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Tree Species as Forage for Apis dorsata Binghamii and Impact on Tree Health in Mangolo Nature Tourism Area, Indonesia

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ABSTRACT

Apis dorsata Binghamii is an endemic forest bee found on the Sulawesi Island. Forest ecosystems provide perfect conditions for bee survival. The goal of this research is to identify feasible tree species as feed sources and to analyze the physical harm to trees as beehives. Purposive sampling is used in the site determination strategy, which entails putting observation stations on trees that host forest bee colonies. The sample center point (nest tree) is the starting point for drawing transects in the four cardinal directions, each 500 meters apart and measuring 20m × 20m with 20 plots. Vegetation analysis includes species diversity using the Shannon-Wiener method and the Importance Value Index using the Mueler-Dombois and Ellenberg methods. Physical damage to forest bee foraging trees was assessed using the Forest Health Monitoring method. The results indicated a high diversity of tree species (H'= 3.14). The major species are Castanopsis buruana Miq. and Payena acuminate (Blume) Pierre (Kuma). This plant has a wide and tall tree diameter, produces nectar and pollen through blossoms, and bees use it as a nest. However, this study discovered a variety of trees that had been damaged. The most common causes of tree damage are lianas and termites, accounting for 30% of the total. The Eha (Castanopsis buruana Miq.) sustained the most damage. As a result, forest conservation measures are required to restore the health of trees used as beehives and food sources for Apis dorsata Binghamii bees, as well as to increase honey production.

1. INTRODUCTION

Forest is a very valuable and fundamental natural resource [1], because they contain biodiversity [2] as a source of germplasm [3], sources of wood and non-wood (timber and non-timber) [4], water management [5], flood and erosion prevention [6], water and air purification [7, 8] and recreation [9]. To protect the diversity of biological resources, the Indonesian government enacts Law Numbers 5 of 1990, 23 of 1997, and 41 of 1999 [10].

Forest areas are regions designated by the government as permanent forests, whereas forests are classified as conservation, protected, or producing forests [10].

These places play an essential role in reducing deforestation and environmental degradation. The Mangolo Area, located in Kolaka Regency, Southeast Sulawesi Province, has been recognized by the government as a conservation area in the form of a Nature Tourism Park under the Minister of Forestry's Decree No. 142/Kpts-II/1990 dated April 2, 1990, with an area of 5,200 Ha.

The Mangolo Nature Tourism Area features a lowland tropical rainforest ecology. Vegetation diversity in tropical rainforest environments is characterized by broad-leaved, green vegetation and high levels of tree density [11, 12]. Throughout the year, this forest receives adequate sunlight, water, and rainfall. As a result, tropical woods provide a perfect habitat for wildlife and plants alike. It is corroborated by statistics showing that tropical rainforests have the highest degree of species richness and endemicity in the world [13].

The utilization of the Mangolo natural tourist park region is mostly for forest products. Forest bees are a forest product found in this area. As pollinating insects, forest bees can work in harmony with forest ecosystems. Forest bees (Apis dorsata Binghamii) are honey-producing insects. Apis dorsata Binghamii is the largest subspecies of Apis dorsata, with a white stripe on its stomach [14, 15]. This species is only found on Sulawesi Island and is considered endemic to the island [16, 17]. Currently, it cannot be cultivated [18]. It can also be found in the Mangolo Nature Tourism Area.

Apis dorsata Binghamii bees play a crucial role in the maintenance of forest ecosystems by pollinating numerous forest trees. This species needs woodlands for nesting and foraging [19]. As a result, any disturbance to the forest ecosystem will have an impact on its survival. Apis dorsata Binghamii bees typically nest in trees at elevations greater than 5 meters above ground [17]. Furthermore, discovered 9 families of various types of plants as nests: Arecaceae (Arenga pinnata), Myrtaceae (Psidium sp), Anacardiaceae (Mangifera sp), Malvaceae (Ceiba pentandra), Melastomataceae (Melastoma sp), Sapindaceae (Nephelium lappaceum), Fabaceae (Gliricidia sepium), Verbenaceae (Lantana camara), and Lythraceae (Lagerstroemia sp). Because it produces more nectar and pollen, the Arengan pinnata plant species has the highest percentage frequency among the others. Forage plants are the plants that produce food sources.

Apis dorsata Binghamii bees rely heavily on nectar and pollen [20] for nutrition [21] and protein for sexual maturity and body development [22]. This will have an impact on bee breeding. Meanwhile, plant abundance and flowering season have a significant impact on the availability of nectar and pollen. The abundance of flowering plants improves bee habitat and food availability. This is critical for honey production [23].

Apis dorsata Binghamii bees have a high honey production capacity, with 10-50 kg per nest [20]. This has an impact on local communities that rely on hunting in the forest for revenue. Aside from that, forest degradation in the Mangolo natural tourism region continues, therefore bee forage plants, which provide food for bees, are declining and even threatened with extinction. Parasitic larvae and pupae also drive bee colonies to migrate [24-26]. As a result, it is vital to assess the health of woods, particularly those that supply fodder for bees in the Mangolo natural tourist park area.

2. MATERIAL AND METHOD

The study is conducted in the Mangolo Nature Tourism Park Area, Ulunggolaka Village, Latambaga District, Kolaka Regency, Southeast Sulawesi Province (Figure 1). It was launched from April to July 2023. The study focused on bee plant species found in the study area.

The research materials were flowering plants at tree level. The tools utilized were innovative, including a machete, compass, Abney level, and GPS. Plant measurement instruments include meter tape, meter roll, tally sheet, paper, pencil, and pen. The documentation tool is a camera.

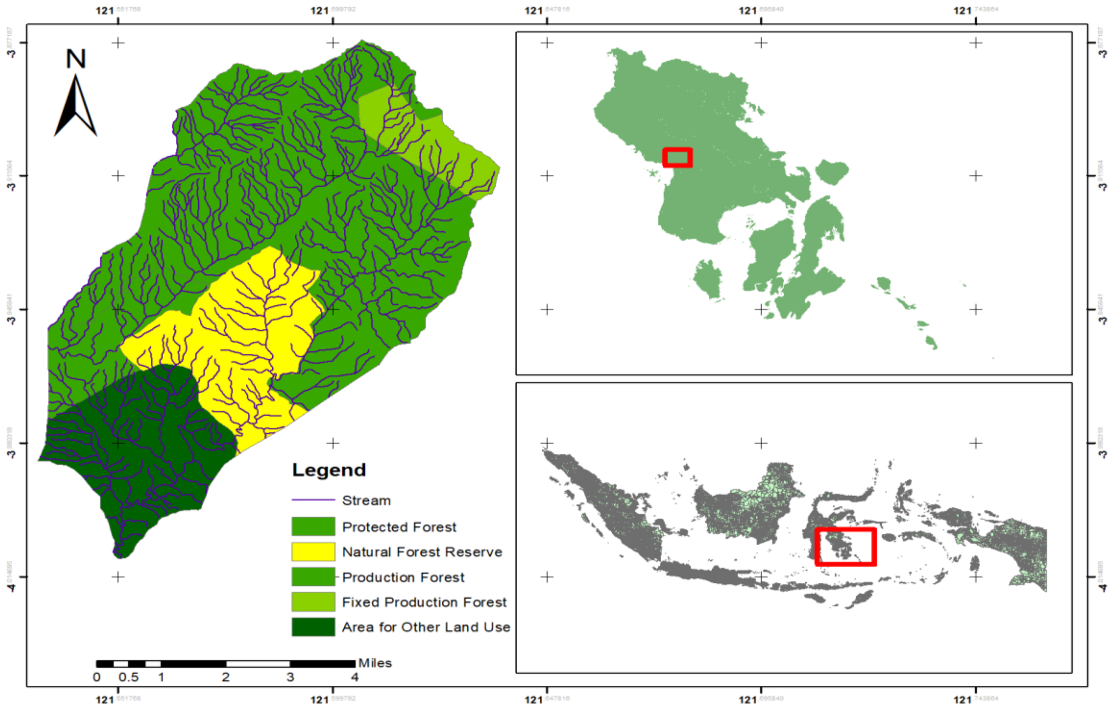

Figure 1. Study site

The sampling procedure is carried out at tree observation sites where forest bees (Apis dorsata Binghamii) live. The sample center point (nest tree) serves as the starting point for drawing transects 500 metres apart in four cardinal directions: east, west, north, and south. Each transect consists of five plots measuring 20m × 20m that are ordered sequentially. The total number of observation plots was twenty (Figure 2). Plant specimens are collected and identified in the field. Unknown plant species were maintained in a dry herbarium at Halu Oleo University's Forestry Department Laboratory.

The sampling method employs a systematic approach with random stars. The first measuring plot is randomly placed based on the type of tree containing the beehive, while the second plot is systematically placed based on the honey bee radius of ± 700 meters or ± 154 ha per day. The measuring plot was designed as a circle with a radius of 17.8 meters, encompassing a total area of 0.10 hectare. The sampling intensity employed was 1.54 hectares, resulting in 16 measurement plots. The distance between the measuring plots is 100 meters (Figure 2).

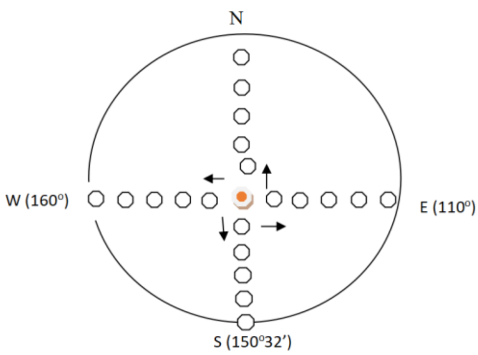

Figure 2. Observation plot

Inventory plants by noting the plant type, number of plants, plant density, and presence of blooms in each measuring plot. At the Forestry Department Laboratory, Faculty of Forestry and Environmental Sciences, Halu Oleo University, unknown plant species were preserved in a dry herbarium for identification purposes.

The data used for analysis include the number of individuals per species, the number of species, stem diameter, nectar and pollen producing plants, flowering status, and the shape and type of tree damage. The data was then analyzed to determine forest bee forage using the descriptive method, species diversity index using the Shannon-Wiener method in Soegianto [27], Importance Value Index (IVI) using the Mueler-Dombois and Ellenberg method [28], and forage tree physical damage by forest bees (Apis dorsata Binghamii) using the Forest Health Monitoring Method [29].

$$\text{Shannon-Wiener index, } H' = -\sum_{i=1}^{s} \left(\frac{ni}{N}\right) 1n \left(\frac{ni}{N}\right) \quad (1)$$

where, Shannon-Wiener index is the species diversity index, ni is the number of type I individuals, N is the total number of individuals, and S is the number of species found. According to Aye and Shibata [12], the H' index typically ranges from 1.5 to 3.5, but seldom exceeds 4.5. The higher the H' number, the greater the diversity.

$$\text{Mueler-Dombois and Ellenberg index, IVI} = \text{frekuensi relatif} + \text{densitas relatif} + \text{dominasi relatif} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1 Plant species as potential forage for Apis dorsata Binghamii

Flora types were identified in the Mangolo Nature Tourism Park area to learn more about the forest bee Apisdosata bringhamii's food sources. There were 276 possible vegetation specimens found, including 43 kinds and 24 families (Table 1). Fabaceae, Anacardiaceae, and Moraceae have the most forage source species producing nectar, pollen, and nest trees, with four species each, followed by Meliaceae, Dilleniaceae, Chrysobalanaceae, Simaroubaceae, Annonaceae, Hypericaceae, Guttiferaceae, Fagaceae, Burseraseae, Podocarpaceae, Myristicaceae, Verbenaceae, and Crustacean, each with one species (Figure 3). The genetic mix of plants in an area can influence their distribution and availability as a food source [30].

The number of nectar-producing plants is bigger than that of pollen sources and nest trees, with 35, 27, and 9 species, respectively. Honey bees feed mostly on nectar and pollen from flowering plants. Nuraeni et al. [17] reported similar findings. Flowering plants (Angiosperms) and bees form a symbiotic, mutually beneficial interaction. Flowers produce nectar and pollen, which worker bees collect to nourish their colonies, whilst bees pollinate flowering plants, increasing their output [31, 32]. Similar to this study, bees gather food to maintain their species' survival [33].

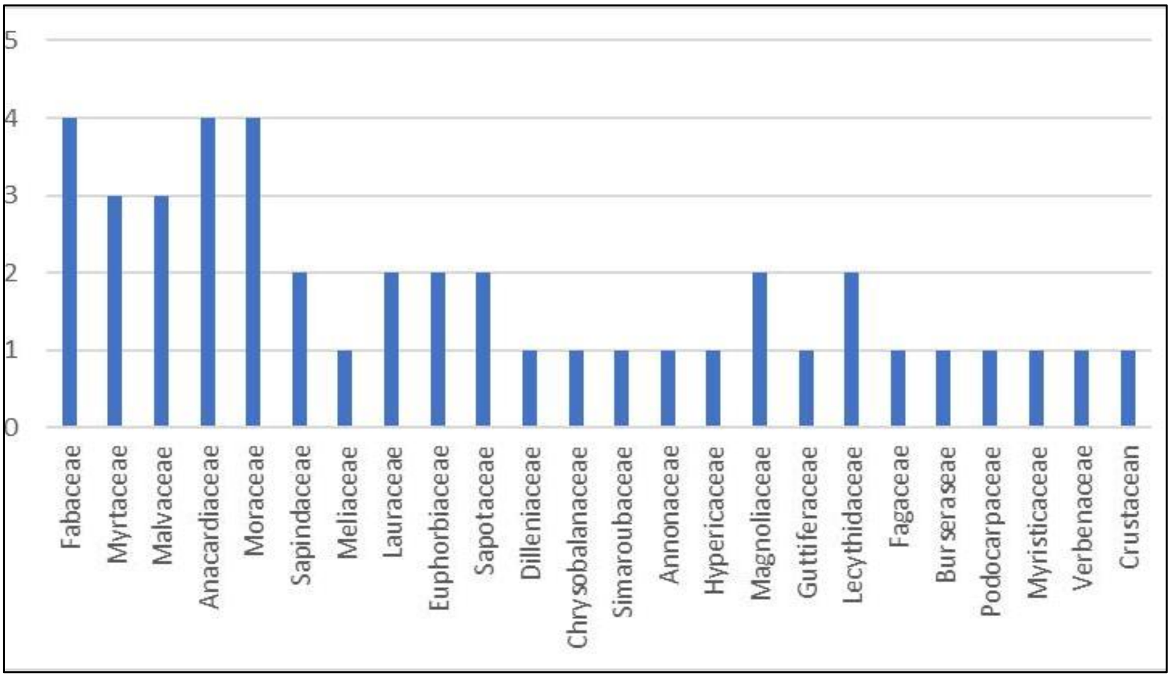

Figure 3. Amount of bee feed based on family

Nectar is frequently used as a source of carbonates and amino acids, which bees convert into honey. Pollen as a source of protein, lipids, vitamins, and minerals [34], and resin as propolis to fill gaps, caulk cracks, reduce and plug holes [35], and as a material for building beehives [36].

The Fabaceae family is one of the three plant groups most usually seen producing nectar and pollen at the research site. This is consistent with research undertaken by Al-Ghamdi and Al-Sagheer [37]. However, unlike the findings of Nuraeni et al. [17], the types of nectar and pollen generating plants are from the Arecaceae family, namely the Arenga pinnata type. This is due to fabaceace's high adaptability in ecosystems and global dissemination [38]. The Fabaceae plant family contains approximately 19,500 species divided into 720-730 genera. This plant tribe is worldwide and divided into three subtribes: Caesalpinioideae, Faboideae, and Mimosoideae. Morphologically, the leaves are compound, unifoliate, or bifoliate, the flowers are bisexual, unisexual, symmetrical actomorphic or zygomorphic, hypogynous or perigynous, and the fruit is winged pods (samara) or drupe [39]. The fabaceaceae tribe includes plants that are widely used and have high economic value as a green plant, food source, medicinal plant, ornamental plant, wood producer, erosion control, and land reclamation [40]. As a result, this plant plays a vital role in maintaining the forest resource ecology.

Table 1. Plant species as potential forage

No.	Botanical Name	Family	Source of Forage	Flowering Calendar	IVI (%)	H'
1	Castanopsis buruana Miq.	Fabaceae	NS + N + P	Jul., Aug., Sept., and Dec.	48.15	0.27
2	Lithocarpus glutinosus	Fabaceae	NS + N + P	Jun., Jul., Aug., Sept., and Dec.	2.19	0.04
3	Inocarpus fagiferus Fosb.	Fabaceae	N	Jul., Aug. and Sept.	2.18	0.04
4	Kalappia celebica Kosterm	Fabaceae	N	Apr. and May	5.47	0.09
5	Tetrameles nudiflora	Myrtaceae	N + P	Jul., Aug. and Sept.	2.14	0.04
6	Eugenia sp.	Myrtaceae	N + P	Mar., Apr., May, Jun., Jul., Aug. and Sept.	3.95	0.04
7	Syzygium cumini	Myrtaceae	N + P	Mar., Apr., May, Jun., Jul., Aug. and Sept.	3.9	0.06
8	Microcos paniculata L.	Malvaceae	N + P	Mar., Apr., May and Jun.	5.29	0.09
9	Durio zibethinus	Malvaceae	NS + N + P	Mar., Apr. and May	4.62	0.06
10	Ceiba pentandra	Malvaceae	NS + N + P	May, Jun., Jul., Aug. and Sept.	4.95	0.06
11	Semecarpus cuneiformis	Anacardiaceae	N	Jun., Jul., Aug. and Sept.	2.16	0.04
12	Koordersiodendron pinnatum	Anacardiaceae	N	Jul., Aug., Sept. and Oct.	10.97	0.09
13	Dracontomelon dao	Anacardiaceae	N + P	Jul., Aug. and Sept.	4.6	0.06
14	Agathis dammara	Araucariaceae	N	Mar. and Apr.	2.58	0.04
15	Artocarpus sp.	Moraceae	P	Aug., Sept. and Oct.	2.13	0.04
16	Ficus sp.	Moraceae	NS + P	Mar., Apr., Aug., Sept. and Oct.	6.27	0.06
17	Artocarpus champeden	Moraceae	NS + P	Aug., Sept. and Oct.	13.16	0.11
18	Artocarpus integra	Moraceae	P	Jul., Aug. and Sept.	2.69	0.04
19	Nephelium ramboutan	Sapindaceae	NS + N + P	Sept., Oct. and Nov.	14.11	0.06
20	Schleichera oleosa	Sapindaceae	N	Sept. and Oct.	2.17	0.04
21	Sandoricum koetjapi	Meliaceae	N	May, Jun., Aug., and Sept.	4.2	0.09
22	Cinnamomum celebicum Miq	Lauraceae	N + P	Feb, Mar., Apr., May, Jun., Jul. and Aug.	6.75	0.09
23	Litsea grandis Hook	Lauraceae	NS + N + P	Jun., Jul., Aug., Sept., and Dec.	8.7	0.11
24	Mallotus philippensis Lam	Euphorbiaceae	N	Jul., Aug., Sept., and Oct.	2.16	0.04
25	Mallotus paniculatus	Euphorbiaceae	N	Jul., Aug., and Sept.	6.73	0.11
26	Palaqium obovatum	Sapotaceae	N + P	Sept., Oct., Nov. and Dec.	55.34	0.34
27	Palaqium obtusifolium	Sapotacea	N + P	Jul., Aug., and Sept.	3.2	0.06
28	Dillenia cerrata	Dilleniaceae	N	Sept. and Oct.	17.11	0.16
29	Maranthes corymbose Bl.	Chrysobalanaceae	N	Jun., Jul., Aug., Sept. and Oct.	2.82	0.04
30	Ailanthus integrifolia	Simaroubaceae	P	Mar., Apr. and May	2.3	0.04
31	Mitrephora macrocarpa	Annonaceae	N	Aug. and Sept.	12.81	0.14
32	Cratoxylum hypericinum	Hypericaceae	N + P	Apr., May, Jun., Jul., Aug., and Sept.	3.77	0.06
33	Adenandra celebica	Magnoliaceae	N	Feb, Mar., Apr. and May	3.37	0.06
34	Magnolea pterocarpan Roxb	Magnoliaceae	N	Mar., Apr., May, Jun., Jul., Aug. and Sept.	2.16	0.04
35	Calophyllum waworoenti	Guttiferaceae	N + P	Mar., Apr., May, Sept. and Oct.	2.15	0.04
36	Gustafia augusta L.	Lecythidaceae	N	Jun., Jul., Aug., and Sept.	2.2	0.04
37	Lithocarpus celebicus	Fagaceae	P	Apr., May, Jun., Jul., Aug., Sept. and Oct.	2.15	0.04
38	Garuga floribunda Decne	Burseraseae	N	6-9Jun., Jul., Aug. and Sept.	14.11	0.06
39	Dacrydium elatum	Podocarpaceae	P	May, Jun., Jul., Aug. and Sept.	4.68	0.06
40	Knema cinerea	Myristicaceae	P	Jul., Aug. and Sept.	2.3	0.04
41	Planchonia valida Blume	Lecythidaceae	N	Jan., Feb, Mar. and Dec.	2.24	0.04
42	Vitex cofassus	Verbenaceae	NS + N + P	7-10Jul., Aug. Sept. and Oct.	2.5	0.04
43	Anthocepalus cadamba	Crustacean	P	Mar. and Apr.	4.46	0.06
			∑		300	3,14

Note: NS (Nest Trees), N (Nectar), Polen (P).

3.2 Flowering calendar

The flowering calendar helps to determine the availability of bee feed at the research site. If there is a lot of forage available, honey bees can collect nectar or pollen to store in their nest. The nest's forage will be used to meet daily needs as well as fodder reserves. During the flowering season, bees are constantly building nests; queen bees lay eggs, while worker bees actively collect nectar and pollen [41].

Observations demonstrate that plants with the potential to be used as food for honey bees have various life cycles. However, it is available all year, albeit the quantity varies month to month. This condition is also consistent with study conducted in Negeria [42], India [43], Saudi Arabia [37] and Nepal [44]. In general, the plants found in this locality are annuals with flowering periods that vary greatly depending on the planting season. Plants such as Castanopsis buruana Miq., Ficus sp. and Calophyllum waworoenti can bloom twice a year. Because the bee food plants flower at different times, honey bee food is always available. According to Setiawan and Susilawati [45], when certain plants do not flower, other plants can meet the food needs of bees.

3.3 Importance Value Index

The Importance Value Index (IVI) is a metric used to assess the dominance of a plant type in its community. A species' IVI value indicates its importance in the community. The dominant plants at this area are Palaqium obovatum from the Sapotaceae family and Castanopsis buruana Miq. from the Fabaceae family, with IVI values of 55.34% and 48.15%, respectively. This plant has a high dominance value due to its huge stem diameter and is typically found in forests. Palaqium obovatum and Castanopsis buruana Miq. are bee-friendly plants because they have blooms and nectar. This tree's properties are similar to research [45], while having a distinct species of plant.

3.4 Diversity index

The Shannon-Wiener diversity index measures species richness and abundance in vegetation [46]. The analysis results suggest that the diversity value at the research location was 3.14, which is considered good (>3) [47]. A great diversity of species in an area suggests good environmental stability, thus bee food is readily available. This has a good impact on honey production. Diversity of forest resources for nesting and honey production.

3.5 Forest health index

Environmental degradation, limited food supply, and parasites on larvae and pupae all contribute to forest bees (Apis dorsata Binghamii) migratory behavior. As a result, this research was continued by assessing environmental damage at the research site. Environmental degradation is approached by looking at the trees physical damage as a bee's habitat. A tree is considered healthy or normal if it can perform its physiological functions in accordance with its genetic potential, and it is considered damaged if it is disturbed by pathogens or certain environmental conditions, causing one of its physiological functions to deviate from normal conditions [48].

According to data from observations of physical damage to trees at the study site, out of the 236 trees that were found, 71 (or 30%) had physical damage, and 164 (or 70%) were considered to be in good health. Liana, Termites, Konk, Excessive Brum, Cancer, Open Wounds, Broken Branches, Tumors, Broken Stems, Resin, Broken Roots > 3 feet, and Other Types are the 12 categories of damage (Table 2).

Vines account for 27% of tree damage in this region, followed by termites (15%), open wounds (11%), tumors (9%), cones (8%), excessive brums, cancer, and broken branches, each at 6%, damaged stems and others (4%), resin and broken roots >3 feet, each at 3% (Figure 4). Liana is a plant that propagates or is supported by trees, yet its root system is located in the ground and serves as a source of nutrition. Liana attacks can harm or even kill trees. Plants that are entangled with lianas include Castanopsis buarana Miq., which forest bees employ as nest trees, nectar producers, and pollen producers. This physical damage to the tree shows that the tree's health is at risk, which affects bee migration to better sites [49]. This verifies Chase et al.'s [50] research, which found that forest loss can have a wide-ranging impact on the forest resource ecology, including a drop in the honey bee population, specifically the Apis dorsata Binghamii.

Table 2. Trees physical damage

Code	Damage Type	Type	Amount Tree
01	Cancer	*Artocarpus chempeden, Artocarpus integer Castanopsis buruana Miq. (2 trees),Garuga floribunda*	5
02	Conc	*Inocarpus fagiferus, Coordersiodendron pinnatum,nephelium ramboutan,Palaquium obtusifolium, Pterospermum celebicum, Kalappia celebica*	6
03	Open Wounds	*Pterospermum celebicum, Agathis dammara, Calophyllum inophylum, Mitrephora macrocarpa (2 trees), Nephelium ramboutan, Tetrameles nudiflora, Spiraeopsis celebica*	8
04	Resinosis	*Agathis dammara, Nephelium ramboutan*	2
05	Broken Stem	*Tetrameles nudiflora, Xanthostemon petiolatus*	2
06	Termite	*Ailanthus integrifolia, Nephelium ramboutan, Dacrydium elatum, Semecarpus cuneiformis, Payena sp, Castanopsis buruana Miq., Eugenia sp. (2 trees), lithocarpus glutinosus*	9
20	Liana	*Artocarpus sp, Palaqium obovatum (3 trees), Inocarpus fagiferus (2 trees), Palaquium obtusifolium, Mitrephora macrocarpa, Parinari corimbosum Miq., Tetrameles nudiflora (3 trees), Microcos paniculata L, Castanopsis buruana Miq., Cratoxylum hypericinum, Knema cinerea, Lithocarpus glutinosus, Coordersiodendron pinnatum*	17

22	Broken branch	*Castanopsis buruana Miq., Tetrameles nudiflora, Calophyllum inophylum, Dillenia cerrata*	4
23	Excessive Brum	*Castanopsis buruana Miq., Eugenia sp (2 trees), Mitrephora macrocarpa*	4
26	Tumor	*Castanopsis buruana Miq., Cinnamomum celebicum, Cratoxylum hypericinum, Gustavia augusta L*	4
31	Tunnel	*Coordersiodendron pinnatum*	1
05.06	Broken stems & Termites	*Lithocarpus celebicus*	1
06, 20	Termites & Liana	*Palaquium obtusifolium, Semecarpus cuneiformis*	2
05, 26	Broken stems & Tumors	*Castanopsis buruana Miq.(2 trees)*	2
22.31	Broken Branch, Tunnel	*Mallotus philippensis*	1
20.26	Liana & Tumor	*Spiraeopsis celebica*	1
13.23	Broken roots > 3 feet, Brum excessive	*Microcos paniculata L*	1
03.20.31	*Liana, open wounds, tunnels*	*Tetrameles nudiflora*	1
		∑	71

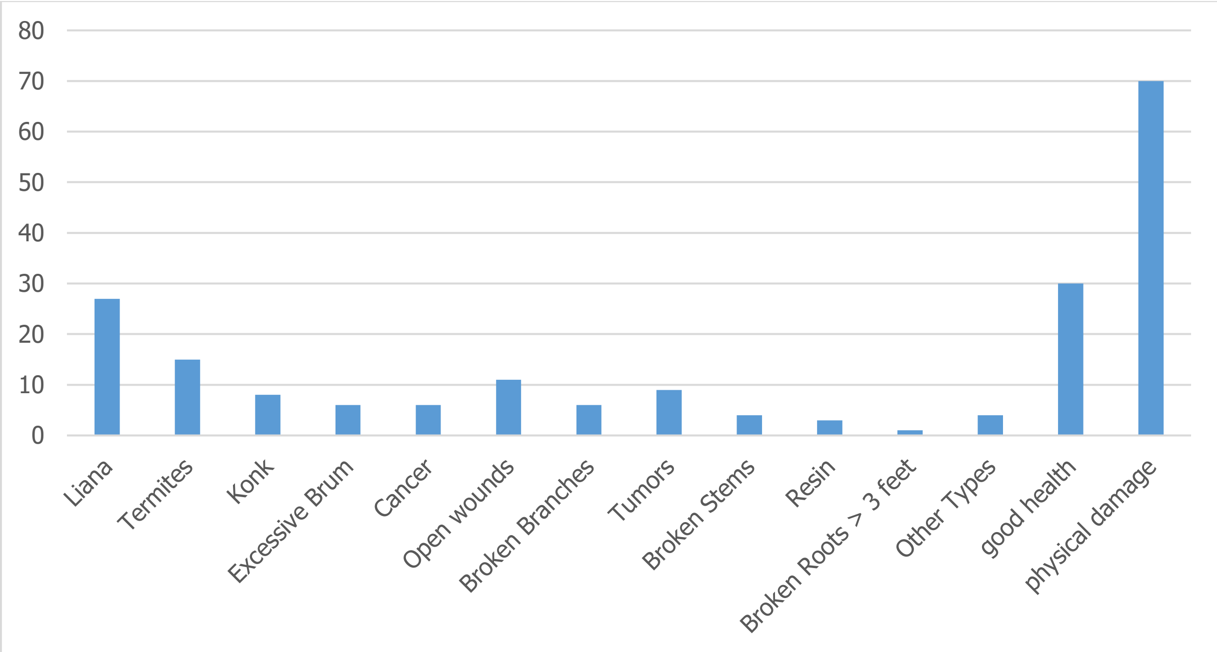

Figure 4. Type and percentage of trees physical damage

Based on the health of the trees, stakeholders must conduct regular monitoring, particularly in terms of pest and disease prevention and treatment, in order to reduce the extent of tree damage. This is because the honey bee Apis dorsata Binghamii relies on the tree's health for feeding and nesting. Apart from that, Apis dorsata Binghamii, an endemic species to Sulawesi, must be protected in accordance with the mandate of Law No. 5 of 1990 Concerning the Conservation of Biological Natural Resources and Their Ecosystems.

4. CONCLUSIONS

The diversity of tree species foraged by the forest bee Apis dorsata Binghamii in the Mangolo Nature Tourism Park is classed as high abundance (H'= 3.14), dominated by the Castanopsis buruana Miq. species (IVI= 48.15) and the Palaqium obovatum species (IVI= 55.34). There are nine varieties of nest trees, 35 plants that provide flowers nectar, and 27 plants that generate pollen. Each plant's flowering time varies, however the distribution of flowering times is available from January to December. Physical damage to bee foraging trees was 30% (71 trees), while those that remained healthy were 70% (164 trees). The most common causes of tree physical harm are liana entanglements and termite assaults.

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