Study of species associations in native habitats of the genus Dacrydium Lamb. (*Podocarpaceae*) in Central Kalimantan, Indonesia

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Abstract. The tropical coniferous genus *Dacrydium* Lamb. is occurring with some species in various habitat types in Kalimantan, Indonesia. So far four species are recorded for that area. Even though the species are considered globally as Endangered and Least Threatened species by the IUCN, in Central Kalimantan the genus is under threat from pressures related to logging, fire and land conversion. Locally known as Alau, this genus prospers in a range of habitats from heath to deep-peat swamp forests in Central Kalimantan. Data from field plots across four sites in Central Kalimantan are used to compare variations in habitat and species composition where Alau trees are present. The results of the analysis show the wide range of habitat structure as well as species diversity where Alau tends to thrive. The characterization of these sites may be helpful in protecting and conserving Alau forest areas under social forestry and local forest management resource use plans.

1. Introduction

The tropical coniferous genus *Dacrydium* Lamb. (*Podocarpaceae*) is occurring with four species in Kalimantan, Indonesia. So far *D. beccarii* Parl., *D. xanthandrum* Pilg., *D. pectianum* de Laub, and *D. elatum* Roxb. are reported from Kalimantan [1]. The genus *Dacrydium* is called “Alau” locally a name widely used by the Ibans in Central Kalimantan. The species are listed in the IUCN Red List of Threatened Species 2013 but have been categorized globally as “Least Concern” species. The “Least Concern” category indicates that after evaluation against the IUCN Red List criteria it does not qualify for classification as “near threatened” or other more serious conservation categories [2]. *D. pectinatum* is classified as Endangered in the red list [1]. A second species, also known locally as Alau, and present in Central Kalimantan is *Dacrydium xanthandrum* [3]. Also listed as a Least Concern species by IUCN, even less is known about its global population. However, it faces the same logging and wood harvesting threats [3] in Central Kalimantan. The wood of both species is valued for construction and, because of its beauty, it used for furniture making. Locally the wood is known as “melur” or “cemantan” (Ngaju Kapuas language).
The global classification for the several species may be Least Concern, but Alau may be under more serious threat locally. Professor Dr. Ir. Soekotjo, forestry expert at the Forestry Faculty of Gadjah Mada University once commented that the species was extinct in Kalimantan [4]. Dr. Adriyanti, a dendrology expert in the Faculty of Forestry at Gadjah Mada University, however, has identified it in Central Kalimantan [5] as have Farjon and Filer [1]. While the genus, globally, is considered stable it does face several threats and stresses, including logging and wood harvesting and habitat loss due to fire or conversion to other land uses for (oil palm?) concession area, especially in peatland areas of Central Kalimantan.

Published research on Alau in Central Kalimantan is very limited. The occurrence of Alau, generally, in large intact forests is good and Alau are known to remain and recover in logged over forest areas [2]. However, the increasing pressures from logging, land use conversion, and fire in Central Kalimantan put stress on Alau that possibly does not exist elsewhere. Survival of out-planted seedlings is unfortunately low which means assisted natural regeneration is not presently an option for highly degraded forest areas. This study fills an important gap in understanding the site conditions and species compositions in forested areas in Central Kalimantan where Alau is present. The aim of the research is to document site conditions and species composition characteristics across several forest areas in Central Kalimantan where Alau is naturally growing. Identifying specific ecological conditions where Alau is present may contribute to the preservation, protection, and conservation of such areas through inclusion in social forestry and forest management unit (KPH) management plans.

The tropical coniferous genus *Dacrydium* or Alau belongs to the Pinophyta clade, thus cone bearing seed plants. The genus *Dacrydium* belongs to the Podocarpaceae family which are Southern hemisphere coniferous evergreen trees. Podocarpaceae species are diverse morphologically and ecologically. Alau has a sympodial or bifurcating type of branching and are commonly found in heath and peat swamp forests in Central Kalimantan.

Alau thrives in heath or *kerangas* forest ecosystems. In Indonesia, Kalimantan exhibits the most extensive area of health forests. Of all lowland rainforest ecosystems, heath is perhaps the most easily recognizable [6] due to the nutrient poor soil condition. The word *kerangas* is derived from the Iban Dayak language which means land that cannot be planted with rice. Heath forests grow on Podsol soil with low pH and high sand content and shallow peat [7]. Heath forest soil structure is characterized by a dominant sand layer with a thin organic horizon on top. Heath forest ecosystems are fragile to disturbance and easily degraded. Heath forests are commonly located between more nutrient rich Dipterocarp lowland forests in hilly areas and swamp or deep peat forests. Despite their nutrient poor soil condition health forest ecosystems exhibit a rich floral biodiversity. Tropical Heath Forests have been understudied and undervalued for many years, considered as a low-diversity habitat due to a nutrient–poor sandy soil, unable to aggregate and bind nutrients, resulting in stunted, low canopy forest [8]. Alau appears to grow in both shallow and deep peat systems spanning both heath (*kerangas*) and swamp forest ecosystems [9].

2. Methods

2.1. Study sites characteristics and field plot data collection

The research study sites include four specific forest areas in Central Kalimantan where Alau is present. These includes one area within the Genetic Resources area of PT Dasa Intiga (312.67 ha), two sites within PT Taiyoung Engreen (321.67 ha), and an area within Sebangau National Park (159.81 ha). Tree and seedling species data were collected in fixed area field plots measuring 50 x 80 meters (0.4 ha) in each of the four forest areas. In site 1 of PT Taiyoung Engreen data were collected in four sample plots. In site 2 of PT Taiyoung Engreen data were collected in two sample plots. Data from six sample plots were collected in PT Dasa Intiga and from three sample plots in Sebangau National Park. In addition to species counts, tree diameter at breast height (DBH) and height data were also collected. Table 1 provides the research study site area, number of plots, total plot area sampled and location (see Figure 1 for a map of the study area locations.
### Table 1. Research study site plot areas and location information.

| Study Sites            | PT Taiyoung Engreen (1) | PT Taiyoung Engreen (2) | PT Dasa Intiga | Sebangau National Park |
|------------------------|-------------------------|-------------------------|----------------|------------------------|
| Area (ha)              | 195.51                  | 126.16                  | 312.67         | 159.81                 |
| Sample intensity       | 0.82                    | 0.63                    | 0.77           | 0.75                   |
| No of sample plots     | 4                       | 2                       | 6              | 3                      |
| Plot size (ha)         | 0.40                    | 0.40                    | 0.40           | 0.40                   |
| Total plot area (ha)   | 1.60                    | 0.80                    | 2.40           | 1.20                   |
| Lat. Coordinates (dd)  | S 01.325038             | S 01.313704             | S 01.216722    | S 02.51493             |
| Long. Coordinates (dd) | E. 113.721327           | E 113.676631            | E 114.506997   | E 114.02885            |

Table 2 summarizes the ecological habitat conditions across several characteristics for the four areas. They range from shallow to deep peat soils, with or without the presence of sand under the peat, the existence of a hardpan layer, presence of surface water, water depth, etc. The four represent a gradient of ecological habitat conditions where the presence of Alau is observed.

### Table 2. The ecological habitat conditions across several characteristics for the four areas.

| Ecological Habitat Characteristics | PT Taiyoung Engreen (1) | PT Taiyoung Engreen (2) | PT Dasa Intiga | Sebangau National Park |
|-----------------------------------|-------------------------|-------------------------|----------------|------------------------|
| Peat depth                         | 6.5 cm                  | 10 cm                   | 12 cm          | > 3 m                  |
| The presence of sand under the peat layer | Present              | Present                 | Present        | Not Present            |
| Sand color                         | Black                   | White                   | White          | Not Present            |
| The presence of hardpan layer      | Present                 | Present                 | Not Present    | Not Present            |
| Forest Type                        | Heath                   | Heath                   | Heath          | Peat swamp             |
| Light intensity                    | 50 %                    | 60 %                    | 45 %           | 40 %                   |
| Puddle conditions                  | Not Present             | Not Present             | Present (some) | Present               |
| Ground water depth                 | NA                      | NA                      | NA             | 11 cm                  |
| Species (local name) found only at this area. | Pilau (*Agathis borneensis* Warb.) | Meranti kahiu (*Shorea xanthophylla* Symington) | Supang (*Shorea pachyphylla* Ridl.) | Belangaran (*Shorea balangeran* (Korth.) Burck) |
| Presence of Alau seedlings in 2 x 2 m plot | 8                       | 13                      | 16             | 11                     |
| Relative abundance of liana (inc. rattan) | ++                     | +++                    | +              | -                      |
| Relative abundance of pandan       | +++                     | +++                    | ++             | +                      |
2.2. Data analysis methods
Two Excel-based tools developed by Michigan State University under the USAID LESTARI Project (2015 – 2020) were used to compute biodiversity indices, wood volume (m$^3$ ha$^{-1}$), and stand density (trees ha$^{-1}$) from the collected field data. The tools compute species richness and dominance as well as several other biodiversity indicators. We use the output from these two tools to report species composition and stand habitat characteristics for the four study areas.

3. Results
3.1. Size class distribution of Alau in the study site areas
Data collected in the field show the observation of Alau in all four study areas. Table 3 lists these observations along with the range and mean DBH values and frequency distribution for size classes between 10 – 60 cm DBH.

The largest Alau trees are in PT Taiyoung Engreen and PT Dasa Intiga. While there are significantly more Alau trees observed in Sebangau National Park over the other areas, the size class of these trees are much smaller. In PT Taiyoung Engreen and PT Dasa Intiga more than 70% of the trees observed were greater than 30 cm DBH. In PT Taiyoung Engreen (2) there were only five trees observed, but they were all over 40 cm DBH. The least number of observed Alau trees was in PT Taiyoung Engreen (32 trees), even combining sites 1 and 2, followed next by PT Dasa Intiga (48 trees), and even though Sebangau National Park only included 3 plots (half the sample area as the other two sites) this site had the most observed Alau trees (78 trees).

Table 3. Number and size classes of Alau trees present in the study areas.

| Study Area Alau | PT Taiyoung Engreen (1) | PT Taiyoung Engreen (2) | PT Dasa Intiga | Sebangau National Park |
|-----------------|-------------------------|-------------------------|----------------|------------------------|
| Number of Alau trees all plots | 27 trees (4 plots) | 5 trees (2 plots) | 48 trees (6 plots) | 78 trees (3 plots) |
| Min DBH (cm) | 14.01 | 43.61 | 10.50 | 10.98 |
| Max DBH (cm) | 59.84 | 54.11 | 59.84 | 32.79 |
The species composition of Alau habitat shows several common tree species across the study area sites and a gradient of species that are only observed in one study site area. For this analysis we combined the species data from the two sites in PT Taiyoung Engreen. Across the study areas we have identified 126 different tree species (Table 4). Forty-two species (33.33 %) are observed in all three areas. Twenty-six (20.63 %) are observed in two of the three areas. Fifty-eight (46.03 %) are species that are observed in only one of the three sites: 16 in PT Taiyoung Engreen, 19 in PT Dasa Intiga, and 23 in Sebangau National Park. Observations in the field found 3 phenotypes of alau trees with local name alau bakam, alau kelangkang and alau tombak, but it is not yet known the exact scientific name of them.

### Table 4. Species (local name) common across sites and found only in one site.

| Species found in all three areas | Alau bakam (Dacrydium spp.) | Alau Kelangkang (Dacrydium spp.) | Alau tombak (Dacrydium spp.) | Belawan merah (Tristaniopsis obovata) | Belawan putih (Tristaniopsis whiteana) | Selumbor/belawan punei (Tristaniopsis maingaiyi) | Bintan (Licani siong Bakh.) | Ehang haduk (Diospyros siamang Bakh.) | Galam tikus (Syzygium zeylanicum (L.)DC.) | Geronggang (Cratoxylum arborescens (Vahl)Blume) |
|---------------------------------|-------------------------------|----------------------------------|-------------------------------|-------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------|----------------------------------|----------------------------------------|-----------------------------------------|
| Hanyer bajai (Adinandra bancana (Miq.) King Ex. B.D. Jacks) | Jambu merah (Eugenia spp.) | Jambu putih (Eugenia spp.) | Jinjit (Calophyllum hosei Ridl.) | Kajalaki (Aglaia rubiginosa (Hiern) Pannell) | Kambasira (Ilex cymosa Blume) | Kambasira merah/sabun (Dacryodes macrocarpa (King H.J.Lam.) | Kapurnaga kelakai (Calophyllum grandflorum J. J. Sm.) | Kamehas (Memecylon sumatrense Bakh. f) | Kayu sapat daun besar (Mitragyna speciosa (Korth.) Havil) | Kayu sapat daun kecil (Trichilia hirta L.) |
| Kerandau jangkar (Blumeodendron todkbrai (Blume),Kurz.) | Malam-malam/tutup kabali (Diospyros borneensis Hiern.) | Mangkinang (Elaeocarpus tomentosa Blume) | Medang batu/pahawas (Litsea ferruginea Blume) | Meranti bitik (Shorea parvifolia Dyer) | Nyatoh bawui (Madhuca sericea (Miq.) S. Moore) | Nyatoh puntik (Palaquium pseudorostratum H.J. Lam.) | Pasir-pasir (Stemonorus scorpionides, Becc.) | Rahanjang merah (Xylopia altissima Boerl.) | Rahanjang putih (Xylopia fusca Maingay ex Hook. f. & Thomson) | Rambutan berbulu panjang (Nephelium meduseum Leenh) |
| Species names in Malay | Scientific names | Species found in two of the three areas |
|-----------------------|-----------------|----------------------------------------|
| Gantalang/manggis hutan | *Garcinia bancana* Miq. | Kayu tulang hitam (*Aploebia spp.*) | Resak putih (*Cotylelobium laneolatum* Craib.) |
| Hampuak (*Baccaurea bracteata* Mull.Arg.) | Kayu tulang putih (*Alseodaphne umbilliflora* Blume Hook f.) | Resak tembaga/merah (*Cotylelobium flavum* Pierre) |
| Hantangan (*Campnosperma minor* Corner) | Kemuning (?) | Sagagulang/rambangun/kayu tepung (*Acronychia pedunculata* (L.) Miq.) |
| Gantalang/manggis hutan | *Garcinia bancana* Miq. | Kayu tulang hitam (*Aploebia spp.*) | Resak putih (*Cotylelobium laneolatum* Craib.) |
| Resak putih | *Cotylelobium laneolatum* Craib. | Resak tembaga/merah (*Cotylelobium flavum* Pierre) |
| Kayu arang | *Diospyros confertiflora* (Hiern) Bakh. | Sagagulang/rambangun/kayu tepung (*Acronychia pedunculata* (L.) Miq.) |

### Species only found in Sebangau National Park

| Species names in Malay | Scientific names | Species found in two of the three areas |
|-----------------------|-----------------|----------------------------------------|
| Bati-bati | *Syzygium griffithii* | Kelampis/selumbar (*Jackia ornata* Wall. Ridsdale) | Meranti buaya (*Shorea uliginosa* Foxw.) |
| Guthie Merr. & L.M. Perry | *Syzygium zeylanicum* (L.) DC | Keput bejukuh (*Stemonorus secundiflorus* Blume.) | Mertibu (*Dactylocladus stenostachys* Oliv.) |
| Galam tikus jangkar/jambu | *Syzygium zeylanicum* (L.) DC | Keput bejukuh (*Stemonorus secundiflorus* Blume.) | Mertibu (*Dactylocladus stenostachys* Oliv.) |
| Kahoi | *Shorea balangeran* (Korth.) Burck | Kerandau/Pupu pelanduk (*Neoscorthechnia kingii* Hook. F. Pax. K hoff) | Tabati (*Syzygium lineatum* (DC)Merill & Perry) |
| Kambalitan | *Mezzettia macrocarpa* Heyden & Kessler | Langsat burung (*Dacryodes rugosa* (Blume.) H.J. Lam) | Takerung (*Pithecellobium splendens* Prain.) |
| Kambalitan | *Mezzettia macrocarpa* Heyden & Kessler | Langsat burung (*Dacryodes rugosa* (Blume.) H.J. Lam) | Takerung (*Pithecellobium splendens* Prain.) |
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Analysis of the species grouped by family is shown in Figure 2. Of the 29 tree families present in the Alau study area sites five tree family types were most abundant in terms of the most species observed: Myrtaceae (16), Dipterocarpaceae (n=16), Guttiferae (n=11), Lauraceae (n=11), and Annonaceae (n=7). Other family types are associated with Alau in smaller numbers, from one to six species only.

### Species only found in PT Dasa Intiga

| Species Only Found | Family Name |
|--------------------|-------------|
| Kayu asam/salintit (Plaiarium alternifolium) | Myrtaceae |
| Medang telur (stenomonorus scorpionides) | Myrtaceae |
| Acis merah (Garcinia lateriflora) | Myrtaceae |
| Kayu busi (Syzygium bankensis) | Myrtaceae |
| Bintan putih (Kokonna reflex Law. Ding Hou) | Myrtaceae |
| Kempas merah (Koompassia beccariana) | Myrtaceae |
| Cangal Padi (Anisoptera grossivenia) | Melastomataceae |
| kerandau putih (Neoscorthechnia kingii) | Melastomataceae |
| Darah-darah (Myristica maxima) | Myristicaceae |
| Kumpang putih (Knema latericia) | Myristicaceae |
| Ehang jambu (Syzygium incarnatum) | Myrtaceae |
| Lanan/ hopea (Shorea hopeifolia) | Myrtaceae |
| Hangkang (Palaquium leiocarpum) | Myrtaceae |
| Medang miang (Litsea firma) | Myrtaceae |
| Jambu daun kecil (Eugenia incarnatum) | Myrtaceae |
| Medang putih (Cinnamomum parthenoxylon) | Myrtaceae |

### Species only found in PT Taiyoung Engreen

| Species Only Found | Family Name |
|--------------------|-------------|
| Balau (Casuarina sumatrana) | Casuarinaceae |
| Jambu putih berbulu (Eugenia spp.) | Myrtaceae |
| Bengkirai/ meranti kuning (Hopea bracteata) | Myrtaceae |
| Jambu daun kecil (Eugenia incarnatum) | Myrtaceae |
| Jinjit mahadingan (Calophylum pulcherrimum) | Calophyllaceae |
| Kayu sial (Diospyros malabarica) | Myrtaceae |
| Kelampis putih (Shorea pauciflora) | Myrtaceae |
| Baloh/lampudak (Eugenia spp.) | Myrtaceae |
| Keruing kedau/pajut/getah (Dipterocarpus coriacea) | Dipterocarpaceae |
| Bengkirai/ meranti kuning (Hopea bracteata) | Myrtaceae |
| Jambu putih berbulu (Eugenia spp.) | Myrtaceae |
| Jinjit mahadingan (Calophylum pulcherrimum) | Myrtaceae |
| Kayu sial (Diospyros malabarica) | Myrtaceae |
| Meranti kahiu/lentang padi (Shorea xanthophylla) | Myrtaceae |
| Pilau (Agathis borneensis) | Cunoniaceae |
| Ramuhiun (Hopea bracteata) | Myrtaceae |
| Sintuk (Cinnamomum coriaceum) | Lauraceae |
| Tagula (Litsea mappacea) | Lauraceae |

Analysis of the species grouped by family is shown in Figure 2. Of the 29 tree families present in the Alau study area sites five tree family types were most abundant in terms of the most species observed: Myrtaceae (16), Dipterocarpaceae (n=16), Guttiferae (n=11), Lauraceae (n=11), and Annonaceae (n=7). Other family types are associated with Alau in smaller numbers, from one to six species only.
The type of Dipterocarpaceae species present in the study area varies. This is due to habitat differences, mostly related to depth of the peat layer. Table 5 shows the variation of Dipterocarpaceae species listing the scientific name and the local name in the Alau site area where present. There are more Dipterocarpaceae species observed in the drier health forest habitat of PT Taiyoung Engreen (n=8) than in the more wet and deeper peat area of PT Dasa Intiga (n=8) and Sebangau National Park (n=6).

Table 5. Dipterocarpaceae species by Alau study site area.

| Dipterocarpaceae Species | PT Taiyoung Engreen (1 & 2) | PT Dasa Intiga | Sebangau National Park |
|--------------------------|-----------------------------|----------------|------------------------|
| Dipterocarpus coriaceus  | Keruing                     |                |                        |
| Slooten                  | kedau/pajut/getah           |                |                        |
| Dipterocarpus crinitus Dyer | Keruing uhit               |                |                        |
| Cotylelobium laneolatum  | Crail                       |                |                        |
| Shorea pachyphylia Ridl. | -                           |                |                        |
| Hopea bracteata Burck    | Meranti                     |                |                        |
| Shorea xanthophylla      | Meranti kahiu/lentang padi |                |                        |
| Symington                |                            |                |                        |
| Shorea uliginosa Foxw.   | -                           |                | Meranti buaya          |
| Shorea balangeran (Korth.) | -                         |                |                        |
| Burck                    |                            |                |                        |
| Anisoptera grossivenia Slooten | -                         |                |                        |
| Cotylelobium flavum Pierre | Resak tembaga/merah        |                | Resak tembaga/merah    |
| Shorea rugosa Heim.      | Meranti batu                |                |                        |

Figure 2. Frequency distribution of species by tree family type in Alau habitat study areas.
Table 6. Wood volume and tree density for all trees in the study area sites.

| Tree Size | PT Taiyoung Engreen (1) | PT Taiyoung Engreen (2) | PT Dasa Intiga | Sebangau National Park |
|-----------|-------------------------|-------------------------|----------------|------------------------|
| Sapling   | 17.07                   | 31.44                   | 36.55          | 50.62                  |
| Pole      | 87.98                   | 83.37                   | 110.15         | 397.48                 |
| Trees     | 186.99                  | 207.95                  | 288.70         | 235.44                 |
| Total     | 292.04                  | 322.75                  | 435.40         | 683.54                 |

Table 7 compares several biodiversity indices for the tree species data across the study sites and by tree and seedling. It also lists the five most abundant species in each site by tree and seedling type.
4. Discussion

Site conditions, species compositions and habitat characteristics between four study areas where Alau is present were analysed. Alau trees in the four sites were characterized by their size class distribution. By comparing the similarities and differences of observed Alau species with the site characteristics and conditions we can draw several inferences.

First, Alau is present in Heath forests with shallow peat and high sand content (black and white sand) with and without hardpan below the peat/sand layer, and it is also present in deep peat swamp-forest conditions with a high level water table. Alau grows under habitat conditions that include rich tree species diversity (richness of trees from 63 – 79 species) with high evenness factors (for trees 0.77 to 0.84). It was not obvious from our data that shallow peat, sandy soil and hardpan conditions constrain the size and age of Alau. In both PT Taiyoung Engreen 1 and 2 and PT Dasa Intiga 100% and 33%, respectively, of the observed Alau trees were 40 cm DBH or greater. In PT Taiyoung Engreen 2, in fact, there were no observed Alau trees less than 40 cm DBH. However, site conditions do seem to inhibit Alau in Sebangau National Park where there are no Alau trees greater than 40 cm DBH and the dominant size class of Alau is 10 – 20 cm DBH, 49% of all Alau trees at this site. There are, however, in the Sebangau National Park site, the greatest number of Alau trees observed (n=78), the highest total wood volume, and most tree density for all species in the sapling and pole classes, and it has the least light availability. These are all indicators that are likely to limit the growth of Alau due to high nutrient competition of densely growing tree species with limited light conditions.

Alau also grows in conditions with a diversity of other tree species. Only a third of the total observed tree species across the study area site were present in all areas. Whereas, close to half of all the observed tree species only grew on one of study site areas. Alau, therefore, seems to have a wide range in terms of habitat conditions in Central Kalimantan. Dominant in all study area sites, however, are Myrtaceae, Dipterocarpaceae, and Gutiferae. The 43 species present in the study areas from these three tree family
types, accounting for 35% of all species observed. Within the Dipterocarpaceae family, we observed fourteen different species. The presence of these species and tree family types coincided with those habitats where Alau also persist and thrive.

5. Conclusion
Alau is an important tree genus in Central Kalimantan and while Alau may not be threatened regionally or globally, exploitation by logging for use in construction and furniture making, fire and land conversion locally may threaten its existence. Understanding the variation of the habitat where it grows, the specific site conditions and species compositions, can help in protection, conservation, and management efforts. As communities and forest management units develop forest management plans under social forestry and FMU/KPH programs, knowledge about these specific habitats may be useful for improved Alau habitat conservation at the local level.

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