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Research Article

Diversity and Distribution of *Ficus* (Moraceae) in The Karst Ecosystem of Bantimurung Bulusaraung National Park

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ABSTRACT
Bantimurung Bulusaraung National Park is an area that has the largest karst ecosystem in Indonesia. Karst is prone to damage and difficult to reuse, so it requires conservation efforts. One of the plant species that can maintain this sustainability is *Ficus* which acts as key species in karst ecosystems. However, at this time the species is experiencing disturbances, one of which is due to the experience of invasive plants that can threaten the existence of *Ficus* because the weeds can colonize habitats and are dominant which can change species diversity. This study aimed to analyze the diversity and distribution of *Ficus*, compare species composition, and analyze environmental factors that affect *Ficus* spp. in Pattunuang Resort and Bantimurung Resort. Vegetation analysis method with nesting plots placed by purposive sampling and supported with environmental and soil data measurements to determine the factors that indicate the habitat preference of *Ficus*. We found 18 plant species of *Ficus* spp. in total. At Resort Pattunuang we found 14 *Ficus* species with the highest abundance being *Ficus sundaica* (27.55%), while we recorded 15 *Ficus* species at Resort Bantimurung with the highest abundance being *Ficus ampelas* (29.23%). *Ficus* species were uniformly distributed with a relatively high ratio of species composition in both resorts. Principal Component Analysis (PCA) showed that the presence of *Ficus* in Pattunuang Resort is influenced by wind speed, soil temperature, air temperature, soil moisture, soil pH, and air humidity. In Bantimurung Resort, the existence of *Ficus* is influenced by wind speed, soil temperature, soil moisture, and air humidity.

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INTRODUCTION
Karst areas cover approximately 12-15% of the world's total land area (Zhao et al. 2014; Zhu et al. 2017; Liu et al. 2020), providing water supply for 25% of the world's water population (Bystriakova et al. 2019). Karst landscapes are formed due to the dissolution of rocks (Waele 2016; Sun et al. 2018), which are dominated by carbonate rocks consisting of calcite as the main mineral (Retnowati et al. 2014). Indonesia, with a land area of around 1.919.440 km^2, has a karst area of aproximately 154.000 km^2 in total (Cahyadi 2017), or equal to 8% of the total land area of Indonesia. One of these Indonesian karst areas is in South Sulawesi, the largest karst area in Indonesia and the second largest karst area in the

world after China (Achmad & Hamzah 2016). The area is located in Pangkep Regency and Maros Regency with a part of the area included in the Bantimurung Bulusaraung National Park. The area of Bantimurung Bulusaraung National Park is ± 437,5 km² with a karst area of 228 km² which has a geological expanse in the form of a distinctive and unique landscape and landform with the main characteristic of a karst shape that resembling a tower (karst tower). The topographical terrain of this area is the form of rock outcrops, karst caves, sinkholes, and underground rivers (Pepe & Parise 2014).

The diversity of a species is one of the essential things in ecology because it is related to ecosystem function (Zhenming et al. 2020). One of the supporting plants in the ecosystem is a plant originating from the *Ficus* genus (Moraceae), which acts as a key species because it has a major impact on the ecosystem as a food source and animal habitat. In addition, *Ficus* a root system that can store water reserves and can maintain slope, and also has a lush canopy that can absorb CO_2 in the air (Hao et al. 2016; Hendrayana et al. 2021). *Ficus* is a widely distributed pantropical plant with high diversity (Harrison et al. 2012; Wijaya & Defiani 2021). These species can be distinguished from other plant species by their unique fruit called syconium. The fruit is the enlarged part of the receptacle and contains hundreds of tiny flowers (Berg & Wiebes 1992). In addition, the fruit has a hole called an ostiole as an entrance after the compound is released to attract specific pollinators (Harrison & Rasplus 2006). Insects can only pollinate *Ficus* from the Agaonidae, Hymenoptera, and Chalcidoidea families (Serrato et al. 2004; Pothasin et al. 2014; Chiang et al. 2018). *Ficus* has 735 species spread throughout the world (Berg & Corner 2005; Bain et al. 2015), 367 *Ficus* species are found in the Malesiana area, 81 species are found in Sulawesi (Berg & Corner 2005), and 47 species are found in Bantimurung Bulusaraung National Park (Achmad & Hamzah 2016).

Ficus is a plant that is a key species because it can bear fruit throughout the year, so it becomes a food source when natural resources are scarce (Shanahan & Compton 2001; Tello, 2003; Pothasin et al. 2014). However, the existence of *Ficus* in Bantimurung Bulusaraung National Park is experiencing disturbance due to invasive plants threatening the existence of *Ficus* (BKSDAE 2017). Invasive plants can colonize a habitat and become dominant, which can change the composition of species diversity and even cause the extinction of native species unable to compete. These have a sustainable impact on the existence of *Macaca maura*, *Aceros cassidix*, and *Strigocuscus celebensis* as endemic animals of Sulawesi which are protected because *Ficus* is a source of food for these animals (Kinnaird et al. 1996; Dwiyahreni et al. 1999; Labahi 2021). Ecological studies of *Ficus* as a key species are still limited which causes the lack of information to carry out efforts to protect and conserve the species. Conservation of species is essential to consider the status of Bantimurung Bulusaraung National Park, which is currently included in the UNESCO Global Geoparks. Therefore, this study aimed to analyze the diversity and distribution of *Ficus*, compare its species composition, and analyze abiotic factor of habitat preferences of *Ficus* in Pattunuang Resort and Bantimurung Resort.

MATERIALS AND METHODS

Study Site

This research was conducted from January 2022 to June 2022 in the karst ecosystem of Pattunuang Resort and Bantimurung Resort, Bantimurung Bulusaraung National Park, Maros Regency, South Sulawesi

(Figure 1). Bantimurung Bulusaraung National Park has seven resorts. The highest area of the region is in the North Bulusaraung Mountain with an altitude of 1.565 m asl (Bantimurung Bulusaraung National Park Hall (BTNBB) 2016).

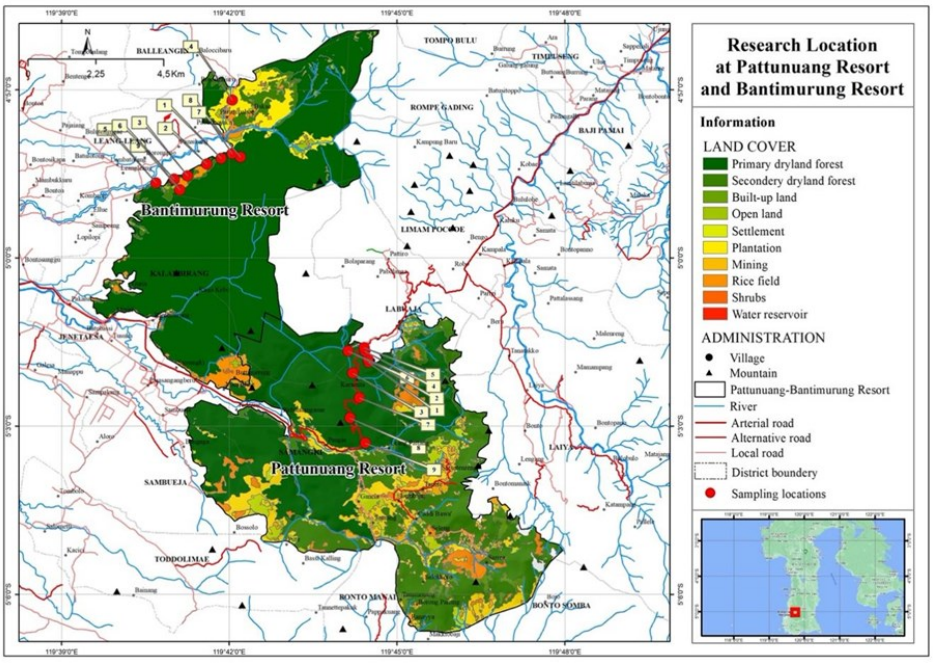

Figure 1. Sampling locations at Pattunuang Resort dan Bantimurung Resort.

Materials and Methods

Vegetation data were collected using the roaming method to determine field conditions and the presence of *Ficus* (Serrato et al. 2004). Each location that is considered representative of the population is made into multilevel square plots which are placed by purposive sampling with an undetermined distance between plots because the sampling is based on the presence of *Ficus* in the field (Tongco 2007). Plot sizes used are 20 m x 20 m for trees, 10 m x 10 m for poles, 5 m x 5 m for saplings, and 2 m x 2 m for seedlings (Mueller-Dombois & Ellenberg 1974). At Pattunuang Resort and Bantimurung Resort, 9 plots were made using the same method.

The collected microclimate data were air humidity, air temperature, light intensity, and wind speed. These microclimate data were measured using a 4 in 1 environmental tester. Collected soil data consisted of soil temperature, soil pH, and soil moisture and were measured using a soil tester. In addition, soil texture identification and chemical analysis were carried out by taking 1 kg of soil samples at each sampling location and then composited and tested in the laboratory for nutrient content and soil texture.

Data Analysis

Ficus spp. was identified based on Flora Malesiana *Ficus* (Berg & Corner 2005). Other plant species were identified in he Flora Malesiana (Flora Malesiana 2022). The accepted species naming system follows the species classification on the Plants of The World (POWO 2022). The calculation of the Important Value Index (INP) with the accumulative parameters of relative density, relative frequency, and relative dominance was following Cox (1978). The calculation of the Summed Dominance Ratio (SDR) by dividing the INP value with the number of parameters that compile the INP (Kusmana 2017). Other calculations of biodiversity index parameters

such as the Shannon-Wiener Diversity Index (H') (Krebs 1989), the Margelaf Wealth Index (R) (Magurran 2004), the Evenness Index (E) (Magurran 1988), and the Dominance Index (C) (Misra 1988) was processed using Past software version 4.03 (Hammer et al. 2001). The species distribution was analyzed using the Morisita Index (Brower et al. 1989) and the vertical distribution of species was analyzed using the Past software version 4.03. Microclimate data were analyzed using Principal Component Analysis with R software version 4.0.4. (Husson et al. 2017).

RESULTS AND DISCUSSION

Species Diversity of *Ficus* spp.

The identification results show that Pattunuang Resort contains as many as 14 species of *Ficus* spp. we found as many as 15 species of *Ficus* at Bantimurung. Berg & Corner (2005) stated that *Ficus* has six subgenuses: *Ficus*, *Pharmacosycea*, *Sycidium*, *Sycomorus*, *Urostigma* and *Synoecia* distinguished by basis of the vegetative parts and the exterior of the fruit. There were 1 species of *Ficus* found from the *Ficus* subgenus, 2 species of *Pharmacosycea* subgenus, 5 species of *Sycidium* subgenus, 4 species of *Sycomorus* subgenus, and 6 species of *Urostigma* subgenus (Table 1). The number of *Ficus* individuals observed was 103 individuals from both resorts.

Table 1. Diversity of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort.

Species	Reproduction system	FR (%)	Growth phase	Plant height (m)*
Subgenus *Ficus*				
Ficus fulva Reinw ex. Blume[B]	Gyno[1]	1,16	Tr	20
Subgenus *Pharmacosycea*				
Ficus albipila (Miq.) King[A]	Mono[2]	2,33	Tr	40
Ficus callosa Willd.[AB]	Mono[3]	9,30	Tr	45
Subgenus *Sycidium*				
Ficus ampelas Burm f.[AB]	Dioe[4]	12,79	Tr	15 – 25
Ficus pisifera Wall ex. Voigt[B]	Dioe[5]	9,30	Tr, Sp	10
Ficus gul K.Schum. & Lauterb.[AB]	Dioe[6]	5,81	Tr, Sp	25
Ficus obscura Blume[AB]	Dioe[1]	3,49	Tr, Pl, Sp	8
Ficus subulata Blume[A]	Dioe[1]	4,65	Tr	15
Subgenus *Sycomorus*				
Ficus fistulosa Reinw ex. Blume[B]	Dioe[7]	3,49	Sp	10 – 18
Ficus septica Burm.f.[B]	Dioe	1,16	Tr	25
Ficus racemosa L.[AB]	Mono[9]	3,49	Tr	30
Ficus variegata Blume[AB]	Dioe[8]	4,65	Tr	40
Subgenus *Urostigma*				
Ficus benjamina L.[AB]	Mono[10]	3,49	Tr	35
Ficus callophylla Blume[AB]	Mono[11]	4,65	Tr	25
Ficus drupacea Thunb.[AB]	Mono[7]	8,14	Tr	35
Ficus sumatrana Miq.[A]	Mono[11]	2,33	Tr	30
Ficus sundaica Blume[AB]	Mono[10]	11,63	Tr	35
Ficus virens Aiton[AB]	Mono[12]	8,14	Tr	35

FR: relative frequency; m: meter; A: Pattunuang Resort; B: Bantimurung Resort; Gyno: gynodioecious; Dioe: dioecious; Mono: monoecious; (1) Shanahan & Compton (2001); (2) Weiblen (2000); (3) Tarachai et al. (2011); (4) Bain et al. (2013); (5) Huang et al. (2019); (6) Wijaya & Defiani (2021); (7) Corlett (2006); (8) Bain et al. (2015); (9) Teixeira et al. (2018); (10) Harrison (2008); (11) Shanahan (2000); (12) Fu et al. (2017); Tr: Tree; Pl: Pole; Sp: Sappling; (*): Berg & Corner (2005).

The recorded growth phase *Ficus* in the study sites are trees, poles, and saplings. The seedling growth phase was not found in the study sites. The relation between the presence of *Ficus* in nature and frugivore is an influential factor in seed distribution. The different sizes of fruit have implications for the frugivorous species that feed on them. *Ficus* fruit is mainly eaten by birds and is placed in the tree canopy so that it is easy to germinate because it is exposed to direct sunlight. In mammals, frugivores with a larger size require more f ood. In addition, these frugivores travel longer distances. Therefore, *Ficus* seeds are not found close to the tree (Shanahan 2000). Competition with understorey plants in obtaining nutrients and sunlight access to the forest floor makes it difficult for *Ficus* to grow and develop (Rodrigues et al. 2018), so the seedling phase is not found.

Most of the recorded *Ficus* species belong to the subgenus *Urostigma*. All species of *Urostigma* are monoecious that live as hemi-epiphytes by starting the life phase in the tree canopy. Species of the subgenus *Urostigma* are easily pollinated because male and female flowers are in the same fruit. Therefore, their presence is found throughout the year. Fruits of the subgenus *Urostigma* are eaten and carried by birds with comprehensive mobility, so *Ficus* of *Urostigma* is found in both resorts except *F. sumatrana* (Berg & Corner 2005). Species from the subgenus *Synoecia* were not found in this study. All species of the subgenus *Synoecia* live as climbers. This can be caused by several factors, such as the ability of the host tree to get sunlight, the frequency of trees suitable for plant development, features of the bark of plants (Berg & Corner 2005), and stagnant development due to shade so that not all trees are suitable for use as a tree host (Harrison 2005).

Distribution of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort

Pattunuang Resort has a hilly topography with less dense vegetation conditions. Some of Sulawesi's endemic animals are in the area, such as *Macaca maura* and *Tarsius fuscus*, so this location is often used as an animal observation area. Bantimurung Resort has a more open land cover and denser vegetation. Bantimurung Resort has several natural attractions, one of which is the famous natural tourist attraction Bantimurung like The Kingdom of Butterfly. *Ficus* INP values that exceeded or equal to 20% are presented in Table 2.

Pattunuang Resort is dominated by *F. sundaica*, *F. callophylla*, and *F. subulata*. *Ficus sundaica* and *F. callophylla* are subgenus *Urostigma* species that are distributed mainly by birds and arboreal mammals, so these species are commonly found in the study site. *Ficus sundaica* and *F. callophylla* live as epiphytes in the tree canopy. Seeds carried by animals are stored in gaps or tree trunks that support growth and development. *Ficus subulata* belongs to the subgenus *Sycidium* and is a common species found in large forest areas. *Ficus subulata* can produce a massive number of fruits. This species can serve as a refuge area and a niche for some frugivores by forming dense branches (Wijaya & Defiani 2021). The three *Ficus* species were found to have tree trunk diameters of more than 50 cm such as *F. benjamina*, *F. callosa*, *and F. variegata* with deep roots. The root system of *Ficus* can maintain the integrity of the slope so that it can act as erosion control (Vannoppen et al. 2017; Chen et al. 2022).

Bantimurung Resort was dominated by *F. ampelas*, *F. virens*, and *F. drupacea*. *Ficus ampelas* belongs to the subgenus *Sycidium*, a species that inhabits primary and secondary forests and is eaten by birds that forage under tree canopies. *Ficus virens* and *F. drupacea* are species from the sub-

Table 2. Composition of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort with INP values that exceeded or equal to 20%.

Location	Growth	Species	KR (%)	FR (%)	DR (%)	INP (%)
PTN	Tree	*Ficus sundaica*	5,88	7,35	14,32	27,55
		Ficus callophylla	2,35	2,94	18,50	23,79
		Ficus subulata	5,88	5,88	11,26	23,02
BTM	Tree	*Ficus ampelas*	6,85	8,47	13,90	29,23
		Ficus virens	8,22	10,17	9,93	28,32
		Ficus drupacea	6,85	8,47	8,18	23,51
	Pole	*Ficus pisifera*	14,71	10,34	14,82	39,87
	Sappling	*Ficus pisifera*	4,30	7,55	11,67	23,52

PTN: Pattunuang Resort; BTM: Bantimurung Resort; KR: relative density; FR: relative frequency; DR: relative dominance; INP: important index value.

genus *Urostigma*, categorized as potential and high-potential species. They are consumed by animals that forage above and under the tree canopy, so their presence is often found due to having many fruit dispersal agents (Rahayuningsih et al. 2020). *Ficus pisifera* was found to dominate the growth phase of the poles and saplings in Bantimurung Resort. This species has small fruit with a diameter of less than 5 cm. It is consumed by animals that forage under the tree canopy (Cruaud et al. 2012) with mobility that is not too far from where it forages. Possibly this is why the species is only found in Bantimurung Resort only. Various index values that indicate *Ficus* diversity in the Pattunuang Resort and Bantimurung Resort are shown in Figure 2 and Figure 3 respectively.

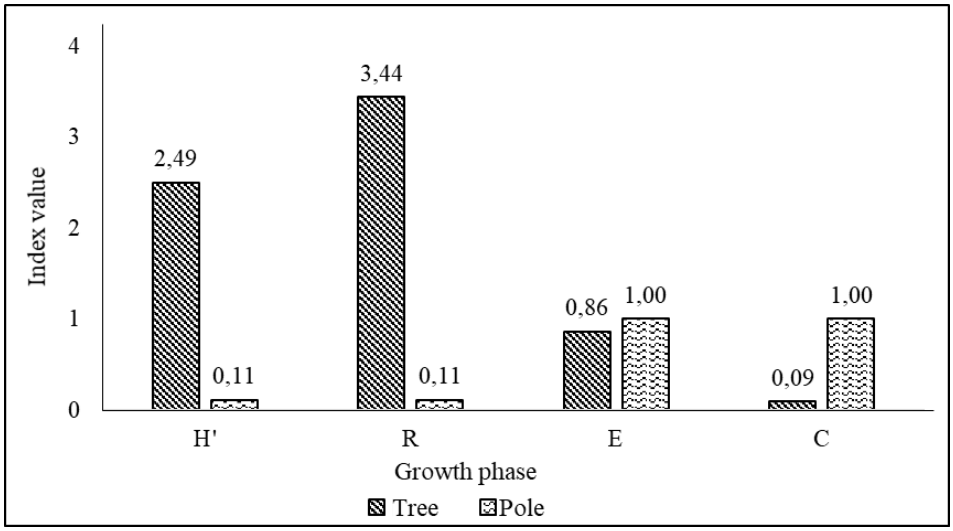

Figure 2. Diversity of *Ficus* spp. at Pattunuang Resort; H': species diversity; R: species richness; E: species evenness; C: species dominance.

The diversity (H') of *Ficus* at Pattunuang Resort for the tree and pole phases is classified as moderate with an index value of more than 1 and less than 3. In contrast, the pole has a low category because the index value is less than 1. Species richness (R) for all growth phases shows a value of less than 3.5 which indicates that the species richness is low. The level of evenness (E) in all growth phases shows a value close to 1, indicating that all species are evenly distributed. The dominance (C) in the tree phase is close to 0, which indicates that there is less concentration of species in the tree growth phase. In contrast, the dominance value of the pole is near to 1, indicating that *Ficus* in the pole phase is the dominant concentration in the Pattunuang Resort.

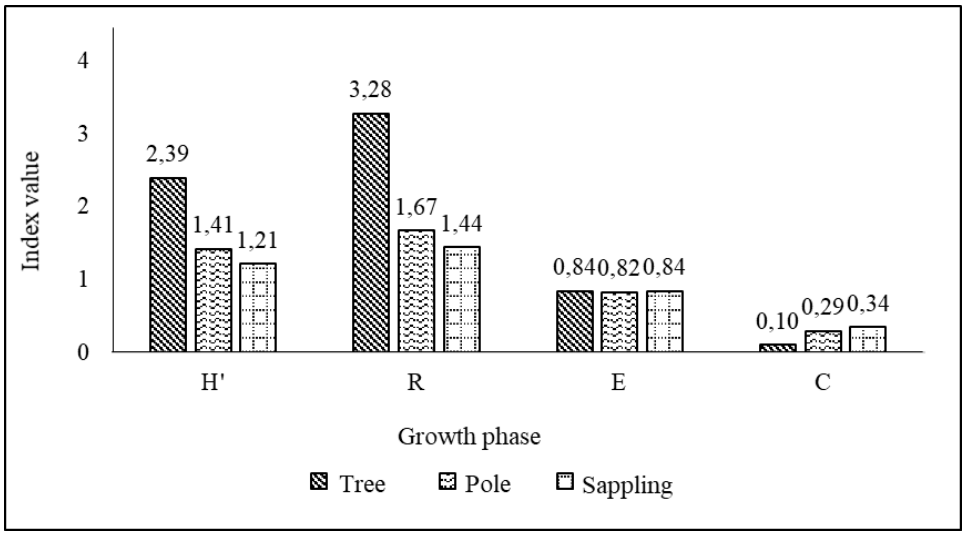

Figure 3. Diversity of *Ficus* spp. at Bantimurung Resort; H': species diversity; R: species richness; E: species evenness; C: species dominance.

The diversity (H') of *Ficus* at Bantimurung Resort for all growth phases is moderate because it has an index value greater than 1 but below 3. Species richness (R) is low because it shows a value of less than 3,5 for all growth phases. The level of evenness (E) in all growth phases shows a value close to 1, indicating that all species are evenly distributed. That is in line with a dominance value close to 0, which indicates no particular dominant growth phases of *Ficus* species in Bantimurung Resort.

Based on the data analysis, it was found that *Ficus* spp. has a uniform distribution pattern in both resorts. The relevant index value are presented in Table 3.

The distribution pattern of *Ficus* spp. has a uniform pattern, shown by the value of the Standardized Morisita Index (Ip) below 0. The distribution with a uniform pattern was also found in the study of Geekiyanage et al. (2019), which shows that tree species with non-random distribution patterns found in karst areas are closely related to their edaphic variations. The uniform distribution pattern occurs due to competition between individuals which causes equal or even distribution of space so that there is no tendency to group. In addition, the uniform distribution pattern is associated with a specific pollination system (Harrison et al. 2012). *Ficus* distribution is often found in the tropics and thrives in the lowlands (Bain et al. 2015). Bantimurung Bulusaraung National Park with an altitude of 1,565 m asl is similar to the *Ficus* habitat elevation as stated by Berg and Corner (2005) that *Ficus* mainly grows on plains of 1,500 m asl. The vertical distribution of *Ficus* was found evenly along the elevation gradient of the sampling locations at both resorts. The distribution can be seen in Figure 4.

In the field, exploration results found *Ficus* at an altitude of 35 – 334 m asl (Figure 4). *Ficus* at altitudes 0-100 m asl found 15 species at an altitude of 100-200 m asl, as many as 9 species, at an altitude of 200-300 m asl found 8 species, and at an altitude of 300-400 m asl there were 10 species. *Ficus ampelas* is a species found at an altitude of 36 m asl and is a species found at the lowest location. *Ficus obscura* is a species found at the highest location with an altitude of 334 m asl. *Ficus albipila* and *F. sumatrana* are species found in almost every altitude interval. *Ficus albipila* is a large tree species and is often found because its disperser insects can regularly spread seeds over long distances (Harrison & Rasplus 2006). *Ficus sumatrana* is a species that has various morphological variations so that it is easy to adapt, including at different altitudes (Berg & Corner 2005).

Table 3. Composition of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort.

Resort name	Disperse Morisita index (Id)	Uniform index (Mu)	Clumped index (Mc)	Standard Morisita index (Ip)	Distribution pattern
PTN	0,91	0,87	1,22	-0,32	Uniform
BTM	0,86	0,85	1,25	-0,45	Uniform

PTN: Pattunuang Resort; BTM: Bantimurung Resort.

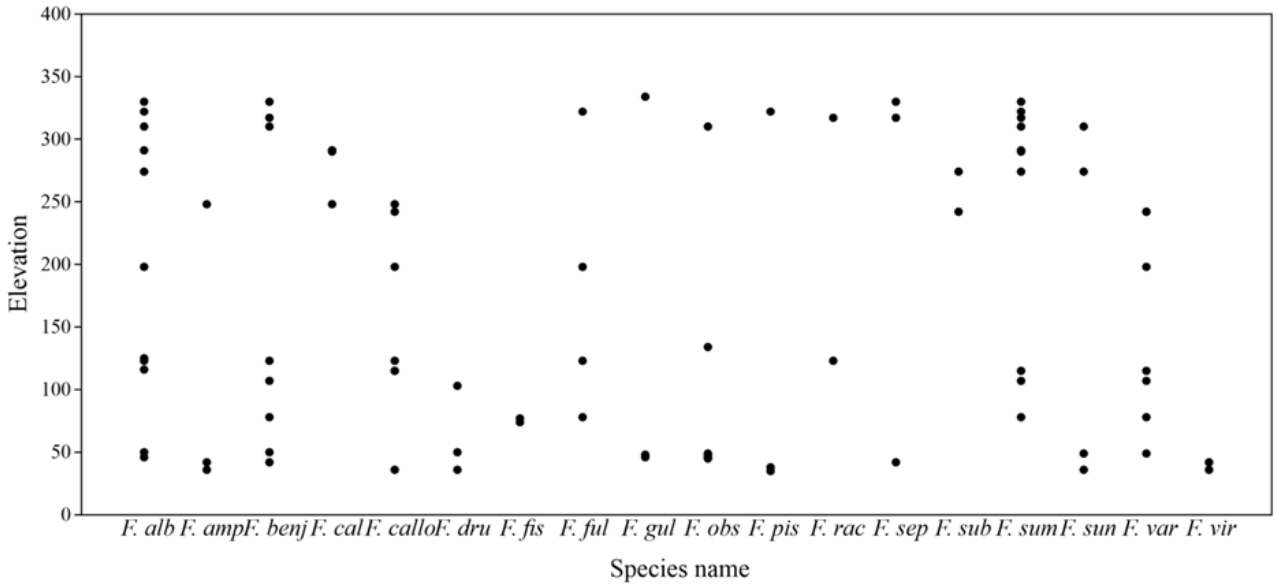

Figure 4. Vertical distribution of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort; F. alb: *F. albipila*; F. amp: *F. ampelas*; F. benj: *F. benjamina*; F. cal: *F. callosa*; F. callo: *F. callophylla*; F. dru: *F. drupacea*; F. fis: *F. fistulosa*; F. ful: *F. fulva*; F. gul: *F. gul*; F. obs: *F. obscura*; F. pis: *F. pisifera*; F. rac: *F. racemosa*; F. sep: *F. septica*; F. sub: *F. subulata*; F. sum: *F. sumatrana*; F. var: *F. variegata*; F. vir: *F. virens*.

Organisms that occupy the same space tend to be dependent on and influence each other so that if there is a disturbance to the organism and its environment, it will affect the community as a whole (Barbour et al. 1987). The studied forest area dominated by karst hills and rocks, makes *Ficus* can only be observed along the observation path. A total of 11 species of *Ficus* spp. was found in both observation resorts, namely *F. ampelas*, *F. benjamina*, *F. callophylla*, *F. callosa*, *F. drupacea*, *F. gul*, *F. obscura*, *F. racemosa*, *F. sundaica*, *F. variegata*, and *F. virens*.

The species similarity at both locations is indicated by the Jaccard similarity index value is 61% which illustrates the similarity of *Ficus* spp. between the two resorts is high based on the criteria by Mueller-Dombois & Ellenberg (2016). The presence of the same species indicates that *Ficus* can occupy ample space and grow well in extreme karst environments. Achmad & Hamzah (2016) found as many as 47 species of *Ficus* spp. scattered throughout the Bantimurung Bulusaraung National Park area and in this study 18 species were found, indicating that the recorded species of *Ficus* spp. in this study is equal to 38% of the total *Ficus* in Bantimurung Bulusaraung National Park.

Habitat Characteristics as Habitat Preference of *Ficus* spp.

Ficus is widely distributed in the tropics, including in the karst ecosystem. The distribution can be influenced by the suitability between environmental conditions (such as light intensity, soil, wind, and humidity) and the character possessed by plant species. The ability to grow well and develop in *Ficus* makes it used as an important species in karst slope

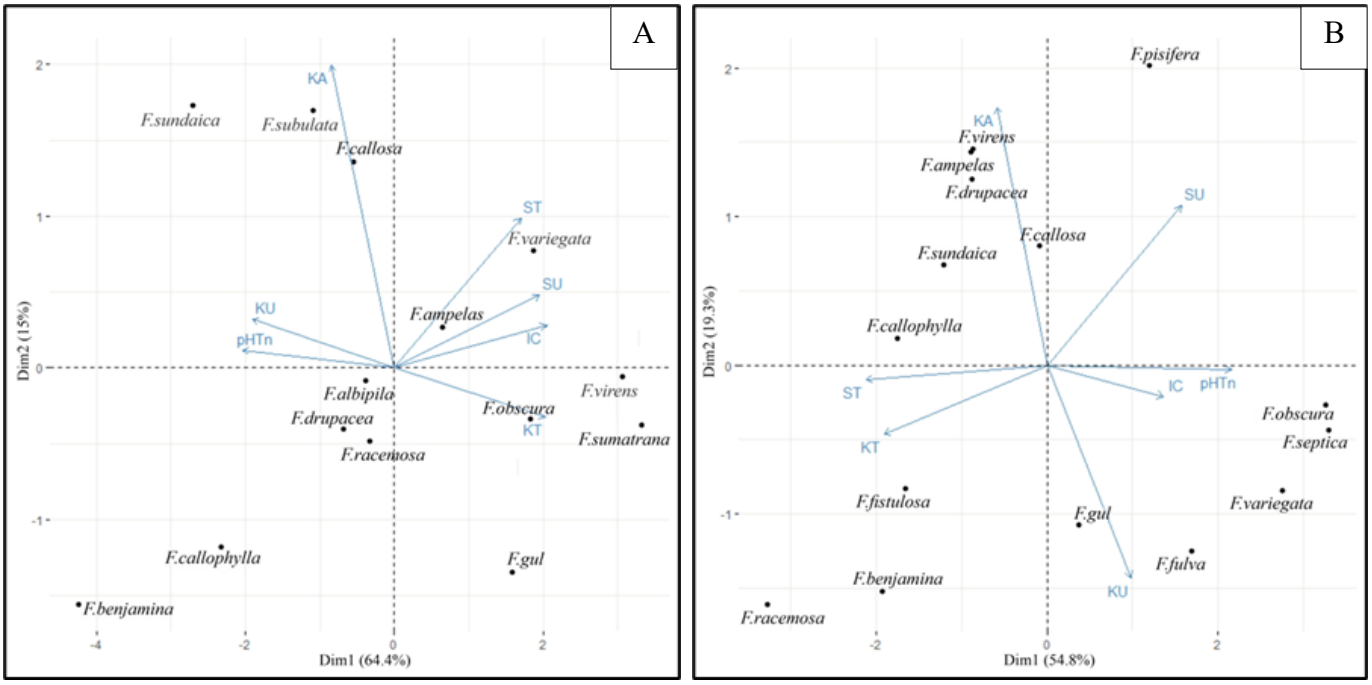

Figure 5. A: Pattunuang Resorts; B: Bantimurung Resorts; IC: light intensity; SU: air temperature; ST: soil temperature; KA: wind velocity; KU: air humidity; pHTn: soil pH: soil moisture.

areas to prevent erosion (Chen et al. 2022). The existence of *Ficus* is often used as an indicator of the process of forest succession because of its flexibility to grow as epiphytes, hemi-epiphytes, and trees, as well as efficient pollination that lasts for a long time, making it considered a pioneer plants (Berg & Corner 2005). PCA results that indicate the relation of environmental characteristics with the presence of *Ficus* spp. can be seen in Figure 5.

Pattunuang Resort (Figure 5A) has an eigenvalue of 4,51 (Dim 1) and 1,05 (Dim 2), respectively. Dim 1 explains 64,4% of data diversity and Dim 2 explains 15% of data diversity. *Ficus sundaica*, *F. drupacea*, *F. racemosa*, *F. callophylla*, *F. benjamina*, *F. gul*, *F. sumatrana*, and *F. virens* are far from vectors of environmental factors, so there are no environmental factors that precisely characterize the existence of the species. In contrast to *F. subulata* and *F. callosa* were influenced by wind speed. Soil temperature and air temperature influence the presence of *F. variegata* and *F. ampelas*. The presence of *F. obscura* is influenced by soil moisture. Air humidity and soil pH influence the presence of *F. albipila*. Bantimurung Resort (Figure 5B) has an eigenvalue of 3,83 (Dim 1) and 1,34 (Dim 2), respectively Dim 1 explains 54,8% and Dim 2 explains 19,3% of data diversity. *Ficus sundaica*, *F. benjamina*, *F. racemosa*, *F. variegata*, *F. septica*, *F. obscura*, and *F. pisifera* are far from vectors of environmental factors. Hence, the existence of these species is not significantly influenced by environmental factors. Wind speed affected the species of *F. virens*, *F. ampelas*, *F. drupacea*, and *F. callosa*. Soil temperature influences the presence of *F. callophylla*. Soil moisture affects *F. fistulosa*. The presence of *F. gul* and *F. fulva* was influenced by air humidity.

Environmental factors that have been grouped into PCA show the results of species based on the seven environmental factors, the majority have a distribution of *Ficus* spp. uniformly distributed species. Various environmental factors play an essential role in the distribution of a plant species (Körner 2007). None of the *Ficus* found in the study site were dominant because the overall INP values of *Ficus* were below 40%. BKSDAE South Sulawesi has reported that the presence of *Ficus* is threatened

Table 4. The results of the analysis of chemical properties of soil texture.

Parameters	PTN		BTM	
	Value	Criteria*	Value	Criteria*
Soil texture		Clay loam		Clay loam
Soil pH¨	6,43	Slightly acid	6,55	Slightly acid
C-Org (%)	1,73	Low	1,57	Low
N-Total (%)	0,17	Low	0,11	Low
Rasio C/N	10	Low	14	Medium
P_2O_5 Olsen (ppm)	9,81	Low	12,48	Medium
Ca ($cmol_c$/kg)	5,63	Medium	4,95	Low
Mg ($cmol_c$/kg)	1,69	Medium	1,06	Medium
K ($cmol_c$/kg)	0,47	Medium	0,28	Low
Na ($cmol_c$/kg)	0,18	Low	0,11	Low
SO_4 (ppm)	25,32	Low	24,19	Low
KTK ($cmol_c$/kg)	23,95	Medium	19,69	Medium
KB (%)	33	Low	33	Low

PTN: Pattunuang Resort; BTM: Bantimurung Resort; ¨: measurement data in field; *: criteria fo assessing the results of soil analysis according to Eviati & Sulaeman (2009).

by invasive species. *Spathodea campanulata* is an invasive species in Bantimurung Bulusaraung National Park (BKSDAE 2017). That species can grow and spread significantly through the production of up to 1.000 seeds per fruit and having the ability to develop vegetatively by stolons. The results of the composite soil analysis are shown in Table 4.

The analysis showed that the soil conditions were not significantly different at the two resorts. The two resorts criteria for different soil nutrients are the C/N ratio, P_2O_5, Ca, and K content. Karstification is a long-term phenomenon that affects the heterogeneity of nutrients along the topography of the karst ecosystem (Geekiyanage et al. 2019) so that some pathways in carbonate rocks result in faster soil leaching, causing reduced nutrient availability (Zhang et al. 2007). On the other hand, soil nutrient elements with medium and low criteria can indicate the presence of allelopathic compounds caused by invasive species. Lack of nutrients can lead to deficiencies in plants, making them unproductive (Osman 2013).

Conservation Strategy of *Ficus* spp. as Key Species of Karst Ecosystem in Bantimurung Bulusaraung National Park

Bantimurung Bulusaraung National Park has three main ecosystem types: karst ecosystems, non-dipterocarp rainforest ecosystem, and low mountain ecosystems. This type of ecosystem describes a high diversity and abundance of plant as reported by Achmad & Hamzah (2016). The peculiarities and uniqueness of the karst ecosystem store the potential that can be developed as an object and natural tourist attraction. All this potential is in the utilization zone known as The Seven Wonder (BTNBB 2016). Karst can be degraded due to geological activities, climate, and utilization, so vegetation is considered necessary to prevent damage.

Conservation of natural resources is a continuous conservation and protection activity that is carried out so that ecological processes are maintained. Conservation is carried out to deal with the biodiversity crisis (Heywood & Iriondo 2003). Based on the International Union for Conservation of Nature shows that all *Ficus* species found in this study have Least Concern conservation status (IUCN 2022), which means all species have been evaluated except *F. pisifera* and *F. callosa* which do not has a conservation status because it has not been evaluated (Table 5).

Table 5. Conservation status of *Ficus* spp. at Pattunuang Resort and Bantimurung Resort.

No.	Spesies	SDR (%)	Conservation status	Last reviewed
1	*Ficus sundaica*	8,05	Least Concern	2019
2	*Ficus pisifera*	7,84	-	-
3	*Ficus subulata*	7,67	Least Concern	2018
4	*Ficus variegata*	5,62	Least Concern	2018
5	*Ficus callosa*	5,50	-	-
6	*Ficus callophylla*	5,28	Least Concern	2018
7	*Ficus virens*	5,19	Least Concern	2018
8	*Ficus drupacea*	4,98	Least Concern	2018
9	*Ficus ampelas*	4,97	Least Concern	2018
10	*Ficus fistulosa*	4,52	Least Concern	2018
11	*Ficus albipila*	3,17	Least Concern	2019
12	*Ficus racemosa*	3,16	Least Concern	2018
13	*Ficus sumatrana*	3,14	Least Concern	2018
14	*Ficus gul*	2,49	Least Concern	2018
15	*Ficus benjamina*	2,30	Least Concern	2018
16	*Ficus obscura*	2,02	Least Concern	2018
17	*Ficus septica*	1,55	Least Concern	2018
18	*Ficus fulva*	1,42	Least Concern	2018

SDR: summed dominance ratio.

Ficus spp. at Pattunuang Resort and Bantimurung Resort show the highest dominance of 8% based on the Summed Dominance Ratio (SDR) value derived from the accumulated values of relative density, relative frequency, and relative dominance (Table 5). The SDR value illustrates the amount of control of a species over other species in the community (Kusmana 2017). Although *Ficus* is not a dominating species, its presence in the karst ecosystem has a significant role in maintaining the balance of the ecosystem. One of them is to provide food for protected animals such as *Macaca maura*, *Tarsius fuscus*, *Aceros cassidix*, *Ailurops ursinus*, and *Cervus timorensis* (Shanahan & Compton 2001).

Ficus is a threatened species due to the presence of *Spathodea campanulata* as an invasive species in the karst area of Bantimurung Bulusaraung National Park (BKSDAE 2017), making it necessary to conserve even though it is still listed in the IUCN Red List with Least Concern (LC) status. This is in line with the Bantimurung Bulusaraung National Park Long Term Management Plan 2016-2025 to realize the ideal governance of the area, maintain the karst ecosystem and its biodiversity, and improve ecosystem functions (BTNBB 2016). The study of *Ficus* diversity and distribution that has been carried out in this study provides information about efforts to achieve this. Conservation activities have implications for maintaining ecological processes, genetic diversity, and sustainable use of species and ecosystem.

CONCLUSIONS

There are 18 species of *Ficus* spp. found at Pattunuang Resort and Bantimurung Resort. Pattunuang Resort and Bantimurung Resort have a diversity index classified as moderate because the value of H' is more than 1 and less than 3. *Ficus* spp. uniformly distributed in both resorts. Comparison of the species composition of *Ficus* spp. classified as high in both Resorts with an IS_J value of 61%. Environmental factors affecting *Ficus* presence in Pattunuang Resort are wind speed, soil temperature, air temperature, soil moisture, soil pH, and air humidity. The presence of *Ficus* in Bantimurung Resort is influenced by wind speed, soil temperature, soil moisture, and air humidity.

AUTHOR CONTRIBUTIONS

In this research, Y, S, and RND designed research; Y has been tasked with sampling and observing the existence of *Ficus* and its ecological character in the field, data analysis, and manuscript writing. S and NRD supervised the identification process in the laboratory, data analysis, manuscript writing, and editing

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CONFLICT OF INTEREST

There is no conflict of interest in this research.

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