the southern belt of the island where most school locations fall inside the boundary shown on the Standard Distance Map. The radius creates a coverage zone that intersects Yapen Selatan, Yapen Timur, and parts of Yapen Barat, while Wanaw, Poom, Kurudu, and Yapen Utara remain outside or on the edge of this spatial extent. The distribution of points inside the radius is dense, while the outer sectors contain limited facilities at greater spacing. The southern coastline is enclosed by the circle more effectively than the central interior or northern districts, which appear at increasing distances from the radius boundary. The coverage pattern suggests that the standard distance captures the dominant spatial band of school presence rather than the full geographical range of the regency.
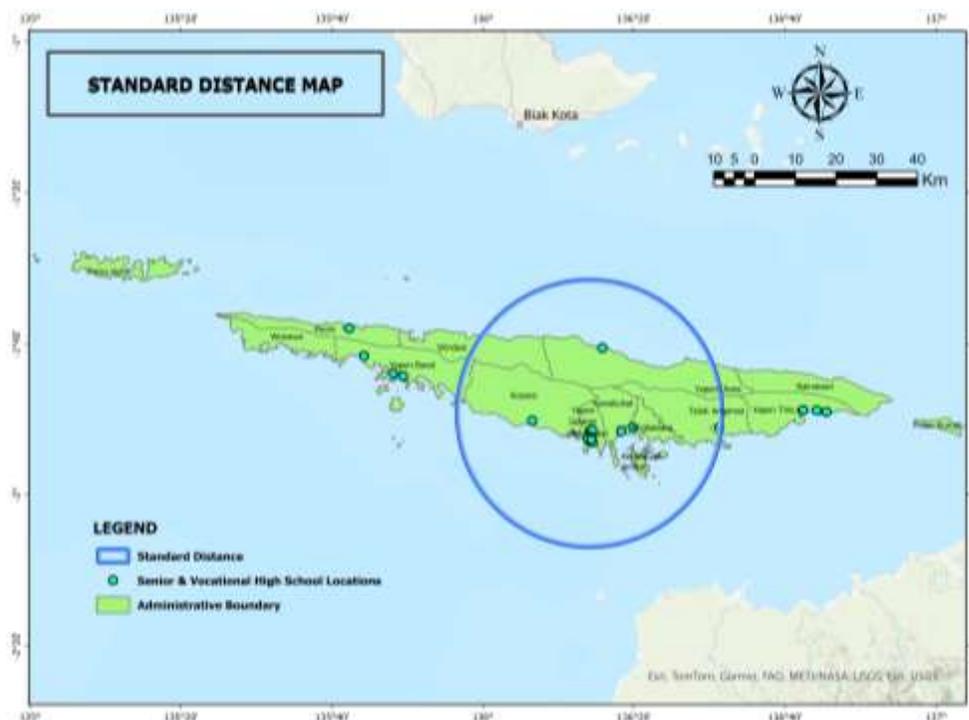
Figure 5. Standard Distance Map

The Standard Deviational Ellipse forms a horizontally elongated shape that stretches across the southern side of the island from Yapen Barat to Yapen Timur, as illustrated on the Standard Deviational Map. The ellipse widens toward the southeastern and southwestern sectors while narrowing toward the central interior, producing an east–west orientation that aligns with the denser settlement corridor and coastal distribution of schools. The upper portion of the regency sits beyond the ellipse boundary as the northern districts record fewer facilities and broader spacing. The ellipse indicates that the primary directional trend of school distribution follows the southern coastal axis rather than expanding toward the northern or inland areas. The alignment of the ellipse follows the orientation of the mapped points and reflects the spatial tendency toward the southern sector of the island without extending into the more remote zones.
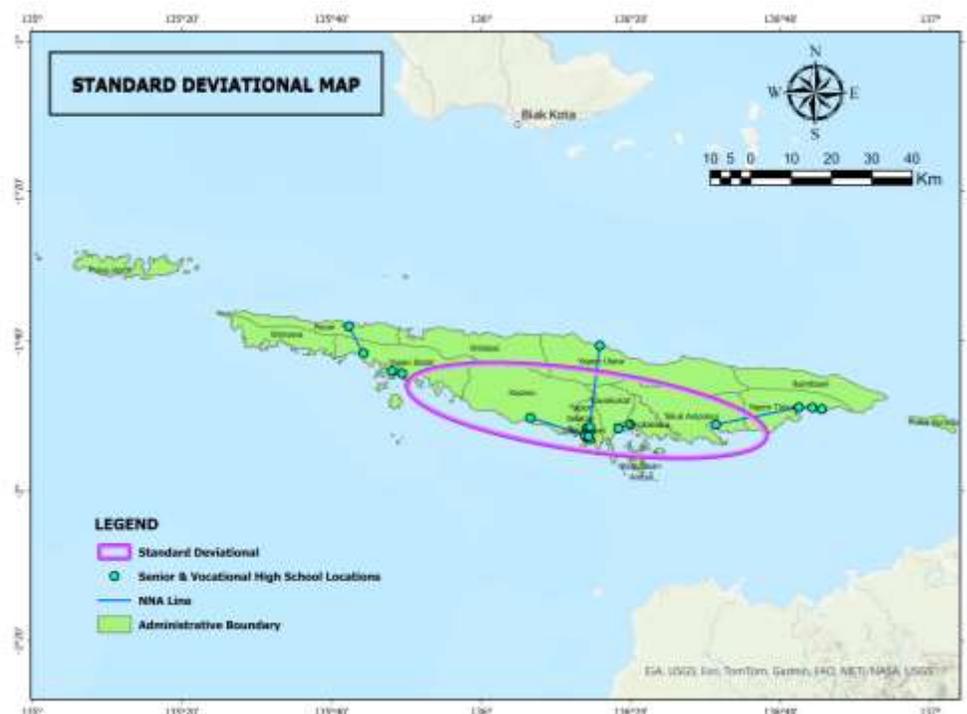
Figure 6. Standard Deviational Map

Comparative Interpretation of Spatial Patterns and Literature References

The distribution of senior and vocational high schools in Kepulauan Yapen is concentrated along the southern coastal sector, especially in Yapen Selatan, Anotaurei, and Angkaisera, as indicated by the dense cluster of points near the administrative and residential core. The Average Nearest Neighbor results, which show a ratio of 0.779877, a z-score of −1.975184, and a p-value of 0.048247, indicate a clustered pattern rather than a random configuration. The standard distance forms a radial spread centered around Serui, while the standard deviational ellipse extends along the coastal axis, and the mean center lies close to Serui as the spatial gravity point of the education network. This outcome aligns with the pull of population concentration, administrative activity, and the available road corridors in the southern zone. The situation aligns with findings from Kotabumi Selatan, where Cahyani and Tridawati (2025) identified clustering of senior and vocational schools around settlement density and service centers supported by significant z-score values in their analysis.

A comparison across similar studies shows that the spatial condition in Yapen stands parallel to patterns identified elsewhere but maintains distinct characteristics. Sibly, Deffry, and Khairunnisa (2023) in Koja, North Jakarta reported a nearest neighbor ratio of 1.402073 and a z-score of 2.175608, indicating a dispersed trend influenced by dense urban structure and broader service coverage. The results differ from Yapen, which shows a stronger direction toward clustering. Rahmawati et al. (2025) in Cihideung, Tasikmalaya describe a cluster tendency approaching statistical neutrality due to uneven school availability between subdistricts, which creates irregular access across the region. Kepulauan Yapen follows a similar gravity pattern

toward central service areas, while peripheral districts remain outside the core coverage radius, forming spatial gaps between the southern service center and outer zones.

CONCLUSION

The findings indicate that the spatial distribution of senior and vocational high schools in Kepulauan Yapen is concentrated in a single dominant sector, centered in Yapen Selatan and specifically the Serui area, where administrative functions and population density are highest. The initial distribution map already shows the majority of coordinate points located in the southern coastal belt of the island, while other districts contain fewer institutions at wider intervals. This outcome is reinforced by the Average Nearest Neighbor results, which record an observed mean distance of 4323.2397 meters, an expected mean distance of 5543.4885 meters, a nearest neighbor ratio of 0.779877, and a z-score of −1.975184 at a p-value of 0.048247, placing the distribution in a clustered category at the 95 percent confidence level. The statistical indication of clustering aligns with the visual accumulation of schools in Serui and its surrounding subdistricts rather than across the full geographic extent of the regency. The mean center generated through ArcGIS Pro confirms that the spatial midpoint of the educational facilities lies in the Serui urban core rather than approaching a geographic balance between western, northern, and eastern districts. This reinforces the interpretation that the system gravitates toward the administrative center rather than forming an even spread. The standard distance radius further emphasizes this condition through a spatial reach that encloses the southern districts more effectively than the outer islands or northern interior, which remain outside the dominant service zone. The standard deviational ellipse strengthens this pattern by forming an elongated east–west axis that aligns with the coastal corridor and fails to extend toward Kurudu, Raimbawi, Angkaisera, or Yapen Utara, indicating that the distribution follows a directional concentration instead of expanding in a multidirectional pattern.

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