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Structure and composition of understory vegetation in urban forest of Pekanbaru, Riau Province, Indonesia

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Abstract. *Darmawati, Silitonga LB, Nursal, Sayuti I, Mahadi I, Alamsjah F. 2025. Structure and composition of understory vegetation in urban forest of Pekanbaru, Riau Province, Indonesia. Biodiversitas 26: 4628-4639.* Urban forests play a crucial role in maintaining biodiversity; however, human disturbances and the spread of invasive species pose significant challenges to the resilience of understory vegetation. This study examined the structure and composition of understory vegetation in the Pekanbaru Urban Forest in Riau Province, Indonesia and formulated strategies for sustainable management. Research was carried out from June to December 2024 across two canopy conditions Closed Canopy Forest (CCF) and Partial Canopy Forest (PCF) using ten 2×2 m plots in each site (80 m² total). The analyses encompassed species composition, Shannon-Wiener Diversity Index (H′), Evenness Index (E), Dominance Index (D), invasive species proportion, correlation between H′ and light intensity, as well as a T-test to compare H′ between canopy types. Results revealed that the Poaceae family was the most dominant, with *Brachiaria decumbens* as the representative species. The T-test showed no significant difference in H′ between CCF (2.67) and PCF (2.98), both classified as moderate. Evenness Index values were high (0.89 and 0.87), while dominance values were very low (0.08 and 0.07), indicating a relatively even distribution of species. In total, 38 species were identified, half of which (19 species) were invasive, with a higher abundance recorded in PCF. These findings suggest that canopy mosaics comprising both closed and partially open areas are essential for maintaining understory vegetation in urban forests, as they help support species diversity while limiting invasive dominance. Recommended management strategies include preserving canopy mosaics, controlling invasive species, promoting native species planting, and strengthening conservation policies through active community participation.

Keywords: Dominance Index, Evenness Index, invasive spesies, Shannon-Wiener Diversity Index, understory vegetation

INTRODUCTION

Urban forests within city boundaries play a vital role in mitigating greenhouse gases by absorbing carbon through photosynthesis. As highlighted by Rózová et al. (2020) and Klein et al. (2021), these forests act as both oxygen producers and carbon sinks, helping to reduce pollution from human activities. Public green spaces, serving as semi-natural ecosystems, further contribute to carbon neutrality while providing essential ecosystem services that support human health and well-being, particularly through carbon sequestration (Mori et al. 2017; Hutt-Taylor et al. 2022; Miao et al. 2024; Nayak et al. 2024). A key component of these ecosystems is understory vegetation.

Comprising herbs, shrubs, ferns, and grasses, understory vegetation provides multiple ecological benefits. It enhances soil organic carbon and total nitrogen (Zhao et al. 2022; Xu et al. 2024), prevents erosion (Kim et al. 2025), and offers habitat for soil fauna (Brown and Anand 2024; Kim et al. 2025). Additionally, it improves soil fertility and productivity (Deng et al. 2023; Fuentes et al. 2023) while also contributing to aesthetics, traditional medicine, and ornamental horticulture (Sidabukke et al. 2021).

The conversion of parts of the Pekanbaru Urban Forest in Indonesia into areas for educational tourism and recreation has altered the natural structure and functions of the landscape, potentially affecting understory composition and diversity. Anthropogenic pressures, including littering, stepping off trails, and misuse of facilities, further exacerbate ecological stress. Invasive plant species also pose a serious threat. Similar patterns have been observed elsewhere, such as forest fragmentation in Marilog, Philippines, caused by land clearing, agriculture, and local community activities (Acma et al. 2021). Land-use changes disrupt ecological balance and biodiversity (Li et al. 2022), often driven by limited public awareness of conservation (Xing et al. 2024). In Argentina, Rosas et al. (2024) reported that human pressures facilitate the invasion of non-native species, altering understory structure in *Nothofagus antarctica* forests. In Beijing, anthropogenic disturbances modify soil properties, reduce diversity, and shift understory composition (Meng et al. 2023). Invasive species can homogenize vegetation, reduce biodiversity, and fundamentally alter ecosystem functions, often growing rapidly and exhibiting allelopathic effects (Kalisz et al. 2021; Balah et al. 2022; Dáttilo et al. 2023). Understory plant communities are highly sensitive to environmental changes, including light intensity, humidity, and human disturbance (Zhang et al. 2023), and their diversity reflects ecological stability and resilience. High dominance of one or a few species may indicate stress or imbalance, highlighting the need to assess not only species diversity but also evenness and dominance indices for a comprehensive understanding of community structure (Antão et al. 2021).

Despite its ecological significance, research on understory vegetation in Pekanbaru's urban forests remains limited. Most studies have focused on tree communities, while the understory layer has often been overlooked or treated as a mere weed that inhibits tree regeneration, particularly in monoculture systems, leading to its frequent removal (Nugroho et al. 2021). This perspective underestimates the role of understory vegetation in sustaining urban forest ecosystems, which are highly susceptible to environmental pressures. Therefore, this study aims to examine the structure and composition of understory vegetation in the Pekanbaru Urban Forest and to propose strategies for its sustainable management. Therefore, this study aims to examine the structure and composition of understory vegetation in the Pekanbaru Urban Forest and to propose strategies for its sustainable management. This study hypothesizes That Partial Canopy Forests (PCF) have higher understory plant diversity than Closed Canopy Forests (CCF), and that invasive species dominate the understory community. The results are expected to provide a comprehensive understanding of the current condition of understory vegetation and serve as a data-driven basis for conserving urban green spaces in Pekanbaru. The results are expected to provide a comprehensive understanding of the current understory condition and to inform data-driven approaches for conserving urban green spaces in Pekanbaru.

MATERIAL AND METHODS

Study area

This study was conducted from June to December 2024 in the Pekanbaru Urban Forest, located on Diponegoro Street, Suka Mulia, Sail Sub-district, Pekanbaru City, Riau Province, Indonesia, covering an area of 7.12 acres (Figure 1). A descriptive quantitative approach was employed, using survey methods to collect direct field data. Sampling stations were selected purposively based on scientific criteria, such as the diversity of understory vegetation (avoiding areas dominated by a single type) and accessibility for the research team. Areas with dense ground cover that prevented the growth of understory vegetation were excluded. The minimum sampling area was determined using the species-area curve method, with the plot size set at the point where, expanding the area further yielded less than a 10% increase in new species. Two stations were established: Station I, representing Closed Canopy Forest (CCF), and Station II, representing Partial Canopy Forest (PCF) (Figure 2). Station I was located on the left side of the forest, near a water channel and SMP Negeri 13 Pekanbaru, while Station II was situated on the right side, directly across from the city park.

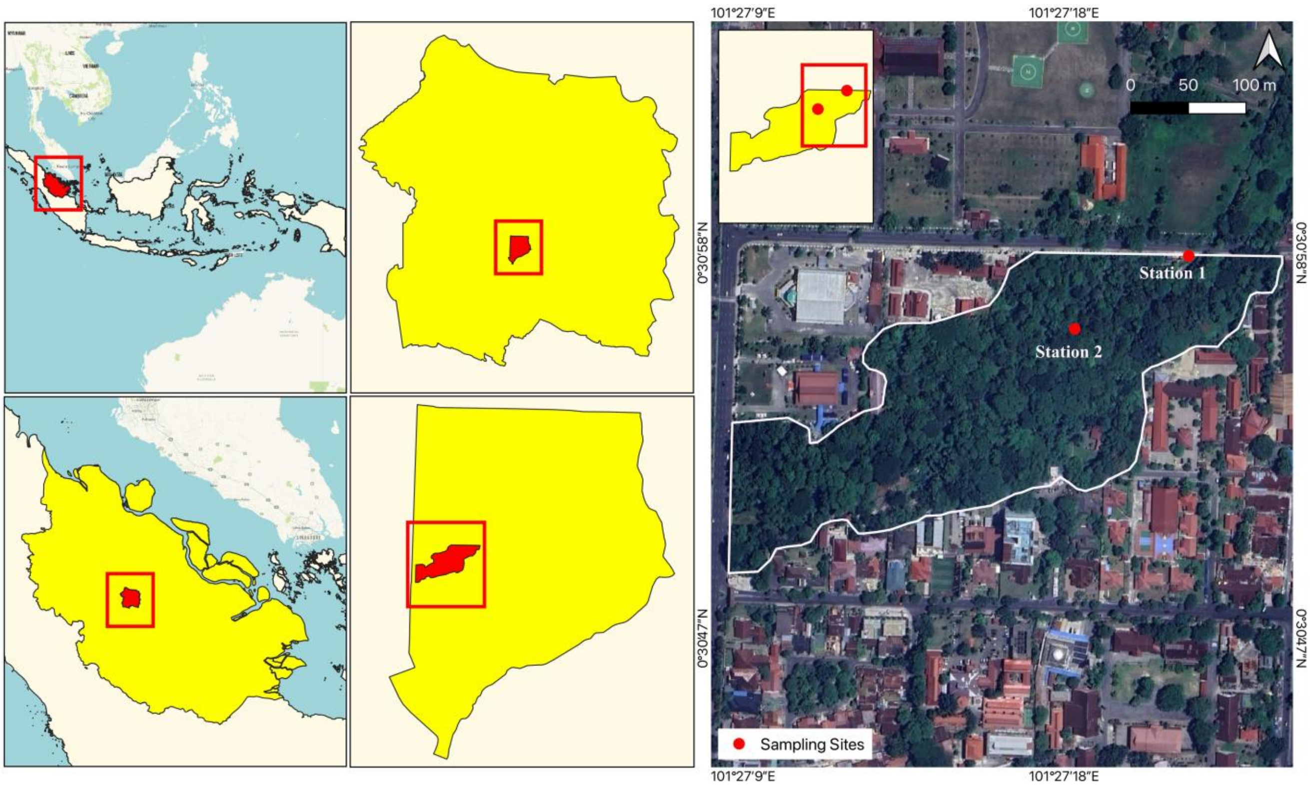

Figure 1. Study area in Pekanbaru Urban Forest, Pekanbaru, Riau Province, Indonesia

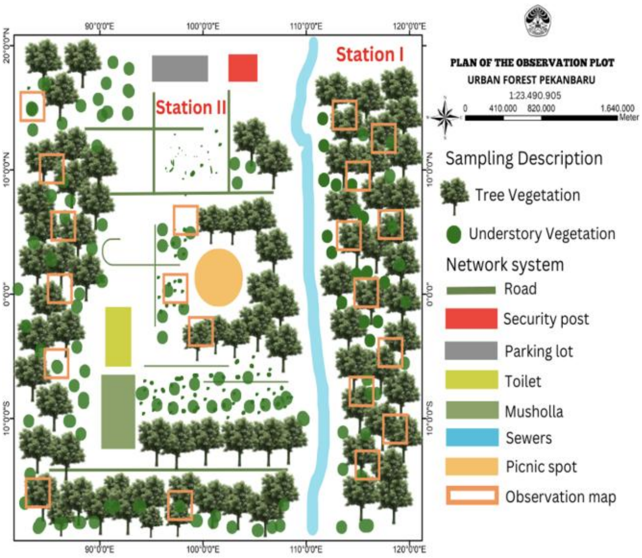

Figure 2. Study station in Pekanbaru Urban Forest, Pekanbaru, Riau Province, Indonesia

Procedures

The sampling area was determined using the species-area curve method, in which the minimum plots size is identified at the point where further enlargement results in no more than a 10% increase in new species. Based on this method, the minimum observation area was found to be 32 m². Accordingly, 2×2 m plots were employed, following the recommendation of Mueller-Dombois and Ellenberg (2016), as this size is considered representative for understory communities such as herbs, small shrubs, and ferns. This small plot size is sufficiently large to capture species variation, yet remains homogeneous and practical for detailed field recording. Plots were randomly placed in two canopy types, Closed Canopy Forest (CCF) and Partial Canopy Forest (PCF), using randomly generated coordinates while ensuring no overlap. A total of 10 plots per station (40 m²) were established, exceeding the minimum area requirement (32 m²) and providing adequate representation of understory variation in the Pekanbaru Urban Forest.

Species identification was conducted through direct field observations, photographic documentation of plant parts, and verification using reference materials (Setyawati et al. 2015), digital tools such as PlantNet, POWO, and TopTropical.com, as well as herbarium collections. Individual counts were then recorded, with plants at plot boundaries included if more than half of their body was within the plot, and clumped plants recorded as a single individual. For each record, local names, scientific names, and the number of individuals per plot were documented.

Data analysis

Species diversity was evaluated using Shannon-Wiener Diversity Index, which accounts for the proportion of individuals in each species relative to the total number of individuals (Ricotta 2023). Evenness was assessed using Pielou's Evenness Index, reflecting how evenly individuals are distributed within the community (Siefert and Fridley 2023). Dominance was determined with Simpson's Index, based on the proportion of individuals in each species relative to the total community (Kitikidou et al. 2024). In addition, a correlation test was conducted between H' and light intensity, and a T-test was applied to compare H' values between CCF and PCF. Quantitative vegetation analysis of the understory was carried out using these indices and statistical tests.

Importance Value Index (IVI)

$$IVI = RD + RF$$

Where, IVI: Importance Value Index, RD: Relative Density, RF: Relative Frequency.

Shannon-Wiener Diversity Index (H')

$$H' = - \Sigma \, Pi \ln Pi$$

Where, H': Shannon-Wiener Diversity Index, Pi: Proportion (ni/N), ni: The number of individuals of species *i,* N: The total number of individuals across all species, ln: Natural logarithm, Σ: The total number of species. Criteria: H'>3: High species diversity, H'1≤H'≤3: Moderate species diversity, H'<1: Low species diversity.

Evenness Index (E)

$$E = \frac{H'}{Ln\,(S)}$$

Where, E: Evenness Index, H': Species Diversity Index, S: The total number of species. Criteria Evenness Index (E): E<0.25: Very uneven distribution, E 0.26-0.50: Uneven distribution, E 0.51-0.75: Moderately even distribution, E 0.76-1.00: Even distribution.

Dominance Index (D)

$$D = \Sigma \, (ni/N)^2$$

Where, D: Simpson Dominance Index, ni: The number of individuals of species I, N: The total number of individuals of all species. Criteria Dominance Index (D): D<0.20: Very low dominance, 0.21-0.40: Low dominance, 0.41-0.60: Moderate dominance, 0.61-0.80: High dominance, D>0.80: Very high dominance.

RESULTS AND DISCUSSION

Composition of understory vegetation in Pekanbaru Urban Forest

This study identified 23 families of understory vegetation in the Pekanbaru Urban Forest, comprising 38 species with a total of 700 individuals. In the Closed Canopy Forest (CCF), 20 species with 289 individuals were recorded, while the Partial Canopy Forest (PCF) hosted 31 species totaling 411 individuals (Table 1). Among the families observed, Poaceae exhibited the highest species composition with 249 individuals across 7 species, followed by Acanthaceae and Commelinales. This high abundance is likely influenced by local environmental conditions as well as the biological characteristics of these families, which allow faster growth and dispersal compared to others. The dominant species recorded within these families included *Brachiaria decumbens* (syn. *Urochloa decumbens*) and *Centotheca lappacea* (Poaceae), *Asystasia gangetica* (Acanthaceae), and *Commelina diffusa* (Commelinales) (Figure 3).

Figure 3. Understory vegetation species frequently found in the Pekanbaru Urban Forest, Pekanbaru, Riau Province, Indonesia. A: *Brachiaria decumbens*, B: *Asystasia gangetica*, C: *Commelina diffusa*, D: *Centotheca lappacea*

Table 1. Composition of understory vegetation species in Pekanbaru Urban Forest, Pekanbaru, Riau Province, Indonesia

Family	Species	Local name	Number of individuals		Total of individual
			Station I	Station II	
Acanthaceae	*Asystasia gangetica*	*Ara sungsang*	32	42	74
	Andrographis paniculata	*Sambiloto*	4	21	25
	Clinacanthus nutans	*Dandang gendis*	-	10	10
Phyllanthaceace	*Phyllanthus urinaria*	*Meniran*	25	11	36
Poaceae	*Brachiaria decumbens*	*Rumput signal*	35	56	91
	Pennisetum purpureum	*Rumput gajah*	18	2	20
	Brachiaria mutica	*Rumput malela*	30	-	30
	Eleusine indica	*Rumput belulang*	-	22	22
	Megathyrsus maximus	*Rumput benggala*	-	19	19
	Ischaemum muticum	*Rumput tembaga jantan*	-	25	25
	Centotheca lappacea	*Rumput lilit kain*	-	42	42
Araceae	*Anthurium balaoanum*	*Keladi kuping gajah*	27	5	32
	Dieffenbachia bowmannii	*Keladi daun bahagia*	11	1	12
Commelinales	*Commelina diffusa*	*Aur-aur*	33	5	38
Convolvulaceae	*Ipomoea triloba*	*Lonceng kecil*	4	-	4
Dryopteridaceae	*Polystichum acrostichoides*	*Pakis natal*	8	2	10
	Dryopteris marginalis	*Pakis kayu*	7	2	9
Pteridaceae	*Adiantum capillus-veneris*	*Suplir*	14	-	14
Asteraceae	*Struchium sparganophorum*	*Awa lanaru*	11	8	19
	Wedelia trilobata	*Matahari mini*	-	9	9
	Gynura procumbens	*Sambung nyawa*	-	39	39
	Cyanthillium cinereum	*Sawi langit*	-	3	3
Lygodiaceae	*Lygodium circinnatum*	*Paku hatta*	1	-	1
Smilacaceae	*Smilax rotundifolia*	*Daun bungkus*	15	-	15
Euphorbiaceae	*Euphorbia hirta*	*Patikan kebo*	8	1	9
Cleomaceae	*Cleome rutidosperma*	*Maman lanang*	3	6	9
Nyctaginaceae	*Mirabilis jalapa*	*Bunga pukul empat*	2	-	2
Polypodiaceae	*Microsorum musifolium*	*Pakis buaya*	1	-	1
Amaranthaceae	*Cyathula prostrata*	*Bayam pasir*	-	8	8
Cyperaceae	*Cyperus rotundus*	*Teki ladang*	-	5	5
	Kyllinga brevifolia	*Jukut pendul*	-	3	3
	Eleocharis dulcis	*Purun tikus*	-	14	14
Rubiaceae	*Spermacoce ocymoides*	*Kancing palsu*	-	6	6
Nephrolepidaceae	*Nephrolepis cordifolia*	*Paku sepat*	-	14	14
Melastomataceae	*Melastoma malabathricum*	*Senduduk*	-	11	11
Fabaceae	*Mimosa pudica*	*Putri malu*	-	13	13
Oxalidaceae	*Oxalis barrelieri*	*Calincing tanah*	-	4	4
Balsaminaceae	*Impatiens balsamina*	*Pacar air*	-	2	2

Notes: Station I: CCF, Station II: PCF, -: No species found

Overall, Poaceae, Acanthaceae, and Commelinales dominated the understory vegetation of the urban forest due to their ecological traits that support adaptation and rapid dispersal. Poaceae are widely recognized as pioneer species with fast growth, lightweight seeds, and high tolerance to variations in light and soil conditions (Haq et al. 2024; Kim et al. 2025; Ge et al. 2025). Their broad distribution is supported by cosmopolitan occurrence and adaptability to diverse environmental conditions, particularly soil types (Farooq et al. 2024; Vanjil et al. 2024), as well as extensive root systems, including rhizomes (underground stems) and stolon's (above-ground stems), which enable rapid spread and colonization of new areas (Bellis et al. 2022; Borden et al. 2022; Rayment et al. 2022). Species within this family often act as pioneers, being among the first to establish in disturbed or open areas (Linder et al. 2024). Meanwhile, Acanthaceae are shade-tolerant and frequently spread as ground cover, while Commelinales can thrive in disturbed sites due to their adventitious roots, branched stems, and relatively short life cycle (Linder et al. 2024). These findings emphasize the ecological significance of understory vegetation in urban forest ecosystems and highlight the importance of sustainable management to conserve biodiversity and maintain ecosystem stability.

These results can be compared with studies conducted in other urban ecosystems. Haq et al. (2024) and Kim et al. (2025) reported that Poaceae and Asteraceae often dominate pioneer vegetation in urban landscapes due to their lightweight seeds, rapid growth, and tolerance to light variation. Similarly, Ge et al. (2025) found that these families are highly adaptable to soil and light gradients in urban ecosystems. However, the findings in the Pekanbaru Urban Forest show a slightly different pattern, where Acanthaceae was more prominent than Asteraceae alongside the dominance of Poaceae. This difference is likely influenced by local conditions, particularly shaded areas under the canopy, which favor shade-tolerant Acanthaceae that spread effectively as ground cover, in contrast to Asteraceae that generally thrive in more open habitats.

The dominance of *B. decumbens* in the Pekanbaru Urban Forest aligns with observations from other tropical regions. Studies indicate that *B. decumbens* thrives in mixed vegetation areas, such as open spaces under tree canopies, similar to urban green spaces. In the Peruvian Amazon, its productivity and nutritive value were strongly influenced by shading and soil conditions, with moderate shading enhancing microclimate humidity but heavy shading reducing yield (Díaz et al. 2025). In Brazil, *B. decumbens* in agricultural and degraded forest areas, including post-mining sites, dominated the understory and suppressed regenerating species diversity, altering vegetation composition (Ferreira et al. 2016). These findings suggest that while *B. decumbens* is highly adaptive in urban green spaces, its dominance may have ecological implications for the regeneration of native species. Nevertheless, this study is limited to observations within a single urban forest and a specific sampling period, with environmental parameters focused on selected factors, indicating that broader spatial and temporal studies are needed to better understand the ecological dynamics of understory vegetation in urban forests.

The understory was largely dominated by herbs, which accounted for 60.53% of the vegetation, including species such as *A. gangetica* and *Andrographis paniculata*, followed by grasses, ferns, and shrubs (Figure 4). The predominance of herbs suggests that environmental conditions, particularly canopy openness and light availability, are highly favorable for the growth of short-lived and perennial non-woody species. Herbs are characterized by rapid growth, short life cycles, and strong regenerative capacity through both seeds and vegetative organs. These traits allow them to quickly exploit available space and resources, especially following moderate disturbances such as thinning or canopy openings (Liu et al. 2023; Zhang et al. 2024). The success of herbs in dominating the understory is also linked to their sensitivity to microclimatic variations and preference for relatively fertile soils, which enhance photosynthetic rates and biomass production (Deng et al. 2023). These observations align with the intermediate disturbance hypothesis, which posits that moderate disturbance levels can maintain high diversity in the understory while supporting the dominance of herbs.

Grasses, particularly Poaceae members like *B. decumbens* and *Pennisetum purpureum*, thrive due to their C4 photosynthetic pathway and high tolerance to full sunlight, allowing rapid growth and space occupation (dos Santos et al. 2025). However, over time, these grasses may reduce species diversity, particularly in the presence of invasive species (Edwards et al. 2010). Ferns, such as *Polystichum acrostichoides* and *Dryopteris marginalis*, indicate moist, shaded microhabitats and contribute to soil stabilization while enhancing the structural diversity of vegetation (Zhang et al. 2024).

Variation in understory composition between the CCF and PCF was evident. Of the 38 species identified, 20 occurred in CCF, 31 in PCF, and only 13 were shared between both sites (Figure 5), reflecting a relatively low level of community similarity at around 34%. This pattern highlights differences in micro-environmental conditions and canopy structure at each location. For example, variations in light intensity strongly influence the composition and distribution of understory plants (Gairola et al. 2021; Zhang et al. 2023). The higher species richness in PCF may result from its more open canopy, which allows greater light penetration and supports the growth of pioneer or heliophilic species. In contrast, the dominance of shade-tolerant species in CCF suggests that its understory is adapted to low-light conditions, reinforcing the role of tree canopy structure in filtering which species can persist beneath a closed canopy (Verheyen et al. 2024).

The presence and distribution of plant species are strongly influenced by environmental factors (Wang et al. 2019; Haq et al. 2022a, b; Khan et al. 2022). The structure and composition of understory vegetation result from complex interactions among multiple environmental components. Consequently, the understory develops as a product of these interactions. Differences in environmental conditions between the CCF and PCF contributed to variations in species composition at the two stations. Key factors influencing the growth and development of understory vegetation include soil pH, soil moisture, soil temperature (Stevens et al. 2015), air temperature (Ustin and Middleton 2021), and light intensity (Xu et al. 2023). In addition, forest management practices, human disturbances (Sturtevant and Fortin 2021), grazing (Deng et al. 2023), canopy structure (Yu et al. 2022), and altitude affect the availability of light, water, and nutrients necessary for understory biomass production (Jin et al. 2022). Field measurements showed that soil pH at CCF was 5.3, while at PCF it was slightly higher at 5.5. Both values are within the suitable range for understory vegetation, as most plants grow well in soils with a natural pH of 5.0-8.0, with optimal growth occurring between 6.5 and 7.8 depending on species (Sirisuntornlak et al. 2021). Soil temperature and moisture are crucial for plant growth. Low soil temperatures reduce root water uptake, potentially causing wilting (Bhattacharya 2022), while sudden temperature drops can disrupt water absorption. Air temperature also affects plant metabolic processes and understory composition. High temperatures may impair metabolism, whereas low temperatures can deactivate enzymes, halting metabolic activity. Soil moisture determines nutrient availability; insufficient moisture limits plant function, whereas excessive moisture can reduce transpiration and limit water and mineral uptake. At CCF, soil temperature was 27°C, air temperature 30.6°C, and soil moisture 55%. In PCF, soil temperature was higher at 30°C, air temperature 31.7°C, with slightly lower soil moisture at 53%.

Light intensity is another critical factor, as it drives photosynthesis. In this study, CCF recorded 717 lux, whereas PCF had a higher intensity of 1654 lux. The increased light in PCF is due to a more open canopy, allowing greater sunlight penetration. In contrast, dense canopies in CCF limited light availability, affecting understory growth. Shading has been shown to influence species composition by restricting light penetration (Gálhidy et al. 2006; Su et al. 2024). At CCF, dominant trees such as *Syzygium polyanthum*, *Samanea saman*, and *Swietenia macrophylla* formed dense canopies, resulting in relatively sparse understory vegetation. *Swietenia macrophylla*, commonly planted in urban green areas of the Universitas Riau, Indonesia is valued for its deep root system, high temperature tolerance, and resistance to strong winds, making it an ideal shade-providing species (Darmawati et al. 2021).

This study highlights a distinct difference in the relationship between light intensity and understory plant diversity in two urban forest canopy types CCF and PCF. In CCF, a negative correlation was observed (R: -0.4615), indicating that as light intensity increases, the Shannon diversity index (H′) decreases (Figure 6). This pattern reflects the characteristics of a closed canopy, where limited light penetration creates a shaded environment that favors shade-tolerant species such as ferns, herbs, and regenerating young trees (Zhu et al. 2024). Under these conditions, the establishment of invasive species is relatively low, as restricted light availability suppresses the growth of most light-demanding non-native plants.

In contrast, PCF exhibited a strong positive correlation (R: 0.7037) between light intensity and understory diversity (Figure 7). The partially open canopy allows moderate light to reach the forest floor, creating a heterogeneous mosaic of microhabitats where both shade-tolerant and light-loving species can coexist. Moderate increases in light have been shown to enhance understory primary productivity, facilitate regeneration, and increase community complexity (Zhang et al. 2024). These results align with the intermediate disturbance hypothesis, which proposes that moderate levels of disturbance, in this case, partial canopy openings can maximize species diversity. However, excessive canopy openings in PCF may create ecological gaps, enabling invasive species to establish more easily. For example, *A. gangetica*, a fast-growing and light-tolerant species, can quickly dominate open areas, outcompeting native species.

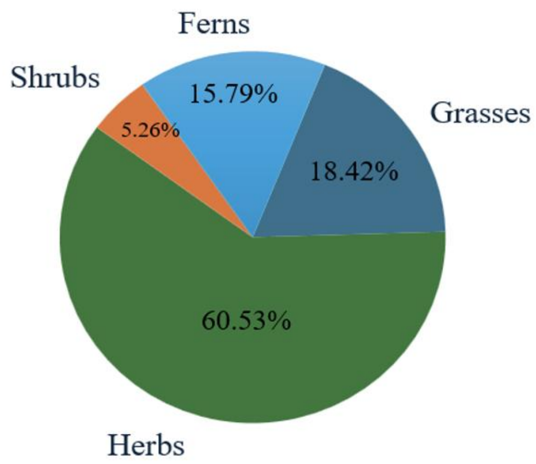

Figure 4. Percentage of growth forms in the understory vegetation across all identified species

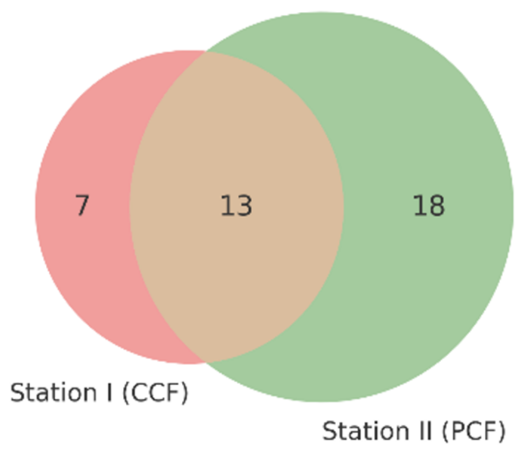

Figure 5. Venn diagram of understory vegetation species

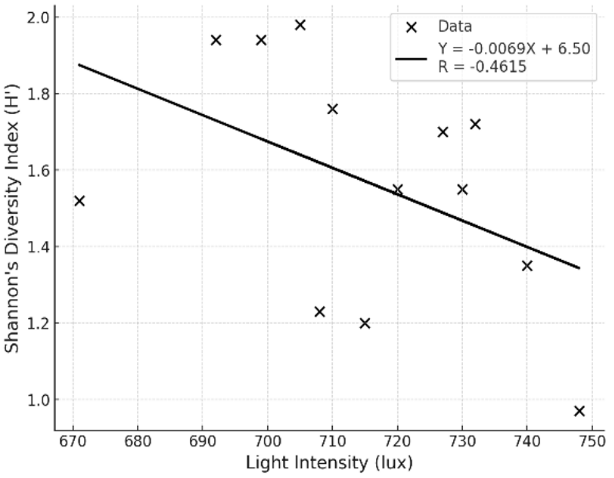

Figure 6. Correlation between diversity index and light intensity in CCF

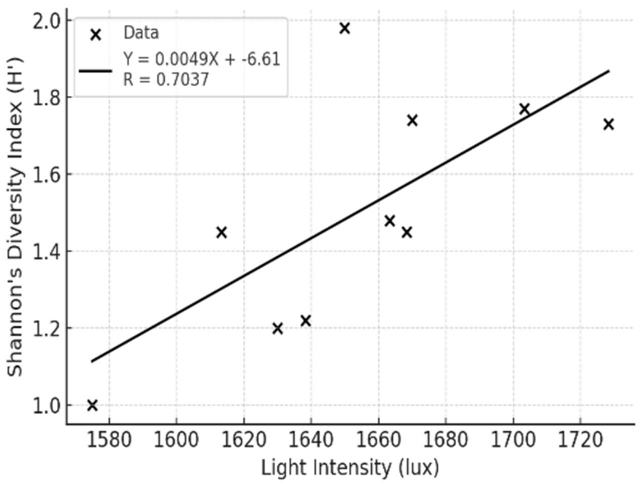

Figure 7. Correlation between diversity index and light intensity in PCF

In this study, 19 species, representing 50% of the total understory vegetation in the Pekanbaru Urban Forest, were identified as invasive (Table 2). Invasive plants are defined as species that negatively impact habitats, degrade the environment, cause economic losses, or pose risks to human health (Setyawati et al. 2021; Wang et al. 2024). They can reduce biodiversity by altering soil structure, decomposition rates, and nutrient cycling (Weidenhamer and Callaway 2010; Miniat et al. 2021). The dominance of invasive species can hinder the regeneration of native trees, modify forest composition, and threaten overall biodiversity (Patra and Saskia 2025).

The prevalence of invasive plants in the Pekanbaru Urban Forest represents a serious threat to its ecological integrity. The most harmful species are typically those that lack natural predators, reproduce rapidly, and spread aggressively to form dense canopies (Meyer et al. 2021; Xu et al. 2023; Yamamoto and Jones 2024; Kim et al. 2025). If left uncontrolled, these species can dominate the understory, displacing native vegetation. Invasive alien species have been reported to affect all components of natural ecosystems, often leading to local extinctions (Wardle and Peltzer 2017; Miniat et al. 2021). Their rapid growth can disrupt ecosystem balance, degrade environmental quality, and reduce biodiversity by interfering with the life cycles of native species. Such impacts highlight the necessity for careful monitoring and management, as invasive species can significantly influence populations, communities, and ecosystem functions (Cutway 2017; Wardle and Peltzer 2017). Variations in canopy cover between CCF and PCF were associated with differences in understory species distribution. Invasive species emerged as a key factor disrupting ecological balance by outcompeting native vegetation. These findings emphasize the importance of managing environmental conditions and controlling invasive species to maintain ecosystem stability, protect biodiversity, and sustain the critical functions of understory vegetation in urban forests.

The prevalence of invasive plants in the Pekanbaru Urban Forest represents a serious threat to its ecological integrity. The most harmful species are typically those that lack natural predators, reproduce rapidly, and spread aggressively to form dense canopies (Meyer et al. 2021; Xu et al. 2023; Yamamoto and Jones 2024; Kim et al. 2025). If left uncontrolled, these species can dominate the understory, displacing native vegetation. Invasive alien species have been reported to affect all components of natural ecosystems, often leading to local extinctions (Wardle and Peltzer 2017; Miniat et al. 2021). Their rapid growth can disrupt ecosystem balance, degrade environmental quality, and reduce biodiversity by interfering with the life cycles of native species. Such impacts highlight the necessity for careful monitoring and management, as invasive species can significantly influence populations, communities, and ecosystem functions (Cutway 2017; Wardle and Peltzer 2017). Variations in canopy cover between CCF and PCF were associated with differences in understory species distribution. Invasive species emerged as a key factor disrupting ecological balance by outcompeting native vegetation. These findings emphasize the importance of managing environmental conditions and controlling invasive species to maintain ecosystem stability, protect biodiversity, and sustain the critical functions of understory vegetation in urban forests.

Vegetation structure

The Importance Value Index (IVI) provides an overview of a species' dominance and ecological role within a particular area, reflecting its overall contribution to the community (Mustapha et al. 2022). The presence of a species also indicates its successful adaptation to the habitat. According to Jadhav (2021), species with higher IVI values tend to be more resilient and stable in terms of growth. In CCF, the highest IVI was recorded for *Anthurium baloanum* (22.04%) from the Araceae family, while the lowest IVI was observed for *Lygodium* *circinnatum* (1.93%) (Figure 8). At PCF, *B. decumbens* (25.05%) from the Poaceae family had the highest IVI, whereas *Euphorbia hirta* (1.67%) from Araceae had the lowest. Araceae, commonly known as the aroid family, was frequently observed and mainly comprises tropical plants thriving in equatorial regions. Indonesia hosts approximately 25% of the global Araceae species, covering around 31 genera. Generally, Araceae species are found in moist and wet habitats and exhibit diverse life forms, including submerged or free-floating aquatic plants, terrestrial species, epiphytes, hemi-epiphytes, and climbers (Ortiz et al. 2019; Croat and Ortiz 2020).

In the PCF, the high light intensity allowed Poaceae species to spread extensively, with *B. decumbens*, an invasive plant, demonstrating remarkable adaptability. Invasive alien plants significantly impact native biodiversity, particularly local species, by occupying habitats, utilizing environmental resources such as nutrients, light, and water, and dominating vegetation structure and composition (Huda et al. 2022). The dominance of *B. decumbens* in the Pekanbaru Urban Forest was attributed to its highly adaptable root system, which enables rapid spread. According to Conrado et al. (2021), this species easily develops roots from nodes along its creeping stems, enhancing growth in favorable conditions, especially in fertile and adequately moist soils.

Analysis of the average Importance Value Index (IVI) of understory vegetation showed that *B. decumbens* had the highest IVI at 22.55%. It was recorded with 35 individuals at CCF (IVI 20.05%) and 56 individuals at PCF (IVI 25.05%) (Figure 9). Its high IVI was due to its large population and frequent occurrence across surveyed plots, reflecting high relative density and relative frequency, and underscoring its significant role in the understory community of Pekanbaru Urban Forest. The species' presence illustrates its strong adaptability and tolerance to local environmental conditions. Conversely, *Impatiens balsamina* had the lowest IVI at only 0.96%, occurring exclusively in PCF with 2 individuals (IVI 1.92%) and absent in CCF. Variation in IVI among species reflects differences in adaptability and competitive ability. The presence of a species in an area indicates its capacity to adjust to local conditions. According to Uvere et al. (2024), a species' success in establishing and proliferating is closely linked to its ability to persist under prevailing environmental conditions.

Table 2. Invasive plant species, invasion traits, and ecological impacts

Species	Invasive traits	Ecological impacts
Asystasia gangetica	Fast-growing creeper, forms dense ground cover, produces phytotoxic effects on some species	Covers soil surface, suppresses regeneration, and reduces herbaceous plant diversity
Andrographis paniculata	Rapid growth in open areas, adaptable to various growing conditions	Replaces native herbs in open land
Phyllanthus urinaria	Produces abundant seeds, quickly colonizes disturbed soil	Becomes a dominant weed, reducing regeneration of native plants
Brachiaria decumbens	Creeping growth, forms dense carpet on soil surface	Suppresses seedlings and native herbs; high
Pennisetum purpureum	Tall grass, rapidly forms clumps/colonies, reproduces both vegetatively and by seeds	shading inhibits regeneration and replaces native vegetation
Brachiaria mutica (syn. *Urochloa mutica*)	Dense clumps, rapid vegetative spread	Forms monocot swards, displacing native vegetation
Eleusine indica	High seed production, drought tolerant, often a persistent weed	Becomes dominant, sometimes herbicide-resistant, difficult to control
Megathyrsus maximus (*Guinea grass*)	Tall grass, large biomass, highly competitive, potential allelopathic effects	Dominates grasslands, reduces native biodiversity
Commelina diffusa	Creeping habit, capable of covering ground surface	Covers the understory layer, suppressing regeneration
Ipomoea triloba	Fast-growing vine/twiner, produces abundant seeds	Twines and covers host plants, leading to host plant mortality
Cyanthillium cinereum	Fast-growing annual, spreads via wind-dispersed seeds	Forms dense patches, suppressing native herbs
Euphorbia hirta	Rapid reproduction, tolerant of poor soils, toxic latex	Common weed, inhibits growth of surrounding plants
Cleome rutidosperma	Annual sedge; spreads quickly through seeds and small rhizomes	Suppresses native herbs; difficult to control mechanically
Cyperus rotundus	Tubers difficult to remove; strong vegetative regeneration	One of the most difficult weeds to eradicate, displaces native species, and disrupts restoration efforts
Kyllinga brevifolia	Forms dense clumps in moist soils	Alters sedge and marsh herb communities
Melastoma malabathricum	Woody shrub, bird-dispersed seeds allow long-distance spread	Becomes dominant shrub in disturbed areas, changes shrub structure
Mimosa pudica	Produces many seeds, forms dense colonies, easy vegetative growth	Covers soil surface, reduces movement and regeneration of other species
Oxalis barrelieri	Fast growth in shaded areas, adaptable to understory	Competes with tree seedlings and native herbs
Impatiens balsamina	Explosive seed dispersal over long distances, quickly forms populations	Dominates moist areas, suppresses native herbs and seedlings

Source: Setyawati (2015), CABI digital laboratory, Wiley online library, USDA plant data base, IUCN, GISD

Diversity Index, Evenness Index, and Dominance Index

The diversity index is a key parameter used to evaluate the influence of environmental factors on a community and to describe its overall structure (Su et al. 2024). In understory vegetation, diversity is determined by both the number of species and the abundance of individuals within the area. According to Rex et al. (2023) and Zhang et al. (2023), species diversity also serves as an indicator of community stability, reflecting the ability of a community to maintain equilibrium despite disturbances.

In this study, the diversity index of understory vegetation in the Pekanbaru Urban Forest was recorded at 2.67 (moderate) in the CCF station and 2.98 (moderate) in the PCF station (Figure 10). These results suggest that species abundance was higher in PCF than in CCF, likely due to differences in environmental conditions such as canopy cover and light availability. Environmental factors that influence plant species distribution include elevation, humidity, temperature, and light intensity (Maciel-Nájera et al. 2021; Deng et al. 2023). The Evenness Index, in contrast, measures how evenly individuals are distributed among species in a given area (Hordijk et al. 2023). Higher evenness values indicate a more balanced distribution, where species occur at similar abundances. In this study, evenness was 0.89 (even) in CCF and 0.87 (even) in PCF. Lower evenness values suggest uneven distribution of individuals, often resulting in dominance by certain species.

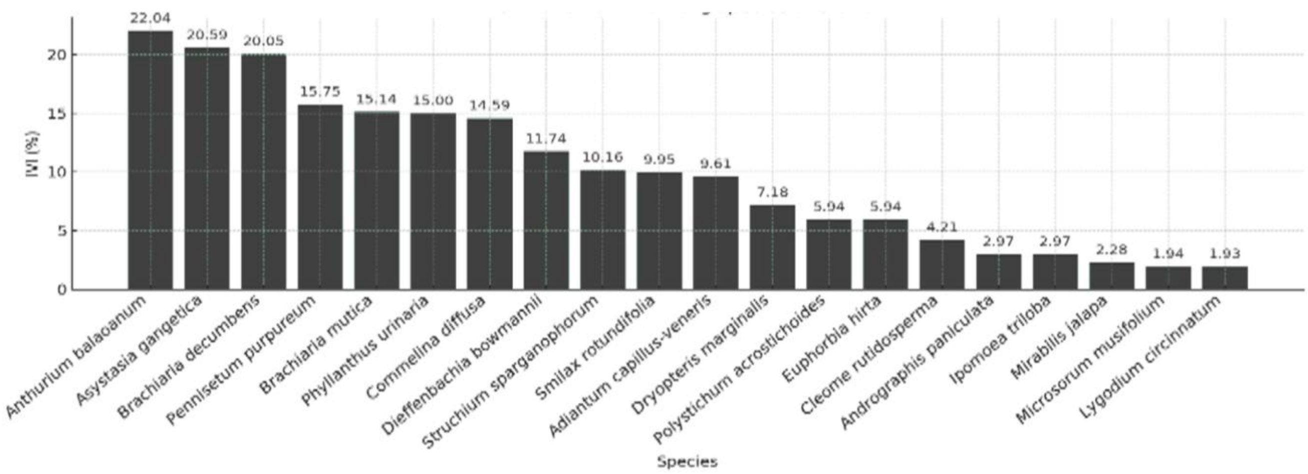

Figure 8. Distribution of IVI among understory vegetation species in CCF

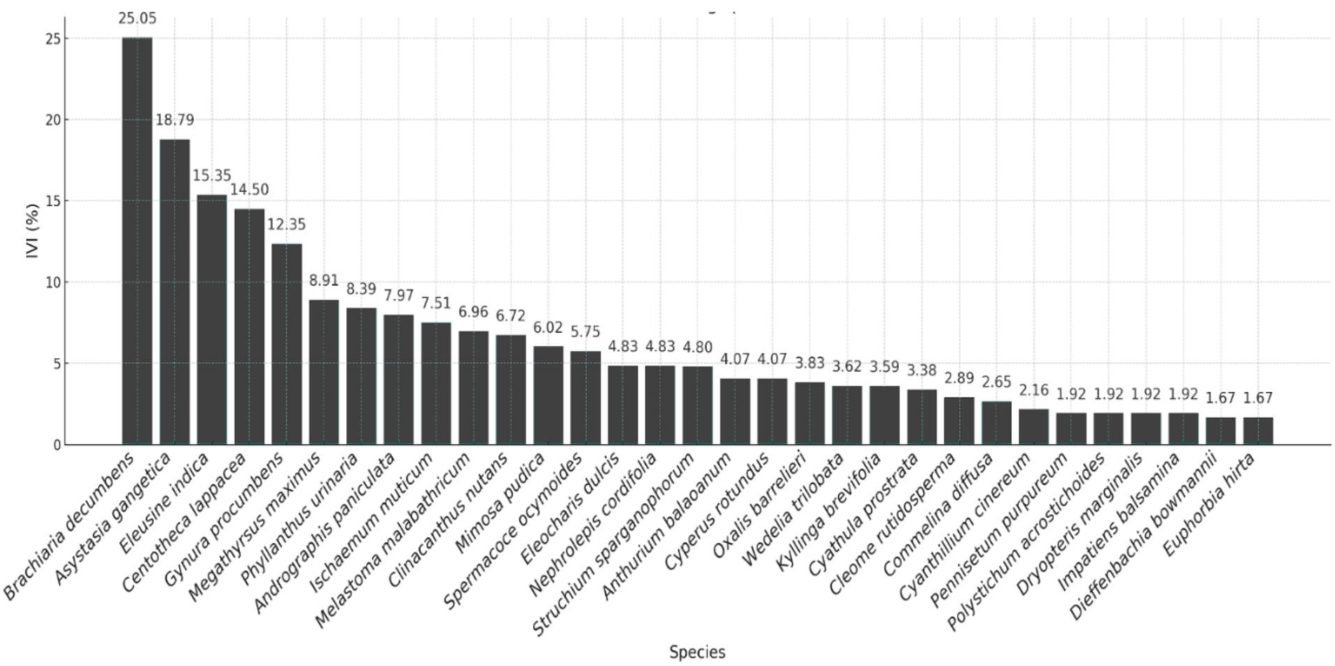

Figure 9. Distribution of IVI among understory vegetation species in PCF

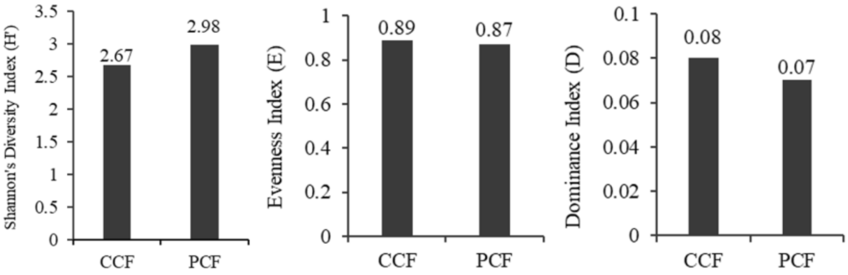

Figure 10. Shannon-Wiener Diversity Index**,** Evenness Index, Dominance Index in CCF and PCF

The Dominance Index reflects the relative abundance of species within a community. Communities with high dominance are typically more unstable or stressed (Antão et al. 2021). Together, these indices diversity, evenness, and dominance provide a comprehensive understanding of community structure and ecological balance in understory vegetation. The Dominance Index at CCF was 0.08 (very low), and at PCF, it was 0.07 (very low), indicating that the understory vegetation in Pekanbaru Urban Forest exhibits low dominance and a relatively even distribution of species. Generally, as the diversity index increases, the Dominance Index tends to decrease, which aligns with the findings of this study. High diversity reflects a complex community structure, promoting species interactions such as energy transfer through food webs, predation, and niche partitioning, which collectively contribute to greater ecosystem complexity and stability (Mori et al. 2017).

However, the independent t-test on the Shannon-Wiener Diversity Index revealed no significant difference between CCF (mean H′ per plot: 1.549±0.326) and PCF (mean H′ per plot: 1.502±0.305) (t: 0.333; p: 0.743). Statistically, the diversity level per plot at both stations was relatively comparable, although the number of recorded species differed, with 20 species in CCF and 31 species in PCF. This difference in species richness did not directly affect the total H′ values (2.67 in CCF and 2.98 in PCF), as Shannon's index accounts not only for species richness but also for the evenness of individual distribution across species (Chen et al. 2024). The very high and nearly identical evenness values at both stations (0.89 in CCF and 0.87 in PCF) indicate that individuals were distributed relatively evenly among species. This high level of evenness offsets the difference in species richness, resulting in comparable H′ values between the two sites. Furthermore, the low Dominance Index (0.08 in CCF and 0.07 in PCF) suggests that no single species excessively dominated the community, thereby maintaining a similar level of diversity. Data variability among plots also contributed to the non-significant difference in H′, despite differences in species counts. These findings highlight that a higher number of species does not necessarily translate into a higher diversity index, as community structure is strongly influenced by evenness and dominance (Zhang et al. 2023; Chen et al. 2024; Sun et al. 2022).

This study concludes that a total of 38 understory plant species were identified across two observation stations, with 20 species found in CCF, 31 species in PCF, and 13 species shared between both sites. Shannon-Wiener Diversity Index was categorized as moderate in both stations (H′ CCF: 2.67; PCF: 2.98), and the t-test results indicated no significant difference, despite the higher number of species recorded in PCF. Of the total species, 19 were invasive plants that may suppress native species and alter community structure, thereby threatening ecosystem balance. The differences in species composition between stations highlight the influence of habitat heterogeneity on understory distribution, while the moderate diversity values reflect a certain level of community stability. These findings emphasize the importance of long-term management strategies, including maintaining canopy variation, controlling invasive species, planting native species, and strengthening conservation policies alongside active community participation.

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