Journal of Developments in Sustainable Agriculture 7: 97−102 (2012)

Integrating Biodiversity Conservation and Agricultural Production in Mine Reclamation for Sustainable Development

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Mining operations, despite their significant contribution to the Indonesian national income, have been criticized for causing environmental degradation and biodiversity loss. The removal of vegetation, soil, and overburden (i.e., rock covering coal or ores) before excavating coal and mineral ores destroys ecosystems and degrades soil quality. After a mining operation is completed, an extensive open area with one or several ponds needs to be restored. In the last decade there has been significant progress in the management of former mine sites in Indonesia. New policies based on tougher regulations and supervision, the education of mining staff, and awards for environmentally sound practices have stimulated mining companies to integrate biodiversity conservation and agricultural production into their mine reclamation programs to ensure sustainable development of the local area as well as nationally. In their mine reclamation programs, several companies have replaced monocultures of exotic tree species, especially *Acacia mangium* and *Falcataria moluccana*, with diverse local tree species, such as ebony (*Diospyros celebica*), ironwood (*Eusideroxylon zwageri*), and many dipterocarp species, merbau (*Intsia* spp.). Model systems for the integration of agricultural production on former mine sites have also been demonstrated, such as growing cover crops to reduce surface erosion and as fodder for cattle farming as well as growing food crops (upland rice and sorghum), estate crops (oil palm, rubber, and cacao), and biofuel crops (*Jatropha, Calophyllum*). Vast ponds have been converted into productive fish or shrimp farms or are being used as water reservoirs to supply high-quality fresh water for the companies as well as nearby towns. However, studies are still needed to investigate the productivity and safety of products from former mine sites. Education and capacity-building programs to prepare competent mining staff to manage and utilize former mine sites for biodiversity conservation and agricultural production are also needed.

Key words: mining, reclamation, biodiversity, agriculture, sustainable

Introduction

Indonesia has the third largest tropical forest in the world, after Brazil and Zaire, and the forest is the home to a rich diversity of flora and fauna. Underneath the forest lay many economically valuable materials, including coal and mineral ores, such as bauxite, copper, gold, iron, nickel, and tin. Thus, Indonesia is rich in both renewable and nonrenewable natural resources.

Mining is a growing industry in Indonesia and an important source of national income. As oil prices increase, the price of coal also increases significantly, which attracts businesses to invest in coal mining. The production of coal in Indonesia jumped from around 20 million tonnes in 1992 to 275 million tonnes in 2010, according to various sources at the Ministry of Energy and Mineral Resources (MEMR) of the Republic of Indonesia (www.esdm.go.id). Unfortunately, there is also a growing concern regarding the negative environmental impacts of mining operations, which involve the removal of flora and fauna above the reserves (coal and mineral ores), reduction of soil fertility, potential air and water pollution (production of acid mine drainage; Lottermoser, 2007), and the formation of ponds

Received: November 11, 2011, Accepted: February 8, 2012
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(Sengupta, 1993).

Agriculture, including food crops, horticulture, estate crops, biofuel crops, forestry, fisheries, and livestock production, is also important in Indonesia. Considering that the population has reached 230 million people, the need for food, feed, fiber, and fuel is also increasing. Indonesia must rely on imports for some major agricultural products, such as meat, rice, soybeans, milk, and fruits, to meet these needs. Agricultural production requires land with fertile soil and a sufficient supply of water.

Mining operations destroy flora and fauna and reduce soil fertility, which are important requirements for biodiversity conservation and agricultural production. Thus, mining operations, biodiversity conservation, and agricultural production seem to be mutually exclusive undertakings. However, there have been some good examples of the integration of mining operations and agricultural production in Indonesia. In addition, some mining companies in Indonesia have integrated biodiversity conservation in the reclamation of former mining sites. A great challenge for agricultural education programs is to increase the competence of students to transform former mining sites with adverse conditions into productive land suitable for biodiversity conservation and agricultural production.

Mine Reclamation and Biodiversity Conservation

Prior to 2005, mine reclamation programs commonly used only a single, exotic, fast-growing species, especially *Acacia mangium* and *Falcataria moluccana*. In 2005, however, the mining company PT INCO Tbk. introduced the first project integrating biodiversity conservation by using local tree species in its mine reclamation program. Techniques were developed to extract seeds and seedlings from the natural forest near the mining area, vegetatively propagate the species collected, cultivate the plants in a nursery, and plant and maintain them (Mansur *et al*., 2005). Since then, courses have been conducted by Research Centre for Bioresources and Biotechnology-Bogor Agricultural University to train mining company staff how to integrate biodiversity conservation into their mine reclamation programs.

Former mine sites have proven to be good places for conserving biodiversity, especially for slow-growing, economically valuable local tree species. Because mining companies are not expecting to harvest the timber, they are not opposed to planting slow-growing tree species. Mining companies also have a high standard of security, including securing tree conservation areas. In addition, funding for the conservation efforts is available from the mining companies because Indonesian law specifies that mine reclamation is the responsibility of the companies. There is no significant difference in terms of cost between planting *Acacia* and local tree species, yet conserving local forest species builds a positive image for the companies. Table 1 lists some of the mining companies engaged in the conservation of local forest tree species.

Since 2007, the MEMR of the Republic of Indonesia has included the use of diverse local tree species as a criterion when assessing mine reclamation programs. Companies that plant local tree species receive a higher grade than those that plant monocultures of exotic species. Each year the MEMR gives the Mining Environmental Award to those mining companies achieving a certain grade of environmental performance. There are three categories for the award: bronze for basic compliance to the environmental regulations; silver for even better performance; and gold for going far beyond the compliance standards. In 2009, the Government of Indonesia through the Ministry of Forestry introduced a new regulation on mine reclamation (No. P. 60/Menhut-II/2009), in which slow-growing, economically valuable, local forest tree species must account for at least 40% of the total number of trees planted.

In addition to integrating slow-growing local tree species, since 2010 some mining companies have also replaced the exotic fast-growing species *A. mangium* and *Falcataria moluccana* with the local fast-growing species *Anthocephalus cadamba* (Mansur and Tuheteru, 2010). Other fast-growing local species that could be used in the reclamation of former mine sites are *Anthocephalus macrophyllus*, *Duabanga moluccana*, *Octomeles sumatrana*, and *Ficus variegata*. These pioneer species grow in disturbed natural forest of Indonesia, and the timber is marketable for various purposes, such as furniture, plywood, molding, pulp, and paper.

Mine Reclamation and Agricultural Production

Mine reclamation is an integral part of the sequence of mining operations that aims to return the function and productivity of the land after it has been mined. To minimize the loss of soil fertility, several steps

should be followed during mining: removing and processing organic debris from shrubs and trees into compost for later use; removing and preserving soil in one designated location and treating the soil to avoid erosion and degradation by covering it with mulch or planting legume cover crops; and properly treating potentially acid-forming rock from overburden to avoid the production of acid mine drainage with extremely low pH (pH of the water could be less than 3).

After mining in one block is completed, the pond created during the mining operation is usually filled with overburden and regraded to meet the required slope. Then the preserved soil is spread evenly to a certain depth (30−275 cm), depending on the availability of the soil. Because reconstructed soil on former mine sites is prone to erosion, cover crops are immediately planted after regrading and soil spreading are completed. Legumes, such as *Pueraria javanica*, *Centrosema pubescens*, *Calopogonium mucunoides*, and *Mucuna* spp., are the most common species used as cover crops (Mansur, 2010). These plants could be used for fodder, such that livestock production could be integrated into mine reclamation programs. Manure produced by livestock is an important source of fertilizer for reclamation programs, and it is also an important material for producing biogas for the community. However, integrating livestock production with mining operations requires caution due to possible contamination of heavy metals in the water and livestock fodder. Laboratory analyses to check the levels of heavy metal contamination in the water, fodder, and meat are necessary.

Recently, upland rice has also been used successfully as a cover crop by PT INCO Tbk., a nickel mining company based in Sorowako, South Sulawesi. Experiments to grow sorghum on former mining sites have also been conducted by several mining companies, including PT Baramulti and PT Galuh Cempaka, two coal mining companies based in South Kalimantan province. Sorghum is an important source of grain for food to replace wheat flour and for feed (Rungkat, 2010; Supriyanto, 2010; Winugroho, 2010). In addition, the sap collected from the stems of sorghum can be used to produce bio-ethanol (Yudiarto, 2010).

As part of its mine reclamation program, PT Adaro Indonesia, a coal mining company based in South Kalimantan province, is planting oil palm (*Elaeis oleifera*) and jatropha (*Jatropha curcas*) to produce biodiesel. Hauling trucks and light vehicles used for mining operation are commonly fueled with diesel. The cost for fuel would be reduced if biodiesel could be used as a partial substitute for the current fuel, and this option is also more environmentally friendly.

Cacao (*Theobroma cacao*) and rubber trees (*Hevea brasiliensis*) have also been planted as part of reclamation programs. At the former mining sites of PT Berau Coal, a coal mining company based in East Kalimantan, cacao trees were planted after shade trees (*F. moluccana*) had been planted and grew sufficiently to provide shade for the cacao trees. Rubber trees are usually used for mine reclamation at the request of the landowner, whether an individual or private company.

Planting fast-growing tree species, especially *A. mangium* and *F. moluccana*, is the most common practice for the reclamation of former mining sites. These two species have outstanding performance on former mining sites as compared to other fast-growing species commonly used in plantation forests. The trees produce abundant seeds that can be stored for up to 2 years, and the seeds are available year round and are easy to germinate to produce seedlings. *Acacia mangium* and *F. moluccana* are both legumes. They form symbiotic relationships with mycorrhizal fungi, which help the trees to absorb phosphorous from the acid soil, and with rhizobia, which enable them to fix nitrogen from the atmosphere (Mansur, 2000). Therefore, these trees survive well even in unfertile soil. Although former mining sites might be turned into productive monocultural plantations of *A. mangium* and *F. moluccana*, using local trees that can form such symbiotic relationships would be a more environmentally friendly option.

Mining operations sometimes leave ponds that cannot be filled with overburden and soil because there are no more materials to use for this purpose. After subsequent rains, these indentations fill with water and form ponds. By transforming these ponds into water reservoirs or utilizing them for fish or shrimp farms, they can become useful and productive economically and ecologically. As with livestock production on former mining sites, however, the water and fish and shrimp need to be checked for possible heavy metal contamination.

Mining companies have established large-scale experiments on biodiversity conservation and agricultural production at their former mine sites, driven by their obligation to develop a good mine closure scheme and

in the short term to improve the welfare of the surrounding communities while benefitting the company image. After mining contracts are terminated, the companies hand off the now-productive sites to the central government, local authority, or foundation established within the surrounding community. Table 1 lists some companies' work to integrate biodiversity conservation and agricultural production, and these mine reclamation programs could be developed, copied, or scaled up to meet national policy objectives in the future.

Agricultural Education and Mine Reclamation for Sustainable Development

Several mining companies have successfully integrated biodiversity conservation and agricultural production into their mine reclamation programs (Table 1). However, to make these practices standard procedure for every mining company, large numbers of competent mining staff will be needed, which will require agricultural education on topics such as agriculture, forestry, fisheries, and animal husbandry. Agriculturists will need to resolve problems related to the adverse conditions of former mine sites, including unfertile and erosion-prone soil; potential contamination of soil and water; completely open areas that are not suitable for growing shade-demanding slow-growing tree species; and the remoteness of the areas, which means they are far from sources of fertilizer and compost needed to improve soil fertility, as well as from potential markets. Furthermore, because agricultural products have relatively low economic value per unit volume, approaches used to improve the productivity of former mine sites should be realistic both technically and economically.

The Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB), Indonesia, is aiming to educate qualified staff for mining companies, especially to support timber production and biodiversity conservation of tree species at former mine sites. In the department's undergraduate program, students now learn silvicultural techniques suitable for mine reclamation and participate in practical fieldwork. In their final year, students may work on mine reclamation projects, helping mining companies to grow trees better and to conserve local tree species at their former mine sites. Only two mining companies worked with forestry students when this program began in 2005, but now companies are requesting to be involved in the program after they learned of its benefits. The department's postgraduate program has introduced the subject of restoration ecology, which covers ecological principles and approaches and silvicultural techniques important for the reclamation of former mine sites. In addition, the department's faculty provides assistance and consultation to mining companies that are committed to growing local trees species, both for production and for conservation purposes. Thus far, the Departments of Agriculture, Fisheries, and Animal Husbandry at IPB have not yet adopted these approaches, but some attempts are in progress. For example, the Department of Animal Husbandry is currently engaged in a long-term project with a coal mining company in East Kalimantan province to integrate mine reclamation with livestock production to utilize cover crops, planted initially for erosion control, as animal feed, and to utilize manures to improve soil fertility of ex-mine sites.

Outside of the university system, faculty members of the Department of Silviculture have also conducted various training courses for government officials and staff of mining companies. Furthermore, in 2007 the Department of Silviculture was appointed by the MEMR to be part of a team that monitors the progress and success of mining companies as part of the yearly national evaluation. During monitoring visits, the appointed faculty members share their knowledge with the mining staff to improve mine reclamation practices. In turn, the experiences the faculty members gain while in the field monitoring the reclamation programs are then incorporated into their teaching activities. Therefore, the students are continually updated with new information on the new approaches and technologies implemented in the field.

Conclusions

It is important to integrate biodiversity conservation and agricultural production into the reclamation of former mine sites to ensure sustainable local and national development. Good examples of ways to integrate biodiversity conservation, agricultural production, and mine reclamation have been demonstrated by some mining companies in Indonesia. However, agricultural education needs to be improved to provide competent human resources to do this work. Exposing lecturers and students to mine reclamation activities in the field is a good way to build their competence. This is important for the future development of mine recla-

Table 1. Mining companies that have integrated biodiversity conservation and agricultural production in their mine reclamation programs

Field of Agriculture	Activities	Companies Involved	Notes
Forestry	Monoculture plantation forest	Almost all mining companies in Indonesia	Using the exotic tree species *Acacia mangium* and *Falcataria moluccana*
	Conservation of forest tree biodiversity	PT INCO Tbk., PT Indominco Mandiri, PT Bukit Asam, PT Newmont Minahasa Raya, PT Newmont Nusa Tenggara, PT Kaltim Prima Coal, PT Berau Coal	Important local tree species being conserved include ebony (*Diospyros celebica*), ironwood (*Eusideroxylon zwageri*), merbau (*Intsia* spp.), dipterocarp species, *Palaquium* spp., and *Agathis loranthifolia*. (About 65 species of local trees have been planted by PT INCO Tbk.)
Agriculture	Rice plants for cover crops	PT INCO Tbk.	
	Sorghum for cover crops	PT Galuh Cempaka, PT Baramulti	
	Oil palm plantation	PT Kaltim Prima Coal, PT Adaro Indonesia	
	Rubber plantation	PT Teguh Sinar Abadi, PT Firman Ketaun, PT Karya Utama Tambang Jaya	
	Cacao plantation	PT Berau Coal	
	Biofuel crops	PT Adaro Indonesia	Species planted are *Jatropha curcas* and *Calophyllum* spp.
Animal Husbandry	Cattle farming	PT Adaro Indonesia, PT Kaltim Prima Coal, PT Berau Coal	Use cover crops for fodder
	Biogas production	PT Adaro Indonesia	In collaboration with local communities
	Compost production	PT Adaro Indonesia, PT INCO Tbk.	
Fisheries	Fish farming in Former mine ponds	PT Adaro Indonesia, PT Berau Coal, PT Arutmin Indonesia	
	Shrimp farming in former mine ponds	PT Adaro Indonesia, PT Berau Coal	
	Processing water from former mine ponds	PT Adaro Indonesia	Supply fresh water to nearby towns

mation programs in the country.

Acknowledgements

We thank the Ministry of Energy and Mineral Resources and mining companies mentioned in this paper for funding and the opportunity to visit the site, to conduct research, and information provided. We thank the Director of SEAMEO BIOTROP and the Ag-ESD Organizing Committee, University of Tsukuba Agricultural and Forestry Research Center (AFRC), University of Tsukuba for support to attend the Ag-ESD Symposium, and Dr. DeMar Taylor for his continued support during the writing of this paper.

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