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**Research Article**

# Biodiversity and Ecosystem Services Analysis to Develop a University Botanical Garden: A Case Study in the University of Palangka Raya, Central Kalimantan

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**ABSTRACT**
Information on existing site characteristics both biotic and abiotic factors is mandatory to provide an initial picture for a baseline to develop a botanical garden. This study aimed to analyse the biodiversity and ecosystem services in the candidate botanical garden area as an existing site, a case study in the University of Palangka Raya (UPR) to prepare the university botanical garden development. The fieldwork was conducted in 5 transects consisting of 100 plots with a plot size of 20x20 m$^2$. The results showed that the site is categorized as a Sundaland peat swamp forest ecoregion. The peatlands thickness varies from shallow to medium and deep, with the remaining area reaching 75 % of the total campus. The floristic condition is categorized as an early stage of succession after fires, consisting of 26 plant species belonging to 25 genera and 18 families, with various potential uses. Wildlife comprised 42 species including amphibians, reptiles, birds, fishes and prawns, also insects. Three high conservation value plants and two wildlife were documented. The stand carbon storage reached 14.33 tons ha$^{-1}$. A botanical garden consists of both natural and artificial ecosystems, thus it is important to strategically plan in setting the plant collections layout and species enrichment efforts. The UPR botanical garden will provide the conservation of native and endemic plants of Kalimantan, with high conservation value, potentials, and local wisdom value; and provide ecosystem services for storing carbon, improving hydrological services, habitat and protection for various existing and incoming wildlife.



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## INTRODUCTION

Many universities in the world today have botanical gardens for student teaching and academic research, such as the University of Padua Botanical Garden, Italy; University of Cambridge Botanical Garden, UK; Hortus Botanicus Leiden, Netherlands; University of California Botanical Garden at Berkeley, USA; the Bonn University Botanical Garden, Germany; and many more. Furthermore, the University of Padua Botanical Garden was awarded UNESCO World Heritage status in 1997 as the world's first botanical garden, created in 1545 (UNESCO 1997). Until today, it continues to serve its original purpose as a center for scientific research of medicinal plants (UNESCO 2024). Meanwhile, the Sumatera Institute of Technology Botanical Garden, Lampung, is the first university botanical garden that has been developed in Indonesia (Purnomo et al. 2020), followed by the University of Halu Oleo Botanical Garden, Kendari, Southeast Sulawesi, which is still in progress; and several other universities will follow.

University of Palangka Raya (UPR) is a state-governed university strategically located at Palangka Raya, the provincial capital of Central Kalimantan, which has a strong commitment to biodiversity conservation. The main UPR campus in Tunjung Nyaho, with an area of about 365 ha, is considered a green campus as only ± 5 % of the area is used for building academics, research, and student affairs, and the remaining ± 95 % area is green space (UPR 2018). Interestingly, the UPR campus is located very close to Sebangau National Park one of the largest tropical peat swamp and *in-situ* conservation forest areas in Indonesia and Southeast Asia. Thus, it is a strategic and valuable factor supporting UPR as a research and development center for science and technology, including biodiversity and local wisdom related to swamp peatland forests. Moreover, as mentioned in the long-term UPR Master Plan (2018-2034), UPR plans to develop a university botanical garden (UPRBG) in their green spaces with a sustainability concept to harmonize people and plants.

A comprehensive master plan is necessary to establish a botanical garden. It is a dynamic long-term planning document that provides a conceptual layout to guide current and future growth/development. It is based on public inputs, surveys, planning initiatives, existing development, physical characteristics, and social and economic conditions (Purnomo et al. 2020). In particular, existing site characteristics, including both biotic and abiotic factors, are mandatory since they give an initial picture for a baseline to maintain and develop the *ex-situ* conservation area and also for infrastructure and plant collections strategic planning (Siregar et al. 2020). The principle of developing a botanical garden is to the greatest extent to keep the existing natural landscape to ensure the sustainability of the existing ecosystem. One of the conservation functions of a botanical garden is the protection of existing ecological services. Nevertheless, establishing a botanical garden also means creating value-added new ecosystems and services due to ecological system development. Meanwhile, the development of botanical gardens (landscape and infrastructure) has the potential to disrupt the habitat of native plants, so it needs to be planned carefully (Witono et al. 2020).

The existing site characteristics of a botanical garden candidate can be identified through ecoregion and vegetation analyses. The ecoregion is a geographical area with similar characteristics of climate, soil, water, native plants, wildlife, and patterns of human interaction with nature, which describe the integrity of natural systems and environment (Olson & Dinerstein 2002). Vegetation analysis, also known as phytosociological analysis, is the method to study species composition and structure of plant communities. Hence, this study aimed to analyse the biodiversity and ecosystem services in the UPRBG candidate area as the existing site. The biodiversity analysis was approached from both a floristic and wildlife perspective; in addition, their conservation status was also assessed. At the same time, the ecoregion and habitat characteristics were identified and its ecosystem services were approached from the regulatory function based on carbon storage, provisioning function through bioprospecting potential utilization of plant and wildlife; supporting function through discussing habitat for plants and wildlife and hydrological aspects; and cultural function through discussing the development of botanical gardens as means of recreational, education, and culture. The result of this study will provide essential information as the basis for developing UPRBG particularly. It can also serve as a reference and give insight to other universities to initiate and develop a university botanical garden, also for regional and international policymakers in general.

## MATERIALS AND METHODS

### Study area, ecoregion, and habitat characteristics identification

This study was conducted in the UPR campus at Tunjung Nyaho, Palangka Raya, Central Kalimantan, Indonesia, specifically at the candidate botanical garden area. Geographically, the study area is located at the coordinates of 02°12'52.43" S to 02°13'40.77" S and 113°53.23.67" E to 113°52'15.52" E (Figure 1).

Characteristics of landscape, soil, water, and vegetation were observed in the study area. Peat soil thickness was measured manually using a measuring tape after digging the hole in the peat soil. The soil and water pH were measured using a pH meter. Furthermore, the ecoregion and vegetation habitat analyses were carried out by identifying the characteristics of the ecosystem in the area according to Olson and Dinerstein (2002) and the Indonesian Institute of Sciences's head regulation no. 1 of 2017.

### Vegetation analysis

Fieldwork was undertaken in October 2020. The sampling method of vegetation analysis used the transect method adjusted to the characteristics of the area's landscape by making observation plots (20x20 $m^2$) at every 20 m distance on the transect line alternately (Figure 1). The transect location was chosen because it is an area that is planned to be a candidate botanical garden according to the UPR master plan. The nested sampling plots were established to record four vegetation layers including understory (including tree seedlings, herbaceous, and shrubs) with a plot size of 2x2 $m^2$, saplings (trees with a diameter at breast height/DBH of less than 7 cm) with a plot size of 5x5 $m^2$, poles (trees with a DBH of 7-22 cm) with a plot size of 10x10 $m^2$, and trees (trees with minimum DBH 23 cm) with a plot size of 20x20 $m^2$ (Indriyanto 2010). For each transect, 5 plots were laid out with 4 layers, so 100 plots were observed in this study. The plant species name, number of species, and number of individuals for each species were recorded.

The data obtained from the field were then tabulated in an Excel format table for further analysis using vegetation analysis formulas. The parameters of floristic diversity indices were calculated, including the Importance Value Index (IVI), the Shannon-Wiener diversity index, the species richness index, and the species evenness index (Indriyanto 2010).

The IVI was calculated using the formula as follows:

$$IVI\ (\%) = RDe + RF + RDo$$

in which,

RDe (Relative Density) = (density of species-i/ total density of all species) x 100

RF (Relative Frequency) = (frequency of species-i total frequency of all species) x 100

Rdo (Relative Dominance) = (dominance of species-i/ total dominance

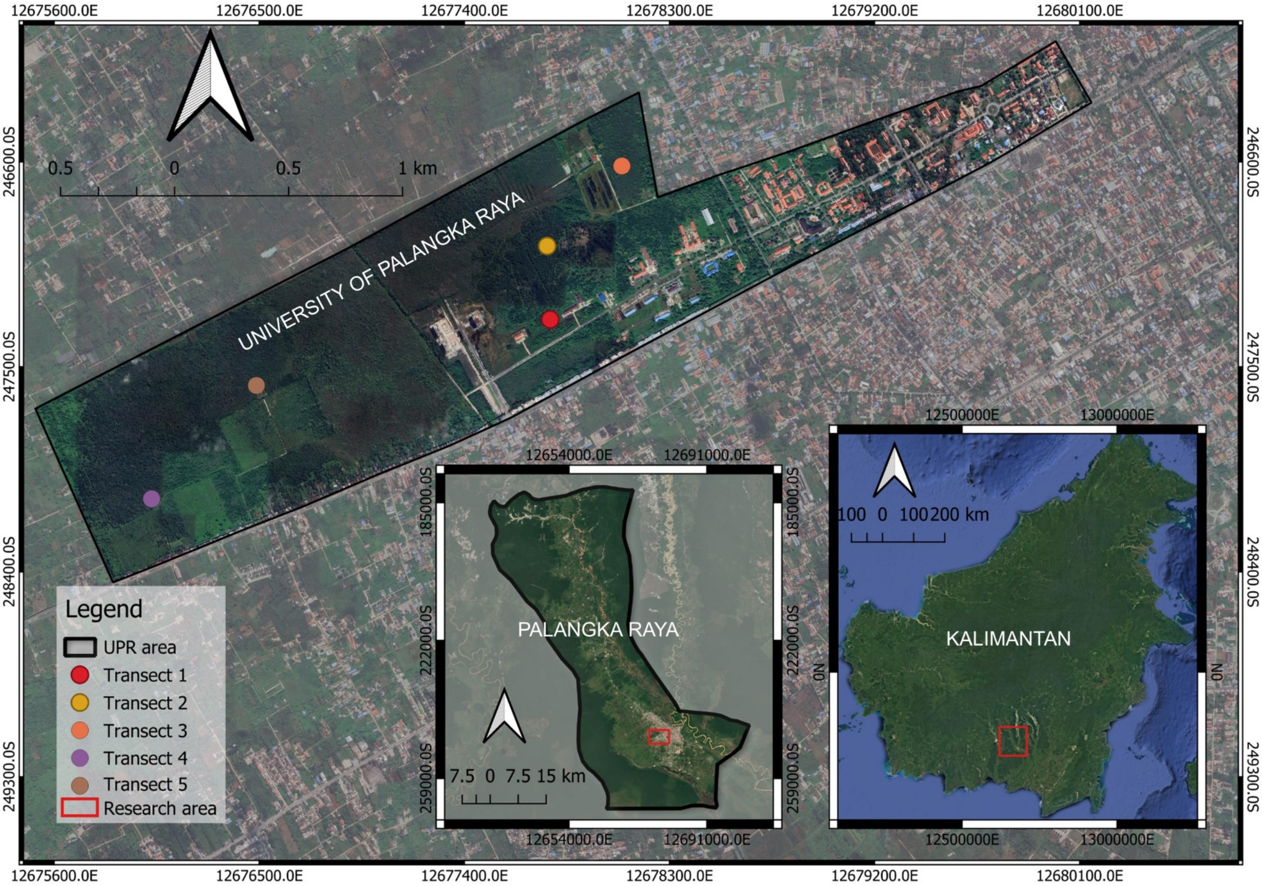


**Figure 1.** Map of study area in UPR, Central Kalimantan, Indonesia.

of all species) x 100

The Shannon-Wiener Diversity Index (H') was calculated using the equation:

$$H' = -S\, pi \times \ln pi; \text{ and } pi = ni / N$$

in which,

ni = number of individuals of species I, N = total individuals of all species. The diversity level (H') can be classified into three classes, i.e., low if H'<1; moderate if 1≤H'≤3, and high if H'>3 (Indriyanto 2010).

The species richness index (R) was calculated using the formula:

$$R = (S\text{-}1) \div \ln (N)$$

in which,

S = total number of species, N= total number of individuals in the community. The species richness is low if R<3.5, moderate if 3.5 ≤R≤ 5.0, and high if R> 5.

The evenness index (E) was calculated as:

$$E = H \div \ln (S)$$

in which,

E = evenness index, H = diversity index, S = number of species. The evenness is small (the community has low distribution among species) if 0< E≤0.4, moderate if 0.4<E≤0.6, and high (the community has equal distribution among species) if 0.6<E≤1.0 (Indriyanto 2010).

## Wildlife inventory

The occurrence of wildlife was recorded using the Visual Encounter Survey (VES) method with a time-constrained search (Doan 2003). The VES method was used to capture species of wildlife based on direct encounters on a transect in terrestrial and aquatic areas. Wildlife inventoried comprised of amphibians, reptiles, birds, fishes, and insects. Several previous studies were also compiled to enrich the results of this study.

### Plant and wildlife conservation status assesment and potential uses

The conservation status of plant and wildlife species was evaluated using the application of the International Union for Conservation of Nature (IUCN): Conservation Categories and Criteria at http://iucnredlist.org/search and also checked in the document of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) at https://cites.org/. In addition, interviews with local people were conducted to gather information on the potential uses of the plant and wildlife species; also verified through scientific literature study. Specifically for plants, we also checked the database of Plant Resources of Southeast Asia (PROSEA) at https://www.prota4u.org/prosea/search.aspx,

### Carbon storage estimation

The estimation of stand carbon storage was carried out on sapling, pole, and tree layers using allometric equations. Growth parameters related to plant biomass measured include trunk diameter, plant height, and wood density. The diameter of the stand was employed by measuring the circumference of the trunk at DBH (approximately 1.30 m from the ground). The wood density was obtained from the global wood density database (http://www.globallometree.org/). The calculation of standing carbon storage using the equation as follows (Chave et al. 2005):

$$C = \text{Tree volume} \times \text{wood density} \times 0.5$$

Tree volume was calculated using the formula: $V = \frac{1}{4} \pi D2 \times T \times FF$,
in which,
C = carbon storage (ton/ha), $\pi = 3.14$, D = Tree diameter at breast height (1.3 m), T = Tree height, and FF = Form factor, the constant value of tree geometric shape of 0.6.

### Development strategy planning of UPRBG

Based on characteristics of the study area gathered from this fieldwork including ecoregion, habitat, biodiversity (floristic and wildlife), and ecosystem services; conceptual frameworks and strategy planning for developing a botanical garden in UPR can be formulated. The development strategy planning of UPRBG was conducted following the regulation of the Indonesian Institute of Sciences no. 4 of 2019 concerning a botanical garden development. The conceptual frameworks developed and discussed in this study include vision, mission, icon or flagship species, plant collection zone, species collection priority, recreational zone, research, and education functions.

## RESULTS AND DISCUSSION

### Ecoregion and habitat characteristics

The ecoregion and forest ecosystem based on vegetation habitat in the UPRBG candidate area is categorized as a Sundaland peatswamp forest. It has the unique characteristics of saturated organic peat soil, which grows in waterlogged areas under acidic conditions with a low pH of 3.5-4.0. The peat soil thickness varies from shallow (10-40 cm) to medium (100-200 cm) and deep (>200 cm). Approximately 75 % of the UPR campus area is still an empty expanse, which is dominated by shallow to medium thickness of peat soil (Figure 2). The peat soil is formed by the accumulation of organic matter derived from the remains of plant tissue/natural vegetation in the past, which prevents it from fully decomposing due to frequent flooding (Posa et al. 2011).

Furthermore, in the intact Sundaland peatswamp forests particularly in Borneo (Kalimantan) are habitats for a large number of rare, specialized, and threatened species. This includes numerous endemic plants like various rattan species and unique dipterocarps, as well as a rich array of wildlife, such as the Bornean orangutan and pygmy elephants. The ecosystem's adaptation to waterlogged conditions has led to specialized plant and animal interactions, making it a critical area for biodiversity conservation (Olson & Dinerstein 2002; Posa et al. 2011).

Peat swamp forests are typically surrounded by lowland rain forests on better-drained soils and brackish or salt-water mangrove forests near the coast. Peat swamp forest has a high conservation value, which supports many important services in the ecosystem, such as the protection and preservation of unique plant and wildlife diversity, hydrological service, climate regulation, carbon storage, nutrient cycling, and other ecological services, therefore need to be managed wisely and sustainably (Kalima & Denny 2019). Meanwhile, peat swamp forest is considered a fragile ecosystem that is easily disturbed and damaged, making it difficult to return to its original state. Peat swamp forests are vulnerable to fire hazards during the dry season (Yulianti et al. 2020). Several patches of peat swamp forests in UPR have experienced reccurent fires in 1997, 2002, 2015, and 2019, causing damage to natural ecosystems. The plant succession process is currently underway. However, restoring the damage will take a very long time and result in changes to species composition.

### Floristic community structure, conservation status, and potential uses

The floristic community structure had a high number of species and individual abundance in the understory layer and decreased in the sapling, pole, and tree layers. The number of species and individual abundance at the pole and tree layers were low. Likewise, the species diversity and richness indices were categorized as moderate at the understory layer and low at the sapling, pole, and tree layers. Meanwhile, the species evenness index is considered high at understory and tree layers but low at sapling and pole layers (Figure 3). Hence, the floristic community structure of the UPRBG candidate area is categorized as an early stage, characterized by a high number of species and individual abundance in the understory layer and decreasing in the sapling, pole, and tree layers (Trimanto et al. 2021). It is also recognized that the vegetation succession is still in the early stage, which is indicated by the abundance growth of understory that accumulates biomass and covers the site

**Figure 2.** The peatswamp forest landscapes in the UPRBG candidate area.

with a large leaf surface area and the presence of saplings that face competitive challenges (Hapsari et al. 2020).

Within 100 observation plots, there were recorded 26 plant species belonging to 25 genera and 18 families (Table 1). The dominant families that have the most species are Myrtaceae (4 species), Cyperaceae (3 species), Rubiaceae (3 species), and Blechnaceae (2 species). The complete plant species list found is presented in Table 1. There were 7 plant life forms recorded. Trees are the most common life form found (11 species), followed by grasses (4 species), terrestrial ferns (3 species), lianas (3 species), shrubs (3 species), terrestrial orchids (1 species), and rhizomatous herb (1 species). The plant species numbers recorded in the UPRBG candidate area were considered very low compared to those found in the Sebangau National Park (NP), which is the nearby natural peat swamp forest adjacent to the UPR campus. Several previous plant inventory studies in some areas of Sebangau NP reported that there were at least 310 species (78 families) (Simbolon 2008); 133 species (34 families) (Mirmanto 2010) and 99 plant species comprised 77 genera and 42 families (Kalima & Denny 2019). Although they cannot be compared equally due to different study area extent, those previous studies can provide an overview of the estimated number of plant species in the nearest conservation area that probably once existed in UPR.

Importance value index analysis showed that terrestrial ferns from the species of *Stenochlaena palustris* and *Blechnum* sp. dominated the understory layer. Whilst, seedlings from *Cratoxylum glaucum*, *Melaleuca cajuputi*, *Ploiarium elegans*, and *Melastoma malabathricum* dominated in almost all transects. The sapling and pole layers were dominated by *Melaleuca cajuputi*, *Cratoxylum glaucum*, *Combretocarpus rotundatus*, *Acacia mangium*, and *Rubroshorea balangeran*. *Melicope lunu-ankenda* and *Ploiarium elegans* species were only found in the sapling layer; neither species was found in the pole layer. The tree layer was dominated by the same species, with only three species recorded: *Combretocarpus rotundatus*, *Acacia mangium*, and *Cratoxylum glaucum* (Figure 4 & 5).

Therefore, plant species composition with a high IVI in all layers is relatively homogeneous (Figure 4). Interestingly, most species with high importance values are considered pioneers typical of post-fire peatlands and tolerant species in acidic soil habitats, such as *Stenochlaena palustris*, *Cratoxylum glaucum*, *Melaleuca cajuputi*, *Ploiarium elegans*, *Melastoma malabathricum*, *Combretocarpus rotundatus*, and *Acacia mangium* (Davies & Semuit 2006; Graham 2009).

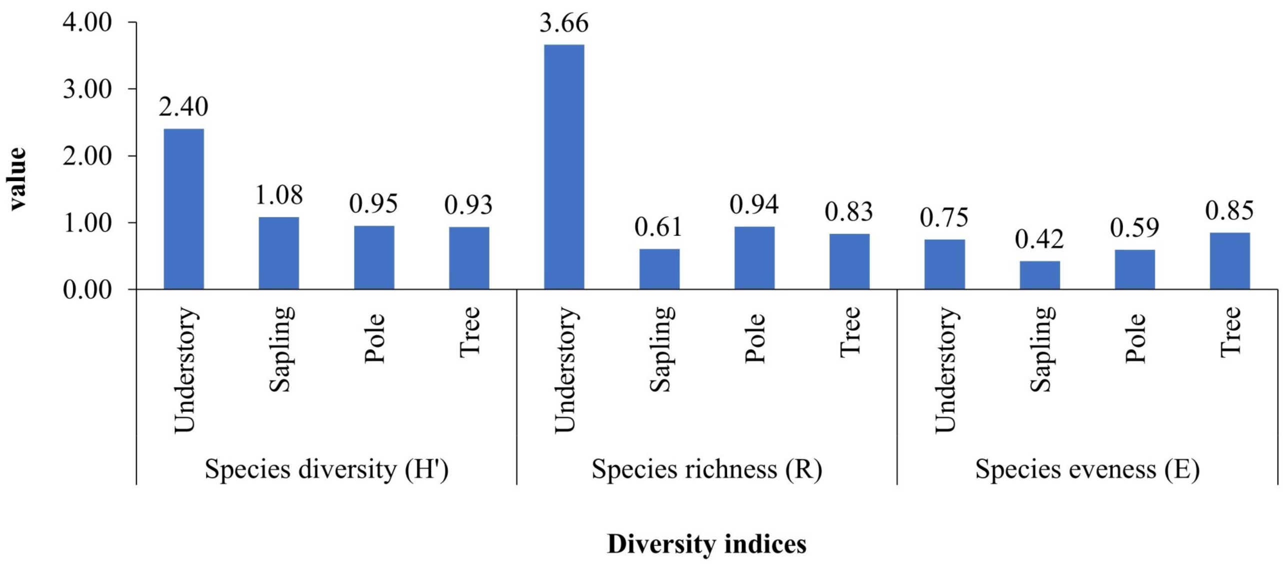


**Figure 3.** Vegetation diversity indices in the UPRBG candidate area.

Furthermore, two IUCN red listed plant species were found, i.e., a rhizomatous herb, *Etlingera balikpapanensis* (Endangered), and a tree species, *Rubroshorea balangeran* (Vulnerable) (Table 2; Figure 5A-B). Nevertheless, *Rubroshorea balangeran* is not a spontaneous plant that grows naturally in the UPRBG candidate area but is the result of species enrichment planting. In addition, there is one species of Kalimantan orchid whose trade is restricted, listed in CITES Appendix II, i.e., *Dipodium paludosum* (Table 2; Figure 5C).

**Table 1.** List of plant species recorded in the area of candidate UPRBG.

| No | Species name | Vernacular name | Family | Life form | IUCN/ CITES | Potential uses & prospects |
|---|---|---|---|---|---|---|
| 1 | *Acacia mangium* Willd. | Akasia | Fabaceae | Tree | LC | Timber, industry |
| 2 | *Blechnum* sp. | | Blechnaceae | Fern | - | Ornamental fern, fiber |
| 3 | *Combretocarpus rotundatus* (Miq.) Danser | Tumih | Anisophyllaceae | Tree | LC | Timber, industry |
| 4 | *Cratoxylum glaucum* Korth. | Gerunggang | Hyperaceae | Tree | NE | Timber |
| 5 | *Cyperus* sp. | Hiring | Cyperaceae | Grass | - | Fiber |
| 6 | *Dicranopteris linearis* (Burm.f.) Underw. | Paku ata | Gleicheniaceae | Fern | LC | Fiber, handicraft, medicinal, ornamental fern |
| 7 | *Dipodium paludosum* (Griff.) Rchb.f. | Anggrek | Orchidaceae | Orchid | CITES | Ornamental orchid |
| 8 | *Fimbristylis* sp. | Purun | Cyperaceae | Grass | | Fiber, handicraft |
| 9 | *Etlingera balikpapanensis A.D.Poulsen* | Jahe raksasa | Zingiberaceae | Herb | EN | Medicinal, ornamental ginger |
| 10 | *Ficus oleifolia* King | Nunuk nahi | Moraceae | Shrub | LC | Ecological service |
| 16 | *Gynochthodes umbellata* (L.) Razafim. & B.Bremer | Mengkudu akar | Rubiaceae | Liana | NE | Medicinal |
| 11 | *Imperata cylindrica* (L.) Raeusch. | Ilalang | Poaceae | Grass | NE | Fiber, handicraft, medicinal |
| 12 | *Lepironia articulata* (Retz.) Domin | Purun | Cyperaceae | Grass | NE | Fiber |
| 13 | *Melaleuca cajuputi* Maton & Sm. ex R.Powell | Galam | Myrtaceae | Tree | LC | Medicinal, essential oil |
| 14 | *Melastoma malabathricum* L. | Karamunting | Melastomataceae | Shrub | NE | Medicinal |
| 15 | *Melicope lunu-ankenda* (Gaertn.) T.G.Hartley | Sempayang | Rutaceae | Tree | LC | Timber, industry |
| 17 | *Nepenthes rafflesiana* Jack | Kantong semar | Nepenthaceae | Liana | LC | Ornamental carnivorous |
| 18 | *Ploiarium elegans* Korth. | Masam-masam, beriang | Bonnetiaceae | Tree | LC | Timber |
| 19 | *Rubroshorea balangeran* (Korth.) P.S.Ashton & J.Heck. | Balangeram, balau merah, | Dipterocarpaceae | Tree | VU | Timber |
| 20 | *Stemonurus secundiflorus* Blume | Mempasir | Stemonuraceae | Tree | NE | Timber |
| 21 | *Stenochlaena palustris* (Burm.f.) Bedd. | Kelakai | Blechnaceae | Fern | NE | Edible vegetable, handicraft, medicinal, ornamental fern |
| 22 | *Syzygium acuminatissimum* (Blume) DC. | Ubah samak | Myrtaceae | Tree | LC | Edible fruit for wildlife |
| 23 | *Syzygium incarnatum* (Elmer) Merr. & L.M.Perry | Jambu-jambu | Myrtaceae | Tree | NE | Edible fruit for wildlife, roadside and garden tree |
| 24 | *Syzygium pycnanthum* Merr. & L.M.Perry | Jambu-jambu | Myrtaceae | Tree | NE | Edible fruit, natural dye |
| 25 | *Timonius flavescens* (Jack) Baker | Kaum kopi | Rubiaceae | Shrub | NE | Timber |
| 26 | *Uncaria attenuata* Korth. | Gambir | Rubiaceae | Liana | NE | Medicinal |

Notes: NE = not evaluated, LC = least concern, VU = vulnerable, EN = endangered

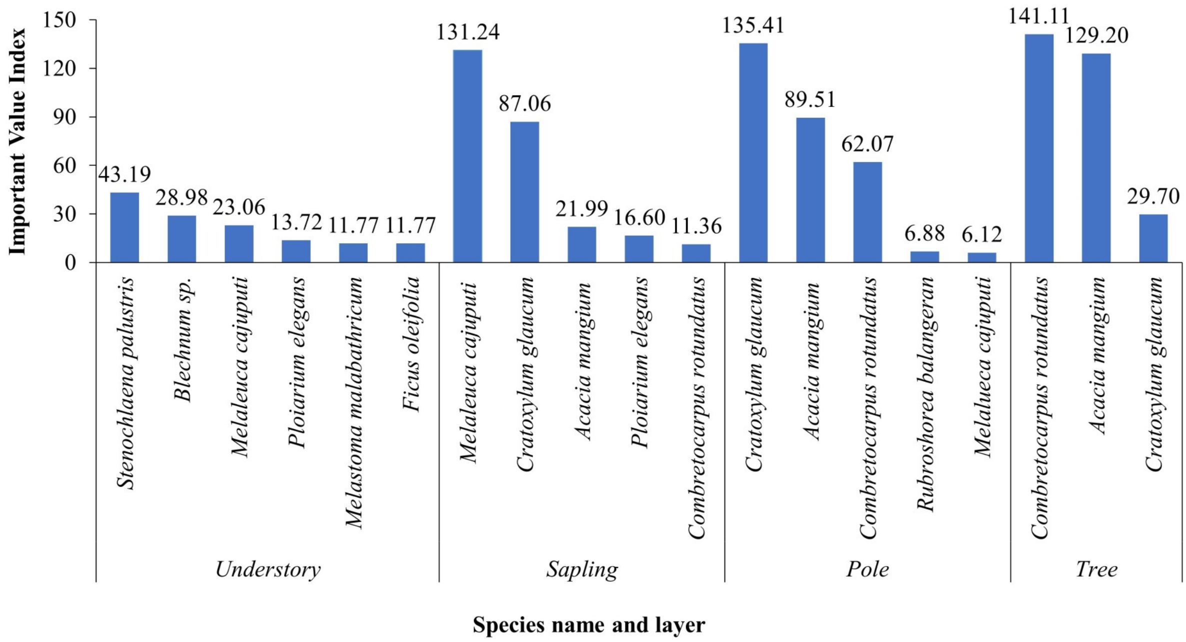


**Figure 4.** Plant species with high IVI per layer in the UPRBG candidate area.

Hence, those three plant species are highly prioritized for conservation in the botanical garden.

Plants provide provisioning services in the ecosystem. Uses evaluation showed that the plant species recorded have many potential prospects such as for timber, fiber, medicinal, ornamentals, food, etc. (Table 1, Figure 5). Some of the tree species, such as *Rubroshorea balangeran*, *Acacia mangium*, *Cratoxylum glaucum*, *Combretocarpus rotundatus*, and *Melicope lunu-ankenda*, prospect for timber and industry (pulp, particleboard, panel, etc.). Most fern, orchid, and ginger species are potential for ornamental plants. Ferns and grasses are potentially prospected as fiber and handicraft materials. As for medicinal purposes including *Melaleuca cajuputi*, *Gynochthodes umbellata*, *Uncaria attenuata*, etc. The information on existing plant species becomes a reference for plan-setting recommendations for plant collections and species enrichment efforts in developing the botanical garden (Usmadi et al. 2018).

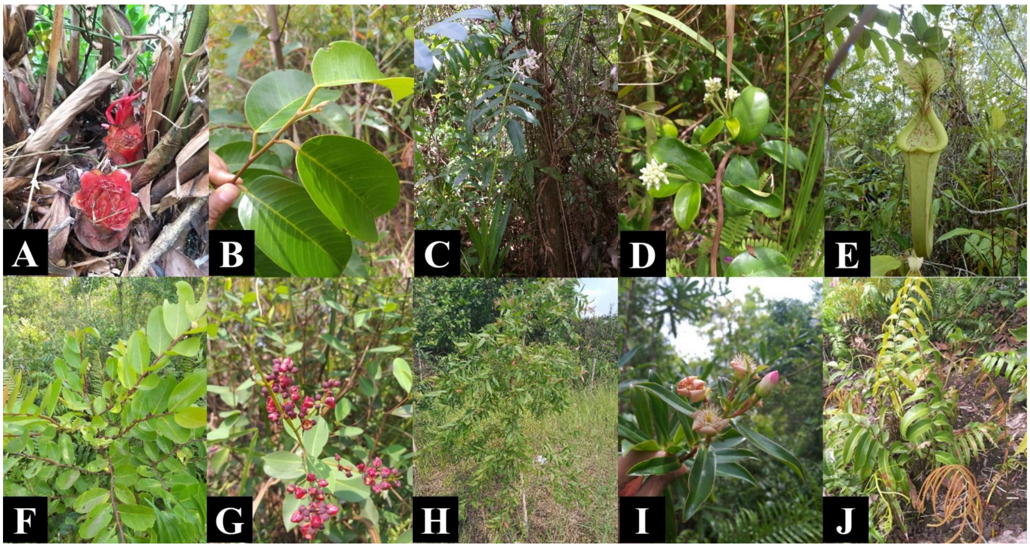


**Figure 5.** Some plant species documented in the UPRBG candidate area. IUCN red-listed: A. *Etlingera balikpapanensis* (EN) and B. *Rubroshorea balangeran* (VU); CITES App. II: C. *Dipodium paludosum*; Potential species: D. *Gynochthodes umbellata* and E. *Nepenthes rafflesiana*; Dominant species: F. *Combretocarpus rotundatus*, G. *Cratoxylum glaucum*, H. *Melaleuca cajuputi*, I. *Ploiarium elegans*, and J. *Stenochlaena palustris*.

## Wildlife species, conservation status, and potential uses

There were at least 14 species of herpetofauna (amphibians and reptiles) found in the area of candidate UPRBG, including frogs, toads, snakes, lizards, and turtles. Four local fish species were found in the reservoir or surrounding waters, and one prawn species. Three bird species were identified, comprised of scarlet-backed flowerpecker, sooty-headed bulbul, and little egrets. In addition, the diversity of insects is also quite high, consisting of 12 species of butterflies, 5 species of dragonflies, 2 species of grasshoppers, and 1 leafhopper (Table 2, Figure 6).

The remnant peat swamp forest in the area of candidate UPRBG is a habitat for various types of wildlife with high diversity and endemicity. Two of the reptile species are included in the IUCN red list, i.e., endangered Southeast Asian box turtle (*Cuora amboinensis*) and vulnerable king cobra snake (*Ophiophagus hannah*) (Figure 6E- F; Maulidi et al. 2020), so they need to be of conservation priority. However, it was identified an invasive alien species of prawn *Macrobrachium lanchesteri* in the surrounding waters (Figure 6J). It has become a precaution for conservation management to monitor its population so that it does not invade the local fish and prawn populations (Maulina et al. 2020).

The diversity of wildlife, both permanent and migratory, plays an important role in provisioning and supporting services in the plant life cycle and maintains the balance of the forest ecosystem. They also have a positive relationship between habitat environmental factors such as water availability, temperature and humidity; and diversity of vegetation as a source of food and shelter (Gonggoli et al. 2021). Wildlife such as mammals, amphibians, reptiles, insects, birds, etc. are crucial as pollinators, seed dispersal agents, and predators to control the populations of certain plants and other wildlife species in the forest ecosystem (Brockerhoff et al. 2017).

## Carbon storage in the UPRBG candidate area

The peatland has an important role in climate regulation through carbon storage, which involves above-ground vegetation and peatland biomass. There are carbon balance processes in the peatlands related to carbon, including the absorption of $CO_2$ in the atmosphere, the emission of $CH_4$, and the production and export of dissolved organic carbon (Harenda et al. 2018). However, this study focused solely on measuring the carbon storage contained in the standing biomass of plants, including saplings, poles, and trees. Meanwhile, the carbon contribution from the peat itself was not evaluated in this study.

Results from this study showed that the total stand carbon storage value in the UPRBG candidate area reached 14.33 tons/ha, with the sapling layer as the most carbon contributor up to 8.32 tons/ha, followed by the pole layer at 5.18 tons/ha and tree layer at 0.83 tons/ha (Table 3). Trees are generally much larger than saplings and possess greater biomass, which means they can store more carbon. As trees mature, they accumulate more mass in their trunks, branches, and leaves, leading to higher carbon stocks (Chave et al. 2005). However, since the UPRBG candidate area is a secondary peatforest that experienced frequent fires. The trees are very sparse, while the number and density of saplings and poles are very high, resulting in a carbon stock stand from sapplings and poles higher than trees.

The last fire incident in the area UPRBG candidate area occurred in 2019, about two years ago from this study. The stand carbon storage value in the UPRBG candidate area is considered to be approximately the same as reported in previous study by Dharmawan et al. (2013) on three years post-burned peat forest in Central Kalimantan, i.e., 13.64 tons/ha. Meanwhile, according to Jaya et al. (2007), the stand carbon storage in ten years post-

**Table 2.** List of wildlife species recorded in UPRBG candidate area.

| Group | Species | Vernacular name | Family | IUCN |
|---|---|---|---|---|
| **Amphibia** | *Hylarana erythraea* | Common green frog | Ranidae | LC |
| | *Pulchrana baramica* | Baram river frog | Ranidae | LC |
| | *Fejervarya cancrivora* | Crab-eating frog | Dicroglossidae | LC |
| | *Polypedates leucomystax* | Common tree frog | Rhacophoridae | LC |
| | *Duttaphrynus melanostictus* | Southeast Asian toad | Bufonidae | LC |
| | *Ingerophrynus biporcatus* | Crested frog | Bufonidae | LC |
| | *Eutropis multifasciata* | Common mabuya lizard | Scincidae | LC |
| **Reptile** | *Cuora amboinensis* | Southeast Asian box turtle | Geoemydidae | EN |
| | *Ophiophagus hannah* | King cobra snake | Elapidae | VU |
| | *Dendrelaphis pictus* | Painted bronzeback snake | Colubridae | NE |
| | *Pareas carinatus* | Keeled slug-eating snake | Pareidae | LC |
| | *Xenochrophis trianguligerus* | Red-sided keelback water snake | Natricidae | LC |
| | *Rhabdophis flaviceps* | Orangeneck keelback snake | Natricidae | LC |
| | *Phytolopsis punctata* | Blackwater mud snake | Homalopsidae | DD |
| **Fish** | *Rasbora laticlavia* | Clown rasbora | Danionidae | LC |
| | *Belontia hasselti* | Kapar fish, Malay combtail | Osphronemidae | LC |
| | *Trichogaster trichopterus* | Three spot gourami | Osphronemidae | LC |
| | *Osteochilus hasseltii* | Nilem fish, Bonylip barb | Cyprinidae | LC |
| **Prawn** | *Macrobrachium lanchesteri* | Riceland prawn | Palaemonidae | LC |
| **Bird** | *Dicaeum cruentatum* | Scarlet-backed flowerpecker | Dicaeidae | LC |
| | *Pycnonotus aurigaster* | Sooty-headed bulbul | Pycnonotidae | LC |
| | *Egretta garzetta* | Little egret | Ardeidae | LC |
| **Butterfly** | *Hypolimnas bolina* | Brush-footed butterfly | Nymphalidae | NE |
| | *Junonia atlites* | Grey pansy | Nymphalidae | NE |
| | *Junonia orityha* | Blue pansy | Nymphalidae | NE |
| | *Junonia coenia* | Common buckeye | Nymphalidae | NE |
| | *Acraea terpsicore* | Tawny coster | Nymphalidae | NE |
| | *Catopsilia pumona* | Lemon emigrant | Pleridae | NE |
| | *Catopsilia pyranthe* | Mottled emigrant | Pleridae | NE |
| | *Appias olferna* | Striped albatross | Pleridae | NE |
| | *Appias libythea* | Striped albatross | Pleridae | NE |
| | *Eurema blanda* | Three-spot grass-yellow | Pleridae | NE |
| | *Papilio demoleus* | Lime swallowtail | Papilionidae | NE |
| | *Udara placidula* | Glassy butterfly | Lycaenidae | NE |
| **Dragonfly** | *Cariagrion cerinorubellum* | Orange-tailed marsh dart | Coenagrionidae | NE |
| | *Rhyothemis phyllis* | Yellow-barred flutterer | Libellulidae | LC |
| | *Neurothemis fluctuans* | Red grasshawk | Libellulidae | LC |
| | *Brachydiplax chalybea* | Blue dasher | Libellulidae | LC |
| | *Trithemis aurora* | Crimson marsh glider | Libellulidae | LC |
| **Grasshopper** | *Acrida* sp. | Silent slant-faced grasshoppers | Acrididae | NE |
| | *Phlaeoba* sp. | Short-horned grasshopper | Acrididae | NE |
| **Leafhopper** | *Zelus* sp. | Assassin bugs leafhopper | Reduviidae | NE |

Notes: NE = not evaluated, DD = data deficient, LC = least concern, VU = vulnerable, EN = endangered

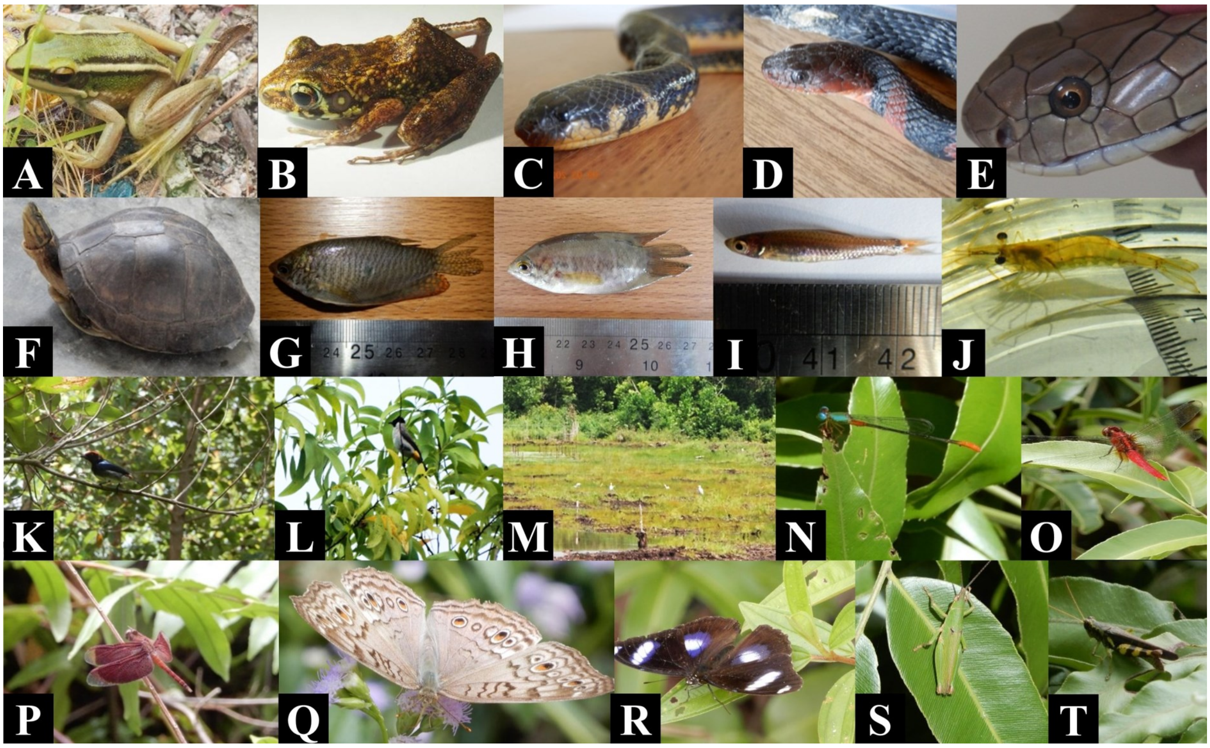


**Figure 6.** Some wildlife species documented in the UPRBG candidate area. Amphibians: A. *Hylarana erythraea*, and B. *Pulchrana baramica.* Reptiles: C. *Phytolopsis punctata*, *D. Rhabdophis flaviceps*, *E. Ophiophagus hannah* (VU), and F. *Cuora amboinensis* (EN). Fishes and prawn: G. *Trichogaster trichopterus*, H. *Belontia hasselti*, I. *Rasbora laticlavia*, and J. *Macrobrachium lanchesteri*; Birds: K. *Dicaeum cruentatum*, L. *Pycnonotus aurigaster*, and M. *Egretta garzetta.* Insects: N. *Cariagrion cerinorubellum*, O. *Trithemis aurora*, P. *Neurothemis fluctuans*, Q. *Junonia atlites*, R. *Hypolimnas bolina*, S. *Acrida* sp., and T. *Phlaeoba* sp.

burned peat forests (burned twice) is 15-21 tons/ha. However, it is much lower than eight years post-burned peat forest, i.e., 26.13 tons/ha; and is quite higher than stand carbon storage ini peat forest which burns repeatedly each year, i.e., 4.94 tons ha$^{-1}$ (Dharmawan et al. 2013). The stand carbon storage in post-burned peat forests must be lower than in intact peat forests, but recovery can occur over time as succesion occurs and vegetation regrows.

The findings of this study reflect only the carbon storage potential of the stand carbon storage, leaving out a potentially significant component of the overall carbon dynamics in the ecosystem. This could lead to an incomplete understanding of the total carbon storage in the area of candidate UPRBG, as peat soils can store large amounts of carbon. Therefore further study to measure the carbon contribution on the peatland biomass is suggested.

**Table 3.** Stand carbon storage estimation in the UPRBG candidate area

| Site | C-storage (tons/ha) | | |
|---|---|---|---|
| | Tree | Pole | Sapling |
| Transect 1 | 1.24 | 9.61 | 11.72 |
| Transect 2 | 0.73 | 11.58 | 12.88 |
| Transect 3 | 0 | 0.43 | 5.80 |
| Transect 4 | 0.91 | 1.45 | 5.32 |
| Transect 5 | 1.26 | 2.83 | 5.90 |
| **Total** | **4.14** | **25.90** | **41.61** |
| **Average** | **0.83** | **5.18** | **8.32** |

## Development strategy planning of UPRBG

The UPR area will be developed into a botanical garden with a landscape consisting of several types of natural and artificial ecosystems, which provide some ecosystem services. The UPRBG will provide the service of conservation of Kalimantan plant in the form of various plant collections, prioritized to native, endemic, high conservation value, high potentials, high value of local wisdom, etc. However, in the development process, species prioritization is needed to allocate limited resources for *ex-situ* conservation planning and action effectively (Purnomo et al. 2015).

The development of a new botanical garden is prioritized to conserve the richness of local plant species based on their habitat suitability. Hence, based on the type of ecosystem that characterizes the UPRBG candidate area from this study, the recommended plant collection theme for the UPRBG is an *ex-situ* conservation of peat swamp plants. In the context of peatlands, water is considered the first-level factor that determines its emergence, growth, and development (Harenda et al. 2018). The development of UPRBG will improve hydrological services by protecting and providing water reserve balance. Peatlands serve as a buffer for the water landscape through the rapid absorption of rainwater to reduce the impact of flooding. Therefore, the existing water reservoir in UPRBG needs to be maintained by conserving the above vegetation integrity and species enrichment with water-storing plants around the riparians and water catchment area.

The vision of the proposed UPRBG is to be the best botanical garden in the world in the fields of conservation, research, and education based on Kalimantan peat swamp plants for sustainable use. With several considerations, including local species and high conservation value species, well adapted to peat swamp habitat and have high economic values for the community. The proposed iconic or flagship species for UPRBG is *Gonystylus bancanus* (Miq.) Kurz (vernacular name: Ramin, family: Thymelaeaceae). According to this study, this species is no longer found in the UPRBG candidate area. However, it is found in abundance and is a key species in Sebangau NP, yet it is at a high risk of extinction with an IUCN status of critically endangered (Karni et al. 2021).

Due to the low vegetation diversity index and species richness in the UPRBG candidate area, it is important to strategically plan the layout of plant collections and species enrichment efforts. Plant collection block planning or lay-outing of collection zones is one of the important formulations of a botanical garden master plan (Purnomo et al. 2020). Management of some existing valuable species, such as *Etlingera balikpapanensis*, *Rubroshorea balangeran*, *Dipodium paludosum*, *Nephenthes rafflesiana*, and *Gynochthodes umbellata* (Figure 5A-E) in the UPRBG candidate area, are prioritized to be recorded as spontaneous collections. Their populations must be maintained for their best performance, survive for a long time, and be well-reproduced.

The proposed green layout concept (collection zone) can be in taxonomic classification patterns and thematic gardens. The recommended taxonomic classification gardens in UPRBG include Dipterocarpaceae, Apocynaceae, Myrtaceae, Arecaceae, Thymelaeaceae, Pandanaceae, Zingiberaceae, Moraceae, Anacardiaceae, Gymnospermae, Dicotyl, and Monocots, meanwhile, for the thematic gardens including medicinal and spices, ornamentals, aromatic, aquatic, fiber, natural dyes, timber, local fruit, carnivorous, industry, wildlife fodder, honorary, and peat swamp.

UPRBG will provide habitat and protection for various existing wildlife and invite more of them (Figure 6). This service can be maintained by providing a jungle zone or forested area. The jungle zone is characterized by high canopy density, many species of fruit-producing trees, and water source areas. Guided tours with birdwatching routes can be developed in the jungle zone. Artificial lakes and riparian zones will protect habitats, especially for freshwater fishes, prawns, amphibians, reptiles, and peat swamp water birds.

The plant collections, ecosystem sevices, and facilities of the UPRBG combined with university research facilities at UPR may become valuable assets as teaching and learning media to strengthen the education functions of the academic community. The valuable plant collections may serve as materials to support various research and teaching projects. Furthermore, it can be used for teaching purposes by various related departments in many subjects, such as Integrative Biology, Botany, Zoology, Molecular Systematics, Ecology and Evolution, Medicinal and Therapeutics, Landscape Architecture, etc. In addition, to promote and engage public understanding of the importance of plants and the environment, UPRBG may develop various educational curricula and seasonal thematic courses for wider audiences, community, school students, children, and the general public.

In addition, to accelerate the development of a new botanical garden, it is encouraged to collaborate with some strategic parties, namely academic, business/private, community, and government. The collaboration can be in infrastructure development support, collection enrichment through exploration, collection maintenance, internship, research, etc. (Purnomo et al. 2020). In particular, the UPRBG needs to collaborate with the management of the Sebangau NP as a partner in the context of species enrichment and maintenance (sources of plant collection materials) and further develop a research center in various disciplines, especially in the fields of Botany, Ethnobotany, Ecology, and Forestry about the conservation of peat swamp forest.

## CONCLUSIONS

The UPRBG candidate area is categorized as the Sundaland peat swamp forest ecoregion. The plant community structure was identified as an early stage with low vegetation diversity and species richness. Most plant species are typical pioneers of post-fire peatlands. At least 26 species of plant and 42 species of wildlife have been recorded. Five species of plant and wildlife of high conservation value have been identified. Standing carbon stocks reached 14.33 tons/ha, indicating the contribution value of two years post-burning peat forests. Therefore, in developing it into a university botanical garden, it is necessary to plan the layout of plant collections and species enrichment, especially with native and endemic species, well adapted to peat swamp habitats; have high conservation value, utilization potential, local wisdom value, and other thematic issues. UPRBG will provide ecosystem services to store carbon, improve hydrological services, and provide habitat and protection for various wildlife. The richness of biodiversity, ecosystem services, and botanical garden facilities combined with university research facilities at UPR can become a valuable asset as a teaching and learning medium to strengthen education and research functions, also recreational for general public.

## AUTHOR CONTRIBUTION

L.H., M.R., A.M., J.R.W., I.P.A, designed the research, collected and analysed the research data, D.S., W, E.S., Y.E.G, H.S., S.G. supervised the entire research process. All authors were involved in writing and revising the manuscript.

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## CONFLICT OF INTEREST

There is no conflict of interest regarding the research or the research funding.

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