14-Stand performance of revegetation of post coal mining

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Abstract. The success of revegetation can be monitored by an assessment of the performance of the revegetation stand. This study aims to analyze and comparing the performance of post-coal revegetation stands conventional cropping patterns and hydroseeding planting patterns. The research location is revegetation area of PT. Adaro Site Tanjung Tabalong. The research took place for 2 months from data collection, analysis of data and reporting article. Data is collected using nested plot, the main plot size used is 10 m x 40 m. The main plot is divided into 4 measuring plots measuring 10m x 10m. The main plot measuring 10m x 40m was purposively placed on 2 locations of conventional cropping revegetation stands and 4 locations for revegetation stands of hydroseeding planting patterns. Data collected are stand dimensions data in the form of individual numbers, diameter and height of trees. The composition of plant species was analyzed by tabulation matrix, the percentage of plant growth was calculated based on number of plant growth/ha, stand diversity was assessed by the Shanon-Wiener index (H '), stand volume was analyzed by volume formula, plant health was analyzed qualitatively from observations of visualization of revegetation stand. The composition of plant species used in revegetation is 6 species. The percentage of planting success for conventional planting patterns is 93.5%, while the hydroseeding planting pattern is can't be determined by the percentage of growth. The number of revegetated plants compared to the two cropping patterns has exceeded the established revegetation success rules (625 individuals / ha). Conventional plants have fewer plants/ ha than the hydroseeding pattern, but have a higher average diameter, height, stand volume and diversity index value. Based on visual observations, there was no difference in plant health between the two revegetation plots. The revegetation stand performance from the results of this study can be categorized as good.

1. Introduction

The Various types of vegetation cover change as a result of mining activities. Coal mining has changed the existing vegetation formation into open areas. Land clearing that has occurred must be following with reclamation and revegetation activities.

Based on [1,2], the area of after mining is required to carry out reclamation activities that aim to restore the land condition as according to its designation. The importance of reclamation activities in mining operation makes the techniques in reclamation activities must be planned so that reclamation activities can reach the target. Reclamation is an activity carried out throughout the mining business stage to organize, restore, and improve the quality of the environment and ecosystem so that it can function again according to its designation [1]. Revegetation is an effort to repair and restore damaged vegetation through planting and maintenance activities on ex-forest land use [3]. Revegetation is a

plant development activity in order to cover open land with certain types of plants so that it is expected to reduce land degradation that will occur.

Government Regulation Number 60/2009 concerning guidelines for evaluating the success of forest reclamation explains that the criteria for success in forest reclamation is indicated by the activities of land management, erosion control and sedimentation, and the existence of revegetation or tree planting [4]. Revegetation is part of land reclamation activities. Revegetation is an effort to restore land cover in the ecosystem of various types of plants that are adaptive to land after coal mining. The success of reclamation activities is an important stage in the improvement of the degraded environment.

The purpose of revegetation can include the re-establishment of indigenous plant communities, reducing erosion or surface flow, improving biodiversity and restoring landscape aesthetics. Landscape recovery is directly beneficial to the environment through improved wildlife habitat, biodiversity, soil productivity and water quality. There are several methods to do revegetation, such as planting adaptive seeds conventionally using planting holes and applying hydrosedding techniques to after coal mining land. Enrichment planting on land that has reached a certain age is done to increase crop diversity

The implementation of revegetation based on several research results has experienced many problems. These problems can be indicated by the bad performance of revegetation plants. Various characteristics that can be identified from the inhibition of plant growth can be seen from stagnation of growth, yellowing leaves, low growth percentages and some other plant health symptoms.

Monitoring of the success of revegetation is very important as a reference to identify problems in implementing revegetation. Stand performance is a measure that can be used to assess the success of revegetation. Stand performance was measured by approach: species composition, percentage of success of revegetation plant growth, plant diversity, pontential of stand and plant health. This study aims to analyze and compare the performance of the revegetation stand between conventional and hydroseeding cropping patterns.

2. Methods

2.1. Object and tools of research

The monitoring object is in the form of plants in the reclamation and revegetation area of PT Adaro Site Tanjung Tabalong, South Kalimantan. The main plant species is dominated by Acacia (*Acacia mangium*) and Sengon (*Paraserianthes falcataria*) and Johar (*Cassia siamea*). Enrichment plants are planted under the main vegetation stand. Some species planted are types of Gaharu (*Aquilaria malaccensis*), Jabon (*Anthocepalus cadamba*) and Pulai (*Alstonia scholaris*).

The tools used in the study are: diameter bands to measure diameter, Christen meters to measure tree height, ropes to make measuring plots, GPS to determine the coordinates of the measuring plot, Tally sheet to record measurement results, Computer hardware and software for data analysis, and documentation equipment.

2.2. Time and location of research

The implementation of the study lasted for ± 2 months from the stage of preparation, data collection, reference review, data analysis and preparation of reports. The time of data collection was conducted in March 2018. Data collection in the field lasted 4 days covering 1 day for the planning and preparation stages and 3 days of effective observation in the field.

The planting technique in revegetation activities used by the company is conventional planting using a spacing of 2 m x 5 m and planting using hydroseeding techniques. The study was conducted at 6 revegetation plant locations. 2 locations in the form of revegetation plants with conventional techniques and 4 locations with hydroseeding techniques

2.3. Procedure of data collection

Vegetation data collection is carried out using a double plot, where the main plot size used is 10 m x 40 m. The main plots are placed in several different revegetation plant locations. The main plot is

divided into 4 plots measuring 10 m x 10 m. Data collected in the form of the number of individuals, number of types and circumference / diameter.

Measurements are made on all types of revegetation plants contained in the measurement plot. Each tree in the plot is measured in height Measurement of tree diameter using phi band and measuring diameter at breast height (DBH). There are 7 locations for revegetation plots with different locations of revegetated land that are monitored. Descriptive observation through visualization is done on tree health

2.4. Analysis of data

Some analytical approaches that indicate the performance of the revegetation stand are as follows:

1. Type composition is analyzed by species list tabulation matrix,
2. The percentage of revegetation success is calculated by number of growing plants per ha. Comparative standard for success of revegetation refers to [3] that has exceeded the amount specified as a revegetation success indicator = 625 stems/ ha
3. The potential of stand is calculated by using the tree volume per hectare. The volume formula approach is:

$$v = 1/4\ \pi d^2 dt \quad (1)$$

Where:
v: tree volume
d: tree diameter
t: tree height

4. Stand diversity is calculated using the Shannon-Wiener Diversity Index [5]. The grouping of plants for the calculation of diversity index is all plants that have a diameter of ≥ 1 cm. Shanon-Wiener diversity is calculated by the formula:

$$H = -\sum Pi \ln Pi \quad (2)$$

with:
H = Shannon Diversity Index
Pi = proportion of the number of species i to the total number of species

The diversity index value category used is high for H '=> 3, while for H' = 2-3, and low for H '= <2 [6]

5. Plant health is detected from appearance or visualization of the leaves, skin and stems of plants and the presence of disturbing plants

3. Result and Discussion

3.1. Revegetation stand of conventional planting patterns

The conventional planting plot is a revegetation area that was planted on 2013. Conventional cropping patterns use planting holes and spacing of 2m x 5m. The main plot for conventional planting is plot 1 and plot 2. Plot 1 is located at the coordinates of 9758769.78 mN and 333857.88 mE, and plot 2 is located at coordinates 9757674.26 mN 333723.85 mE. The results of the calculation of plant species composition, stand volume, tree density / ha and tree diversity in the conventional cropping pattern plots are listed in Table 1.

Table 1. Ecological characteristics of revegetation plot of conventional planting pattern

No	Plant Species	mean diameter (cm)	mean Tinggi (cm)	Volume (m^3)	N/ha	H'
1	Akasia (*Acacia mangium*)	11,78	5,59	3,68	50	0,17
2	Gaharu (*Aquilaria malaccensis*)	2,83	4,00	0,13	50	0,16
3	Johar (*Cassia siamea*)	10,63	6,82	18,75	280	0,37
4	Jabon (*Anthocepalus cadamba*)	5,20	5,00	0,11	10	0,06
5	Pulai (*Alstonia scholaris*)	3,50	3,32	0,68	220	0,34
6	Sengon (*Paraserianthes falcataria*)	12,49	6,93	41,90	325	0,35
		7,74	**5,28**	**65,25**	**935**	**1,44**

There are 6 species of plants in this plot. 3 species are fast-growing plants and 2 species have medium growth species (gaharu and pulai). Early revegetation plants were *A.mangium, C.siamea* and *P.falcataria*. Enrichment activities were carried out by planting species of Pulai (*Alstonia malaccensis*) and gaharu (*Aquilaria malaccensis*). Plant species with a high tree diameter size among other species are *A.mangium, P.falcataria* and *C.siamea*. While the species that have the highest size are *P.falcataria* and *C.siamea*.

The growth of revegetation plants in conventional pattern plots is relatively good, although the value of the diversity index is still relatively low (H '= 1.44). The number of individual plants in this location ranges from 935 stems / ha. Based on the cropping pattern used, the percentage of plant growth exceeds 93,5%. The number of plants in this plot refer to [3] has exceeded the amount set as a revegetation success indicator = 625 stems / ha (Table 2). Percentage of revegetated plant growth of after coal mine land in PT Kitadin Embalut site in East Kalimantan's Kutai Kartanegara Regency for Sengon buto, trembesi and Johar plants ranged from 88% for 7-year-old plants, 77.7% for 6-year-old plants and 83,6 % for 5-year-old revegetated plants [7]. The results of the analysis of plant health, land conditions and the percentage of plant growth in plot 1 are listed in Table 2.

Table 2. Plant health and the percentage of plant growth in conventional planting plots

Plant Health	Percentage of Growth
The health of the plants from the appearance of the stems, leaves, roots and canopy of the plant is considered healthy. Number of plants / ha: 935 stems	Based on spacing 2m x 5m, the percentage of growth is 93,5% Based on RI Minister of Forestry Regulation No: P. 4 / Menhut-II / 2011 concerning Forest Reclamation Guidelines, the number of plants exceeded the target of 625 stems / ha or equivalent planting distance of 4m x 4m

The results of health analyze of plants are classified as healthy, some plants are disturbed by weeds. Weed disorders are relatively low and do not kill plants. Revegetation stand performance with conventional cropping patterns can be categorized as good.

3.2. Revegetation stand of hydroseeding pattern

The main plot of observation for revegetation of the hydroseeding pattern consists of 4 observation plots (plots 3,4,5, and plots 6). Plot 3 is located at the coordinates: 9757917.10 mN; 334266.67 mE. Plot 4 is located at the coordinate point: 9757867.23 mN; 334134.93 mE. Plot 5 is located at the coordinate point: 9757938.16 mN; 333616.04 mE, and plot 6 is located at coordinates: 9757674.26 mN; 333723.85 mE. The results of the calculation of plant species composition, stand volume, tree density / ha and tree diversity in the conventional cropping pattern plots are listed in Table 3.

Table 3. Ecological characteristics of revegetation plot of hydroseeding pattern

No	Plant Species	mean diameter (cm)	mean high (m)	Volume (m3)	N/ha	H'
1	Akasia (*Acacia mangium*)	7,21	5,13	25,70	1055	0,29
2	Gaharu (*Aquilaria malaccensis*)	2,61	2,99	0,11	73	0,13
3	Jabon (*Anthoce palus cadamba*)	2,42	3,38	0,08	58	0,11
4	Johar (*Cassia siamea*)	5,52	4,68	1,36	13	0,19
5	Pulai (*Alstonia scholaris*)	2,48	2,97	1,18	125	0,19
6	Sengon (*Paraserianthes falcataria*)	8,38	5,28	8,53	315	0,28
		4,77	**4,07**	**36,95**	**1639**	**1,19**

A.mangium, *C.siamea* and *P.falcataria* are species with the highest dimensions of trees among other species (indicated by diameter and height). *A. mangium* is the type with the highest number of individuals in the location of plot revegetation. The plot of revegetation stand is good, although the value of the diversity index is still relatively low (H '= 1.19).

Percent growth of revegetation plot of hydroseeding pattern cannot be measured at the beginning of this monitoring because there is no definite spacing of the hydroseeding system. The number of plants in plot 2 if referring to [12] far exceeds the amount determined as a revegetation success indicator of 625 stems / ha (Table 4). The results of the analysis of plant health, land conditions and the percentage of plant growth in hydroseeding plots are listed in Table 4.

Table 4. Plant health and percentage of growing plots of plants planting hydroseeding patterns

Plant Health	Percentage of Growth
The health of plants from the appearance of stems, leaves, roots and plant roots is classified as healthy. Number of plants / ha: 1639 stems	The percentage of growth cannot be calculated because of planting using the hydro seeding method Based on RI Minister of Forestry Regulation No: P. 4 / Menhut-II / 2011 concerning Forest Reclamation Guidelines, the number of plants exceeded the target of 625 stems / ha or equivalent planting distance of 4m x 4m

The results of the health analysis of plants are classified as healthy. The advantages of the hydroseeding system are that soil cover is more dense than conventional systems, so that from the aspect of soil protection against erosion it is relatively better. Disorders of plant weeds also occur in hydroseeding planting plots, but are still within tolerable limits. The revegetation stand performance with a hydroseeding planting pattern can be categorized as good.

3.3. The performance comparison the revegetation plots between conventional patterns and hydroseeding patterns

Comparison of performance between conventional pattern and hydroseeding revegetation patterns is shown in Table 5. The dimensions of stand dimensions used were diameter, height, tree volume, stand density (N / ha) and diversity index (H ').

Table 5. The Comparison of Ecological Characteristics between Plot of Conventional Pattern and Hydroseeding Pattern

Planting Pattern of Revegetation Stand	mean diameter (cm)	mean high (m)	Volume (m3)	N/ha	H'
Conventional Planting Pattern	7,74	5,28	65,25	935	1,44
Hydroseeding Pattern	4,77	4,07	36,95	1639	1,19

The crown closure at this location is relatively tight. The advantages of the hydroseeding system are that soil cover is more dense than conventional systems, so that from the aspect of soil protection against erosion it is relatively better. The lack of a hydroseeding cropping pattern is that the amount of stand biomass is relatively smaller per unit area compared to conventional cropping patterns. Based on visual observations, there was no difference in plant health between the plot of revegetation stands.

Revegetation activities can be carried out using conventional techniques using planting holes and using hydroseeding techniques. Conventional planting is generally carried out on relatively flat, easily accessible and light slopes. Planting a hydroseeding system is carried out on relatively extreme land, which is difficult to access manually.

There are differences in biomass (volume) and stand density between conventional revegetation systems using planting holes and hydroseeding systems. The selection of revegetation techniques can be adjusted to the needs, field conditions, character of the habitat and funding.

4. Conclusion

There are six types of plants used in revegetation activities in the observation plot. The percentage of planting success can only be measured on hydroseeding plots with a value of 93.5%. Based on the number of stands / ha, both observational plots of both revegetation with conventional and hydroseeding planting patterns exceed the established revegetation success rules (625 individuals / ha). There is a difference in the size of the comparison between the revegetation stand of conventional planting patterns and the hydroseeding pattern. Conventional plants have fewer plants than the hydroseeding pattern, but have a higher average diameter, height, stand volume and diversity index value. Based on visual observations, there was no difference in plant health between the two revegetation plots. The revegetation stand performance from the results of this study can be categorized as good.

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