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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 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-Dombois & 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

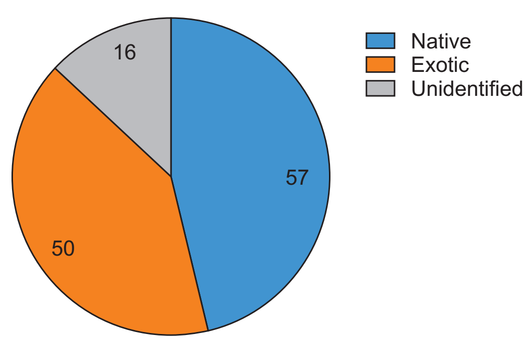

Fig. 1. Number of native and exotic plant species on overburden heaps.

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 Degrade 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	*Acacia mangium* Wild.	Pt			0.506		0.036	1.080		v	Maluku to N. Queensland
2	*Ageratum conyzoides* Linn.	Ah				0.021	0.001	0.003		v	Central America and the Caribbean, is now found throughout the world
3	*Alternanthera pungens* Kunth.	Ph	0.288		0.194					v	South America; naturalized in Bhutan, Myanmar, Thailand, other parts of Indo-China, Australia, and United States
4	*Alternanthera sessilis* Linn.	Ph	1.445	3.687	6.442		3.947	0.041		v	South America
5	*Andropogon aciculatus* Retz.	Ph						0.036	v		Indian Ocean, Tropical & Subtropical Asia to Pacific
6	*Andropogon chinensis* (Ness) Merr.	Ah						0.021		v	Tropical & S. Africa, SW. Arabian Peninsula, India to S. China and Indo-China
7	*Anthocephalus macrophyllus* Havil	Pt					0.023		v		South Asia and Southeast Asia, including Indonesia
8	*Araujia hortorum* E. Four	Pl			0.484		0.127	1.626		v	South America
9	*Axonopus compressus* (Sw.) P.Beauv.	Ah		0.125						v	Tropical America
10	*Benincasa hispida* (Thunb.) Cogn	Pl			0.190				v		Probably native in Japan and Java
11	*Blechnum orientale* Linn.	Pf			0.033			0.138	v		Tropical & Subtropical Asia to Pacific
12	*Blumea balsaminifera* (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	*Blyxa japonica* (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	*Celosia argentea* Linn.	Ah		1.878			0.014	0.001		v	The tropical Americas
16	*Centotheca lappacea* (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	*Centrosema molle* Benth.	Pl					0.052	0.048		v	The native range of this species is S. Mexico to Tropical America
18	*Centrosema pubescens* Benth.	Pl					0.488	0.056		v	Mexico to Tropical America
19	*Chloris barbata* Swartz.	Ph					0.009		v		Tropical & Subtropical Old World
20	*Christella dentata* (Forsk.) Browney & Jerm	Ph				0.005			v		Tropical & Subtropical Old World to Pacific
21	*Chromolaena odorata* (Linn.) King & Robinson	Ps	2.855	0.564	0.617	2.436	5.281	2.676		v	Central & South America
22	*Citrullus lanatus* (Thunb.)	Al				0.047				v	Egypt, Ethiopia, Libya, Sudan
23	*Clibadium surinamense* Linn.	Ps	2.053	0.270	10.64	6.946	0.602	6.811		v	Tropical America
24	*Cynodon dactylon* (Linn.) Pers.	Ph	0.234	1.261	0.225		4.633	0.236	v		Temp. & Subtropical Old World to Australia
25	*Cyperus babakans* Steud.	Ah			0.041		0.023		v		South East
26	*Cyperus brevifolius* (Rottb.) Hass	Ah						1.239	v		Tropics & Subtropics
27	*Cyperus compactus* Retz.	Ah			0.141	0.094	0.297	0.005	v		Madagascar, Tropical & Subtropical Asia to N. Australia
28	*Cyperus compressus* Linn.	Ah					0.005	0.096	v		Tropics & Subtropics
29	*Cyperus difformis* Linn.	Ah			0.017		0.303		v		Tropical & Subtropical Old World
30	*Cyperus entrerianus* Boeckl.	Ah					0.211	0.610		v	Mexico to N. Argentina, Caribbean
31	*Cyperus halpan* Linn.	Ah		0.072				0.108	v		Tropics & Subtropics
32	*Cyperus iria* Linn.	Ah			0.208		0.007		v		Tropical & Subtropical Old World to Central Asia
33	*Cyperus javanicus* Houtt	Ah	0.894	1.593	0.398		0.040	0.059	v		Indian Ocean, Tropical & Subtropical Asia to Pacific
34	*Cyperus kyllinga* Endl.	Ah	0.043							v	SE. U.S.A. to N. South America
35	*Cyperus polystachyos* Rottb.	Ah					2.220	1.363	v		Tropics & Subtropics
36	*Cyperus pulcherrimus* Will. Ex. Kunth.	Ah			0.071			0.002	v		Tropical Asia

Table 2. Continued

No.	Species	Life form	Time (mo) 7	10	11	42	59	64	N	E	Origin region
37	*Cyperus pygmaeus* Rottb.	Ah						0.042	v		Tropical & Subtropical Old World to Russian Far East
38	*Cyperus* sp.1	Ah					0.012				
39	*Cyperus* sp.2	Ah					0.036				
40	*Cyperus* sp.3	Ah					0.006				
41	*Cyperus* sp.4	Ah			0.007		0.063	0.015			
42	*Cyperus* sp.5	Ah			0.065						
43	*Cyperus* sp.6	Ah			0.039						
44	*Cyperus sulcinux* C. B. Clarke.	Ah	0.037	0.310	1.280	0.117	0.233	1.641	v		Tropical & Subtropical Asia to Queensland
45	*Dactyloctenium aegyptium* (Linn.) Willd.	Ph					0.034		v		Tropical & Subtropical Old World
46	*Desmodium heterophyllum* (Willd.) DC.	Ah						0.121	v		Madagascar, Tropical & Subtropical Asia
47	*Digitaria ciliaris* (Retz.) Koeler	Ph			0.064					v	Tropical & Subtropical Old World
48	*Echinochloa colona* (Linn.) Link	Ah	1.134	3.939	4.291	0.007	0.001	0.370		v	India (Gujarat)
49	*Eclipta prostrata* Linn.	Ah					3.859			v	Tropical America
50	*Elaphoglossum blumeanum* (Fée) J. Sm	Ph					0.003	0.003	v		Malesia to Solomon Islands
51	*Eleocharis dulcis* (Burm. f.) Trin. ex. Henschel.	Ah			1.470	0.097		0.671	v		Tropical & Subtropical Old World
52	*Eleusine indica* (L.) Gaertn.	Ah	0.115	0.022	2.036		0.041	0.018		v	India
53	*Emilia sonchifolia* (Lin.) DC	Ah			0.016	0.004	0.194	0.014		v	Tropical Africa
54	*Eragrostis japonica* (Thunb.) Trin.	Ah		4.505	7.391	5.387	0.356	1.571	v		Tropical & Subtropical Old World
55	*Eragrostis leptostachya* (R. Br.) Steud	Ah		0.369						v	E. & SE. Australia
56	*Eragrostis tenella* (Linn.) P Beau	Ah	1.530		1.650	1.165	0.056	0.421	v		Tropical & Subtropical Old World.
57	*Eragrostis unioloides* (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	*Erechtites valerianifolia* (Wolff) DC.	Ah						0.028		v	Tropical & Subtropical America
59	*Erigeron sumatrensis* Retz.	Ah					0.012	0.011		v	Mexico to S. Tropical America
60	*Eulophia graminea* Lindl.	Ah						0.007	v		Tropical & Subtropical Asia to Marianas (Guam)
61	Fern/Paku sp.1						0.001				
62	*Fimbristylis dichotoma* (Linn.) Vahl.	Ah	13.810	15.680	2.611	1.897	7.986	0.013	v		Tropics & Subtropics
63	*Fimbristylis litoralis* Gaudich	Ah			0.672		2.282	4.841	v		Tropics & Subtropics
64	*Fimbristylis miliaceae* (Linn.) Vahl	Ah	0.448	0.833		0.025				v	Tropical America
65	*Fimbristylis schoenoides* (Retz.) Vahl	Ah					0.056	0.912	v		S. E. Asia
66	*Fimbristylis* sp.1	Ah						0.152			
67	*Fimbristylis* sp.2	Ah						0.013			
68	*Hodgsonia heteroclita* (Roxb.) Hook f. & Thomson	Pl		1.037						v	E. Himalaya to China (S. Yunnan, Guangxi) and Indo-China
69	*Homalanthus populifolius* 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	*Hyptis capitata* Jacq.	Ah					0.012	0.075		v	Tropical America
71	*Imperata cylindrica* (L.) Raeuschel	Ph	5.909	0.151	2.134	4.147	3.752			v	Medit. to Africa and Afghanistan
72	*Ipomoea aquatica* Forsk.	Ah		0.111					v		Tropical & Subtropical Old World
73	*Lantana camara* Linn.	Ps						0.064		v	Tropical America
74	*Leea indica* (Burm.f.) Merr.	Ps						0.014	v		Tropical & Subtropical Asia to W. Pacific
75	*Leersia hexandra* Swartz	Ph	0.437	0.166	0.022	0.047	1.790	0.538		v	Tropical America
76	*Lindernia crustacea* (Linn.) F.Muell.	Ah			0.588		0.023		v		Tropics & Subtropics
77	*Ludwigia hyssopifolia* (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	*Lycopodium cernuum* Linn.	Af	0.004				0.013		v		Tropics & Subtropics
79	*Lygodium microphyllum* (Cav.) R Br.	Af			0.149	0.028			v		Tropical & Subtropical Old World
80	*Macaranga gigantea* (Reichb.f.& Zoll.) Műll. Arg.	Pt		0.040					v		S. Myanmar to W. & Central Malesia
81	*Macaranga tanarius* (L.) Muell.Arg.	Pt					0.018	0.002	v		Tropical & Subtropical Asia to W. Pacific
82	*Melastoma malabathricum* Linn.	Ps	0.108	0.004	1.089		0.077		v		Asia
83	*Melochia corchorifolia* Linn.	Ah	0.114				0.020	0.000		v	Tropical & Subtropical Old World
84	*Merremia peltata* (L.) Merr.	Pl	6.485						v		Tanzania, W. Indian Ocean, Tropical Asia to Pacific
85	*Mikania micrantha* Kunth.	Pl			0.336			0.288		v	Central and South America
86	*Mimosa pudica* Linn.	Ps			1.736	4.349	6.627	5.488		v	Tropical America/S. America
87	*Mitracarpus hirtus* (Linn.) DC	Ah			0.004					v	Mexico to Tropical America
88	*Mollatus paniculatus* (Lam.) Mull.Arg.	Pt			0.326			0.579	v		Tropical & Subtropical Asia to N. & NE. Queensland
89	*Morinda citrifolia* Linn.	Pt						0.006	v		Tropical & Subtropical Asia to N. Australia
90	*Nephrolepis* sp.	Af				0.000					
91	*Neyraudia reynaudiana* (Kunth) Keng ex Hitchc	Ph	0.325		0.487	0.533	2.059	15.590	v		Himalaya to Central China and Malesia
92	*Ochroma pyramidale* (Cav. Ex Lam.) Urb.	Pt	0.241							v	S. Mexico to Tropical America
93	*Palaquium oblongifolium* (Burck) Burck	Pt						0.145	v		W. Malesia
94	*Panicum repens* Linn.	Ph				0.778			v		Asia or Africa
95	*Paspalum conjugatum* Berg.	Ph	20.620	32.610	13.56	55.030	22.310	6.439		v	Tropical America
96	*Paspalum dilatatum* Poir.	Ph	7.501	8.441	3.756	1.131	7.594	14.670		v	SE. & S. Brazil to S. South America
97	*Paspalum scrobiculatum* Linn.	Ph	1.104	1.163	0.882	0.140	0.547	7.468	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	*Passiflora foetida* Linn.	Pl	3.306		8.001	0.321	1.926	1.505		v	Tropical America
99	*Phyllanthus urinaria* Linn.	Ah					0.184	0.571	v		Tropical Asia
100	*Piper aduncum* Linn.	Ps						0.002		v	Mexico to Tropical America
101	*Pityrogramma calomelanos* (Linn.) Link	Pf	0.017		0.193	0.289	0.200	0.265		v	Mexico to Tropical America
102	*Polygala paniculata* Linn.	Ah						0.430		v	Tropical America from Mexico and the Antillies to Brazil
103	*Porophyllum ruderale* (Jacq.) Cass.	Ah		0.025	0.035	0.043	1.318	1.187		v	C. & S. America
104	*Psidium guineense* Swartz	Pt						0.004		v	Mexico to Tropical America
105	*Pteridium esculentum* (G. Forst.) Cockayne	Pf				0.002			v		Tropical & Subtropical Asia to SW. Pacific
106	*Pteris vittata* Linn.	Pf			0.235	0.351	0.686	3.039	v		Tropical & Subtropical Old World
107	*Rhyncospora corymbosa* (Linn.) Britton	Ph	10.930	2.064	6.577	3.562	4.055	0.495	v		Tropics & Subtropics
108	*Saccharum spontaneum* Linn.	Ph					1.273	0.002	v		Sicilia, Africa, Asia to N. & NE. Australia.
109	*Sacciolepis indica* (Linn.) Chase	Ph	0.199	0.152				0.025		v	India
110	*Scirpus mucronatus* (Linn.) Palla	Ph		0.069	0.952	0.103				v	Europe to Central Siberia and Himalaya, Africa, Brazil to NE. Argentina
111	*Scleria bancana* Miq.	Ah						0.007	v		Tropical & Subtropical Asia to Caroline Islands
112	*Scleria sumatrensis* Retz.	Ah	4.734	0.090	2.256	7.885	0.352	0.508	v		Seychelles, Hainan to Tropical Asia and N. Australia
113	*Solanum torvum* Swartz	Ps	0.013	0.012	0.057		0.045	0.237		v	The Antiles
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	*Trema micrantha* (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) 7	10	11	42	59	64	N	E	Origin region
119	*Trema orientalis* (L.) Blum	Ps	1.660	0.729	7.853	2.572	0.224	2.701	v		Tropical & Subtropical Old World
120	*Typha angustifolia* Linn.	Ph	10.110	17.990	1.523	0.018	5.164	0.269		v	Temp. Northern Hemisphere
121	*Vernonia cinerea* (L.) Less	Ah			0.042		0.177	0.277	v		Unknown/Old World
122	Vitaceae	Pl					2.293	0.100			
123	*Wedelia trilobata* (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% (α=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 sulcinux, 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 conjugantum*, 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

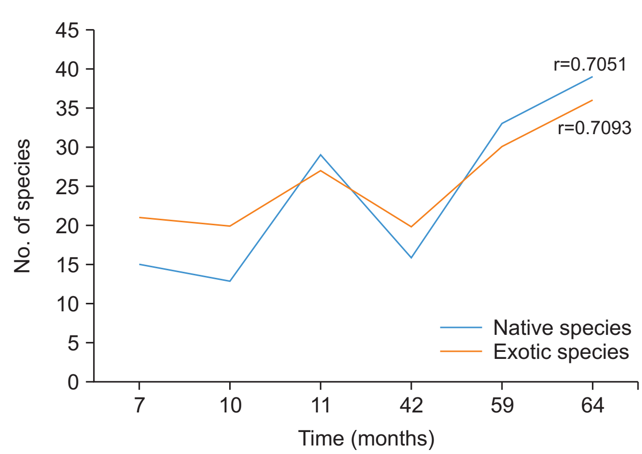

Fig. 2. Correlation between time (months) and number of native and exotic species on the chrono sequence on coal overburden spoils

Table 3. Top species with top 10 relative dominances

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

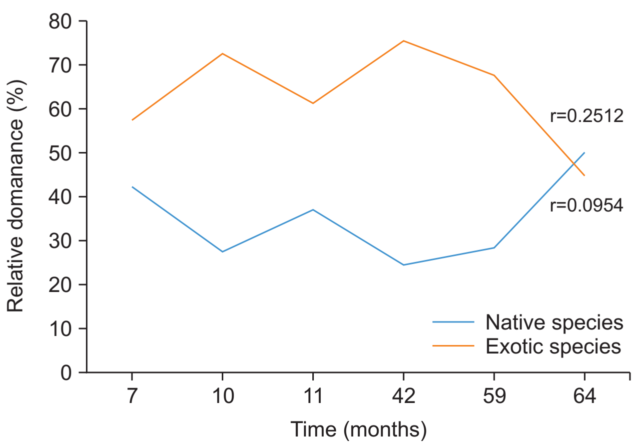

Fig. 3. Correlation between time (months) and total relative dominance of native and exotic species on the chronosequence on coal overburden spoils.

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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