Final Project Report (to be submitted by 30th September 2016)

Instructions:

- Document length: maximum 10 pages, excluding this cover page and the lastpage on project tags.
- Start with an abstract (max 1 page).
- Final report text: Do not forget to mention your methodology; the people involved (who, how many, what organization they are from – if applicable); and the expected added value for biodiversity, society and the company. Finally, state whether the results of your project can be implemented at a later stage, and please mention the ideal timing and estimated costs of implementation.
- Annexes are allowed but will not be taken into account by the jury and must be sent separately.
- Word/PDF Final Report files must be less than 10 MB.
- If you choose to submit your final report in your local language, you are required to also upload your final report in English if you wish to take part in the international competition.
- To be validated, your file must be uploaded to the Quarry Life Award website before **30th September 2016** (midnight, Central European Time). To do so, please log in, click on 'My account'/ 'My Final report'.
- In case of questions, please liaise with your national coordinator.

1. Contestant profile

▪ Contestant name:	**BAGUS HERWIBAWA**
▪ Contestant occupation:	LECTURER
▪ University / Organisation	DIPONEGORO UNIVERSITY
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▪ Number of people in your team:	**2**

2. Project overview

Title:	i-Drive: a quick, practical, and inexpensive method to design recommendation of reclamation in Hambalang quarry
Contest:	Indonesia
Quarry name:	Hambalang
Prize category: (select all appropriate)	☐Education and Raising Awareness ☒Habitat and Species Research ☒Biodiversity Management ☐Student Project ☐Beyond Quarry Borders

Research Article

i-Drive: a quick, practical, and inexpensive method to design recommendation of reclamation in Hambalang Quarry

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Abstract

i-Drive (*identification of drought-resistant vegetation*) is a fast, practical, and affordable method developed to design the reclamation recommendation in Hambalang Quarry with the main focus on vegetation resistance on drought stress. Five stages of i-Drive are (1) preliminary survey, (2) vegetation identification, (3) quantification of nitrogen-fixing bacteria, phosphate solubilizing bacteria, and chemical properties of soil, (4) determination of vegetation resistance on drought stress, and (5) the mapping of land reclamation strategy recommendation. The research was performed at four land types, including post mining site which has been reclaimed since 2004 (R-1), post mining site which has been reclaimed since 2008 (R-2), post mining site which has not yet been reclaimed since 2012 (R-3), active mine in 2016 (R-4), with three land surface groups, namely sunken (A-1), flat (A-2), and convex surfaces (A-3). The research shows the result that the reclamation which has been done since the last 12 years significantly reduces the light intensity, but it is not yet able to improve the microclimate significantly. There are 48 plant species with the highest diversity in the post mining site which has not yet been reclaimed since 2012. The reclamation without considering the improvement effort on microclimate for 12 years is proven not yet significant to increase the number of individuals in every growth rate. No nitrogen-fixing bacteria were found, but the phosphate solubilizing bacteria were found on every land type, and the various chemical compositions in soil among the land types. There are many local vegetations which actually drought stress resistant, namely *Acacia* spp., *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Swietenia mahagoni*, *Gliricidia sepium*, *Leucaena leucocephala*, *Panicum repens*, *Cyperus exaltatus*, *Pennisetum polystachion*, *Pennisetum purpureum*, and *Imperata cylindrica*. The reclamation strategy is compiled into three stages as follows: (1) first stage, the local plant revegetation in the alley cropping pattern between *Gliricidia sepium* tree legume and several local grass species, with the main focus on the improvement of soil fertility in the first year; (2) second stage, the local plant revegetation in the alley cropping model between *Gliricidia sepium* tree legume and several grass species dominated by Pennisetum genus, with the main focus on the improvement of soil fertility and bioenergy production from second year to third year; (3) third stage, the introduction of perennials among the alley crops to be developed into agroforestry system, with the focus to maintain soil fertility and biodiversity, and improving sustainable bioenergy production starting from fourth year. First stage, dry matter of 3,400 *Glirisidia sepium* trees is predicted to reach 59.84 ton/ha/year, while dry matter from several grass species is predicted to reach 60 ton/ha/year. Therefore, total dry matter resulted from the alley cropping model in one year is predicted to reach 119.84 ton/ha/year. Thus, the formed humus reaches 29.96 ton/ha/year, and it is predicted to increase the height of soil layer 5 cm/year. Second stage, there are many local grass species potentially as the bioethanol feedstocks, such as *Panicum maximum*, *Brachiaria brizantha*, *Cynodon dactylon*, *Dichanthium aristatum*, *Pennisetum ciliare*, *Pennisetum purpureum*, *Brachiaria humidicola.* The dry matter production of several grasses dominated by Pennisetum genus is predicted to reach 127.20 ton/ha/year with the bioethanol production of 51,810 L/ha/year. Assuming the bioethanol price is IDR 14,0000/L, the potency of gross income may reach IDR 725,340,000/ha/year with return of investment can be done in 2 years after production started. Thus, it provides ecological and economic benefits simultaneously starting from second year. Third stage, the introduction of perennials in agroforestry system, in which the chosen perennials can be potential plants to provide alternative energy, such as *Michelia champaca*, *Garcinia indica*, *Jatropa curcas*, *Pongamia pinnata*, *Calophyllum inophyllum*, *Madhuca indica*, *Azadirichta indica*, *Sterculia foetida*, *Havea brasilliensis*, and/or other crops. After the fourth year, the environment is not the obstacle anymore for the growth of perennials since the increasing thickness of humus soil layer is predicted to be more than 20 cm and can be the indicator of soil fertility environment. The soil fertility which has been improved since the first year will increase the biodiversity, since the condition of environment is optimal for the growth of many animal and plant species. These potencies will encourage the shareholders and stakeholders, especially farmers and people around quarry, to care about the revegetation activity and its management, so the obtained economic benefit will contribute to the cost efficiency in company for land reclamation, and maintain biodiversity in Hambalang Quarry.

Keywords: alley cropping, bioethanol, drought resistant vegetation, grasses, legumes trees

1. Introduction

The post mining site is a degraded zone with low physical, chemical, and biological fertility level in the soil (Mushia *et al.*, 2006). The land reclamation effort is often done by closing the excavated area with cover soil (Zulkarnain *et al.*, 2014), which has low nutrition, beneficial microbe, and water holding capacity (Dhal *et al.*, 2011). Besides, the revegetation is usually conducted by spreading cover crop seeds and timber nursery using low quality seeds (Azalia *et al.*, 2016). Several reclamation efforts require high cost and a long time to give economic benefit for shareholders and stakeholders. Therefore, the efficient, effective, and economic effort to improve land quality is really required through the revegetation of local plant which provide immidiate economical benefit.

The revegetation by planting leguminous tree/ shrub in alley cropping model supported with the activity of local microbe can accelerate the improvement of structure and soil texture, as well as soil nutrition (Kebede, 2016). Besides, leguminous tree/shrub will adaptively contribute in improving microclimate by reducing the evaporation rate of soil, reducing and stabilizing the temperature of soil and air, and maintaining the nutrition of ground water (Stinca *et al.*, 2015). Research on alley cropping model between leguminous tree/shrub and grass has been interesting since 20 years ago for its proven benefit for the ecosystem and its ability to improve total biomass (Yuhaeni *et al.*, 1997). The potency of alley cropping model with grass as the alley crop has been researched and it is able to improve the benefit of grass as a bioenergy source (Ehret *et al.*, 2015). Besides, there are many reports about the potency of several grass species as alternative energy plants (Wongwatanapaiboon *et al.*, 2012). Based on the problems, it requires a fast, practical, and affordable method to design the recommendation of soil reclamation strategy adjusted to the land condition in Quarry, so it can be expected to give faster the economic benefit. However, shallow soil solum in Quarry affects low capacity to hold water (Jim, 2001; Khan dan Kamalakar, 2012). Therefore, it requires an in-depth study on the identification of drought resistant vegetation to compile the reclamation strategy.

The suitable reclamation strategy is expected to accelerate the soil fertility improvement, so it supports the vegetation growth on soil and affects the improvement of biodiversity in Hambalang Quarry. Besides, this reclamation strategy is also expected to bring the economic benefit faster for farmers and people around Hambalang Quarry by opening new employment opportunity, and cost efficiency spent by the company for the reclamation. This research aims to (1) see the potency of land based on the preliminary survey, (2) see the potency of vegetation adaptability based on vegetation identification, (3) see the soil potency based on the quantification of nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and chemical properties of soil; (4) see the potency of vegetation development based on the vegetation resistance on drought stress; (5) compile the map of strategy recommendation for land reclamation strategy based on several existing potencies, so it is able to accelerate the restoration of soil fertility, provide economic benefit through the revegetation of short-lived species, and improve biodiversity in Hambalang Quarry.

2. Methodology

This research was conducted in Hambalang Quarry, Citeureup District, Bogor Regency, West Java Province, Indonesia, in May 2016. Five stages of i-Drive method are as follows:

2.1. Preliminary Survey. The environmental condition is marked in general based on coordination and height of place (Garmin GPS Map 62s), and it is followed by the determination of sampling location. The determined sampling location is based on the land type with the interval of 4 years as follows:

1. The post mining site which has been reclaimed since 2004 (R-1),
2. The post mining site which has been reclaimed since 2008 (R-2),
3. The post mining site which has not yet been reclaimed since 2012 (R-3),
4. Active mine in 2016 (R-4).

Every land type is grouped into three groups of land surfaces as follows:

1. Land with sunken surface (A-1),
2. Land with flat surface (A-2),
3. Land with convex surface (A-3).

In every land type and land surface group, the observation was done on some parameters of microclimate such as wind speed, temperature, relative humidity, and light intensity (Lutron LM-8000) on five observation points at 11.00-12.00 Western Indonesian Time when the research was conducted.

***2.2. Vegetation Identification*.** The vegetation sample was taken on every land type and land surface group based on the technique of quadrats (plots of a standard size) in quarry (modified from Kusmana, 1997; Trnkove *et al*., 2010). The vegetation resources inventory in the sample plots was repeated twice and conducted on five growth levels (trees, poles, saplings, and seedlings) and the ground cover with provisions as follows:

1. Criteria of trees, poles, saplings, seedlings, and ground cover are as follows:
    a. Trees: for every woody plant with a diameter of ≥ 20 cm
    b. Poles: for every woody plant with a diameter of 10-19 cm
    c. Saplings: for every woody plant with a height of > 1.5 m and diameter of < 10 cm,
    d. Seedlings: regeneration starting from sprout until it reaches a height of 1.5 m,
    e. Ground cover: every plant covering ground, from the family of grasses, sedges, plants with large leaves, and ferns.
2. The quadrats is with a size of 20 x 20 m for trees level, 10 x 10 m for poles level, 5 x 5 m for saplings level and ground cover, and 2 x 2 m for the seedlings level (Figure 1).

3. The data collected for trees, poles, saplings, seedlings and ground cover are name of species and individual number in every growth rate.

2.3. Quantification of Nitrogen-Fixing Bacteria and Phosphate-Solubilizing Bacteria, and Chemical Properties of Soil. The samples of composite soil were taken diagonally from 9 points in soil sampling on every land type and land surface group (Elfiati, 2016). The depth of soil sampling is 0-20 cm. The quantification on the population of nitrogen-fixing bacteria (Hastuti, 2007), phosphate-solubilizing bacteria (Santosa, 2007), and chemical properties of soil includes pH (H_2O), C-organic (walkley dan black), N total (kjeldahl), P available (bray 1), K-dd and cation-exchange capacity (*N* NH_4Oac pH 7,0), H-dd and Al-dd (*N* KCl), Al, Al_2O_3, Fe_2O_3, MgO, CaO, dan SiO_2.

2.4. Determination of Vegetation Resistance under Drought Stress. The resistance under drought stress was determined based on pot test and literature review. The pot test was conducted on several local vegetations which are potential to be developed as the bioethanol feedstocks, while there is no study yet related to the resistance to drought stress. The chosen local vegetation was then isolated from land with its soil into the pot (volume ± 0,125 m^3) with three repetitions. The plant was conditioned on the field capacity for three days (Zettl *et al.* 2011), then it was left without watering on the roofed open space (RH ± 73%, T ± 29 ^{0}C, LI ± 58.380 lux). The resistance to drought stress is categorized into three levels as follows:

1. Very drought resistant (VDR): the plant is not dead until > 60 days after planting.
2. Drought resistant (DR): the plant is not dead 30-60 days after planting.
3. Drought sensitive (DS): the plant is not dead 20-30 days after planting.
4. Very drought sensitive (VDS): the plant is not dead until < 20 days after planting.

***2.5.* The Mapping of Land Reclamation Strategy Recommendation**. The reclamation strategy was compiled based on the collected research data, and the strategy was mapped. The mapping was conducted with the base map of Hambalang Quarry overlay with satellite map (Google Earth).

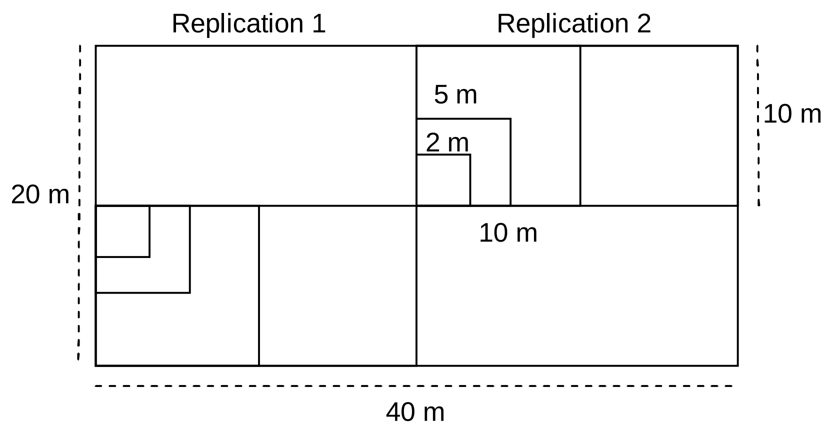

Figure 1. Sampling location based on quadrats

3. Result and Discussion

The most expensive land treatment after mining is reclamation (250-400 euro per m^2), compared with remediation (35 euro per m^2) and restoration (0.32-2.5 euro per m^2) (Lima *et al.*, 2016). However, the land restoration after mining by adopting the natural succession is proven to have the vegetation succession rate only 10-15 years, and more than 20 years on dry land in quarry (Chauman, 2015). In fact, the condition of degraded environment after mining needs immediate and affordable restoration of environmental condition, in which it can be realized through suitable reclamation strategy.

The post-mining environmental condition in general really determines the compiled reclamation strategy. Table 1 shows that light intensity on the post mining site which has not yet been reclaimed since 2012 and active mine in 2016 are higher than the post mining site which has been reclaimed since 2004 and 2008, but the wind speed, temperature, and humidity is not different on every land type. It indicates that the reclamation which has been done since the last 12 years significantly reduces the light intensity, but it is not yet able to improve the microclimate obviously. In fact, the microclimate affects the distribution of plant species (Batori *et al.*, 2014).

The plant species from every type and land surface group in this research have been successfully identified (Tabel 2). There are 49 plant species with the highest diversity in the post mining site which has not yet been reclaimed since 2012. According to Juwarkar *et al.* (2015), the reclamation in a short time reduces the species diversity and the whole ecosystem turns into the top succession species. Bowen *et al.* (2005) also reported that the species diversity decreases along with the increasing thickness of top soil, in which the local plant in a natural way grows fast in open space on thin top soil layer.

The reclamation which has been done since 2004 also affects the individual number in every growth rate (Tabel 3). The individual number in the growth level of trees and saplings is not different on the post mining site which has been reclaimed since 2004 and 2008. The poles growth level is often found on the post mining site which has been reclaimed since 2004. The growth level of seedlings and ground cover is not different between the post mining site which has been reclaimed since 2004 and 2008 and post mining site which has not yet been reclaimed since 2012. The reclamation without considering the improvement effort on microclimate for 12 years is proven could not significantly increase the individual number in every growth level. The stagnation is probably caused by the soil fertility improvement effort which is not done optimally. The soil fertility can be described through the quantity parameter of some useful bacteria and chemical properties of soil, in which the interpretation can explain the suitability of soil for the plant growth.

Table 4 shows that the nitrogen-fixing bacteria are not found in all of land types and land surface groups, while the phosphate-solubilizing bacteria are often found on the post mining site which has been reclaimed since 2004. However, the abundance of phosphate-solubilizing bacteria is not followed by the availability of phosphate significantly. The contents of available phosphate, exchangeable potassium and total nitrogen obviously are the highest on the post mining site which has been reclaimed since 2008. The restoration of undergrowth biomass, dominated by local grasses, by cutting grass periodically, supposedly affects the chemical properties of soil.

Table 1. Environmental condition from every type and land surface group in Hambalang Quarry

Land Types	Land Surfaces Groups	Elevation MSL	Slope %	Wind Speed m/s	Light Intensity x100 lux	Temperature °C	Humidity %
R-1	A-1	212.00	1.40	0.00	406.80	32.80	52.25
	A-2	240.00	0.00	1.10	50.80	30.95	60.10
	A-3	254.00	3.80	0.00	467.40	31.45	58.45
	Averages	**235.33 b**	**1.73 a**	**0.37 a**	**308.33 b**	**31.73 a**	**56.93 a**
R-2	A-1	193.00	4.20	0.00	404.20	31.20	51.30
	A-2	217.00	0.00	0.16	367.60	31.60	56.40
	A-3	235.00	0.20	0.00	439.40	38.75	42.20
	Averages	**215.00 b**	**1.47 a**	**0.05 a**	**403.73 b**	**33.85 a**	**49.97 a**
R-3	A-1	219.00	0.70	0.00	604.60	36.33	48.67
	A-2	223.00	0.00	0.70	653.40	32.90	55.40
	A-3	241.00	0.40	1.10	634.80	32.20	56.00
	Averages	**227.67 b**	**0.37 a**	**0.60 a**	**630.93 a**	**33.81 a**	**53.36 a**
R-4	A-1	248.00	0.90	0.70	628.20	35.40	47.40
	A-2	282.00	0.00	0.70	664.40	34.90	49.70
	A-3	284.00	0.70	0.00	690.80	34.30	48.60
	Averages	**271.33 a**	**0.53 a**	**0.47 a**	**661.13 a**	**34.87 a**	**48.57 a**

Remarks: R-1= the post mining site which has been reclaimed since 2004, R-2= the post mining site which has been reclaimed since 2008, R-3= the post mining site which has not yet been reclaimed since 2012, R-4= active mine in 2016, A-1= land with sunken surface, A-2= land with flat surface, dan A-3= land with convex surface. Means followed by the same letters in a column are not significantly different ($P \leq 0.05$).

The effect of biomass restoration to soil is also marked by C-organic contents, significantly the highest on the post mining site which has been reclaimed since 2008. Based on the research, Li *et al.* (2011) stated that cutting the grass periodically has positive effect on soil, such as increasing C-organic content, total nitrogen, available nitrogen, total phosphate, available phosphate, ground water, and C/N of soil. However, total nitrogen (0.06-0.15%), available phosphate (2.54-6.40 ppm), and exchange potassium (0.14-0.32 $cmol^{(+)}$/kg) on the post mining site which has not yet been reclaimed or which was reclaimed, especially on the texture of sandy clay, are still very low (Samuel dan Ebenezer, 2014). Since the availability of essential nutrient is low, the availability of nutrient source which should be made available for plant must be sought.

The source of organic nutrient from biomass of local plants becomes the only affordable choice. However, the soil solum in the quarry is shallow, so the capacity to hold ground water is low and should be considered in developing the local plants (Jim, 2001; Khan and Kamalakar, 2012). After local vegetation has been successfully identified (Tabel 2; Figure 2), its resistance was determined on the drought stress based on literature review and pot test. There are many local vegetations which are actually resistant to drought stress, such as wattles (*Acacia* spp.) (Cheng et al., 2002), calopo (*Calopogonium mucunoides*) and puero (*Pueraria phaseoloides*) (Purbajanti *et al.*, 2013), west indian mahogany (*Swietenia mahagoni*) (Saha *et al.*, 2011), quick-stick (*Gliricidia sepium*) and white leadtree (*Leucaena leucocephala*) (Fagbola *et al.*, 2001). Besides, the resistance to drought stress based on pot test has been known, such as torpedo grass (*Panicum repens*) and sedges (*Cyperus exaltatus*) which are very resistant to drought, mission grass (*Pennisetum polystachion*), elephant grass (*Pennisetum purpureum*), and bladdy grass (*Imperata cylindrica*) are drought resistant, while spinifex (*Spinifex littoreus*) and misimisi (*Scipodendron ghaeri*) are drought sensitive (Tabel 5).

Table 2. Plant species from every type and land surface group in Hambalang Quarry

No	Common Name	Scientific Name	R-1			R-2			R-3			R-4		
			A-1	A-2	A-3	A-1	A-2	A-3	A-1	A-2	A-3	A-1	A-2	A-3
1	Banana	*Musa* spp.	-	-	-	+	+	+	-	-	-	-	-	-
2	Mango	*Mangifera indica*	-	+	+	-	-	-	-	-	-	-	-	-
3	Guava	*Psidium guajava*	-	+	+	-	-	-	-	-	-	-	-	-
4	Noni	*Morinda citrifolia*	-	-	-	-	-	-	-	+	-	-	-	-
5	West Indian mahogany	*Swietenia mahagoni*	+	+	+	+	+	+	-	-	-	-	-	-
6	Quick-stick	*Gliricidia sepium*	+	+	+	+	+	+	-	-	-	-	-	-
7	White leadtree	*Leucaena leucocephala*	+	+	+	-	+	+	-	-	+	-	-	-
8	Wattles	*Acacia* spp.	-	-	-	-	-	-	+	-	+	+	-	-
9	Crown flower	*Calotropis gigantea*	-	-	-	-	-	-	-	+	+	-	-	-
10	Goatweed	*Ageratum conyzoides*	-	-	-	+	+	+	-	-	-	-	-	-
11	Wild ground nut	*Calopogonium mucunoides*	-	-	-	-	-	-	-	-	-	-	-	+
12	Tropical kudzu	*Pueraria phaseoloides*	-	-	-	-	-	-	-	-	-	-	-	+
13	Purslane	*Portulaca oleracea*	-	-	-	-	-	-	-	-	-	-	-	+
14	Sedges	*Cyperus* spp.	-	-	-	-	-	-	+	+	+	-	-	-
15	Blady grass	*Imperata cylindrica*	-	-	-	-	-	-	+	+	+	-	-	-
16	Ayapana	*Eupatorium triplinerve*	-	-	-	-	-	+	-	-	-	-	-	-
17	Setaria	*Setaria sphacelata*	-	-	-	-	-	-	+	-	-	-	-	-
18	Wild sugarcane	*Saccharum spontaneum*	-	-	-	-	-	-	+	-	+	-	-	-
19	Elephant grass	*Pennisetum purpureum*	-	-	-	-	-	-	-	+	+	-	-	-
20	Mission grass	*Pennisetum polystachion*	-	-	-	+	+	+	+	+	+	-	-	+
21	Kikuyu grass	*Pennisetum clandestinum*	-	-	-	-	-	-	+	-	-	-	-	-
22	Buffel grass	*Pennisetum ciliare*	-	-	-	-	-	-	-	-	+	-	-	-
23	Bermuda grass	*Cynodon dactylon*	-	-	-	-	-	-	+	-	-	+	-	-
24	Torpedo grass	*Panicum repens*	-	-	-	-	-	-	+	-	-	-	-	-
25	Indian goosegrass	*Eleusine indica*	-	-	-	-	-	-	-	+	-	-	-	-
26	Marvel grass	*Dichanthium annulatum*	-	-	-	-	-	-	+	+	-	-	-	-
27	Para grass	*Brachiaria mutica*	-	-	-	-	-	+	-	-	-	-	-	-
28	Beard grass	*Brachiaria brizantha*	-	-	-	+	+	-	-	-	-	-	-	-
29	Koronivia grass	*Brachiaria humidicola*	-	-	-	-	+	-	-	-	-	-	-	-
30	Bufallo grass	*Panicum maximum*	-	-	-	-	-	+	-	-	-	-	-	-
31	Angleton grass	*Dichanthium aristatum*	-	-	-	-	-	-	-	-	+	-	-	-
32	Bahia grass	*Paspalum notatum*	-	+	+	-	+	-	-	-	-	-	-	-
33	Ditch Millet	*Paspalum orbiculare*	-	-	-	-	-	-	-	+	-	-	-	-
34	Hairy crabgrass	*Digitaria sanguinalis*	-	-	-	-	-	-	-	+	-	+	-	-
35	Southern crabgrass	*Digitaria ciliaris*	-	-	-	-	-	-	-	+	-	-	-	-
36	Fiveminute grass	*Tripogon* spp.	-	-	-	-	-	-	-	-	-	+	-	+
37	Red Natal Grass	*Rhyncelytrum repens*	-	-	-	-	-	-	-	-	-	+	-	+
38	Isachne	*Isachne pangerangensis*	-	-	-	-	-	-	-	-	-	-	-	+
39	Sleepy plant	*Mimosa* spp.	-	-	-	-	-	-	+	-	+	+	-	-
40	Swollen finger grass	*Chloris barbata*	-	-	-	-	-	-	-	+	+	-	-	-
41	Spinifex	*Spinifex littoreus*	-	-	-	-	-	-	-	-	+	-	-	-
42	Rostelularia	*Rostellularia sundana*	-	-	-	-	+	+	-	-	-	-	-	-
43	Coatbuttons	*Tridax procumbens*	-	+	-	-	-	-	-	-	-	-	-	-
44	Gale of the wind	*Phyllanthus* spp.	-	-	-	-	-	-	-	-	-	+	-	+
45	Big sahe	*Lantana camara*	-	-	-	-	-	+	-	-	-	-	-	-
46	Fringed spiderflower	*Cleome rutidosperma*	-	-	-	-	-	+	-	-	-	-	-	-
47	Wood fern	*Dryopteris arida*	-	+	+	-	-	-	-	-	-	-	-	-
48	Guaco	*Mikania* spp.	-	-	-	-	-	-	+	-	-	-	-	-
49	Misimisi	*Scirpodendron ghaeri*	-	-	-	-	-	-	-	-	-	+	-	-

Remarks: R-1= the post mining site which has been reclaimed since 2004, R-2= the post mining site which has been reclaimed since 2008, R-3= the post mining site which has not yet been reclaimed since 2012, R-4= active mine in 2016, A-1= land with sunken surface, A-2= land with flat surface, dan A-3= land with convex surface. (+): presence, (-): absence.

The choosing of drought-resistant vegetation will be very helpful in improving soil fertility, especially in the first years of reclamation, since the soil solum in quarry is still shallow. The soil fertility improvement effort can be accelerated through the implementation of alley cropping model. The alley cropping with leguminous tree as the hedgerows is suitable with the condition of Hambalang Quarry, since the contents of nitrogen in the soil is low and there are no nitrogen-fixing bacteria found (Tabel 4). The leguminous tree can symbiote with the nitrogen-fixing bacteria, so it is able to improve the contents of nitrogen and carbon (C-organic) in soil, and give contribution in restoring ecosystem diversity (Chaer *et al.*, 2011). The alley crop is chosen from the local drought resistant ground cover which is dominated by grasses. The grasses are plants with the most positive response to nitrogen as the essential nutrient (Lowe *et al.*, 2002), and the need for nitrogen will be met by leguminous tree as the hedgerows through the underground process exclusively (Sierra dan Nygren, 2006). Besides, the grasses are also potentially able to improve the availability of nitrogen in the soil (Parker dan Schimel, 2010).

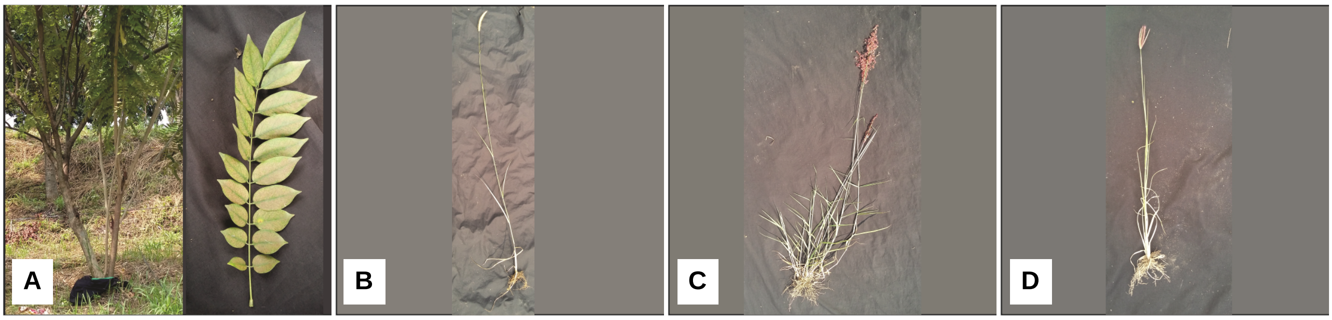

Figure 2. Several plant species in Hambalang Quarry; A= *Gliricidia sepium*, B= *Pennisetum polystachion*, C= *Rhyncelytrum repens*, D= *Chloris barbata*

Tabel 3. The individual number in every growth level in quadrats from every type and land surface group in Hambalang Quarry

Land Types	Land Surface Groups	Trees 20 m x 20 m	Poles 10 m x 10 m	Saplings 5 m x 5 m	Seedlings 2 m x 2 m	Ground Cover 5 m x 5 m
R-1	A-1	7	6	3	6	84
	A-2	32	8	2	4	191
	A-3	16	6	5	12	312
Averages		**18.33 a**	**6.67 a**	**3.33 a**	**7.33 a**	**195.70 ab**
R-2	A-1	14	2	4	2	128
	A-2	8	5	3	2	506
	A-3	13	4	3	2	110
Averages		**11.67 ab**	**3.67 b**	**3.33 a**	**2.00 ab**	**248.00 ab**
R-3	A-1	0	0	0	1	2735
	A-2	0	0	0	0	557
	A-3	0	0	2	6	637
Averages		**0.00 b**	**0.00 c**	**0.67 b**	**2.33 ab**	**1309.70 a**
R-4	A-1	0	0	0	3	18
	A-2	0	0	0	0	0
	A-3	0	0	0	0	13
Averages		**0.00 b**	**0.00 c**	**0.00 b**	**1.00 b**	**10.30 b**

Remarks: R-1= the post mining site which has been reclaimed since 2004, R-2= the post mining site which has been reclaimed since 2008, R-3= the post mining site which has not yet been reclaimed since 2012, R-4= active mine in 2016, A-1= land with sunken surface, A-2= land with flat surface, dan A-3= land with convex surface. Means followed by the same letters in a column are not significantly different ($P \leq 0.05$).

Leguminous tree as the hedgerows and grasses as the alley crops potentially result in larger biomass (Garcia *et al.*, 2001; Costa *et al.*, 2016). The biomass must be returned to soil by cutting it periodically. According to Li *et al.* (2011), periodical cutting will improve the allocation of underground biomass and species diversity. The increasing plant species diversity is actually an indicator of success in restoring environment since it has a better capacity to dampen perturbation (Li *et al.*, 2014). Therefore, the reclamation strategy must be compiled based on the identification of drought-resistant vegetation in Hambalang Quarry.

Reclamation strategy is compiled into three stages based on the purposes as follows:

1. First stage, the revegetation of local plant in the alley cropping model between leguminous tree (*Gliricidia sepium*) and several local grass species with the main focus on the improvement of soil fertility in the first year.
2. Second stage, the revegetation of local plant in the alley cropping model between leguminous tree (*Gliricidia sepium*) and several grass species

dominated by Pennisetum genus, with main focus on the improvement of soil fertility and bioenergy production from second year to third year.

3. Thirdstage, the introduction of perennials among the alley crops to be developed in the agroforestry system, with the focus to maintain soil fertility and biodiversity, and improving sustainable bioenergy production starting from fourth year.

There are many local leguminous tree which are successfully identified and drought resistant, but *Gliricidia sepium* is chosen as hedgerow in firstyear, since the biomass production is higher than other local tree legumes (Fagbenro *et al.*, 2015). Alley crops are chosen from several local grass species and drought-resistant, such as Panicum, Cyperus, Pennisetum, and Imperata. The alley cropping model is regulated with double hedgerows in which the space among tree is 1 meter, the space in tree line is 1 meter, and the space among tree lines is 5 meter, while several grass species are planted in the alley (Figure 3; inset map) (Sutarno, 2015).

Gliricidia sepium as the hedgerows with the space with closer distance is reported to result in higher biomass and nitrogen (until 60 ton/ha/year and 503 kg N/ha, respectively) (Karim and Savil, 1991). In fact, giving nitrogen 100 kg N/ha can increase the production of dry matter of *Pennisetum purpureum* until 11% (Flores *et al.*, 2012), while giving nitrogen up to 500 kg N/ha will increase the production of dry matter of *Brachiariabrizantha* by 112% (Dourado *et al.*, 2015).

The considerable biomass potency must be returned to soil by cutting it periodically. The cutting of leguminous tree with the frequency once every 4 months is reported to produce total dry matter up to 157 ton/ha/year (Kabi dan Lutakome, 2013). Meanwhile, the cutting of grass with the frequency once every 1.5 months is reported to produce total dry matter up to 14.9 ton/ha/year (Sollenberger, 2008), and the cutting should be done at the height of 15 cm on soil surface in order to achieve the optimal result (Wijitphan *et al.*, 2009).

Tabel 4. Quantities of nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and chemical properties of soil from every type and land surface group in Hambalang Quarry

Land Types	Land Surface Groups	Nitrogen-Fixing Bacteria	Phosphate Solubilizing Bacteria	pH 1:5	W & B	Kjeldahl	Bray 1	*N* NH_4Oac pH 7.0		*N* KCl		Al	Al_2O_3	Fe_2O_3	CaO	MgO	SiO_2
				H_2O	C	N	P	K	KTK	H	Al						
		(CFU/g)	(CFU/g)		%	%	ppm	cmol[(+)]/kg		cmol[(+)]/kg		%					
R-1	A-1	0	8.0 x 10^3	6.95	1.45	0.11	3.99	0.14	8.32	0.10	tr	9.95	7.63	3.73	0.37	0.56	75.94
	A-2	0	7.0 x 10^3	7.57	0.84	0.10	4.35	0.17	7.92	0.10	tr	4.37	14.94	5.29	0.30	1.02	65.24
	A-3	0	2.0 x 10^3	7.02	1.15	0.11	3.62	0.12	8.32	0.10	tr	4.76	13.70	6.46	0.32	0.99	65.23
Averages		**0**	**5.7 x 10^3**	**7.18**	**1.15**	**0.11**	**3.99**	**0.14**	**8.19**	**0.10**		**6.36**	**12.09**	**5.16**	**0.33**	**0.86**	**68.80**
		a	**a**	**b**	**b**	**b**	**b**	**b**	**b**	**a**		**a**	**a**	**a**	**c**	**b**	**a**
R-2	A-1	0	0	5.48	1.61	0.14	5.98	0.23	12.28	0.10	tr	4.50	14.45	5.76	0.37	0.99	65.01
	A-2	0	1.0 x 10^3	5.66	1.38	0.15	5.98	0.33	12.68	0.10	tr	8.40	8.81	4.31	0.43	0.50	73.99
	A-3	0	2.0 x 10^3	5.90	1.61	0.15	7.25	0.40	14.26	0.10	tr	7.31	9.89	4.18	0.64	0.76	72.26
Averages		**0**	**1.0 x 10^3**	**5.68**	**1.53**	**0.15**	**6.40**	**0.32**	**13.07**	**0.10**		**6.74**	**11.05**	**4.75**	**0.48**	**0.75**	**70.42**
		a	**b**	**c**	**a**	**a**	**a**	**a**	**a**	**a**		**a**	**a**	**a**	**c**	**b**	**a**
R-3	A-1	0	0	8.62	0.69	0.08	3.08	0.18	10.70	0.10	tr	4.31	14.94	4.86	1.63	1.29	64.38
	A-2	0	1.5 x 10^3	8.59	0.46	0.06	2.90	0.21	9.11	0.10	tr	4.70	13.61	4.99	2.24	1.80	63.95
	A-3	0	2.0 x 10^3	8.61	0.69	0.08	3.08	0.18	9.51	0.10	tr	5.06	13.06	4.31	2.54	1.20	66.04
Averages		**0**	**1.2 x 10^3**	**8.61**	**0.61**	**0.07**	**3.02**	**0.19**	**9.77**	**0.10**		**4.69**	**13.87**	**4.72**	**2.14**	**1.43**	**64.79**
		a	**b**	**a**	**c**	**c**	**bc**	**b**	**b**	**a**		**a**	**a**	**a**	**a**	**a**	**a**
R-4	A-1	0	0	8.37	0.38	0.06	2.54	0.23	9.91	0.10	tr	3.72	16.47	6.03	1.33	1.57	61.33
	A-2	0	0	7.97	0.38	0.07	3.44	0.22	10.30	0.10	tr	3.73	16.78	5.19	0.95	1.54	62.63
	A-3	0	2.5 x 10^3	8.24	0.38	0.06	1.63	0.19	8.32	0.10	tr	4.42	14.79	4.62	1.10	1.37	65.42
Averages		**0**	**0.8 x 10^3**	**8.19**	**0.38**	**0.06**	**2.54**	**0.21**	**9.51**	**0.10**		**3.96**	**16.01**	**5.28**	**1.13**	**1.49**	**63.13**
		a	**b**	**a**	**c**	**c**	**c**	**b**	**b**	**a**		**a**	**a**	**a**	**b**	**a**	**a**

Remarks: R-1= the post mining site which has been reclaimed since 2004, R-2= the post mining site which has been reclaimed since 2008, R-3= the post mining site which has not yet been reclaimed since 2012, R-4= active mine in 2016, A-1= land with sunken surface, A-2= land with flat surface, dan A-3= land with convex surface; tr= not measured. Means followed by the same letters in a column are not significantly different ($P \leq 0.05$).

The considerable biomass potency must be returned to soil by cutting it periodically. The cutting of tree legume with the frequency once every 4 months is reported to produce total dry material up to 157 ton/ha/year (Kabi dan Lutakome, 2013). Meanwhile, the cutting of grass with the frequency once every 1.5 months is reported to produce total dry material up to 14.9 ton/ha/year (Sollenberger, 2008), and the cutting should be done at the height of 15 cm on soil surface in order to achieve the optimal result (Wijitphan *et al.*, 2009).

Total dry matter resulted from the alley cropping system in one year is predicted to reach 119.84 ton/ha. According to Mutasers (2007), the conversion rate of dry matter into humus is 25%, so total humus in one year reaches 29.96 ton/ha. The humus is predicted to increase the height of soil layer by 5 cm, so it is ready for grass cultivation with the higher composition of ethanol-cellulose in the beginning of second year. There are many local grass species which have been successfully identified and can be potentially used as bioethanol feedstoks. These grass species are *Panicum maximum* (285,70 L/dry metric ton) (Lima *et al.*, 2014), *Brachiaria brizantha* (311,57 L/dry metric ton), *Cynodon dactylon* (376,30 L/dry metric ton), *Dichanthium aristatum* (426,42 L/dry metric ton), *Pennisetum ciliare* (438,90 L/dry metric ton), *Pennisetum purpureum* (466,91 L/dry metric ton), *Brachiaria humidicola* (545,49 L/dry metric ton) (Cardona *et al.*, 2012). The dry matter production of several species of grass dominated by Pennisetum genus is predicted to reach 127.20 ton/ha/year with the bioethanol production of 51,810 L/ha/year. According to Putro *et al.* (2013), when the bioethanol price is IDR 14,0000/L, the potency of gross income can reach IDR 725,340,000/ha/year. Based on calculation on capital cost and production cost arranged by Kumar and Murthy (2011) using hot water method in pretreatment and production process of ethanol, the capital cost is estimated to be IDR 631,200,000 and production cost around IDR 297,244,000/year/ha production capacity. The return of investment can be done in the second year after the first production started.

Table 5. The resistance of local vegetations as potential bioethanol feedstock under drought stress based on pot test

Common Name	Scientific Name	Replication	Resistance Level
Sedges	*Cyperus exaltatus*	1	VDR
		2	VDR
		3	VDR
Mission grass	*Pennisetum polystachion*	1	DR
		2	DR
		3	DS
Torpedo grass	*Panicum repens*	1	VDR
		2	VDR
		3	VDR
Elephant grass	*Pennisetum purpureum*	1	DR
		2	DR
		3	DR
Blady grass	*Imperata cylindrica*	1	DR
		2	DR
		3	DR
Spinifex	*Spinifex littoreus*	1	DS
		2	DS
		3	DS
Misimisi	*Scirpodendron ghaeri*	1	DS
		2	DS
		3	DS

Remarks : VDR= very drought resistant, DR= drought resistant, DS= drought sensitive, VDS= very drought sensitive

The fermentation waste from the bioethanol process must be returned to land. The waste can potentially be the phosphate source (Liao *et al.*, 2016), and it will be decomposed into the humus as a new soil layer. Thus, it provides ecological and economic benefits simultaneously starting from second year. The alley cropping model between *Gliricidia sepium* as tree legume and several grass species dominated by Pennisetum genus is maintained until the third year. In the fourth year, the perennials are introduced in the agroforestry system.

The chosen perennials can be plants to potentially provide alternative energy, such as *Michelia champaca, Garcinia indica* (Hosamani *et al.*, 2009), *Jatropa curcas* (Pandey *et al.*, 2012), *Pongamia pinnata* (Ahmad *et al.*, 2009), *Calophyllum inophyllum* (Agroramoorthy *et al.*, 2012), *Madhuca indica* (Ghadge dan Raheman, 2005), *Azadirichta indica* (Joel *et al*. 2016), *Sterculia foetida* (Bindhu *et al.*, 2012), *Havea brasilliensis* (Hassan *et al.*, 2014), and/or other crops. The perennials were planted exactly in the center of alley crop, with the space of 12 x 10 m (Figure 3, inset map). After third year, the environment is not the obstacle anymore for the growth of perennials. The increasing thickness of humus soil layer which is predicted to be more than 20 cm, can be the indicator of soil fertility improvement.

The soil fertility which has been improved since the first year will increase the biodiversity since the condition of environment is optimal for the growth of many animal and plant species. These potencies will encourage the shareholders and stakeholders, especially farmers and people around quarry, to care about the revegetation activity and its management, so the obtained economic benefit will contribute to the cost efficiency in the company for land reclamation, and maintain biodiversity in Hambalang Quarry.

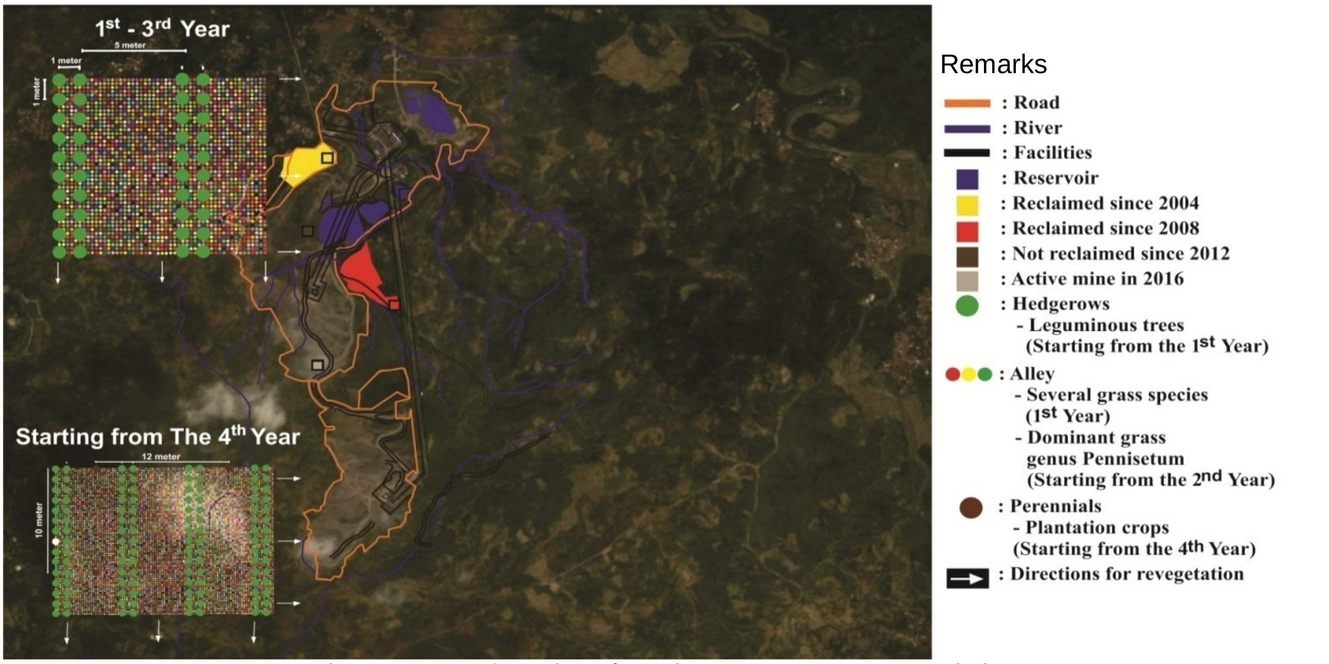

Figure 2. Map of Land Reclamation Strategy Recommendation

REFERENCES

Agoramoorthy, G., J. Sarnaik, R. Mungikar, S. Punde, and M.J. Hsu. 2012. Non-edible oil seed producing *Calophyllum inophyllum* ideal for India's future biofuel development. GCB Bioenergy 4 (6): 708-712

Ahmad, M., M. Zafar, M.A. Khan, and S. Sultana. 2009. Biodiesel from Pongamia pinnata L. oil: a promising alternative bioenergy source. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 31 (16): 1436-1442

Azalia, D., C. Retnaningdyah, and E. Arisoesilaningsih. 2016. Germination of seeds of some local pioneer plant species in different hydroseeding mulches for revegetation of post-coal mining soil. Journal of Degraded and Mining Lands Management 3 (4): 609-615.

Batori, Z., A. Lengyel, M. Maroti, L. Kormoczi, C. Tolgyesi, A. Biro, M. Toth, Z. Kincses, V. Cseh, and L. Erdos. 2014. Microclimate-vegetation relationships in natural habitat islands: species preservation and conservation perspectives. Quarterly Journal of the Hungarian Meteorological Service 118 (3): 257-281

Bindhu, C., J.R.C. Reddy, B.V.S.K. Rao, T. Ravinder, R.P. Chakrabarti, M.S.L. Karuna, and R.B.N. Prasad. 2012. Preparation and evaluation of biodiesel from *Sterculia foetida* seed oil. Journal of the American Oil Chemist' Society 89 (5): 891-896

Bowen, C.K. G.E. Schuman, and R.A. Olson. 2005. Long-term plant community development in response to topsoil replacement depth on post mining site in Wyoming. Proceeding America Society of Mining and Reclamation. pp. 108-114.

Cardona, E.M., Rios, L.A., and Pena, J.D. 2012. Availability of grasses and forages as potential lignocellulosic materials for bioethanol production in Colombia. Informacion Tecnologica 23 (6): 87-96 (in Spanish, English abstract).

Chaer, G.M., A.S. Resende, E.F.C. Campello, S.M. de Faria, R.M. Boddey, and S. Schmidt. 2011. Nitrogen-fixing legume tree species for the reclamation of severely degraded lands in Brazil. Tree Physiology 31 (2): 139-149.

Cheng, M. H., J.A. McConchie, and C.D. Qiang. 2002. The drought resistance of Acacia and Eucalyptus in Yuanmou dry-hot valley Yunan province. Research of Forestry Science 15(1): 101-103 (in Chinese, English abstract).

Chuman, T. 2015. Restoration practices used on post mining sites and industrial deposits in the Czech republic with an example of natural restoration of Granodiorite quarries and spoil heaps. Journal of Landscape Ecology 8 (2): 29-46

Cordeiro, Y.E.M., H.A. Pinheiro, B.G.dos-Santos-Filho, S.S. Correa, J.R.R. e Silva, and M.B. Dias-Filho. 2009. Physiological and morphological responses of young mahogany (Swietenia macrophylla King) plants to drought. Forest Ecology and Management 258: 1449-1455

Costa, S.B.M. A.C.L. de Mello, J.C.B. Dubeux, M.V.F. dos Santos, M.A. Lira, J.T.C. Oliveira, and V.X.O. Apolinario. 2016. Livestock performance in warm-climate silvopastures using tree legumes. Agronomy Journal 108 (5): 2026-2035

Dhal, B., N.N. Das, B.D. Pandey, and H.N. Thatoi. 2011. Environmental quality of the Boula-Nuasahi cromite mine area in India. Mine Water and the Environment 30 (3):191-196.

Dourado, R.L., A.L. de Souza, A. M. Zanine, F.L.B. Toral. D.J. Ferreira, and J.G. de Abreu. 2015. Structural and production characteristics of piata grass forage submitted to levels of nitrogen. American Journal of Plant Sciences 6(5):693-701.

Ehret, M., L. Buhle, R. Graβ, N. Lamersdorf, and M. Wachendorf. 2015. Bioenergy provision by an alley cropping system of grassland and shrub willow hybrids: biomass, fuel characteristics, and net energy yields. Agroforestry Systems 89 (2): 365-381.

Elfiati, D. 2016. Biological properties of soils of former forest fires in Samosir regency of North Sumatera. Journal of Degraded and Mining Lands Management 3(3): 603-607

Fagbenro, J.A., S.O. Oshunsanya, P.A. Aluko, and B.A. Oyeleye. 2015. Biomass production, tissue nutrient concentration, and N_2 fixing potentials of seven tropical leguminous species. Communications in Soil Science and Plant Analysis 46:709-723

Fagbola, O, O. Osonubi, K. Mulongoy, and S.A. Odunfa. 2001. Effects of drought stress and asbuscular myorrhiza on the growth of *Gliricidia sepium* (Jacq). Walp, and *Leucaena leucocephala* (Lam.) de Wit. In simulated eroded soil conditions. Mycorrhiza 11:215-223

Flores, R.A., S. Urquiaga, B.J.R. Alves, L.S. Collier, and R.M. Boddey. 2012. Yield and quality of elephant grass biomass produced in cerrados region for bioenergy. Engenharia Agricola 32(5): 831-839

Franzluebbers, A.J., and J.A. Stuedemann. 2. Bermudagrass management in the Southern Piedmont USA. III. Particulate and biologically active soil carbon. Soil Science Society of America Journal 67 (1):132-138

Garcia, H., P. Nygren, and L. Desfontaines. 2001. Dynamics of nonstructural carbohydrates and biomass yield in a fodder legume tree at different harvest intensities. Tree Physiology 21 (8): 523-531

Ghadge, S.V., and H. Raheman. 2005. Biodiesel production from mahua (*Madhuca indica*) oil having high free fatty acids. Biomass and Bioenergy 28 (6): 601-605

Hassan, S.N.A.M., M.A.M. Ishak, K. Ismail, S.N. Ali, and M.F. Yusop. 2014. Comparison study of rubber seed shell and kernel (*Hevea brasiliensis*) as rawa material for bio-oil production. Energy Procedia 52: 610-617

Hastuti, R.D. 2007. Bakteri Penambat Nitrogen Hidup Bebas. *In*: R. Saraswati, E. Husen, R.D.M. dan Simanungkalit (Eds.). Metode Analisis Biologi Tanah. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor. (In Indonesian)

Hosamani, K.M., V.B. Hiremath, and R.S. Keri. 2009. Renewable energy sources from *Michelia champaca* and *Garcinia indica* seeds oils: a rich source of oil. Biomass and Bioenergy 33 (2): 267-270

Jim, C.Y. 2001. Ecological and landscape rehabilitation of a quarry site in Hong Kong. Restoration Ecology 9 (1): 85-94.

Joel, T.K., S. Marcel, D.R. Djoulde, and A. Ngakou. 2016. Assessment of biofuel potential of dead neem leaves (*Azadirachta indica*) biomass in Maroua town, Cameroon. African Journal of Biotechnology 15(34): 1835-1840

Juwarkar, A.A., L. Singh, S.K. Singh, H. P. Jambhulkar, P. R. Thawale and H. Kanfade. 2016. Natural vs. Reclaimed forests- a case study of successional change, reclamation techniques and phytodiversity. International Journal of Mining, Reclamation and Environment 29 (6): 476-498

Kabi, F., and P. Lutakome. 2013. Effect of harvesting *Gliricidia sepium* at different cutting frequencies on quantity and quality of herbage biomass for diary cattle nutrition. Journal of Animal Science Advances 3 (6): 321-336

Karim, A.B., and P.S. Savill. 1991. Effect of spacing on growth and biomass production of *Gliricidia sepium* (jacq) walp in an alley cropping system in Sierra Leone. Agroforestry Systems 16 (3): 213-222.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, P.P Wiatrak, and J.R. Rich. 2005. Cotton roots, earthworms, and infiltration characteristics in Sod-Peanut-Cotton cropping systems. Agronomy Journal 99(2): 390-398

Kebede, D. 2016. Role of *Leucaena leucocephala* (Lam.) de Wit in soil management: a review. Agricultural Science Research Journal 6(3): 71-78.

Khan, M.A.A., and J. Kamalakar. 2012. Physical, physico-chemical and chemical properties of soild of newly established Agro-biodiverity Park of Acharya NG Ranga Agricultural University, Hyderabad, Andhra Pradesh. International Journal of Farm Sciences 2 (2): 102-116.

Kusmana, C. 1997. Metode Survei Vegetasi. PT. Penerbit Institut Pertanian. Bogor, Bogor.

Li, W., H.Z. Huang, Z.N. Zhang, and G.L. Wu. 2011. Effects of grazing on the soil properties and C and N storage in relation to biomass allocation in an alpine meadow. Journal of Soil Science and Plant Nutrition 11 (4): 27-39

Li, W., R. Tan, Y. Yang, and J. Wang. 2014. Plant diversity as a good indicator of vegetation stability in a typical plateau wetland. Journal of Mountain Science 11 (2): 464-474

Liao, X., B. Hogue, S. Zhu, Z. Tong, G. Liu, and Y. Li. 2016. Using bioethanol wastes as an alternative phosphorus source for snap bean and radish production. American Journal of Environmental Science 12 (1): 1-7

Lima, A.T., K. Mitchell, D. W. O'Connell, J. Verhoeven, and P.V. Cappellen. 2016. The legacy of surface mining: Remidiation, restoration, reclamation and rehabilitation. Environmental Science and Policy

Lima, M.A., L.D. Gomez, C.G. Steele-King, R. Simister, O.D. Bernardinelli, M.A. Carvalho, C.A. Rezende, C.A. Labate, E.R. deAzevedo, S.J. McQueen-Mason, and I. Polikarpov. 2014. Evaluating the composition and processing potential of novel sources of Brazilian biomass for sustainable biorenewables production. Biotechnology for Biofuels 7 (1): 10

Lowe, P.N., W.K. Lauenroth, and I.C. Burke. 2002. Effects of nitrogen availability on the growth of native grasses exotic weeds. Journal of Range Management 55 (1): 94-98

Mushia, N.M., A. Ramoelo, and K.K. Ayisi. 2016. The impact of the quality of coal mine stockpile soils on sustainable vegetation growth and productivity. Sustainability 8 (6): 546.

Mutsaers, H.J.W. 2007. Peasant, farmers and scientist: a chronicle of tropical agriculrural science in the twentieth century. Springer Netherlands

Pandey, V.C., K. Singh, J.S. Singh, A. Kumar, B. Singh, and R.P. Singh. 2012. Jatropha curcas: a potential biofuel plant for sustainable environment development. Renewable and Sustainable Energy Reviews 16 (5): 2870-2883

Parker, S.S., and J.P. Schimel. 2010. Invasive grasses increase nitrogen availability in Calofornia grassland soils. Invasive Plant Science and Management 3 (1): 40-47

Purbajanti, E.D., Widyati, and F. Kusmiyati. 2013. Response of Indonesian tropical legumes to PEG 6000 drought stress. Journal of Biology, Agriculture and Healthcare 3 (15):115-121

Putro, H.H., C. Nugraha, and H. Setyo. 2013. Analisis kebijakan menggunakan pemodelan matematika untuk pengembangan industri bahan bakar nabati bioetanol dari mikroalga. Reka Integra 1 (1): 143-155 (In Indonesian)

Saha, A.K., S. Saha, J. Sadle, J. Jiang, M. S. Ross, R. M. Price, L.S.L.O. Sternberg, and K. S. Wendelberger. 2011. Sea level rise and South Florida coastal forests. Climatic Change 107 (1): 81-108

Samuel, A.L., and A. O. Ebenezer. 2014. Mineralization rates of soil forms of nitrogen, phosphorus, and potassium as affected by organomineral fertilizer in sandy loam. Advances in Agriculture, Article ID 149209, 5 pages. http://www.hindawi.com/ journals/aag/2014/14909/abs/

Santosa, E. 2007. Bakteri Penambat Nitrogen Hidup Bebas. *In*: R. Saraswati, E. Husen, R.D.M. dan Simanungkalit (Eds.). Metode Analisis Biologi Tanah. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor. (In Indonesian)

Sierra, J., and P. Nygren. 2006. Transfer of N fixed by a legume tree to the associated grass in a tropical silvopastoral system. Soil Biology and Biochemistry 38 (7): 1893-1903

Sollenberger, L.E. 2008. Sustainable production systems for Cynodon species in the subtropics and tropics. Revista Brasileira de Zootecnia 37:85-100

Stinca, A., G.B. Chirico, G. Incerti, and G. Bonanomi. 2015. Regime shift by an exotic nitrogen-fixing shrub mediates plant facilitation in primary succession. PloS ONE 10(4): e0123128 doi:10.1371/ journal.pone.0123128

Sutarno. 2015. Penyediaan hijauan pakan ternak kambing secara berkesinambungan dengan model modifikasi pertanaman lorong berbasis Gamal (*Gliricidia sepium*). Disertasi. Universitas Diponegoro. Semarang. (in Indonesian)

Trnkova, R., K. Rehounkova, and K. Prach. 2010. Spontaneous succession of vegetation on acidic bedrock in quarries in the Czech Republic. Preslia 82: 333-343.

Wijitphan, S., P. Lorwilai, and C. Arkaseang. 2009. Effect of cutting heights on productivity and quality of king napier grass (Pennisetum purpureum cv. King Grass) under irrigation. Pakistan Journal of Nutrition 8 (8): 1244-1250.

Wongwatanapaiboon, J., K. Kangvansaichol, V. Burapatana, R. Inochanon, P. Winayanuwattikun, T. Yongvanich, and W. Chulalaksananukul. 2012. The Potential of Cellulosic Ethanol Production from Grasses in Thailand. Journal of Biomedicine and Biotechnology 2012: Article ID 303748 doi:10.1155/2012/303748

Yuhaeni, S., N.P. Suratmini, N.D. Purwantari, T. Manurung, and E. Sutedi. 1997. Pertanaman lorong (*alley cropping*) leguminosa dengan rumput pakan ternak: Pengaruh jenis rumput dan jarak larikan glirisidia terhadap pertumbuhan dan produksi hijauan pakan. Jurnal Ilmu Ternak dan Veteriner 2 (4): 242-249 (in Indonesian)

Zulkarnain, B. Joy, P. Tuhpawana, and I. Prawira. 2014. Soil erosion assessment of the post-coal mining site in Kutai Kartanagera District, East Kalimantan Province. International Journal of Science and Engineering 7 (2): 130-136.

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Project tags (select all appropriate):

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☒ Biodiversity management
- ☐ Cooperation programmes
- ☐ Education and Raising awareness
- ☐ Endangered and protected species
- ☒ Invasive species
- ☒ Landscape management - rehabilitation
- ☒ Rehabilitation
- ☒ Scientific research
- ☒ Soil management
- ☐ Urban ecology
- ☐ Water management

Flora:

- ☐ Conifers and cycads
- ☐ Ferns
- ☒ Flowering plants
- ☐ Fungi
- ☐ Mosses and liverworts

Fauna:

- ☐ Amphibians
- ☐ Birds
- ☐ Dragonflies & Butterflies
- ☐ Fish
- ☐ Mammals
- ☐ Reptiles
- ☐ Spiders
- ☐ Other insects
- ☒ Other species

Habitat:

- ☐ Cave
- ☐ Cliffs
- ☐ Fields - crops/culture
- ☒ Forest
- ☒ Grassland
- ☐ Human settlement
- ☐ Open areas of rocky grounds
- ☐ Recreational areas
- ☐ Screes
- ☒ Shrubs & groves
- ☒ Soil
- ☐ Wander biotopes
- ☐ Water bodies (flowing, standing)
- ☐ Wetland

Stakeholders:

- ☒ Authorities
- ☒ Local community
- ☐ NGOs
- ☐ Schools
- ☐ Universities