Summary of Doctoral Thesis

Enrollment year:2021
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Title	Characteristics of post mining soils in Indonesia and its remediation

Tropical rainforests in Indonesia supply the world's abundant terrestrial biodiversity and play an important role in the global climate. However, area of rainforest in Indonesia has been decreasing from time to time. Opencast bauxite mining, opencast nickel mining, gold tailings and oil extraction have significant impacts on tropical rainforests, affecting their vegetation and animal biodiversity, soil fertility, ecological function and services. Land remediation activities are required for reduction of damage caused by opencast mining, gold tailings and oil extraction. The remediation of damaged forests in Indonesia is difficult, due to effect of mining and oil extraction process on the landscape of the local environment. It is necessary to select plant species, and to use microbial activity for remediation of degraded areas. The aims of this study were (1) to clarify the effects of opencast bauxite mining on the chemical characteristics of soil and its effect on the plant growth, (2) to clarify chemical characteristics of gold mine tailings and its effect on the growth of plants under greenhouse conditions, (3) to determine the impact of opencast nickel mining on soil chemical properties and its effect on the growth of two fast-growing tropical tree species under greenhouse conditions, (4) to determine the effect of inoculation with two indigenous arbuscular mycorrhizal (AM) fungi on the growth of plants in the nursery and post-opencast bauxite mining field conditions, and (5) to clarify the effect of Asteraceae plants on degradation of petroleum hydrocarbon in contaminated soils.

Soils were collected from both natural forest and post mining land in Indonesia, nearby bauxite mining site in Bintan Island, Sumatera; nickel mining site at Sorowako, East Luwu, South Sulawesi and gold mining site at Pongkor, Bogor, West Java. Soil pH, total carbon (C), nitrogen (N), and available phosphorus (P) concentrations, cation exchange capacity (CEC), C/N ratio and exchangeable K, Na, Mg, Ca, Fe and Ni

concentrations of post mining soil from bauxite, nickel and gold tailings were analyzed.

The plant species used in this investigation were *Gmelina arborea* (Verbenaceae), *Samanea saman* (Fabaceae), *Falcataria moluccana* (Fabaceae), *Enterolobium cyclocarpum* (Fabaceae). Aster family plants were also used, including *Achillea filipendulina* Lam., *Anthemis tinctorial* (L.) J. Gay ex Guss., *Tagetes erecta* L., *Chrysanthemum coronarium* (L.) Cass. Ex Spach., *Calendula officinalis* L., *Zinnia elegans* Jacq., and *Callistephus chinensis* L., *Cosmos caudatus* Kunth, and *Tagetes* sp. *F. moluccana* and *S. saman* were grown for 15 weeks and shoot heights, shoot and root dry weights were measured. Two native AM fungi, *Rhizophagus clarus* and *Gigaspora decipiens*, were inoculated into seeds of *G. arborea*, *S. saman*, *F. moluccana*, and *E. cyclocarpum*. The seeds were sown in post-bauxite mining soil and grown in the nursery for three months. The seedlings were transplanted into a post-opencast bauxite mining field and grown for 12 months. AM fungal colonization and shoot and root dry weights were measured. Initial soils with 40 and 90 g kg^{-1} of total petroleum hydrocarbon (TPH) were prepared. There were three treatments: (1) no addition, (2) addition of $FeCl_3$ and nitrilotriacetic acid (NTA) solution, and (3) addition of $FeCl_3$ and NTA and the cultivation of nine Asteraceae plants. The concentration of (TPH) was measured using infrared spectrophotometer, 2 and 3 months after transplanting (MAT). Shoot and root dry weight were measured 3 MAT.

Total N, C, and available P concentrations and exchangeable Ca, Mg, and Na concentrations in the post bauxite mining soils decreased by 75, 75.7, 15.7, 92, 100, and 52%, respectively, in comparison with the natural forest soils. The shoot and root dry weights of *F. moluccana* when grown in the post bauxite mining soils were also lower than those from the natural forest soils. There was no difference in the shoot and root dry weights of *A. saman* when grown in the two soil types. Total N, C and available P of gold mine tailings were lower than that of forest soil. CEC, Mg, K and Fe of gold mine tailings were lower than that of forest soil. C/N ratio of gold mine tailings were higher than that of forest soil. The pH (KCl), pH (H_2O), Ca and Na concentration of gold-mine tailings were higher than that of forest soil. There was no difference in Ni concentration between forest soil and gold mine tailings. Shoot dry weight and root dry weight of *F. moluccana* on gold mine tailings were lower than that of forest soil. Shoot and root dry weight of *A. saman* grown on gold mine tailings were higher than that of forest soil. The post nickel mining soils TN, TC, available P, CEC, and exchangeable Ca and Na concentrations decreased by 98%, 93%, 11%, 62%, 85%, and 74%, respectively, in comparison with the natural forest soils. The pH of post nickel mining soil was higher than natural forest soil. Shoot dry weight of *F. moluccana* seedlings grown in post mining soil was lower than that of seedlings grown in natural forest soil. There was no difference in shoot dry weight between *A. saman* seedlings grown in natural forest soil and post mining soil, as well as root dry weights of both species. Under nursery conditions, *G. arborea* inoculated with *G. decipiens* increased shoot and root dry weights by 1,431 and 359 %, respectively, while shoot dry weight of *E. cyclocarpum* inoculated with *R. clarus* and *G. decipiens* increased by 510 and 220%, respectively, in comparison with control seedlings. Root dry weight of *E. cyclocarpum* inoculated with *R. clarus* increased by 224%, in comparison with control seedlings. Shoot dry weight of *E. cyclocarpum* inoculated with *R. clarus* increased by 90%, in comparison with seedlings inoculated by *G. decipiens*. Twelve months after transplanting into post-opencast field conditions, the shoot dry weight of *F. moluccana* inoculated with *G. decipiens* was higher than that of the control seedlings by 188%. Shoot dry weight of *E. cyclocarpum* inoculated with *R. clarus* and *G. decipiens* increased by 198% and 149%, respectively, in comparison with control seedlings. Shoot dry weight of *E. cyclocarpum* seedlings inoculated with *R. clarus* was higher by 20% than that of seedlings inoculated with G. decipiens.

The concentration of TPH in soil cultivated with *C. caudatus* was lower than that of the initial soil (40 g kg^{-1} TPH), 2 MAT. The concentrations of TPH in soils cultivated with Calendula officinalis, *C. chinensis*, *C. caudatus*, and *Tagetes* sp. were also lower than that in the initial soil, 3 MAT. The concentrations of TPH in soils cultivated with *A. filipendulina*, *A. tinctoria*, *T. erecta*, *C. coronarium*, *C. officinalis*, *C. chinensis*, and *C. caudatus* were lower than that in the initial soil (90 g kg^{-1} TPH), 2

MAT. The concentrations of TPH in soils cultivated with *T. erecta, A. tinctoria, Zinnia elegans, C. chinensis, C. caudatus*, and *Tagetes* sp. were lower than that in the initial soil, 3 MAT. *A. filipendulina* and *C. coronarium* died at both 40 and 90 kg^{-1} TPH soils.

These findings suggest that opencast bauxite mining, opencast nickel mining and gold tailings decreased the soil fertility, low fertility inhibited the initial growth of two leguminous tree, *F. moluccana* and *A. saman* were adapted better to post mining land. AM fungal inoculation promoted the growth of tropical tree species on post opencast bauxite mining land both in the nursery and field conditions. The roots of Asteraceae plants degraded petroleum hydrocarbon in contaminated soil and *C. chinensis* and *Z. elegans* were more suitable for TPH remediation. Plant survival and extensive root system were important factors for the remediation of TPH in contaminated soil.

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