VOL. 5, NO. 2 (August 2025) 302-324
https://jagst.utm.my

JAGST
Journal of Advanced Geospatial Science & Technology

GIS-Based Site Suitability for 5G Telecommunication Towers Enhancing Mobile Network Coverage

Nur Fasihah Maisarah Azizan, Zakri Tarmidi*

Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

*Corresponding author: zakritarmidi@gmail.com

Abstract **–** Wireless communications require infrastructure for network access and coverage, which is provided by telecommunication towers. These towers are essential for 4G and 5G networks, necessary for wireless communications, mobile networking, and radio broadcasting. Considering the limited adoption of 5G technologies in Malaysia, this research focuses on a spatial and suitability analysis that will evaluate existing networks based on the existing towers in Kulai, Johor, while assessing site suitability based on several criteria. This study aims to propose new potential areas for 5G towers that will accelerate the expansion of the 5G coverage in Kulai, Johor. The objectives of this study include (1) to identify the parameters for site suitability analysis for proposing a new location for 5G telecommunication towers, (2) to evaluate the current 4G and 5G mobile towers based on the location of existing telecommunication towers, and (3) to propose a new area of 5G telecommunication towers in Kulai, Johor. The scope of this study focuses on 5G telecommunication towers in the Kulai District, Johor. The methodology of this study consists of 3 phases: research formulation, data collection and processing, and analysis. The analysis employed Spatial Multi-Criteria Analysis (SMCA), which comprises four parameters: the locations of existing towers, the signal radius coverage of the towers, terrain, and population density. The analysis reveals that 4G infrastructure currently provides coverage to 76.7% of the study area, whereas 5G coverage is limited to only 7.9%, primarily due to its shorter signal range necessitating a denser tower network. Population density assessment indicates that urban areas generally receive partial 5G access, while rural and low-density zones remain underserved, underscoring the need for prioritised deployment in these locations. Furthermore, elevation and site suitability analyses demonstrate that flat, low-lying areas offer the most favourable conditions for future 5G tower placement, thereby supporting efficient network expansion and enhanced performance. Furthermore, the results of this study will be crucial for the deployment of 5G infrastructure and strategic planning, ensuring enhanced network availability and connectivity.

Keywords *– Site suitability, Spatial analysis, Spatial multi-criteria analysis, 5G coverage, 5G spatial analysis*

Article History: Received 1 July 2025, Accepted 25 August 2025, Published 31 August 2025

How to cite: Azizan, N. F. M. and Tarmidi, Z. (2025). GIS-Based Site Suitability for 5G Telecommunication Towers to Enhance Mobile Network Coverage. Journal of Advanced Geospatial Science and Technology. 5(2), 302-324. DOI: https://doi.org/10.11113/jagst.v5n2.113

1.0 Introduction

Telecommunication towers, also known as cell towers, are structures equipped with antennas, transmitters, receivers, electronic components, and power sources that enable the transmission of mobile phone signals (Baharim et al., 2022). These towers are essential for supporting wireless communications, mobile networking, radio broadcasting, and television signal transmission. In the current technological era, Fourth Generation (4G) and Fifth Generation (5G) are the most widely used mobile network technologies (Baharim et al., 2022). Telecommunication towers serve as critical nodes that facilitate connectivity for both mobile and fixed-line services. In wireless networks, these towers play a vital role in ensuring reliable coverage and connectivity (Singh, 2015).

As technology continues to evolve, the application of Geographic Information Systems (GIS) has become increasingly significant in the telecommunications and broadband industries (Aderibigbe & Gumbo, 2023; Singh, 2015). GIS provides a dynamic platform for the visualisation and analysis of geospatial data, enabling telecom providers to make informed and strategic decisions (Singh, 2015). One key application of GIS in telecommunication network planning is site selection (Asassfeh et al., 2017; Singh, 2015). Site selection represents a crucial early stage in network development, involving the identification and analysis of suitable locations for establishing telecommunication towers and related infrastructure (Asassfeh et al., 2018; Chaabane et al., 2024; Singh, 2015). This process must consider various parameters to ensure optimal network coverage and efficiency (Aderibigbe & Gumbo, 2023).

This study addresses the growing demand for 5G network deployment by evaluating current mobile network coverage in relation to the distribution of existing telecommunication towers. In addition, it aims to propose new potential locations for additional 5G towers through a site suitability analysis using GIS. This involves mapping the current tower locations, identifying coverage gaps, evaluating site suitability, and determining optimal locations for new infrastructure.

Therefore, the primary aim of this research is to propose new potential areas for 5G telecommunication towers based on a GIS-based site suitability analysis, to enhance mobile network coverage in Kulai, Johor. To achieve this aim, three objectives have been outlined, (1) to identify key parameters for site suitability analysis in proposing new locations for 5G telecommunication towers; (2) to evaluate the current distribution of 4G and 5G towers based on the locations of existing telecommunication infrastructure; and (3) to propose new suitable areas for 5G telecommunication tower deployment in Kulai, Johor. The analysis in this paper is limited to the use of two-dimensional (2D) geospatial data due to constraints in data availability. As such, vertical elements such as building heights, tree canopies, and mountainous terrain, which may influence signal propagation, are excluded from this research.

2.0 Background of Study

Throughout this study on 5G site suitability, several research papers have been reviewed. Based on the reviewed documents, a few key parameters have been identified as primary. Previous studies have mainly focused on indicators such as terrain, existing towers, reserved areas, signal radius, mobile network coverage area, population density, site properties, interference, and non-preferred positions. Table 1 below shows the parameters that are frequently mentioned in previous studies.

Table 1. Parameters extracted from previous studies

Parameters	Definitions	Authors
Ground Terrain	Physical characteristics of the land surface or surface on which the cellular tower is to be installed	(Singh, 2015)
Interference	Physical obstructions, such as buildings, trees, and other objects, between the user and the tower can block or disrupt the signal, leading to lower speeds	(Singh, 2015)
Existing Tower	Types of existing towers	(Premarathne et al., 2021)
Reserved Area	Specific areas where the placement of telecommunication towers is restricted or not preferred	(Asassfeh et al., 2018)
Signal Radius	Distance from the signal source at which the signal strength is sufficient for reliable communication	(Asassfeh et al., 2018)
Non-preferring position	Location that is not ideal or optimal for antenna placement in the selection process for telecommunication tower sites	(Asassfeh et al., 2018)
Site properties	Characteristics or attributes of a specific location that make it suitable for a particular purpose	(Asassfeh et al., 2018)
Antenna position	Location and placement of antennas for communication	(Asassfeh et al., 2018)
Population Density	Number of people living within a specific area	Kashyap et al. (2014)
Coverage Area of Cellular Network	The geographical area covered by the network of a cellular network	(Mauludiyanto & Pranata, 2019)

Previous studies have predominantly integrated GIS and spatial analysis to determine the suitable locations of telecommunication towers. However, there is limited research that specifically focuses on 5G technology.

3.0 Methodology

This study comprises three phases: Research Formulation (Phase 1), Data Collection and Processing (Phase 2), and Analysis (Phase 3). Research formulation is the initial stage of research that thoroughly defines the topic, goals, objectives, and scope of the study. It involves establishing research questions that support the objectives and serve as an outline for the whole research. This phase establishes the overall approach and guides the other research phases, ensuring that the research addresses specific issues. Parameters were also identified in this phase. Phase 2 involves collecting existing tower data, residential data, and Digital Elevation Model (DEM) data. All the data were collected from three different sources. This phase also involved data processing of the obtained data. In Phase 3, all the collected data will be analysed to produce results that achieve the objectives of this study. Figure 1 below illustrates the overall methodology of this study.

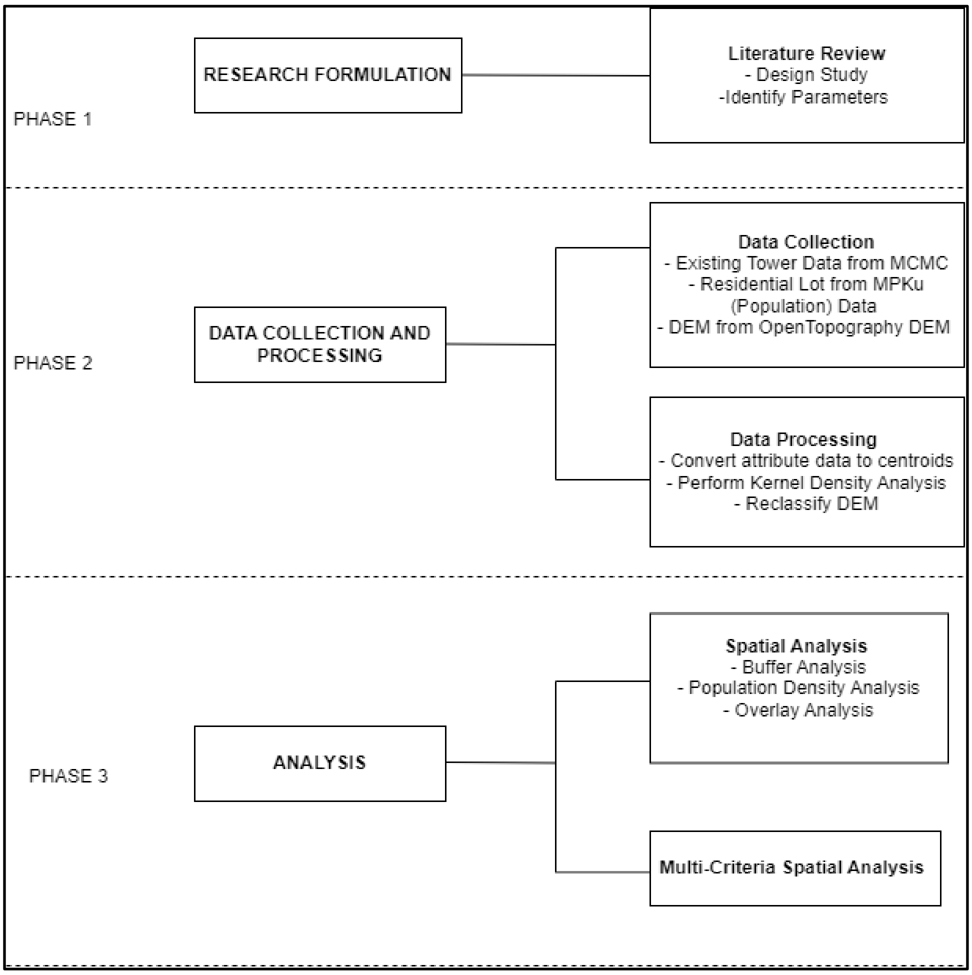

Figure 1. Methodology used in this study

3.1 Research Formulation

In the first phase of the research project, a literature review is a crucial component, involving an in-depth examination of previous studies. This chapter discusses a few types of telecommunication networks and towers. It aims to establish and identify suitable parameters for assessing the suitability of sites for telecommunication towers, thereby providing a comprehensive understanding of the research background. Based on previous studies reviewed, various parameters are used to determine the suitability of a site for the placement of a telecommunication tower. However, only several parameters are chosen to determine the site suitability of the telecommunication tower. Table 2 presents the parameters selected for this research.

Table 2. Parameters used in this study

Parameters	Description	Criteria	Authors
Existing Tower	Existing tower locations that provide mobile network coverage	• 4G Tower • 5G Tower	(Mauludiyanto & Pranata, 2019)
Signal Radius	Coverage distance from the signal source at which the coverage is sufficient for reliable communication	• 2 km • 0.5 km	(Asassfeh et al., 2017)
Ground Terrain	Physical characteristics of the land surface on which the mobile tower is to be installed	• Low Elevation • Medium Elevation • High Elevation	(Singh, 2015)
Population Density	Number of people living in a given area	• Low Density • Moderate Density • High Density	(Kashyap et al., 2014)

3.2 Data Collection and Data Processing

In this phase, data were collected based on parameters relevant to the study, namely existing towers, signal radius, population density, and elevation. The data comprised both spatial and attribute components, and were obtained from the Malaysian Communications and Multimedia Commission (MCMC) and Majlis Perbandaran Kulai (MPKu) through semi-structured interviews and questionnaires. These included data on the current locations of all telecommunication towers in Kulai, as well as their attributes, and data on residential housing within the Kulai District.

In addition to data from MCMC and MPKu, elevation data—specifically a Digital Elevation Model (DEM)—was sourced from OpenTopography DEM Downloader. The initial tower location data, containing latitude and longitude coordinates in tabular format, was converted into CSV format. This CSV file was then imported into the GIS software and visualised as point layers.

For residential data, the original dataset was in polygon shapefile format, where each polygon represented a residential lot in the Kulai area. These polygons were converted to centroid points for each lot. A Kernel Density Analysis was then conducted using these centroid points to identify areas with high and low concentrations of residential units. For elevation data, the DEM obtained from OpenTopography was classified into several elevation categories for further analysis.

3.3 Analysis and Results

This final phase involves analysing and evaluating the collected data. The primary analyses performed include buffer analysis, population density analysis, terrain analysis, and overlay analysis.

- Buffer analysis was conducted to determine the distribution and signal coverage areas of existing 4G and 5G towers.
- Population density analysis used the Kernel Density heatmap derived from residential data. The density values were then reclassified into three (3) classes for suitability assessment.
- Terrain analysis involved reclassifying the DEM data into three elevation classes, also for suitability purposes.

Once individual analyses were completed, an overlay analysis was conducted to combine all relevant spatial layers. This process resulted in a final suitability map, highlighting the most suitable areas for installing new 5G towers. From this suitability map, two key outputs were derived:

1. Identified suitable areas for 5G tower placement, and
2. Proposed specific locations for the new towers within those areas.

Additionally, a viewshed analysis was performed to validate the proposed sites, ensuring that towers placed at those locations would provide adequate coverage to users in the surrounding areas. The viewshed analysis, based on DEM data, is essential for assessing visibility and signal reach across the terrain.

4.0 Results

The findings of this study are organised into seven parts. The initial results present a buffer analysis for signal coverage of both current 4G and 5G towers. The second section focuses solely on 5G coverage and 5G towers. The third section provides a heatmap of population density. The fourth section details the classification and reclassification of DEM data, reflecting the elevation of the study area. The fifth section displays the integration of all data layers, overlaid according to each relevant parameter of the study. The sixth and seventh sections outline the proposed areas and locations for new 5G towers, which will help achieve the study's primary objective. The final section includes an additional map showing existing 4G towers that could potentially be upgraded to 5G technology.

4.1 Buffer Analysis

The results of buffer analysis are to show the spatial distribution of both 4G and 5G Towers in Kulai, Johor. Based on Figure 2, it was found that 4G mobile towers cover approximately 76.7% of the Kulai District. This indicates that the 4G network has achieved widespread coverage across most areas in Kulai, Johor. In contrast, 5G towers currently cover only 7.9% of the district, highlighting the limited deployment and distribution of 5G infrastructure compared to 4G LTE towers. This also suggests that 5G adoption in Malaysia is still in its early stages and has not yet been fully implemented.

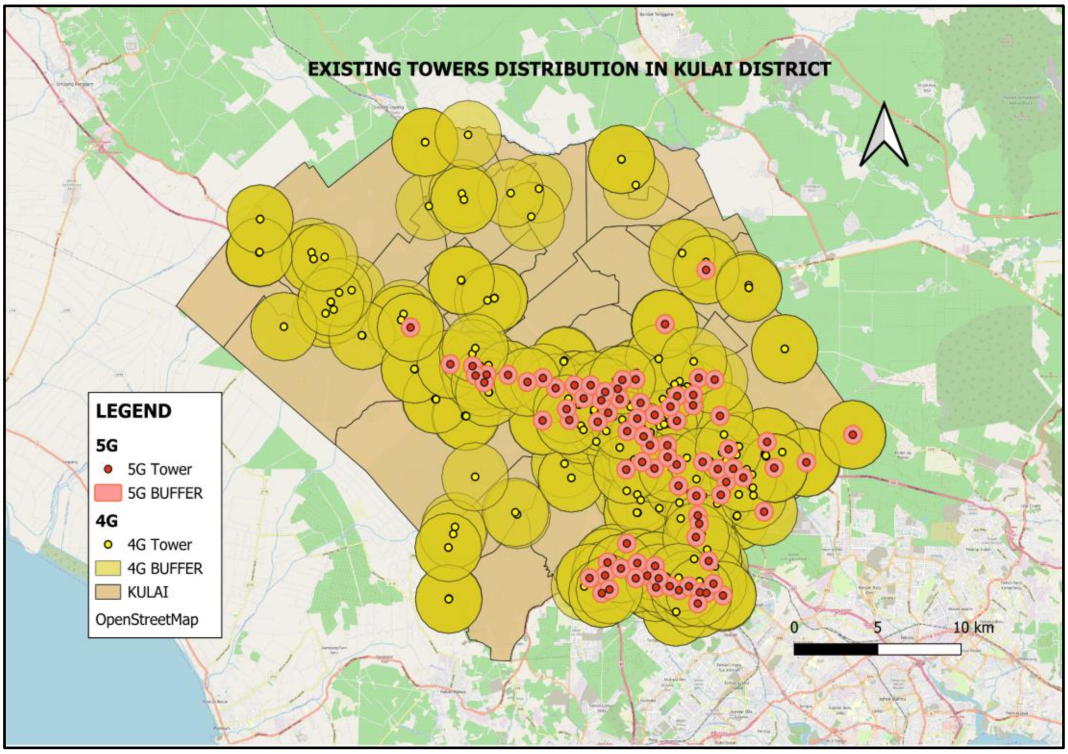

Figure 2. Distribution of existing towers with signal covering area

Table 3. Coverage percentage of 4G and 5G towers

Technology	Total Area Covered (Meter Square)	Percentage (%)
4G (LTE)	579582454.600	76.7
5G	59484988.370	7.9

Understanding the signal radius of a tower is crucial in planning the strategic placement of future towers, helping to maximise coverage while minimising gaps and overlaps. This study's findings underscore the need to expand 5G coverage not only by introducing new tower sites but also by upgrading existing 4G LTE infrastructure to support 5G. It was also observed that many 4G towers have overlapping coverage, which can potentially cause network interference and inefficiencies in service quality.

In terms of signal radius:

- 4G towers have a coverage radius of approximately 2 kilometres.
- 5G towers have a much smaller coverage radius of about 0.5 kilometres, consistent with the higher frequency and shorter range of 5G technology.

The 0.5 km radius is deemed optimal for 5G deployment, especially in areas where towers are located close to one another. This enables 5G to deliver consistent, high-speed connectivity. On the other hand, a 2 km signal radius is considered less suitable for 5G, as longer distances tend to reduce data transmission rates due to the nature of 5G frequency bands. The suitability classification for the 5G signal radius is presented in Table 4.

Table 4. Suitability classes for the signal radius of 5G Towers

Signal Radius (KM)	Suitability	Class
2	Least Suitable	1
0.5	Most Suitable	3

Figure 3 shows the distribution pattern of 4G Towers in Kulai. According to Figure 3, the given z-score is -39.816533. Hence, the distribution pattern of 4G Towers is said to be clustered. Figure 4 shows the distribution pattern of 5G Towers in Kulai. According to Figure 4, the given z-score is -1.979238. Hence, the distribution pattern of 5G Towers is said to be clustered. The pattern is almost similar to 4G; the difference is that the number of 5G towers is significantly less than that of 4G towers, although they are all clustered together.

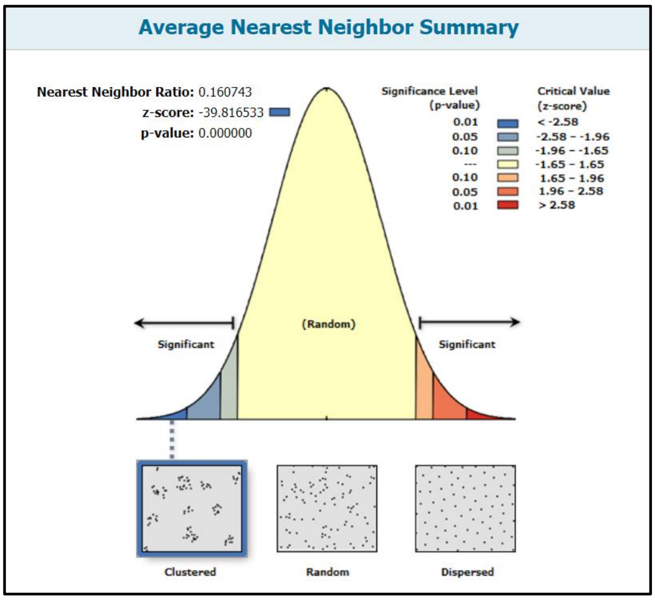

Figure 3. Distribution pattern of 4G towers in Kulai

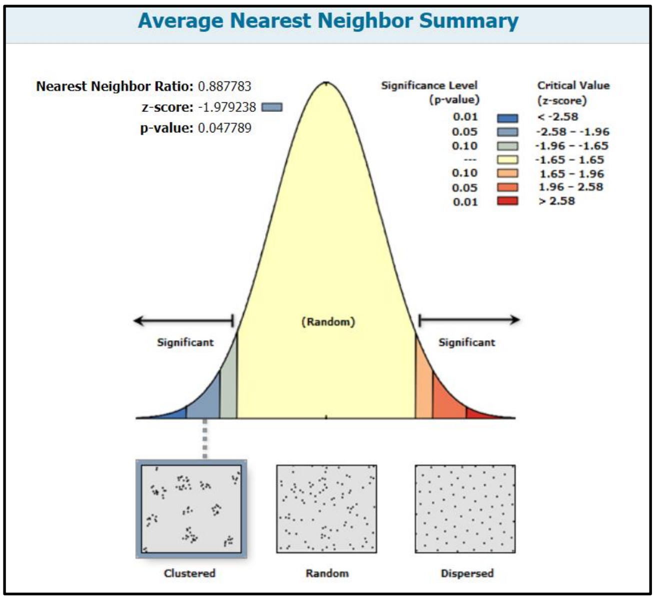

Figure 4. Distribution pattern of 5G towers in Kulai

4.2 Population Density Analysis

The population density analysis was derived from a Kernel Density Analysis, where the resulting values represent the distribution of the population in Kulai. These values are illustrated in Figure 5, which shows varying shades to indicate demographic concentration. The darkest areas on the map represent urban and densely populated zones, while the lighter shades signify rural or undeveloped regions. The overlay of residential lot boundaries confirms that the darkest areas correspond to locations with a high number of residential properties.

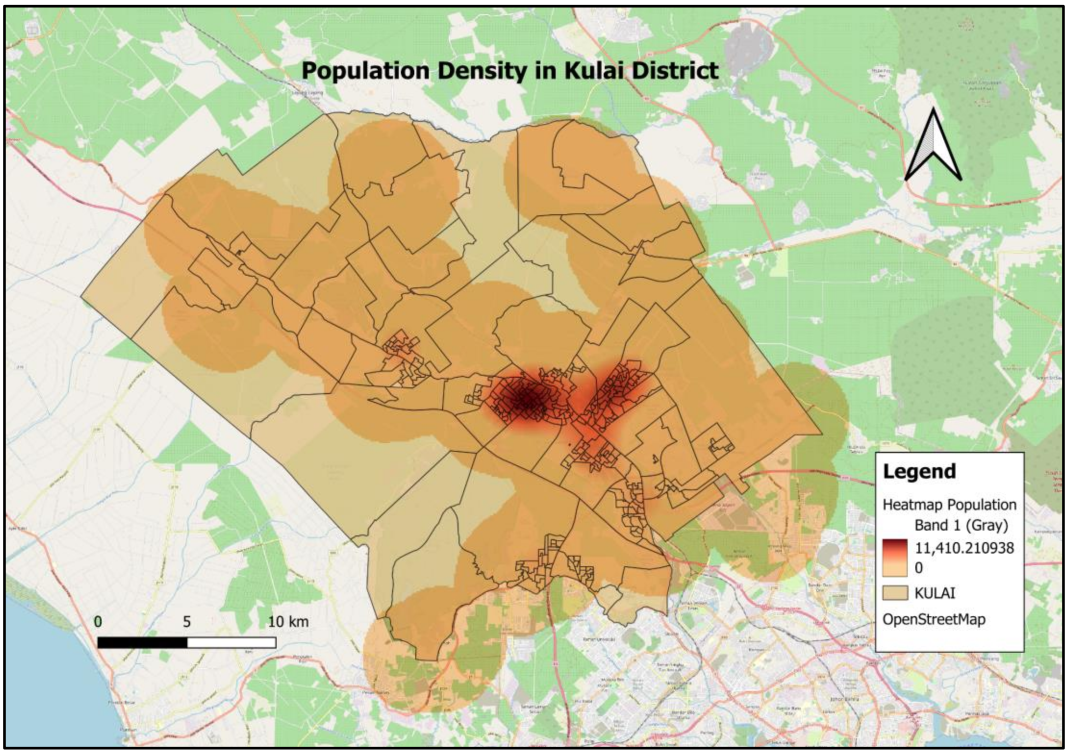

Figure 5. Population density heatmap in Kulai District

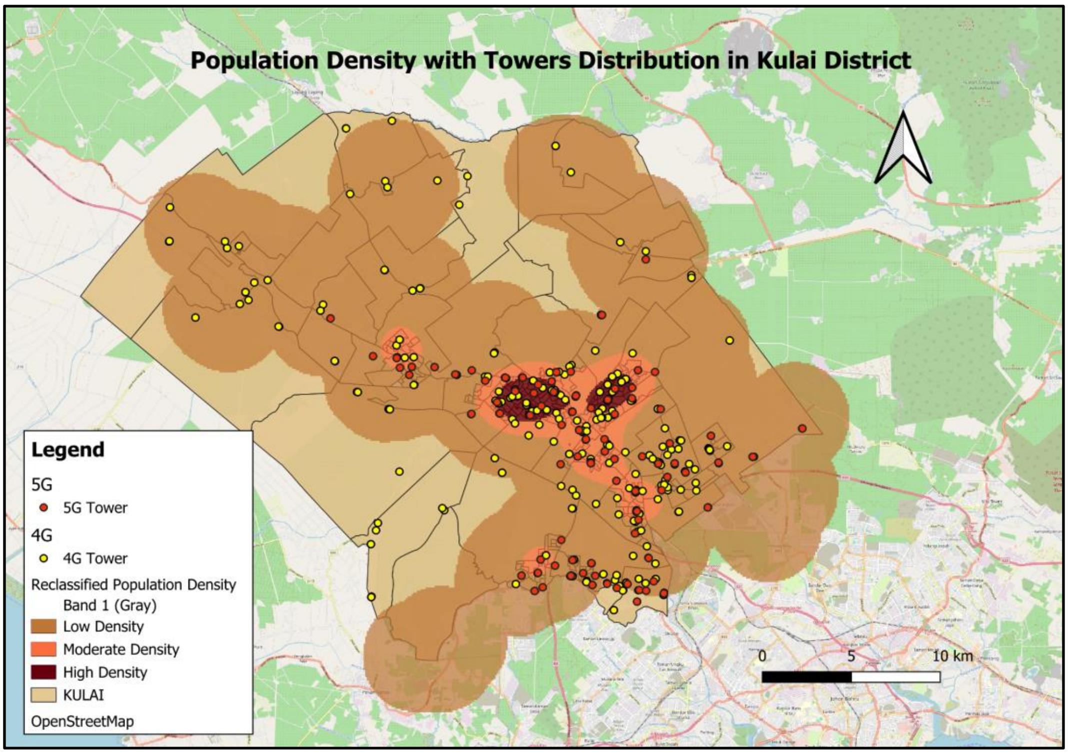

Figure 6. Reclassified population density with tower distribution in Kulai

In the reclassified heatmap (Figure 6), dark red indicates high population density, red indicates moderate density, and orange represents low density. The analysis reveals that densely populated areas typically have partial 5G coverage; however, several zones still require enhanced coverage to meet the growing demand for reliable high-speed connectivity. Given this, areas with high population density are considered the most suitable for the placement of new 5G towers. Strategically placing towers in these zones ensures the network can support a large number of devices while maintaining high data rates and capacity.

4.3 Classification of DEM

The classification of DEM is for categorising the elevation values provided by the DEM layer. This DEM classification provides information about the terrain of the study area that can be used in analysis later. The elevation data were generated using the Digital Elevation Model (DEM) and subsequently classified into three categories representing low, moderate, and high elevation areas. These classifications were reprocessed using continuous linear interpolation in QGIS. Based on the elevation map, it is observed that most parts of Kulai consist of flat terrain, with only a few areas, such as Gunung Pulai and its surroundings, exhibiting slightly higher elevations. The elevation classes are as follows: low (−11 m to 210 m), moderate (211 m to 431 m), and high (432 m to 653 m), as presented in Figure 8. Given that Kulai is predominantly a lowland area, the majority of the existing 4G and 5G towers are situated in low-elevation zones.

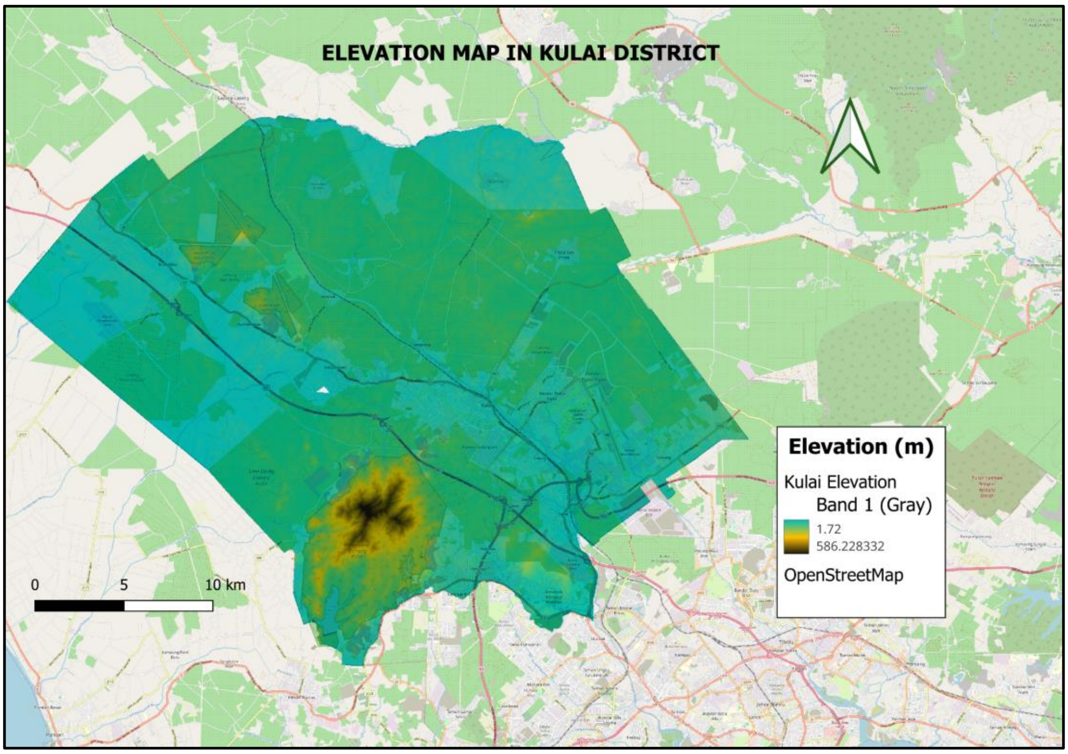

Figure 7. Elevation map of Kulai District

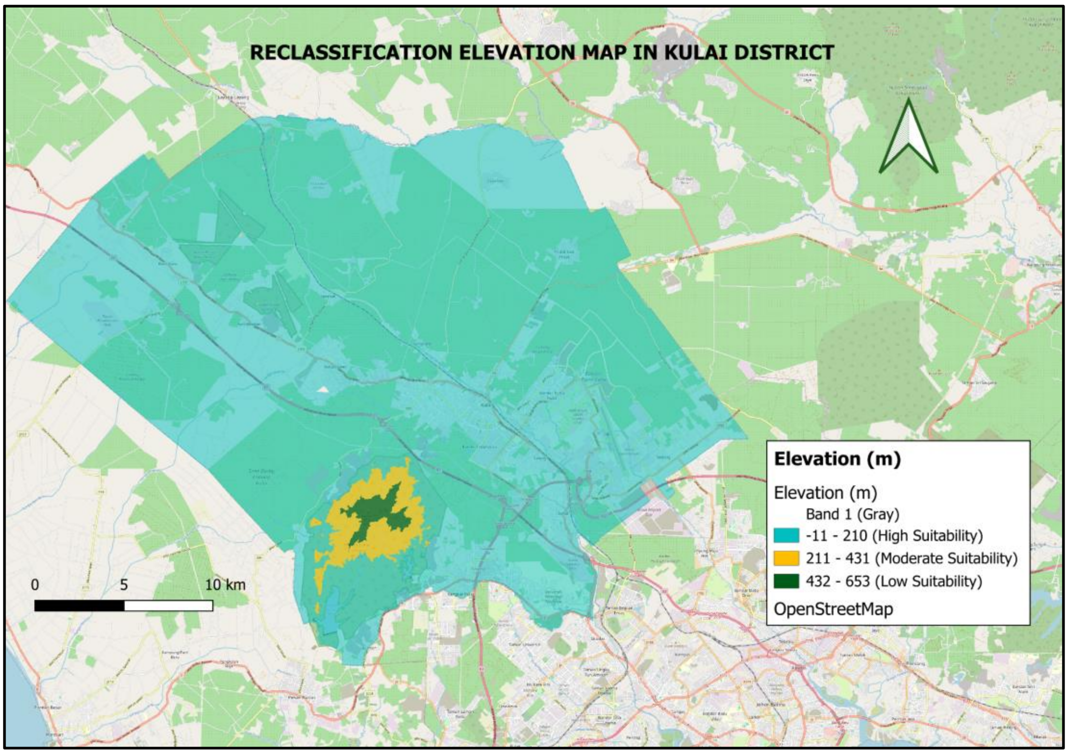

Figure 8. Reclassified elevation map in Kulai District

The elevation in Kulai ranges from −11 meters to 653 meters. For optimal placement of 5G towers, low-elevation areas are generally more suitable, as flat terrain is typically integrated with existing infrastructure, such as streetlights or utility poles, facilitating the efficient deployment of 5G small cells. Additionally, since 5G operates at higher frequencies with shorter ranges, minimising physical obstructions is crucial. Flat areas provide a more consistent environment for signal propagation, enhancing overall performance. In fact, according to MCMC, towers installed on flat land are capable of covering wider areas. Therefore, low-elevation zones in Kulai are ideal for current and future 5G infrastructure development. The suitability classification for elevation is summarised in Table 5.

Table 5. Suitability classes based on elevation

Elevation (m)	Elevation Class	Score	Suitability Class
432 - 653	High Elevation	1	Least Suitability
211- 431	Moderate Elevation	2	Moderate Suitability
-11 - 210	Low Elevation	3	High Suitability

4.4 Spatial Multi-Criteria Analysis (SMCA)

The SMCA method facilitates the decision-making process. This technique considers multiple parameters to ensure the proposed area provides adequate coverage. The analysis overlays the related data layers based on each parameter, which include existing towers, signal coverage, population density, and elevation. Each parameter has been filtered out according to its importance. The result of this SMCA provides a suitability map that highlights the proposed area for the 5G tower and its proposed location.

4.5 Overlay Analysis

The result of this overlay analysis shows that all layers of different parameters are overlaid to assess the suitability of the 5G tower and identify areas that need improvement in the 5G network. By combining all parameters, it will represent the areas that 5G has covered and those that it does not cover. Figure 9 shows the area that was covered in the 5G line, and Figure 10 shows the area uncovered by the 5G line. This indicates that the 5G coverage is limited to the Kulai city area. This shows improvement in coverage for the 5G line.

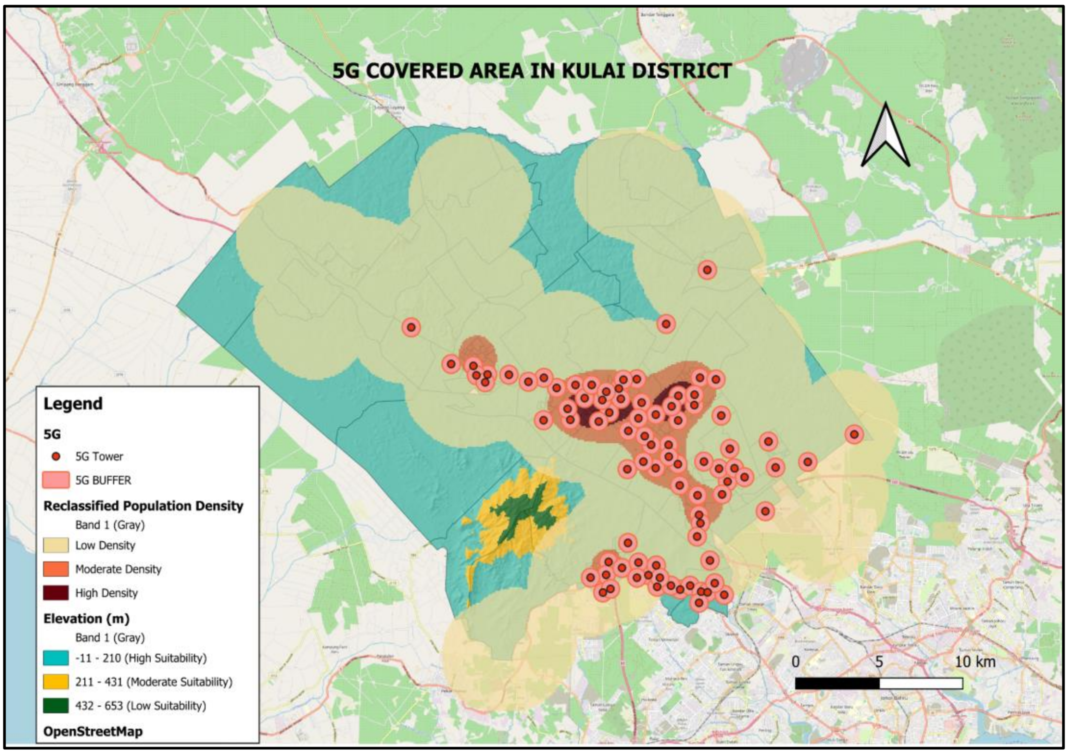

Figure 9. Overlay map with the 5G covered area

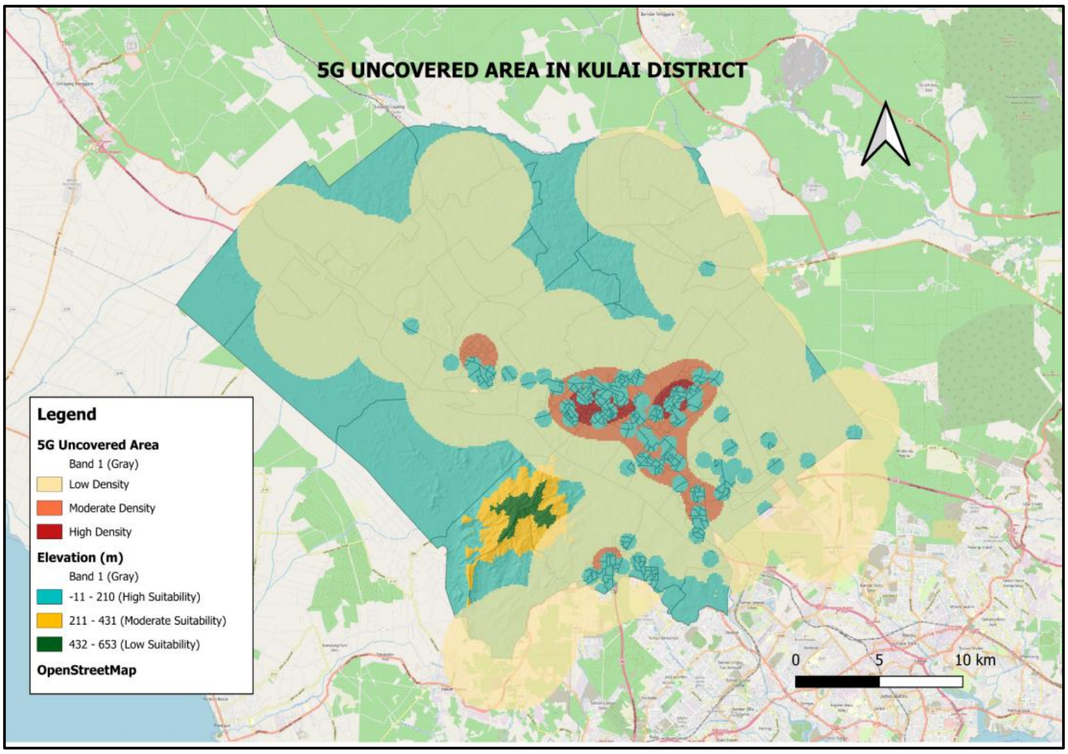

Figure 10. Overlay map with the 5G uncovered area

4.6 Proposed Area for 5G Tower

To propose a suitable area for locating a 5G tower, potential areas are selected based on each criterion, which includes signal coverage radius, population density, and elevation level. Initially, the potential area is selected based on the population density parameter, where the area with the highest density is considered the most suitable, and areas with moderate density are considered moderately suitable, as shown in Table 6.

Table 6. Suitability based on population density

Population Density	Density Class	Score	Suitability Class
4001 - 8000	Moderate Density	2	Moderate Suitability
8001 - 12000	High Density	3	High Suitability

To select the potential area, the least suitable layer is separated from the hierarchy. It indicates that every hierarchy that holds a score of 1 is not selected and removed from the suitability classes for all parameters. Therefore, the suitability scoring and classification for the other parameters are stated in Tables 7 and 8.

Table 7. Suitability based on the signal radius of the 5G Tower

Signal Radius (Km)	Score	Suitability Class
0.5	3	High Suitability
More than 0.5	0	Not Suitable

Table 8. Suitability based on elevation

Elevation Values (m)	Elevation Class	Score	Suitability Class
-11 - 210	Low Elevation	3	High Suitability

As for elevation, the suitability classes with scores of 1 and 2 are eliminated from the selection because a 5G tower is suitable for locations with low elevation, which is considered flat ground. Hence, the selection of potential areas based on elevation differs from that of other parameters.

4.7 Potential Area 1 for 5G Tower

To select the potential area, a suitability level with a score of 3 is chosen. This level indicates the highest suitability level and has the best conditions for locating a 5G tower. Figure 11 illustrates the potential area for new 5G towers.

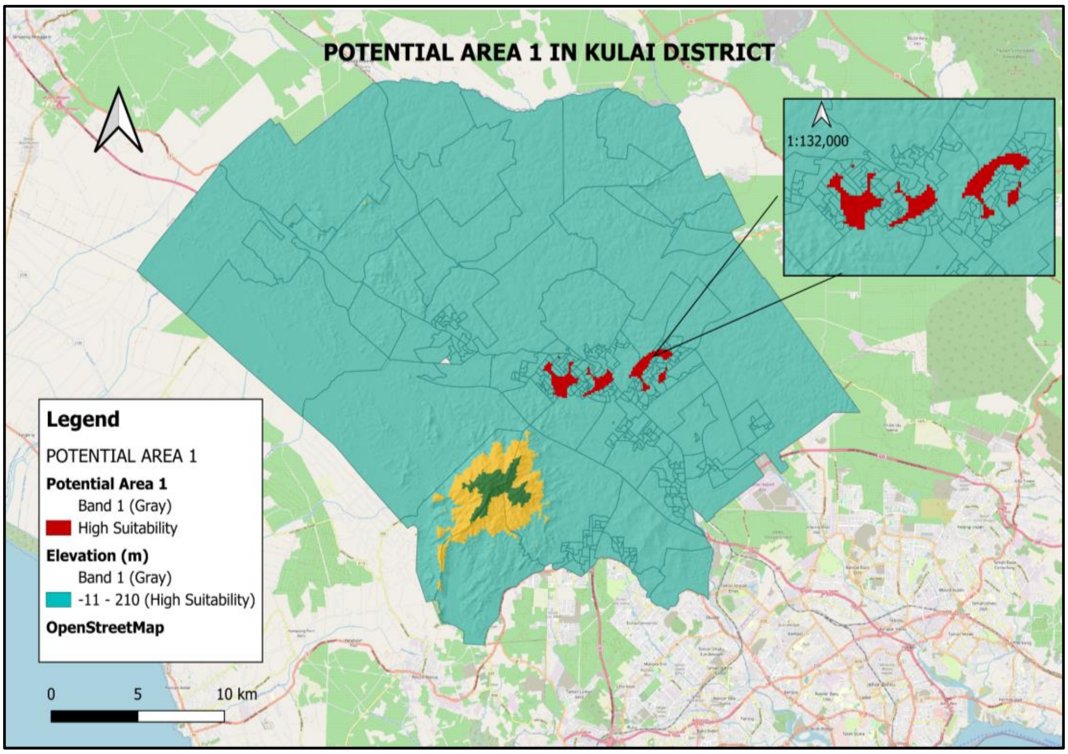

Figure 11. Proposed Area for 5G Tower (Potential Area 1)

4.8 Proposed Locations for 5G Tower

The following proposed location map highlights the specific location of the proposed 5G tower within the proposed area. Figure 12 illustrates the results of an alternative option for the proposed 5G tower locations. The figure shows the potential location of 5G towers within the high suitability area (potential area 1). For the high-suitability area, a few possible locations have been selected. The 500-meter buffer created around the locations indicates the most suitable signal radius that ensures the proposed location can also provide 5G tower coverage of 500 meters.

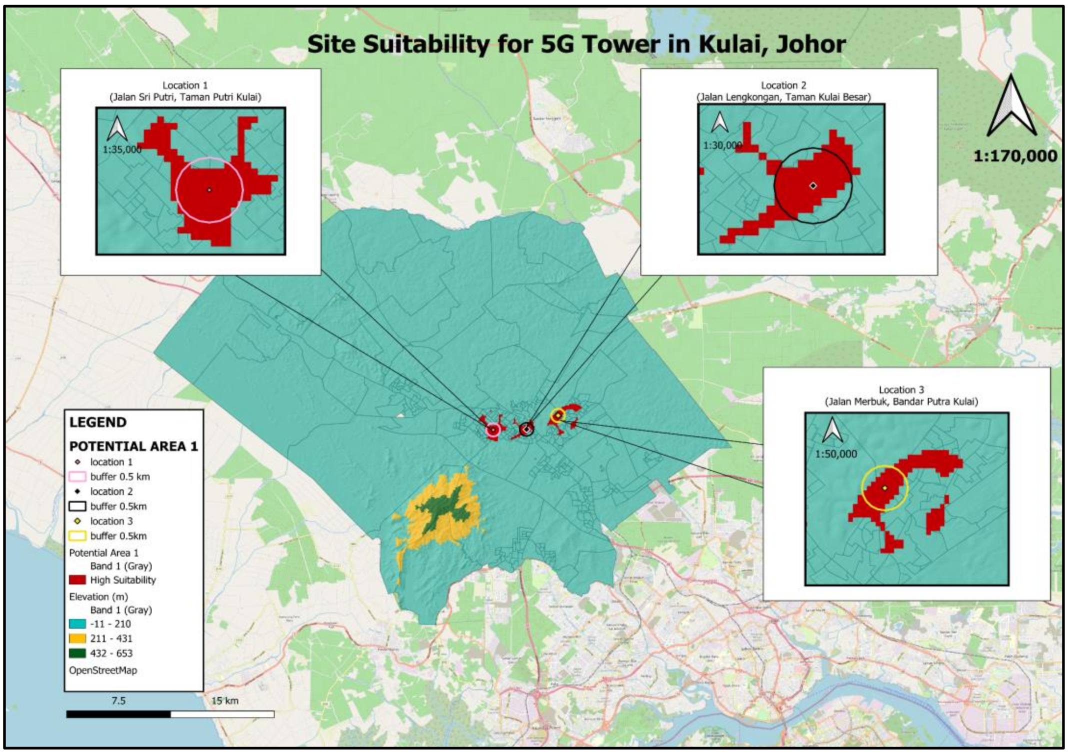

Figure 12. Proposed Locations for 5G Tower

4.9 Viewshed Analysis

Viewshed analysis is a spatial analysis used to assess the accessibility and visibility of a specific point within an area. In the context of a 5G tower, this additional analysis helps evaluate the potential coverage area by identifying which areas will be visible from the proposed tower. Hence, viewshed analysis highlights areas where good signal coverage is likely to occur around the proposed area. Additionally, this analysis ensures that the proposed area for the 5G tower will meet coverage and performance goals, thereby supporting the goal of providing reliable and fast connectivity. Figure 13 shows the visibility map from the viewshed analysis of the proposed location within the proposed area for the 5G tower.

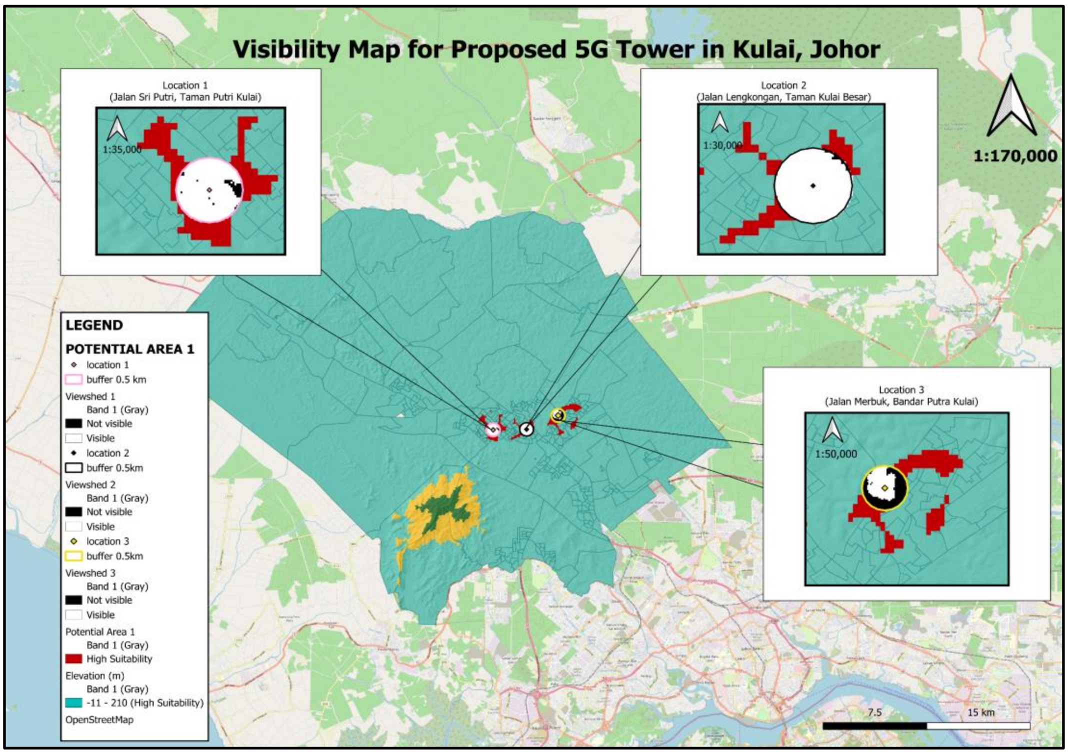

Figure 13. Visibility map for proposed locations for 5G Tower

The visibility map in Figure 13 above represents areas within the line of sight (potential good coverage areas) and areas outside the line of sight (potential poor coverage areas). Based on the symbology, the white shade represents the visible area and the black shade represents the non-visible area to the tower. Based on the results, the proposed location within proposed area 1 (high suitability) produced a result that shows most areas within 500 meters are visible to the proposed tower.

4.10 Potential 4G Tower to be Upgraded to 5G

An additional analysis is done to identify which existing 4G towers near the proposed 5G tower have the potential to be upgraded to the 5G network. The existing 4G towers are selected to see their potential in covering the high suitability area (proposed area 1) when they are upgraded to 5G. Based on the results in Figure 14, a few 4G towers were selected, which proved that they might cover the proposed area well. Therefore, by considering the existing 4G towers, this will optimise the existing infrastructure to improve the deployment of the 5G network in the Kulai area.

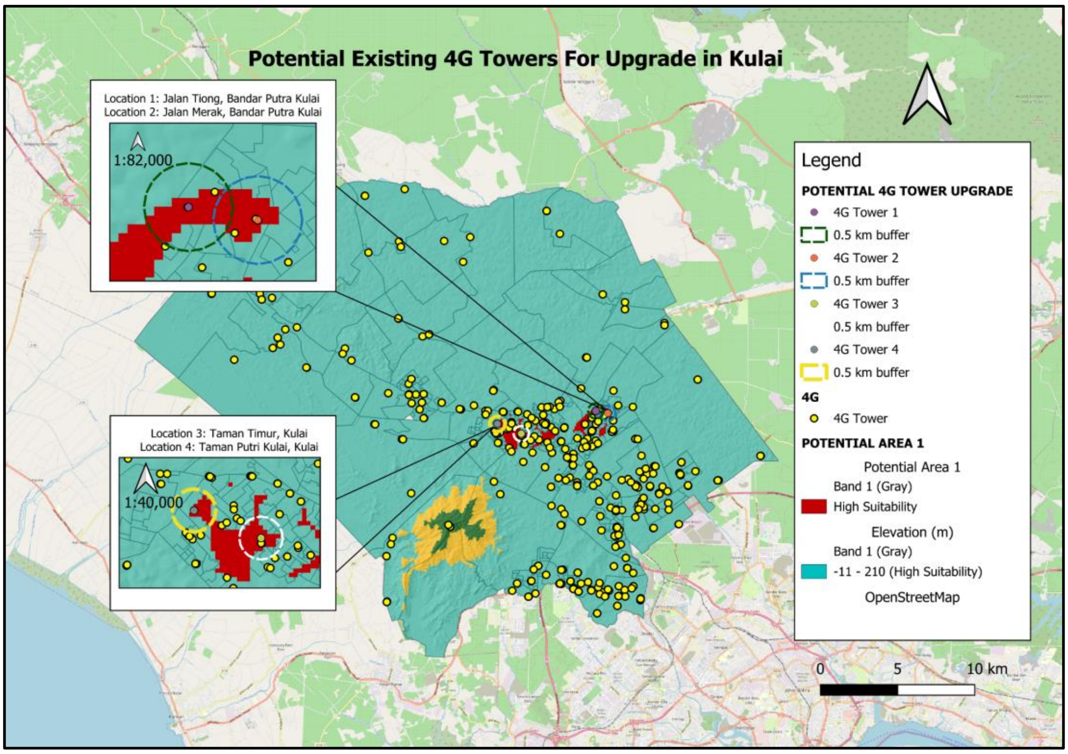

Figure 14. Potential existing 4G tower for upgrade

5.0 Discussions

This study explores the spatial patterns and site suitability for 5G tower deployment in Kulai District, Johor. Through various geospatial analyses, the findings highlight the current gaps in mobile network coverage, especially the limited reach of 5G compared to 4G infrastructure. The results also emphasise the importance of using GIS-based analysis to identify optimal tower locations by considering key factors such as signal coverage, population density, and elevation. These insights serve as a foundation for more strategic planning to support the expansion of 5G infrastructure and enhance overall digital connectivity in the region.

The analysis reveals a significant disparity in mobile network coverage within Kulai District, where 4G towers provide coverage to approximately 76.7% of the area. In comparison, 5G towers cover only 7.9% of the area. This suggests that the 4G infrastructure is well-established, whereas 5G deployment remains limited, reflecting its early stage of adoption in Malaysia. The limited 5G coverage is further influenced by its shorter signal range (0.5 km compared to 2 km for 4G), necessitating a denser network of towers. In addition, overlapping signal coverage from 4G towers highlights the need for network optimisation to reduce inefficiencies and potential signal interference.

The findings also underscore the importance of strategic planning for future 5G expansion. A targeted approach, such as upgrading selected 4G towers and deploying new 5G towers in high-demand or underserved areas, can ensure the efficient use of resources. GIS-based site suitability analysis proves to be an effective tool for identifying optimal tower locations, taking into account factors such as population density, elevation, and existing infrastructure. Overall, this study supports the goal of enhancing digital connectivity through informed infrastructure development, aligned with national initiatives such as the Jalinan Digital Negara (JENDELA) and Malaysia's broader IR4.0 aspirations.

The population density analysis highlights that densely populated urban areas in Kulai generally receive partial 5G coverage, whereas rural and low-density areas remain underserved. This indicates a positive correlation between population concentration and current network infrastructure, although some high-density zones still lack sufficient 5G access. Therefore, these areas should be prioritised in future 5G tower placement to meet growing user demands. Strategically expanding 5G infrastructure in these locations would enhance connectivity, support higher data traffic, and align with efforts to ensure equitable digital access across the district.

The elevation analysis reveals that most of Kulai consists of flat, low-lying terrain, with only a few high-elevation areas such as Gunung Pulai. The majority of existing 4G and 5G towers are located in low-elevation zones, which aligns well with network deployment needs. Flat areas are more suitable for 5G infrastructure due to their minimal physical obstructions and integration with existing utilities, allowing for efficient signal propagation. Therefore, the topographic characteristics of Kulai support the suitability and future expansion of 5G towers in low-elevation areas, ensuring optimal coverage and performance.

The suitability analysis, based on signal coverage, population density, and elevation, effectively narrows down the most suitable areas for 5G tower placement. Areas with high population density were prioritised, aligning with the need to support a large number of users and devices. In contrast, areas with low suitability scores were excluded to ensure efficient network planning and avoid coverage redundancy.

Moreover, elevation played a crucial role in the site selection process. Since 5G signals perform better in flat, low-lying areas with fewer physical obstructions, locations with low elevation were deemed most suitable. The exclusion of higher elevation areas further supports the technical advantage of placing 5G towers on flat ground. The multi-criteria approach ensures that proposed sites balance population demand, topographic suitability, and adequate signal coverage, ultimately contributing to a more strategic and optimised deployment of the 5G network in Kulai.

Future geospatial research on 5G infrastructure planning can explore more dynamic and real-time data integration, such as mobile user demand patterns, live network traffic, and temporal population movements (e.g., during peak hours or events). This would enhance the precision of tower placement and capacity planning. Incorporating 3D GIS and urban morphology analysis can also provide deeper insights into signal obstruction from buildings and terrain, which is critical in dense urban environments.

Moreover, research can expand into predictive modelling using machine learning and AI-driven spatial analytics to simulate future network needs under various growth scenarios. Collaboration with national geospatial data platforms and innovative city initiatives will also be vital in ensuring consistent, scalable, and policy-aligned infrastructure development. These advancements would support not only 5G but also future 6G networks, enabling more robust, inclusive, and adaptive digital connectivity planning.

6.0 Conclusion

This study employed a Spatial Multi-Criteria Analysis (SMCA) to assess existing telecommunication towers and identify potential areas for future 5G tower deployment in Kulai, Johor. Based on key parameters such as signal coverage, population density, and elevation, the analysis revealed that the distribution of 5G towers remains limited, particularly in densely populated areas with a growing demand for high-speed connectivity. Through the integration of spatial analysis, several high-suitability areas were identified and proposed for future 5G expansion. These findings support the study's overall aim of enhancing mobile network coverage in Kulai, ensuring more efficient, targeted infrastructure development that complements and strengthens existing networks. Looking ahead, future research may explore dynamic geospatial modelling that incorporates real-time user demand, land-use changes, and infrastructure readiness. Integrating advanced geospatial technologies such as remote sensing, LiDAR, or AI-driven spatial analytics can further optimise 5G planning and support long-term digital infrastructure strategies at the national level.

Acknowledgement

The authors would like to express their sincere gratitude to Mrs. Nur Jannah and Mr. Azril from Majlis Perbandaran Kulai (MPKu) for their invaluable support and assistance in collecting and preparing the essential data for this study. Their cooperation and contributions were instrumental in facilitating the successful completion of this research.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

References

Aderibigbe, O., & Gumbo, T. (2023). Geospatial analysis of telecommunication and travel behaviour of households: Lessons from a developing city in Nigeria. *Journal of Sustainable Development of Transport and Logistics*, *8*(2), 71–85.

Asassfeh, J. A., AlTarawneh, M., & Samson, F. (2018). Integrative Model for Quantitative Evaluation of Selection Telecommunication Tower Site. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, *16*(3), 1158–1164.

Asassfeh, J. A., Samson, F., & AlTarawneh, M. (2017). Reviewing and classifying the effective factors in selection telecommunication antenna towers sites. *International Journal of Digital Information and Wireless Communications*, *7*(3), 178–184.

Baharim, M. S. A., Sabri, N. H., Umar, R., Othman, A. N., & Rahman, S. N. D. A. (2022). Assessment of radio telecommunication coverage signal using geospatial analysis. *Jurnal Teknologi (Sciences & Engineering)*, *84*(2), 59–69.

Chaabane, F., Réjichi, S., Ben Salem, H., Elmabrouk, H., & Tupin, F. (2024). Strategic Planning of Rural Telecommunication Infrastructure: A Multi-Source Data Fusion and Optimization Model. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, 73–78.

Kashyap, R., Bhuvan, M. S., Chamarti, S., Bhat, P., Jothish, M., & Annappa, K. (2014). Algorithmic approach for strategic cell tower placement. *2014 5th International Conference on Intelligent Systems, Modelling and Simulation*, 619–624.

Mauludiyanto, A., & Pranata, Y. D. (2019). Planning of number and location of new Base Transceiver Station (BTS) tower in mobile telecommunication system in Jombang using analytical hierarchy process method and geographic information system approach. *JAREE (Journal on Advanced Research in Electrical Engineering)*, *3*(2).

Premarathne, B. M. N., Bamunusinghe, B., & Malavipathirana, C. G. (2021). *An Analysis of Suitable Location for Establishing Telecommunication Tower at General Sir John Kotelawala Defence University, Southern Campus*.

Singh, C. (2015). Analysis and Identification of Potential Cell Tower Sites using GIS. *International Journal of Scientific & Engineering Research*, *6*(10).