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Greenspace Evaluation And Risk Assessment In An Industrial Area: The Case Of PT. Pupuk Sriwidjaja Palembang

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Abstract: Effective greenspace management in industrial areas hinges on systematic assessment and early risk identification, particularly concerning tree health. Tree health assessment is a key diagnostic tool that uses empirical indicators to detect signs of stress, damage, and structural weaknesses, factors critical to evaluating potential risks and estimating tree longevity. This study evaluates the condition of trees within the greenspaces of PT. Pupuk Sriwidjaja Palembang, aiming to support informed decision-making for maintenance and risk mitigation. Field surveys employed the Visual Tree Assessment (VTA) method and applied criteria from the USDA Forest Health Monitoring (FHM) protocol, focusing on key indicators such as physical damage, crown condition, and site quality. esults showed that 57.7% of trees were healthy, while 42.3% exhibited varying levels of damage: 29.5% with light damage, 11.1% with moderate damage, and 1.7% with heavy damage. Common types of damage included broken or dead branches, brums, conks, and open wounds. Spatial analysis demonstrated that tree damage was predominantly concentrated in the northern zones, especially in road corridors, office areas, and parks, whereas minimal damage was observed in the green barrier. These findings highlight the importance of routine tree health monitoring, targeted maintenance strategies, and the integration of spatial risk mapping to ensure safer, healthier, and more resilient green infrastructure in industrial landscapes.

Keywords: Greenspace, Tree Health Evaluation, Risk Assessment, PT. Pupuk Sriwidjaja Palembang

I. INTRODUCTION

Trees in greenspaces, including those in industrial environments, play critical roles in enhancing environmental quality and supporting human well-being (Pandit et al., 2013; Taylor et al., 2015). Their services include improving air quality, regulating microclimates, supporting biodiversity, and contributing aesthetic and recreational value (Pandit et al., 2013; Linhares et al., 2021). In urban settings, these benefits further align with broader sustainability goals (Roy et al., 2012). However, trees in such environments may also pose hazards, such as falling branches or entire tree failures, which can endanger public safety and nearby infrastructure (Roy et al., 2012). These risks are often intensified by stressors such as air pollution, pest infestations, diseases, water stress, vandalism, and mechanical damage (Mangold, 1998; Chi et al., 2020; Linhares et al., 2021). Consequently, routine assessment of tree health is essential, not only to maintain ecological functionality but also to minimize hazards and enhance the safety and resilience of urban landscapes (Fink, 2009).

Tree health assessment methods encompass a broad spectrum, ranging from basic visual inspections to sophisticated diagnostic technologies. Among these, visual assessments remain the most commonly employed, relying on systematic observation of external symptoms such as crown dieback, bark lesions, cavities, fungal fruiting bodies, or abnormal coloration patterns (Mattheck and Breloer, 1994; Mangold, 1998). While effective for initial evaluations, visual inspections can be enhanced by the integration of advanced diagnostic tools, including acoustic tomography, resistance drilling, and hyperspectral imaging, which provide detailed insights into internal wood conditions, decay progression, and physiological stress indicators (Karlinasari et al., 2018; Hanum et al., 2020; Linhares et al., 2021).

PT. Pupuk Sriwidjaja Palembang (PUSRI), a key player in Indonesia's fertilizer industry, has integrated green infrastructure throughout its premises as part of its commitment to environmentally responsible industrial operations. The company maintains various types of greenspace, including road corridors, buffer zones, residential greenery, and park areas. These greenspaces serve not only as ecological assets but also as integral components of the company's environmental management system. Assessing the health of trees in these areas is crucial to support evidence-based maintenance, risk reduction, and sustainability planning.

This study aims to assess the health status of trees and the associated risks they pose within the greenspaces of PUSRI. The findings are intended to inform and strengthen the company's greenspace management strategies by identifying priority zones for intervention, mitigating potential hazards, and enhancing the delivery of ecosystem services. In doing so, the assessment underscores Pusri's broader environmental stewardship goals and reinforces the importance of integrating ecological health into industrial risk management frameworks.

II. RESEARCH METHODOLOGY

2.1. Study Area

PT. Pupuk Sriwidjaja Palembang is located approximately 7 km from the city center, on Jalan Mayor Zen, Sungai Selayur, Ilir Timur II District, Palembang, which lies at an elevation of 14 meters above sea level (see Figure 1). Field measurements showed that air temperatures during the study period ranged from 28°C to 31°C, with relative humidity levels between 65% and 81%. Light intensity under the tree canopy varied from 520 to 5,046 lux. According to the BPS-Statistics of Palembang Municipality (2025), the highest average air temperatures typically occur between June and October, reaching up to 35.1°C, while the lowest are recorded in September, dropping to 19.8°C. Wind speeds in the Palembang region remain relatively stable throughout the year, ranging from 3.20 to 4.40 m/s. Seasonal rainfall varies significantly, with averages ranging from 97.2 mm in July to 407.3 mm in January.

PT. Pupuk Sriwidjaja Palembang actively demonstrates a strong commitment to environmental management. This is evident in the formal designation of several greenspaces aimed at conservation and biodiversity protection, as outlined in the Director's Decree No. SK/DIR/122/2023. The designated areas include Green Barrier zones, wildlife breeding areas (for deer, birds, and butterflies), rare plant cultivation zones, residential and office greenspaces, and an orchid garden.

Figure 1. Map of study area.

2.2. Data Collection Method

The greenspaces within PUSRI were initially classified into four zones: Road Corridor, Office and Park, Residential, and Green Barrier. Sampling points were subsequently distributed randomly across these zones using QGIS, guided by a risk-based stratification approach that prioritized areas with greater potential threats to human safety and economic assets. As a result of this weighted distribution, 35% of the sampling points were allocated to the Road Corridor, 30% to the Office and Park areas, 25% to Residential zones, and 10% to the Green Barrier (see Figure 2). This method was designed to ensure both spatial representativeness and strategic focus on zones of higher vulnerability. In instances where a randomly generated point did not coincide with an actual tree location, the point was manually adjusted to the nearest tree to ensure data relevance and methodological consistency.

Figure 2. Spatial distribution of sampling points across greenspaces at PT. Pupuk Sriwidjaja Palembang.

Tree health assessments were carried out using an integrated approach that combined Visual Tree Assessment (VTA) and Forest Health Monitoring (FHM) methodologies (Tallent-Halsell, 1994; Fink, 2009; Mattheck and Breloer, 1994). These approaches evaluate tree vitality based on physical damage, crown condition, and site quality. Each tree was systematically inspected based on three primary indicators: damage location (L), damage type (T), and damage severity (K). These parameters were assessed through visual inspection of all major structural components of the tree and were subsequently classified according to the standardized coding system described by Tallent-Halsell (1994) (see Table 1 and Figure 3).

Table 1. Codes and corresponding descriptions of tree damage locations.

Code	Description
L0	Healthy (no visible damage)
L1	Exposed roots and stumps (up to 30 cm above ground level)
L2	Damage to roots and lower bole
L3	Damage to the lower bole (lower ½ of the trunk between the stump and the base of the living crown)
L4	Damage to both lower and upper bole
L5	Damage to the upper bole (upper ½ of the trunk between the stump and the base of the living crown)
L6	Damage to the crown stem (main stem within the living crown, above the base of the crown)
L7	Damage to branches (>2.54 cm in diameter at the branching point from the main trunk or crown stem within the living crown area)
L8	Damage to buds and shoots (recent years' growth)
L9	Foliage

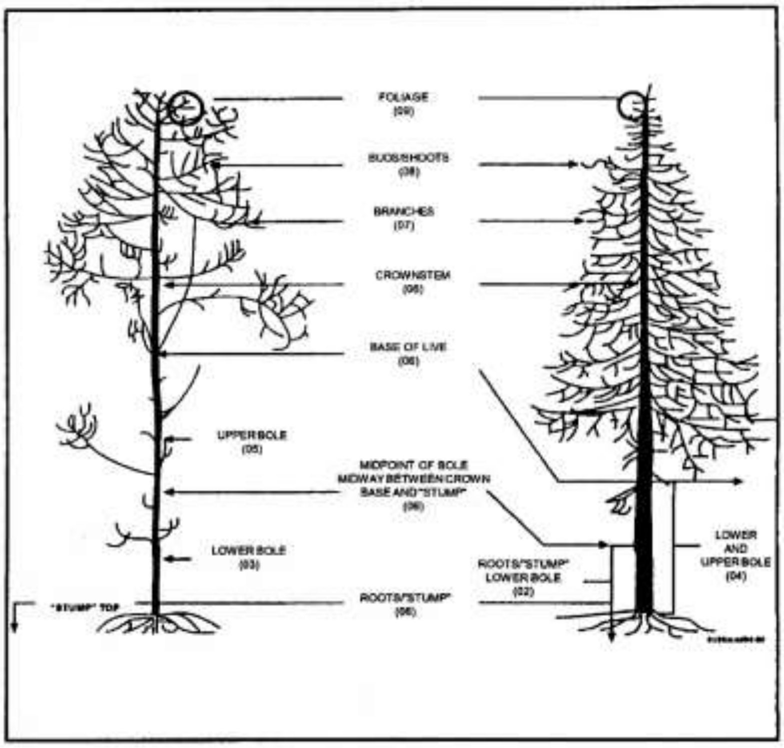

Figure 3. Damage location code on trees (Tallent-Halsell, 1994).

The type of damage for each tree was identified based on the coding system presented in Table 2. Damage types represent conditions that could result in tree mortality or significantly impair long-term vitality. Severity was evaluated on a scale from 0% to 99% (Nuhamara and Kasno, 2001). A maximum of three distinct damage occurrences were recorded per tree. If multiple damages were found at the same location, only the most severe instance was documented (Pertiwi et al., 2019; Nuhamara and Kasno, 2001).

Table 2. Damage type codes and descriptions.

Code	Damage Type	Characteristic
T1	Canker or gall	Swelling found on roots, trunks, or branches
T2	Conk and fruiting bodies	Presence of conks, fruiting bodies, or other signs of advanced decay
T3	Open wound	The bark or inner part of the wood peels off
T4	Resinosis/gummosis	Resin or gum exuding from branches or trunks
T5	Broken trunk	Breakage in the trunk, branch, or root
T6	Termite nest	Presence of termite nests on any part of the tree
T7	Lianas on the trunk	Lianas or woody vines growing on the trunk
T11	Broken roots or trunks	Breakage in roots or trunk less than 0.91 meters (3 feet) from the trunk
T12	Brum on roots or trunks	Abnormal excessive branching with dense twig clusters on roots or trunks
T13	Broken or dead roots	Dead or broken roots more than 0.91 meters from the trunks
T14	Wax lice	Presence of white waxy secretions (from scale insects) between leaf nodes
T20	Lianas on crown or mistletoe	Lianas on crown/leaves or presence of parasitic plants like mistletoe
T21	Dead or missing dominant shoot	Loss or death of the main crown stem tip
T22	Broken or dead branches	Branches that are broken or no longer living
T23	Excessive branching or brum	Dense, clustered, or abnormal twig growth
T24	Damaged leaves, buds, or shoots	Visible breakage or deformities in young growth
T25	Leaf discoloration	Rusty brown, purple, black, gray, or white spotting on leaves
T31	Etc	Other observable damage not listed above

2.3. Data Analysis

All data recorded from fieldwork, including damage types, locations, and severity levels, were used to calculate the Damage Index (DI) for each tree, following the system outlined by Safe'i et al. (2020) (Table 3). A maximum of three DI scores were considered for each tree, representing up to three distinct damage observations (Safe'i et al., 2020; Tallent-Halsell, 1994; Nuhamara and Kasno, 2001). These scores were then summed to obtain the Tree Damage Level Index (TDLI). The TDLI values were subsequently used to classify each tree into one of four condition categories: healthy, light damage, moderate damage, or heavy damage (Table 4). Finally, the spatial distribution of tree condition was analyzed using Kernel Density Estimation (KDE) in QGIS to identify areas with a higher density of heavily damaged trees, which were interpreted as high-risk zones.

Table 3. Assigned values for damage type, location, and severity.

Damage Type (T)	T Value	Damage Location (L)	L Value	Severity Percentage (K)	K Value
T1	1.9	L0	0	0-9	1
T2	1.7	L1	2	10-19	1.1
T3, T4	1.5	L2	2	20-29	1.2
T5	2	L3	1.8	30-39	1.3
T6, T7	1.5	L4	1.8	40-49	1.4
T11	2	L5	1.6	50-59	1.5
T12	1.6	L6	1.2	60-69	1.6
T13, T20	1.5	L7	1	70-79	1.7
T21	1.3	L8	1	80-89	1.8
T14, T22, T23, T24, T25, T31	1	L9	1	≥ 90	1.9

The following equations were used to calculate the Damage Index (DI) and Tree Damage Level Index

$$\text{DI} = \text{T Value} \times \text{L Value} \times \text{K Value} \ldots\ldots\ldots\ldots (1, 2, 3)$$

$$\text{TDLI} = \text{DI}_1 + \text{DI}_2 + \text{DI}_3$$

Table 4. Classification of tree condition levels based on TDLI.

TDLI Score	Category
≤ 5	Healthy
06-10	Light Damage
11-15	Moderate Damage
≥ 16	Heavy Damage

III. RESULT AND DISCUSSION

3.1 Diversity and Composition

Tree health assessments were carried out across four ecologically distinct zones within the greenspaces of PT. Pupuk Sriwidjaja Palembang: the Road Corridor, Office and Park Areas, Residential Areas, and the Green Barrier. A total of 468 individual trees were surveyed, encompassing 36 species from 21 different families (Table 7). Among the 36 recorded species, the three most abundant were Filicium decipiens (115 individuals, 24.57%), Pterocarpus indicus (99 individuals, 21.15%), and Swietenia macrophylla (84 individuals, 17.94%). Mimosoideae family exhibited the highest species richness, represented by five species: Acacia auriculaeformis, Pithecellobium dulce, Falcataria moluccana, Acacia mangium, and Albizia saman. This was followed by the Moraceae family, which included four species such as Ficus benjamina, Artocarpus heterophyllus, Calophyllum inophyllum, and Artocarpus altilis.

Table 5. Tree species composition in the greenspace of PT. Pupuk Sriwidjaja Palembang.

Family	Species	Amount
Anacardiaceae	Mangifera indica	1
Annonaceae	Polyalthia longifolia	2
	Stelechocarpus burahol	3
Apocynaceae	Alstonia angustiloba	3
Araucariaceae	Araucaria heterophylla	1
Caesalpinioideae	Tamarindus indica	3
	Delonix regia	1
Casuarinaceae	Casuarina equisetifolia	2
Combretaceae	Terminalia catappa	7
	Terminalia mantaly	1
Ebenaceae	Diospyros discolor	1
Euphorbiaceae	Hura crepitans	5
Lamiaceae	Tectona grandis	2
Lythraceae	Lagerstroemia floribunda	6
Meliaceae	Swietenia macrophylla	84
	Sandoricum koetjape	1
Mimosoideae	Acacia auriculaeformis	1
	Pithecellobium dulce	3
	Falcataria moluccana	13
	Acacia mangium	1
	Albizia saman	34
Moraceae	Ficus benjamina	2
	Artocarpus heterophyllus	1
	Calophyllum inophyllum	2
	Artocarpus altilis	7
Myrtaceae	Melaleuca leucadendra	2
	Syzygium polyanthum	7
	Cynometra browneoides	1
Papilionoideae	Pterocarpus indicus	99
Pinaceae	Pinus caribaea	1
	Pinus merkusii	2
Rubiaceae	Neolamarckia cadamba	2
Sapindaceae	Filicium decipiens	115
	Pometia pinnata	4
Sapotaceae	Mimusops elengi	43
Sterculiaceae	Sterculia foetida	5
		468

3.2 Damage Location

As illustrated in Figure 4, damage to the crown stem (Code 6) was the most frequently observed, accounting for 267 cases or approximately 34.42% of all recorded damage. This is followed by damage to branches (Code 7) with 88 cases (11.35%), lower trunk (Code 3) with 84 cases (10.83%), and upper trunk (Code 5) with 80 cases (10.32%). The least observed damage occurred at code 8 (buds and shoots) and code 9 (leaves) with only 3 and 4 cases, respectively. Tree damage location refers to the specific part of the tree affected by injury, which may result from physical trauma, biotic factors such as pests and pathogens, or abiotic stressors like wind or pollution (Tallent-Halsell, 1994). Identifying the exact location of the damage is critical, as different tree components contribute uniquely to both structural stability and physiological function.

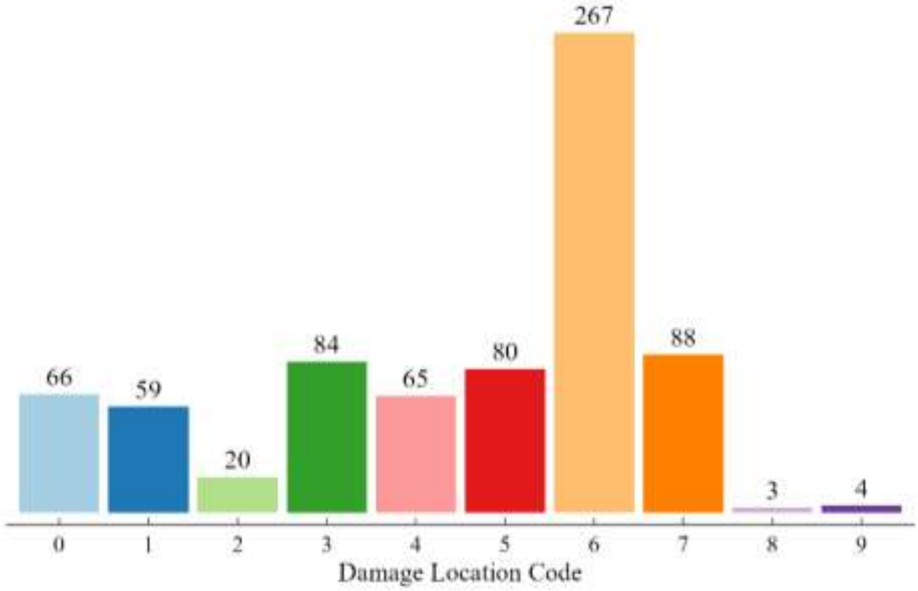

Figure 4. Number of trees by damage locations.

The high frequency of crown stem damage indicates potential issues with upper canopy stress, which can destabilize the tree under strong wind loads due to imbalanced weight distribution (Schomaker et al., 2007). Similarly, damage to the lower and upper trunk (Codes 3 and 5) is particularly concerning, as these zones play a pivotal role in supporting the tree's vertical structure (Nuhamara and Kasno, 2001; Nuhamara et al., 2001). While crown damage may lead to dieback or reduced photosynthesis, structural damage in the trunk and major branches can significantly increase the risk of tree failure and pose safety hazards. In terms of structural risk, damage to the lower trunk is often considered the most critical due to its central role in anchoring the tree, followed by the upper trunk, main branches, and crown, in descending order of severity (Nuhamara and Kasno, 2001; Tallent-Halsell, 1994; Nuhamara et al., 2001).

3.3 Type of Damage

A total of 17 types of tree damage were recorded in the greenspace areas of PT. Pupuk Sriwidjaja Palembang (Figure 5). The four most common types were brum on branches (code 23), broken or dead branches (code 22), conk (code 2), and open wounds (code 3), with frequencies of 144 (30.79%), 138 (29.48%), 119 (25.43%), and 100 (21.36%), respectively. In terms of impact on tree health, conk was considered the most serious, followed by open wounds, brum, and then broken or dead branches (Nuhamara et al., 2001). These damages may result from a range of causes, including weather events (like strong winds or storms), pests, diseases, or human activities such as poor pruning or accidental damage (Safe'i et al., 2014). For example, brum, or irregular shoot growth, usually develops after poor pruning and can add extra weight to branches and allow pests or diseases to enter. Broken or dead branches reduce the tree's ability to produce energy through photosynthesis and may invite fungi or insects, while also creating imbalance that increases the risk of falling. Conk, which appears as sunken or dark spots, is often a sign of internal rot caused by fungi or bacteria that weaken the tree and disrupt the flow of water and nutrients. Open wounds, whether from natural or human causes, can also allow harmful organisms to enter. While trees have a natural healing process, large wounds may not close completely, leaving the tree vulnerable to further damage and weakening over time (Tallent-Halsell, 1994; Nuhamara and Kasno, 2001; Nuhamara et al., 2001; Safe'i et al., 2014).

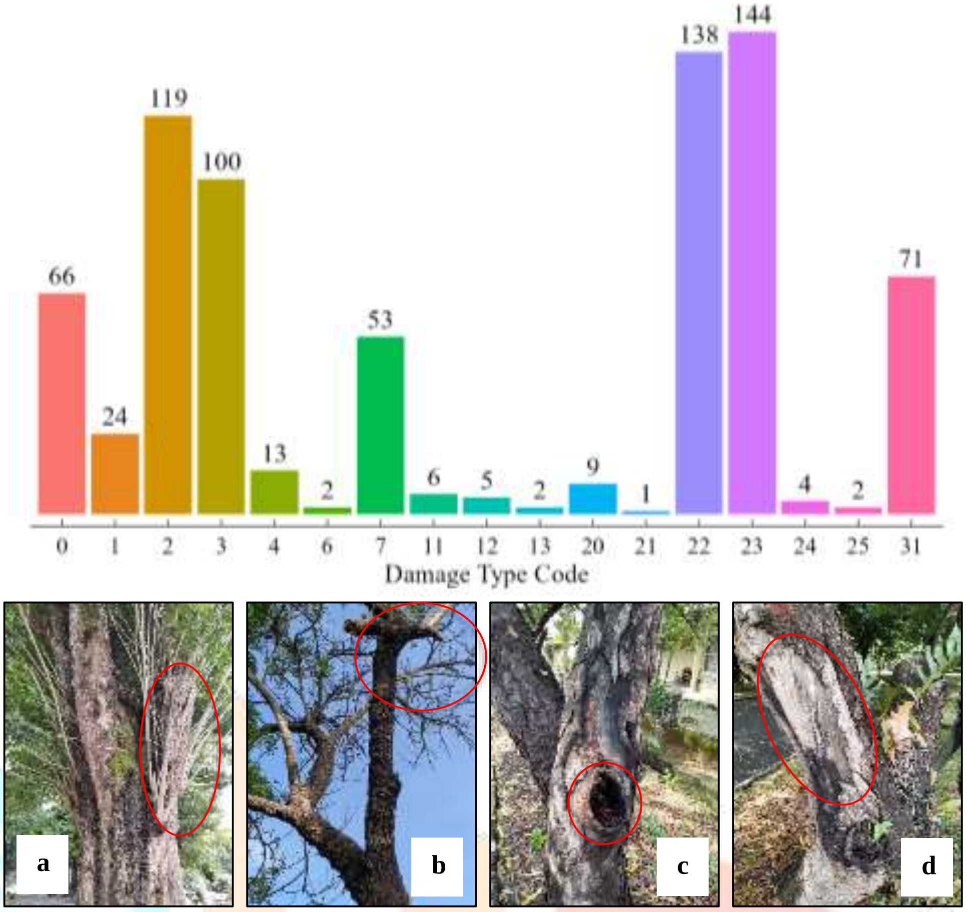

Figure 5. Number of trees by damage type: a) brum, b) dead branch, c) conk, and d) open wound.

3.4 Tree health status

Tree health status in this study was categorized into four levels: healthy, light damage, moderate damage, and heavy damage. As shown in Figure 6, the majority of trees in the greenspace of PUSRI were in healthy condition, accounting for 57.7% of the total. This was followed by trees with light damage (29.5%), moderate damage (11.1%), and heavy damage (1.7%). Trees with heavy damage status were identified in two main locations, i.e., the road corridor, with a total of three trees, and the residential areas, which recorded five trees in this condition. Moderate damage was more widely distributed, with the highest number found in the residential areas (22 trees), followed by the road corridor (13 trees) (see Figure 7).

A healthy tree is characterized by vigorous growth, dense green foliage, and the absence of visible structural damage to its roots, trunks, or branches. There are no signs of decay, infection, or physiological stress, and any minor physical imperfections are negligible and do not compromise the tree’s overall vitality (Safe’i et al., 2014). In contrast, a slightly damaged tree may show minor issues, such as dead twigs, small branches, superficial trunk wounds, or early signs of biotic or abiotic stress, but these do not significantly affect its structural integrity or function. Moderate damage is more severe and may include multiple large dead branches, deeper trunk wounds, canopy thinning, or early decay and infection, often accompanied by discolored or sparse foliage. Such trees require timely intervention, including pruning, structural support, or wound treatment, especially ahead of adverse weather conditions. Severely damaged trees exhibit extensive structural failure, such as cracked or rotting trunks, dead or compromised roots, widespread decay, and major loss of foliage, rendering them high-risk. These trees often pose serious safety hazards, and immediate action, typically tree removal, is necessary to protect surrounding people, property, and infrastructure (Tallent-Halsell, 1994; Nuhamara and Kasno, 2001; Nuhamara et al., 2001; Hanum et al., 2020; Caggiu et al., 2023).

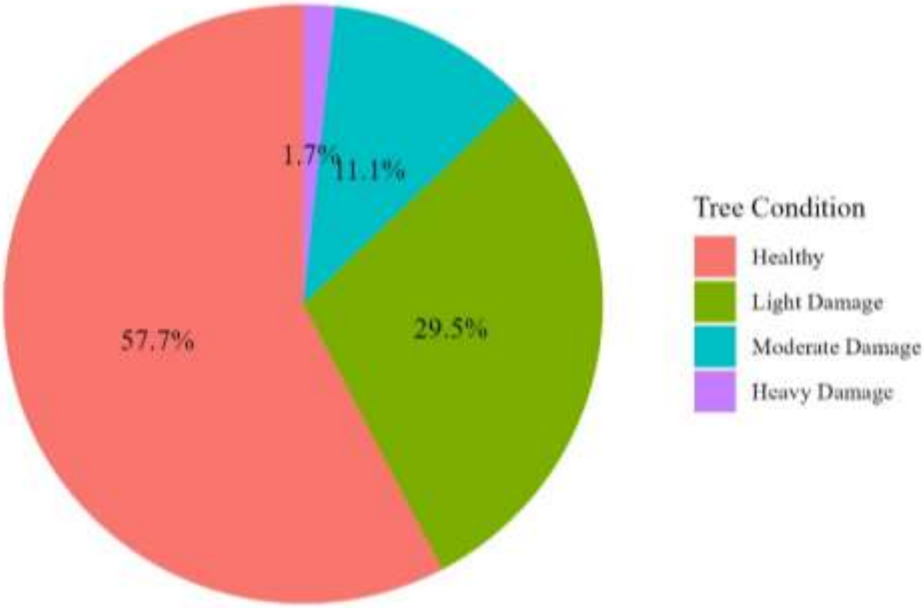

Figure 6. Proportion of trees by health status.

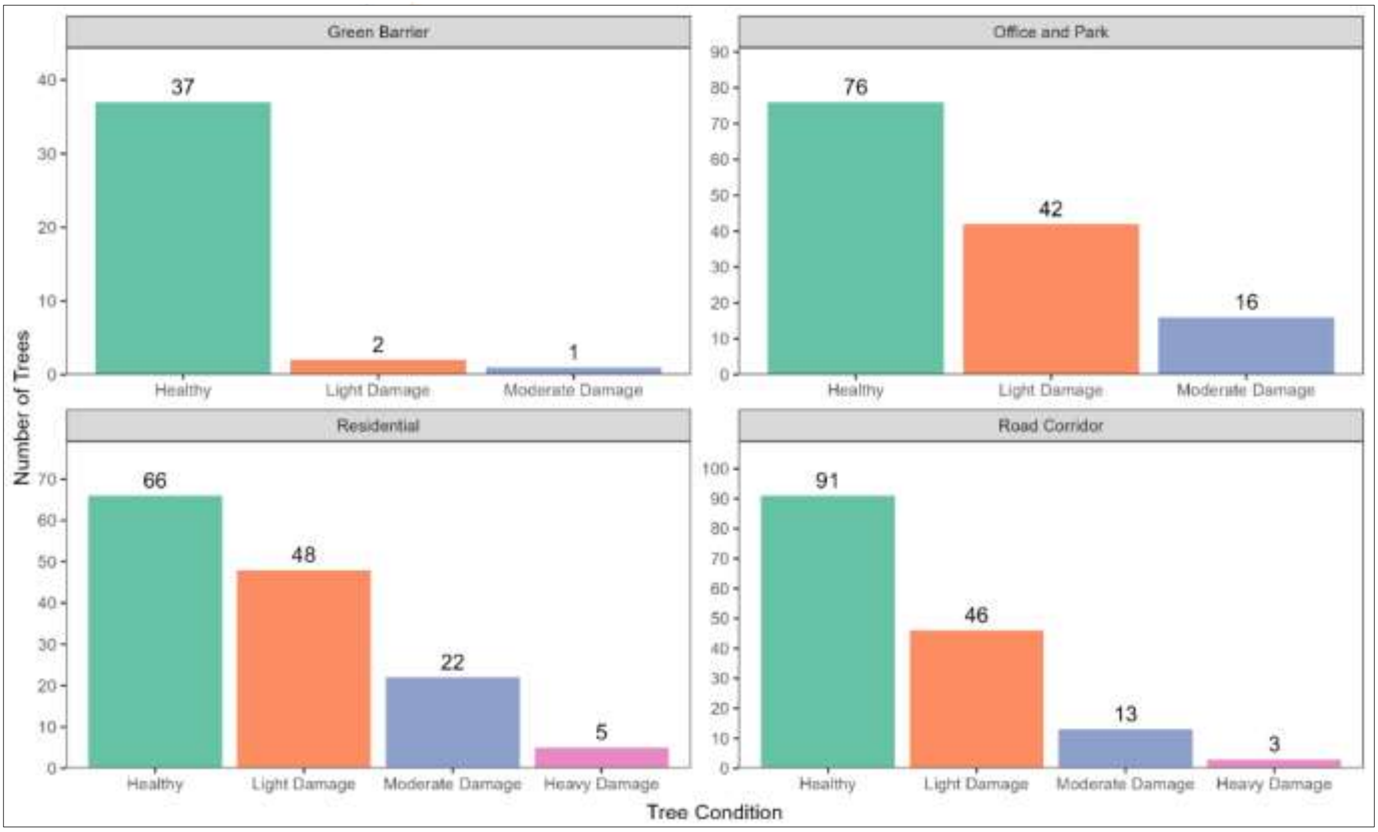

Figure 7. Number of trees by health status across surveyed greenspaces.

3.5 Spatial distribution of tree damage risk

Figure 8 reveals the spatial distribution of tree damage risk across the PUSRI area, highlighting key zones for management focus. The highest-risk zones are predominantly located in the northern section, specifically within road corridors and office and park areas. Additional high-risk clusters are also present in the northeastern parts, overlapping with residential areas. These areas exhibit a dense concentration of trees with moderate to heavy damage. Conversely, the southwestern part of PUSRI, which includes green barrier zones and residential areas, shows low to very low risk. From a management perspective, these spatial insights are crucial. They underscore the need for targeted interventions in high-risk zones, including routine health assessments, site-specific pruning programs, and restoration planning. Integrating this spatial risk mapping into a broader environmental monitoring framework can help anticipate structural tree failures, mitigate safety hazards, and ultimately enhance the provision of ecosystem services (Caggiu et al., 2023) within PUSRI's green spaces.

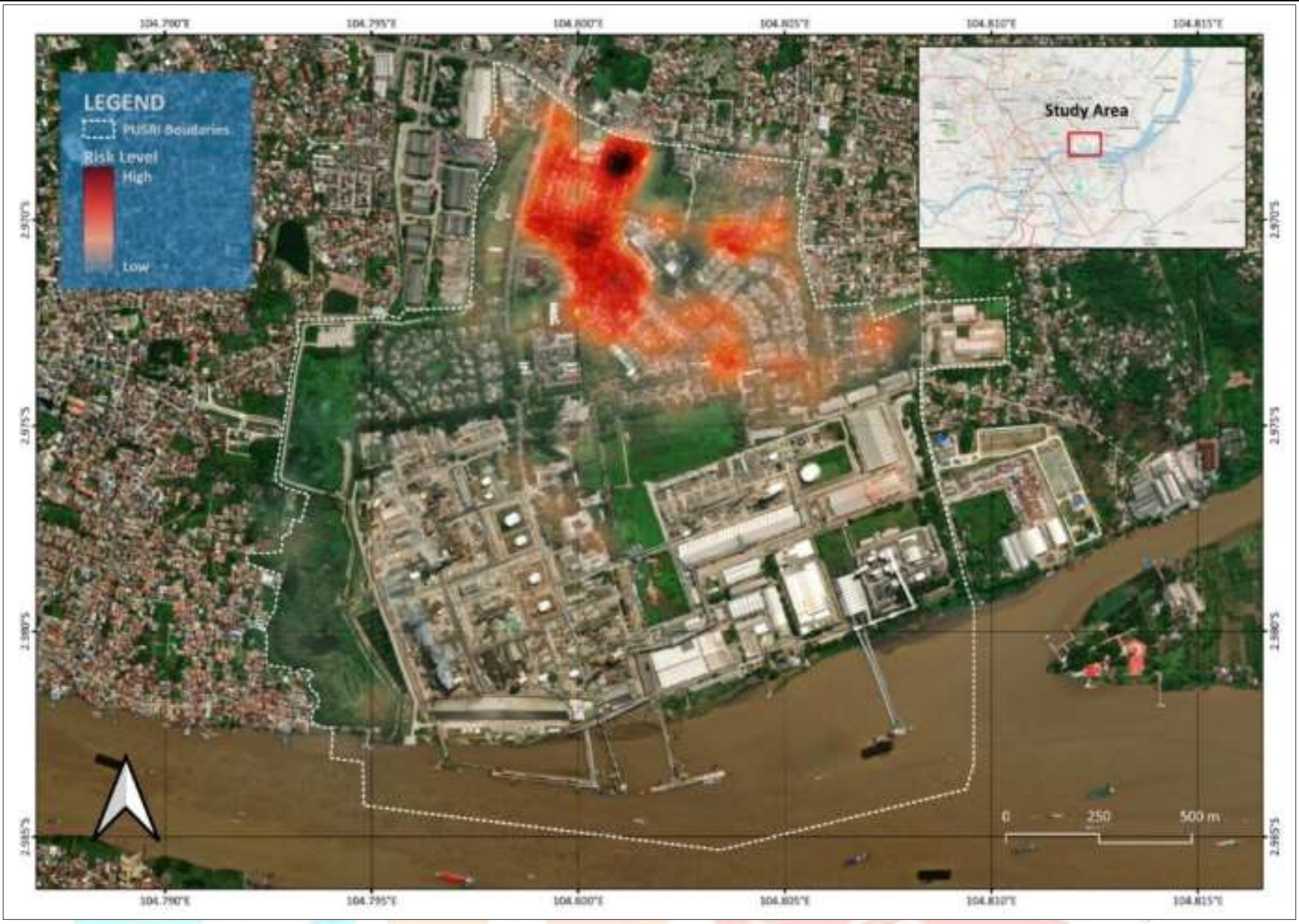

Figure 8. Risk level based on tree health conditions.

IV. CONCLUSION

Tree health assessment in the greenspaces of PT. Pupuk Sriwidjaja Palembang identified 468 trees from 36 species and 21 families. The dominant species were Filicium decipiens, Pterocarpus indicus, and Swietenia macrophylla. Overall, 57.7% of trees were healthy, while 42.3% showed varying levels of damage: 29.5% slight, 11.1% moderate, and 1.7% severe. The most common damage types included brum on branches, broken or dead branches, conk, and open wounds. Spatial analysis identified concentrated tree damage risks in northern zones, particularly in the road corridor, office, and park areas, contrasting with low-risk levels in the green barrier. These results underscore the need for targeted maintenance, regular health monitoring, and the integration of spatial risk mapping to support safer, healthier, and more resilient green infrastructure.

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