Spatial Analysis of the Affordability of Information and Communication Technology (ICT) Services to the Community of Gunungkidul Regency

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Abstract. Gunungkidul Regency still has a limited internet network. The local communication and informatics office stated that 5% of the area does not have proper signals for telecommunication. The population has encouraged the construction of new towers. Therefore, it is necessary to pay attention to the surrounding community's aesthetics, security, safety, and health. This study aims to evaluate and plan the distribution of information and communication technology service towers using a spatial approach. Methods used involved distance analysis (buffer), nearest neighbor analysis, overlay, and spatial evaluation in determining alternative locations for new towers. The data used in this study was secondary data obtained from related agencies. The results showed 217 service towers in Gunungkidul Regency in 2019 were spread over 18 sub-districts. The construction was focused on Wonosari District as the center of government and the sub-district with the largest population of 87331, or 11.38% of the total population. The internet network could serve 66.28% of the entire Gunungkidul Regency area with a strong signal, 30.20% with a moderate signal, 3.47% with a weak signal, and 0.05% with a very weak signal. The distribution pattern of BTS tower service facilities in Gunungkidul Regency was clustered with an average nearest-neighbor ratio value of 0.466294 and associated with built-up areas. Alternative locations for the new BTS towers include Purwosari, Panggang, Tepus, Girisubo, Rongkop, Playen, Patuk, Ponjong, and Gedangsari sub-districts.

Keywords: Information and communication technology services · population · coverage · distribution patterns

1 Introduction

The development of technology, information, and communication in Indonesia has increased rapidly. The Central Statistics Agency (BPS) noted that the value of Indonesia's Technology, Information, and Communication Development Index (IP-TIK) in 2020 was 5.59 points. This figure increased by 5.08% compared to 2019, which was 5.32 points. Indonesia's IP-TIK continues to grow yearly, with an average growth of 7.69% from 2015–2020 (BPS, 2020).

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The rapid development of technology, information, and communication must be balanced with information and communication technology services as internet providers, one of which is the construction of Base Transceiver Station (BTS) towers to support information and communication technology services. Based on the 2022 Indonesia Internet Profile Survey conducted by the Association of Indonesian Internet Service Providers (2022), 77.64% of internet users used mobile data from cellular operators, making cellular operators compete to build information and communication technology service infrastructure to serve customers throughout Indonesia. In June 2021, PT Telkomsel (Telekomunikasi Selular) was the cellular operator that had the most BTS, with 237.300 towers (Katadata.co.id, 2021).

BTS is a cellular radio device with an antenna that connects cell phones with cellular devices (Perda, 2011). Cellular operators have built BTS infrastructure every year. However, some areas are still not covered by the internet network. Gunungkidul Regency is one of them. The affordability of information and communication technology services is included in the Strategic Plan (2021) of the Gunungkidul Regency Communication and Information Service (Diskominfo) for 2016–2021. Data from BPS (2020) showed increased building permits (IMB) for BTS towers. According to the Head of the Gunungkidul Diskominfo in Radar Jogja (2022), 95% of the 140 proposed sub-districts have been served, and the remaining 5% have not due to the geographic factors of Gunungkidul Regency (Diskominfo, 2020).

The location of BTS towers can determine the distribution pattern of towers in an area. Kurniawan & Ahyuni (2019) used the Nearest Neighbor Analyst (NNA) method to determine the distribution pattern of BTS towers in the Merangin District. They proved that the distribution pattern of BTS towers in the Merangin Regency was clustered with an average (Expected Mean Distance) of 0.042598 and a z-score of −1.894107. Two sub-districts have not been included in the service range from the buffer results within a distance of 5 km. Unfortunately, the researchers did not use the multiple-ring buffer method in determining the coverage area, so they could only know the range of services at one distance.

Evaluating the affordability of BTS tower services needs to determine whether any BTS towers cover the areas. Susanti & Rahardjo (2013) in Buleleng Regency, Bali Province, found that 325.45 km2, or 80.74% of the area, had good signal service, and 77.63 km2 or 19.26% did not. In this study, an analysis of the distribution pattern of BTS locations was not carried out, so the distribution pattern of BTS locations in Buleleng Regency was unknown.

Meanwhile, the government and the local Diskominfo must think about structuring the BTS towers' location to realize the local community's aesthetics, security, safety, and health. Controlling the construction of BTS towers as information and communication technology services must follow the established zones as stipulated in Regional Regulation (2011) of Gunungkidul Regency Number 12 of 2012 CHAPTER II "Provisions for Tower Construction" part one related to "Determination of Tower Development Zones/Organizational Plans" Place the Tower" especially setting a safe distance between BTS tower construction and housing or buildings because it can cause health problems due to electromagnetic wave radiation, such as headaches, brain tumors, cancer, and fetal disorders in pregnant women due to the imperfect formation of deoxyribonucleic acid (DNA) (Valberg et al., 2007; Kesari et al., 2013).

Considering the development of BTS tower construction and the increasing need for information and communication technology services in areas still not covered by the internet network, it is necessary to study these objects. This study used a spatial approach to evaluate and plan the distribution of BTS as information and communication technology service facilities for the people of Gunungkidul Regency.

2 Method

2.1 Study Area

Gunungkidul Regency is located in the Special Region of Yogyakarta, whose capital is called Wonosari, karst area (Marfai et al., 2013). The astronomical location of Gunungkidul is 110° 21′–110° 50′ East Longitude and 7° 46′–8° 09′ South Latitude. The total area of Gunungkidul Regency is 1485.36 km^2, or about 46.63% of the total area of the Special Province of Yogyakarta. The Gunungkidul Regency area is divided into 18 sub-districts and 144 villages. Gunungkidul Regency is bordered by Bantul and Sleman Regencies (DIY Province) to the west, to the north by Klaten and Sukoharjo Regencies (Central Java Province), to the east by Wonogiri Regency (Central Java Province), and to the south by the Indian Ocean (BPKP Kabupaten Gunungkidul, 2021). The research locations can be seen in Fig. 1.

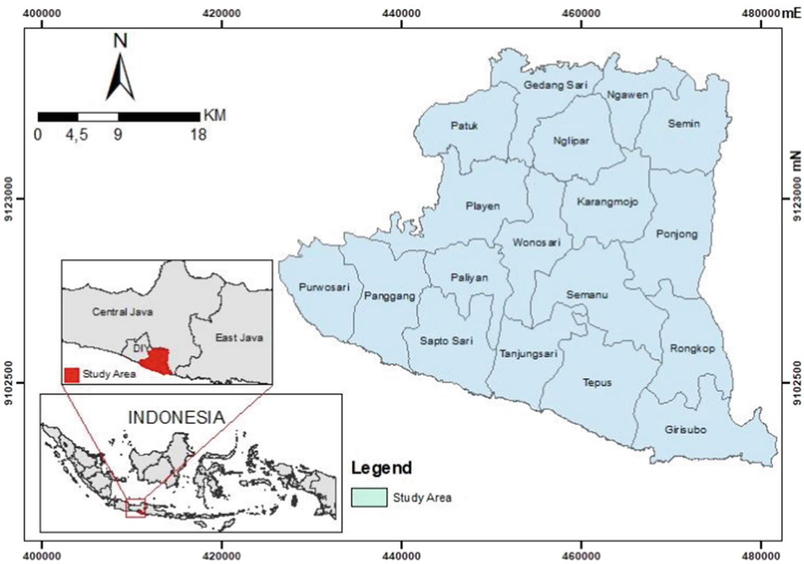

Fig. 1. Map of the study area

Table 1. Research data

Data	Source
2019 BTS Tower Coordinate Location Data	The Communication and Information Gunungkidul Regency (Diskominfo, 2019)
Data on the population of Gunungkidul district in 2019	Statistics Indonesia (BPS Gunungkidul, 2021)
Administrative boundary spatial digital data	Geospatial Information Agency (2021)
Street digital spatial data	Geospatial Information Agency (2021)
Residential spatial digital data	Geospatial Information Agency (2021)
Geological spatial digital data	Geospatial Information Agency (2021)
Digital Elevation Model Data	Geospatial Information Agency (2021)

2.2 Data Collection

The data used secondary data from coordinate location data for BTS towers in Gunungkidul Regency in 2019 based on Gunungkidul Regency's Diskominfo. In addition, other secondary data used were administrative boundary shapefile data, road network shapefile data, settlement shapefile data, geological shapefile data, and slope shapefile data. The data is illustrated in Table 1.

2.3 ANN (Average Nearest Neighbor)

The researchers created the map of the distribution of BTS tower locations using the ArcMap application by adding a Comma Separated Values (CSV) file and extracting the XY coordinate data to see the location points of the BTS towers. From the distribution map, ANN aimed to determine the distribution pattern of BTS tower locations. The nearest neighbor analysis measures the spread or distribution of something over geographic space. This analysis provides a numerical value that describes the extent to which a set of points is clustered or uniformly spaced (Royal Geographical Society, 2017). The mean nearest neighbor ratio is calculated as the observed mean distance divided by the expected mean distance (with the expected mean distance being based on a hypothetical random distribution with the same number of features covering the same total area (ESRI, 2022). For more details, Table 2 shows the average ratio of nearest neighbors**.**

Table 2. Average nearest neighbor ratio

Average Nearest Neighbor Ratio	Pattern
0–0.7	Cluster
0.71–1.4	Random
1.41–2.15	Uniform

Table 3. Distance of multiple ring buffer

Distance	Signal Strength
0–2 km	Strong
2–4 km	Currently
4–6 km	Weak
6–8 km	Very Weak

Table 2 reveals the average value of the nearest neighbor ratio, where the ANN results will produce values ranging from 0 to 2.15, values 0 values for cluster distribution patterns, and values 0.71 to 1.4 are values for random distribution patterns, and values 1.41 to 2.15 are values for uniform distribution (Riadhi et al., 2020).

2.4 Buffer

The buffer method determined the affordability of BTS towers in Gunungkidul Regency in 2019. Buffers from points usually describe conditions regarding a function's coverage or service range at that point (Aqli, 2010). Susanti & Rahardjo (2013) showed that in mapping the service coverage of BTS towers, a distance of 10 km is required. This distance is the range emitted by the BTS tower in reaching the serviced area. This study used multiple ring buffers with a distance of 2, 4, 6, and 8 km. For more details regarding the distance of multiple rings, buffers can be seen in Table 3.

The coverage area of the internet network produced by BTS towers varies. The factors that affect the coverage area include the geographical conditions of the study area and human factors such as landscape and customer behavior (Virgunzena et al., 2014).

2.5 Determining Locations for the New BTS Towers

The new BTS tower's new location is determined through a spatial analysis of a Geographic Information System (GIS), which includes analysis of environmental and geological parameters in the form of lithology and slope; then, buffer with residential objects and roads will determine the location of the new BTS tower and performing the award. Spatial analysis is one of the facilities available in ArcGIS software (Harini et al., 2022).

3 Results and Discussion

3.1 Location Distribution of Gunungkidul Regency BTS Towers in 2019

Gunungkidul Regency Diskominfo reported that in 2019 BTS towers in Gunungkidul Regency were spread over 18 sub-districts, where each sub-district had a different number and owner of towers. A spatial analysis approach is used to obtain the distribution phenomenon (Ritohardoyo, 2016). Owners of operator towers entering Gunungkidul Regency include PT. Centratama Menara Indonesia, PT Dayamitra Telekomunikasi, PT

Indosat, PT Inti Bangun Sejahtera, PT Komet Intra Nusantara, PT Kopnatel Jaya, PT Mitrayasa Sarana Informasi, PT Profesional Telecommunications, PT Sinar Harapan Dirga Terdepan, PT Solusi Menara Indonesia, PT Solusi Tunas Pratama, PT Telkomsel, PT Tower Bersama Group, PT Towerindo Convergence, and PT XL Axiata. Table 4 reveals the distribution of towers for each district.

Table 4 shows 217 BTS towers in Gunungkidul Regency. The district with the highest number of BTS towers is Wonosari District, with 33 towers, and the district with the least is Gedangsari District, with 5 towers. Several factors, such as the number of residents, internet users, and the area of settlement in the local area, can influence unfair distribution. Wonosari District is the sub-district with the highest number of BTS because Wonosari District is the center of the Gunungkidul Regency government and has the largest population, 87331 or 11.38% of the total population of Gunungkidul Regency in 2019. The map of the distribution of BTS towers for Gunungkidul Regency in 2019 can be seen in Fig. 2.

Based on Fig. 2, the location of the distribution of BTS towers tends to be associated with built-up areas and is clustered in Wonosari District. Pusvita et al. (2018) reported

Table 4. Number of towers per district in Gunungkidul Regency (BPS and Diskominfo Gunungkidul, 2019)

Sub-district	Number of BTS Towers	Total Population
Gedangsari	5	44819
Girisubo	8	26848
Karangmojo	19	57058
Ngawen	10	34931
Nglipar	7	34006
Paliyan	11	32750
Panggang	10	29580
Patuk	15	33996
Playen	23	59510
Ponjong	11	57777
Purwosari	10	21038
Rongkop	6	29820
Saptosari	6	38919
Semanu	16	58299
Semin	9	57100
Tanjungsari	11	26246
Tepus	7	36834
Wonosari	33	87331
Total	**217**	**766862**

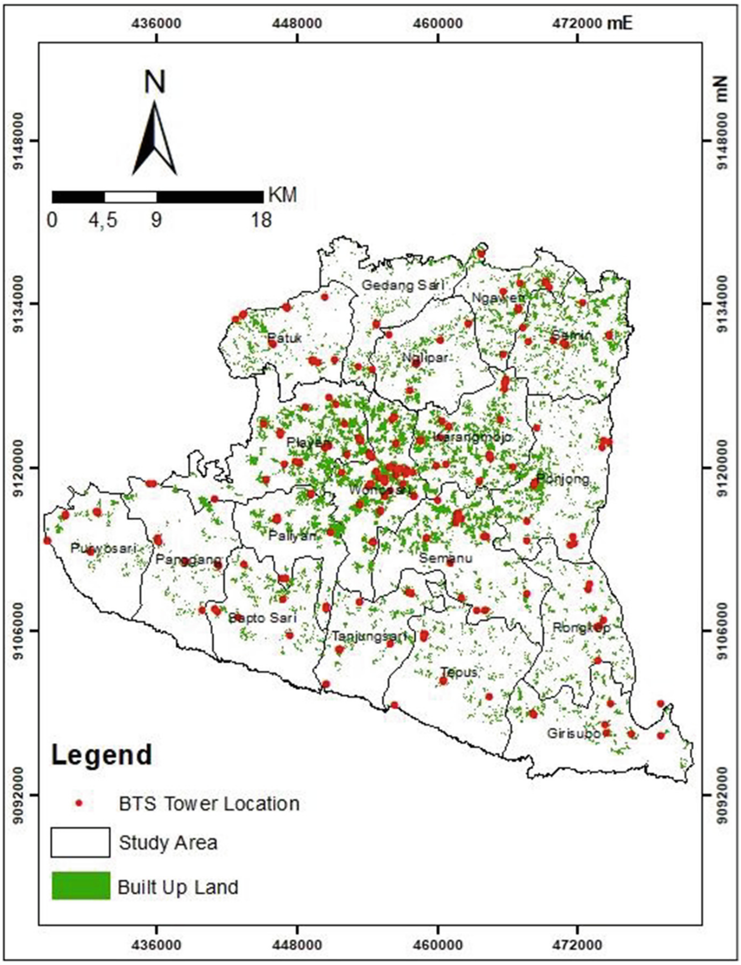

Fig. 2. Location of the Gunungkidul Regency BTS tower locations in 2019

that the number of telecommunications towers in suburban areas dominates compared to rural areas because development in rural areas has almost no economic value for service providers and the influence of regional topography. Making maps is related to GIS because it is easier to manage and utilize spatial data. Distribution mapping is done by combining BTS tower location data and administrative boundaries (Pusvita et al., 2018; Hadibasyir et al., 2021; Fikriyah et al., 2022).

3.2 Distribution Pattern of BTS Towers in Gunungkidul Regency in 2019

The distribution pattern of BTS towers can be identified through the nearest neighbor analysis conducted on ArcMap. The nearest neighbor analysis measures the distance between each feature center and the location of the center of the closest neighbor by

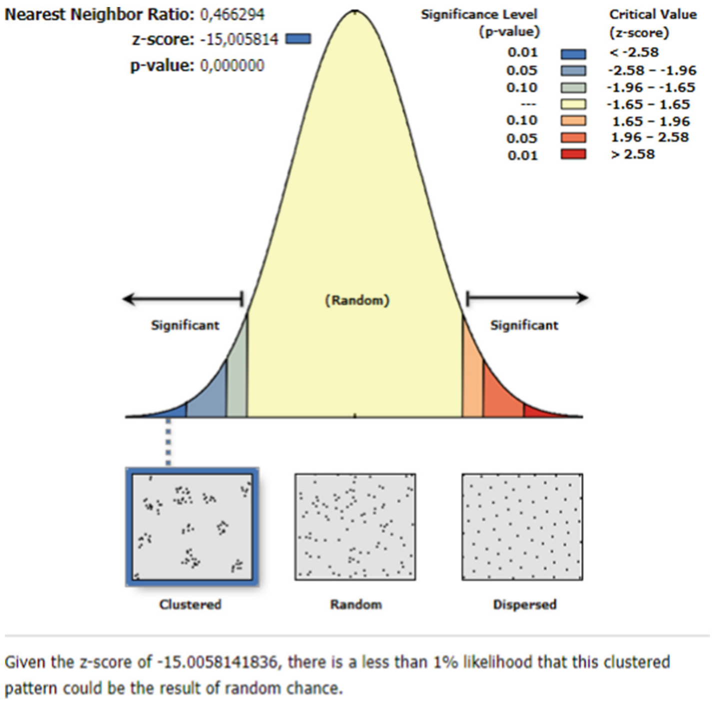

Fig. 3. Nearest neighbor analysis results

considering the distance, the number of location points, and the area. The average ratio of nearest neighbors shows the distribution pattern of the object under study. The distribution pattern of the nearest neighbor results includes a group, random, or spread pattern. Figure 3 reveals the results of the nearest-neighbor analysis.

Figure 3 shows that the average ratio value of the nearest neighbors of the 217 BTS towers in Gunungkidul Regency in 2019 is 0.466294. Hence, the average ratio is between 0–0.7 and shows a clustered distribution pattern. This pattern of clustering can be seen clearly in Fig. 2. There is a tendency to cluster in several districts, such as Wonosari District and Playan District. The average distance (expected mean distance) between BTS towers in Gunungkidul Regency is 4354.5504 m. This distance meets the standard distance for constructing BTS towers with other towers. The Z-score or standard deviation value from the nearest neighbor analysis is −15.005814, and the p-value is 0.

3.3 BTS Tower Coverage Area in Gunungkidul Regency in 2019

Mapping signal coverage from BTS tower services to the Gunungkidul community used data on the location of BTS towers. A BTS tower coverage area is not always an area that can be covered by the signal emitted by the BTS tower because the signals emitted by BTS towers can be blocked by various obstacles, such as the topography of the area, thereby blocking the signal from reaching the coverage area of a BTS tower. The signal range mapping results use multiple ring buffers, as seen in Fig. 4.

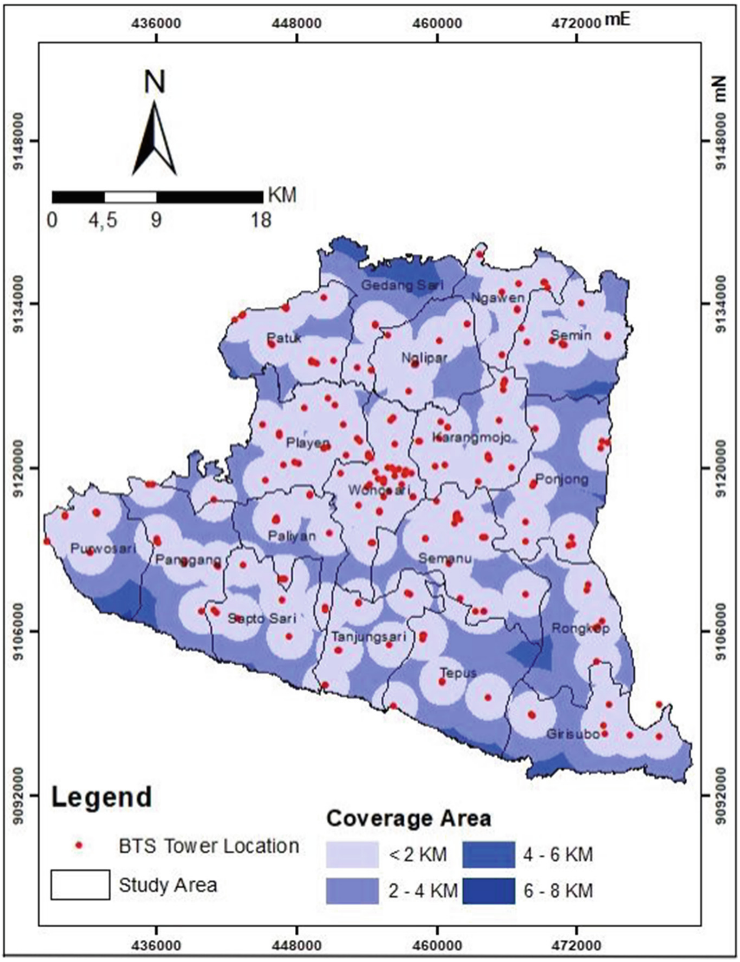

Fig. 4. Coverage of the Gunungkidul Regency BTS tower in 2019

Multiple ring buffer analysis is carried out in Fig. 4 to determine the signal coverage in the study area at a certain distance range. This analysis determines an area that can be seen or reached from the point of observation at different distances. Based on Fig. 4, all study areas are covered by signals from BTS towers with different network categories. The distance between the tower and the device influences the strength of the network obtained. Researchers categorize tower distances of 0–2 km with devices including strong network categories, 2–4 km medium, 4–6 km weak, and 6–8 km very weak. The closer the device is to the BTS tower, the better the signal strength. The sub-districts with weak signal coverage (8 km) are parts of Gedangsari District, Purwosari District, Panggang District, Tepus District, and Girisubo District. The signal coverage area of BTS towers can be seen in Table 5.

Table 5. The width coverage area

Distance (km)	Signal Strength	Area (km^2)	Percentage (%)
0–2	Strong	978.34	66.28
2–4	Currently	445.83	30.20
4–6	Weak	51.27	3.47
6–8	Very Weak	0.69	0.05
Total Area		**1476.13**	**100.00**

Table 5 shows that the internet network has served 66.28% of the entire area of Gunungkidul Regency with a strong signal, 30.20% with a medium signal, 3.47% with a weak signal, and 0.05% with a very weak signal.

3.4 Locations of New BTS Towers in Gunungkidul Regency in 2019

Based on Fig. 4, new BTS towers need optimization in some areas in Gunungkidul Regency that have not been covered well by internet services. Alternative locations for tower construction can be seen in Fig. 5.

The selection of alternative locations for new BTS towers considers several variables such as geological conditions, distance to settlements, distance to roads, distance to other BTS towers, and slope. The maximum recommended slope in constructing BTS towers is <20%. After weighing and overlaying each variable, the results of determining the location of new towers get several new locations. These locations include Purwosari, Panggang, Tepus, Girisubo, Rongkop, Playen, Patuk, Ponjong, and Gedangsari districts.

In constructing towers, the safe distance between alternative locations and housing must be considered. Electromagnetic waves generated by BTS towers are of particular concern to the local community's health. Swamardika (2009) obtained uncertain results about the effect of electromagnetic wave radiation on the surrounding community's health.

Determining the optimal location of shared towers is the next step that must be taken by taking into account the quality of coverage for cellular users so that the construction and use of shared telecommunication towers can be maximized while still paying attention to aspects of spatial aesthetics, and security, safety and public health. In addition, tower owners must also pay attention to standard standards to ensure environmental safety while still considering the determining factors for the strength and stability of BTS towers. Other factors include tower height, tower structure, tower structure frame, and tower foundation.

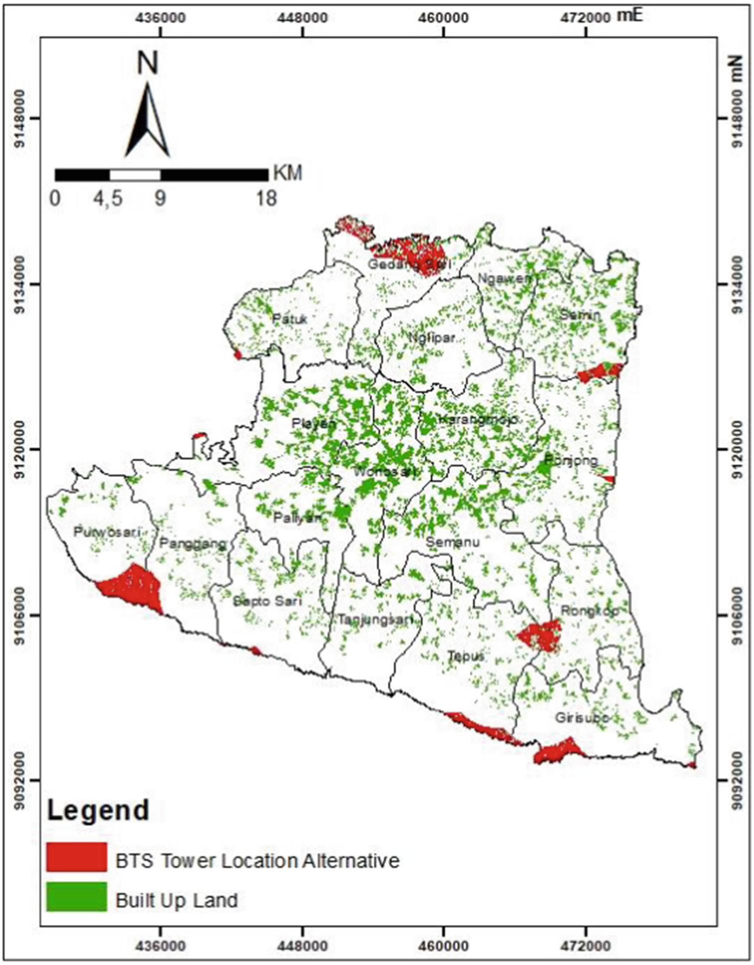

Fig. 5. BTS tower location alternative

4 Conclusions

Based on the analysis, 217 BTS towers in Gunungkidul Regency have been spread across 18 sub-districts. The construction of BTS towers in Gunungkidul Regency is more centered in Wonosari District. Wonosari District is the sub-district with the highest number of BTS because it is the administrative center of Gunungkidul Regency and has the largest population, 87331 or 11.38% of the total population of Gunungkidul Regency in 2019. The internet network could serve 66.28% of the entire Gunungkidul Regency area with a strong signal, 30.20% with a moderate signal, 3.47% with a weak signal, and 0.05% with a very weak signal. The distribution pattern of BTS tower service facilities in Gunungkidul Regency was clustered with an average nearest-neighbor ratio value of 0.466294 and associated with built-up areas. Alternative locations for the new BTS towers include those in the Sub-districts of Purwosari, Panggang, Tepus, Girisubo, Rongkop, Playen, Patuk, Ponjong, and Gedangsari.

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