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The use of Drone for Identifying and Mapping of Revegetation Plant in Coal Post-mines in Tanjung Enim, South Sumatra, Indonesia

D Setyawan^{1*}, H Hanum², Warsito¹, T Achadi³, and KD Paserena¹

¹ Department of Soil Science Universitas Sriwijaya, Kampus Inderalaya Km 32 Ogan Ilir 30662, Indonesia

² Department of Mathematics Universitas Sriwijaya, Kampus Inderalaya Km 32 Ogan Ilir 30662, Indonesia

³ Department of Agronomy Universitas Sriwijaya, Kampus Inderalaya Km 32 Ogan Ilir 30662, Indonesia

* dsetyawan@unsri.ac.id

Abstract. Land reclamation and revegetation of post-mines need to be monitored regularly to ensure their progress. The drone is potential due to its high resolution and simplicity in operation and image processing. This study aimed to use the drone as an alternative in identifying and mapping land after the revegetation of coal post-mines in Tanjung Enim, South Sumatra, Indonesia. The research was conducted at the IUP Banko Barat of PT. Bukit Asam Co. Ltd, Indonesia. This research was conducted from September to December 2021. The method used in this study was a manual interpretation by making a delineation of the boundaries between types of revegetation plants in 2014, 2015, 2016, 2017, 2018, 2019, and 2020 planting years. The use of drones in this study was able to determine the distribution of revegetation plants used and produce the revegetation plant distribution map with 5 land cover classes, including Eucalyptus as the dominant species while Angsana (*Pterocarpus indicus*), Merbau (*Intsia* sp), Mahogany (*Swietenia macrophylla*), and Johar (*Senna siamea*) species with their patchy patterns, covering a total area of 22.52 ha or 66.44%. Eucalyptus is the most dominantly used as revegetation species in the coal post-mine in Tanjung Enim, with an area of 22.39 ha or 66.04% of the land. The drone is reliable for monitoring revegetation progress and may be used as a supplemental tool for evaluating post-mine conditions.

1. Introduction

Land reclamation is not separated from mine operation in all cases. By Government Regulation, it is obligatory for the mine operator to improve environmental condition as soon as possible after the excavation of mine deposit. Site revegetation using fast growing species which is combined with local or indigenous plant is mostly preferred treatments [1]. On the other side, plant condition and progress needs to be monitored subsequently and on regular basis. As required by the regulation, it is important to achieve plant canopy sufficiently within the first five years of revegetation. To obtain the results, the company may use aerial monitoring [2,3].

Advances in technology are currently developing rapidly so that through technological sophistication, it is possible to process and do a job that has been done manually so far, it becomes easier, faster, and more accurate [4]. One of the technologies currently being developed in the field of mapping is the use of drones. The drone is a vehicle that can be controlled remotely [5]. The use of drones or unmanned aircraft is an alternative to identify and monitor the condition of land resources. In addition, the drone can also be used to identify the presence and distribution of revegetation plants in post coal mining areas [6,7].



Plant revegetation is an effort carried out in the restoration of post-coal mining land in carrying out land reclamation [8]. The selection of plants to be used as revegetation plants for post-coal mining must pay attention to the history of land use because the content of residual mining materials can affect the growth of these plants [9,10].

Drone has advantages when compared to satellite imagery in monitoring land and using it for mapping, including being able to operate relatively quickly and repeatedly, and being able to fly low to produce high-resolution images [8,11]. The results of an aerial survey using a drone at a low altitude will produce an aerial photo. This technology can make it easier to analyze and determine the distribution of revegetation plants through monitoring so that the weaknesses in making maps manually can be more practical [12]

This study aimed to use drone as an alternative in identifying land mapping and monitoring the area of each land cover on revegetation plants used in coal post mine at Tanjung Enim, South Sumatra. This research is expected to be used as information to obtain basic mapping data in the revegetation plant area, which is expected to be useful for the management in coal post mine ecosystem.

2. Materials and methods

2.1 Site description

This research was conducted at the mine lease of IUP Banko Barat operated by PT. Bukit Asam Tbk in Tanjung Enim, South Sumatera (Figure 1). The field research was conducted from September 2021 to December 2021. The region is mostly under humid tropical climate with annual rainfall more than 2500 mm with monthly precipitation may exceed 200-400 mm especially during November to February. Native soils generally belong to Ultisol along the hilly and sloping areas, while in the lowland is Entisol and Inceptisol.

2.2. Drone capture and image processing

The drone used in this study was the DJI Mavic 2 Pro. This drone is used for aerial photography for it has high-resolution aerial photos and a battery capacity of 10-15 minutes. This study used three kinds of software, namely 1) Software to reduce photo resolution using FastStone Photo Resizer Software, 2) Software for aerial photo processing using Agisoft Methashape Pro Software, and 3) ArcGIS 10.7 software for mapmaking of land cover

The applications in this study used 1) Pix4D, 2) DJI GO 4 and 3) Google Earth applications. This study used a method in the form of manual interpretation by making a delineation of the boundaries between types of revegetation plants found in coal post mine at Tanjung Enim. This was done directly on a computer screen or on-screen digitizing with the help of remote sensing using high-resolution drones and field data support.

Field observations are aimed at knowing firsthand the state and condition of the research location to be carried out, as well as preparing the materials and equipment needed during the research, such as drones and several applications and software that must be downloaded to facilitate research activities.

Flyway creation was designed to track fly or flight missions for drones using the Pix4D app. The function of this Pix4D is to make the drone fly according to the mission we want for research purposes and the drone will land itself at the point where the drone took off before.

Aerial photography was taken using a drone with a height of 80 meters and a drone speed in the medium category. Before the drone is flown according to the flight path that has been made, it is necessary to calibrate the drone using the DJI GO 4 application to connect the drone to help operate the drone (Figure 2).



Figure 1. Aerial view of Banko Barat coal mine area showing different years of revegetation. The dotted red lines indicate current boundary of reclamation. The gray area indicates the former pit of coal reserves.

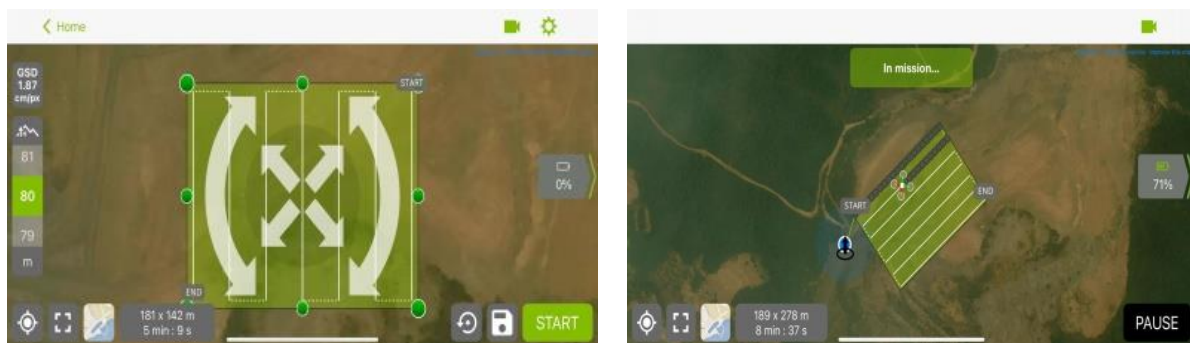


Figure 2. Example of flayway creation (left) and flying path (right).

The first processing process uses FastStone Photo Resizer Software, this software serves to reduce the image resolution of aerial photos that have been obtained using drone. The next process after the image resolution is to reduce further using Agisoft Methashape Software. The process is namely orthophoto making. The stages in this software consist of Import photo, Align photo, Build photo, Build dense point clouds, Build mesh, Build texture, DEM development, and Export orthophoto (Ikhwan *et al.*, 2021). The next step is to use ArcGIS software. This process was done by grouping each type of plant. Then, a landuse map was made by digitizing and adding file attributes in the form of a regional administration shapefile that had been prepared to strengthen the data from the map. Aerial photo analysis carried out in this study was an orthophoto accuracy test using the Root Mean Square Error (RMSE) method. The RMSE value can be obtained using the following Equation 1, 2 and 3.

$$RMSE_r = \sqrt{\frac{\sum((\Delta_r)^2)}{n}} \quad (1)$$

$$(\Delta_r)^2 = \sqrt{\Delta x^2 + \Delta y^2} \quad (2)$$

$$RMSE_z = \sqrt{\frac{\sum((Z_{data} - Z_{cek})^2)}{n}} \quad (3)$$

In which

n = Total number of checks on map

r = The value of the difference between the distance between orthophoto coordinates with field coordinates

x = Coordinate difference value on X-axis

y = Coordinate difference value on Y-axis

z = Coordinate value on the Z-axis

After that, the Circular Error (CE) 90 and Linear Error (LE) 90 are calculated as in Equation 4 and 5. Based on USNMAS (United States National Map Accuracy Standards) the CE90 and LE90 values can be obtained based on the following formula [13].

$$CE90 = 1.5175 \times RMSE_r \quad (4)$$

$$LE90 = 1.6499 \times RMSE_z \quad (5)$$

In which

RMSE_r = Root Mean Square Error on x and y positions (horizontally)

RMSE_z = Root Mean Square Error on z position (vertical)

3. Results and Discussion

The shape of the drone is represented by a red-green color that is in the flight path following the path that has been created. When the drone is in the air and has taken aerial photos of the land, the result of the track record is in the form of a camera symbol as shown in Figure 2.

Table 1. Land area in each planting year and the proportion being sampled for drone mapping

Planting Year	Land area (ha)	50% of land area (ha)	Land area on map taken using drone (ha)
2014	3	1.5	1.9
2015	10	5	5.2
2016	16.87	8.435	8.7
2017	6.82	3.41	4.3
2018	10	5	5.1
2019	7.74	3.87	4.0
2020	6.8	3.4	4.7

The area used in making the land cover map is 50% of the existing land area, as presented in Table 1. The results of the analysis of aerial photography based on the land area in Table 1 have significant comparisons such as from the total number of aerial photos obtained in the individual planting years of 2014, 2015, 2016, 2017, 2018, 2019, and 2020. FastStone Photo Resizer software can change the size of aerial photos that have been obtained using drones, this process is carried out to facilitate the next processing process, namely orthophoto formation. In processing aerial photos in this software, it can be done en masse, which means that in one processing process, the number of aerial photos to be processed can be up to hundreds of photos. Aerial photos obtained from drones have a fairly large size as shown in Table 2. Aerial photos which initially have a fairly large size from each planting year taken using drones will experience a decrease in the size of aerial photos after resizing aerial photos in this software.

Aerial photos which initially have a fairly large size from each planting year taken using drones will experience a decrease in the size of aerial photos after resizing aerial photos in this software. Aerial photos that have gone through the process of resizing in the FastStone photo resizer software will be processed again into orthophotos. The results of orthophoto on Agisoft Methashape software can be seen in Figure 3.



Figure 3. Results of the orthophoto merger (left) planting years 2014, 2015, and 2016 and (right) planting years 2017, 2018, 2019, and 2020.

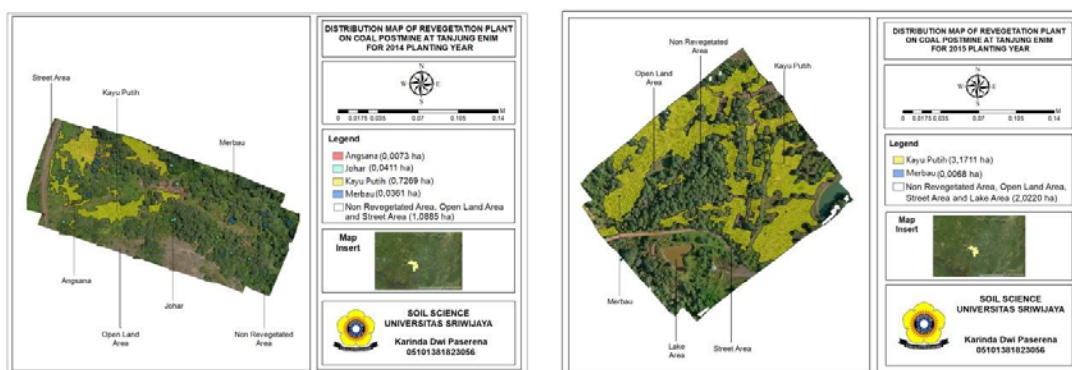


Figure 4. Distribution map of revegetation plants in coal postmine at Tanjung Enim (left) 2014 Planting Year (right) 2015 Planting Year.

The interpretation results are based on 9 elements of interpretation, namely hue, color, shape, size, texture, pattern, shadow, site, and association. The aerial photo shows 5 types of revegetation plants as land cover in coal postmine at Tanjung Enim consisting of Eucalypt, Angsana, Merbau, Mahogany, and Johar plants species (Figure 4) for the older sites and Figure 5 for the more recent sites. The distribution of the types of cover and the characteristics of each land cover is presented in Table 2. As the main plant species used for revegetation, eucalyptus occupied the largest part of the reclaimed area. However, the use of eucalyptus poses side effects due to its lower canopy cover [14–17]. Originally this species is intended for aromatic oil production. However, the higher demand of greening faster makes eucalyptus is reconsidered with less planting distance, thus more population.

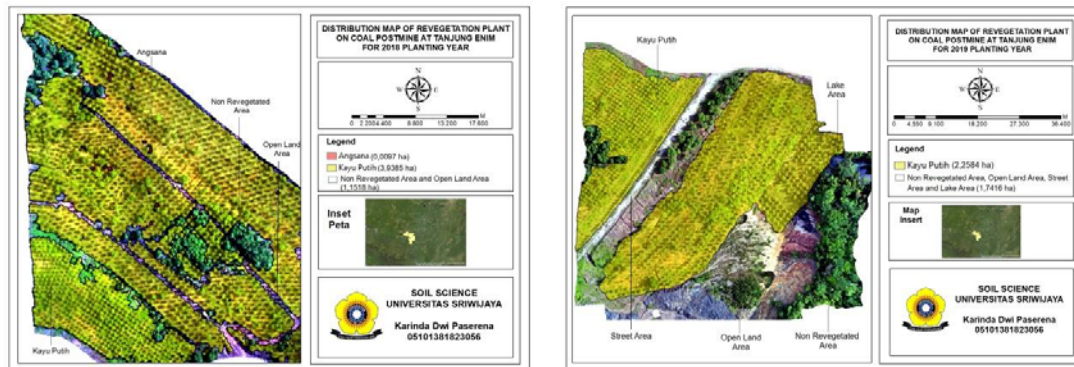


Figure 5. Distribution map of revegetation plants in coal postmine at Tanjung Enim (left) 2018 Planting Year (right) 2019 Planting Year.

Table 2. Results of calculation of the distribution area of revegetation plants in coal postmine at Tanjung Enim.

Land Cover	Total area (ha)	Coverage (%)
Angsana	0.0267	0.0787
Johar	0.0411	0.1212
Eucalyptus	22.39	66.0471
Mahogany	0.0025	0.0073
Merbau	0,0668	0,1970
Non Revegetation, Open Land, Road and Lake	11,3725	33,5471
Total	33,9	100

4. Conclusion

Utilization of the DJI Mavic 2 Pro drone in identifying and monitoring the area of revegetation land cover in coal post mine at Tanjung Enim is more efficient than conventional methods because data collection is faster and has high image resolution results.

Land cover classes can be identified into 5 classes, including Eucalypt plants, Angsana, Merbau, Mahogany, and Johar with a total area of 22.52 ha or 66.44% covering the land. Eucalyptus is more dominantly used as a revegetation plant in coal post mine at Tanjung Enim, with an area of 22.39 ha or 66.04% covering the land.

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