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Human-plant interactions in the urban vegetation: A comparative study between the National Botanical Garden and Ramna Park, Dhaka

Md. Abul Kashem[1]*, Mohammad Ataur Rahman[1], Sirajum Munira Hussaini[1], Md. Somajol Islam[2] and Mohammad Zabed Hossain[1]

[1]Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh, [2]Department of Soil, Water and Environment, University of Dhaka, Dhaka 1000, Bangladesh.

***Corresponding e-mail:** kashembotany@du.ac.bd

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Abstract

Rapid urbanization exerts considerable pressure on urban vegetation, affecting plant structure, health, and ecological resilience. This study assessed anthropogenic stress and structural damage in vegetation across two urban green spaces, the National Botanical Garden and Ramna Park in Dhaka, Bangladesh. The study was conducted in mid-September 2025 to avoid heavy rainfall and leaf fall effects. For data collection, a 10 × 10 m² quadrat was set up along the pathways at each site in the National Botanical Garden and Ramna Park, ensuring at least 200 m spacing between adjacent plots. A total of 295 individual plants representing 59 species were surveyed to evaluate population structure, species composition, and types of structural damage. Four major damage categories were considered: stem incision, leaf splitting, stem breakdown, and signboard attachment. Results revealed notable site-specific differences. The National Botanical Garden hosted a higher number of individuals (214) but experienced on incised plant body damage, indicating a relatively protected and managed environment. In contrast, Ramna Park exhibited slightly higher species richness but greater overall damage frequency, particularly incision and stem injury, reflecting stronger anthropogenic pressures such as visitor activity and traffic exposure. The results emphasize the influence of management intensity and visitor pressure on the health and structural stability of plants within urban green spaces. Minimizing physical disturbances, strengthening monitoring systems, and promoting resilient native species emerge as key measures to sustain ecological balance. This comparative evaluation offers important guidance for urban vegetation management and highlights the importance of sustainable planning to reduce human-induced stress in rapidly expanding tropical cities.

Keywords: Management effects, human-plant interactions, tree health, urban green spaces, Dhaka city

Introduction

Rapid urbanization has profoundly transformed natural landscapes into densely populated built environments, resulting in significant pressures on urban vegetation (Du *et al.* 2019, Kisvarga *et al.* 2023, Kashem *et al.* 2023). Urban green spaces, including parks, botanical gardens, and street trees, are critical components of urban ecosystems, providing multiple ecological, social, and economic benefits. They improve air quality by filtering particulate matter and pollutants, moderate microclimatic conditions through shading and evapotranspiration, reduce urban heat island effects, enhance carbon sequestration, and provide habitats for urban biodiversity (Satu *et al.* 2019, Escobedo *et al.* 2019, Raihan 2023, Murugadoss *et al.* 2024, Singh 2025). In addition, urban vegetation contributes to human well-being by offering recreational opportunities, improving aesthetics, and promoting mental health (Vujcic *et al.* 2017, Feng *et al.* 2025).

Despite their advantages, urban trees and green spaces are exposed to several anthropogenic and environmental stressors that may threaten their health and sustainability. Other anthropogenic stress factors that affect trees are soil compaction, rooting volume restriction, air pollution, mechanical wounding, nutrient deficiency and water stresses, and direct human disturbance together lower plant vitality, transform community structure, and perturb the function of the ecosystem (Marion and Leung 2001, Satu *et al.* 2019, Czaja *et al.* 2020, Gaur and Singh 2024). Physical injury, for example, bark cutting, leaf splitting, and causing stem breakage may have profound but localized effects on tree growth, erosion, photosynthetic capacity, and vulnerability to pathogens, which affect survival and long-term durability (Percival and Sheriffs 2002, Nowak *et al.* 2013). The urban vegetation, especially in developing megacities, has been exposed to great vulnerability due to dense human populations, rapid infrastructural development, and limited regulatory oversight, which exacerbate exposure to these stressors (Bernhardt *et al.* 2008, Meerow 2017).

In the case of megacities such as Dhaka, Bangladesh, increasing population pressure, vehicle emissions, along with unplanned infrastructure development marked by recreational overexploitation; over exploitation has escalated problems for maintaining urban vegetation as healthy (Meerow 2017, Escobedo *et al.* 2019, Kashem *et al.* 2023). Urban parks and botanical gardens are essential remnants of green infrastructure in this highly urbanized situation. They are not only elements of green recreation and aesthetics, but also living laboratories for the study of plant-environment relations in an urban setting under stress conditions (Satu *et al.* 2019, Raihan 2023). However, these sites are often subject to direct physical injury (e.g., stem cuts, leaf tears, and mechanical damage) as a result of visitors' or environmental variation accounts for more deaths than all other causes combined (Draper and Richards 2009, Marion *et al.* 2016). These injuries may affect photosynthetic efficiency, make the trees more susceptible to attack by pathogens, and limit survival over the long term (Percival and Sheriffs 2002, Satu *et al.* 2019).

Botanical gardens are usually more intensively managed and less open to the public, and thus provide less mechanical stress, or their planted individuals are better protected. In addition, city parks are mostly public and open to visiting, and their plants grow under strong disturbance of human-induced factors and natural environments to maintain their vitality (Sarah and Zhevelev 2015, Kashem *et al.* 2022). Knowledge of these differences is fundamental to measuring species-specific resilience, advising and implementing management and conservation actions. Prior studies focused mostly on plant species composition, air pollution tolerance, and physiological responses to abiotic stress (Sadia *et al.* 2019, Jashim *et al.* 2020).

Understanding these differences is essential for assessing species-specific resilience, guiding planting decisions, and developing effective management and conservation strategies. Previous research on urban vegetation in Dhaka has largely focused on species composition, air pollution tolerance, and physiological responses to abiotic stress (Sadia *et al.* 2019, Jashim *et al.* 2020). However, there has been limited investigation into the patterns of direct structural damage, which provide practical indicators of ongoing anthropogenic and environmental pressures. Damage such as stem incisions, leaf splitting, and stem breakage not only compromises individual tree health but also reflects broader urban ecosystem stress, highlighting locations and species most vulnerable to disturbance (Draper and Richards 2009, Marion *et al.* 2016, Satu et al. 2019, Czaja *et al.* 2020). Comparative studies evaluating structural damage alongside population and species composition across different urban green spaces remain infrequent in rapidly urbanizing tropical cities.

The National Botanical Garden and Ramna Park are two of the most important urban green spaces in Dhaka city, differing in management intensity, public accessibility, and environmental exposure. Although the Botanical Garden is relatively protected and managed, but Ramna Park experiences higher public activity and traffic-related disturbances, potentially leading to distinct damage profiles (Kashem *et al.* 2022, 2023). Therefore, this study aims to compare plant population structure and species composition between the Botanical Garden and Ramna Park; evaluate the types and frequencies of anthropogenic and structural damage affecting vegetation, and identify species-specific patterns of resilience and vulnerability. By elucidating these dynamics, the study provides critical evidence for improving urban green space management and developing conservation strategies to mitigate anthropogenic stress in rapidly urbanizing tropical cities such as Dhaka.

Materials and methods

Study area: The research was carried out in two major urban green spaces, the National Botanical Garden and Ramna Park of Dhaka city, Bangladesh. The National Botanical Garden (23°81' N and 90°34' E) is a restricted area where uniform maintenance is assured with no direct human interference. The Garden has many rare, threatened, and endangered plant species from around the world, with a variety of age-worthy trees in a less exposed environment. On the other hand, Ramna Park (23°44′N 90°24′E) is a much-traveled park located in the heart of the city.

Survey design: The survey was conducted in plots selected following a systematic random sampling design in the National Botanical Garden and Ramna Park. The plots (10×10 m²) were established along the pathway, with a minimum distance of 200 m between plots. A total of 22 square plots has been established for both study

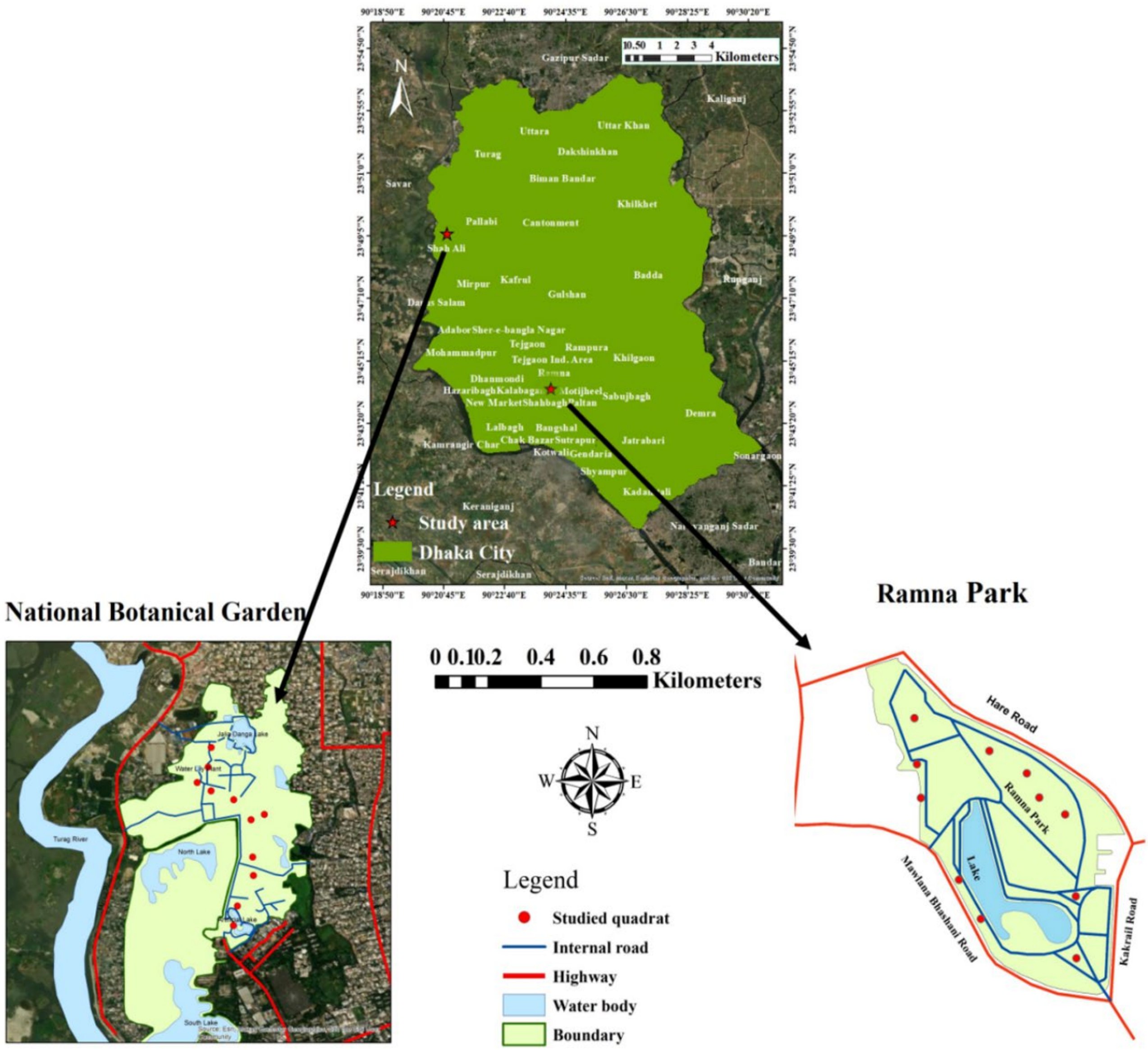

Figure 1. Map showing the survey sites of the National Botanical Garden and Ramna Park selected for the present study.

sites. For each species, all individuals within the plots were assessed, and a detailed survey was conducted to examine species-specific vulnerability to damage types.

Assessment of structural and anthropogenic damage: Plant damage was classified into four categories: i) Incision: Cuts or carvings on the stem or bark surface, indicative of human interference. ii) Split leaf: Mechanical tearing or splitting of leaves, possibly due to human activity or environmental stress (wind, rain). Iii) Stem breakdown: Fractures or breakage of branches or main stems. iv) Hanging signboards: Damage caused by attached signs or objects. Each plant was visually inspected, and the presence or absence of each damage type was recorded. The proportion of affected individuals per species and site was calculated to quantify the severity of damage. Unaffected plants were also recorded to assess the distribution of healthy individuals.

Data collection and recording: Data collection was conducted in mid-September 2025 to minimize the confounding effects of heavy rainfall or seasonal leaf fall. GPS coordinates of surveyed plants were recorded, and species were identified. Plant counts, type of damage, and severity were recorded in field datasheets and later compiled in Excel.

Data analysis: The data were analyzed by using Excel to compare the species richness and abundance between sites, the proportion of individuals affected by each damage type, and species-specific vulnerability, based on the percentage of individuals affected. Descriptive statistics (mean, percentage, frequency) were used to summarize damage patterns. Additionally, the distribution of unaffected individuals was also analyzed to assess ecological resilience and population stability within each site.

Results

Variation in vegetation structure and abundance: Comparing the Botanical Garden and Ramna Park reveal differences in plant populations and damage profiles. Though Ramna Park shows slightly higher species diversity (31 species vs. 28 species), the Botanical Garden contains a significantly larger number of individual plants (214 individuals vs. 81 individuals) (Table 1).

However, Ramna Park experiences a higher proportional impact of damage, with 35.48% of its species and of 35.80% its individuals affected, compared to and respectively in the Botanical Garden. The nature of the damage also varies distinctly: the Botanical Garden's damage is dominated by incised plants (21.5%), whereas Ramna Park is the exclusive location for plants with split leaves (17.28%) and breakdown stems (3.7%), suggesting different primary damaging agents are at play in each area. Neither park recorded damage from hanging signboards (0%).

Patterns and types of plant damage and species-specific vulnerability: In the Botanical Garden, an analysis of six affected plant species revealed varying degrees of incised-type damage. The total number of individual plants surveyed across these species was 95. The dominant form of damage recorded was incision on the plant body, with all other types—stem breakdown, split leaf, and plants with signboards hanging—registering 0% across all species. *Eucalyptus* (n=1) was found to be 100% incised, where *Bambusa* (n=65) had the highest absolute number of incised plants (38 individuals), representing 58.46% of its population, with the remaining 27 individuals unaffected (Table 2, Figure 2).

Table 1. Type of damage and its frequency recorded in the plants of selected plots of the National Botanical Garden and Ramna Park, Dhaka

Type of damage to plants	National Botanical Garden	Ramna Park
Total species	28	31
Total number of individual plants	214	81
Total affected species	6 (21.43%)	11(35.48%)
Total number of affected individual plants	46 (21.5%)	29 (35.80%)
Incised plant	46 (21.5%)	12 (14.81%)
Breakdown stem plants	0	3 (3.70%)
Plants with split leaves	0	14 (17.28%)
Plants with signboards hanging	0	0

Table 2. Frequency of damage to the different plant species of the selected plots of the National Botanical Garden, Dhaka

Species name	Number of plants	Incision on plant body	Stem breakdown	Split of leaf	Signboard hanging	Unaffected plants
Eucalyptus sp.	1	1 (100%)	0	0	0	0
Bambusa sp.	65	38 (58.46%)	0	0	0	27 (41.54%)
Lagerstroemia speciosa	14	1 (7.14%)	0	0	0	13(92.86%)
Senna siamea	2	1 (50%)	0	0	0	1 (50%)
Lophopetalum fimbriatum	8	4 (50%)	0	0	0	4 (50%)
Terminalia arjuna	5	1 (20%)	0	0	0	4 (80%)

L. speciosa demonstrated the highest damage, with only 1 plant incised (7.14%) and the vast majority, 92.86% remaining unaffected. Other species, including *S. siamea* and *L. fimbriatum*, showed a 50% incidence of incised damage, leaving an equal percentage of unaffected individuals. Finally, *T. arjuna* had a 20% incision rate and 80% unaffected individuals. Overall, the data indicate that incision is the exclusive type of recorded anthropogenic damage in the Botanical Garden, with vulnerability varying significantly across species, from 100% in *Eucalyptus* to 7.14% in *L. speciosa*.

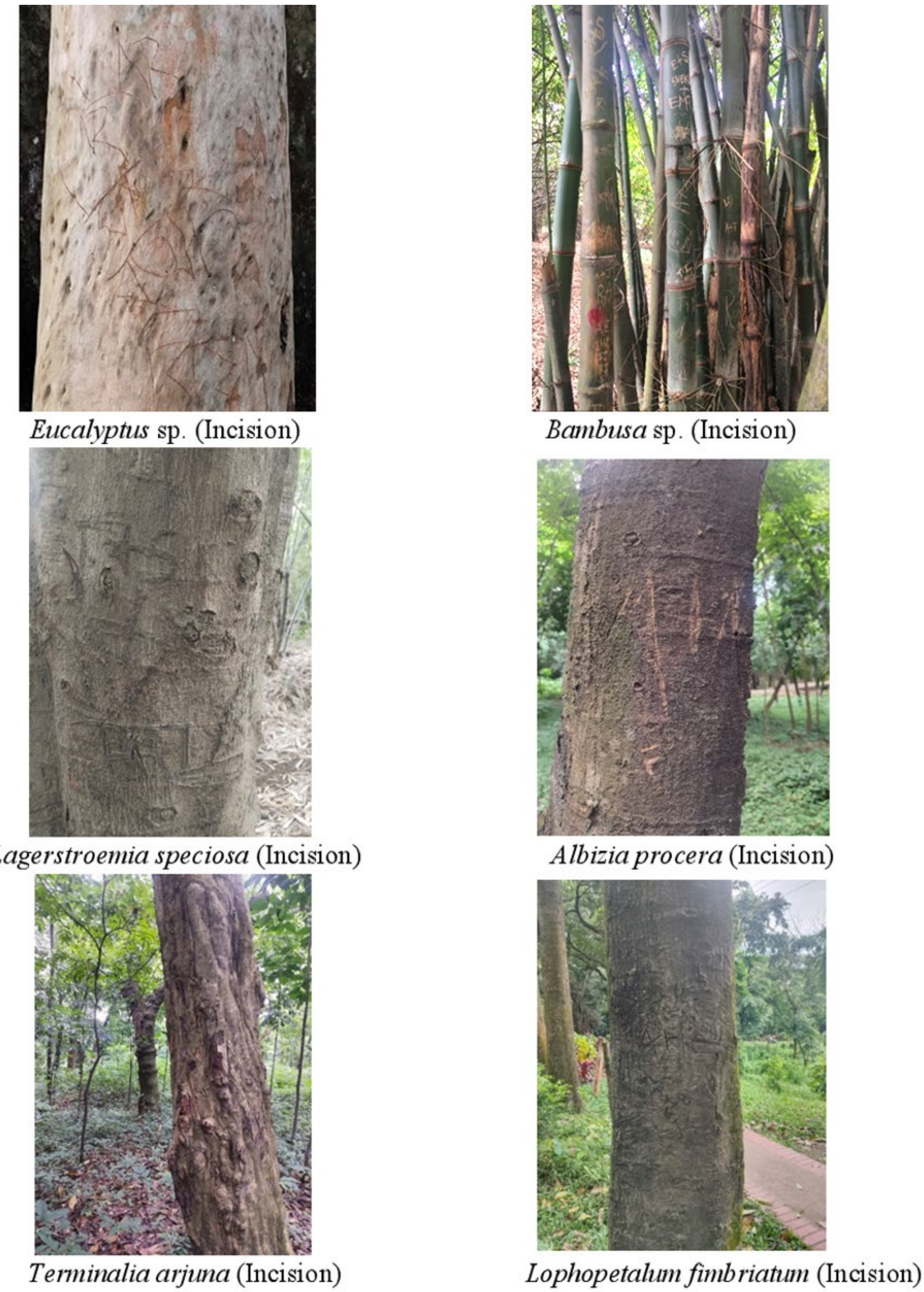

Figure 2. Representative photographs showing physical damage (incision) in selected tree species at the national botanical garden, Dhaka.

Table 3. Frequency of damage to the different plant species of the selected plots of the Ramna Park, Dhaka.

Species name	Number of plants	Incision on plant body	Split of leaf	Stem breakdown	Signboard hanging	Unaffected plants
Ficus elastica	2	1 (50%)*	0	1 (50%)*	0	1
Ixora coccinea	9	0	5*	1*	0	4 (44.44%)
Terminalia arjuna	5	3 (60%)	0	0	0	2 (40%)
Azadirachta indica	1	0	0	1 (100%)	0	0
Mangifera indica	3	2 (66.67%)	0	0	0	1 (33.33%)
Swietenia mahagoni	2	1 (50%)	0	0	0	1 (50%)
Adansonia digitata	1	1 (100%)	0	0	0	0
Brunfelsia pauciflora	2	0	2 (100%)	0	0	0
Caryota mitis	12	0	7 (58.33%)	0	0	5 (41.67%)
Artocarpus heterophyllus	1	1 (100%)	0	0	0	0
Artocarpus chaplasha	3	3 (100%)	0	0	0	0

*Indicates both affected types are common in the same plant

An analysis of 11 affected plant species in Ramna Park, totalling 41 individual plants, revealed a more diverse damage types compared to the National Botanical Garden. The species showed differential vulnerability to incision on the plant body, split leaf, and stem breakdown. Full (100%) incision was recorded in three species: *A. digitata*, *A. heterophyllus*, and *A. chaplasha*. *T. arjuna* and *M. indica* also showed high incision rates at 60% and 66.67%, respectively. The split leaf damage was notably prominent in *B. pauciflora*, which was 100% affected, and was also common in *C. mitis* and *I. coccinea*. Stem breakdown was the exclusive damage type in *A. indica* (100%) and affected a single plant each in *F. elastica* and *I. coccinea* (both 50% of their respective affected groups). *F. elastica* was unique in recording both incision and stem breakdown at the same plant. Despite the variety of damage, a high proportion of individuals remained unaffected in several species, including *I. coccinea* (44.44%), *T. arjuna* (40%), and *C. mitis* (41.67%). No plants in the surveyed area were found to be affected by the signboard hanging (Table 3, Figure 3).

Distribution of unaffected individuals: Based on the provided Table 4, which lists 21 species with their total number of unaffected individuals in the National Botanical Garden, the data highlights the distribution of healthy plant populations across different families. The total count of unaffected individuals across these 21 species is 119. *S. mahagoni* has the highest number of unaffected individuals at 22, making it the most dominant healthy and common species in this sample.

Ficus elastica (Stem breakage)

Artocarpus heterophyllus (Incision)

Ixora coccinea (Split leaves, stem breakage)

Ochna squarrosa (Split leaves)

Artocarpus chaplasha (Incision)

Caryota mitis (Split leaves)

Figure 3. Representative photographs showing physical damage (incision, stem breakage, split leaves) in selected tree species at the Ramna park, Dhaka.

Table 4. List of plant species reported as unaffected during the survey conducted in the selected plots (n=11) at the National Botanical Garden

Scientific name	Local name	Family	Total number
Casuarina equisetifolia	Jhau	Casuarinaceae	5
Vitex pubescens	Poshmihorina	Lamiaceae	4
Senna siamea	Minjiri	Caesalpiniaceae	4
Albizia procera	Sada Koroi	Fabaceae	9
Terminalia chebula	Horitoki	Combretaceae	6
Swietenia mahagoni	Mahagoni	Meliaceae	22
Artocarpus chaplasha	Chapalish	Moraceae	8
Mangifera indica	Aam	Anacardiaceae	6
Mallotus philippensis	Sinduri	Euphorbiaceae	1
Diospyros blancoi	Beelati gab	Ebenaceae	2
Madhuca longifolia	Baro mahua	Sapotaceae	1
Acacia sp.	Acacia	Fabaceae	4
Artocarpus heterophyllus	Kathal	Moraceae	11
Casuarina equisetifolia	Jhau	Casuarinaceae	2
Mimusops elengi	Bokul	Sapotaceae	6
Saraca asoca	Ashok	Fabaceae	7
Aegle marmelos	Bel	Rutaceae	1
Syzygium sp.	Jaam	Myrtaceae	4
Zanthoxylum rhetsa	Bajnagota	Rutaceae	4
Barringtonia acutangula	Hijal	Lecythidaceae	7
Tectona grandis	Segun	Lamiaceae	5

Other highly represented species include *A. heterophyllus*, with 11 individuals, *A. procera,* with 9 individuals, and *A. chaplasha* with 8 individuals. The Fabaceae family is well-represented, including *S. asoca* (7 individuals), *A. procera* 9 individuals), and *Acacia* (4 individuals). Conversely, 10 species, including *M. philippensis*, *M. longifolia*, *A. marmelos,* and *D. blancoi*, are represented by only 1 or 2 unaffected individuals, indicating a sparse distribution for these healthy populations.

Table 5. List of plant species reported as unaffected during the survey conducted in the selected plots (n=11) at the Ramna Park

Scientific name	Local name	Family	Number
Tectona grandis	Segun	Lamiaceae	3
Syzygium sp	Jaam	Myrtaceae	1
Eucalyptus sp	Eucalyptus	Myrtaceae	3
Albizia procera	Sadakoroi	Fabaceae	2
Cassia fistula	Badorlathi	Fabaceae	1
Ochna squarrosa	Chapa	Ochnaceae	1
Mesua ferrea	Nagesshwar	Calophyllaceae	1
Terminalia bellirica	Bohera	Combretaceae	2
Mimusops elengi	Bokul	Sapotaceae	3
Samanea saman	Rain tree	Fabaceae	2
Polyalthia longifolia	Debdaru	Annonaceae	7
Mangifera indica	Aam	Anacardiaceae	1
Melaleuca citrina	Bottle brush	Myrtaceae	1
Artocarpus heterophyllus	Kathal	Moraceae	5
lagerstroemia speciosa	Jharul	Lythraceae	1
Plumeria alba	Kathgolap	Apocynaceae	1
Borassus flabellife	Tal	Arecaceae	1
Cocos nucifera	Narikel	Arecaceae	2
Dillenia indica	Chalta	Dilleniaceae	1
Swietenia mahagoni	Mahagoni	Meliaceae	1

Based on Table 5, which lists 20 species with their total number of unaffected individuals in Ramna Park, the healthy population is sparsely distributed, totalling 40 individuals. *P. longifolia* is the most dominant unaffected species, accounting for the highest count with 7 individuals. *A. heterophyllus* is the next most numerous with 5 individuals. Three species, *T. grandis, Eucalyptus*, and *M. elengi*, each account for 3 unaffected individuals. *A. procera*, *T. bellirica, S. saman*, and *C. nucifera* each have 2 individuals. A significant majority of the sampled species - 11 out of the 20 listed, are represented by only a single unaffected individual each, including species such as *Syzygium* sp, *C. fistula, O. squarrosa, M. ferrea*, and *S. mahagoni*. This distribution highlights that while a few species are relatively robust in their unaffected populations, the healthy plant count in Ramna Park is broadly fragmented, with low numbers across most species.

Discussion

The comparison between the Botanical Garden and Ramna Park highlights distinct patterns in plant population, species composition, and structural integrity, reflecting differences in site characteristics and management intensity. Although Ramna Park exhibited slightly higher species diversity (31 vs. 28 species), the Botanical Garden supported a much larger number of individuals (214 vs. 81). This inverse relationship between species richness and abundance is typical of urban green spaces where spatial constraints and management regimes influence vegetation structure (Jim and Chen, 2008, Satu *et al.* 2019). The controlled access and scientific management of the Botanical Garden likely promote plant survival and density, whereas open and recreational nature of Ramna Park contributes to lower individual counts and greater disturbance exposure.

Ramna Park experienced a higher overall proportion of damage (35.48% of species and 35.80% of individuals affected) compared with the Botanical Garden, indicating stronger anthropogenic and environmental stress. This pattern is consistent with studies reporting that trees in high-traffic urban parks are more susceptible to mechanical injury, trampling, and vandalism (Alvey 2006, Satu *et al.* 2019, Burdová 2024). The National Botanical Garden, by contrast, exhibited less frequent and more uniform damage dominated by incised stems (21.5%), suggesting limited but consistent human interference. The nature of damage in Ramna Park was more diverse, encompassing incision, split leaf, and stem breakdown, while both sites recorded 0% damage from hanging signboards. The occurrence of split leaves (17.28%) and stem breakdown (3.7%) exclusively in Ramna Park suggests additional stress factors such as high wind exposure, rainfall events, or structural weakness of individual trees (Tzoulas *et al.* 2007, Nowak *et al.* 2013). This complexity indicates that multiple damaging agents operate simultaneously, amplifying the vulnerability of trees in open-access urban parks.

Marked interspecific variation in susceptibility to damage was evident in both sites. In the National Botanical Garden, *Eucalyptus* was completely incised (100%), whereas *L. speciosa* exhibited the highest resistance, with only 7.14% of individuals affected. *Bamboo* showed the greatest absolute incidence (58.46%), possibly due to its soft culm structure and placement in accessible areas. Moderate damage was recorded for *Terminalia arjuna* and *L. fimbriatum* (20–50%), while *S. siamea* displayed intermediate resistance. These results indicate that bark texture, growth form, and accessibility are key determinants of mechanical injury risk. In Ramna Park, the damage spectrum was broader, reflecting diverse stress exposure. Complete incision occurred in *A. digitata*, *A. heterophyllus*, and *A. chaplasha*, likely due to frequent human contact or ornamental prominence. *T. arjuna* (60%) and *M. indica* (66.7%) also showed high incision rates, confirming their vulnerability under high visitor density. Split leaf damage was most common in *B. pauciflora* (100%) and *C. mitis* (58.33%), both species with delicate foliage prone to mechanical tearing. The presence of both incision and stem breakdown in *F. elastica* suggests combined anthropogenic and climatic stresses. These findings are consistent with reports that tree species vary widely in their tolerance to mechanical and structural stress depending on morphology and site context (Read and Stokes 2006)

The distribution of unaffected individuals provides further insight into site-level resilience. In the Botanical Garden, healthy plants were concentrated in a few dominant species such as *S. mahagoni*, *A. heterophyllus*, and *A.*

procera, indicating effective species adaptation and management. In contrast, Ramna Park exhibited a fragmented pattern, with only 40 unaffected individuals across 20 species, and most represented by single trees. The fragmentation of healthy populations along these lines has been associated with chronic, anthropogenic disturbance and micro-environmental variation in other urban tropical cities (Dubois and Cheptou 2017, Satu *et al.* 2019). Our results indicate that ecological resilience within urban parks may be governed by population structure and management continuity, rather than characterized purely by species richness (Alberti and Marzluff 2004, Nielsen *et al.* 2014).

Conclusion

This study unravels clear contrasts between the National Botanical Garden and Ramna Park in plant population structure and damage patterns. While Ramna Park exhibits slightly higher species diversity, the National Botanical Garden supports a greater number of individuals and shows lower damage intensity. Damage in Ramna Park is more diverse and severe, reflecting stronger anthropogenic and environmental pressures. Species responses varied widely, indicating differential resilience to stress. Overall, effective urban vegetation management through minimizing human interference and prioritizing resilient native species is vital for sustaining ecological health and stability in urban green spaces of the Dhaka megacity.

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