



Assessment and Planning Green Open Spaces for Sustainable Urban Development: A Case Study in Kota Kisaran Timur, Asahan Regency, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The provision of Green Open Space (GOS) in Kota Kisaran Timur, located in Asahan Regency, North Sumatra, Indonesia, falls critically below national standards. In 2023, only 81.46 hectares of GOS were recorded, reflecting minimal growth from 71.58 hectares in 2013, while rapid

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urbanization significantly increased built-up areas. This study assesses the current state of GOS in Kota Kisaran Timur, projects future requirements based on population growth, and identifies optimal locations for new GOS development using GIS-based spatial analysis. Results reveal that the subdistrict requires a minimum of 522.64 hectares of GOS to meet the national standard of 20% GOS coverage. By 2043, a projected population of 122,421 will necessitate 244,842 m² of public GOS, yet only two villages—Selawan and Siumbut Baru—currently meet these needs. Among the subdistrict's villages, Mutiara Village emerges as the most suitable site for new park development due to its extensive vacant land and ability to serve the largest population. This research provides a strategic framework for addressing GOS deficits at the subdistrict level and offers actionable insights for policymakers to ensure sustainable and equitable urban development.

Keywords: Green open space; urban planning; sustainable development; spatial analysis; Kota Kisaran Timur; Jumantik.

1. INTRODUCTION

Urban areas play a strategic role in supporting economic, social, and cultural activities. Effective and sustainable spatial planning is essential to maintaining the quality of life for urban residents (FAO, 2020). One critical aspect of spatial planning is the provision of Green Open Spaces (GOS), which serve as water catchment areas, microclimate regulators, carbon dioxide absorbers, and public recreational spaces (Forest Service Publications, 2003; Ministry of Agriculture, 2023). However, rapid urbanization and insufficient planning frequently threaten the existence and effectiveness of GOS (Hakim & Utomo, 2004).

The provision of GOS in Indonesia is governed by Law Number 26 of 2007 on Spatial Planning, which mandates a minimum allocation of 30% of the total urban area, comprising 20% public GOS and 10% private GOS. Despite these regulations, many regions, including Asahan Regency, struggle to meet these standards. For instance, while the Regional Spatial Plan (RTRW) of Asahan Regency for 2013–2033 plans a 30% GOS allocation, specific locations remain undetermined, and the lack of a Detailed Spatial Plan (RDTR) further exacerbates the situation (Dinas PUPR Kabupaten Humbang Hasundutan, 2023; Bappenas, 2021).

Kota Kisaran Timur, part of the capital of Asahan Regency, faces significant challenges from rapid population growth and urban development. Between 2013 and 2023, the population increased from 70,415 to 85,596, with density rising from 1,809 people/km² to 2,837.33 people/km² (BPS, 2023). This growth drives extensive residential and infrastructure development, often at the expense of GOS.

Furthermore, Kota Kisaran Timur lags behind Kisaran Barat, which has more developed public green spaces, such as urban forests and squares (Ministry of Environment and Forestry, 2022).

Spatial planning challenges in Kisaran City also stem from plantation land dominance, disaster risks, and deviations from regional planning predictions. Addressing these issues requires prioritizing decentralization, creating growth centers, and improving infrastructure to support sustainable urban development (Abdul et al., 2024). Similar to other regions, the transition from agricultural to non-agricultural land introduces socio-economic challenges such as job displacement and reduced social interaction, underscoring the need for balanced growth through sustainable land management and alternative agricultural development (Eko Suharizki et al., 2024).

Urban GOS not only ensures ecological balance but also contributes to community welfare. Studies highlight the significant role of sustainable practices, such as oil palm cultivation, in rural development, despite challenges like labor management and environmental concerns. This underscores the importance of governance structures and holistic approaches to land use management (Arga et al., 2024). These findings align with urban GOS planning, where the integration of ecological, social, and economic factors is critical.

Community empowerment strategies, such as "one house one jumantik," demonstrate the potential for localized programs to improve urban environments. However, limited resources and infrastructure often hinder the success of these initiatives, as seen in Pekanbaru City (Arga Abdi Rafiud Darajat Lubis et al., 2024). Similarly, the

success of ecotourism initiatives, such as those in Sei Nagalawan Village, shows that creative economic solutions can strengthen community welfare and ensure long-term benefits, provided technological and governmental support are improved (Anisah, 2024).

Research emphasizes the importance of data-driven approaches to GOS planning. Tinambunan (2006) identified insufficient green space in Pekanbaru City, while Siregar (2016) stressed the need for analysis based on population and oxygen demand. Moreover, integrating advanced tools such as satellite imagery and Geographic Information Systems (GIS) can yield accurate evaluations of GOS adequacy and distribution. The development of sustainable food systems and agribusiness, as observed in Medan City and Lintong Nihuta, further demonstrates the intersection of land use, economic resilience, and regional growth (Muliadi et al., 2024; Lubis, S. N., 2023).

This study aims to analyze the GOS needs in Kota Kisaran Timur comprehensively by evaluating the balance between built-up land and GOS, projecting GOS requirements based on population growth, and identifying optimal locations for GOS development. By addressing these challenges, this research contributes to sustainable spatial policies that align with ecological and socio-economic goals, reflecting broader efforts to enhance urban resilience and community welfare (Satia Negara Lubis & Arga Abdi Rafiud Darajat Lubis, 2024).

2. RESEARCH METHODOLOGY

This study employs a descriptive approach using qualitative methods to analyze the demand and availability of Green Open Space (Ruang Terbuka Hijau, RTH) in Kota Kisaran Timur, Asahan Regency. The qualitative approach facilitates the extraction of descriptive narratives from various sources, enabling a comprehensive understanding of the phenomenon (Bodgan & Taylor in Barowi & Suwandi, 2009).

Study Area: The research was conducted in Kota Kisaran Timur, a district in Asahan Regency, North Sumatra, Indonesia. This area was selected due to its rapid residential development, which poses a significant threat to ecological balance by reducing green open spaces. Furthermore, the district is one of the regions with the highest population growth in Asahan

Regency, making it a critical focus for urban planning.

Data Sources and Collection: The study utilized secondary data obtained from relevant government agencies and official websites, including the Environmental Agency, the Public Works and Spatial Planning Agency of Asahan Regency, and the Central Bureau of Statistics (BPS). The collected data included land cover information (shapefiles) for 2013 and 2023, population data from 2000 to 2023, and administrative boundary and land-use data.

Data collection was conducted through formal requests to government institutions for public green space location data and land cover shapefiles. Additionally, population data were obtained from the BPS website. To ensure the accuracy of the secondary data, ground checks were performed. These involved capturing GPS coordinates, conducting direct observations, and documenting the conditions of existing green spaces.

Data Analysis: Data analysis was conducted using Geographic Information Systems (GIS) and Microsoft Excel. The analysis included several key steps:

- 1. Land Cover Analysis:** The study area was delineated based on administrative boundaries using QGIS. Field observations were conducted to validate the interpreted map data, and land cover classifications were created to distinguish green open spaces, built-up areas, and other land uses.
- 2. Calculation of RTH Needs:**
 - Area-Based Analysis:** The ideal green open space requirement was calculated using the formula: $RTH_{Requirement} (Ha) = Area (Ha) \times 20\%$
 - This estimation aligns with national standards requiring 20% of a region's total area to be designated as green open space.
 - Population-Based Analysis:** The green open space needed per capita was calculated using the formula: $RTH_{pi} = P_i \times K$
where P_i represents the population of area i , and K is the required RTH per capita as stipulated by the Ministry of

Public Works Regulation No. 05/PRT/M/2008.

3. Optimal Location Analysis: Potential locations for green space development were identified based on two variables: land availability and population density. Grid-based spatial analysis was employed to determine areas with the greatest potential for new green open spaces, factoring in the service radius for maximum population coverage.

Operational Definitions of Variables:

- **General Spatial Plan:** A framework outlining optimal and efficient spatial utilization in Kota Kisaran Timur over a specified period.
- **Green Open Space Development:** Changes in the extent and distribution of green open spaces within the study area.
- **RTH Requirements:** The ideal green open space area determined based on land size and population parameters.

3. RESULTS AND DISCUSSION

3.1 Results

General Overview of Kota Kisaran Timur: Kota Kisaran Timur District is part of the capital of Asahan Regency, with a total area of 3,892 hectares (38.92 km²). This area is bordered by Rawang Panca Arga Subdistrict in the north, Air Joman Subdistrict in the east, Sei Dadap Subdistrict in the south, and Kisaran Barat

Subdistrict in the west. This subdistrict consists of 12 villages, with the largest village being Karang Anyer (5.97 km²) and the smallest being Kota Kisaran Timur (0.51 km²). The distribution of the area of each village is presented in Table 1.

Availability of Green Open Space in Kota Kisaran Timur: The availability of public Green Open Space (GOS) in Kota Kisaran Timur is still very minimal compared to the standard requirements. According to data from the Environmental Agency of Asahan Regency, GOS managed by the government is predominantly concentrated in Kisaran Barat, while Kota Kisaran Timur only has several GOS locations, such as Taman Mantri Madjizat, Taman Sentang, and Stadion Mutiara. A detailed comparison of built-up land and GOS area between 2013 and 2023 is presented in Table 2.

3.2 Land Cover Analysis

Map Cropping: The analysis began with cropping maps using shapefile data from 2013 and 2023 for land cover and administrative boundary data from the Geospatial Information Agency (BIG). After the cropping and standardization process, the total area of Kota Kisaran Timur was determined to be 26,132,225.28 m².

Ground Check: Ground checks were conducted to verify map analysis results with field conditions. Documentation of several GOS areas such as Taman Mantri Madjizat, Taman Sentang, and Stadion Mutiara is included in the following images.

Table 1. Area of Villages in Kota Kisaran Timur

No.	Urban Village	Area (km ²)	Percentage (%)
1	Sentang	4,14	10,64
2	Kedai Ledang	3,10	7,94
3	Kisaran Naga	2,19	5,63
4	Teladan	0,70	1,80
5	Kisaran Timur	0,51	1,31
6	Selawan	2,78	7,14
7	Mutiara	2,00	5,14
8	Siambut Baru	2,70	6,94
9	Siambut-umbut	2,90	7,45
10	Karang Anyer	5,97	15,34
11	Gambir Baru	5,97	15,34
12	Lestari	5,96	15,31
Total		38,92	100,00

Source : BPS Kota Kisaran Timur, 2024

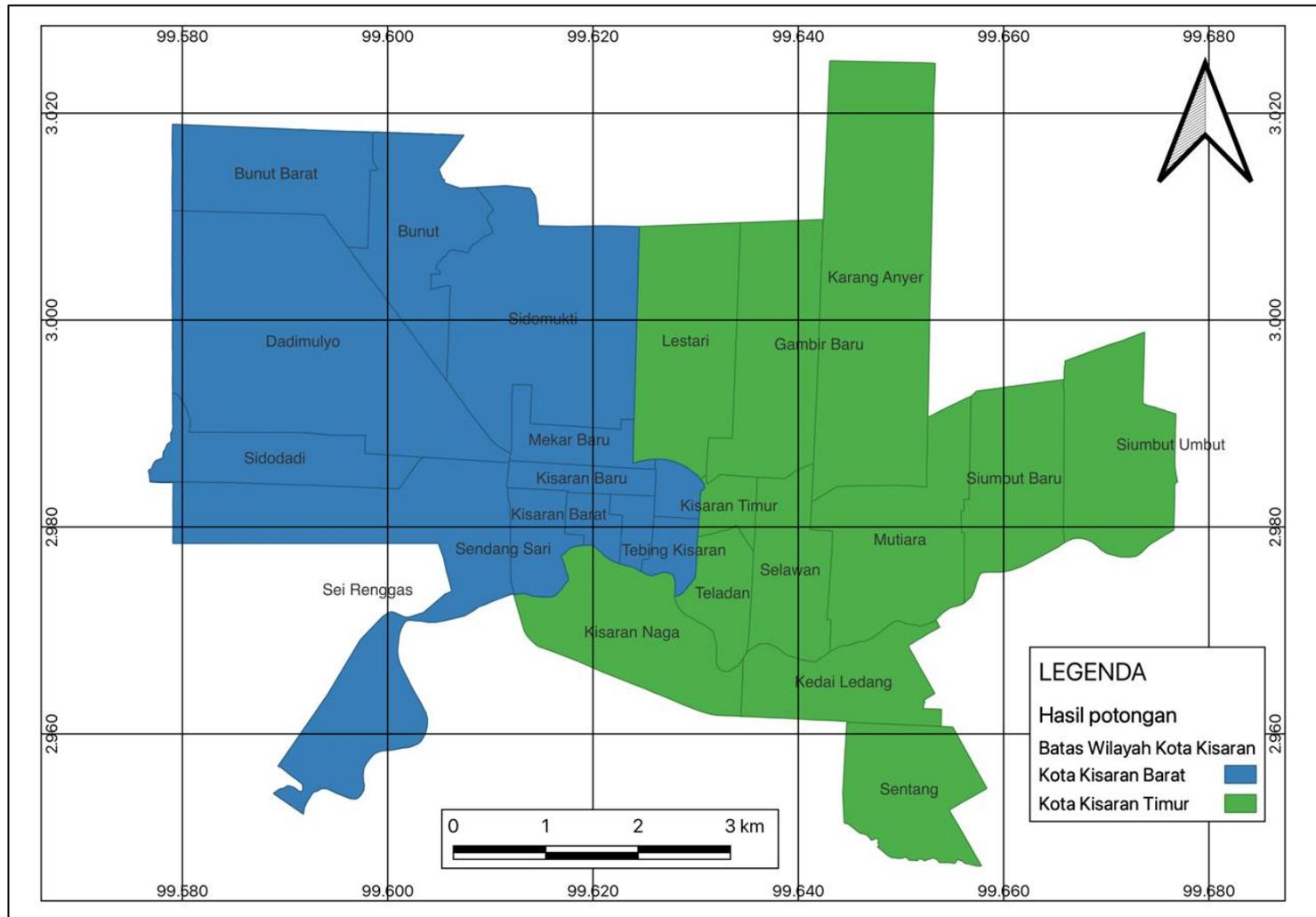


Fig. 1. Cropped Map of Kota Kisaran Timur

Table 2. Comparison of Built-up Land and GOS Areas in 2013 and 2023

No	Urban Village	Build-up Land Area (Ha)			GOS Area (Ha)		
		2013	2023	difference	2013	2023	Difference
1	Sentang	15,34	21,10	5,76	-	0,90	0,90
2	Kedai Ledang	10,44	28,72	18,28	12,16	12,31	0,15
3	Kisaran Naga	21,80	44,56	22,76	19,22	19,37	0,15
4	Teladan	16,75	22,27	5,52	9,56	12,35	2,79
5	Kisaran Timur	8,32	9,88	1,56	-	0,01	0,01
6	Selawan	23,08	31,11	8,03	10,62	11,71	1,09
7	Mutiara	15,61	36,56	20,95	8,18	8,57	0,38
8	Siambut Baru	7,46	26,92	19,47	4,79	9,13	4,34
9	Siambut-umbut	10,98	24,95	13,97	5,31	5,31	0,00
10	Karang Anyer	7,97	13,38	5,41	-	-	0,00
11	Gambir Baru	12,05	21,10	9,04	-	0,07	0,07
12	Lestari	14,65	25,39	10,74	1,74	1,74	0,00
TOTAL		164,44	305,94	141,50	71,58	81,46	9,88



Fig. 2. Green Open Space: Taman Mantri Madjizat



Fig. 3. Green Open Space Taman Sentang in Kisaran Naga



Fig. 4. Green Open Space: Stadion Mutiara

Land Cover Classification: Based on land cover classification, in 2013, Kota Kisaran Timur had 71.58 hectares of GOS, which increased to 81.46 hectares in 2023. However, this growth in GOS was not proportional to the increase in built-up land, which reached 141.50 hectares. Detailed information can be seen in Tables 3 and 4, and Figs. 5 and 6.

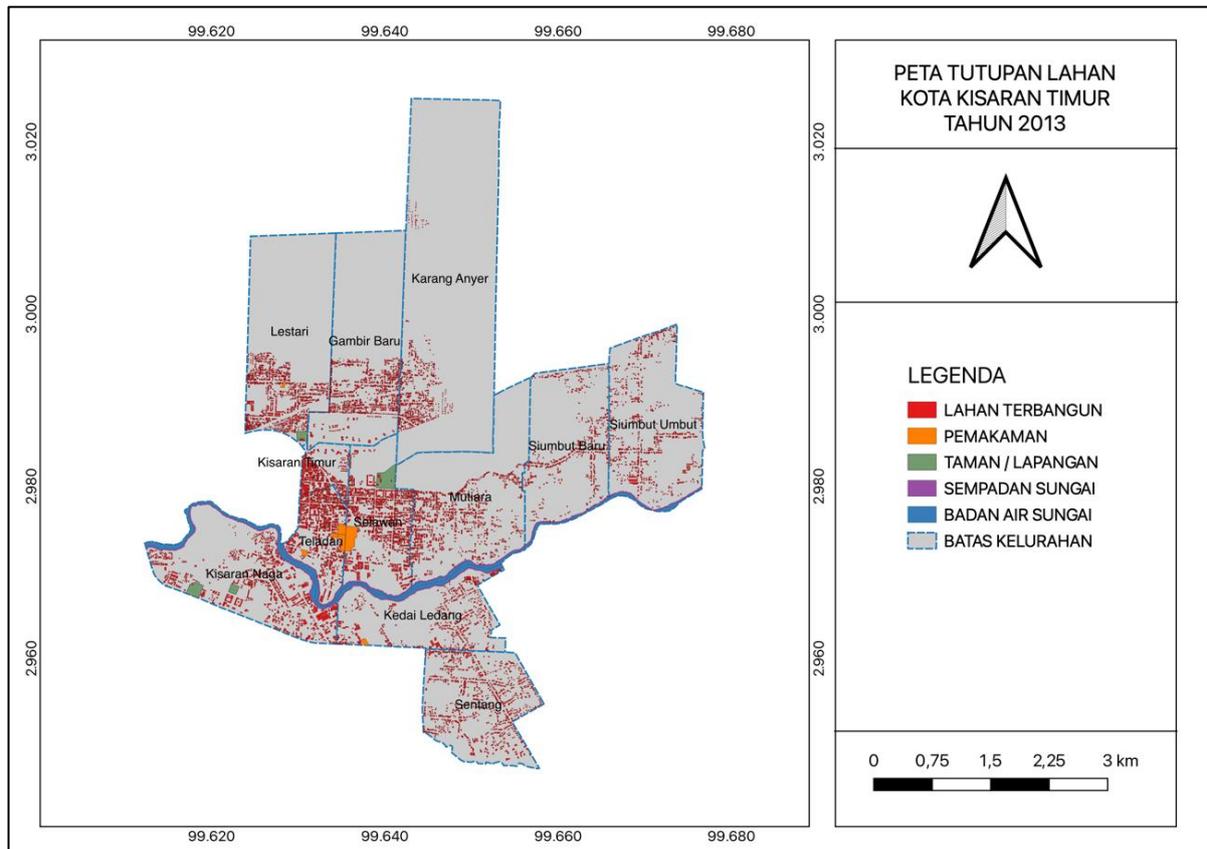


Fig. 5. Land Cover Map of Kota Kisaran Timur (2013)

Table 3. GOS Distribution in Kota Kisaran Timur (2013)

No	Village	Built-up Land Area (Ha)	GOS Area by Type (m ²)				Total GOS Area (Ha)
			Park	Public Cemetery	River Body	Riverbank	
1	Sentang	15,34					-
2	Kedai Ledang	10,44		4.788,50	78.925,10	37.842,53	12,16
3	Kisaran Naga	21,80	620,57		130.360,31	61.252,30	19,22
4	Teladan	16,75		35.468,69	37.560,60	22.544,12	9,56
5	Kisaran Timur	8,32					-
6	Selawan	23,08	26.922,13	39.436,33	23.250,46	16.585,64	10,62
7	Mutiara	15,61			54.457,19	27.378,00	8,18
8	Siumbut Baru	7,46			25.638,99	22.286,96	4,79
9	Siumbut-umbut	10,98			30.817,18	22.263,15	5,31
10	Karang Anyer	7,97					-
11	Gambir Baru	12,05					-
12	Lestari	14,65	14.481,48	2.917,38			1,74
	TOTAL	164,44	42.024,18	82.610,90	381.009,82	210.152,70	71,58

Table 4. GOS Distribution in Kota Kisaran Timur (2023)

No	Village	Built-up Land Area (Ha)	GOS Area by Type (m ²)				Total GOS Area (Ha)
			Park	Public Cemetery	River Body	Riverbank	
1	Sentang	21,10	8.986,92				0,90
2	Kedai Ledang	28,72		6.301,32	78.925,10	37.842,53	12,31
3	Kisaran Naga	44,56	620,57	1.490,28	130.360,31	61.252,30	19,37
4	Teladan	22,27		63.394,48	37.560,60	22.544,12	12,35
5	Kisaran Timur	9,88	83,91				0,01
6	Selawan	31,11	26.922,13	50.347,32	23.250,46	16.585,64	11,71
7	Mutiara	36,56		3.826,64	54.457,19	27.378,00	8,57
8	Siumbut Baru	26,92	38.874,33	4.508,16	25.638,99	22.286,96	9,13
9	Siumbut-umbut	24,95			30.817,18	22.263,15	5,31
10	Karang Anyer	13,38					-
11	Gambir Baru	21,10	660,86				0,07
12	Lestari	25,39	14.481,48	2.917,38			1,74
	TOTAL	305,94	90.630,20	132.785,58	381.009,82	210.152,70	81,46

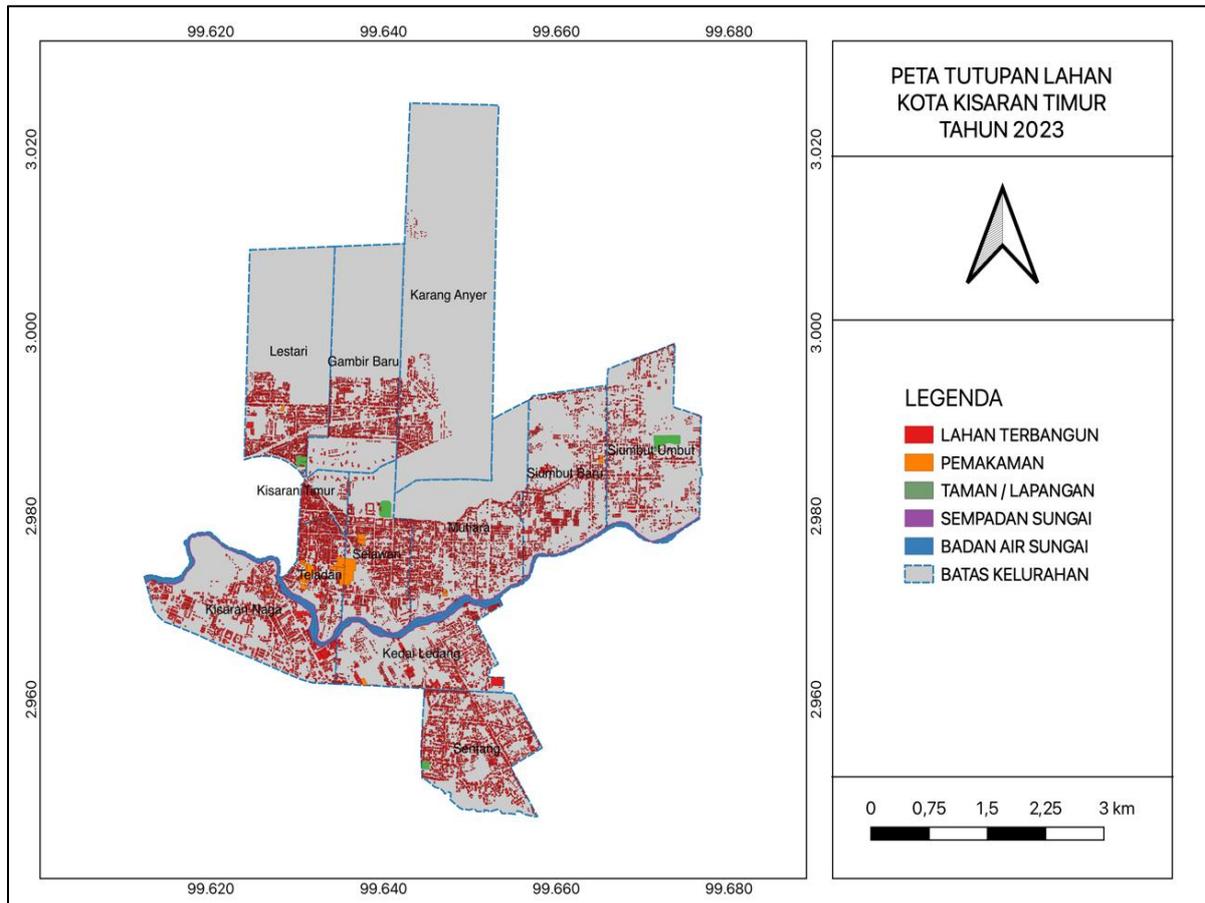


Fig. 6. Land Cover Map of Kota Kisaran Timur (2023)

Analysis of Public GOS Needs Based on Area: According to regulations, the minimum public Green Open Space (GOS) requirement is 20% of the total area. For Kota Kisaran Timur, this translates to 522.64 hectares. However, current GOS fulfills only 15.59% of this requirement, leaving a significant deficit. Detailed results are presented in Table 5, while the analysis is visualized in Fig. 7.

Table 5. Public GOS Needs Based on Area in Kota Kisaran Timur

Urban Village	Area (Ha)	Required GOS Area (Ha)	Current GOS Area (Ha)	Deficit (Ha)	Current GOS (%)	Notes
Sentang	181,26	36,25	0,90	-35,35	2,48	insufficient
Kedai Ledang	166,28	33,26	12,31	-20,95	37,01	insufficient
Kisaran Naga	233,37	46,67	19,37	-27,30	41,50	insufficient
Teladan	80,37	16,07	12,35	-3,72	76,83	insufficient
Kisaran Timur	37,05	7,41	0,01	-7,40	0,11	insufficient
Selawan	148,18	29,64	11,71	-17,93	39,51	insufficient
Mutiara	267,49	53,50	8,57	-44,93	16,01	insufficient
Siumbang Baru	202,79	40,56	9,13	-31,43	22,51	insufficient
Siumbang-umbut	233,46	46,69	5,31	-41,38	11,37	insufficient
Karang Anyer	539,33	107,87	0,00	-107,87	0,00	insufficient
Gambir Baru	253,52	50,70	0,07	-50,64	0,13	insufficient
Lestari	270,10	54,02	1,74	-52,28	3,22	insufficient
	2613,22	522,64	81,46	-441,19	15,59	

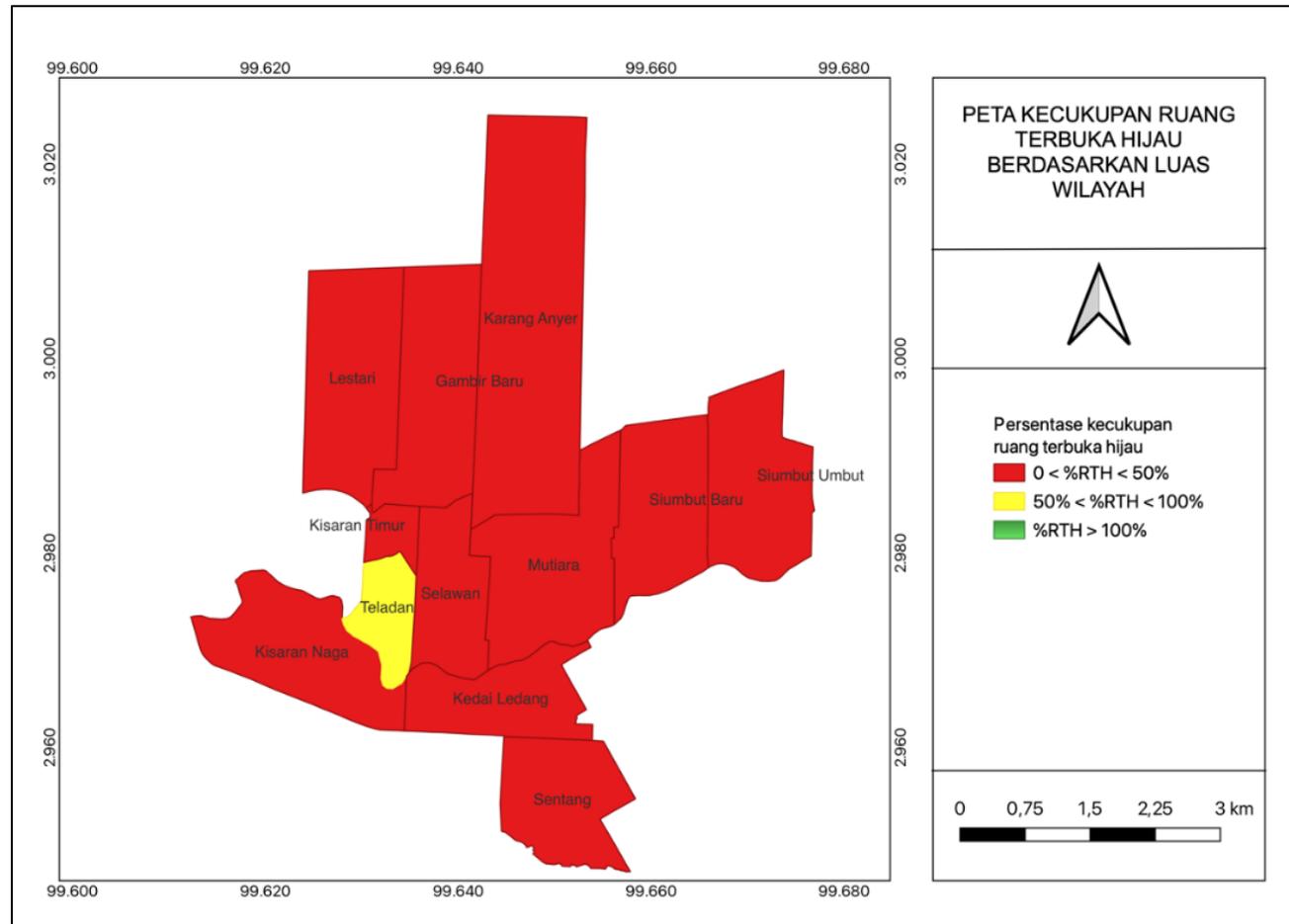


Fig. 7. Results of Public GOS Needs Analysis Based on Area

Analysis of Public GOS Needs Based on Population: The analysis of GOS needs based on population projections for 2043 reveals a significant deficit. With an estimated population of 122,421, the required GOS for public spaces is 244,842 m², based on the standard of 0.2 m² per person for subdistrict parks. Currently, only two villages—Selawan and Siumbut Baru—meet this requirement. Detailed results are presented in Table 6, while the analysis is visualized in Fig. 8.

Table 6. Analysis of Minimal Public GOS Needs Based on Population

Urban Village	Required GOS (m ²)	Current GOS (m ²)	Deficit (m ²)	Current GOS (%)	Notes
Sentang	28.616	8.986,92	-19.629,08	31,41	Insufficient
Kedai Ledang	15.774	0,00	-15.774,00	0,00	Insufficient
Kisaran Naga	17.752	620,57	-17.131,43	3,50	Insufficient
Teladan	13.094	0,00	-13.094,00	0,00	Insufficient
Kisaran Timur	6.056	83,91	-5.972,09	1,39	Insufficient
Selawan	21.186	26.922,13	5.736,13	127,08	Sufficient
Mutiara	39.834	0,00	-39.834,00	0,00	Insufficient
Siumbut Baru	29.864	38.874,33	9.010,33	130,17	Sufficient
Siumbut-umbut	31.352	0,00	-31.352,00	0,00	Insufficient
Karang Anyer	10.880	0,00	-10.880,00	0,00	Insufficient
Gambir Baru	13.562	660,86	-12.901,14	4,87	Insufficient
Lestari	16.872	14.481,48	-2.390,52	85,83	Insufficient
	244.842	90.630,20	-154.211,80		Insufficient

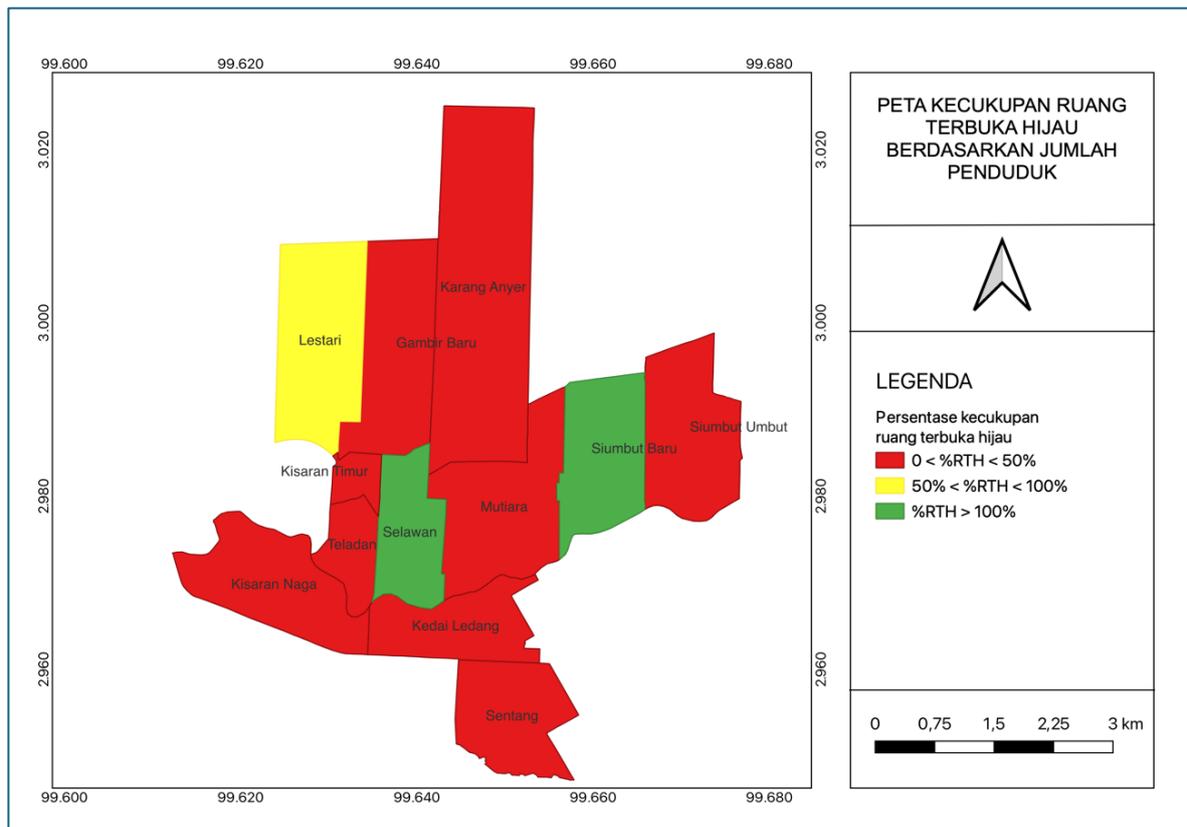


Fig. 8. Results of Minimal Public GOS Needs Analysis Based on Population

Analysis of Potential Locations for GOS Development: The analysis of potential GOS locations used a 125 x 125-meter grid based on a 2,500-meter service radius. After the elimination process, 105 grids were identified as potential locations for GOS development. Among the identified areas, Mutiara Village emerged as the most suitable, with the highest potential population served within the service radius. The results are visualized in Figs. 9 and 10.

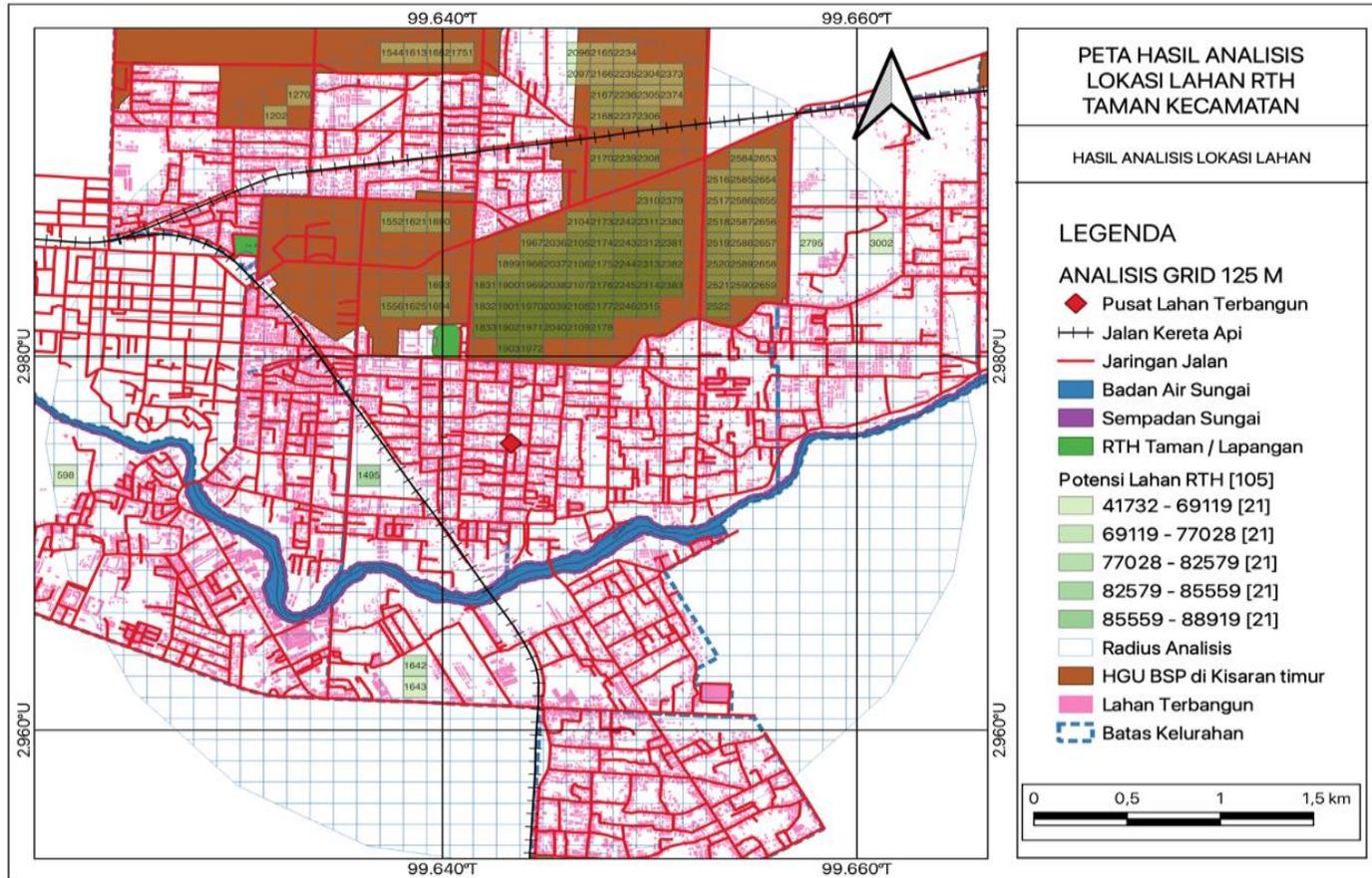


Fig. 9. Map of Potential GOS Locations in Kota Kisaran Timur

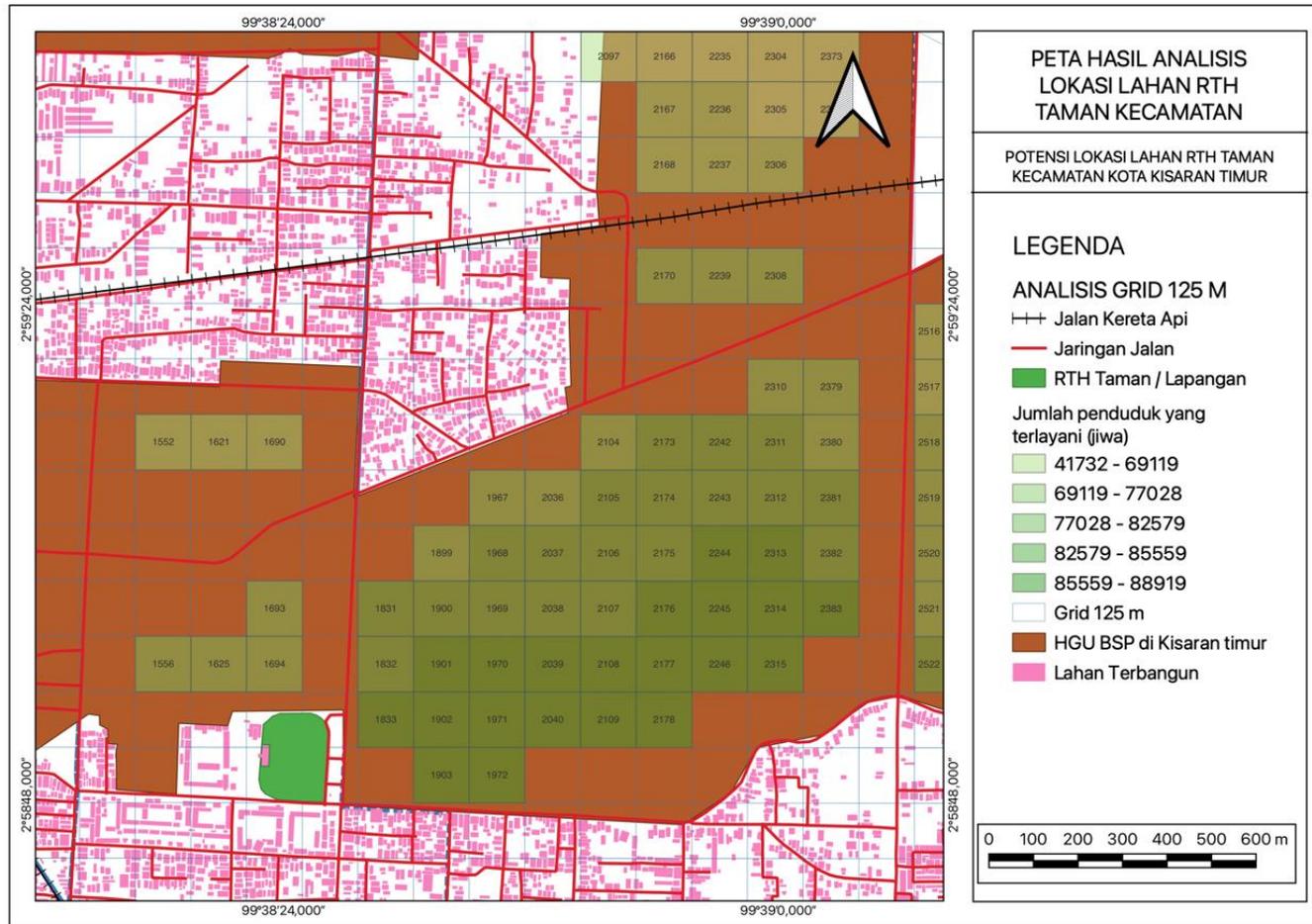


Fig. 10. Optimal Locations for GOS Development in Kota Kisaran Timur

Table 7. Proposed GOS for Villages to Meet Requirements

Urban Village	GOS Area (m ²)			Required GOS (m ²)	Notes
	Existing GOS	Planned GOS	TOTAL GOS		
Sentang	8.986,92	26.850,74	35.837,66	28.616	Sufficient
Kedai Ledang	0,00	20.325,52	20.325,52	15.774	Sufficient
Kisaran Naga	620,57	28.718,19	29.338,76	17.752	Sufficient
Teladan	0,00	13.343,29	13.343,29	13.094	Sufficient
Kisaran Timur	83,91	6.860,66	6.944,57	6.056	Sufficient
Selawan	26.922,13	15.876,87	42.799,00	21.186	Sufficient
Mutiara	0,00	43.644,80	43.644,80	39.834	Sufficient
Siumbut Baru	38.874,33	14.981,68	53.856,01	29.864	Sufficient
Siumbut-umbut	0,00	34.191,58	34.191,58	31.352	Sufficient
Karang Anyer	0,00	17.433,04	17.433,04	10.880	Sufficient
Gambir Baru	660,86	14.918,83	15.579,69	13.562	Sufficient
Lestari	14.481,48	26.824,58	41.306,06	16.872	Sufficient
JUMLAH	90.630,20	263.969,78	354.599,98	244.842	Sufficient

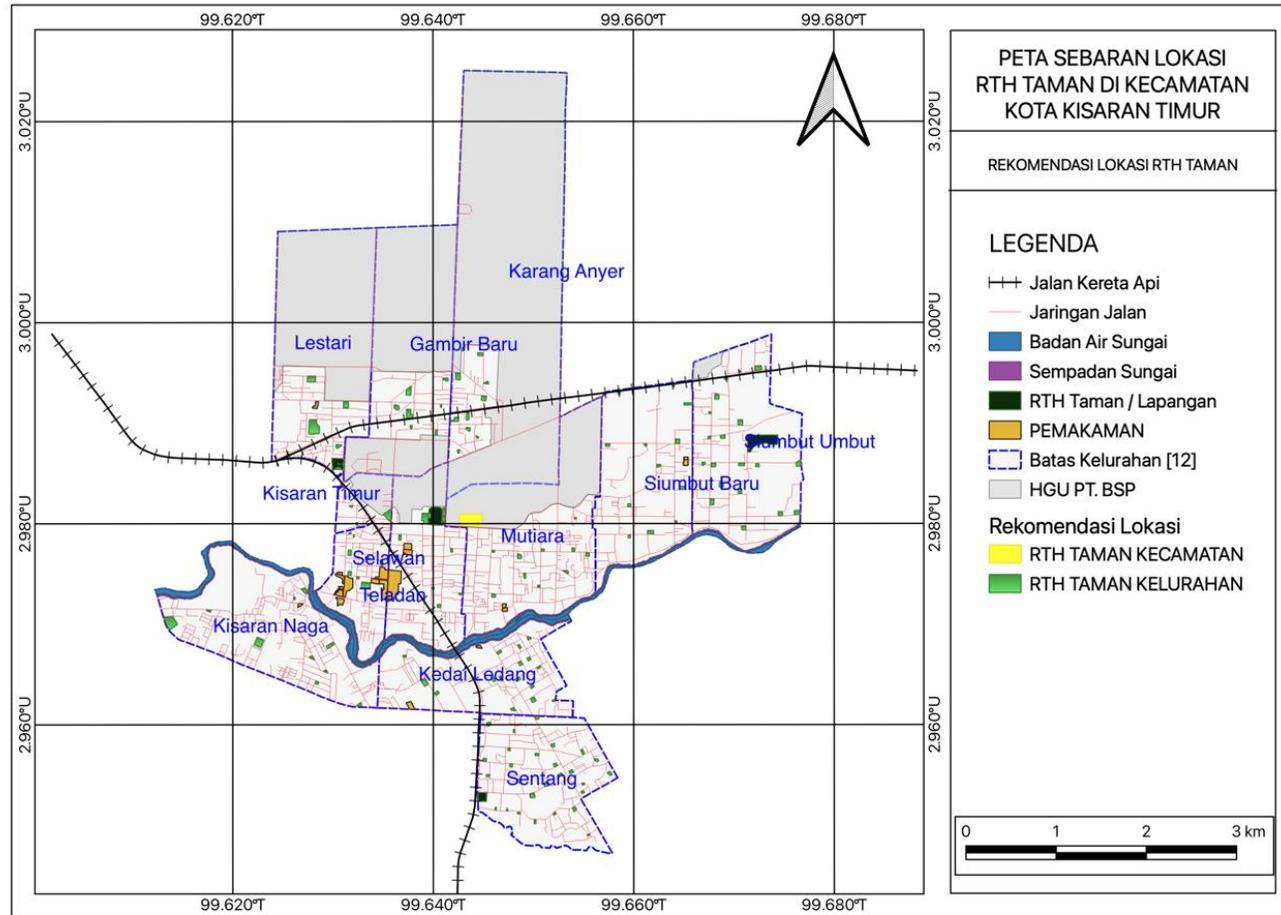


Fig. 11. Recommended GOS Locations in Kota Kisaran Timur

Recommendations for Village-Level GOS Planning: Based on the analysis, the total recommended GOS area is 354,599.98 m², spread across 135 locations in Kota Kisaran Timur. This additional GOS would enable all villages to meet the minimum GOS requirements. A breakdown of the proposed GOS expansions is detailed in Table 7, and the spatial distribution is shown in Fig. 11.

3.3 Discussion

Kota Kisaran Timur experienced an increase in Green Open Space (GOS) from **71.58 hectares in 2013** to **81.46 hectares in 2023**. However, this 9.88-hectare increase over a decade is considered insufficient to meet the ideal requirement of 20% of the total area. This highlights a significant gap between the current conditions and the GOS standards outlined in regulatory provisions.

The GOS deficit in Kota Kisaran Timur is further evidenced by population growth and its impact on public space needs. With the population projected to reach **88,919 by 2043**, the required public GOS for parks is estimated at **244,842 m²**. Based on the standards outlined in **Regulation of the Ministry of Public Works No. 05/PRT/M/2008**, each individual requires at least **0.3 m² for village parks** and **0.2 m² for subdistrict parks**. This underscores the need for accelerated GOS development to balance population growth and address socio-ecological needs.

The concentration of GOS in Kisaran Barat Subdistrict poses a challenge for Kisaran Timur. Most GOS facilities, such as **Hutan Kota** and **Alun-Alun Kota**, are located in Kisaran Barat, while Kisaran Timur has only a few small-scale GOS, such as **Taman Sentang** and **Stadion Mutiara**. This imbalance in distribution creates inequities in public access to green spaces and environmental quality.

From an ecological perspective, the lack of adequate GOS in Kota Kisaran Timur has the potential to negatively impact local environmental quality. The limited green areas reduce water absorption capacity, increase flood risks, and exacerbate air pollution. Additionally, sufficient green spaces are critical for mitigating urban heat islands, improving air quality, and supporting urban environmental sustainability.

Spatial analysis identified Mutiara Village as the most promising area for GOS development. The

village has sufficient vacant land and a high potential population to serve. Using spatial analysis with GIS, approximately **135 potential locations** for GOS development were identified in Kota Kisaran Timur, reflecting significant opportunities to meet future green space needs.

The designation of new GOS locations requires a strategic approach that integrates land availability and population needs. This study recommends the development of subdistrict parks with a **minimum area of 15,000 m²** as a priority solution. These parks can function not only as water absorption areas but also as venues for social and recreational activities. With a service radius of **2,500 meters**, these parks are expected to reach a larger population in the surrounding areas.

Effective GOS planning must also consider sustainability aspects. Beyond meeting ecological needs, GOS can provide social and economic benefits, such as enhancing urban aesthetics, reducing community stress, and supporting local economic activities through tourism. Thus, GOS is not only a critical element of urban spatial planning but also an integral part of sustainable urban development.

The development of GOS in Kota Kisaran Timur requires collaboration among the government, community, and private sectors. The government must ensure supportive regulations for land acquisition for GOS, while the community and private sectors can contribute to greening efforts and maintaining green areas. These efforts demand a long-term commitment to creating a healthier and more comfortable living environment for residents.

The importance of spatial planning policies oriented toward ecological and social needs cannot be overstated. With rapid population growth and extensive land conversion, providing sufficient GOS in Kota Kisaran Timur is an urgent priority. The sustainability of the region depends not only on physical infrastructure development but also on balancing human needs with environmental preservation.

Through appropriate planning measures, Kota Kisaran Timur has significant potential to enhance its environmental quality through adequate GOS development. This study provides an empirical foundation for local governments to develop more targeted policies toward realizing

environmentally friendly and sustainable urban development.

4. CONCLUSION AND RECOMMENDATIONS

Kota Kisaran Timur faces significant challenges in providing Green Open Space (GOS) in accordance with national standards. In 2023, the total GOS in the subdistrict was recorded at 81.46 hectares, an increase from 71.58 hectares in 2013. However, this growth is disproportionate to the expansion of built-up areas, which reached 141.50 hectares over the same period. Based on the needs analysis, the subdistrict requires at least 522.64 hectares of public GOS, equivalent to 20% of the total area, as mandated by Law No. 26 of 2007. This shortfall means that most villages, including those with high population densities, fail to meet the ideal public GOS requirements.

Additionally, with the projected population in 2043 expected to reach 122,421 residents, the calculated public GOS requirement is 244,842 m². However, only two villages—Selawan and Siumbut Baru—currently meet these needs. The uneven distribution of GOS exacerbates the limited public access to the ecological, social, and aesthetic benefits of green spaces.

This study also identified Mutiara Village as the optimal location for subdistrict park development, offering the largest land potential and the highest number of residents that can be served. Overall, the findings emphasize the critical need for more targeted planning and management of GOS to achieve ecological and social balance in urban areas.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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