

Community Structure, Diversity, and Regeneration Patterns of *Ficus* Species in The Manggis Gadungan Nature Reserve, Kediri

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ABSTRACT

The genus *Ficus* plays a vital role in tropical forest ecosystems as a keystone species that supports biodiversity and ecosystem stability. This study aims to analyse vegetation structure, species diversity, regeneration patterns, and the influence of environmental factors on *Ficus* communities in the Manggis Gadungan Nature Reserve, East Java. The study employed a hierarchical plot method across 40 plots (20 × 20 m) with a total area of approximately 1.6 ha. Vegetation data were collected at the seedling, sapling, pole, and tree levels, and analysed using the Importance Value Index (IVI), the Shannon–Wiener index (H'), evenness index (E), Simpson's dominance index (D). Environmental factors measured included light intensity, air humidity, soil pH, and soil moisture. Results showed 15 *Ficus* species with a total of 129 individuals. H' values ranged from 2.1 to 2.8 (moderate to high diversity), with evenness of 0.62–0.81, indicating that individual distribution was not yet even. Dominance patterns varied between strata, with the highest INP at the pole level. Regeneration indicated a bottleneck at the seedling stage (regeneration bottleneck). Environmental factors, particularly light intensity and soil moisture, influenced species distribution. In conclusion, the *Ficus* community exhibits relatively high diversity, yet its regeneration is not yet stable and is influenced by environmental conditions.

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INTRODUCTION

Biodiversity is a key component in maintaining stability, resilience and the sustainability of tropical forest ecosystem functions, especially in the face of climate change, habitat fragmentation, and increasing land degradation (Zhao *et al.*, 2021). In tropical forest communities, some groups of plants play an ecological role that is disproportionate to the structure and function of the ecosystem, and are therefore known as a keystone species. One notable group is the genus *Ficus* (Moraceae), which is widespread in tropical regions and plays a vital role in maintaining the stability of ecosystems (Abuel *et al.*, 2021). The presence of *Ficus* provides a year-round food source for various frugivorous fauna, thereby supporting the sustainability of trophic interactions whilst contributing to the regeneration

process through the intensive and continuous dispersal of seeds (Raji & Downs, 2022). In addition, this genus exhibits a high degree of ecological adaptability across a range of habitat conditions, ranging from primary forests to disturbed areas, and are therefore often involved in the processes of succession and ecosystem recovery (Yang *et al.*, 2021).

At the community level, vegetation structure and species diversity reflect the interactions between species' life strategies, regeneration dynamics and environmental selection processes environmental filtering (Fujita, 2021). Variations in species dominance and distribution across different growth stages from seedlings, saplings, and young trees to mature trees serve as key indicators for assessing the stability and sustainability of a tropical forest ecosystem (Naharuddin, 2020). The success of natural regeneration is also greatly influenced by dispersal processes, microhabitat conditions and competitive pressure during the early stages of growth (Razafindratsima *et al.*, 2021). In the genus *Ficus*, these dynamics become more complex due to the variety of life strategies it exhibits, including its ability to act as both a hemi-epiphyte and a pioneer in disturbed habitats. This characteristic enables *Ficus* to occupy a wide range of ecological niches and exhibits different community responses to varying habitat conditions (Raji & Downs, 2022).

Various studies on *Ficus* indicate that community structure, diversity levels and regeneration success are strongly influenced by habitat characteristics. A study at the Lambung Mangkurat University Campus, Banjarmasin, recorded seven *Ficus* species with a total density of 2.09 individuals ha^{-1} and a Shannon–Wiener diversity index of 1.31, which is classified as low moderate (Azhari *et al.*, 2024). Conversely, research in subtropical landscapes in China indicates that the success of *Ficus* recruitment is heavily influenced by environmental filtering processes, where the emergence rate of seedlings reached only around 31.8%, whilst establishment success fell to 0.33% due to limitations in light, moisture, and unfavourable microhabitat conditions (Yang *et al.*, 2021).

With regard to regeneration, a study by Castillo-Díaz *et al.*, (2021) reported that only around 3.24% of *Ficus* seedlings were able to survive the early stages of growth, whilst the final recruitment rate was recorded as very low at around 0.06% indicating high environmental pressure and competition during the natural regeneration phase. Furthermore, the study by Raji & Downs (2022) indicates that *Ficus* species act as keystone species with high visitation rates by frugivorous fauna, where more than 20 vertebrate species were recorded utilising *Ficus* trees as both a food source and a seed dispersal agent, supporting vegetation regeneration dynamics in both tropical and disturbed habitats. These findings indicate that previous research has provided insights into the diversity, vegetation structure, and regeneration of *Ficus* communities. However, these three aspects are generally still studied in isolation, meaning that the interrelationships between species diversity, community dominance, multi-level vegetation structure, regeneration patterns, and environmental conditions within *Ficus* communities have yet to be analysed in an integrated manner.

The Manggis Gadungan Nature Reserve is a lowland tropical forest conservation area with a high degree of microhabitat heterogeneity, which has the potential to support a high level of *Ficus* diversity (Azizah *et al.*, 2024; Nurlaili *et al.*, 2025). Variations in topography, canopy cover, light intensity and moisture conditions in this area create a diverse range of environmental conditions, enabling the formation of varied community structures at different stages of growth (Castillo-Díaz *et al.*, 2021). To date, studies of *Ficus* communities in this area remain limited and have not comprehensively assessed the relationship between community structure, diversity levels, regeneration success and environmental conditions at the site level.

This study offers an integrative approach by linking analyses of species diversity, community dominance, inter-level community structure, regeneration patterns, and environmental conditions within a single ecological framework. Consequently, this study aims to analyze community structure, species diversity, regeneration patterns, and environmental conditions associated with *Ficus* communities in the Manggis Gadungan Nature Reserve. The results of this study are expected to provide a scientific basis for understanding the dynamics of tropical ecosystems and to support the development of adaptive, ecology-based conservation strategies.

MATERIALS AND METHODS

This study was conducted in the Manggis Gadungan Nature Reserve Kediri, East Java in March–April 2026. The study employed a quantitative approach to analyse community structure, species diversity, regeneration patterns and environmental conditions within the *Ficus* community. A vegetation survey was carried out using the multi-stage plot method, based on the approach of Mueller-Dombois and Ellenberg (1974), which is still widely used in studies of tropical vegetation ecology.

A total of 40 main plots, each measuring 20×20 m, were established using a purposive sampling approach, covering a total study area of approximately 1.6 ha. This approach was chosen because the study focused on communities of the genus *Ficus* as the primary subject; consequently, the plots were established in locations where *Ficus* individuals were present, based on the results of preliminary field surveys. The plot layout also into account variations in habitat conditions, such as canopy density, disturbance levels and environmental heterogeneity, to represent the variation in *Ficus* community structure within the study area (Koilola *et al.*, 2021).

In each main plot, observations were carried out at different levels according to growth stage: the tree level in the 20×20 m plot, the sapling level in the 10×10 m subplot, the seedling level in the 5×5 m subplot, and the seedling level in the 2×2 m subplot. The growth stage classification follows the standard for tropical vegetation studies, namely seedling (height < 1.5 m), sapling (height ≥ 1.5 m with a diameter < 10 cm), pole (diameter 10–20 cm), and trees (diameter > 20 cm). At each observation unit, all individuals and species of *Ficus* at each growth stage were recorded.

The analysis in this study focused on the community structure, diversity and regeneration patterns of the genus *Ficus*, rather than on the vegetation community of the area as a whole. The data collected included the number of individuals, stem diameter and tree height. Stem diameter measurements were taken at breast height (DBH, 1.3 m) for saplings and trees using a diameter measuring tape (Chave *et al.*, 2022), whereas at the seedling and sapling stages, data are recorded based on the number of individuals and growth categories. Tree height is measured using a clinometer or a standardised visual method.

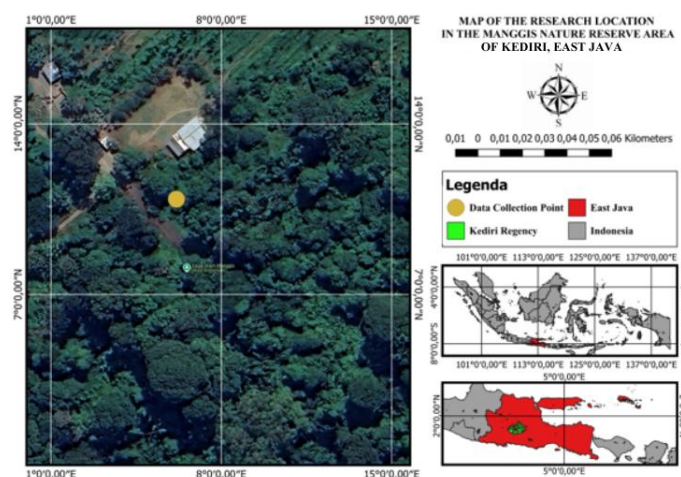


Figure 1. Map showing the location of the Manggis Gadungan Nature Reserve

The environmental parameters observed included air temperature and humidity, measured using a thermo-hygrometer; light intensity, measured using a lux meter; soil pH, measured using a soil tester; and soil moisture, measured using a soil moisture meter. Environmental data were used to describe microhabitat conditions at the study site and to support the interpretation of patterns in vegetation structure, diversity and regeneration within the *Ficus* community.

The vegetation structure of the *Ficus* community was analysed by calculating density, frequency, dominance and the Importance Value Index (IVI) in accordance with the method of Curtis

and McIntosh. Species diversity was analysed using the Shannon–Wiener index (H'), evenness (E) and Simpson's dominance (C). Regeneration patterns were analysed based on the distribution of species and individuals at each growth stage seedlings, saplings, pole, and mature trees to describe the regeneration dynamics of the Ficus community. Environmental parameter data, including air temperature, air humidity, soil moisture, soil pH, and light intensity, were analysed descriptively to support the interpretation of microhabitat conditions at the study site.

RESULTS AND DISCUSSION

A total of 15 *Ficus* species were successfully recorded across 40 observation plots in the Manggis Gadungan Nature Reserve Kediri East Java, comprising a total of 129 individuals, as shown in Table 1. The species composition indicates that the Ficus community at the study site is composed of species with varying abundances. *Ficus montana* Burm. f. was the most abundant species, with 34 individuals, followed by *Ficus subulata* (23 individuals), *Ficus hispida* L.f. (15 individuals), *Ficus septica* Burm. f. (14 individuals), and *Ficus variegata* Blume (10 individuals). Conversely, some species were found only in limited numbers, such as *Ficus callophylla* Blume, *Ficus drupacea* Thunb., and *Ficus microcarpa* L.f., of which only one individual of each was recorded.

Table 1. Species of *Ficus* found in the Manggis Gadungan Nature Reserve

No	Local Name	Latin Species Name	Total
1	Leses	<i>Ficus albipila</i> (Miq.) King	4
2	Bunut/wanut	<i>Ficus virens</i> Aiton	6
3	Magnolifolia	<i>Ficus magnoliifolia</i> Blume	5
4	Beringin	<i>Ficus benjamina</i> L.	2
5	Ringin Walik	<i>Ficus kurzii</i> King	2
6	Apak	<i>Ficus nervosa</i> B. Heyne ex Roth	8
7	Gondang Ijo	<i>Ficus variegata</i> Blume	10
8	Luwingan	<i>Ficus hispida</i> L.f.	15
9	Ilat-ilatan	<i>Ficus callosa</i> Willd	3
10	Calophylla	<i>Ficus callophylla</i> Blume	1
11	Awar-awar	<i>Ficus septica</i> Burm.f.	14
12	Uyah-uyahan	<i>Ficus montana</i> Burm.f.	34
13	Bulu, Kowang	<i>Ficus drupacea</i> Thunb	1
14	Preh/Ipreh	<i>Ficus microcarpa</i> L.f.	1
15	Subulata	<i>Ficus subulata</i>	23
Total			129

The distribution of species also reveals differences in occurrence across growth levels. Some species, such as *Ficus variegata*, *Ficus septica*, and *Ficus hispida*, are found at more than one growth level, whilst other species are only found at specific levels. These variations in occurrence across levels indicate differences in recruitment ability, growth persistence, and response to microhabitat conditions within the *Ficus* community.

The presence of 15 *Ficus* species indicates that the Ficus community in the Manggis Gadungan Nature Reserve possesses relatively high species richness at the plot scale. This figure is higher than that reported in a study at Lambung Mangkurat University, which documented seven *Ficus* species (Ahzari *et al.*, 2024). This difference is thought to be related to the higher microhabitat heterogeneity

of the conservation area, including variations in topography, canopy cover, and environmental humidity that support the presence of more species (Yang *et al.*, 2021).

The dominance of certain species in terms of individual numbers, particularly *Ficus montana* and *Ficus subulata*, suggests that not all species contribute equally to the community. Conversely, the presence of several species with low individual numbers indicates that the *Ficus* community at the study site comprises a combination of common species and species with limited abundance (Hendrayana *et al.*, 2022). This pattern reflects variations in life strategies among species, including differences in colonisation ability, tolerance to microhabitat conditions, and regeneration success across various growth stages (Qayim & Chikmawati, 2022).

Community Vegetation Structure

The vegetation structure of the *Ficus* community in the Manggis Gadungan Nature Reserve exhibits distinct dominance patterns at each growth stage. In Figure 1, at the seedling stage, *Ficus montana* Burm. f. has the highest Importance Value Index (IVI) of 63.52%, followed by *Ficus subulata* at 39.76% and *Ficus hispida* L.f. at 28.85%. These values indicate that during the early regeneration phase, there is a tendency for relatively strong dominance by certain species (Wijaya & Defiani, 2021). The Importance Value Index is a composite parameter comprising relative density, relative frequency, and relative dominance, and is therefore widely used to describe the ecological contribution of species within a vegetation community (Mensah *et al.*, 2020).

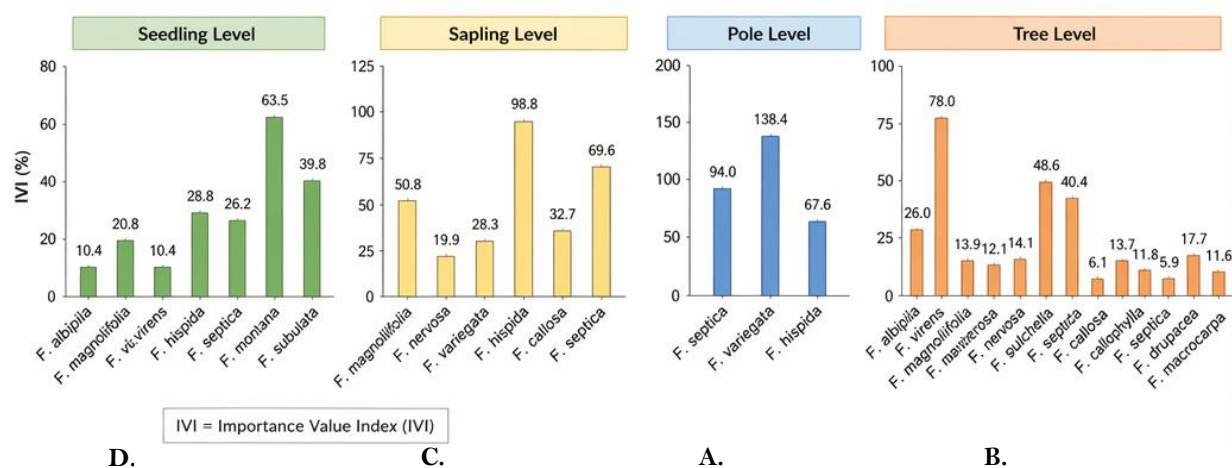


Figure 2. IVI values by growth stage: A) Seedling Level, B) Sapling Level, C) Pole Level, D) Tree Level.

As the growth stage progresses, there is a shift in the dominance pattern between stages. In Figure 2, at the sapling level, *Ficus hispida* exhibited the highest IVI value of 98.80%, whilst at the pole stage, the highest dominance shifted to *Ficus variegata* Blume with a value of 138.40%. At the tree level, the species with the highest IVI value was *Ficus virens* Aiton at 78.01%. These changes indicate that species dominance within the *Ficus* community is determined not only by the number of individuals but also by the frequency of occurrence and stem size, which contribute to relative dominance (Hendrayana *et al.*, 2022). Consequently, species with larger stem diameters can still exhibit high dominance values even if their numbers are relatively smaller (Maulidia *et al.*, 2025).

The distribution of IVI values across levels indicates a dominance shift, i.e., a change in the composition of dominant species from lower levels to higher levels (Matsuo *et al.*, 2023). Bongers *et al.* (2020) also explain that species dominant in the early growth phase do not always maintain their dominance into the adult phase. Conversely, some species show an increase in ecological contribution at higher trophic levels (Matsuo *et al.*, 2023). This pattern suggests that the dynamics of *Ficus* community regeneration are non-linear and are thought to be linked to differences in adaptive capacity, tolerance to microhabitat conditions, and survival rates at each growth stage (Poorter *et al.*, 2021).

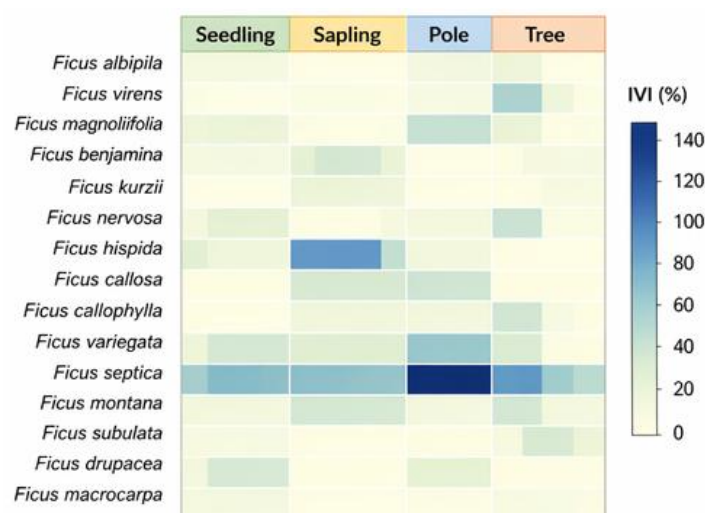


Figure 3. IVI values for Ficus communities at each growth stage.

Ecologically, variations in dominance between levels also reflect the presence of vertical stratification within the community (Hartati *et al.*, 2025). Species at the lower levels tend to demonstrate successful early recruitment, whilst species at the tree level reflect long-term persistence and competitive ability (Diena *et al.*, 2025). This pattern of dominance change indicates that the structure of the Ficus community at the study site is shaped by a dynamic regeneration process. Consequently, dominance patterns and shifts between levels serve as key indicators for assessing stability and sustainability (Prastyaningsih *et al.*, 2025).

Diversity

The diversity indices of the Ficus community at each growth level show quite clear variations (Figure 4). The Shannon–Wiener index (H') ranges from 1.055 to 2.299, with the lowest value at the sapling level and the highest at the tree level. The tree layer had the highest H' value of 2.299 with 13 species, whilst the pole layer showed the lowest H' value of 1.055 with 3 species. These values indicate that the tree layer has a more diverse species composition compared to other growth layers (Kailola *et al.*, 2021). The Shannon–Wiener index is a widely used parameter for describing community complexity as it takes into account both species richness and relative abundance simultaneously (Maulidia *et al.*, 2025).

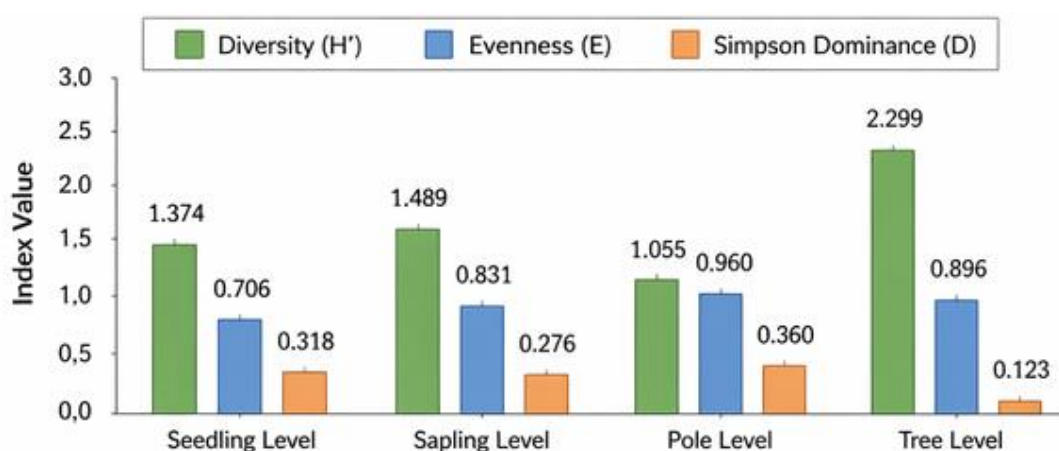


Figure 4. Values for the Simpson's diversity, evenness and dominance indices

The evenness (E) values ranged from 0.706 to 0.960. The highest value was found at the pole level (0.960), whilst the lowest was at the seedling level (0.706). The high evenness value at the pole

level indicates that the distribution of individuals across species at that level is relatively even, although fewer species were found (Mensah *et al.*, 2020). Conversely, the lower evenness value at the seedling level indicates a tendency for dominance by certain species. This pattern is consistent with the results of vegetation structure analysis, which showed the dominance of *Ficus montana* during the early regeneration phase (Qayim & Chikmawati, 2022).

Simpson's dominance (D) values ranged from 0.123 to 0.360. The sapling stage had the highest dominance value (0.360), whilst the tree stage had the lowest (0.123). These values indicate that at some stages there is a tendency for abundance to be concentrated in certain species, whilst at other stages the distribution of abundance is more widely spread across species (Bongers *et al.*, 2020). In general, the relationship between the H', E, and D values indicates that the diversity of *Ficus* communities is determined not only by the number of species, but also by the distribution patterns of individuals at each growth stage (Hartati *et al.*, 2025).

Ecologically, variations in diversity values across growth stages reflect community structure dynamics related to regeneration processes and vertical stratification (Qayim & Chikmawati 2022). A higher H' value at the tree level indicates that the adult stage has a more diverse species composition and a relatively more balanced abundance distribution. Conversely, stronger dominance at the lower levels indicates that the early growth phase is still dominated by a few species with higher early recruitment capacity (Poorter *et al.*, 2021). This pattern suggests that the *Ficus* community at the study site is in a dynamic state, where species composition and ecological contributions change throughout the growth stages (Matsuo *et al.*, 2023).

Regeneration

The regeneration pattern of the *Ficus* community reveals differences in the distribution of individuals across growth stages (Table 2). Seven species were found at the seedling stage, six at the sapling stage, three at the pole stage, and 13 at the tree stage. The difference in species numbers between these stages indicates that not all species present in the early growth phase successfully reach higher stages (Komul *et al.*, 2024). Some species showed dominance at the seedling stage but did not maintain their dominance at the tree stage. This pattern indicates a mismatch between the success of early recruitment and the success of reaching the adult phase within *Ficus* communities (Bongers *et al.*, 2020).

Table 2. Distribution of *Ficus* species numbers at each growth stage.

Level	Number
Seedling	7
Sapling	6
Pole	3
Tree	13

The distribution across growth stages also indicates changes in species composition throughout the growth stages. Species such as *Ficus variegata*, *Ficus septica*, and *Ficus hispida* were found at more than one growth stage, whilst several other species were only found at specific growth stages. The presence of tree species that is not always accompanied by the presence of seedlings suggests that the presence of mature individuals does not necessarily reflect actual regeneration, but may represent populations established in previous periods (Poorter *et al.*, 2021). This condition is commonly found in tropical tree communities that have long lifespans and regeneration dynamics occurring over longer timescales (Bongers *et al.*, 2020).

Ecologically, this pattern indicates the presence of a regeneration bottleneck, a condition where some species successfully emerge in the early phase, but only a fraction are able to survive and develop to a higher stage (Poorter *et al.*, 2021). The decline in species numbers from the seedling stage to the sapling stage indicates the presence of a critical stage in the early growth phase. This condition is thought to be related to differences in species' adaptive capabilities to microhabitat conditions, shade tolerance, and survival ability during the early stages of development (Ledo *et al.*, 2022).

Variations in regeneration patterns between species also indicate that the *Ficus* community at the study site does not have a uniform regeneration strategy (Sullivan *et al.*, 2020). Some species exhibit relatively high early recruitment success, whilst others are more dominant at the adult stage (Idris *et al.*, 2020). These patterns suggest that the regeneration dynamics of *Ficus* communities do not proceed linearly, but rather through changes in the ecological contributions of species at each growth stage (Mensah *et al.*, 2020). Thus, the resulting regeneration structure reflects the interaction between species' biological characteristics and local environmental conditions in shaping the dynamics of *Ficus* communities (Matsuo *et al.*, 2023).

Environmental Factors

Environmental conditions at the study site provide a general overview of the microhabitat characteristics of the *Ficus* community in the Manggis Gadungan Nature Reserve. The environmental parameters observed included air temperature, air humidity, soil moisture, soil pH, and light intensity (Table 3). The average values recorded were 27.8°C for air temperature, 78.00% for air humidity, 5.6 for soil moisture, 7 for soil pH, and 81.25 for light intensity. These parameters indicate that the study habitat has a relatively humid microclimate with varying light intensity beneath the forest canopy (Sulfayanti *et al.*, 2023).

Table 3. Average values of environmental parameters at the study site

Parameter	Average value
Temperature (°C)	27,8
Air humidity (%)	78,00
Soil moisture	5,6
Soil pH	7
Light intensity	81,25

Ecologically, these microhabitat conditions are thought to be linked to variations in vegetation structure and interstratum species composition. Light intensity is a key factor in determining vegetation growth as it influences photosynthesis, early recruitment, and the growth success of individuals at various stages of development (Wang *et al.* 2023). In tropical forest ecosystems with complex canopy stratification, light heterogeneity often plays a role in shaping species distribution patterns at both lower and upper levels (Idris *et al.*, 2020).

Air humidity, soil moisture, and soil pH conditions also play a role in determining habitat suitability for vegetation growth and survival (Maulidia *et al.*, 2025). Environments with relatively high humidity can support early growth phases, particularly during germination and seedling development (Salsabila *et al.*, 2021). Although this study did not analyse statistical relationships between environmental variables and community structure, these variations in microhabitat conditions provide an important ecological context for understanding the differences in species dominance, inter-storey distribution, and regeneration patterns observed in *Ficus* communities (Hendrayana *et al.*, 2019).

When considered in relation to vegetation structure and regeneration, local environmental conditions are thought to play a role as one of the factors influencing species success at each stage of growth (Mensah *et al.*, 2020). Species with a broader tolerance to variations in microhabitat conditions tend to have a greater chance of surviving at more than one level, whereas species with a narrower tolerance tend to be restricted to specific levels (Wang *et al.*, 2023). This pattern indicates that the vegetation structure, diversity, and regeneration of *Ficus* communities are interrelated components shaped by the interaction between species' biological characteristics and local environmental conditions (Abuel *et al.*, 2025).

In general, the results of this study indicate that vegetation structure, diversity, regeneration, and environmental conditions interact to shape the dynamics of *Ficus* communities. These findings underscore the importance of an integrative approach in understanding the sustainability of *Ficus*

populations and can serve as a scientific basis for habitat management that supports natural regeneration processes within conservation areas.

CONCLUSION

The *Ficus* community in the Manggis Gadungan Nature Reserve comprises 15 species with a total of 129 individuals. The Shannon–Wiener diversity index (H') ranges from 1.055 to 2.299, indicating a moderate to high level of diversity across various growth stages. The vegetation structure reveals a shift in dominance between growth stages, where species dominant in the early growth phase do not always maintain their dominance into the mature phase. Regeneration patterns indicate a mismatch in species distribution across growth stages. The decline in species numbers from the seedling to the sapling stage, which then increases again at the tree stage, indicates that not all species appearing in the early growth phase are able to maintain their presence at every stage of development. Environmental conditions such as light intensity, air humidity, soil moisture, and soil pH are thought to be associated with variations in vegetation structure, diversity, and regeneration patterns of the *Ficus* community.

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- Data Availability** : The raw data on the community structure, species diversity, and regeneration of *Ficus* species generated during this study are available from the corresponding author upon reasonable request.
- Ethical Approval** : This study was conducted under a Conservation Area Entry Permit (SIMAKSI) issued by the Natural Resources Conservation Agency, Number SI.554/K.2/BIDTEK/KSA.03.01/B/3/2026. The research was also supported by a research permit from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya (Letter No. B/23926/UN38.3/LT.0202/2026, dated 13 February 2026).
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