



Temporary Dominance of Exotic Plant Species on Overburden Coal Mines in South Kalimantan

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ABSTRACT

Primary succession on bare rocks is a challenge for invaders, including one of which was plants. The invasion of bare rock by exotic species raises the question of whether their presence hinders or facilitates succession. This study aimed to determine the role of exotic species in primary succession in six overburden (OB) coal mines using a chronosequence approach. Vegetation analysis was undertaken using line transects. Measurements were carried out on the absolute and relative coverage of each species. Native and exotic species were identified and grouped using information from local communities, identification books, and websites. The relationship between time and number of species, time, and relative dominance of exotic and native species was analyzed using Pearson's correlation. Species number and dominance data were analyzed descriptively. The number of native species from the six OB heaps was higher (57) than that from exotic heaps (50). Neither the number of species nor the coverage showed a significant relationship with time. Exotic species predominated throughout the age of the embankment but tended to decrease over time. Temporary dominance by exotic species plays a role in assisting primary succession in the OB. This process might be prolonged without the temporary dominance of exotic species during early primary succession.

Keywords: Chronosequence, Dominance, Exotic species, Native species, Primary succession

Introduction

An overburden is known as the dumping of coal mine tailings and other reject materials. It is nutrient-poor, contains elevated concentrations of trace metals and loosely adhered particles of shale, stones, and boulders, and is devoid of true soil characteristics (Dowarah *et al.*, 2009; Novianti *et al.*, 2018). Therefore, the presence of plants on the overburden (OB) is crucial, because not all species can colonize the sites under these conditions, and

their presence may facilitate the presence of subsequent species. Some plants do grow on the OB (Novianti *et al.*, 2017). However, a few of these have been identified as exotic species.

Invasion by exotic plant species in an ecosystem is considered a threat because of the deleterious effects they have for people and nature (Kawaletz *et al.*, 2013; Setyawati *et al.*, 2015), and exotic species should be removed or killed whenever possible. However, the potential consequences of invasive species vary widely across ecosystems (Pejchar & Mooney, 2009), and for both people and nature (Koutika & Richardson, 2019). In Indonesia, there are more than 2000 exotic species, 300 of which are classified as invasive (Setyawati *et al.*, 2015), indicating that possibly not all exotic species are invasive. According to Woods and Mariarty (2001), the role of exotic species is unclear.

In previous studies, 123 plant species have been identi-

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fied from OB (Novianti *et al.*, 2017). The aim of this study was to classify the species in the OB as native and exotic, and to determine the role of the exotic species. Relative coverage was used to determine the dominance of the species. In primary succession, coverage of species may be more representative in describing the dominance of space than the density of species. OB is presented as a model system to study primary succession (Prach *et al.*, 2013) because it is one of the most important human-mediated disturbances that create this condition.

Information about plant species and their roles is essential to understand succession and restoration. An understanding of succession can be used as a tool for restoration efforts (Kangas, 2004) because it can be used to accelerate natural succession (Bradshaw, 1987). Therefore, it is necessary to investigate changes in species composition and associated substrates over time to manipulate succession (Dowarah *et al.*, 2009; Novianti, 2020; Walker *et al.*, 2007).

Materials and Methods

Description of study area

The study was conducted in a coal OB dumping area located in Satui District, South Kalimantan, Indonesia. The sampling was carried out on an out-pit dump (i.e., on an OB dumped at certain disposal sites outside of the mine pit), and without leveling on its surface (known as free dump). The determination of OB heaps was based on the following conditions: (1) no disposal process (final dump), (2) known age, (3) identified origin depth, and (4) identified geological formation. According to this, six OBs were used as the study area of primary succession using a chronosequence approach (Table 1).

Vegetation analysis

OB heaps of different ages were selected, that is, 7, 10, 11, 42, 59, and 64 months old. A vegetation study was conducted using the line-transect method. For each transect, the line-intercept method was used (Mueller-Dom-

bois & Ellenberg, 1974); each plant species that was covered by the transect line was recorded, and plant coverage was estimated by measuring the width of each individual from the transect line. This coverage measurement can produce >100% coverage because of overlapping plants. The number of transect lines was adjusted according to the length of the area with a distance between lines of 5 m, while the length of the transect line followed the width of each area (Novianti *et al.*, 2017; 2018).

Species identification

All vegetation was identified using information from the local communities, plant identification books, and environmental impact assessment reports of PT. Al Satui Mine Project, and websites. Exotic and native species and the origin region were identified based on the identification books of Flora van Java (Van Steenis, 1992), a guidebook for invasive alien plant species in Indonesia (Setyawati *et al.*, 2015), and websites (<https://powo.science.kew.org/>).

Data analysis

Data for the native and exotic species were analyzed descriptively. The relationship between the number of species and time was analyzed using linear correlation at

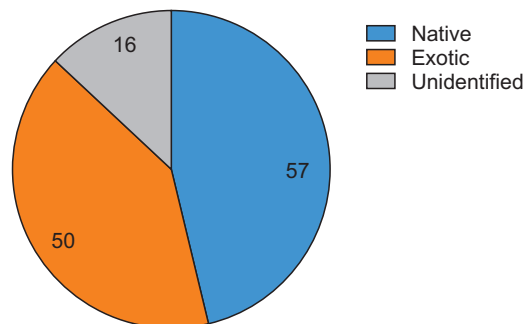


Fig. 1. Number of native and exotic plant species on overburden heaps.

Table 1. Characteristics of OB dumping sites that were selected as the study area

No.	Age of mine OB (mo)	Height of OB dump (m)	Width of OB dump (ha)	Origin depth (m asl)
1	7	38.18	2.68	30 to -80
2	10	20.07	2.06	30 to -80
3	11	16.18	3.66	30 to -80
4	42	19.90	7.09	30 to -80
5	59	24.11	2.14	30 to -80
6	64	29.85	11.87	30 to -80

OB, overburden.

Data from the article of Novianti *et al.* J Degrad Min Land Manage 2017;4:927-936.

Table 2. Native and exotic plant species and their relative dominances on the chronosequence on coal overburden spoils

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
1	<i>Acacia mangium</i> Wild.	Pt			0.506		0.036	1.080	v		Maluku to N. Queensland	
2	<i>Ageratum conyzoides</i> Linn.	Ah				0.021	0.001	0.003	v		Central America and the Caribbean, is now found throughout the world	
3	<i>Alternanthera pungens</i> Kunth.	Ph	0.288		0.194				v		South America; naturalized in Bhutan, Myanmar, Thailand, other parts of Indo-China, Australia, and United States	
4	<i>Alternanthera sessilis</i> Linn.	Ph	1.445	3.687	6.442		3.947	0.041	v		South America	
5	<i>Andropogon aciculatus</i> Retz.	Ph						0.036	v		Indian Ocean, Tropical & Subtropical Asia to Pacific	
6	<i>Andropogon chinensis</i> (Ness) Merr.	Ah						0.021	v		Tropical & S. Africa, SW. Arabian Peninsula, India to S. China and Indo-China	
7	<i>Anthocephalus macrophyllus</i> Havil	Pt					0.023		v		South Asia and Southeast Asia, including Indonesia	
8	<i>Araujia hortorum</i> E. Four	Pl			0.484		0.127	1.626	v		South America	
9	<i>Axonopus compressus</i> (Sw.) P.Beauv.	Ah		0.125					v		Tropical America	
10	<i>Benincasa hispida</i> (Thunb.) Cogn	Pl			0.190				v		Probably native in Japan and Java	
11	<i>Blechnum orientale</i> Linn.	Pf			0.033			0.138	v		Tropical & Subtropical Asia to Pacific	
12	<i>Blumea balsamifera</i> (Linn.) DC	Ps	0.013				0.017	0.051	v		India to Burma (Myanmar), Indo-China, southern China, Taiwan, Malaysia, Indonesia and the Philippines	
13	<i>Blyxa japonica</i> (Mix.) Maxim.	Ah			0.185				v		Bangladesh, China, Hong Kong, India, Irian Jaya, Kalimantan, Japan, Korea, Laos, Malaysia, Myanmar, Nepal, Papua New Guinea, Taiwan, Thailand and Vietnam	
14	Bryophyta		0.497		1.082	0.055	1.615	4.773				
15	<i>Celosia argentea</i> Linn.	Ah		1.878			0.014	0.001	v		The tropical Americas	
16	<i>Cenotheca lappacea</i> (Linn.) Desv.	Ph			0.026			0.055	v		W. & W. Central Tropical Africa, Madagascar, Tropical & Subtropical Asia to Pacific	

Table 2. Continued

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
17	<i>Centrosema molle</i> Benth.	Pl						0.052	0.048	v	The native range of this species is S. Mexico to Tropical America	
18	<i>Centrosema pubescens</i> Benth.	Pl						0.488	0.056	v	Mexico to Tropical America	
19	<i>Chloris barbata</i> Swartz.	Ph						0.009		v	Tropical & Subtropical Old World	
20	<i>Christella dentata</i> (Forsk.) Browney & Jerm	Ph				0.005				v	Tropical & Subtropical Old World to Pacific	
21	<i>Chromolaena odorata</i> (Linn.) King & Robinson	Ps	2.855	0.564	0.617	2.436	5.281	2.676		v	Central & South America	
22	<i>Citrullus lanatus</i> (Thunb.)	Al					0.047			v	Egypt, Ethiopia, Libya, Sudan	
23	<i>Clibadium surinamense</i> Linn.	Ps	2.053	0.270	10.64	6.946	0.602	6.811		v	Tropical America	
24	<i>Cynodon dactylon</i> (Linn.) Pers.	Ph	0.234	1.261	0.225		4.633	0.236		v	Temp. & Subtropical Old World to Australia	
25	<i>Cyperus babakans</i> Steud.	Ah			0.041		0.023			v	South East	
26	<i>Cyperus brevifolius</i> (Rottb.) Hass	Ah						1.239		v	Tropics & Subtropics	
27	<i>Cyperus compactus</i> Retz.	Ah			0.141	0.094	0.297	0.005		v	Madagascar, Tropical & Subtropical Asia to N. Australia	
28	<i>Cyperus compressus</i> Linn.	Ah					0.005	0.096		v	Tropics & Subtropics	
29	<i>Cyperus difformis</i> Linn.	Ah			0.017		0.303			v	Tropical & Subtropical Old World	
30	<i>Cyperus entrianus</i> Boeckl.	Ah					0.211	0.610		v	Mexico to N. Argentina, Caribbean	
31	<i>Cyperus halpan</i> Linn.	Ah		0.072				0.108		v	Tropics & Subtropics	
32	<i>Cyperus iria</i> Linn.	Ah			0.208		0.007			v	Tropical & Subtropical Old World to Central Asia	
33	<i>Cyperus javanicus</i> Hoult	Ah	0.894	1.593	0.398		0.040	0.059		v	Indian Ocean, Tropical & Subtropical Asia to Pacific	
34	<i>Cyperus kyllinga</i> Endl.	Ah	0.043							v	SE. U.S.A. to N. South America	
35	<i>Cyperus polystachyos</i> Rottb.	Ah					2.220	1.363		v	Tropics & Subtropics	
36	<i>Cyperus pulcherrimus</i> Will. Ex. Kunth.	Ah			0.071			0.002		v	Tropical Asia	

Table 2. Continued

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
37	<i>Cyperus pygmaeus</i> Rottb.	Ah							0.042	v	Tropical & Subtropical Old World to Russian Far East	
38	<i>Cyperus</i> sp.1	Ah						0.012				
39	<i>Cyperus</i> sp.2	Ah						0.036				
40	<i>Cyperus</i> sp.3	Ah						0.006				
41	<i>Cyperus</i> sp.4	Ah			0.007			0.063	0.015			
42	<i>Cyperus</i> sp.5	Ah			0.065							
43	<i>Cyperus</i> sp.6	Ah			0.039							
44	<i>Cyperus sulcinus</i> C. B. Clarke.	Ah	0.037	0.310	1.280	0.117	0.233	1.641		v	Tropical & Subtropical Asia to Queensland	
45	<i>Dactyloctenium aegyptium</i> (Linn.) Willd.	Ph						0.034		v	Tropical & Subtropical Old World	
46	<i>Desmodium heterophyllum</i> (Willd.) DC.	Ah						0.121		v	Madagascar, Tropical & Subtropical Asia	
47	<i>Digitaria ciliaris</i> (Retz.) Koeler	Ph			0.064					v	Tropical & Subtropical Old World	
48	<i>Echinochloa colona</i> (Linn.) Link	Ah	1.134	3.939	4.291	0.007	0.001	0.370		v	India (Gujarat)	
49	<i>Eclipta prostrata</i> Linn.	Ah					3.859			v	Tropical America	
50	<i>Elaphoglossum blumeanum</i> (Fée) J. Sm	Ph					0.003	0.003		v	Malesia to Solomon Islands	
51	<i>Eleocharis dulcis</i> (Burm. f.) Trin. ex. Henschel.	Ah			1.470	0.097		0.671		v	Tropical & Subtropical Old World	
52	<i>Eleusine indica</i> (L.) Gaertn.	Ah	0.115	0.022	2.036		0.041	0.018		v	India	
53	<i>Emilia sonchifolia</i> (Lin.) DC	Ah			0.016	0.004	0.194	0.014		v	Tropical Africa	
54	<i>Eragrostis japonica</i> (Thunb.) Trin.	Ah		4.505	7.391	5.387	0.356	1.571		v	Tropical & Subtropical Old World	
55	<i>Eragrostis leptostachya</i> (R. Br.) Steud	Ah		0.369						v	E. & SE. Australia	
56	<i>Eragrostis tenella</i> (Linn.) P Beau	Ah	1.530		1.650	1.165	0.056	0.421		v	Tropical & Subtropical Old World.	
57	<i>Eragrostis uniolooides</i> (Retz.) Nees ex Steud	Ah			0.043		0.015	4.785		v	S. E. Asia	

Table 2. Continued

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
58	<i>Erechtites valerianifolia</i> (Wolff) DC.	Ah							0.028	v	Tropical & Subtropical America	
59	<i>Erigeron sumatrensis</i> Retz.	Ah						0.012	0.011	v	Mexico to S. Tropical America	
60	<i>Eulophia graminea</i> Lindl.	Ah							0.007	v	Tropical & Subtropical Asia to Marianas (Guam)	
61	Fern/Paku sp.1							0.001				
62	<i>Fimbristylis dichotoma</i> (Linn.) Vahl.	Ah	13.810	15.680	2.611	1.897	7.986	0.013		v	Tropics & Subtropics	
63	<i>Fimbristylis litoralis</i> Gaudich	Ah			0.672		2.282	4.841		v	Tropics & Subtropics	
64	<i>Fimbristylis miliaceae</i> (Linn.) Vahl	Ah	0.448	0.833		0.025				v	Tropical America	
65	<i>Fimbristylis schoenoides</i> (Retz.) Vahl	Ah					0.056	0.912		v	S. E. Asia	
66	<i>Fimbristylis</i> sp.1	Ah						0.152				
67	<i>Fimbristylis</i> sp.2	Ah						0.013				
68	<i>Hodgsonia heteroclita</i> (Roxb.) Hook f. & Thomson	Pl		1.037						v	E. Himalaya to China (S. Yunnan, Guangxi) and Indo-China	
69	<i>Homalanthus populifolius</i> Graham	Pt	0.241		0.123	0.328		0.109		v	Papua New Guinea to Solomon Islands, E. Australia, Norfolk Island, Lord Howe Island	
70	<i>Hyptis capitata</i> Jacq.	Ah						0.012	0.075	v	Tropical America	
71	<i>Imperata cylindrica</i> (L.) Raeuschel	Ph	5.909	0.151	2.134	4.147	3.752			v	Medit. to Africa and Afghanistan	
72	<i>Ipomoea aquatica</i> Forsk.	Ah		0.111						v	Tropical & Subtropical Old World	
73	<i>Lantana camara</i> Linn.	Ps						0.064		v	Tropical America	
74	<i>Leea indica</i> (Burm.f.) Merr.	Ps						0.014		v	Tropical & Subtropical Asia to W. Pacific	
75	<i>Leersia hexandra</i> Swartz	Ph	0.437	0.166	0.022	0.047	1.790	0.538		v	Tropical America	
76	<i>Lindernia crustacea</i> (Linn.) F.Muell.	Ah			0.588		0.023			v	Tropics & Subtropics	
77	<i>Ludwigia hyssopifolia</i> (G. Don) Exell.	Ph			0.450	0.004	0.031	0.012		v	S. Mexico to Tropical America, N. Australia	

Table 2. Continued

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
78	<i>Lycopodium cernuum</i> Linn.	Af	0.004					0.013	v		Tropics & Subtropics	
79	<i>Lygodium microphyllum</i> (Cav.) R Br.	Af			0.149		0.028		v		Tropical & Subtropical Old World	
80	<i>Macaranga gigantea</i> (Reichb.f.& Zoll.) Müll. Arg.	Pt		0.040					v		S. Myanmar to W. & Central Malesia	
81	<i>Macaranga tanarius</i> (L.) Muell.Arg.	Pt						0.018	v		Tropical & Subtropical Asia to W. Pacific	
82	<i>Melastoma malabathricum</i> Linn.	Ps	0.108	0.004	1.089			0.077	v		Asia	
83	<i>Melochia corchorifolia</i> Linn.	Ah	0.114					0.020	v		Tropical & Subtropical Old World	
84	<i>Merremia peltata</i> (L.) Merr.	Pl	6.485						v		Tanzania, W. Indian Ocean, Tropical Asia to Pacific	
85	<i>Mikania micrantha</i> Kunth.	Pl			0.336				v		Central and South America	
86	<i>Mimosa pudica</i> Linn.	Ps			1.736	4.349		6.627	v		Tropical America/S. America	
87	<i>Mitracarpus hirtus</i> (Linn.) DC	Ah			0.004				v		Mexico to Tropical America	
88	<i>Mollatus paniculatus</i> (Lam.) Mull.Arg.	Pt			0.326			0.579	v		Tropical & Subtropical Asia to N. & NE. Queensland	
89	<i>Morinda citrifolia</i> Linn.	Pt						0.006	v		Tropical & Subtropical Asia to N. Australia	
90	<i>Nephrolepis</i> sp.	Af					0.000					
91	<i>Neyraudia reynaudiana</i> (Kunth) Keng ex Hitchc	Ph	0.325		0.487	0.533		2.059	v		Himalaya to Central China and Malesia	
92	<i>Ochroma pyramidale</i> (Cav. Ex Lam.) Urb.	Pt	0.241						v		S. Mexico to Tropical America	
93	<i>Palaquium oblongifolium</i> (Burck) Burck	Pt						0.145	v		W. Malesia	
94	<i>Panicum repens</i> Linn.	Ph					0.778		v		Asia or Africa	
95	<i>Paspalum conjugatum</i> Berg.	Ph	20.620	32.610	13.56	55.030		22.310	v		Tropical America	
96	<i>Paspalum dilatatum</i> Poir.	Ph	7.501	8.441	3.756	1.131		7.594	v		SE. & S. Brazil to S. South America	
97	<i>Paspalum scrobiculatum</i> Linn.	Ph	1.104	1.163	0.882	0.140		0.547	v		Tropical & Subtropical Old World to N. & E. Australia	

Table 2. Continued

No.	Species	Life form	Time (mo)							N	E	Origin region
			7	10	11	42	59	64				
98	<i>Passiflora foetida</i> Linn.	Pl	3.306		8.001	0.321	1.926	1.505	v		Tropical America	
99	<i>Phyllanthus urinaria</i> Linn.	Ah					0.184	0.571	v		Tropical Asia	
100	<i>Piper aduncum</i> Linn.	Ps						0.002	v		Mexico to Tropical America	
101	<i>Pityrogramma calomelanos</i> (Linn.) Link	Pf	0.017		0.193	0.289	0.200	0.265	v		Mexico to Tropical America	
102	<i>Polygala paniculata</i> Linn.	Ah						0.430	v		Tropical America from Mexico and the Antillies to Brazil	
103	<i>Porophyllum ruderale</i> (Jacq.) Cass.	Ah		0.025	0.035	0.043	1.318	1.187	v		C. & S. America	
104	<i>Psidium guineense</i> Swartz	Pt						0.004	v		Mexico to Tropical America	
105	<i>Pteridium esculentum</i> (G. Forst.) Cockayne	Pf				0.002			v		Tropical & Subtropical Asia to SW. Pacific	
106	<i>Pteris vittata</i> Linn.	Pf			0.235	0.351	0.686	3.039	v		Tropical & Subtropical Old World	
107	<i>Rhynchospora corymbosa</i> (Linn.) Britton	Ph	10.930	2.064	6.577	3.562	4.055	0.495	v		Tropics & Subtropics	
108	<i>Saccharum spontaneum</i> Linn.	Ph					1.273	0.002	v		Sicilia, Africa, Asia to N. & NE. Australia.	
109	<i>Sacciolepis indica</i> (Linn.) Chase	Ph	0.199	0.152				0.025	v		India	
110	<i>Scirpus mucronatus</i> (Linn.) Palla	Ph		0.069	0.952	0.103			v		Europe to Central Siberia and Himalaya, Africa, Brazil to NE. Argentina	
111	<i>Scleria bancana</i> Miq.	Ah						0.007	v		Tropical & Subtropical Asia to Caroline Islands	
112	<i>Scleria sumatrensis</i> Retz.	Ah	4.734	0.090	2.256	7.885	0.352	0.508	v		Seychelles, Hainan to Tropical Asia and N. Australia	
113	<i>Solanum torvum</i> Swartz	Ps	0.013	0.012	0.057		0.045	0.237	v		The Antilles	
114	Tree sp. 1	Pt			0.123							
115	Tree sp. 2	Pt			0.074							
116	Tree sp. 3	Pt					0.008					
117	Tree sp. 4	Pt					0.001					
118	<i>Trema micrantha</i> (L.) Blume	Ps	0.556	0.152	3.098	0.032	0.009	0.002	v		Tropical & Subtropical America	

Table 2. Continued

No.	Species	Life form	Time (mo)						N	E	Origin region
			7	10	11	42	59	64			
119	<i>Trema orientalis</i> (L.) Blum	Ps	1.660	0.729	7.853	2.572	0.224	2.701	v	Tropical & Subtropical Old World	
120	<i>Typha angustifolia</i> Linn.	Ph	10.110	17.990	1.523	0.018	5.164	0.269	v	Temp. Northern Hemisphere	
121	<i>Vernonia cinerea</i> (L.) Less	Ah			0.042		0.177	0.277	v	Unknown/Old World	
122	Vitaceae	Pl					2.293	0.100			
123	<i>Wedelia trilobata</i> (Linn.) Hitchc.	Ph			0.025		2.020		v	Tropical America	

Ah, annual herb; Ph, perennial herb; Pl, perennial liana; Ps, perennial shrub; Pt, perennial tree; N, native; E, exotic.

a significance level of 5% ($\alpha=5\%$). The range of vegetation was calculated for each species at each site, including coverage and relative coverage, to determine dominance.

Results

The numbers of native and exotic plant species were 57 and 50, respectively. Sixteen species were not identified (Fig. 1). The native species present at all ages of the OB embankment were *Cyperus sulcinus*, *Fimbristylis dichotoma*, *Paspalum scrobiculatum*, *Rhyncospora corymbosa*, *Scleria sumatrensis* (herb), and *Trema orientalis* (shrub). The exotic species consisted of *Echinochloa colona*, *Leersia hexandra*, *Paspalum conjugatum*, *Paspalum dilatatum* (herbs), *Chromolaena odorata*, *Clibadium surinamense*, and *Trema micrantha* (shrub) (Table 2).

Neither the number of exotic species ($r=0.7093$, $N=6$, $P<0.05$) nor the number of native species ($r=0.7051$, $N=6$, $P<0.05$) showed a significant relationship with time. However, the number of native species tended to be higher than that of exotic species over time (Fig. 2). Based on the species dominance, *Paspalum conjugatum*, an exotic plant dominated in the first five heap ages and was replaced at 64 months of stockpiling by *Neyraudia reynaudiana*, a native species. Meanwhile, other species dominated only at a certain age of the heap spoil (Table 3). The relative dominance of native ($r=0.0954$, $N=6$, $P<0.05$) and exotic ($r=0.2512$, $N=6$, $P<0.05$) species did not significantly correlate with time (Fig. 3). In addition, the dominance of exotic species was higher than that of native species at all six stockpile ages. A community dynamic relationship was observed between exotic and native species, that is, a decrease in the percentage coverage area by exotic species was followed by an increase in the

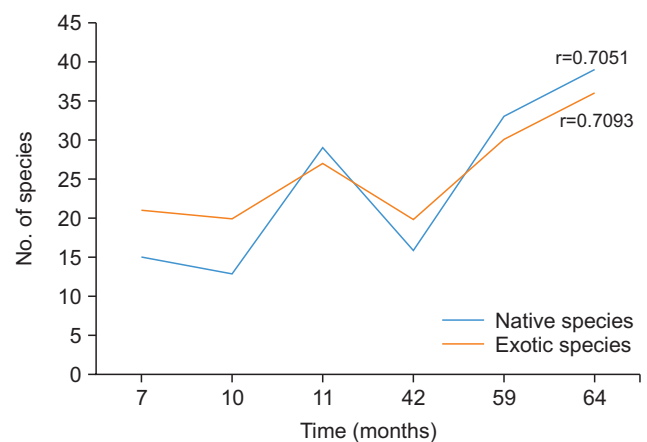
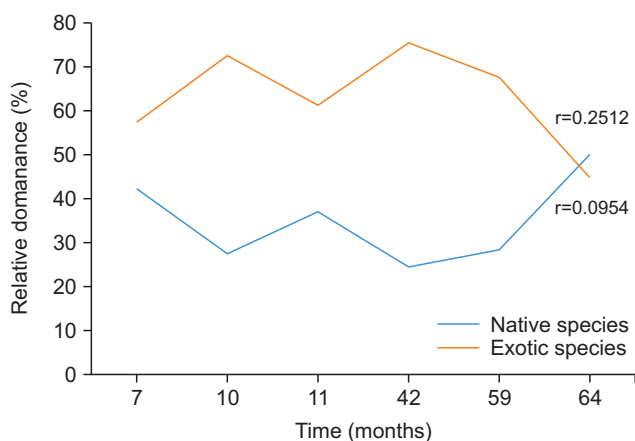


Fig. 2. Correlation between time (months) and number of native and exotic species on the chrono sequence on coal overburden spoils

Table 3. Top species with top 10 relative dominances

No.	Time (mo)					
	7	10	11	42	59	64
1	<i>P. conjugatum</i>	<i>P. conjugatum</i>	<i>P. conjugatum</i>	<i>P. conjugatum</i>	<i>P. conjugatum</i>	<i>N.reynaudiana</i>
2	<i>F. dichotoma</i>	<i>T. angustifolia</i>	<i>C. surinamense</i>	<i>S. sumatrensis</i>	<i>F. dichotoma</i>	<i>P. dilatatum</i>
3	<i>R. corymbosa</i>	<i>F. dichotoma</i>	<i>P. foetida</i>	<i>C. surinamense</i>	<i>P. dilatatum</i>	<i>P. scorbiculatum</i>
4	<i>T. angustifolia</i>	<i>P. dilatatum</i>	<i>T. orientalis</i>	<i>E. japonica</i>	<i>M. pudica</i>	<i>C. surinamense</i>
5	<i>P. dilatatum</i>	<i>E. japonica</i>	<i>E. japonica</i>	<i>M. pudica</i>	<i>C. odorata</i>	<i>P. conjugatum</i>
6	<i>M. peltata</i>	<i>E. colona</i>	<i>R. corymbosa</i>	<i>I. cylindrica</i>	<i>T. angustifolia</i>	<i>M. pudica</i>
7	<i>I. cylindrica</i>	<i>A. sessilis</i>	<i>A. sessilis</i>	<i>R. corymbosa</i>	<i>C. dactylon</i>	<i>F. litoralis</i>
8	<i>S. sumatrensis</i>	<i>R. corymbosa</i>	<i>E. colona</i>	<i>T. orientalis</i>	<i>R. corymbosa</i>	<i>E. uniloides</i>
9	<i>P. foetida</i>	<i>C. argantea</i>	<i>P. dilatatum</i>	<i>C. odorata</i>	<i>A. sessilis</i>	Bryophyta
10	<i>C. odorata</i>	<i>C. javanicus</i>	<i>T. micrantha</i>	<i>F. dichotoma</i>	<i>E. prostrata</i>	<i>P. vittata</i>


Fig. 3. Correlation between time (months) and total relative dominance of native and exotic species on the chronosequence on coal overburden spoils.

percentage coverage area by native species. The decrease in spatial control by exotic species and increase in dominance by native species began to occur at 59 months of stockpiling age.

Discussion

This study showed that both native and exotic species are present at an early successional stage in OB stockpiles. A higher percentage of native species indicated that seed sources were still available. They can be a source for pioneer vegetation during restoration, considering that the plant species used are generally brought from outside Indonesia, such as *Centrosema pubescens* (Hindersah *et al.*, 2021). Moreover, the surroundings of the mine have been dominated by fast-growing trees, such as *Acacia mangium*, as the main tree used in reclamation (Lewis *et*

al., 2022). The native species present throughout the heap were herbs, such as sedges, grasses, and trees, whereas exotic plants were grasses, shrubs, and trees. The presence of plants in the early stages of primary succession is influential because they must cope with unfavorable conditions for establishment. Their growth and distribution are often restricted by nutrient availability because of bare substrates (Dalling, 2008; Glenn-Lewin *et al.*, 1992; Novianti *et al.*, 2018). Furthermore, when these plants die, they become an organic source that will improve substrate conditions, increase safe microsites over time, and consequently increase the number of species (Marrs & Bradshaw, 1993; Novianti, 2013; Walker & del Moral, 2011).

Initially, exotic species dominated both in terms of the number of species and their coverage, perhaps because of their higher response (per capita growth) to the opportunities of niche and resources than that of the resident species (Shea & Chesson, 2002). However, the number of species and the coverage of native species increased with time. Once a surface is colonized, future generations of colonists are likely to be controlled by local seed production or vegetative expansion, and the disturbance may be colonized in successively expanding plant nuclei (Walker & dan del Moral, 2011).

Some native and exotic have roles as pioneers and some as “followers” in the chronosequence of the OB spoil. Pioneers are those that arrive and grow quickly on very poor substrata and appear to facilitate the subsequent vegetation; “followers” are the ones that appear subsequently (Novianti, 2020; Novianti *et al.*, 2018). Temporary dominance by native and exotic plants shows a temporal pattern during succession in post-mining landscapes (Baasch, 2010). These results indicate that both native and exotic species assist in primary succession. These processes may take longer without their presence during the

early primary succession. Herbs are present and dominate at the beginning of succession (Dalling, 2008). In addition, shrubs and trees colonize very quickly and dominate after only 64 months, probably because of their close proximity to a diverse species pool and the constant high spoil moisture content (Maharana & Patel, 2013; Novianti *et al.*, 2018).

In conclusion, the species that predominate at the beginning of primary succession in the OB of coal mines are exotic species. The temporary presence of exotic species assists the primary succession process in OB areas by improving the condition of the OB substrate, without which the succession process may possibly take longer. These results indicate that not all exotic species are invasive. Information about the role of exotic species in primary succession is needed as part of the integration between scientific and management concerns for practical knowledge in doing restoration.

Conflict of Interest

The author declares that (s)he has no competing interests.

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