EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2025, 26(5), 53–60
https://doi.org/10.12912/27197050/202751
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Received: 2025.02.27
Accepted: 2025.03.24
Published: 2025.04.01

Effectiveness of unmanned aerial vehicles use in monitoring plants after forest and land rehabilitation in Barru Regency

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ABSTRACT

Monitoring the success of plant growth after forest and land rehabilitation is very important to ensure the effectiveness of environmental restoration efforts. The usual procedure in monitoring forest and land rehabilitation plants is to manually count the height of the plants and document the plants one by one in the forest and land rehabilitation area. Generally, monitoring of forest and land rehabilitation plants uses conventional methods so that the results obtained are not comprehensive. This is due to human limitations in monitoring plants in locations that are difficult to access and quite far away so that it takes a long time. This study aimed to investigate the application and effectiveness of UAVs in monitoring forest plants sustainably. This research was conducted in the forest and land rehabilitation area in the Allu block, Bonto Payung block and Landange block, Pujananting village, Pujananting district, Barru regency. The types of plants monitored in this study were the results of forest and land rehabilitation planting, namely Acacia (*Acacia manguium*), Pine (*Pinus merkusii*), Banyan (*Ficus benjamina*) and Guava (*Anacardium occidentale*, *Linn*). The data analysis used involved calculating the number of trees using the object base image analysis (OBIA) method and calculating plant height using canopy height model (CHM) analysis. Next, the growth percentage was calculated to evaluate plant growth resulting from forest and land rehabilitation planting activities. The results of analysis using the OBIA method revealed that 19.811 plants were in the Allu block, 11.983 plants were in the Bonto Payung block, and 11.927 plants were in the Landange block. In addition, for canopy height model (CHM) analysis, plant height varies from 0–1 meter, 2–3 meters, and > 3 meters. The results of the study showed that the application of UAVs was more effective than conventional methods.

Keywords: forest and land rehabilitation, monitoring, UAVs, and plants.

INTRODUCTION

Forest deforestation is a human activity that can cause the area of forest land to decrease, such as land conversion for infrastructure, settlements, agriculture, mining and plantations (Yakin, 2017). According to Forest Watch (2019), the rate of deforestation that occurred in Indonesia in 2013–2017 was 1.47 million ha per year. The government issued a policy of delaying the granting of forest use permits with the aim of reducing the rate of deforestation. As a result, in 2019 the deforestation rate was successfully reduced with the deforestation rate dropping to 0.44 million ha/year. Deforestation that continues to occur will cause a decrease in land productivity, often called degradation (Wahyuni & Suranto, 2021). The main benefit of forest and land rehabilitation is to restore critical areas, ensure the availability of natural resources, and avoid several natural disasters (Rachman et al., 2020). Forest and land rehabilitation activities have so far been proven to be able to reduce the area of critical land through restoring and improving forest and land functions, maintaining land carrying capacity, increasing water absorption capacity, and reducing surface water runoff (Narendra and Salim, 2020). By carrying out forest and land rehabilitation plants based on ecological and economic aspects, it will be better than forest areas that are simply left open without carrying out reforestation (Masthurri, 2023).

On the basis of the data from the Ministry of Environment and Forestry of the Republic of

Indonesia, one of the implementation of Forest Rehabilitation activities in south Sulawesi was carried out by the Jeneberang DAS Management and Forest Rehabilitation Center (BPDAS) in 2019 covering an area of 19.600 Ha spread across 16 districts, including the Barru district. Forest and land rehabilitation is a complex program, because it involves various aspects, requires a long period of time (several years), involves various parties, and uses many resources (Jatmiko et al., 2014).

Barru regency, especially Pujananting village, Pujananting district, is one of the villages implementing forest and land rehabilitation activities covering an area of 300 ha. Each location has a block name, namely, the Bonto Payung block covering an area of 100 ha, the Allu block covering an area of 100 Ha, and the Landange block covering an area of 100 ha. To support the success of forest and land rehabilitation, plant monitoring and evaluation methods are needed (Surtiani & Budiati, 2015).

Generally, monitoring of forest and land rehabilitation plants is carried out by manually measuring plant height as well as documenting forest and land rehabilitation plants as a basis for determining the success of forest and land rehabilitation programs. Lack of access to the necessary technology and resources, lack of technical knowledge and skills (Julvin et al., 2024), limited financial and infrastructure support as well as challenges in managing and interpreting data (Sewiko et al., 2023). These problems must be addressed so that forest and land rehabilitation plant monitoring can be carried out effectively and sustainably.

One effort that can speed up plant monitoring for forest and land rehabilitation activities is to utilize unmanned aerial vehicles (UAVs) based on spatial data networks in accordance with the policy direction of the Ministry of Environment and Forestry (Gamin, 2021). The use of UAVs, also known as drones, is a solution for monitoring forest areas because of their ability to survey and monitor large areas, which are difficult to reach and take a long time (Sutrisno et al., 2024). Mapping technology using UAVs is capable of producing photogeometric images of excellent quality and very high resolution (Mohan et al., 2021). Therefore, this study focused more on the application and effectiveness of UAVs in monitoring plants after forest and land rehabilitation in Barru regency.

METHODS

Time and place

The study was carried out in the forest and land rehabilitation area in Bonto Payung village and Landange village, Pujananting district, Barru regency, south Sulawesi province, for three months, namely from May to July 2024 (Fig. 1).

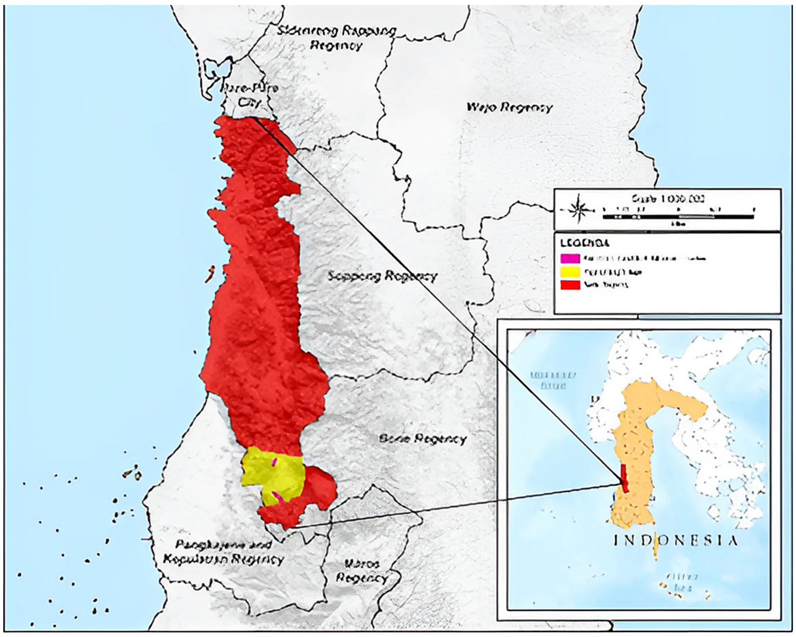


Figure 1. Study place located in Bonto Payung village and Landange village, Pujananting district, Barru regency, south Sulawesi province

Tools and materials

The tools used in this study include: (1) hardware in the form of laptops, drones, mobile phones compatible with mapping, and printers; (2) the software used was GIS; (3) aerial photo processing, SW Maps, Pix4DMapper, and DJI Go; (4) the survey tool used was the DJI Phantom 4 Pro+ V2.0 drone. The materials used in this study include mapping images from the acquisition of drone data, a map of the activity area of forest and land rehabilitation River Watershed Management Center Jeneberang Saddang in 2019, and a working map.

Data collection procedure

Data preparation refers to the data collected or prepared for use in this study. The data taken are aerial photos taken by drones or drones with the DJI Phantom 4 Pro+ V2.0 type. The altitude-adjusted flight plan missions were created. Then, drone data acquisition was performed by drone mapping activities until the overall flight mission was completed. The specifications for drone data acquisition are shown in Table 1.

Processing photo geometry results from drone data acquisition through several stages, including: (1) adding photos, (2) designing photos, (3) building dense clouds, (4) building meshes, (5) building textures, (6) building models, (7) building DEMs, and (7) building ortho mosaics (Farid, 2019). The analysis results are then used to obtain the results of natural images, DEMs, and analysis reports.

Table 1. Drone data acquisition

Types of drones	DJI Phantom 4 Pro+ V2.0.
High flying	50 m
Speed	5 m/s
Angle	90°
Overlap	80%
GSD	1.36 cm/px

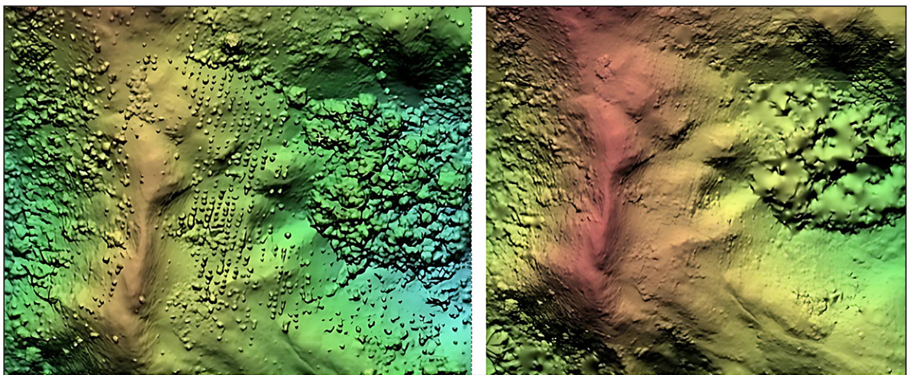
Data analysis

The method used in orthomosaic segmentation to delineate individual tree crowns (CPAs) is object-based image analysis (OBIA) analysis via ArcMap 10.8 software and tree counting via GIS software. Furthermore, the CPA is analyzed via machine learning with GIS software to obtain the Number of trees through the tree-counting process (Hossain and Chen, 2019).

The tree height determination in this analysis stage was performed via canopy height model (CHM) analysis. CHM generates a digital model that depicts the difference in height between the ground level and the roof of the vegetation canopy in an area (Lestari et al., 2023). The canopy height model is a digital surface model (DSM) the height of which is normalized by reducing the digital terrain model (DTM) via the digital surface model (DSM) (Mohan et al., 2017). DTM is used for modeling the elevation of empty land without consider features on the ground surface (Debella Gilo, 2016). The canopy height model (CHM) represents or describes the height of trees in the research area. The following is the formula for calculating the canopy height model (CHM) data (Fig. 2).

$$DSM - DTM = CHM \tag{1}$$

where: DSM – digital surface model, DTM – digital terrain model, CHM – canopy height model.



a) b)

Figure 2. Calculating canopy height model using; a) DSM, b) DTM

RESULTS AND DISCUSSION

On the basis of the results of tree counting using GIS software, orthmosaic segmentation can be performed according to 3 location of Allu block, Bonto Payung, and Landangi Block.

Allu block

Imagery of DTM and DSM of Allu block can be shown in Figure 3. The formation of DTM data for aerial photography uses DSM data which is processed using the Geometica application, removing objects above the ground surface 50 times. This is done to ensure that the DTM data obtained is clean from the objects above it. Several studies have been conducted using different approaches and models for tasks such as land use land cover and crops classification (Al-Najjar et.al, 2019).

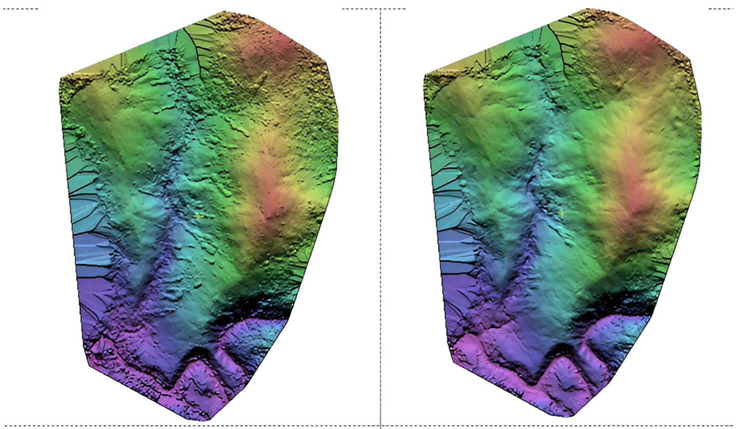
The data processing results show that the DSM data in the data above has a minimum value of 110.57 and a maximum value of 394.18. While DTM data has a minimum value of 110.57 and a maximum value of 392.96 on raster data. The Allu block is in Botopayung village, the object of calculating plant height included forest and land rehabilitation plants, namely Akasia (*Acacia manguium*), Pinus (*Pinus merkusii*), Beringin (*Ficus benjamina*) and Jambu mete (*Anacardium Occidentale, Linn*) which were planted in 2019 on an area of 100 ha.

When calculating the number of plants after forest and land rehabilitation (tree counting) in the Allu block using the OBIA method from aerial photo images, the resulting number of trees was 19.811 plants in the sample study area with an area of 85.04 ha which were identified using UAV (Fig. 4).

Bonto Payung block

To identify CHM values, DSM and DTM data processing is carried out to obtain elevation differences by eliminating or erasing objects above the ground surface. Imagery of DTM and DSM of Allu block is shown in Figure 5.

Data processing using DTM and DSM data produces average tree height by extracting the



a) b)

Figure 3. Processing result of canopy height model of Allu block for: a) DSM, b) DTM

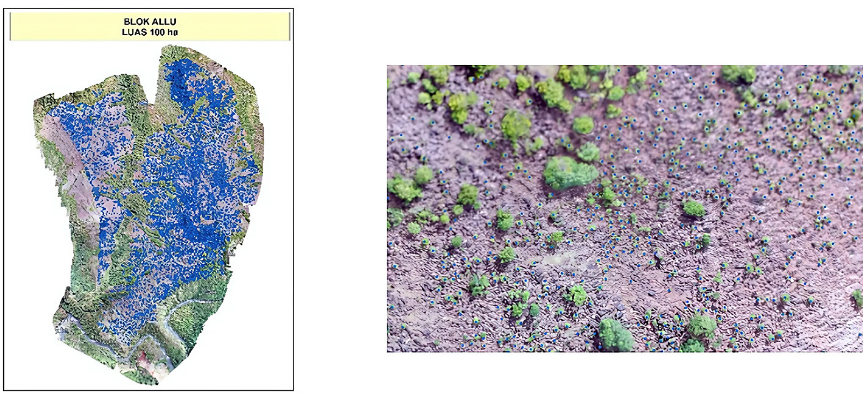


Figure 4. Allu block tree counting results (85.04 ha)

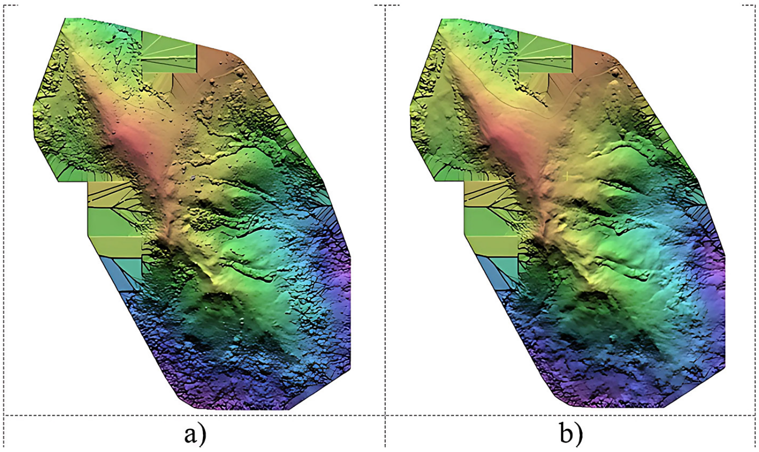


Figure 5. Processing result of canopy height model of Bonto Payung block: a) DSM, b) DTM

data into CHM (Islami et al, 2021). Processing results show that the DSM data in the data above has a minimum value of 268.70 and a maximum value of 566.15. While DTM data has a minimum value of 268.70 and a maximum value of 564.93 on raster data. The Bontopayung block is in Botopayung village, the object of calculating plant height is forest and land rehabilitation plants, namely Akasia (*Acacia manguium*), Pinus (*Pinus merkusii*), Beringin (*Ficus benjamina*) and Jambu mete (*Anacardium Occidentale, Linn*).

Calculating the number of plants after forest and land rehabilitation (tree counting) in the bonto umbrella block via the OBIA method from aerial photo images revealed that the number of trees in the sample study area, which had an area of 48.93 ha, was 11.983 (Fig. 6).

Landange block

Imagery of DTM and DSM of Allu block is shown in Figure 7.

Processing results show that the DSM data in the data above has a minimum value of 299.69 and a maximum value of 629.06. In turn, DTM data has a minimum value of 299.69 and a maximum value of 626.06 on raster data. The Landange block is in Landange village, the object of calculating plant height included forest and land rehabilitation plants, namely Akasia (*Acacia manguium*), Pinus (*Pinus merkusii*), Beringin (*Ficus benjamina*) and Jambu mete (*Anacardium Occidentale, Linn*).

The number of plants after forest and land rehabilitation (tree counting) on the landing block was calculated using the OBIA method from aerial photo images. There were 11 trees, and the number of plant stems in the sample study area was 52.01 ha.

The calculation of plant height in this stage of analysis via CHM analysis can be seen in Table 2.

On the basis of the results of plant monitoring after forest rehabilitation above, it can be seen that the Allu block has 19.811 plants. The majority of plant heights in the Allu block range from 0–1 meter with a total of 18.493 plants. Meanwhile,

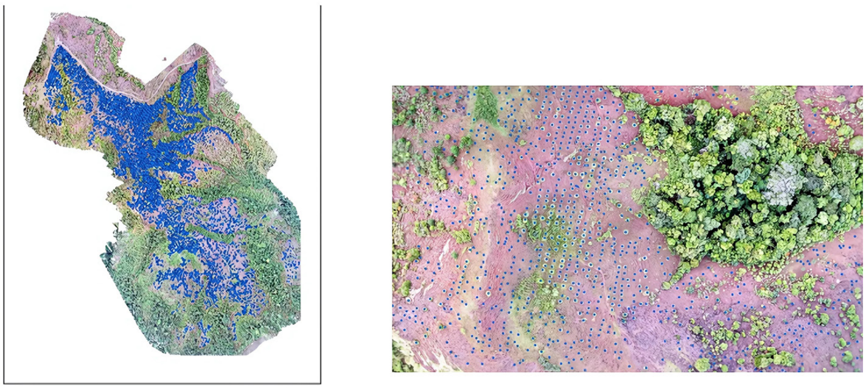


Figure 6. Bonto Payung block tree counting results (48.93 ha)

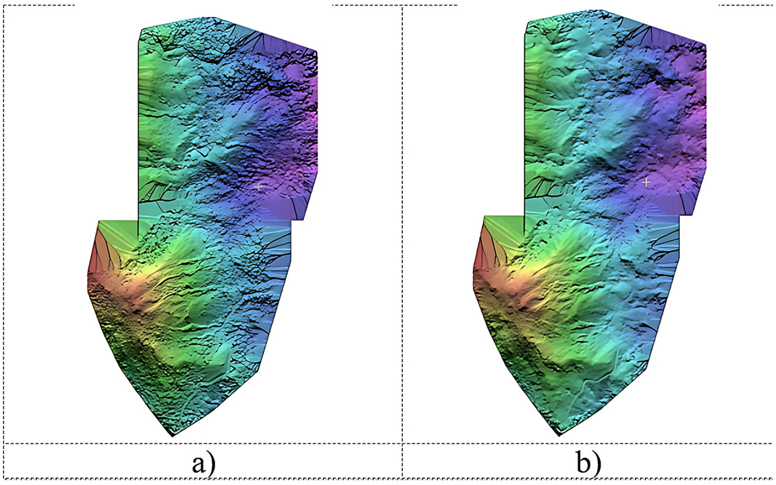


Figure 7. Processing result of canopy height model of Landange block: a) DSM, b) DTM

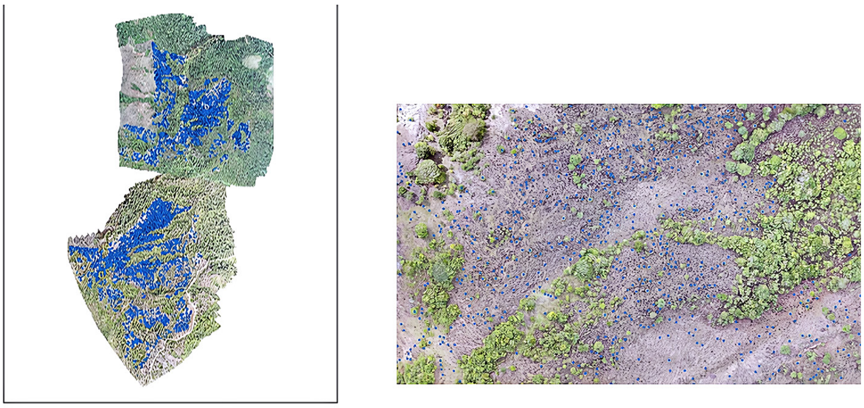


Figure 8. Landange block tree counting results (52.01 ha)

Table 2. The calculation of plant height using canopy height model (CHM)

No	Block	Elevation class (meter)	Sum (tree)	Total (tree)
1	Allu	0–1	18.493	19.811
		2–3	1.227	
		>3	91	
2	Bonto Payung	0–1	9.940	11.983
		2–3	1.882	
		>3	161	
3	Landange	0–1	9.909	11.927
		2–3	1.750	
		>3	268	
Total				43,721

the Bontopayung block and Landange block have 11.983 plants and 11.927 plants respectively and the majority of plant heights at these locations range from 0 – 1 meter. The success rate of forest and land rehabilitation is due to land conditions, suitability of soil type and plant type and the management of the work area (Prawiro et al., 2023). UAVs were used without cloud obstruction, as is usually found in aerial photography and satellite imagery, and this made the data collection process more effective, efficient and accurate (Islami et al., 2021, Zarco-Tejada et al., 2014). UAVs too capable of producing data with high spatial resolution at a lower cost and easier (Klemas & Victor, 2015).

Flying height variations are useful for obtaining representative images with a high level of accuracy and mapping at a detailed scale for object identification, especially in the forestry sector (Mu et al., 2018). Advances in the field of UAV technology and data processing have expanded forestry remote sensing horizon, making the acquisition of high-resolution imagery and 3D data easier available and affordable (Zhang et al., 2016). The use of UAV in monitoring plants after forest and land rehabilitation is very effective and efficient with a very large work area.

CONCLUSIONS

The application of UAVs to monitor plant growth after forest and land rehabilitation is more effective than conventional methods that sometimes do not reach difficult areas and require a long time to monitor plants. In addition to the application of UAVs in monitoring forest and land rehabilitation plants, the application of UAVs can also identify the areas that require additional intervention so that it can support the success of forest and land rehabilitation programs. The results of analysis using the OBIA method found that the number of plants in the Allu block was 19.811 plants, the Bontopayung block was 11.983 plants and the Landange block was 11.927 plants. Meanwhile, for the CHM analysis, plant height varied from 0–1 meter, 2–3 meters, and > 3 meters.

Acknowledgments

We would like to express our deepest gratitude to all the parties who contributed to this research. Thank you to the Faculty of Forestry, Hasanuddin University, for the support of very valuable facilities and resources. We also appreciate the assistance provided by River Watershed Management Center Jeneberang Saddang in providing data and access to research sites in Barru Regency. Special thanks to the field team, who tirelessly collected data in the field, and to the people in Bonto Payung Village and Landange Village, who supported and cooperated during the research. We also thank our Department of Forestry Science colleagues for their constructive intellectual advice and support.

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