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Balancing Biodiversity Availability and Needs among the Orang Rimba in Bukit Duabelas National Park, Jambi

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Abstract: Bukit Duabelas National Park is a protected area that functions as both a biodiversity conservation area and a living space for the Orang Rimba community. While previous studies have mainly documented Orang Rimba ethnobiological knowledge, this study quantitatively links biological resource availability, utilization intensity, and sustainability prospects within an indigenous livelihood system. Field observations, vegetation sampling, line transects, and semi-structured interviews were conducted with 88 respondents from 13 *tumenggung* groups. The data were analyzed using quantitative and qualitative descriptive analysis, and sustainability assessments based on plant regeneration structure and wildlife harvest-to-production ratios. The results showed that the Orang Rimba utilized 74 plant species from 45 families and eight wildlife species for food, medicine, construction, trade, clothing, and cultural purposes. Plant use was dominated by food and medicinal resources, with average harvesting intensities of 245.34 and 203.75 events per year, respectively. A sustainability assessment classified 14.86% of plant species as sustainable, 40.54% as moderately sustainable, and 44.59% as unsustainable. Wildlife use was generally unsustainable because maximum harvest estimates exceeded conservative annual production and upper reproductive estimates for most species. These results stress the need for adaptive and participatory management strategies that prioritize both biodiversity preservation and sustainable Orang Rimba livelihoods.

Keywords: Biodiversity; Bukit Duabelas National Park; Natural resource utilization; Orang Rimba; Sustainability

Introduction

The Bukit Duabelas National Park (BDNP) in Jambi Province represents a distinctive conservation landscape because it functions not only as a biodiversity conservation area but also as a traditional living space and livelihood source for the Orang Rimba, an Indigenous community that has inhabited the forest for generations (Algopeng et al., 2023; Yusuf & Syafrial, 2019). Forest biodiversity supports the Orang Rimba's subsistence needs, including food, medicine, shelter, and sociocultural practices (Prasetijo 2017; Persoon et al., 2023). These resource-use practices are shaped by customary norms and traditional ecological knowledge,

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which regulate human interactions with forest ecosystems and help maintain ecological balance (Tresno et al., 2022). Thus, the forest should be understood not only as a physical setting but rather as a socio-ecological system that combines ecological processes with cultural values and livelihoods (Dorji et al., 2019).

For Indigenous communities, biodiversity is a critical livelihood asset that underpins food security, health, cultural continuity, and social-ecological resilience (Hong et al., 2022; Kasoki et al., 2025; Mashizi & Escobedo, 2025; Palita et al., 2023; Singh et al., 2020). Traditional ecological knowledge embedded in daily resource-use practices can contribute to sustainable resource management, particularly when supported by customary institutions and collective norms (Mistry et al., 2016; Turner et al. 2022). The increasing global recognition of the role of Indigenous peoples and local communities in biodiversity conservation further highlights the need to integrate local knowledge into conservation planning and protected area management (Brittain et al., 2025; Reyes-García et al., 2022; Sangha, 2020). However, the sustainability of biodiversity use cannot be assumed solely from the presence of traditional knowledge. It depends on the balance between resource availability, extraction intensity, species regeneration capacity, and the effectiveness of local governance systems.

From the perspective of common-pool resource management, the Orang Rimba's use of forest biodiversity reflects a system in which access to shared resources is regulated through social institutions, customary rules, and informal enforcement mechanisms (Andrews et al., 2024; Ostrom, 1990). In the BDNP, such mechanisms have traditionally guided forest resource use and helped regulate community interactions with the landscape (Persoon et al., 2023). Nevertheless, these systems have been increasingly challenged by demographic growth and changing livelihoods. Official demographic data show that the Orang Rimba population in the BDNP increased between 2013 and 2018 (Balai Taman Nasional Bukit Duabelas, 2023). This trend may intensify the demand for food plants, medicinal resources, construction materials, and wildlife protein, potentially pushing resource extraction beyond the ecological regeneration limits (Milner-Gulland et al., 2001; Misra et al. 2013).

Previous studies have documented various aspects of Orang Rimba livelihoods, ethnoforestry, local wisdom, and forest dependence (Fauziah, 2022; Masy'ud et al., 2020; Persoon & Wardani, 2023; Prasetijo, 2017; Tresno et al., 2022). However, most of these studies remain largely descriptive and have not sufficiently integrated ecological resource availability, quantitative utilization intensity, and sustainability assessment of both plant and wildlife resources within a single analytical framework. This gap is important because descriptive accounts alone cannot identify which biological resources remain resilient, which are under ecological pressure, and which require priority management intervention. Therefore, a more integrated assessment is needed to support conservation decisions that are both ecologically sound and socially responsive to Indigenous livelihood needs (Balasubramanian & Sangha, 2021; Sangha et al., 2025).

This study attempted to address this gap by providing an integrated quantitative assessment that links biodiversity availability, livelihood-based resource needs, and sustainability prospects among the Orang Rimba in the BDNP. Specifically, this study aimed to identify plant and wildlife resources utilized by the Orang Rimba, estimate their utilization intensity, assess the sustainability of plant resources based on regeneration structure and wildlife resources based on harvest-to-production ratios, and generate implications for adaptive and participatory conservation management. By integrating ecological assessments with Indigenous livelihood perspectives, this study provided a scientific basis to formulate management strategies that equitably and adaptively balance biodiversity conservation and Indigenous livelihoods sustainability.

Method

Time and Study Area

This study was conducted from January 2021 to December 2024 in Bukit Duabelas National Park (BDNP), Jambi Province, Sumatra, Indonesia (Figure 1). BDNP covers approximately 54,780.41 ha and represents one of the remaining lowland tropical forest ecosystems in the region. Administratively, the park extends across Sarolangun, Batanghari, and Tebo Regencies. The park is characterized by a humid tropical climate and lowland dipterocarp forest formations that provide habitat for diverse plant and wildlife species and support various ecosystem services (Anas et al., 2021).

BDNP also functions as a traditional living space for the Orang Rimba, an Indigenous community whose livelihoods remain closely linked to forest biodiversity. The Orang Rimba are semi-nomadic and depend on forest resources for food, medicine, shelter materials, cultural practices, and other subsistence needs (Masy'ud et al. 2020; Persoon and Wardani 2023). Their settlement consists of small social groups led by customary leaders, "tumenggung" (Muchlis et al., 2025). This makes the BDNP a bio-geo-social landscape with competing conservation aims and indigenous lifestyles.

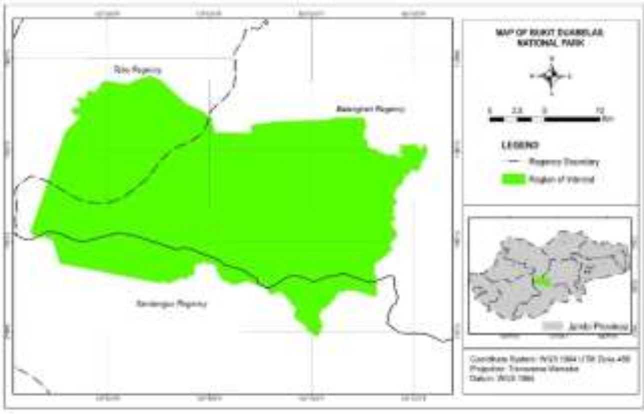

Figure 1. Map of the study area located in Bukit Duabelas National Park, Jambi Province, Indonesia

Data Collection

Data collection in this study used a mixed-methods approach combining ecological surveys, semi-structured interviews, and secondary data. Ecological surveys were conducted to assess the availability of plant and wildlife resources utilized by the Orang Rimba. Plant resource availability was assessed through vegetation analysis to identify species composition and estimate the density of useful plant species (Nugraha et al., 2022). Wildlife data were collected using line transects by recording direct and indirect signs of animal presence, including footprints, feces, feeding remains, nests, feathers, calls, and other activity traces (Fragoso et al., 2016).

Data on biodiversity demand and use were collected through semi-structured interviews with three group representatives from each of the 13 tumenggung, representing 88 Orang Rimba respondents. The interviews collected information on the plant and wildlife species used, forms of utilization, harvesting frequency, harvesting methods, average yield per hunting event, hunting preferences, and customary restrictions related to biodiversity use. Secondary data, including official reports, demographic records, and relevant scientific literature, were used to support the interpretation of resource use, population trends, and sustainability indicators.

Data Analysis

Data were analyzed using quantitative and qualitative descriptive approaches. The estimation of plant and wildlife resource demand followed the calculation procedures presented in Table 1. For plant resources, the analysis considered harvesting frequency and the number of species within each utilization category to estimate average annual harvesting intensity. The plant utilization categories included food, medicine, construction materials, trade commodities, clothing materials, and cultural purposes. For wildlife resources, the annual harvest was estimated based on hunting frequency and average yield per hunting event. These estimates were used to describe the level of resource extraction in relation to Orang Rimba livelihood needs.

Table 1. Formulas Used to Estimate Biodiversity Resource Demand of the Orang Rimba Community

Plant (Cunningham, 2001; Shackleton, Pandey & Ticktin, 2015)	Wildlife (Robinson et al., 1991; Robinson et al., 2000; Milner-Gulland et al., 2001)
$\bar{I}_k = \frac{\sum_{i=1}^{n} I_i}{n}$, Ket : $\bar{I}_k$: harvesting intensity per category per year I_i : harvesting frequency per species (times/year) n : number of species in one category	$H = f \times c$ Ket : H = total offtake (individuals/year) f = harvesting frequency per year c = average yield per hunting event

Table 2. Sustainability Categories Based on Regeneration Structure Following Shankar (2001)

Category	Description	Sustainable Category
Good	Number of seedlings > saplings and number of saplings > trees	Sustainable
Fair	Number of seedlings > saplings and saplings ≤ trees	Moderately sustainable
Poor	Saplings fewer than, greater than, or equal to trees; species found only at sapling and tree stages	
None	Species found only at the tree stage	Unsustainable
New	Species found only at the seedling and/or sapling stage	

The sustainability prospects of plant resources were evaluated using a quantitative descriptive analysis based on vegetation density values obtained from vegetation surveys. The estimated density values were interpreted according to the sustainability categories proposed by Shankar (2001) (Table 2). The sustainability of wildlife utilization was assessed by comparing the estimated annual harvest with the estimated annual offspring production using the exploitation ratio approach (H/P) (Robinson et al., 2000). Wildlife utilization was considered sustainable when the total annual harvest (H) was lower than the estimated annual production (P) (H < P). Utilization was considered unsustainable when harvest exceeded estimated production (H > P). This approach enabled the study to assess whether biodiversity utilization by the Orang Rimba remained within the ecological capacity of plant regeneration and wildlife reproduction. The overall research workflow in this study, including data collection, data analysis, and interpretation processes, is illustrated in Figure 2.

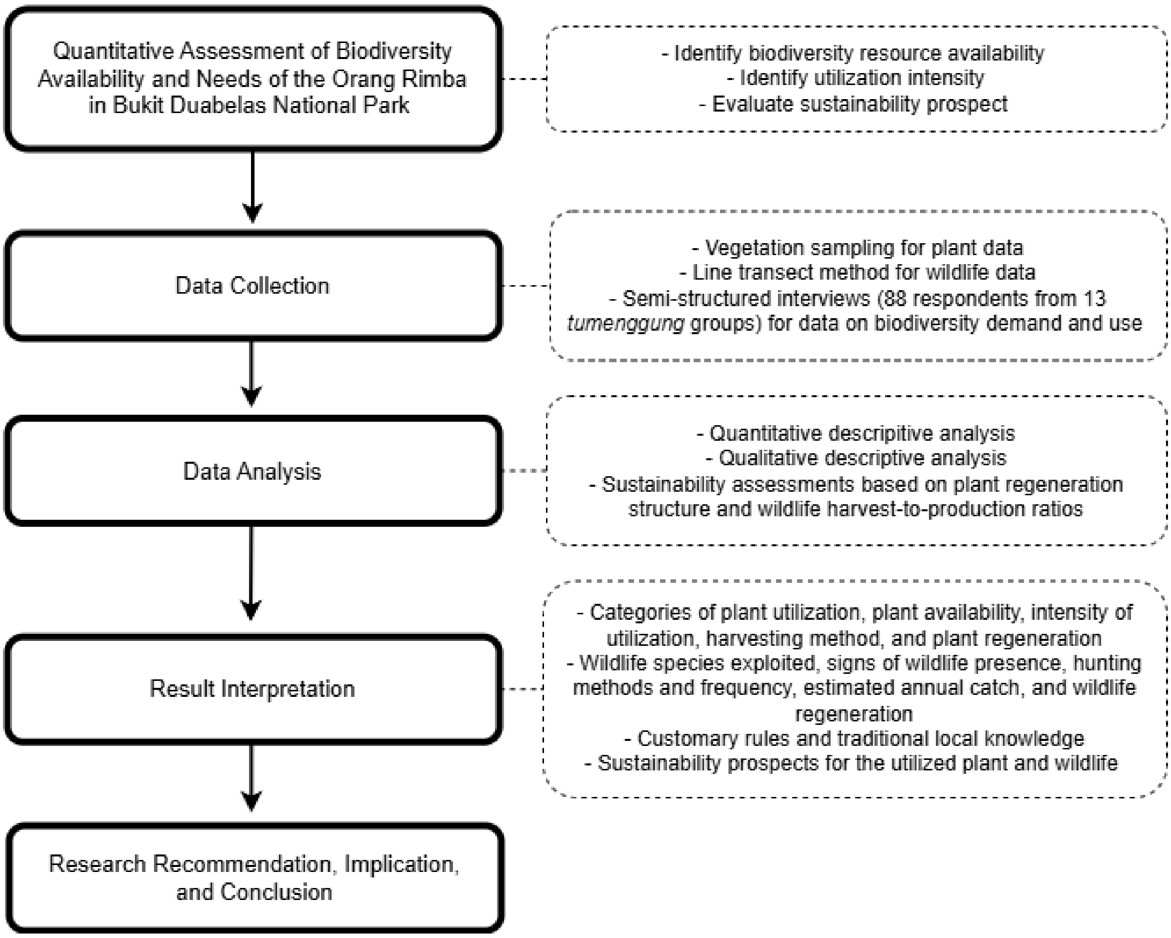

Figure 2. Research flowchart of the study

Result and Discussion

Biodiversity Resources Utilized by the Orang Rimba in Bukit Duabelas National Park

The Orang Rimba utilized diverse biological resources in Bukit Duabelas National Park (BDNP). Interview results identified 74 plant species from 45 families used for food, medicine, construction materials, trade commodities, clothing materials, and cultural purposes. The most frequently represented families were Sapindaceae, Arecaceae, Moraceae, and Phyllanthaceae. Food and medicinal plants formed the dominant utilization categories, followed by construction materials, trade commodities, cultural uses, and clothing materials (Figure 3). For example, *Artocarpus integer* and *Dioscorea alata* were used as food resources, *Bambusa* sp. and *Scorodocarpus borneensis* as construction materials, *Santiria laevigata* and *Tetracera scandens* for medicinal purposes, *Daemonorops draco* and *Dyera costulata* for trade, *Antiaris toxicaria* for clothing materials, and *Camellia lanceolata* and *Drypetes polyneura* for cultural purposes.

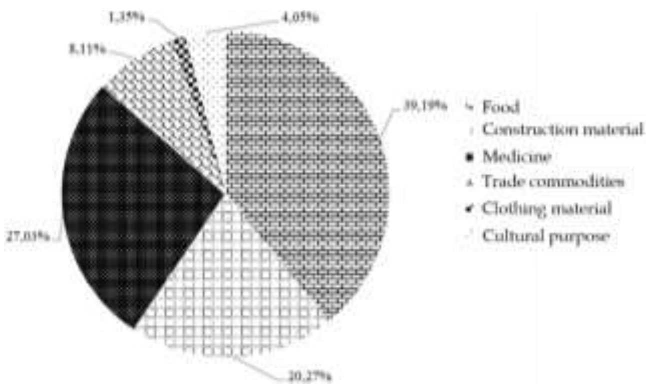

Figure 3. Categories of plant utilization by the Orang Rimba community in Bukit Duabelas National Park

Vegetation analysis showed that all plant species reported by respondents were also recorded in the field, although their densities varied among species and vegetation strata (Table 3). This finding indicates that plant resources used by the Orang Rimba remain available within the traditional-use landscape. However, variation in density also suggests different levels of ecological resilience among species. Species with higher density and more complete regeneration are likely to be more tolerant of repeated use, whereas species with low density or incomplete regeneration are more vulnerable to harvesting pressure. This pattern is consistent with previous studies that have shown that the sustainability of ethnobotanical resource use is influenced by population density, regeneration capacity, species life-history traits, and harvesting methods (de Souza et al., 2020; Fatimata et al., 2024; Kingbo et al., 2023; Kissa et al., 2025; Rawat et al., 2025).

Table 3. Estimated Availability of Plant Species Utilized by the Orang Rimba Community

No.	Local Name	Scientific Name	Density (Ind/ha)	Potential Availability (Ind)
Plants for Food				
1	Bekil	*Artocarpus anisophyllus*	21	676,473
2	Cempedak	*Artocarpus integer*	13	418,769
3	Rambay	*Baccaurea bracteata*	15	483,195
4	Kotopon	*Baccaurea edulis*	5	161,065
5	Tampuy kuning	*Baccaurea macrocarpa*	17	547,621
6	Rinam	*Baccaurea pyriformis*	11	354,343
7	Tampuy rimba	*Baccaurea* sp.	19	612,047
8	Keladi	*Colocasia* sp.	300	9,663,900
9	Kedondong hutan	*Dacryodes rugosa*	20	644,260
10	Tubo manis	*Derris elliptica*	7	225,491
11	Bedaro	*Dimocarpus longan*	13	418,769
12	Banar bebulu	*Dioscorea alata*	450	14,495,850
13	Gadung	*Dioscorea hispida*	400	12,885,200
14	Banar godong	*Dioscorea pyrifolia*	700	22,549,100
15	Paku sayur	*Diplazium esculentum*	300	9,663,900
16	Durian daun	*Durio lowianus*	10	322,130
17	Durian	*Durio zibethinus*	15	483,195
18	Manggis	*Garcinia mangostana*	23	740,899
19	Duku	*Lansium domesticum*	11	354,343
20	Langsat	*Lansium* sp.	21	676,473
21	Kabau	*Archidendron bubalinum*	10	322,130
22	Sagu	*Metroxylon sagu*	7	225,491
23	Pisang	*Musa* sp.	23	740,899
24	Kuduk kuya	*Nephelium uncinatum*	19	612,047
25	Rambutan	*Nephelium lappaceum*	10	322,130
26	Dekat	*Nephelium mutabile*	21	676,473
27	Bayas	*Oncosperma blume*	17	547,621
28	Tampui nasi	*Prunus arborea*	11	354,343
29	Tengguli	*Dialium indum*	8	257,704
Plants for Construction Material				
1	Benal	*Garcinia nervosa*	23	740,899
2	Bambu	*Bambusa* sp.	20	644,26
3	Nyamplung	*Calophyllum* sp.	5	161,065
4	Keriung	*Dipterocarpus hasseltii*	13	418,769
5	Medang	*Litsea* sp.	21	676,473
6	Palem kipas	*Livistona chinensis*	45	1,449,585
7	Mahang	*Macaranga triloba*	12	386,556
8	Kulim	*Scorodocarpus borneensi*	7	225,491
9	Meranti	*Shorea* sp.	56	1,803,928
10	Kelat	*Syzygium plyanthum*	15	483,195
11	Petaling	*Vatica pauciflora*	6	193,278
12	Kayu bulan	*Ployalthia glauca*	5	161,065
13	Medang seluang	*Aromadendron* sp.	3	96,639
14	Sempayang	*Scirpodendron ghaeri*	2	64,426
15	Terap	*Artocarpus elasticus*	25	805,325
Plants for Medicine				

No.	Local Name	Scientific Name	Density (Ind/ha)	Potential Availability (Ind)
1	Akar kuning	*Arcangelisia flava*	15	483,195
2	Capo	*Blumea balsamifera*	17	547,621
3	Tobu pungguk	*Costus specious*	24	773,112
4	Siluk	*Gironiera nervosa*	7	22,491
5	Tomtomu	*Goniothalamus macrophyllus*	3	96,639
6	Jirak	*Symplocos fasciculate*	12	386,556
7	Kayu arang	*Diospyros* sp.	18	579,834
8	Pasak bumi	*Eurycoma longifolia*	25	805,325
9	Tunjuk langit	*Helminthostachys zeylanica*	25	805,325
10	Berumbung	*Dillenia excelsa*	19	612,047
11	Rumput cacing	*Lophaterum gracile*	123	3,962,199
12	Sungkai	*Peronema canescens*	35	1,127,455
13	Sirih kucing	*Piper* sp.	32	1,030,816
14	Kedondong tunjuk	*Sanitria laevigata*	3	96,639
15	Akar kancil	*Smilax zeylanica*	154	4,960,802
16	Akar sempalas	*Tentracera scandens*	7	225,491
17	Salung	*Psychotria viridiflora*	5	161,065
18	Harendong bulu	*Clidemia hirta*	125	4,026,625
19	Pengendur urat	*Tinospora crispa*	21	676,473
20	Leledingon	*Curculigo latifolia*	73	2,352,549
Plants for Trade Commodity				
1	Jernang	*Daemonorops draco*	15	483,195
2	Jernang burung	*Daemonorops* sp.	37	1,191,881
3	Balam	*Palaquium obovatum*	12	386,556
4	Jelutung	*Dyera costulata*	22	708,686
5	Merpayang	*Scaphium maropodum*	36	1,159,668
6	Damar	*Agathis dammara*	12	386,556
Plants for Clothing Material				
1	Ipuh	*Antiaris toxicaria*	6	193,278
Plants for Cultural Purpose				
1	Sebalik sumpah	*Camellia lanceolata*	12	386,556
2	Sentubung	*Drypetes polyneura*	27	869,751
3	Kempas	*Koompassia excelsa*	33	1,063,029

The diversity of plant species used by the Orang Rimba reflects a high level of ethnobotanical knowledge that has developed through long-term interaction with tropical forest ecosystems. Indigenous communities commonly possess detailed knowledge of plant functions, ecological distribution, seasonality, and harvesting practices, which enables them to diversify livelihood strategies and reduce dependence on a limited number of species (Salim et al., 2023). Such diversification represents an adaptive strategy that can strengthen the resilience of forest-dependent communities to ecological and socio-economic change (Chisale et al., 2024; Mawa et al., 2023).

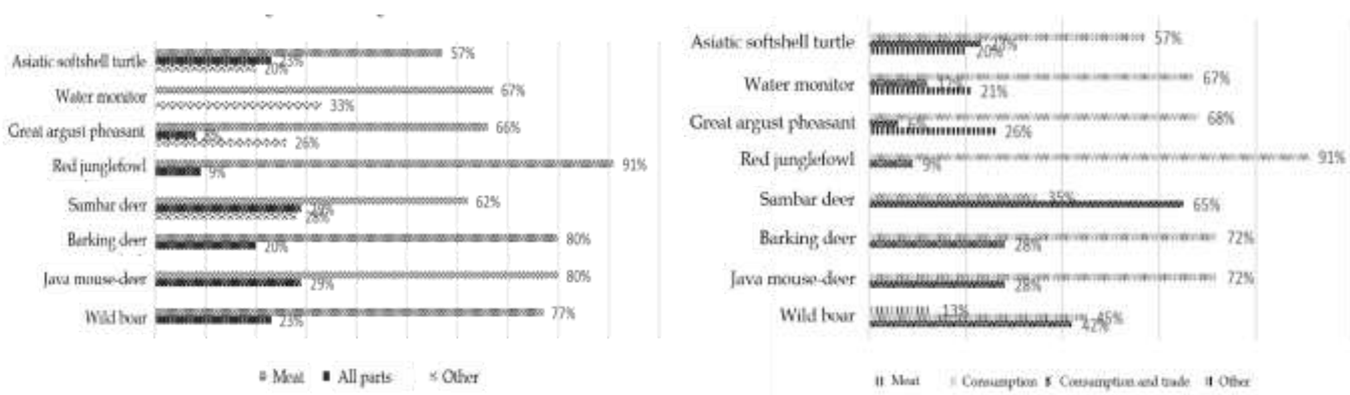

Figure 4. Patterns of wildlife utilization by the Orang Rimba community based on body parts used and forms of use in Bukit Duabelas National Park

Wildlife also formed an important component of the Orang Rimba subsistence system. Previous ethnozoological studies have reported that the Orang Rimba consumed 65 wildlife species (Masyithah, Hariyadi, & Kartika, 2016). However, this study focused on eight intensively hunted species that occur in BDNP, namely wild boar (*Sus scrofa*), Java mouse-deer (*Tragulus javanicus*), barking deer (*Muntiacus muntjak*), sambar deer (*Rusa unicolor*), red junglefowl (*Gallus gallus*), great argus pheasant (*Argusianus argus*), water monitor lizard (*Varanus salvator*), and Asiatic softshell turtle (*Amyda cartilaginea*). These species were primarily used as sources of meat for household consumption (Figure 4).

Field observations recorded wildlife signs across forests, shrublands, riparian zones, mixed gardens, and aquatic habitats (Table 4). Footprints, feces, feeding remains, feathers, nests, calls, wallowing marks, and other activity traces indicated that the hunted species still occurred across several habitat types. Nevertheless, the presence of field signs should not be interpreted as direct evidence of population stability. Species with low reproductive rates, such as deer (e.g. barking deer and sambar deer) and large ground-dwelling birds (e.g. great argus pheasant), may remain detectable while experiencing long-term population decline under sustained hunting pressure (Dawrueng et al., 2017; Nelaballi et al., 2025; Steinmetz et al., 2010). Similarly, aquatic species such as the Asiatic softshell turtle may face combined pressures from harvesting and habitat degradation in Southeast Asian ecosystems (Safi et al., 2025; Sihombing et al., 2021).

Table 4. Habitat Types and Field Signs of Wildlife Species Utilized by the Orang Rimba Community

Types of wild animals	Potential Habitat	Activity Trace Types
Wild boar (*Sus scrofa*)	Forests, shrublands, mixed gardens, and areas near rivers	Footprints, wallowing marks, feces, and scratched soil
Java mouse-deer (*Tragulus javanicus*)	Forests and shrubs near riverbanks	Small footprints, narrow trails beneath shrubs, and feces
Barking deer (*Muntiacus muntjak*)	Forests, river edges, and shrublands	Footprints, feces, barking calls, and feeding marks on vegetation
Sambar deer (*Rusa unicolor*)	Forests, grasslands, and areas near water sources	Footprints, antler rubbing marks, resting sites, feeding remains, feces, and wallowing sites
Red junglefowl (*Gallus gallus*)	Forests, shrublands, and gardens near forest edges	Small footprints, shed feathers, crowing calls, and scratched ground from foraging
Great argus pheasant (*Argusianus argus*)	Forests, forested valleys, and areas near rivers	Distinctive large footprints, shed feathers, and calling sounds
Water monitor lizard (*Varanus salvator*)	Rivers, swamps, riparian forests, and lake edges	Tail drag marks in sand, nesting holes, and feces containing fish scales
Asiatic softshell turtle (*Amyda cartilaginea*)	Slow-flowing rivers, swamps, and small lakes	Tracks on sand or riverbanks, egg nests in sand, and broken eggshells

Overall, the use of both plant and wildlife resources shows that BDNP functions as a socio-ecological landscape in which biodiversity conservation and Indigenous livelihoods are closely connected. The diversity of useful species reflects extensive traditional ecological knowledge, but the ecological consequences of resource use depend on harvesting intensity, harvesting methods, species regeneration, reproductive capacity, and the effectiveness of customary regulation. Incorporating local knowledge into conservation frameworks has been increasingly recognized as an important strategy for strengthening sustainable resource management in protected areas (Djosetro & Behagel, 2024). Therefore, the main conservation issue is not merely whether the Orang Rimba use biodiversity, but whether the scale and method of use remain within ecological limits.

Projected Biodiversity Needs of the Orang Rimba in Bukit Duabelas National Park

Addressing patterns of biodiversity use is important in order to assess the relationship between resource availability and livelihood requirements of forest-dependent communities the findings indicated that the intensity of biodiversity use by Orang Rimba was highly variable depending on resource type and role in their daily livelihoods. Plant resources display varying harvesting profiles, from continuous extraction to the extinct species. The majority of the harvesting of plants is done with machetes (66.50%), while all other harvests are made by hand (Figure 5).

Food and medicinal plants showed the highest average harvesting intensities, reaching 245.34 and 203.75 harvesting events per year, respectively (Table 5). These values indicate that plant resources remain central to daily food security and traditional healthcare. Similar patterns have been reported in tropical forest communities where wild foods and medicinal plants support household resilience, particularly in areas with limited access to markets and formal health services (Asprilla-Perea & Díaz-Puente, 2019; Rahman et al., 2022). Non-timber forest products also contribute to subsistence and economic resilience among forest-dependent communities (Suleiman et al., 2017). In BDNP, this high dependence suggests that conservation policies should recognize subsistence plant use as part of the Orang Rimba livelihood system rather than treating all resource extraction as ecological disturbance.

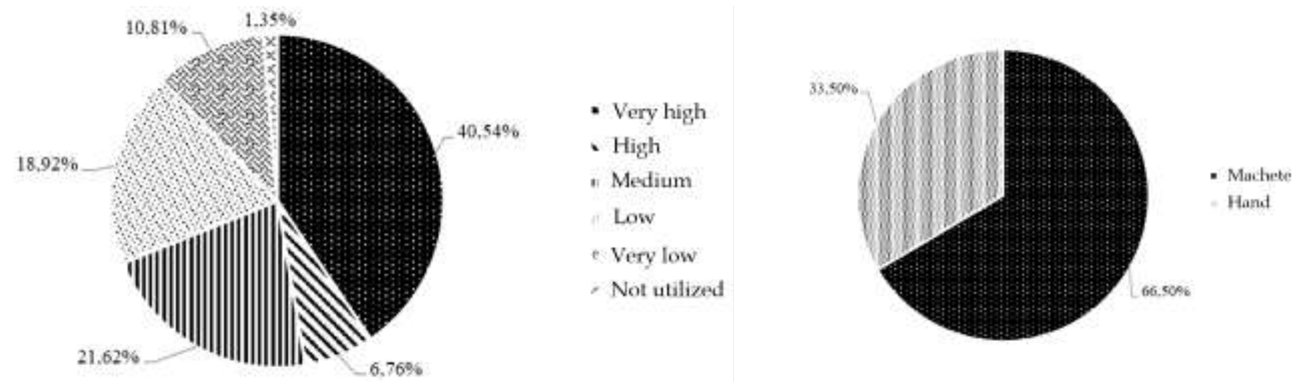

Figure 5. Harvesting intensity and methods of plant utilization by the Orang Rimba community

In contrast, construction materials, trade commodities, and cultural plants had much lower average harvesting intensities (1.28, 3.67 and 1.33 times a year respectively) (Table 5). However, their ecological effects may still be significant when harvesting involves cutting stems, removing bark, or felling whole individuals. Construction species, for example, may be harvested less frequently but can experience stronger demographic impacts if extraction removes mature reproductive trees. This supports Ticktin 2004, who argued that the ecological implications of plant harvesting depend on harvesting technique, plant part removed, and species life-history traits, not only on harvesting frequency. Thus, low use frequency in some plant categories does not automatically indicate low conservation risk.

Table 5. Average Harvesting Intensity of Plant Resources Utilized by the Orang Rimba community

Plant Category	Number of Species	Average Harvesting Intensity (times/year)*	Resource Demand Implications
Food	29	± 245.34	Very high; required for daily food consumption and increasing with population growth
Medicinal plants	20	± 203.75	Very high; essential for healthcare needs and increasing with population growth
Construction materials	15	±1.28	Relatively low pressure; harvesting occurs periodically
Trade commodities	6	±3.67	Relatively low pressure; may increase if economic pressure rises
Clothing materials	1	-	Very low; no longer utilized
Cultural purposes	3	± 1.33	Relatively low pressure; contextual and symbolic use

Note : *the average value of the frequency of plant use in each category annually

Wildlife harvesting was conducted using traditional firearms, snares, air rifles, spears, traps, and dogs, depending on the target species (Table 6). Hunting frequency was generally reported at one to three events per week. Estimated annual harvest varied among species, from approximately 117.5 individuals per year for barking deer to 236.1 individuals per year for water monitor lizards. Although these values reflect subsistence hunting, they indicate continuous pressure on wildlife populations. Subsistence hunting is a common livelihood strategy among forest-dwelling communities in tropical regions, but it may become ecologically unsustainable when harvest levels exceed reproductive capacity (Hallett et al., 2019; Zayonc et al., 2025).

The high estimated harvest per year across eight species of wildlife suggests that hunting pressure on wildlife populations may be substantial, especially if demand for animal protein will increase with population growth. Subsistence hunting is globally considered to be an important livelihood strategy for forest-dwelling communities in the tropics (Zayonc et al., 2025). However, hunting can become ecologically unsustainable when harvest levels exceed the reproductive capacity of wildlife populations (Hallett et al., 2019). Hunting rates that exceed the species' regenerative capacity can make certain populations vulnerable; large birds and mammals (e.g., deer) produce offspring at comparatively low rates. Moreover, ecological resilience differs among species based on life history traits, habitat availability and reproductive strategies.

Table 6. Hunting Methods Used to Harvest Wildlife by the Orang Rimba Community

Wildlife Species	Hunting Tools	Harvesting Frequency (times/week)	Average Success per Hunting Event (individuals)	Estimated Annual Harvest (individuals/year)*
Wild boar (*Sus scrofa*)	*Kecepek* (traditional wooden firearm), snare traps, air rifle, spear	1-3	1.95 ± 1.22	± 202.8
Java mouse-deer (*Tragulus javanicus*)	*Kecepek*, snare traps, air rifle, spear	1-3	2.14 ± 1.73	± 222.6
Barking deer (*Muntiacus muntjak*)	*Kecepek*, snare traps, spear, pitfall trap	1-3	1.13 ± 0.34	± 117.5
Sambar deer (*Rusa unicolor*)	*Kecepek*, snare traps, air rifle, spear, pitfall trap	1-3	1.17 ± 0.47	± 121.7
Red junglefowl (*Gallus gallus*)	*Kecepek*, snare traps, spear, air rifle	1-3	1.37 ± 0.63	± 142.5
Great argus pheasant (*Argusianus argus*)	*Kecepek*, snare traps, spear, air rifle	1-3	1.46 ± 0.73	± 151.8
Water monitor lizard (*Varanus salvator*)	*Kecepek*, snare traps, spear, air rifle, hunted with dogs	1-3	2.27 ± 1.14	± 236.1
Asiatic softshell turtle (*Amyda cartilaginea*)	Spear (*tero*), turtle trap (*tekala*), fishing line	1-3	2.22 ± 2.35	± 230.9

Note: *hunting frequency in a year multiplied by the average catch per hunting activity

The comparison between plant and wildlife use reveals different forms of ecological pressure. Plant resources were used more frequently and across more functional categories, but many species still showed varying degrees of regeneration. Wildlife resources involved fewer species, but their sustainability risk was more immediate because hunting directly removes individuals from populations with limited reproductive capacity. This imbalance indicates that management responses should differ between resource groups. Plant management should prioritize regeneration monitoring and reduced destructive harvesting, whereas wildlife management should focus on hunting regulation, population monitoring, and alternative protein strategies. The integration of Indigenous knowledge into conservation planning remains essential to ensure that such management strategies are culturally appropriate and socially acceptable (Kasoki et al., 2025).

Prospects for Sustainable Biodiversity Utilization by the Orang Rimba

Customary institutions remain important in regulating biodiversity use among the Orang Rimba. Several wildlife species, including the Sumatran tiger (*Panthera tigris sumatrae*), siamang (*Symphalangus syndactylus*), great argus pheasant (*Argusianus argus*), and Sunda pangolin (*Manis javanica*), are protected through customary beliefs or seasonal restrictions (Table 7). Several plant species, including kempas (*Koompassia excelsa*), sentubung (*Drypetes polyneura*), and sialang trees, are also protected because of their ecological, cultural, and livelihood functions. These customary norms show that traditional ecological knowledge can function as an informal conservation mechanism by limiting direct exploitation of culturally or ecologically important species (Ahmed, 2022). Similar patterns have been observed in Indigenous societies where symbolic, ritual, or sacred values contribute to biodiversity protection and long-term ecological stewardship.

However, the effectiveness of customary regulation needs to be understood in relation to current demographic and ecological pressures. The Orang Rimba population in BDNP increased from 1,775 individuals in 2013 to 2,960 individuals in 2018, representing an increase of approximately 66.76%. This population growth may increase demand for food plants, medicinal resources, construction materials, and wildlife protein. In socio-ecological systems, traditional rules can support sustainability, but they may become insufficient when resource demand grows faster than ecological regeneration or reproductive capacity (Maru et al., 2020). Therefore, customary institutions should be strengthened through participatory monitoring rather than assumed to be adequate on their own.

Table 7. Traditional Ecological Knowledge and Customary Rules Related to Biodiversity Among the Orang Rimba Community

Prohibition Category	Plant/Wildlife Species	Form of Customary Prohibition or Cultural Meaning
Customarily protected wildlife (taboo to hunt or kill)	Sumatran tiger (*Panthera tigris sumatrae*)	Hunting, injuring, or consuming this species is strictly prohibited because it is believed to possess sacred or divine attributes
	Siamang (*Symphalangus syndactylus*)	Hunting, injuring, or consuming this species is prohibited because it is considered sacred
	Great argus pheasant (*Argusianus argus*)	Hunting is prohibited during the breeding season because the species is regarded as an ecological indicator signaling the onset of the rainy season
	Sunda pangolin (*Manis javanica*)	Hunting is prohibited because the species is believed to possess sacred protective powers
Customarily protected plants (taboo to cut or damage)	*Sebalik sumpah* (*Camellia lanceolata*)	The seeds are used to make bracelets or necklaces believed to reverse or nullify an oath
	Kempas (*Koompassia excelsa)*	Cutting or damaging the tree is prohibited because its bark is used in traditional rituals for naming newborn babies
	Sentubung (*Drypetes polyneura*)	Cutting or damaging the tree is prohibited because it is used as a marker for the burial place of a newborn's umbilical cord
	Sialang trees (various species such as *Spondias dulcis*, *Koompassia excelsa*, etc.)	Cutting or damaging these trees is prohibited because they serve as nesting sites for wild honeybees, which are an important livelihood resource for the Orang Rimba community

The sustainability assessment of plant resources showed a substantial imbalance. Of the 74 plant species used by the Orang Rimba, only 14.86% were classified as sustainable, 40.54% as moderately sustainable, and 44.59% as unsustainable (Figure 6). This result indicates that plant sustainability is not uniformly secure, even though plant resources are still widely available in the study area. Unsustainable status was mainly associated with incomplete regeneration structures, including species recorded only at mature tree stages or without sufficient representation across seedlings, saplings, and trees. Such patterns suggest that continued harvesting without regeneration management may reduce long-term availability.

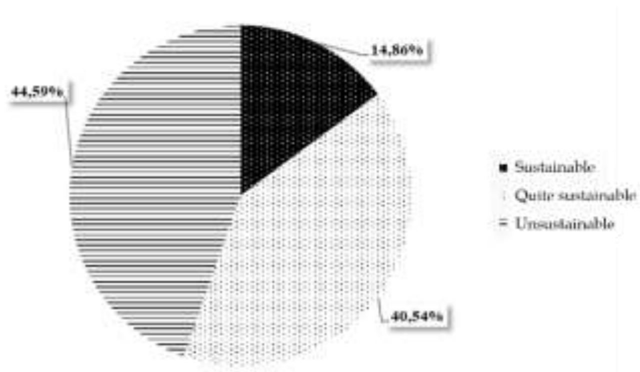

Figure 6. Estimated sustainability status of plant species utilized by the Orang Rimba community

Food and medicinal plants generally showed stronger relevance to daily subsistence, but their high use intensity requires continuous monitoring. Moderately sustainable species were often associated with fruit-bearing trees and useful plants maintained within the Orang Rimba traditional land management system known as "*tano benuaron*". This system protects areas dominated by fruit trees, edible shoots, seeds, and tubers, and prohibits tree cutting or conversion into agricultural land. The role of *tano benuaron* suggests that culturally embedded land-use practices can contribute to plant conservation by maintaining useful species and supporting natural regeneration.

Plant species used for cultural purposes were also largely classified as sustainable or moderately sustainable. This pattern suggests that cultural values associated with particular plant species help protect their populations and maintain regeneration in forest ecosystems. Comparable findings have been reported in Indigenous and local forest management systems, where ritual and symbolic values can reduce direct exploitation and support the persistence of culturally important species (Saensouk et al., 2025). However, cultural protection does not eliminate the need for ecological monitoring because regeneration patterns can still change under demographic and environmental pressures.

In contrast, plant species used for construction materials, clothing fibers, and some trade commodities require greater management attention. These species are often harvested by cutting stems or whole trees, and some were recorded only at mature stages during vegetation surveys. This pattern indicates that low harvesting frequency does not necessarily mean low ecological risk. Slow-growing tree species may decline gradually when mature individuals are removed without sufficient recruitment. Similar sustainability concerns have been documented in tropical forests where selective extraction of high-value species alters forest structure and regeneration dynamics (Kissa et al., 2025). Therefore, plant conservation in BDNP should prioritize species with low regeneration, destructive harvesting methods, and high cultural or livelihood importance.

Wildlife sustainability showed a more critical pattern. Reproductive data indicated that several hunted species had limited reproductive capacity, particularly barking deer and sambar deer, which have gestation periods of six to seven months and produce only one to three offspring per birth (Table 8). Hunting preference was concentrated on barking deer, Java mouse-deer, and sambar deer (Figure 7), indicating that a small number of species bore a disproportionate share of hunting pressure. This concentration increases the risk of local population decline, especially for protected species and large-bodied vertebrates with slow population turnover (Peres et al., 2007).

Table 8. Reproductive Periods and Offspring Production of Wildlife Species Utilized by the Orang Rimba Community

Wildlife Species	Reproductive Period	Potential Number of Offspring per Birth
Wild boar (*Sus scrofa*)	Gestation period approximately 4 months[1]	5–13 individuals[1]
Java mouse-deer (*Tragulus javanicus*)	Gestation period approximately 4 months[1]	1–2 individuals[1]
Barking deer (*Muntiacus muntjak*)	Gestation period approximately 6–7 months[1]	1–2 individuals[1]
Sambar deer (*Rusa unicolor*)	Gestation period approximately 6–7 months[1]	2–3 individuals[1]
Red junglefowl (*Gallus gallus*)	Egg incubation period approximately 19–21 days[2]	4–9 eggs[2]
Great argus pheasant (*Argusianus argus*)	Egg incubation period approximately 24–25 days[3]	2 eggs[3]
Water monitor lizard (*Varanus salvator*)	Egg incubation period approximately 7–8 months[4]	15–30 eggs[4]
Asiatic softshell turtle (*Amyda cartilaginea*)	Lays eggs 3–4 times per year[5]	6–30 eggs[5]

Note: [1]Nowak (1999), [2]Madge et al. (2002), [3] Davidson (1982), [4]Shine (2005), [5]van Dijk et al. (2000)

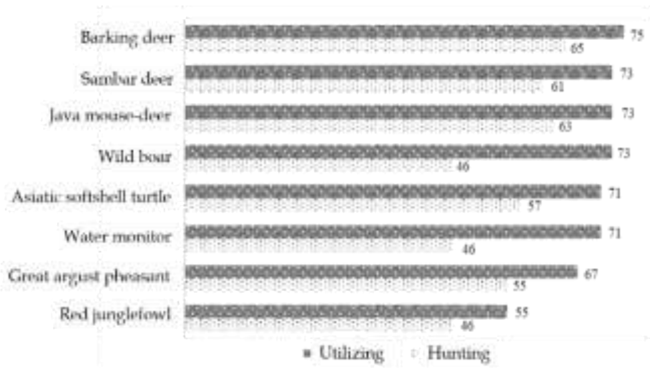

Figure 7. Hunting preferences for wildlife species among the Orang Rimba community

Comparison between estimated annual offspring production and estimated maximum harvest showed that wildlife utilization was generally classified as unsustainable under the criteria of Robinson dan Bennett 2000 (Table 9). For example, wild boar had an estimated annual offspring production of 750–1,950 individuals, while the estimated maximum annual harvest reached 4,080 individuals. Water monitor lizard had an estimated annual production of 2,250–4,500 individuals, while its estimated maximum harvest reached 9,303 individuals. These figures show that maximum harvest estimates exceeded conservative annual production estimates for all analyzed species and surpassed upper reproductive estimates for most species. Therefore, wildlife utilization represents the most urgent sustainability concern in BDNP.

This imbalance between wildlife reproduction and hunting pressure reflects broader conservation challenges in tropical forest ecosystems. Large-bodied vertebrates generally have slower reproductive rates and lower population turnover, making them more vulnerable to sustained hunting pressure (Peres & Palacios, 2007). Intensive hunting can also contribute to defaunation and "empty forest syndrome," in which forest structure remains intact but ecological functions decline due to the loss of wildlife populations (Benítez-López et al., 2019).

Although customary institutions among the Orang Rimba continue to regulate resource use through species taboos, seasonal restrictions, and culturally protected plants, these mechanisms may become insufficient under increasing demographic and livelihood pressures. Within socio-ecological frameworks, sustainable resource use depends on the balance among ecological regeneration capacity, human demand, and institutional regulation (Brown, 2025). Therefore, ensuring the long-term persistence of biodiversity within the BDNP landscape requires stronger community-based conservation approaches that integrate Indigenous knowledge with ecological management strategies.

Table 9. Sustainability Prospects of Wildlife Species Utilized by the Orang Rimba Community

Wildlife Species	Estimated Annual Offspring Production* (Min. 50 reproductive females)	Number of Hunters (Groups)**	Estimated Maximum Annual Harvest***	Sustainability Status****
Wild boar (*Sus scrofa*)	750-1,950	125	4,080	Unsustainable
Java mouse-deer (*Tragulus javanicus*)	150-300	171	1,307	Unsustainable
Barking deer (*Muntiacus muntjak*)	100-200	177	1,351	Unsustainable
Sambar deer (*Rusa unicolor*)	200-300	194	1,481	Unsustainable
Red junglefowl (*Gallus gallus*)	1,000-2,250	125	4,080	Unsustainable
Great argus pheasant (*Argusianus argus*)	200-400	217	1,659	Unsustainable
Water monitor lizard (*Varanus salvator*)	2,250-4,500	285	9,303	Unsustainable
Asiatic softshell turtle (*Amyda cartilaginea*)	900-6,000	154	5,024	Unsustainable

Note:
*= based on potential breeding season and number of offspring per litter in Table 8
**= based on the estimated proportion of respondents who hunt using Orang Rimba population data
***= based on an estimate of 3 successful hunts per week, except for java mouse-deer, barking deer, sambar deer, and great argus pheasant, which hunt once per week because they are protected
****= sustainable criteria = total catch < total estimated production; unsustainable criteria = total catch > total estimated production (Robinson and Bennett, 2000)

Conclusion

An integrated assessment of biodiversity availability, utilization intensity, and ecological sustainability provides a clearer scientific basis for balancing conservation priorities and Indigenous livelihoods in Bukit Duabelas National Park. The Orang Rimba depend on diverse plant and wildlife resources for subsistence, health, material needs, trade, and cultural practices, reflecting the close relationship between forest biodiversity and their livelihood system. Although plant resources remained available within the traditional-use landscape, their long-term sustainability varied according to regeneration structure, harvesting intensity, and harvesting methods. Wildlife utilization showed a more critical pattern, as hunting pressure generally exceeded the reproductive capacity of the analyzed species. This imbalance indicates that customary institutions, including tano benuaron and species-based restrictions, continue to support conservation but may be insufficient without adaptive ecological monitoring. Strengthening community-based conservation in BDNP therefore requires the integration of plant regeneration monitoring, wildlife population monitoring, participatory governance, and Indigenous livelihood empowerment. Such an approach provides a practical basis for developing conservation policies that maintain biodiversity protection while sustaining the livelihoods of the Orang Rimba.

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Conceptualization, H., Y.S., A.S., and D.P.L.; formal analysis, H.; investigation, H., R.S.D., and S.; methodology, H., Y.S., A.S., and D.P.L.; project administration, H.; supervision, Y.S., A.S., and D.P.L.; writing – original draft preparation, H., and R.S.D.; writing – review and editing, Y.S., A.S., and D.P.L., and W.M. All authors have contributed to the completion of this manuscript. They have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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