Effectiveness of Drone Utilization and Spatial Verification of Palm Oil Key Points

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Abstract

The advancement of remote sensing technology has driven the utilization of drones (Unmanned Aerial Vehicle/UAV) in the management of oil palm plantations more efficiently, accurately, and sustainably. This article examines the effectiveness of drone utilization followed by spatial verification of oil palm key points in spatial mapping, oil palm inventory, plant health monitoring, and plantation infrastructure surveillance. The analysis is based on international literature and empirical findings that represent the development of UAV implementation in the plantation industry. The study results indicate that the use of drones and the verification process can improve data accuracy to over 95%, reduce field survey durations, and support data-driven agronomic decision-making. Additionally, drone technology has the potential to strengthen sustainable plantation practices, especially in terms of land efficiency, reducing yield loss, and mitigating environmental risks.

Keywords: Drone, UAV, Oil Palm, Mapping, Plantation Management, Remote Sensing.

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Introduction

Oil palm plantations are a key strategic sector for Indonesia's economy as they contribute significantly to foreign exchange earnings, create wide employment opportunities (4.5 million people), stimulate the growth of related sectors (upstream and downstream), and play a vital role in energy sovereignty. Indonesia is the world's largest producer of palm oil, accounting for more than 55% of global production, and continues to commit to sustainable development through national strategic programs. Oil palm plantations are a strategic sector for Indonesia's economy, contributing more than 55% of global palm oil production. [1], [2]. However, the management of palm oil plantations faces various challenges such as high operational costs, lack of accuracy in manual data collection, difficulties in plant health monitoring, and low land-use efficiency in large plantations (>10,000 ha).

The use of drone technology or UAV (Unmanned Aerial Vehicle) has become one of the modern approaches increasingly adopted to improve plantation management quality. Drones offer advantages such as easy acquisition of high-resolution imagery, quick access to hard-to-reach areas, and spatial analysis capabilities integrated with GIS platforms and artificial intelligence. Research shows that drones play a significant role in enhancing agricultural surveys through the speed of data acquisition and the accuracy of vegetation mapping [3], [4], [5], [6].

In the context of oil palm plantations, UAVs are used to count plant populations, detect vegetation stress, monitor disease outbreaks (e.g., Ganoderma boninense), map infrastructure networks, and evaluate block productivity. This article comprehensively discusses the role of drones, utilization procedures, implementation challenges, and the prospects of developing UAV-based technology in Indonesia's palm oil sector.

Literatur Riew

The use of drones or Unmanned Aerial Vehicles (UAVs) is currently widespread. Many people are using them in various fields, and one of the most important applications is in agriculture. Many large-scale plantations have already adopted this technology, including;

2.1 Spatial Mapping and Orthomosaic Creation

Drones are capable of producing orthorectified imagery with a resolution of 2–10 cm, much more detailed than satellite imagery (30–50 cm). This mapping includes: block and afdeling boundaries, road and drainage networks, vegetation distribution, planting patterns, and planting distances. The orthomosaic from UAVs allows for validation of planted area sizes, land cover audits, and historical condition comparisons. Research conducted on the oil palm plantation area of PT Tolan Tiga (SIPEP Group) showed the land cover on the plantation.

2.2 Oil Palm Inventory (Tree Counting)

Manual data collection is often inaccurate, especially on thousands of hectares of land. With object detection algorithms such as YOLO, Faster R-CNN, or Random Forest, each oil palm tree can be automatically counted from drone imagery (Mubin et al., 2020). The benefits include: identifying missing plants, detecting unproductive plants, and verifying the company's digital counting results. The accuracy of this method can reach 96–99%.

2.3 Plant Health Monitoring

Drone Multispectral and Hyperspectral can facilitating analysis: NDVI, GNDVI, SAVI, OSAVI, leaf chlorophyll index.

Research [7] shows that multispectral UAVs are highly effective in detecting water stress and Ganoderma infestations at an early stage, allowing for quick action before production declines. Drone imagery is very helpful in identifying the health of oil palm plants, considering the vastness of oil palm plantations [8].

2.4 Infrastructure and Productivity Evaluation

Aerial photos help monitor: harvest road conditions, erosion and drainage damage, flood-prone areas, presence of invasive weeds, and access for fresh fruit bunch (TBS) transport vehicles. This information helps plantation managers improve transportation efficiency and harvest management.

Research Methodology

3.1 Data Collection

The initial phase of this research is to determine the Flight Planning Stage, which includes: defining the survey area, altitude (80–120 m), photo overlap (70–85%), grid pattern, camera calibration, and UAV operational permits. The drone is flown using autopilot with a flight plan. Data is collected under stable weather conditions to avoid light distortion and shadows.

3.2 Data Processing

Software such as Agisoft Metashape, Pix4D, or ArcGIS Pro is used to generate: orthomosaic, Digital Surface Model (DSM), 3D point cloud, and canopy extraction.

3.3 Spatial Analysis and Classification

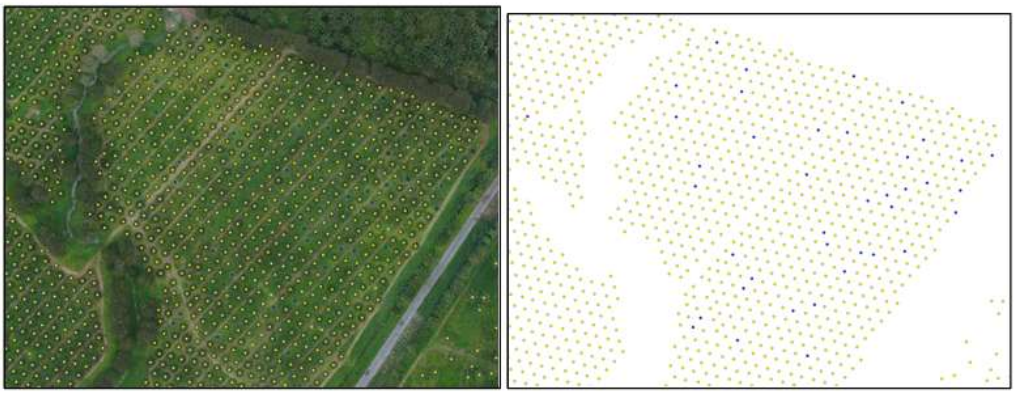
Analysis is conducted to identify oil palm trees, estimate plant age, assess canopy density, and segment problematic areas.

3.4 Field Validation

Ground truthing is performed to ensure the accuracy of image interpretation, particularly for young plants (immature), shaded areas, or locations with low resolution.

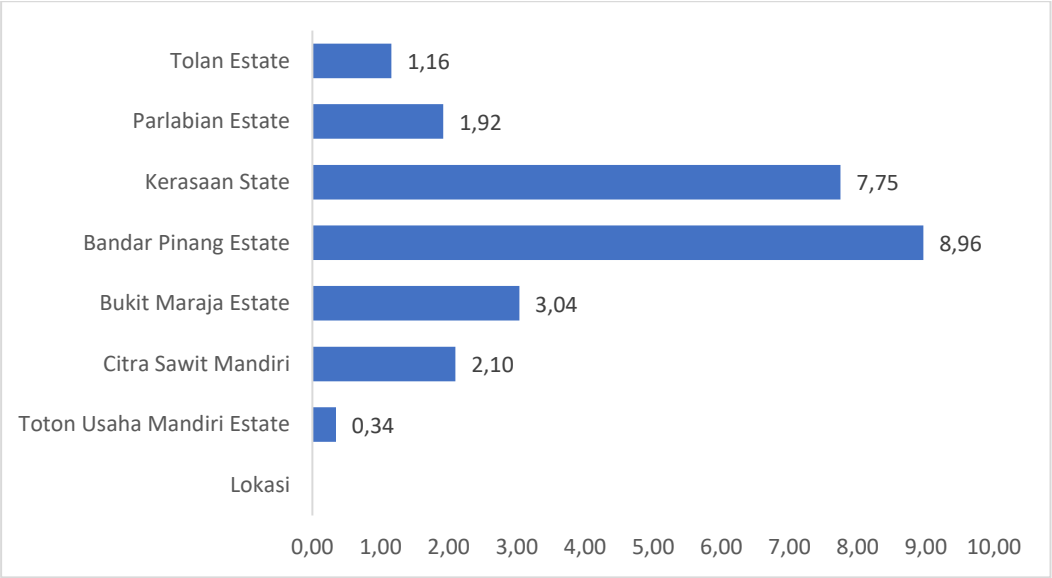
Results

Research conducted on several plantation areas of PT TOLAN TIGA (SIPEP Group) showed that the use of drones can quickly perform oil palm stand calculations. Below are the captured results of the oil palm stand photos from one of PT Tolan Tiga Group's plantations (Picture 1).



Picture 1. Capture Detail from Verivication OP in Bukit Maraja Estate

After obtaining the oil palm stand photos, verification is carried out to ensure more accurate calculations. Several additional oil palm trees were identified, even reaching 8.9% of the initial data (Picture 2).



Picture 2. Percentage of additional oil palm stands after verification.

In addition, the benefits gained from using drones in plantation management include:

a. Time Efficiency
   Surveying an area of 5,000–10,000 ha can be completed in just 5–7 days, compared to manual surveys that require 2–3 months.
b. High Accuracy in Plantation Information Systems
   High-resolution geospatial data enhances the quality of digital monitoring systems (Plantation Management System/PMS).
c. Operational Cost Optimization
   Palm oil companies can reduce labor costs, minimize verification errors, and limit repeated field visits.
d. Strengthening Sustainability Principles (ISPO/RSPO)
   Drones encourage: land use efficiency, environmental monitoring, continuous audit reporting, and reduction of new land clearing.

Among the conveniences gained from using drones, there are also several common challenges, including:

- Initial investment costs for drones and supporting equipment,
- Skills required for operators and GIS analysts,
- Drone battery limitations (20–50 minutes),
- Tropical weather constraints,
- Management of big spatial data,
- UAV flight regulation policies.

The use of unmanned applications is not only implemented in plantation areas but can also be applied in the Sultan Syarif Hasyim Grand Forest Park area. Based on research results, the Tahura SH area has 12 land cover classification types that can be visually identified based on 9 interpretation elements (hue, color, shape, size, texture, pattern, shadow, site, and association), and a ground check or field data collection and observation is conducted. Of the 12 land cover types identified, 10 types can be visually identified, including natural forest, acacia plantation, shrubs, rubber plants, oil palm plants, building site 1, building site 2, lake, river, and road [9]. Additionally, it can also be used to monitor plantation plant conditions against pest and disease attacks, as carried out by [7], [8], [10]

Conclusion

Drone technology has had a transformational impact on the management of oil palm plantations. Through its ability to quickly acquire data, provide high accuracy, and perform in-depth spatial analysis, drones help improve productivity, reduce operational costs, and strengthen sustainability practices. With the integration of AI, IoT, and machine learning, the use of drones is predicted to continue to grow as a key pillar in smart plantation systems in Indonesia. We would like to express our gratitude to PT Tolan Tiga Group for funding this research, and to Universitas Pembangunan Panca Budi for their support.

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