Eco. Env. & Cons. 27 (August Suppl. Issue) : 2021; pp. (S287-S292)
Copyright@ EM International
ISSN 0971–765X

Ecological restoration of gold minedout forest lands in East Kalimantan, Indonesia

[1]Triyono Sudarmadji* and [2]Wahjuni Hartati

[1]Laboratory of Soil-Water Conservation and Climate, Faculty of Forestry, Mulawarman University, Samarinda, Indonesia
[2]Laboratory of Soils and Forest Nutrition, Faculty of Forestry, Mulawarman University, Samarinda, Indonesia

(Received 20October, 2020; Accepted 1 April, 2021)

ABSTRACT

Physical changes in landscape is always followed by existing biological composition changes which can be assessed by analizing their ecological range and its relationship with surrounding biological components. Biological composition is frequently used as bio-indicator of ecological restoration. The research objective was to identify the biological composition after land rehabilitation works. Research was conducted at selected sites of rehabilitated forest lands (Lower Nakan-164, Upper Nakan-138, Lower Bayaq-85 and Lingau Plateau). In Lower Nakan-164, the crown of naturally growing trees have been joined and support the growth of primary plants species of Dipterocarpaceae. In Upper Nakan-138 and Lower Bayaq-85 sites, an intensive liberation cutting was done to provide open space of tree growth for forests ecosystem recovery. Lingau Plateau site showed a mature succession of dominant tree stands close to old secondary forest ecosystem.

Key words : *Mined-out forest lands, Vevegetation, Bio-indicator, Ecological restoration, Succession*

Introduction

PT Kelian Equatorial Mining (KEM) started its operations since 1992 using 1,192 hectares of 6,670 hectares forest production area. Land rehabilitation process begins with water inundation to sterilize hazardous wastes. PT KEM has been carrying out land rehabilitation - reclamation and revegetation which then entering post mining operation period.

Physical changes in landscape is followed by changes of existing biological composition which can be assessed by analyzing their ecological range and its relationship with surrounding biological components (Ann, Darboux, and Cheng, 2013; Blinkov, Kostadinov, Marinov, 2013). Accordingly, biological composition can be used as an indicator of ecological restoration, wether forest ecosystem recovery is unrestrained to the natural mechanism. Forest ecosystem succession is an essential process of changing ecosystem elements of species and vegetation varieties. Judging from existing status, primary succession occurs in area that previously had no vegetation while secondary succession takes place in a degraded areas. Based on the trend of changing present number of species is known as progressive succession. Conversely, it is called retrogressive succession if species number is getting smaller. Allogenic succession is commonly triggered by environmental changes and can be influenced by previous vegetation known as autogenic succession (Arnold and William, 2016).

Minedout forests land revegetation has been carried out to accelerate the ecological process of forest ecosystem recovery. The selection of plant species

***Corresponding author's email:** triyonosudarmadji@gmail.com

was based on the assumption that the species not only has high tolerance for critical extreme conditions but also serves as a catalyst for ecosystem recovery. It is necessary to understand the level of vegetation degradation, improvement of structure and vegetation composition in forest lands (Zhenqi, Peijun, and Jing, 2012).

The main objective of this study was to identify and analyze changes in the biological composition occurrence in the gold mined-out forest land as a guide for possible physical changes to ascertain whether the landscape of rehabilitated forest land unrestrained into natural recovery mechanisms. The expected results was providing a variety of information to determine the extent of the vegetation composition of rehabilitated areas in accelerating the process of ecological recovery.

Materials and Methods

Location and fieldworks

Study on the ecosystem changes of mined-out forest lands was conducted in the former mining area of PT KEM located in West Kutai, East Kalimantan, Indonesia. Implementation of this research activities is for (10) years of 2007-2017. The study sites is under the influence of tropical humid climate with an average of 4,000 mm annual rainfall typically wetter from September to April and drier from May to August with no distinct dry season. Four monitoring sites were purposively applied (Figure 1). Lingau Plateau site situated in pristine rainforest while Lower Nakan, Upper Nakan, and Lower

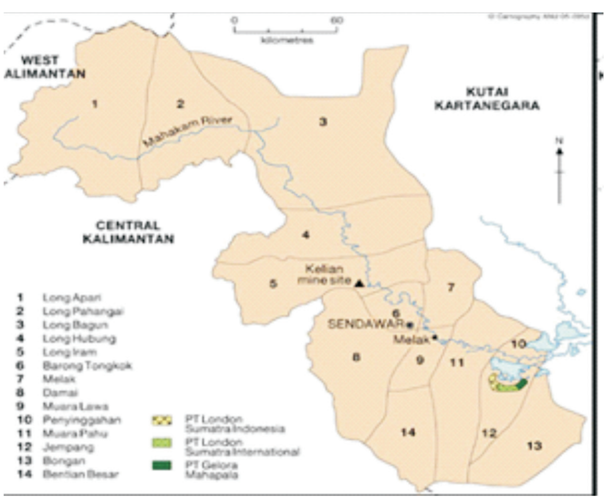

Fig. 1. Study location: Lower Nakan, Upper Nakan, Lower Bayaq, and Lingau Plateau

Bayaq sites were affected by gold mining activities. In the absence of disturbance, study location would have been surrounded by rainforest at all sites and remnants of rainforest were still present along the length of the reach studied.

Procedures

Research activities was initiated by field orientation to obtain a general description of the rehabilitated minedout forest lands followed by inventory of biological diversity. Further, monitoring was done after five and ten years of land rehabilitation works. Vegetation monitoring plots were purposivelly developed at four sites of 100m x 100m (10,000 m^2) in size with a combination of various sizes inside for census purpose. The basic condition of each sites for monitoring progress of revegetation development was desribed in Table 1.

Data Analysis

Data analysis of vegetation conditions and possible changes in biological diversity was done by using the results of the initial monitoring of biological diversity changes (2007). Further analysis of its biological diversity dynamics (planted and wildlife plant species) was carried out in 2011.

Results and Discussion

Land reclamation and revegetation

One of the most important objectives in mine closure design is that all waste dumps and tailings areas be rehabilitated to control erosion, long-term stability of the structures and prevents the exessive discharge acid mine drainage or metal leachate to surface and ground water (Aronson *et al.*, 2016; Datar *et al.*, 2011). Best practices will require detailed risk assessments and design (Balagadde, 2008). This practice should be initiated as part of the early design stages and all closure plans. Minedout forest lands have been rehabilitated to recover biophysical condition and function. Rehabilitation works need knowledges of soils, reclamation and revegetation techniques, selection of plant species in accordance with rules and site conditions, planting techniques and its maintenance (Siswanto *et al.*, 2012).

Forest lands ecosystem is a unity of landscape elements of geology, soils, hydrology, climate, flora-fauna, and usage allocations. It is therefore forest

Table 1. Site and research plots for vegetation monitoring at rehabilitated forest lands

Plot site	Size (m^2)	Sub-plots	Number of plants	Plot description
Lower Nakan-164	10,000	27 m^2 (3m x 9m)	370	Medium size waste rocks, over burden, over layered with topsoils spreading (planting year 2002/2003)
Upper Nakan-138	10,000	12 m^2 (3m x 4m)	833	Big size waste rocks, over burden, over layered with topsoils spreading (planting year 2007)
Lower Bayaq-85	10,000	9 m^2 (3m x 3m)	1.111	Small size waste rocks, over burden, over layered with topsoils spreading (planting year 2006/2007)
Lingau Plateau	10,000	400 m^2 (20m x 20m)	25	Ex ladang (slash and burn for mountain rice and horticulture) (planting year 1994)

Note:Devastated forest for disposal area was ± 1.000 Ha, waste rocks ± 10 million tons from 1 pit mining (1,8 km wide, 2 km depth)

ecosystem recovery is not only about land recovery but also other land components (Dygas, 2015). Land disturbances begins with soil damages followed by other land components. For this reason, assessing the forests ecosystem recovery must start with soils recovery. Soil recovery is seen from the soil forming process and its function as a growing plants media related with production function (Bradshaw, 2002).

Reclamation works followed by revegetation will ensure better aeration and drainage so that rooting develops and performs its functions and can provide nutrient elements (Bradshaw, 2002). Land reclamation was done by adjusting soil materials thickness, arranging contours for better drainage (Kilowasid *et al.*, 2015). In early stages, the results of minedout forest lands reclamation and revegetation are shown in Figure 2. The thickness of topsoil is at least 50 cm, however poor drainage conditions was frequently found in the form of puddles on the surface.

Vegetation dynamics

Lower Nakan (Plot-164) was prepared with medium size waste rocks over layered with topsoils spreading and planted in 2002/2003. *Dryobalanops becarii* is used for enrichment planting climatically matching in this site. Periodical vegetation growth is presented in Figure 3. Wild treesis dominated by *Leucaena leucocephala* L., *Macaranga hypoleuca*, *Octomelessumatrana*, *Ficus benjamina*, *Anthocephaluscadamba*, *Trema canabina*, *Naucleasubdita*, *Vernonia arborea*, *Trema tomentosa*, and *Falcatariamoluccana*., *Macaranga hypoleuca*, *Octomelessumatrana*, *Ficus benjamina*, *Anthocephaluscadamba*, *Trema canabina*, *Naucleasubdita*, *Vernonia arborea*, *Trema tomentosa*, and *Falcatariamoluccana*. *Macaranga hypoleuca* as pioneer species is very competitive in growth.

Upper Nakan (Plot-138) is characterised by big size rocks over layered with topsoils spreading and tree planting in 2007. *Octomeles sumatrana* decreased in number. Similar case occurs of *Macaranga hypoleuca* which is dying due to wild plants e.g. *Ipomoea sp* and *Meremia sp*. Wild plants were *Calliandra calothyrsus*, *Melastoma polyanthum*, *Trema canabina* Lour., *Widelia trilobata*, *Piper aduncum* L., *Musa sp*., *Hibiscus tiliaceus*, *Mimosa pudica*, *Nauclea subdita*, *Sesbania grandiflora* Poir., *Passiflora foetida*, *Trema*

Fig. 2. Initial condition of minedout forest land : A. land preparation layered waste rocks, B. Topsoils spreading, and C. Planting cover crops (2006)

tomentosa, *Ficus sp*., *Zingiber sp*. (Fig. 4).

Lower Bayaq (Plot-85) is characterised with big size waste rocks layered with topsoils spreading and tree planting in 2006/2007. In April 2008, the main plant species that survive only three species. However, an increase was recorded in November 2008. *Octomeles sumatra* Miq. is the main species in Plot-85. The damp conditions are closely related to climber or strangler (Figure 5). Lingau Plateau is the best ecological conditions compared to the other three plots. The species with dominant number was *Macaranga pearsonii* followed by *Durio sp*., *Nephelium lappaceum* and *Macaranga mollisimus* (Figure 6).

Macaranga pearsonii is a pioneer plant that can reach 40 m height. Stems are straight cylindrical, slightly gritty especially when reaching a diameter size above 50 cm. *Macaranga pearsonii* can grow both in secondary and primary forest, can even be found to grow naturally at the 1,500 masl. The shift that arises may be due to several changes of individual death and emerging new species (Isahak *et al.,* 2013). Ecological discussions are aimed at certain species that deserve extra attention in relation to their presence at former dominant site. of mining activities, including future ecological prospect related to its benefits or their role in the ecosystem (Aronson *et al.,* 1993). These species were *Macaranga pearsonii* (dominant in Plot Eks Ladang), *Calliandra calothyrsus* Meissn. (Plot-85), *Octomeles sumatrana* (Plot-164, Plot-85) and *Samanea saman* (Plot-138).

The level of ecological degradation currently occurring across most habitats and ecosystems has seriously decreased biodiversity. The damage is human-caused, and it has altered the fundamental ecological processes that maintain the structure and function of ecosystems (Soule, 1985). Restoration must consider many concepts, such as resilience, pattern- and process-based restoration, scale, uncertainty, level/type of disturbance causing the degeneration, and whether the place of restoration is urban, rural, or wildlands (Webb *et al.,* 2008). It is important to consider challenges and opportunities for ecological restoration, and some of the ways human intervention has altered ecological integrity (Ramirez *et al.,* 2018).

Bio-resource conservation

Conservation biology is the management of nature and of earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction and the erosion of biotic interactions. Therefore, conservation biology addresses the dynamics and problems of perturbed species, communities, and ecosystem (Lei *et al.,* 2015). Forest fragments exhibit striking changes in the vicinity of their borders, known as edge effects (Laurance, 1997; Laurila-Panta *et al.,* 2015). These effects are driven by microclimatic changes which occur in forest edges (Pinto *et al.,* 2010). Microclimatic changes in turn cause a general increase in mortality of plant communities as well as increased turnover and growth (Laurance *et al.,* 2002). Empiri-

Fig. 3. View of vegetation growth: A. 2007, B. 2011, C. 2017 (Lower Nakan Plot 164)

Fig. 4. View of vegetation growth at rehabilitated minedout forest lands: A. 2007, B. 2011, C. 2017 (Upper Nakan Plot-138)

Fig. 5. View of vegetation development at rehabilitated mined-out forest lands: A. 2007, B. 2011, C. 2017 (Lower Bayaq Plot-85)

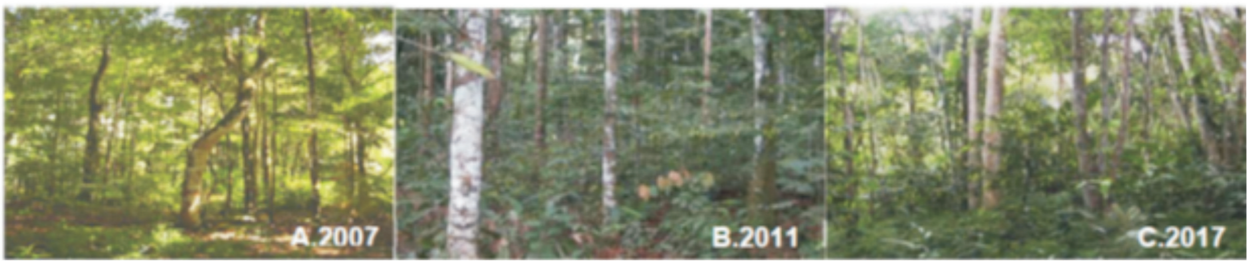

Fig. 6. View of vegetation development at rehabilitated mined-out forest lands: A. 2007, B. 2011, C. 2017 (Lingau Plateau)

cal studies shows that changes in composition are related to their functional type, late-successional, shade-tolerant species showing abundance decline at forest edges, and early-successional, shade-intolerant species increased abundance (Oliveira *et al.*, 2008). Eemergent trees are also vulnerable in small edge-effect dominated areas, and their loss contributes to a reduction biomass values (Dantas de Paula *et al.*, 2011).

Fragmentation and insularization of ecosystems is not individual system disturbance but landscape-level disturbance resulting in the re-arrangement of the landscape matrix. Therefore small patch size does not constrain total species richness (Nilsson *et al.*, 2011). From the perspective of conservation managementwhich species are being favored by edge effects, a higher species richness could be primarily due to an increased number of ruderal or weedy species of low conservation value or to a highernumberofcommunitymember (Santamartaa *et al.*, 2014).

The vegetation growth in rehabilitation area is closely related to the age of rehabilitation works. Lingau Plateau can be said having a mature succession near the old secondary forest, so that if the safe condition of the disturbance can be maintained, it is likely that the old secondary forest can be realized in the near future. Ex-field plots do not require special treatment but safeguards against possible interventions and fires. Plot-164 has ecologically developed. Maintenance needs to be done, especially the exemption of plants against staple crops, not on woody wild plants in the form of prospective trees and shrubs. Plots-138 and 85 need extra of the path, so that the existence of staple crops can be identified and evaluated.

The vegetation development in rehabilitation area was closely related with the age of restoration works. Lingau Plateau has been a mature succession near old secondary forest. Lower Nakan, Upper Nakan and Lower Bayaq sites still required creeper liberation treatment to save planted and natural vegetation potentially growing to be trees. Finally, the vegetation composition is believed accelerating the processes of ecological recovery.

Acknowledgement

The authors express sincere thanks to PT KEM for giving a chance and facilitating this research. Also, the authors gratefully acknowledged reviewers for critical review of the manuscript.

References

An, S.S., Darboux, F. and Cheng, M. 2013. Revegetation as of increasing soil aggregate stability on the Loess Plateau (China). *Geoderma.* 75-85.

Arnold, S. and Williams, E.R. 2016. The influence of soil macrofauna on soil water movement in rehabilitated open-cut mined lands. *Soil.* 2 : 41-48.

Aronson, J., Fled, C., LeFloc'h, E., Ovalle, C. and Pontanier, R. 1993. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands.

Balagadde, F.K., Song, H., Ozaki, J., Collins, C.H., Barnet, M., Arnold, F.H., Quake, S.R. and You, L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. *Mol Syst Biol*. 4 : 187. DOI: 10.1038/msb.2008.

Blinkov, I., Kostadinov, S. and Marinov, I. 2013. *Soil and Water Conservation Research.* 1 : 15-28.

Bradshaw, A.D. 2002. Introduction and philosophy of priciples of restoration. *Handbook of Ecological Restoration.* Vol. 1. Cambridge University Press.

Dantas de Paula, M., Groeneveld, J. and Hutha, A. 2015. Tropical forest degradation and recovery in fragmented landscapes - simulating changes in tree community, forest hydrology and carbon balance. *Global Ecology and Conservation*. 3 : 664-677.

Datar, A., Audet, P. and Mulligan, D. 2011. Post - Mined land rehabilitation in India. The Univ. of Queensland, St. Lucia Campus, *Brisbane*. 4072 QLD, Australia. 8 pp.

Dyguc, K.H. 2015. The role of plants in experimental biological reclamation in a bed of furnace waste from coal based energy. *Ecol. Eng.* 16 (1) : 8-22.

Gashaw, T., Bantider, A. and Silassie, H.G. 2014. Causes, impacts and rehabilitation techniques. *Environ't and Earth Science.* 4 (9) : 98-104.

Gray, A. J. 2002. Handbook of ecological restoration. Vol. 1: Principles of restoration. Cambridge University Press. Edinburgh Bldg, Cambridge CB2 2RU, UK.

Isahak, A., Surif, S., Sahani, M., Gill, A. and Phang, J. 2013. Environmental stewardship for gold mining in tropical regions. *Degraded and Mining Lands Management.* 1 (1) : 37-42.

Kilowasid, L.M.H., Herlina, Syaf, H., Safuan, L.O., Tufaila, M., Leomo, S. and Widiawan, B. 2015. Engineering of soil biological quality from nickel mining stockpile using two earth worm ecological groups. *Degraded and Mining Lands Management*. 2 (3) : 361-367.

Laurila-Panta, M., Lehikoinenb, A., Uusitaloc, L. and Venesjärvib, R. 2015. How to value biodiversity in environmental management?. *Ecological Indicators* 55: 1-11.

Lei, H., Peng, Z., Yigang, H. and Yang, Z. 2015. Vegetation succession and soil infiltration characteristics under different aged refuse dumps at the opencast coal mine. *Global Ecol. and Conservation.* 4 : 255-263.

Nilsson, C. 2011. Evaluating the process of ecological restoration. *Ecol. Society.* 21(1) : 41. http://dx.doi.org/10.5751/ES-08289-210141.

Ramirez, L.E., Yanez, B. and Miller, R. and Reading, P. 2018. Conserving biodiversity by restoring ecological processes. https://doi.org/10.1016/B978-0-12-809665-9.10506-3Get rights and content.

Santamartaa, J.C., Rodríguez-Martín, J., Merinoc, C., Paz Arraizad, M. and López, J.V. 2014. Identification of degraded land in the Canary islands; Tests and reviews. *IERI Procedia.* 8 : 77-82.

Siswanto, B., Krisnayani, B.D., Utomo, W.H. and Anderson C.W.N. 2012. Rehabilitation of artisanal gold mining land in West Lombok, Indonesia: Characterization of over-burden and the aurrounding soils. *Geology and Mining Research.* 4 (1): 1-7.

Soule, M.E. 1985. What is conservation biology?. *Bio Science.* 35 (11) : The Biological diversity crisis. Pp. 727-734.

Webb, C.O., Cannon, C.H. and Davies, S.J. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. Wiley-Blackwell, New York.

Zhenqi, H., Peijun, W. and Jing, L. 2012. Ecological restoration of abandoned mine land in China. *Resources and Ecology.* 3 (4) : 1-7.