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ECOLOGICAL RESILIENCE THROUGH GREEN INFRASTRUCTURE: ANALYZING THE ROLE OF PRIVATE GREEN OPEN SPACES IN TROPICAL MEGACITIES

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Abstract: Green open space is decreasing along with urban development. Development in urban areas has an impact on reducing green land which is important for urban resilience. In Jakarta, the reduction in water-absorbing surfaces has exacerbated environmental problems such as flooding, rising temperatures and decreasing biodiversity. This study aims to evaluate the ecological performance of green open spaces, especially in private homes in the Menteng area, Jakarta, which is recognized as the first garden city in Indonesia, as a representation for understanding the role of green open spaces in advancing urban sustainability and climate resilience. The focus is on the extent of private green open space that still exists in the city area, especially Menteng. Using mixed-method spatial analysis with GIS-based mapping and field surveys of more than 85 residential lots, this study applies the Basic Green Coefficient to measure green space coverage. The results show an average coefficient of 44%, indicating substantial integration of green spaces in the built environment. These private green areas increase rainwater infiltration, reduce flooding, reduce the heat island effect, regulate microclimate, and support air purification, carbon sequestration and biodiversity. Despite developmental pressures, Menteng's environmentally friendly infrastructure continues to provide ecological functions that are in line with sustainability goals. This study aims to offer insights into improving urban ecology through green infrastructure, specifically green open spaces, and its role in strengthening urban sustainability, livability, and public health.

Keywords: Climate resilience, green infrastructure, livability, private open space, sustainability

I. INTRODUCTION

Urban areas are becoming increasingly vulnerable to the impacts of climate change, particularly the impact of rising temperatures, increased rainfall, flooding and decreased air quality. The message is that the growth of urban areas, characterized by the expansion of infrastructure and reduction of vegetation and air catchment areas, has increased temperatures in cities (Silveira et al., 2024). This phenomenon known as Urban Heat Island (UHI) is a known effect of urbanization, where urban areas have higher temperatures than rural areas or vegetated areas (Oke TR et al., 2017). Urban Green Infrastructure (UGI) refers to the arrangement of a network of natural and semi-natural green spaces in an urban setting such as public parks, urban forests, wetlands, street trees, gardens, green roofs, and other green areas. Sustainability awareness has influences global attention,

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which is realized through SDGs (Syukur et al., 2025), according to (Locke & McPhearson, 2018), UGI as a solution for urban sustainability issues, can be applied to face urban challenges, including air pollution and flooding as an effort to maintain ecosystems that may help reduce the impact of climate change.

Green spaces play an important role in this context, as an ecological, aesthetic, and climate resilience solution that increases water infiltration, regulates microclimate and enhances urban biodiversity (de la Barrera et al., 2023). Recent studies emphasize that small-scale green infrastructure, for example private parks or residential yards, can contribute effectively to microclimate regulation (Kim et al., 2022; Shashua-Bar & Hoffman, 2000). These parks can increase biodiversity amidst the ever-decreasing green areas in the city (Hanson et al., 2021). Such findings are especially remarkable as larger cities, such as Jakarta, are known to be dominated by impervious surfaces, which as mentioned by (Estoque et al., 2017), had Land Surface Temperature (LST) that are on average 3°C higher than green spaces. Although their study focused on large-scale landscapes, it highlights the importance of smaller interventions, including private green spaces such as home gardens and yards. These private spaces, if widely distributed, can make a significant contribution to urban cooling and thermal comfort, especially in areas where public green space is scarce. Therefore, integrating government and private greening is very important to mitigate UHI and improve urban livability (Estoque et al., 2017).The challenges faced by cities call for sustainable urban planning that increases climate resilience in fast-growing tropical cities. In Indonesia, the use of green infrastructures as a water resources management strategy can be implemented (Agnes & Naqash, 2025)

Menteng is the first colonial residential area in Indonesia, built in the early 1910s with a garden city concept by architects P.A.J. Moojen and F.J.L. Ghijsel. This area is easily recognizable through its unique design which has large open green spaces, wide roads, and colonial-style residences. Menteng's recognizable features are a result of the planner's vision in pursuing space order and ecological aesthetics which include urban gardens and European-style housing. This area, which was originally developed as an exclusive upper middle class European residence, is officially designated as a protected cultural heritage area through Jakarta Governor Decree No. D.IV-6098 of 1975. Even so, urban modernization and changes in land requirements has been a constant threat to the green open space (RTH) in this district.

Menteng has a large proportion of green open spaces, this is present in both public areas and private residential lands, as it was designed in consideration of balance between the built and natural environment. The regulation governing Green Open Spaces in Indonesia is stipulated under the Regulation of the Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency of the Republic of Indonesia No. 14 of 2022 on the Provision and Utilization of Green Open Space. Local governments continue to face significant challenges in fulfilling the statutory requirement of allocating at least 20% of urban land area for public green open spaces. As a strategic effort to mitigate climate change and achieve net-zero carbon emission targets, local governments are mandated to ensure the provision of high-quality green open spaces. Green open spaces are categorized into two types: Public Green Open Space is owned, managed, and/or acquired by municipal or provincial governments, including the Jakarta Special Capital Region, either independently or in collaboration with other governmental bodies and the community, and is designated for public use. In contrast, private Green Open The spatial structure of Menteng including its green spaces and road networks was meticulously designed based on the principles of the garden city concept, as elaborated in the following section: The primary green open spaces originally planned in the Menteng district include Taman Suropati and Taman Cut Meutia. In addition to these major parks, the area also features several secondary green spaces, historically referred to in Dutch as plantsoen (small gardens), such as the Loge Plantsoen in front of the Bappenas building, the lakeside garden on Jl. Lembang, and the green space on Jl. Sukabumi. The spatial layout of Menteng demonstrates a deliberate arrangement where the park functions as the nucleus of the district. Government buildings and key public facilities are positioned around this central park, while residential zones are configured to radiate outward, maintaining visual and physical orientation toward the center.

In Kubatz's revised urban plan, the concept of a central park remained intact, although the radial housing pattern was loosened, resulting in a more dispersed configuration. Key government buildings continued to encircle the central park, maintaining fidelity to the core tenets of the garden city model. One of the most notable differences between the original plan by P.A.J. Moojen and the revision by Ir. F.J. Kubatz was the elimination of the central round field, which was replaced by the smaller Taman Suropati. The remaining open space was repurposed into a sports field. In 1921, a stadium was constructed in the area, serving as a recreational facility for the Dutch community and the headquarters of the Voetbalbond Indische Omstreken Sport (VIOS) football club. The site later became what is now known as Taman Kota.

This study analyzed 85 residential and institutional plots in Jakarta's Menteng district using spatial analysis and the Green Basic Coefficient as a quantitative indicator to map green space coverage. This is done in order to examine how this spatial alignment may impact urban sustainability.

Green open space is one of the pillars of sustainable cities and architecture, which contributes to environmental quality, public health and urban resilience (Tzoulas & Greening, 2011). The distribution of green open spaces are the key to sustainable urban communities, as stated in global frameworks such as the UN Sustainable Development Goals and the New Urban Agenda. In Indonesia, for example, national law stipulates that at least 30% of city areas be maintained as Green Open Space. These policies reflect a widespread understanding that parks, gardens and other vegetated areas are not just amenities, but important "green infrastructure," providing ecosystem services, from cooling urban heat islands to improving air quality and biodiversity (Zain et al., 2022). At the same time, sustainable architecture has evolved to integrate natural elements, blurring the boundary between building and landscape. Crucially, green open spaces yield co-benefits across environmental, social, and economic dimensions of sustainability. Vegetated areas help regulate microclimates, shading surfaces, and cooling ambient temperatures through evapotranspiration, thus countering the urban heat island effect and reducing building energy use for cooling (Council, 2025).

Accessible green spaces provide cultural and health services for urban residents. Studies show that exposure to nature in cities (e.g. visiting parks) improves physical and mental health outcomes by reducing stress and encouraging exercise (Tzoulas & Greening, 2011). Public green areas also foster social interaction and community cohesion, enhancing quality of life. Well-distributed green open space is now seen as a prerequisite for sustainable, livable cities a principle embraced in global city rankings and programs such as the Green City Index and Indonesia's own Green City Development Program (which explicitly tied the "green city" label to achieving 30% GOS coverage) (Zain et al., 2022). In the context of Jakarta, the Menteng district serves as a relevant case example where private green spaces remain prominent and actively contribute to ecological performance. Menteng's residential plots, with their extensive garden areas, illustrate how private green infrastructure can support stormwater regulation, mitigate heat, and preserve biodiversity within a dense urban setting. Menteng is a residential district that began its development in the early 20th century, the initial development was undertaken by a private real estate company, N.V. Bouwploeg. The original master plan for Menteng was designed by architect P.A.J. Moojen in 1910. Menteng's design was replaced by Ir. F.J. Kubatz, who continued construction in 1922. Menteng holds historical significance as the first residential area in Indonesia to apply the principles of the garden city concept (Alnoza, 2020). The Menteng development is a strategic urban expansion initiative led by the Batavia City Council which adopts the same planning principles. It is hoped that new settlements will provide better health conditions and be better able to adapt to the local climate and environmental context (Tan et al., 2016).

Menteng is the first planned residential area in Batavia, designed as an exclusive living environment. The government aims to showcase the garden city concept through the development of Menteng, making it unique among other contemporary settlements. Moojen's layout was directly inspired by Howard's garden city principles, incorporating long arterial roads that connected to concentric radial streets and centralized public facilities. However, Menteng distinguished itself from other garden city developments in that its layout was not intended to be spatially isolated or self-contained; instead, it was designed to remain organically connected to its surrounding urban fabric (Silver, 2008). The vital role of greenery in urban environments was articulated over a century ago by the Garden City movement, a foundational theory in urban planning. In practical terms, his model Garden City was a self-contained town surrounded by a permanent greenbelt, with a low density layout featuring generous open spaces, parks, and tree-lined avenues woven among homes and workplace, the Garden City was meant to be "a perfect combination of town and country" that would yield economic efficiency, social harmony, and contact with nature. The Dutch interpretation of the Garden City emphasized integrating greenery and housing at various scales, leaving a lasting imprint on the country's urban form and prompting lessons for today's ecological planning.

"City in a Garden" is a relatively new urban design concept that has been adopted by many cities, such as Singapore. This new ethos incorporates aggressive tree planting, park creation, and tighter green building regulations, which has proven to increase Singapore's green area into being 46% of the city area, improving urban biodiversity and comfort (Tan et al., 2016). It has reinforced the idea that sustainable architecture is not just about energy efficient buildings, but about the relationship those buildings have to their environment. Increasingly, architecture and landscape are conceived together much as in the original garden suburbs to maximize benefits like passive cooling, daylighting, stormwater control, and biophilic amenities. Beyond Singapore, a country that shows the importance of private green open space in urban sustainability. In the UK, private domestic gardens represent almost a third of all urban green space, as they support ecological biodiversity and microclimate (Gaston et al., 2005). Japan has traditional courtyard gardens (tsuboniwa) built within dense residential areas in cities such as Tokyo helping to cool the urban environment and improve the mental well-being of its residents (Tanaka et al., 2013). In Brazil, informal settlements such as in Belo Horizonte use backyard gardens for food production and as urban cooling, representing the adaptive value of private greening in fragile urban contexts (Bohn & Vilhena, 2019). Meanwhile, in Melbourne, Australia, private yards account for more than half of the urban tree canopy, playing a massive role in the city's climate adaptation strategy (Davern et al., 2017). These precedents and proven improvements made by other countries illustrate important lessons that can be applied to cities in Indonesia, and in the context of this study, Menteng, where greenery continues to play a role in climate adaptation and urban livability.

II. RESEARCH METHOD

This study deploys a mixed approach, combining quantitative geospatial analysis, qualitative field observations, and review of policy documents. This methodology ensures a robust triangulation across spatial, physical, and regulatory dimensions(Cameron Tijana and Taylor Jon E. and Salisbury Andrew and Halstead Andrew J. and Henricot Béatrix and Thompson Ken, 2012; Dennis Philip and Aldred Debra, 2016) Integrating analytical frameworks using said three aspects are done to measure Private green open space (PGOS) in Menteng. This method has been previously used as it promotes a more inclusive evaluation of urban green infrastructure (Kuras Noel J. and Smith Amanda C., 2020; Lin Justin and Barnett Jon, 2015). This aligns with recent urban ecological study emphasizing the value of small-scale green spaces in mitigating urban heat, enhancing stormwater infiltration, and promoting biodiversity (Cameron et al., 2012; Cheng Edward and Givoni Baruch, 2021). The fieldwork was conducted in three urban corridors within the Menteng district: Jl. Teuku Umar, Jl. Taman Cut Meutia, and Jl. Taman Suropati. These sites were selected as representative of different architectural styles, vegetation intensity, and diversity of zoning classifications. A total of 85 land parcels were sampled, encompassing residential, governmental, and institutional land uses, in order to capture variation in both form and function. Primary data collection involved in situ field surveys using measuring tapes and GPS devices to record total land area, built-up coverage, and green space extent. Simultaneously, remote sensing data were acquired via ArcGIS Pro, employing 2022 high-resolution satellite imagery alongside cadastral maps from the Jakarta government. These data were used to digitize, geo-reference, and validate parcel boundaries. In line with methods used in previous urban green space studies (Gaston et al., 2005; Tanaka et al., 2013), the study included visual documentation through geo-tagged photographs and zoning overlays. The Green Basic Coefficient (GBC) was calculated for each parcel using the formula:

$$Green\ Base\ Coefficient\ (\%) = \left(\frac{Green\ Open\ Space\ Area}{Total\ Land\ Area}\right) \times 100\%$$

Detailed table was compiled presenting data from each of the 85 land parcels, including variables such as building name, category, land area, built-up area, green area, and

Green Basic Coefficient (GBC). The area of built-up land and green land is assessed in order to evaluate its compliance with the GBC requirements, as set out in the 2022 Jakarta RDTR and Ministerial Regulation Number 14 of 2022 concerning Provision of RTH. To ensure the data credibility, the triangulation method is applied, comparing measurements obtained from GIS with field findings and regulatory classifications. Such methods of data collection can then be verified through direct survey to each study location (Bohn & Vilhena, 2019; Davern et al., 2017). Ultimately, this method allows for a more thorough assessment of PGOS, as a passive landscape feature and as an active ecology, embedded in the built environment. This way the significance of private green areas toward ecological resilience, which are often overlooked in official urban green infrastructure planning, may be analyzed further.

III. RESULT AND DISCUSSION

Green infrastructure policy is shaped by spatial planning instruments that outline minimum environmental standards, highlighting those related to land use and vegetation cover, as shown in Jakarta's green open space regulations. Such green open space requirements are primarily guided by zoning regulations, dictating minimum Basic Green Coefficient (GBC) to ensure ecological balance in urban areas. In the Draft Governor's Regulation on Detailed Spatial Planning (RDTR) for 2022, Basic Green Coefficient (GOS) is highlighted as one of the main provisions related to space usage regulations. This coefficient serves as a benchmark for the proportion of land allocated for greenery in relation to the total plot area. Within the Menteng district, zoning classifications have been established, each with specific minimum GOS requirements, typically ranging around 20%, in line with Ministerial Regulation No. 14/2022.

Table 1. GBC Requirement from Regulatory

Zoning Classification	Minimum GBC Requirement
Zone K	20%
Zone SPU	20%
Zone K	20%
Zone R	20%

These requirements reflect an effort to maintain ecological functions across various urban land uses by mandating a baseline proportion of green open space within each development zone. The residential character of Menteng is defined by building setbacks (rooilijn), which establish the spatial distance between the building and the plot boundaries, particularly at the front. On larger parcels, the primary structure is typically set back from all sides: front, rear, and lateral boundaries, resulting in a detached form that prevents the appearance of row housing and reinforces the distinctive spacious character of the district. On smaller plots, however, side setbacks are often permitted on only one side. Parcel boundaries are generally delineated by solid walls or hedges; in some areas, they are marked by subtle changes in elevation between the street and the plot. Plots facing drainage channels are typically fronted by berms that serve as transitional buffers between the roadway and private lots. The application of the garden city concept is evident in the integration of open spaces populated with low vegetation and shade trees, contributing to the aesthetic and ecological quality of the neighborhood. Menteng, as originally designed by P.A.J. Moojen, adopted a villa-based residential typology, in which private green spaces form an intrinsic part of each property, collectively contributing to the district's environmental function and urban character. Public roadways were also designed to include shaded pedestrian paths and communal gardens, enhancing both mobility and visual comfort.

Figure 1. Study Area

The overall spatial structure of Menteng, including its network of roads and green open spaces, reflects the fundamental principles of the garden city concept. The primary public green spaces planned for the district include Taman Suropati (formerly Burgermeester Bisschopplein) and Taman Cut Meutia (formerly Van Heutz Plein/ entrée Gondangdia). In addition, several secondary green areas referred to in Dutch as *plantsoen* (small gardens) complement the district's green infrastructure, such as the Loge Plantsoen in front of the Bappenas building, the lakeside garden on Jl. Lembang, and the green space on Jl. Sukabumi. The district's layout centers around the garden as its nucleus, with civic institutions and public facilities strategically arranged around it, while the residential quarters encircle and orient toward the central park. Kubatz's revised plan, the central garden concept was retained, but the surrounding residential configuration was no longer strictly radial. Instead, it became more dispersed, although government and key institutional buildings continued to frame the central space, maintaining the core intention of the garden city model.

A key distinction between Moojen's and Kubatz's designs lies in the removal of the original circular field, which was replaced by the smaller Taman Suropati. The residual open land was converted into a sports ground. In 1921, a stadium was constructed on the site to serve as a recreational facility for the Dutch colonial community and became the home of the Voetbalbond Indische Omstreken Sport (VIOS) football club. The area is now known as Taman Kota Menteng. The central axis of the Menteng district remains anchored by Taman Suropati, around which primary public institutions such as churches and administrative offices are situated. Menteng is widely recognized as one of Jakarta's most historically significant residential districts, characterized by a unique spatial identity in which villa style homes are enveloped by expansive private gardens.

Table 2. Results of green area, built area, and Green Basic Coefficient (GBC) for 85 land parcels in the study area.

No	Building Name	Category	Land Area (m²)	Built Area (m²)	Green Area (m²)	GBC (%)
1	Office No 1	B	1318	866	452	34%
2	House No 3	B	1233	860	373	30%
3	House No 5	B	2311	887	1424	62%
4	Office Pertimbangan Pajak No 7	C	1866	789	1077	58%
5	Sofian Hotel	C	2014	1501	513	25%
6	Office Departemen Pertanian	C	2153	1713	440	20%
7	Mess Perwira Angkatan Laut	B	5366	1167	4199	78%
8	Mosque Cut Meutia	A	2491	1835	656	26%
9	House A.H Nasution	A	2577	1726	851	33%
10	Embassy Of Vietnam No. 25	C	2477	1652	825	33%

No	Building Name	Category	Land Area (m²)	Built Area (m²)	Green Area (m²)	GBC (%)
11	House No. 11	B	2625	1836	789	30%
12	Art Gallery Kunstkring No.1	A	3249	731	2518	78%
13	House No.9	B	2629	1376	1253	48%
14	House Jl. Teuku Umar No.5a	C	1271	689	582	46%
15	House Jl. Teuku Umar No.5	C	2500	1393	1107	44%
16	House Jl. Teuku Umar No.11	B	2625	1836	789	30%
17	House Jl. Teuku Umar No.15	B	2543	1527	1016	40%
18	House Jl. Teuku Umar No.17	C	2015	1130	885	44%
19	House Jl. Teuku Umar No.19	B	1807	786	1021	57%
20	House Jl. Teuku Umar No.21	C	2633	1146	1487	56%
21	House Jl. Teuku Umar No.23	B	2542	1190	1352	53%
22	House Jl. Teuku Umar No.27	B	3948	1203	2745	70%
23	House Jl. Teuku Umar No.39	B	1210	920	290	24%
24	House Jl. Teuku Umar No.41	C	1102	639	463	42%
25	House Jl. Teuku Umar No.43	B	1116	622	494	44%
26	House Jl. Teuku Umar No.45	N/A	1162	701	461	40%
27	House Jl. Teuku Umar No.47	C	1127	868	259	23%
28	House Jl. Teuku Umar No.49	C	1114	562	552	50%
29	House Jl. Teuku Umar No.53	C	1539	687	852	55%
30	House Jl. Teuku Umar No.55	C	1150	602	548	48%
31	House Jl. Teuku Umar No.57	C	1654	564	1090	66%
32	House Jl. Teuku Umar No.2	B	2975	698	2277	77%
33	House Jl. Teuku Umar No.26-28	C	2778	683	2095	75%
34	House Jl. Teuku Umar No.30	C	815	497	318	39%
35	House Jl. Teuku Umar No.30a	N/A	614	585	29	5%
36	House Jl. Teuku Umar No.30b	C	1246	900	346	28%
37	House Jl. Teuku Umar No.32	C	2642	1207	1435	54%
38	House Jl. Teuku Umar No.34	C	2849	2235	614	22%
39	Office Iraq Republic Embassy Jl. Teuku Umar No.38	C	2848	1500	1348	47%
40	Museum Jenderal Besar Dr. A.H Nasution Jl. Teuku Umar No.40	B	2577	1726	851	33%
41	House Jl. Teuku Umar No.42-44	C	5131	3306	1825	36%
42	House Jl. Teuku Umar No.46	B	2553	1503	1050	41%
43	House Jl. Teuku Umar No.48	C	2368	1291	1077	45%
44	House Jl. Teuku Umar No.50	C	1730	859	871	50%
45	House Jl. Teuku Umar No.52a-52	C	986	402	584	59%
46	House Jl. Teuku Umar No.54	C	775	480	295	38%
47	House Jl. Teuku Umar No.56	B	932	669	263	28%
48	House Jl. Teuku Umar No.58	B	1058	411	647	61%
49	House Jl. Teuku Umar No.60	C	1605	965	640	40%
50	House Jl. Teuku Umar No.62	C	1391	1056	335	24%
51	House Jl. Teuku Umar No.64	N/A	1486	920	566	38%
52	House Jl. Teuku Umar No.66	C	1499	794	705	47%
53	Embassy Of Egypt	C	1505	1136	369	25%
54	House Jl. Teuku Umar No.70	C	1515	1068	447	30%
55	House Jl. Teuku Umar No.72-74	C	3075	992	2083	68%
56	House Jl. Teuku Umar No.76	C	1576	789	787	50%
57	House Jl. Teuku Umar No. 4a	C	341	300	41	12%
58	House Jl. Teuku Umar No. 4	C	348	237	111	32%
59	House Jl. Teuku Umar No. 6	C	440	187	253	58%
60	House Jl. Teuku Umar No. 8	C	1087	905	182	17%
61	Office KPAI Jl. Teuku Umar No. 10-	C	3129	1968	1161	37%

No	Building Name	Category	Land Area (m²)	Built Area (m²)	Green Area (m²)	GBC (%)
	12					
62	House Jl. Teuku Umar No. 14	C	1550	698	852	55%
63	House Jl. Teuku Umar No. 16	C	288	223	65	23%
64	House Jl. Teuku Umar No. 18	C	330	244	86	26%
65	House Jl. Teuku Umar No. 22	C	835	519	316	38%
66	House Jl. Teuku Umar No. 24	C	1000	563	437	44%
67	House Jl. Teuku Umar No. 36	C	2564	2235	329	13%
68	House Jl. Teuku Umar No. 37	C	1158	591	567	49%
69	House Jl. Teuku Umar No. 33	C	1232	924	308	25%
70	House Jl. Teuku Umar No. 27A	C	1312	760	552	42%
71	House Jl. Teuku Umar No. 13	C	2629	1774	855	33%
72	House Jl. Teuku Umar No. 7	C	3750	1392	2358	63%
73	House Jl. Teuku Umar No. 3	C	1914	1255	659	34%
74	House Jl. Teuku Umar No. 1A	C	673	350	323	48%
75	House Jl. Teuku Umar No. 51	B	1753	574	1179	67%
76	House Jl. Teuku Umar No. 55	B	1150	601	549	48%
77	House Jl. Teuku Umar No. 59	-	1810	1477	333	18%
78	House Jl. Teuku Umar No. 61	-	2084	986	1098	53%
79	House of India Ambassador	B	3945	902	3043	77%
80	House of Jakarta Governor	A	3716	1460	2256	61%
81	House Wakil Dubes Belanda	B	2026	861	1165	58%
82	House of US Ambassador	B	9185	940	8245	90%
83	House No.4	B	4120	963	3157	77%
84	Office A. Yani No.10	A	6875	2267	4608	67%
85	Residence Office of deceased Letjen Suprapto	A	786	260	526	67%
					average	44%
					max	90%
					min	5%

Based on the analyzed data from 85 plots, private green open spaces within residential plots in this area exhibit an average Green Basic Coefficient (GOS) of approximately 44%, with observed values ranging from a minimum of 5% to a maximum of 90%. These results exceed the minimum regulatory standard and confirm that nearly half of each parcel's total area remains unbuilt and vegetated. This high average GOS reflects one of the core spatial characteristics of Menteng's original urban design: the deliberate balance between built structures and natural environments to enhance residents' quality of life. The high proportion of private green spaces does more than contribute to the aesthetic appeal and tranquility of the district as they play a critical role in ecological functions. The capacity of these spaces to absorb rainwater and reduce surface runoff, mitigates the risks of inundation and flooding. Permeable ground surfaces facilitate groundwater recharge and minimizes surface runoff, supporting urban flood control strategies (de la Barrera et al., 2023). With a high GOS of 44%, Menteng is proven to have better infiltration performance. The area of green land helps to reduce the impact of the Urban Heat Island (UHI). Vegetation cools the surrounding environment through evapotranspiration, this process can reduce the surrounding air temperature. This aligns with findings by Estoque et al. (2017), who observed that areas with green land were able to reduce surface temperatures by up to 3°C. In this case, Menteng has quite a large area of green land, especially in private housing. Menteng's large private green spaces can significantly improve air quality. Vegetation in Menteng functions as a natural filter for pollutants in the air, capturing dust particles and absorbing harmful gases such as carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_x). Photosynthesis, where plants absorb CO_2 and produce oxygen, has been shown to contribute to climate change mitigation and public health (Hanson et al., 2021), Urban ecology theory states that green land is very important in maintaining the ecological network in the city (Kim et al., 2022). In addition to environmental benefits, green open spaces in Menteng increase urban biodiversity in both city parks and private parks, green spaces allow various species of plants and animals to thrive. Field observations of nesting birds and pollinators in Menteng suggest that this district retains its function as a biodiverse urban habitat.

As densification pressures intensify, urban neighborhoods across Jakarta face the loss of vegetated areas due to unchecked development. However, as shown in Menteng, maintaining high proportions of private green open space enhances a neighborhood's environmental resilience. These findings support the theory that small-scale, widely distributed green infrastructure especially on private plots can contribute meaningfully to urban sustainability goals (Locke & McPhearson, 2018; Shashua-Bar & Hoffman, 2000). Spatial analysis was supported by a street-level visualization of the study area and tabulated data summarizing green area, built area, and calculated GOS for 85 individual land parcels. The table reveals that a majority of parcels maintain a GOS above the 20% regulatory threshold, with a significant number exceeding 44%. This distribution underscores the prevalence of high green coverage across private plots in Menteng, reinforcing the ecological value embedded in the district's original urban design. Although no formal spatial distribution map or histogram is presented, the detailed tabulation serves as a quantitative representation of Menteng's green space configuration and supports the broader conclusion regarding its high ecological performance.

In summary, the analysis confirms that private green open spaces in Menteng, averaging a GOS of 44%, fulfill critical ecological, social, and planning functions. These values significantly exceed the current minimum regulatory requirement of 20% GOS across all zoning classifications in the district, including Zona K, Zona SPU, and Zona R. This gap suggests that the existing minimum thresholds may no longer reflect the actual ecological potential or needs of the area.As such, there is a strong need for revisiting current zoning regulations to raise the minimum GOS requirement as doing so could help preserve ecological functions, encourage sustainable land use, and reinforce Jakarta's broader climate resilience targets. Study results validate the effectiveness of Menteng's historical planning model and provide a case for more ambitious urban greening standards in similar urban contexts. Water absorption, mitigation of urban heat, improvement of air quality, and biodiversity support are all standards that have been shown through Menteng's spatial organization. With proper policy attention and conservation efforts, Menteng should serve as a replicable model for resilient urban neighborhoods in tropical megacities.

The role of PGO in urban resilience and sustainability have been increasingly highlighted in international studies. In the United Kingdom, private residential gardens make up to a third of urban green space, as a fragmented ecological network that contributes to biodiversity and local cooling (Gaston et al., 2005). In Japan, traditional tsuboniwa (courtyard gardens) offer thermal regulation and psychological benefits in dense urban centers like Tokyo (Tanaka et al., 2013). In Brazil, private backyard gardens in informal settlements have been found to provide food provision, cooling, and urban greening (Bohn & Vilhena, 2019). In Australia, private yards account for over half of Melbourne's urban canopy as part of the city's climate adaptation strategies (Davern et al., 2017). All studies above prove a previous finding which states that small-scale green spaces such as private gardens enhance stormwater absorption, mitigate urban heat, and provide refuge for biodiversity in rapidly urbanizing environments (Lin et al., 2015). Similarly, (Dennis & James, 2016) found that incorporating private green spaces into formal urban planning frameworks can improve both ecological connectivity and urban resilience. Private green patches, although small, collectively offer substantial benefits when their role is formally recognized and managed as part of the broader green infrastructure network (Kuras et al., 2020).

(Cheng et al., 2021) emphasize that integrating green elements in urban design improves resilience against extreme weather and increases urban sustainability performance. Private gardens have the potential to serve as multifunctional urban green spaces that yield benefits for individual homeowners and the broader urban community. (Cameron et al., 2012) stress the role of domestic gardens in urban green infrastructure, as they provide a scalable and cost-effective opportunity to improve city-wide environmental outcomes. However, the extent of these benefits is tied to factors such as garden size, layout, and how they are managed (Home M. and Bauer N., 2019; Smith K.J. and Warren P.H. and Thompson K., 2005; van Heezik C. and Porter S. and Dickinson K.J.M., 2013). These underline that PGOS, though often overlooked in planning documents, are critical for climate mitigation, adaptation, and enhancing urban livability.

IV. CONCLUSION

This study confirms the substantial ecological contributions of private green open spaces (PGOS) in Tropical Megacities urban district, demonstrating their value as key assets in climate responsive urban design. With an average Green Basic Coefficient (GBC) of 44% across 85 land parcels significantly exceeding the regulatory minimum of 20%, the findings show that a high proportion of vegetated private land can effectively support multiple ecosystem services. These include enhanced stormwater infiltration, mitigation of the urban heat island effect, carbon sequestration, air purification, and biodiversity support. As such, PGOS play a critical role in reducing urban environmental vulnerability and enhancing livability in tropical megacities. The practical contribution of this study lies in its empirical validation of PGOS performance using parcel-level geospatial analysis and field-based measurements. Theoretically, the study expands current discourse in urban green infrastructure by focusing on the often-overlooked role of privately managed green areas in achieving sustainability goals. Methodologically, the application of the Green Basic Coefficient as a spatial diagnostic tool offers a replicable and policy-relevant metric for assessing urban green performance in contexts where public green spaces are limited. These findings have direct implications for policymakers, urban planners, and regulatory authorities. Given that the actual average GBC exceeds the required minimum by more than double, this study suggests the need to revise existing zoning regulations to raise the baseline requirement, thereby aligning formal standards with the ecological potential and resilience needs of the area. Conservation-oriented planning approaches can help ensure that legacy districts such as this continue to serve as green infrastructure exemplars within Jakarta's broader climate strategy. Internationally, the study contributes to the growing body of study that emphasizes the integration of small-scale green infrastructure, particularly in private domains as a critical component of climate adaptation frameworks. Cities facing rapid densification and land scarcity may benefit from adopting similar green coefficient-based evaluations to regulate and incentivize vegetation retention in private urban developments. Limitations of this study include its spatial focus on a single urban district with historical planning characteristics, which may not reflect conditions in newer or denser urban areas. Additionally, the study prioritized green space quantity (GBC) rather than qualitative aspects such as vegetation type, health, or biodiversity value. Temporal dynamics such as seasonal variation in green cover were also beyond the study's scope. Future study should expand to cover various urban typologies, employ remote sensing or biodiversity indexing for ecological quality assessment, and examine the longitudinal impacts of PGOS under shifting urbanization pressures. Study exploring incentive models for private greening efforts may further inform policy interventions. In summary, this study demonstrates that private green open spaces, when well-integrated and preserved, significantly contribute to urban climate resilience, ecological function, and quality of life. As cities around the world grapple with climate stressors, revisiting planning regulations to embrace and elevate the value of PGOS will be essential in achieving sustainable, inclusive, and adaptive urban futures.

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