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The species diversity and composition of seedlings for degraded land rehabilitation in different phytogeographical regions in Indonesia

WIRYONO[1,♥], AGUNG HASAN LUKMAN[1], STEFFANIE NURLIANA[2]
[1]Department of Forestry, Faculty of Agriculture, Universitas Bengkulu. Jl. WR Supratman Bengkulu, Indonesia.
Tel./fax.: +62-736-21170, Fax.: +62-736-22105, ♥email: wiryonogood@unib.ac.id
[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Bengkulu. Jl. WR Supratman, Bengkulu City 38371, Bengkulu, Indonesia

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Abstract. *Wirnoyo, Lukman AH, Nurliana S. 2022. The species diversity and composition of seedlings for degraded land rehabilitation in different phytogeographical regions in Indonesia. Biodiversitas 23: 5771-5781.* Forest clearing and conversion into cropland without implementing conservation measures have caused land degradation. The total area of degraded land in Indonesia is 14 million hectares. The responsible institution for land rehabilitation in Indonesia is *Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung* (Agency for Watershed and Protection Forest Management), abbreviated as BPDASHL. This study aimed to analyze seedlings' species diversity and composition for degraded land rehabilitation provided by six BPDASHLs located in different phytogeographic regions, i.e., Sunda Shelf, Wallacea, and Sahul Shelf. Data were collected through questionnaires distributed to BPDASHL offices in Papua, West Papua, Gorontalo, Bangka Belitung Islands, Riau, and Aceh. They were analyzed to determine the species richness, indexes of species diversity, equity, and similarity. The clustering of sites based on species composition was done using a dendrogram. This study found that the species richness of seedlings in each site ranged from 25 to 47, the diversity index of Shannon from 2.39 to 2.96, and a Simpson diversity index from 0.80 to 0.94. The species composition differed from one site to another, with similarity indexes of Bray-Curtis and Jaccard of < 0.35. The dendrogram separated western Indonesia (Sunda Shelf) from eastern Indonesia (Sahul Shelf and Wallacea), except for Bangka Belitung Islands, which was clustered in eastern Indonesia despite its location in western Indonesia. Three study sites had more native dominant species, while the other three had more introduced dominant species. We recommend that more native species of seedlings should be provided.

Keywords: Indonesian biogeography, introduced species, land greening, native species, revegetation

INTRODUCTION

Soil as a component of an ecosystem has several functions, for example, (1) basis for the life of plants, animals, and man, and (2) basis for agriculture and forestry (FAO 2015). With the increase in human population, the function of soil as the basis for agriculture should be maintained to secure food production. However, many agricultural lands with fertile soil are converted to other land uses to meet the increased demand for land due to the increased population. With limited agricultural lands, many rural people in developing countries clear the nearby forest and plant the land with crops. For example, from 2001 to 2016, approximately 9.2 million ha of natural forest in Indonesia was converted into other land covers, 23% of which turned to oil palm plantations, 20% to shrub and *alang alang* (*Imperata cylindrica*), 15% to small farms, and the rest to other uses (Austin et al. 2019).

Conversion of forest to cropland, especially in mountainous regions, causes soil loss due to erosion. For example, in North China, extremely severe soil erosion increased, particularly in steep regions, due to the conversion of forest to cropland (Gong et al. 2022). In the mountainous region of Tawang Mangu, Central Java, cultivation of annual crops has also caused soil erosion (Andriyani et al. 2017). In Omo Gibe Basin, Ethiopia, the soil loss rate was higher in the cultivated field than in bare land, forest land, grazing land, and shrub land (Aneseyee 2019). Erosion of the topsoil, which contains the nutrients required by the plants, results in degraded land (Hossain et al. 2020).

The total area of degraded and extremely degraded land in 2020 in Indonesia was approximately 14 million ha (KemenLHK 2021), located in the forest and non-forest areas. The agency responsible for rehabilitating degraded land in Indonesia is the Agency for Watershed and Protection Forest Management, abbreviated as BPDASHL (Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung). The number of BPDASHL in Indonesia is 34. Every year this institution provides seedlings for the rehabilitation of degraded areas. The Indonesian Government Regulation no 76 of 2008 regarding the Forest Rehabilitation and Reclamation stipulates the criteria for species selection of degraded land rehabilitation in conservation forest (article 35 verse 3) and in protection and production forest (article 36 verse 3). For conservation forests, a variety of local species of seedlings suitable for the habitat should be planted. For the protection and production of forests, the species should fit the hydrological function, should be native, if possible, and could be single species or many species.

The selection of species for degraded land rehabilitation is important because it may determine the success rate of the rehabilitation and the species diversity and composition of the vegetation resulting from the rehabilitation. If we want to recover the original ecosystem, we should select species composition of seedlings similar to that of the original vegetation, which varies according to the phytogeographic region. Because of the vast geographic and different geological origins, eastern Indonesia and western Indonesia belong to different phytogeographic regions. Based on the division of van-Steenis (1950) cited in (Richardson et al. 2012), the Indonesian archipelago is located in three phytogeographic regions, i.e., West Malesia (Sumatra and Kalimantan), South Malesia (Java, Bali, Sumba, Sumbawa, and Flores) and East Malesia (Sulawesi, Moluccas, and Papua). Van Welzen et al. (2011) also divided the Indonesian archipelago into three different phytogeographic regions, but the divisions are slightly different from that of van-Steenis, i.e., Sunda Shelf (Sumatra and Kalimantan), Wallacea (Sulawesi, Lesser Sunda Islands, Moluccas, and Java), Sahul Shelf (Papua).

Despite the importance of species selection for degraded land rehabilitation, so far, only one study has analyzed the species diversity and composition of seedlings provided by BPDASHL for degraded land rehabilitation in Serayu, Opak, and Progo watersheds in Central Java and Yogyakarta Provinces (Wiryono and Nurliana 2022), More data from other provinces are needed. Therefore, this study was conducted to analyze the species diversity and composition of seedlings provided BPDAS Memberamo (Papua), Remu Ransiki (West Papua), BPDASHL, BPDAS Bone Bolango (Gorontalo), Indragiri Rokan (Riau), Baturasa Cerucuk (Kepulauan Bangka Belitung), Krueng Aceh (Aceh). The study sites represent three different phytogeographical regions of Van Welzen et al. (2011): Papua and West Papua Provinces are located in Sahul Shelf, the Gorontalo Province in Wallacea, and the rest in Sunda Shelf. Based on the Van-Steenis division (Richardson et al. 2012), they are located in two phytogeographic regions, i.e., West Malesia and East Malesia. For the analysis of the species composition, the criteria of species selection and the locations of the plantation were also recorded.

MATERIALS AND METHODS

Study area

The data for this study were collected from six Agencies for Watershed and Protected Forests Management (BPDASHL), i.e., (1) BPDASHL Memberamo in Papua, (2) BPDASHL Remu Ransiki in West Papua, (3) BPDASHL Bone Bolango in Gorontalo, (4) BPDASHL Indragiri Rokan in Riau, (5) BPDASHL Baturasa Cerucuk in Kepulauan Bangka Belitung, and (6) BPDASHL Krueng Aceh in Aceh (Figure 1). The first two sites are located in the east of the Lydekker's line or the Sahul Shelf, the third between Lydekker's line and Wallace's line or the Wallacea region, and the last three sites are in the west of Wallace's line or the Sunda Shelf (Lohman et al. 2011; Van Welzen et a. 2011).

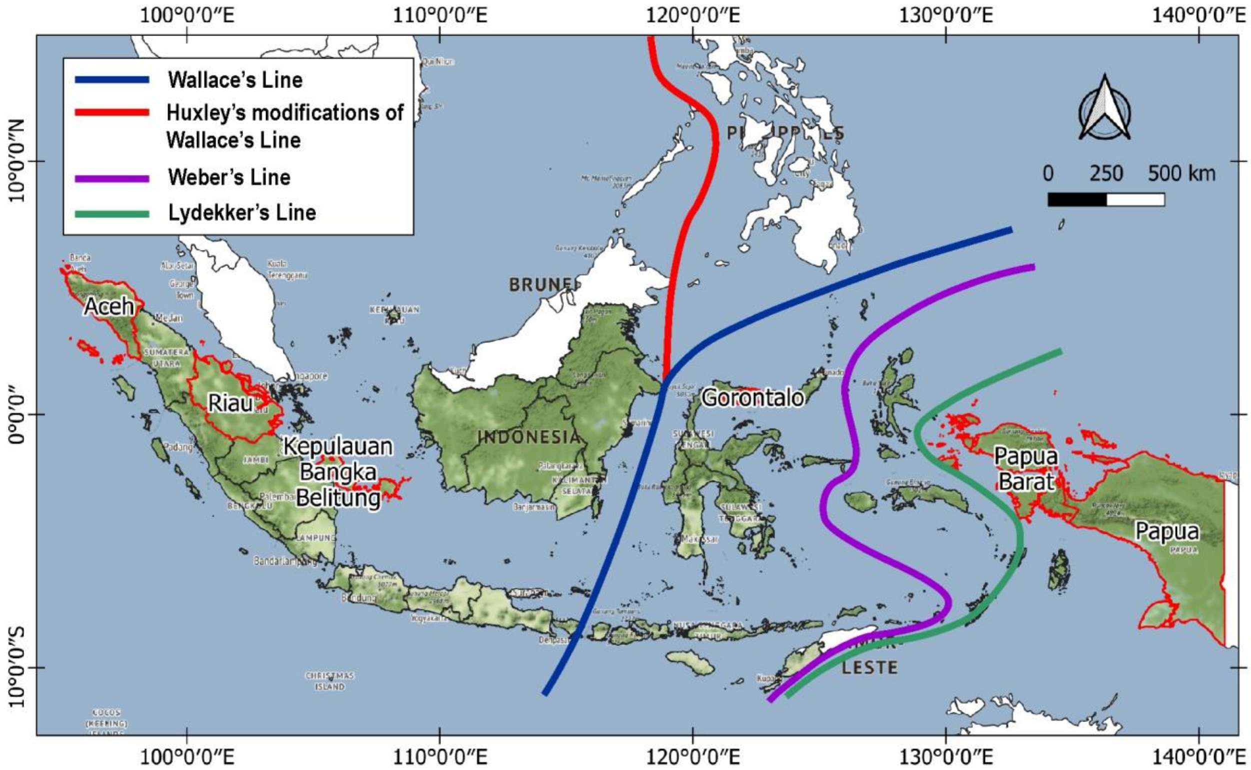

Figure 1. Locations of the six BPDASHLs, i.e., the provinces of Papua, West Papua, Gorontalo, Bangka Belitung Islands, Riau and Aceh, Indonesia

Data collection

The data of this study were gathered through questionnaires distributed to the six BPDASHL in the study sites. The data consisted of species and number of seedlings, the criteria for species selection, and the planting locations. For the criteria of species selection, the choices given in the questionnaire were: (1) It is affordable, (2) It is easy to get, (3) It is easy to grow, (4) It is a local species, (5) It is people's favorite, (6) It is ordered by the central government and (7) other. For the locations, the choices given were: (1) forest area and (2) non-forest area. The BPDASHL gave the name of seedlings mostly in local names. The accepted scientific names were taken from the Plant list (http://www.theplantlist.org/).

Data analysis

The data were analyzed using a paleontological statistics software package, PAST (Hammer et al. 2001), to determine the species richness (S), and species diversity indexes of Shannon (H') and Simpson (1-D), species equality index (E), similarity indexes of Bray-Curtis similarity (IS_{BC}) and Jaccard (I_{SJ}), and to conduct a cluster analysis with a dendrogram.

The top five species with the largest number of seedlings for each site were categorized as native or introduced. A species was categorized as native to a site if it is native to the phytogeographic region where the site is located. For example, if a species is native to the Wallacea region, it was considered native to Gorontalo. The information on the species natural distribution was taken from the Plants of the World Online (2022).

RESULTS AND DISCUSSION

Species diversity

The number of species of seedlings for the six study sites was 99, consisting of 38 families (Table 1). For each site, the species richness varied from 25 to 46, with Gorontalo having the greatest number (Table 2). However, the highest Shannon diversity index (H') and Simpson diversity index (1-D) were found in Bangka Belitung Islands and West Papua (2.96 and 0.94, respectively), although the species richness (30 and 27, respectively) was much lower than in Gorontalo. The high diversity index in the two sites was contributed by their high equity index (0.86 and 0.90, respectively) because the diversity indexes of Shannon and Simpson integrate the species equity and species number.

Family and species composition

Family Myrtaceae had the highest number of species (13), followed by Fabaceae (12), but Fabaceae had the highest number of seedlings (1,884,757), followed by Pinaceae (1,451,592). The other families had a much lower number of species and seedlings (Tables 1 and 3). Out of 99 seedling species, *Pinus merkusii* had the highest number (14,515,920), followed by *Swietenia macrophylla* (977697). The other species had a much lower number (Table 1).

The species composition of seedlings for degraded land rehabilitation differed among sites, with a similarity index of mostly < 0.35 (Table 4). Jaccard similarity index was generally higher than the Bray-Curtis index, except between Aceh and Riau. The dendrogram (Figure 1) shows that the first clustering occurred between Aceh and Riau, followed by Papua and West Papua. At the third clustering, Gorontalo joined the Papua-West Papua cluster. At this stage, it is clear that the western Indonesia sites (Sunda Shelf) were separated from the eastern (Wallacea and Sahul Shelf). Bangka Belitung Islands was clustered the last time, not with the other western Indonesia but with eastern Indonesia.

Criteria for species selection

The BPDASHL selected species for rehabilitation for several reasons (Table 5). The most common reasons varied greatly among offices. In Papua, being a local species was the most important criterium (82.7%), while in Aceh, it was not important (1.5%). On average, however, being a local species had the highest score. The second and third reasons were that people like that species and it is easy to grow.

Planting locations

Degraded land occurs in forest and non-forest areas. In Aceh and Riau, almost all the seedlings were planted in forest areas (99%), while in Gorontalo, most of the seedlings (89%) were planted in the non-forest area (Table 6). There were no data on planting locations in Papua.

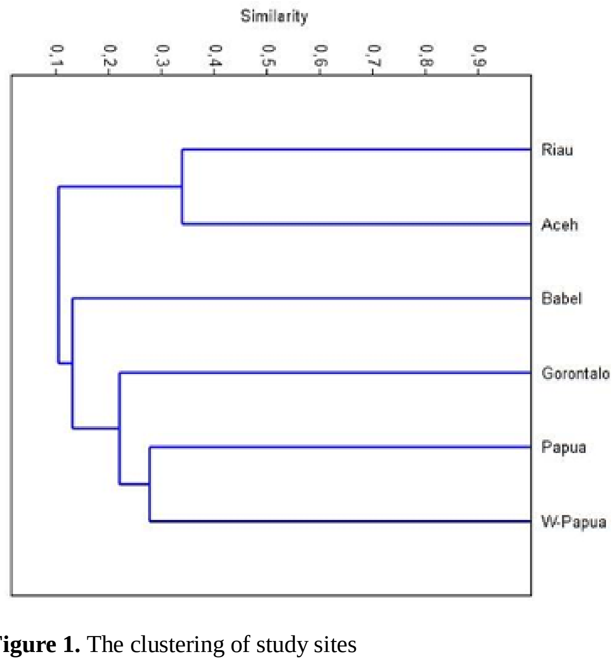

Figure 1. The clustering of study sites

Table 1. The list of species and families of seedlings for degraded rehabilitation in six provinces sorted according to their abundance

Species	Family	Number of seedlings						
		W-Papua	Papua	Gorontalo	Babel	Riau	Aceh	Total
Pinus merkusii Jungh. & de Vriese	Pinaceae	0	10430	62	0	434425	1006675	1451592
Swietenia macrophylla King	Meliaceae	45554	0	650423	21600	226120	34000	977697
Palaquium rostratum (Miq.) Burck	Sapotaceae	9172	203100	215041	26400	0	0	453713
Samanea saman (Jacq.) Merr.	Fabaceae	120252	10000	153502	6200	0	158600	448554
Intsia bijuga (Colebr.) Kuntze	Fabaceae	133403	253750	0	0	0	0	387153
Artocarpus heterophyllus Lam.	Moraceae	29568	0	263909	3000	50930	32100	379507
Rhizophora sp.	Rhizophoraceae	23386	7500	30700	30000	223580	0	315166
Pometia pinnata J.R.Forst. & G.Forst.	Sapindaceae	90009	135475	47973	0	33990	0	307447
Gmelina arborea Roxb.	Lamiaceae	0	10500	286905	0	10000	0	307405
Araucaria cunninghamii Mudie	Araucariaceae	0	301740	0	0	0	0	301740
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	0	0	0	5000	293450	0	298450
Durio zibethinus L.	Malvaceae	34329	0	53175	9500	60255	135550	292809
Archidendron pauciflorum (Benth.) I.C.Nielsen	Fabaceae	0	0	0	1000	217740	62850	281590
Nephelium lappaceum L.	Sapindaceae	68196	16000	189508	0	0	0	273704
Falcataria moluccana (Miq.) Barneby & J.W.Grimes.	Fabaceae	106617	35800	96220	13100	0	2000	253737
Parkia speciosa Hassk.	Fabaceae	0	0	0	12100	137095	90150	239345
Calophyllum inophyllum L.	Calophyllaceae	53265	142350	18970	0	2200	12100	228885
Aquilaria malaccensis Lam.	Thymelaeaceae	2123	5000	0	13000	200312	0	220435
Casuarina equisetifolia L.	Casuarinaceae	3695	140400	6675	46900	0	0	197670
Eucalyptus alba Reinw. ex Blume	Myrtaceae	0	5000	80987	0	5280	96800	188067
Persea americana Mill.	Lauraceae	0	0	0	1000	0	176650	177650
Areca catechu L.	Arecaceae	43606	125025	4925	1000	0	0	174556
Eusideroxylon zwageri Teijsm. & Binn.	Lauraceae	0	124100	0	23400	0	0	147500
Bambusa sp.	Poaceae	128524	0	0	0	0	0	128524
Mimusops elengi L.	Sapotaceae	3437	0	107925	0	0	0	111362
Melaleuca cajuputi Powell	Myrtaceae	18856	27500	0	0	15000	48400	109756
Acacia sp.	Fabaceae	0	27500	75628	0	0	0	103128
Annona muricata L.	Annonaceae	0	0	74823	21200	0	5000	101023
Chionanthus ramiflorus Roxb.	Oleaceae	0	100200	0	0	0	0	100200
Neolamarckia macrophylla (Roxb.) Bosser	Rubiaceae	0	0	98080	0	0	0	98080
Ficus sp.	Moraceae	0	0	0	0	0	96800	96800
Anacardium occidentale L.	Anacardiaceae	0	0	52500	34600	0	0	87100
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	0	0	84893	0	0	0	84893
Shorea sp.	Dipterocarpaceae	0	0	0	0	0	80500	80500
Lansium parasiticum (Osbeck) K.C.Sahni & Bennet	Meliaceae	49619	1000	0	0	0	20000	70619
Terminalia catappa L.	Combretaceae	54845	0	0	12000	0	0	66845
Aleurites moluccanus (L.) Willd	Euphorbiaceae	0	0	58170	0	8000	0	66170
Alstonia scholaris (L.) R. Br.	Apocynaceae	0	0	0	0	65260	0	65260
Artocarpus integer (Thunb.) Merr.	Moraceae	29568	0	0	19600	14812	0	63980

Myristica argantea Warb.	Myristicaceae	0	26150	0	0	0	35200	61350
Myristica fragrans Houtt.	Myristicaceae	52410	0	4415	0	0	4500	61325
Dryobalanops sumatrensis (J.F.Gmel.) Kosterm.	Dipterocarpaceae	0	0	0	0	25740	35200	60940
Agathis sp.	Araucariaceae	10841	0	32190	0	0	15000	58031
Pterocarpus indicus Willd.	Fabaceae	30382	0	15000	0	0	12100	57482
Cupressus sp.	Cupressaceae	0	50000	0	0	0	0	50000
Cinnamomum burmani (Nees & T.Nees) Blume	Lauraceae	0	0	0	0	0	48400	48400
Grevillea papuana Diels	Proteaceae	0	39100	0	0	0	0	39100
Toona sp.	Meliaceae	0	0	0	0	37000	0	37000
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	1190	0	35069	0	0	0	36259
Cinnamomum verum J.Presl	Lauraceae	0	0	27605	0	0	0	27605
Macademia integrifolia Maiden & Betche	Proteaceae	0	0	0	0	0	24200	24200
Bruguiera sp.	Rhizophoraceae	22596	0	0	0	0	0	22596
Avicennia sp.	Acanthaceae	18852	3500	0	0	0	0	22352
Syzygium aromaticum (L.) Merr. & L.M.Perry	Myrtaceae	0	0	3120	0	19075	0	22195
Erythrina variegata L.	Fabaceae	0	0	0	0	0	22100	22100
Mangifera indica L.	Anacardiaceae	0	4000	8030	10000	0	0	22030
Garcinia atroviridis Griff. ex T.Anderson	Clusiaceae	0	0	0	0	0	20500	20500
Pandanus conoideus Lam.	Pandanaceae	0	18500	0	0	0	0	18500
Syzygium malaccense (L.) Merr. &L.M.Perry	Myrtaceae	0	0	0	17400	0	0	17400
Tectona grandis L.f.	Lamiaceae	0	10000	6000	0	0	0	16000
Dipterocarpus sp.	Dipterocarpaceae	0	0	0	0	0	15000	15000
Syzygium polyanthum (Wight) Walp.	Myrtaceae	0	15000	0	0	0	0	15000
Sonneratia caseolaris (L.) Engl.	Lythraceae	0	2500	0	0	12100	0	14600
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	Moraceae	9323	0	5000	0	0	0	14323
Psidium guajava L.	Myrtaceae	0	0	3620	10000	0	0	13620
Schima wallichii Choisy	Theaceae	12673	0	0	0	0	0	12673
Pterospermum acerifolium (L.) Willd.	Malvaceae	0	0	0	0	12200	0	12200
Xanthostemon novaguineensis Valeton	Myrtaceae	0	12000	0	0	0	0	12000
Syzygium samarangense (Blume) Merr. &L.M.Perry	Myrtaceae	0	0	0	11000	0	0	11000
Azadirachta excelsa (Jack) Jacobs	Meliaceae	0	0	0	0	0	10000	10000
Ceiba pentandra (L.) Gaertn.	Malvaceae	0	0	0	10000	0	0	10000
Vitex pinnata L.	Lamiaceae	0	0	0	0	10000	0	10000
Daemonorops draco (Willd.) Blume	Arecaceae	0	0	0	0	2750	6250	9000
Bischofia javanica Blume	Phyllanthaceae	0	8380	0	0	0	0	8380
Diospyros kaki L.f.	Ebenaceae	0	0	0	0	0	6050	6050
Citrus hystrix DC.	Rutaceae	0	0	5595	0	0	0	5595
Melia azedarach L.	Meliaceae	0	0	0	0	0	5500	5500
Bambusa vulgaris Schrad.	Poaceae	0	0	5000	0	0	0	5000
Tristaniopsis merguensis (Griff.) Peter G.Wilson & J.T.Waterh	Myrtaceae	0	0	0	5000	0	0	5000
Delonix regia (Hook.) Raf.	Fabaceae	0	0	4275	0	0	0	4275
Diospyros celebica Bakh.	Ebenaceae	4044	0	84	0	0	0	4128
Garcinia × mangostana L.	Clusiaceae	0	0	0	2000	2000	0	4000
Arenga pinnata (Wurmb) Merr.	Arecaceae	0	0	2600	1000	0	0	3600

Scaphium affine (Mast.) Pierre	Malvaceae	0	0	0	0	3437	0	3437
Bambusa tulda Roxb.	Poaceae	0	0	2500	0	0	0	2500
Syzygium aqueum (Burm.f.) Alston	Myrtaceae	0	0	2500	0	0	0	2500
Eugenia sp.	Myrtaceae	0	0	2476	0	0	0	2476
Annona squamosa L.	Annonaceae	0	0	2247	0	0	0	2247
Calliandra sp.	Fabaceae	0	0	2000	0	0	0	2000
Dimocarpus longan Lour.	Sapindaceae	0	0	2000	0	0	0	2000
Manilkara zapota (L.) P.Royen	Sapotaceae	0	0	2000	0	0	0	2000
Barringtonia asiatica (L.) Kurz	Lecythidaceae	1500	0	0	0	0	0	1500
Dacrydium sp.	Podocarpaceae	0	1500	0	0	0	0	1500
Baccaurea macrocarpa (Miq.) Müll.Arg.	Phyllanthaceae	0	0	0	0	688	0	688
Pandanus conoideus Lam	Pandanaceae	0	500	0	0	0	0	500
Tamarindus indica L.	Fabaceae	0	0	500	0	0	0	500
Syzygium paniculatum Gaertn.	Myrtaceae	0	0	145	0	0	0	145

Table 2. Species richness, Shannon diversity index, Simpson diversity index and equitability index of seedlings for degraded land rehabilitation in the six study sites

Parameters	Sites					
	West Papua	Papua	Gorontalo	Babel	Riau	Aceh
Species richness (S)	30	33	46	27	27	32
Simpson diversity index (1- D)	0.94	0.91	0.91	0.94	0.89	0.80
Shannon diversity index (H')	2.96	2.73	2.82	2.96	2.49	2.39
Equitability index (E)	0.87	0.78	0.74	0.90	0.75	0.69

Note: Babel stands for Bangka Belitung Islands

Table 3. The list of families having the highest number of species or seedlings

Family	No of seedlings	Family	No. of species
Fabaceae	1,884,757	Myrtaceae	13
Pinaceae	1,451,592	Fabaceae	12
Meliaceae	1,100,816	Meliaceae	5
Sapindaceae	583,151	Moraceae	4
Sapotaceae	567,075	Malvaceae	4
Moraceae	554,610	Lauraceae	4
Myrtaceae	462,434	Sapindaceae	3
Lauraceae	401,155	Arecaceae	3
Euphorbiaceae	364,620	Sapotaceae	3
Araucariaceae	359,771	Dipterocarpaceae	3
Rhizophoraceae	337,762	Poaceae	3
Lamiaceae	333,405	Lamiaceae	3
Malvaceae	318,446	Annonaceae	3

Table 4. Similarity index of Bray-Curtis (IS_{BC}) and similarity index of Jaccard (IS_J) among the study sites

	West Papua		Papua		Gorontalo		Babel		Riau	
	IS_{BC}	IS_J	IS_{BC}	IS_J	IS_{BC}	IS_J	IS_{BC}	IS_J	IS_{BC}	IS_J
West Papua	1.00	1.00								
Papua	0.28	0.29	1.00	1.00						
Gorontalo	0.27	0.33	0.17	0.23	1.00	1.00				
Bangka Belitung Islands	0.16	0.27	0.12	0.18	0.12	0.24	1.00	1.00		
Riau	0.12	0.19	0.05	0.18	0.17	0.18	0.09	0.23	1.00	1.00
Aceh	0.17	0.22	0.04	0.14	0.16	0.18	0.05	0.18	0.34	0.23

Note: Babel stands for Bangka Belitung Islands

Table 5. Criteria for species selection

Criteria for species selection	Percentage (%)						
	West Papua	Papua	Gorontalo	Babel	Riau	Aceh	Average
It is a local species	20.9	82.7	6.6	18.7	34.9	1.5	27.56
It is people's favourite	17.6	12.8	20.4	25.2	33.7	11.1	20.13
It is easy to grow	18.2	0.0	26.5	16.3	21.7	23.0	17.60
It is affordable	20.3	0.0	20.1	31.7	0.0	15.6	14.61
It is easy to get	21.6	4.5	25.1	8.1	6.0	21.5	14.48
It is requested by forestry office	0.0	0.0	0.0	0.0	0.0	27.4	4.57
It is suitable to the habitat	0.0	0.0	0.3	0.0	3.6	0.0	0.65
It is ordered by the central government	1.4	0.0	0.5	0.0	0.0	0.0	0.31
It is endemic	0.0	0.0	0.3	0.0	0.0	0.0	0.04
It is used for custom	0.0	0.0	0.3	0.0	0.0	0.0	0.04

Table 6. Planting locations

Location	Percentage					
	West Papua	Papua	Gorontalo	Babel	Riau	Aceh
Forest area	58	NA	11	45	99	99
Non forest area	42	NA	89	55	1	1

Table 7. The five top species with the largest number of seedlings in each site

Top five species in each site	No. of seedlings	Category
Papua		
Araucaria cunninghamii Mudie	301740	Native
Intsia bijuga (Colebr.) Kuntze	253750	Native
Palaquium rostratum (Miq.) Burck	203100	Introduced
Calophyllum inophyllum L	142350	Native
Casuarina equisetifolia L	140400	Native
West Papua		
Intsia bijuga (Colebr.) Kuntze	133403	Native
Bambusa sp.	128524	Native
Samanea saman (Jacq.) Merr.	120252	Introduced
Falcataria moluccana (Miq.) Barneby & J.W.Grimes.	106617	Native
Pometia pinnata J.R.Forst. & G.Forst	90009	Native
Gorontalo		
Swietenia macrophylla King	650423	Introduced
Gmelina arborea Roxb.	286905	Introduced
Artocarpus heterophyllus Lam	263909	Introduced
Palaquium rostratum (Miq.) Burck	215041	Native
Nephelium lappaceum L	189508	Native
Bangka Belitung Islands		
Casuarina equisetifolia L	46900	Native
Anacardium occidentale L	34600	Introduced
Rhizophora sp.	30000	Native
Palaquium rostratum (Miq.) Burck	26400	Native
Eusideroxylon zwageri Teijsm. & Binn.	23400	Native
Riau		
Pinus merkusii Jungh. & de Vriese	434425	Native
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg	293450	Introduced
Swietenia macrophylla King	226120	Introduced
Rhizophora sp.	223580	Native
Archidendron pauciflorum (Benth.) I.C.Nielsen	217740	Introduced
Aceh		
Pinus merkusii Jungh. & de Vriese	1006675	Native
Persea americana Mill.	176650	Introduced
Samanea saman (Jacq.) Merr.	158600	Introduced
Durio zibethinus L	135550	Native
Eucalyptus alba Reinw. ex Blume	96800	Introduced

Note. A species is categorized as native to a site if it is native to the phytogeographic region where the site is located. The information on the species natural distribution was taken from the Plants of the World Online

Discussion

Species diversity

The values of the Shannon diversity index (H') and the Simpson diversity index (1-D) in the study sites showed similar patterns: Bangka Belitung Islands and West Papua had the highest diversity index. However, their species richness was relatively low. These two indexes are determined not only by the number of species but also by the equity among species in abundance (Morris et al. 2014). If two sites have the same number of species, the site having a higher equity index will have a higher diversity index. Based on the range of H' usually found in many studies, i.e., 1.5 - 3.5 (Kent 2012), the diversity index in the study sites may be considered medium. These diversity indexes, however, do not show the real number of species. A simpler and more intuitive measure of diversity is species richness or the number of species. This measure, however, also has a weakness because it is considerably affected by sample size: as sample size increases, the species richness also increases (Roswell et al. 2021). The weakness of species richness was avoided in the present study because the species richness was not measured from samples but from the whole species data.

The species richness for each site in this study is much lower than that in the natural forest in the Indonesian tropical rain forest. For example, in 10 ha of natural forest in Kalimantan, 450 tree species (diameter > 10 cm) were found (Rahayu et al. 2022), and in three ha of natural forest in Sumatra, 300-500 tree species were found (Rennolls and Laumonier 2000). Although the species richness of the seedlings in this study is lower than in the natural forest, it is certainly much higher than in the forest plantation and agriculture plantation, which usually have one or few species. In Indonesia, the most planted genera in plantation forests are only two, i.e., *Acacia* (71%) and *Eucalyptus* (21%) (BPS Indonesia 2020). The species richness in each study site is also higher than that of the rehabilitated forest after mining, usually revegetated with fast-growing species, such as *Paraserianthes falcataria* and *Acacia mangium* (Nazki et al. 2019). Whether the number of species seedlings was sufficient depends on where the seedlings were planted. If they were planted in conservation and protection forest areas, then the species number should be increased to approach the number of species in natural forests. But if they were planted in production forest and non-forest areas, the number of species can be considered sufficient because the production forest and non-forest area can be made into a single-species plantation. Only in BPDASHLs Aceh and Riau that most seedlings (99%) were planted in forest areas (Table 6), but there was no information on the categories of the forest (production, protection, or conservation forest).

Species composition

The selection of species for degraded land is important for several reasons. First, it may determine the rehabilitation's success rate and the resulting vegetation's composition and diversity. The capacity of degraded land to support plants has been reduced (FAO 2015), so the selected species must tolerate poor soil fertility. Fabaceae, which can fix nitrogen, is usually chosen for severely degraded land rehabilitation (Chaer et al. 2011). Two fast-growing species of Fabaceae, *A. mangium* and *P. falcataria*, are planted widely in mined land reclamation in Indonesia (Nazki et al. 2019). Fabaceae was represented by 12 species, ranked second in the number of species, after Myrtaceae (13 species), but it had the highest number of seedlings (Table 2). All the species of Fabaceae in this study have low wood quality, so these species were selected not for producing timber but for rehabilitating degraded land or other purposes. Three of those species produce economically valuable fruit, i.e., *Archidendron pauciflorum*, *Tamarindus indica*, and *Parkia speciosa*. These species are called multipurpose species. Besides restoring degraded land, these species also provide economic value to society. The survival rate for these economically valuable species will be high because the community can benefit from these trees. People choose tree species for their economic value (Martin et al. 2021). It is interesting to note that *A. pauciflorum* and *P. speciosa* were found only in Babel, Riau, and Aceh Provinces. *A. pauciflorum* is not native to Sumatra, but native to Sulawesi (Plants of the World online 2022).

The second reason for the importance of species selection is that it determines the resulting vegetation composition. The composition of seedling species among study sites differed, as indicated by low similarity indexes (< 0.35). The dendrogram (Figure 2), at the second round, separated the Sahul shelf region (West Papua and Papua) from the Sunda Shelf region (Aceh and Riau). Gorontalo (Wallacea region) joined the Sahul Shelf region in the third round. Overall, the dendrogram separated western Indonesia or West Malesia and eastern Indonesia or East Malesia regions (Wallacea and Sahul Shelf), except for Bangka Belitung Islands, which clustered in the eastern Indonesia region despite its position in western Indonesia. The low similarity among sites and the separation of eastern Indonesia from western Indonesia indicate that the seedling supply for degraded land rehabilitation would not lead to floristic homogenization. There is a concern that degraded land rehabilitation with fast-growing introduced species (Hadisusanto et al. 2022) or plantation of commercial species (Martin et al. 2021) would lead to biological homogenization.

The third reason for the importance of species selection is to ensure that degraded land rehabilitation would replace the native species with the introduced ones. The Indonesian Government Regulation no 76 of 2008 regarding the Forest Rehabilitation and Reclamation stipulates that exotic or introduced species should not be used for forest rehabilitation. However, at the lower level of regulation, the Minister of Environment and Forestry Decree no P.105 of 2018 regarding the guidance for land and forest rehabilitation, several species for land and forest rehabilitation have been mentioned without considering their origins, i.e., *sengon* (*Falcataria moluccana*), teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), gmelina (*Gmelina arborea*), cadamba (*Neolamarckia cadamba*), sandalwood (*Diospyros celebica*), cajuput (*Melaleuca cajuput*), candlenut (*Aleurites moluccanus*), champak (*Michelia champaca*), pine (*Pinus merkusii*), and agarwood (*Aquilaria malaccensis*). *Swietenia macrophylla* and *G. arborea* are not from Indonesia. *Pinus merkusii* and *M. champaca* are native to Sumatera but exotic to eastern Indonesia. If introduced species should not be used for land rehabilitation, the guidance for rehabilitation should be accompanied by a list of native species for each phytogeographic region because the officials responsible for purchasing the seedlings may not know the native species in their area.

It is good that a native species to Sumatra, *P. merkusii* (Table 1), had the highest number of individuals (1,451,592) in this study. It was provided by BPDASHLs in Sumatra, i.e., Aceh and Riau. The BPDASHL Gorontalo also provided this species, although this species is exotic to Gorontalo; the number of seedlings was very small. The other three offices did not provide this species. This economically valuable species was originally from the upland, but it also grows well in lowlands, so it is widely planted in reforestation programs (Imanuddin et al. 2020). The second-ranked species (977,697), *S. macrophylla*, is not native to Indonesia. It was provided by all BPDASHLs, except the Papua office. This commercially valuable species is native to South and Central America (Moor et al. 2021) and was introduced to Indonesia in 1870, and has been popular as shade trees in urban areas (Sudrajat et al. 2021). In five cities of Sumatra, it is the most dominant roadside tree (Wiryono et al. 2018). The third-ranked species (453,713), *Palaquium rostratum*, is native to Sumatra and Sulawesi, but exotic to Papua and West Papua. However, BPDASHLs Papua provided this species because they mistakenly considered this species as local species, as shown in the reasons for choosing this species. This species can grow in swamps, even in deep (more than 7 m) peatland (Kato et al. 2021). The fourth-ranked species (448,554), *Samanea saman*, was provided by all BPDASHLs, except Riau. This is an introduced species native Central America, but it has been planted widely in tropical areas because it has a multipurpose species (Vinodhini and Rajesvari 2018). The fifth-ranked species, *Intsia bijuga*, was provided only by Papua and West Papua BPDASHLs. Out of the six BPDASHLs, BPDASHLs Bangka Belitung Islands, West Papua, and Papua had more native species than the introduced one (Table 7).

Conservation agencies are concerned about the danger of introduced species because some introduced species reduce the diversity and abundance of local species through competition or the spread of new diseases (Vilà et al. 2011). A classic example of the decease caused by introduced species is the chestnut blight in the United States that drove the American chestnut, *Castanea dentata*, to the brink of extinction in the 20th century due to the pathogen spread by the introduced Japanese chestnut, *Castanea crenata* (Collins et al. 2017). In Baluran National Park, *Acacia nilotica*, an exotic species introduced to Baluran National Park, in East Java, in 1969, has invaded 50% of the park, reducing the diversity and abundance of flora and fauna in the park (Zahra et al. 2020). In West Sumatra, an invasive tree species, *Bellucia pentamera*, has dominated some parts of the conservation area within the oil palm plantation (Solfiyeni et al. 2022). In many countries, the government has established quarantine offices to prevent the spread of diseases brought by the introduced species. With globalization, however, preventing the coming of exotic species is not easy, as the species propagules may be brought accidentally by the transportation of other goods. Conservation agencies have tried to remove the invasive alien species, but this effort may not always succeed, such as what happened in the

Baluran National Park with the *A. nilotica* (Zahra et al. 2020).

Fortunately, not every introduced species may become invasive, driving away the local species. For example, in rehabilitated mined land in Bengkulu, the introduced, fast-growing species, *A. mangium*, would eventually be replaced by local species through succession (Wiryono and Douny 2013). Rather than removing species, evaluating whether an introduced species is harmful or beneficial to biodiversity is more important because the function of the species is more important than the origin (Davis et al. 2011). For restoration of the conservation forest, however, planting native species is important because one objective of the conservation forest is maintaining the natural diversity of flora and fauna.

In conclusion, this study found that the seedling diversity for rehabilitating degraded land in the study sites was considered medium, much higher than that of the forestry and agriculture plantation but lower than that of natural forests. More introduced dominant species were found in three sites, and more native dominant species were found in the other three sites. The most dominant native species of Papua was *Araucaria cunninghamii*, in West Papua *I. bijuga*, in Gorontalo *P. rostratum*, in Bangka Belitung *Casuarina equisetifolia*, in Riau and Aceh *P. merkusii*. The most dominant introduced species in Papua was *P. rostratum*, in West Papua *S. saman*, in Gorontalo, in Bangka Belitung *S. macrophylla*, in Riau *Hevea brasiliensis*, and in Aceh *Persea americana*. More native species should be planted for degraded land rehabilitation if we want to return the degraded lands to the original ecosystems.

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