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RESEARCH ARTICLE

Identifying the Strata of Sago Stands Using Unmanned Aerial Vehicle Data (Case Study: Ambon Island, Maluku, Indonesia)

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ABSTRACT

Manual measurements to estimate the height and diameter of sago stems can be performed directly. However, estimates of height and diameter from land cover using remote sensing or aerial photographic coverage have not been widely featured in articles at home or abroad. To determine the potential and distribution of sago plant species that can be produced per area in the sago forest area, we mapped the sago land area using drone aircraft to cover the sago land area. We determined the diameter and height classes of sago plants using a Digital Surface Model (DSM) data application method. The results of the analysis showed that there was a distribution of diameter and height of sago plants varying according to height, namely for strata-level seedlings (0 to 6 m) as much as 100, saplings (6 to 12 m) as much as 818, poles (12 to 18 m) as much as 3,332, and trees (> 18 m) as much as 3.79. for the area of sago land mapped, and can be processed into an orthomosaic covering an area of 126,883 ha.

Introduction

Ecologically, sago trees (*Metroxylon sago*) occur in flat areas, areas with basins that may be flooded, and locations that frequently have marsh beds, all of which are located between 0 and 1,500 m high. According to Botanri et al. [1], sago plants on Seram Island, Maluku Province, thrive and develop in four different habitat types: 1) dryland habitat type); 2) non-permanent flooded freshwater); 3) inundated non-permanent brackish water; and 4) permanently flooded. Sago plants grown under moist or watery soil conditions have a clear appearance of tree canopies from the appearance of leaves, stems, branches, twigs, flowers, and fruits. The appearance of sago plants from a height using aerial shooting varied with height.

Seventeen years after planting, sago palms placed in the deep peat soil failed to grow a trunk. This trait, called "non-trunking," reduces the value of palms from an economic perspective [2]. A substantial full genome of various sago palms has recently been obtained, related to the hybrid genomes of sago plants. The phylogenetics of the chloroplast portion of the sago tree genome, which is more informative for a sago plant family member, will be determined by this study of the sago tree genome. Because of the use of the platform that produced the data for this study, sago palm genome completeness was significantly enhanced [3]. The sago palm (*M. sago Rottb*) is a typical indigenous food crop that has received little attention. Sago palm, a new source of staple food that does not compete with other food crops for the use of arable lands, has a strong potential to improve health and human welfare, increase food security, and contribute to these goals [4].

Sago plants can sometimes flourish up to 1,000 m above sea level Unmanned aerial photography was used to describe the distribution of sago stands in the study area to identify and analyze the sago land cover. The shooting results of the DSM data generated from the shooting results can describe the shape of the Earth's surface, as shown by the shooting results [5]. According to Mulyanto and Suwardi [6], survey findings sago

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plants typically grow in Maluku at elevations between 0 and 20 m above sea level. Depending on the info above, it can be concluded that sago plants thrive in alkaline soil quality and are associated with species of seedling, poles, and trees such as Ketapang (*Terminalia catappa*), spinach (*Inicarpus fagifer*), marsegu wood (*Nauclea orientalis*), samama (*Anthocephalus macrophyllus*), and forest guava (*Duabanga molucensis*). Four different types of sago plants dominate tidal areas close to the sea: molat sago (*M. Sago Rottb*), tuni sago (*Metroxylon rumphii Martius*), ihur sago (*M. sylvestre Mart*.), and rattan sago (*Metoxylon microcanthum Martius*).

This study aimed to determine the potential and distribution of sago plant species that can be produced per area in the sago forest area of Negeri Tulehu, Salahutu District, Central Maluku Regency. It maps the area of sago land using drone aircraft and determines the distribution of sago plant species that can be produced using the Digital Surface Model (DSM) data application method.

Material and Methods

Study Area

The sago forests in Tulehu Village, Salahutu District, Central Maluku Regency, owned by the study's objective, were the subject of this investigation. Spatial Spread and Potential of Sagu Plants in Ambon Island in particular at the study site with unequal cluster spread, in lowland areas at an altitude of less than 250 meters above sea level. Sagu plant also tends to grow on flat to steep terrain with a slope slope of 0 to 35%, as shown in Figure 1.

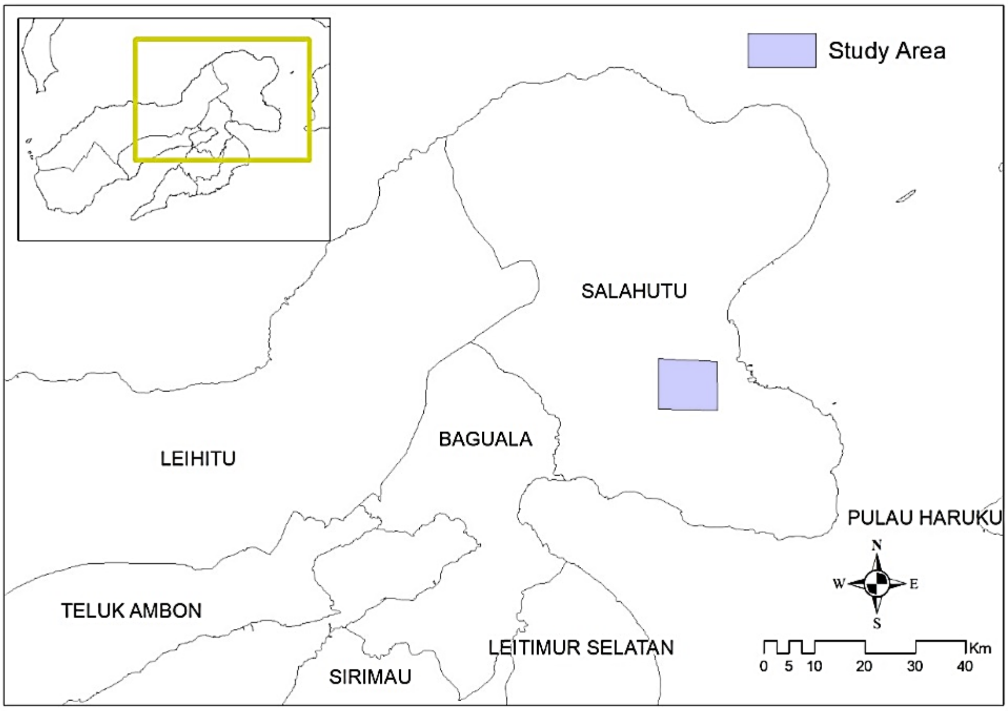

Figure 1. Sagu forest research location.

Data Collection Approach

Information was gathered using two techniques: aerial photography, which used drone aircraft to cover sago land areas, and digital analysis of the mapping results using a DSM data tool [7]. To generate three-dimensional models from various points of view by adding land cover, the DSM data application displays any existing surface shape, such as the height of trees, buildings, rivers, and any objects on the ground [8].

Data Analysis Method

The Digital Elevation Model (DEM) input data used in this study spatial analytical techniques is a database that depicts the surface relief between known elevation locations. The DSM represents the Earth's surface, contains more height information, and includes all objects above the Earth's surface, such as vegetation, buildings, and other features [9]. At the same time, Digital Terrain Model (DTM) data is a coverage model that presents the land surface without objects such as plants and buildings. Only the ground objects are exposed after removing vegetation, building objects, and other cover objects [10]. A study comparing the heights of multiple sample points measured on DSM and DTM is an example, as shown in [11,12]. Such comparisons are frequently used to analyze or validate DEM data (2008). The difference between the height in the DSM and the altitude in the DTM is considered the altitude error value in the DSM, because the altitude in the DTM is the height above the ground (bare earth) [13]. Examples of DSM and DTM features are shown in Figure 2.

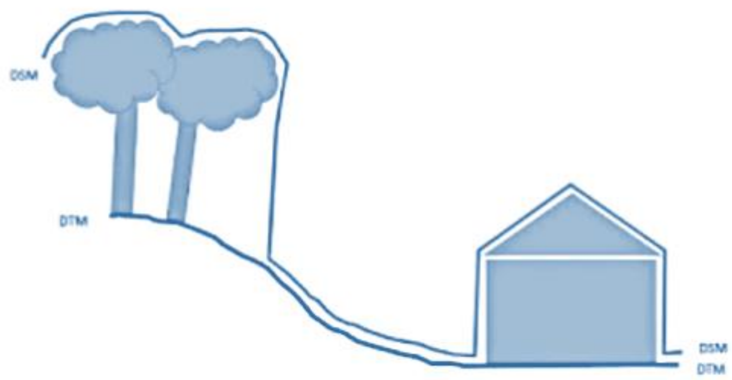

Figure 2. Examples of DSM and DTM.

The DSM is commonly used to correctly reconstruct the appearance of the Earth's surface. According to Zhou et al. [12], these data can be used visually to show immediate data in real time, Simulations of the sago land cover require these details. The mapped sago land area was then processed into an Orthomosaic spanning an area of 126,883 hectares, where the analysis of sago stand type cover was carried out for strata at the level of seedling (0 to 6 m), sapling (6 to 12 m), poles (12 to 18 m), and trees (> 18 m). The research flow diagram in Figure 3 can be explained as follows.

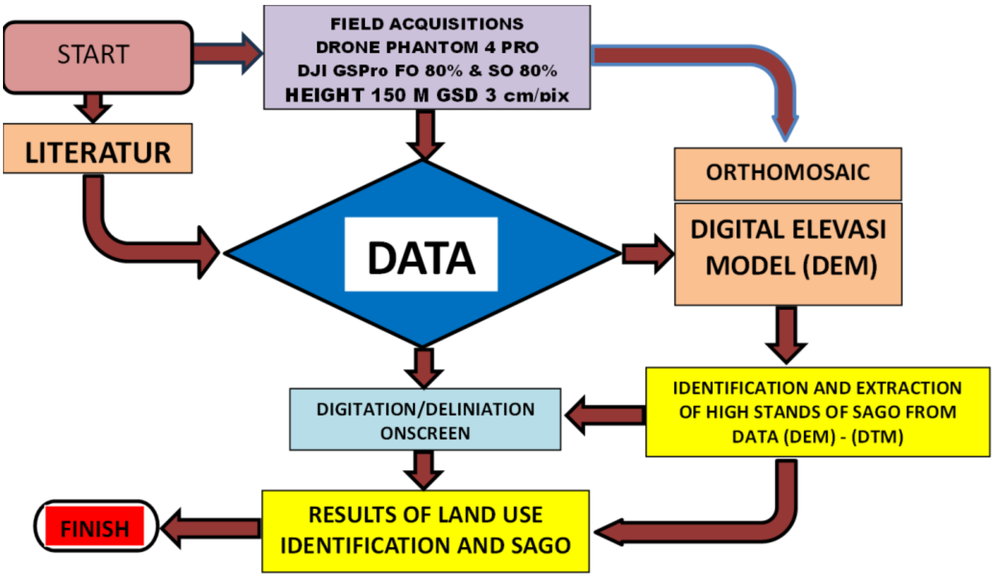

Figure 3. Research flow chart.

A computerized depiction of the ground level that eliminates the need to go above is termed DTM data analysis. A computerized depiction of the ground level that eliminates the need to go above is termed DTM data analysis. The N-DSM can also be created from the DSM and DTM data (Normalized DSM). The height of the covering object is specified by the N-DSM. Considering this, the following formula can be used to determine the values of building height, tree height, and other object heights using the DSM and DTM data.

$$\text{N-DSM} = \text{DSM}–\text{DTM} \quad (1)$$

The N-DSM is frequently used to estimate building heights for spatial evaluation and the quantity of wood generated in plantations and can even be applied to disaster analysis for issues such as flood simulation, landslide monitoring, road design, land cover classification, and forest management [14].

Discussion and Results

Implementation of Field Acquisition

The accuracy and precision of the data produced due to DEM, DTM, and DSM analyses can be used to measure the data quality of DEM, DTM, and DSM. The accuracy and point height values (Z) can then be compared with the actual value that is supposed to be correct. By directly measuring the sample point in the measurement region, it is crucial to determine whether the obtained Z value is realistic [15]. For example, the quantity of information that may be provided is then determined by the accuracy, DEM, DTM, and DSM values. The precision value is significantly affected by the quantity, distribution, and accuracy of the sample point used as input in DEM, DTM, and DSM modeling.

The interpolation model technique often determines the DEM, DTM, and DSM forming point heights. The selection of sample points utilized with the main condition must accurately reflect the general topography of the sampling place in keeping with the different applications for that use [16]. Drones of the Phantom 4 Pro type can be used for field coverage, with flight altitude restrictions of 150 m, a front overlap of 80%, a side overlap of 80%, and a maximum of 1,211 photos with a GSD resolution of 3 cm per shot [17]. The assumption used to determine the height of 150 m is that the appearance of the sago stand object can be accurately determined using the method of interpretation and analysis of appearance based on the reflection of the object's value captured by the sensor because the appearance is based on the ability of the sense of sight and by the standard of object appearance during the process of digitizing and delineating land cover [18].

While column data are obtained from user field observations and used in user accuracy calculations, row data result from image data classification and represent producer accuracy calculations. The overall accuracy value increased as more classification results fitted the observations Accurate data collection using drones is possible in terms of accuracy in certain situations and conditions that require user coordination with the software tools used to support shooting accuracy. Nonetheless, to improve the efficiency of mapping management, new methodologies and technologies are required to conceptualize a system that combines the use of remote sensing equipment with spatially/temporally oriented databases [19]. Orthophoto modeling and mapping have been conducted and developed, proving their potential in many professional fields. Verifying the technology in terms of its application in aerial reconnaissance will improve the efficiency (e.g., time) and effectiveness (e.g., accuracy of data revealed) of the coverage process directly and quickly. The overall assessment process is largely determined by the coverage time and data processing; however, this Drown technology allows for a rapid and precise reduction in analysis work [20].

Drones were used to take aerial photographs, divided into different flight paths and a cover area of 295.88 hectares. Open the DJI GO 4 app first to calibrate the drone and set it to auto-focus before accessing the drone deployment application. Steps involved in developing a route map for drones. Palm plant species (*Arenga pinnata*), swamp thickets, secondary forests, dragon fruit orchards (*Hylocereus undatus*), palm oil plantations (*Elaeis guineensis* jacq.), open land, settlements, dryland agriculture, shrubs, fishponds, mines, and bodies of water were recognized in the spatial analysis of the area. This method involves comparing field data that are thought to accurately depict land cover with an image of the classification results and is used as a basis for the true skill [3].

Processing Data While Recording

The results of aerial photography field acquisitions show that the main benefit of drones beyond manned aircraft is that they can be used in high-risk situations without integrating human lives in danger and inaccessible areas [21]. To ensure that there were no clouds in the final photographs, drones usually flew at low altitudes [22–24]. In this study, after drone photography, the PIX4D Mapper application was used to obtain the results of an orthomosaic raster map and then either digital surface model (DSM) or digital elevation model (DEM) data, as shown in Figure 4. Following the formation of the DEM and DSM models, the sago land area might be processed to create an orthomosaic that encompasses 126,883 ha, as shown in Figure 5.

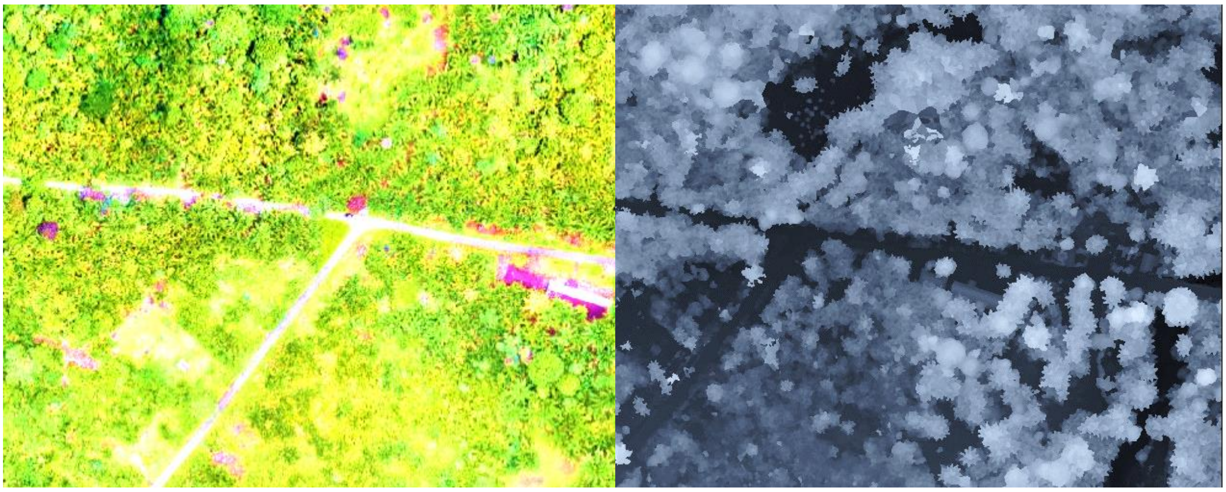

Figure 4. Data Digital Surface Model (DDSM) / Digital Data Elevation Model (DEM) orthomosaic results.

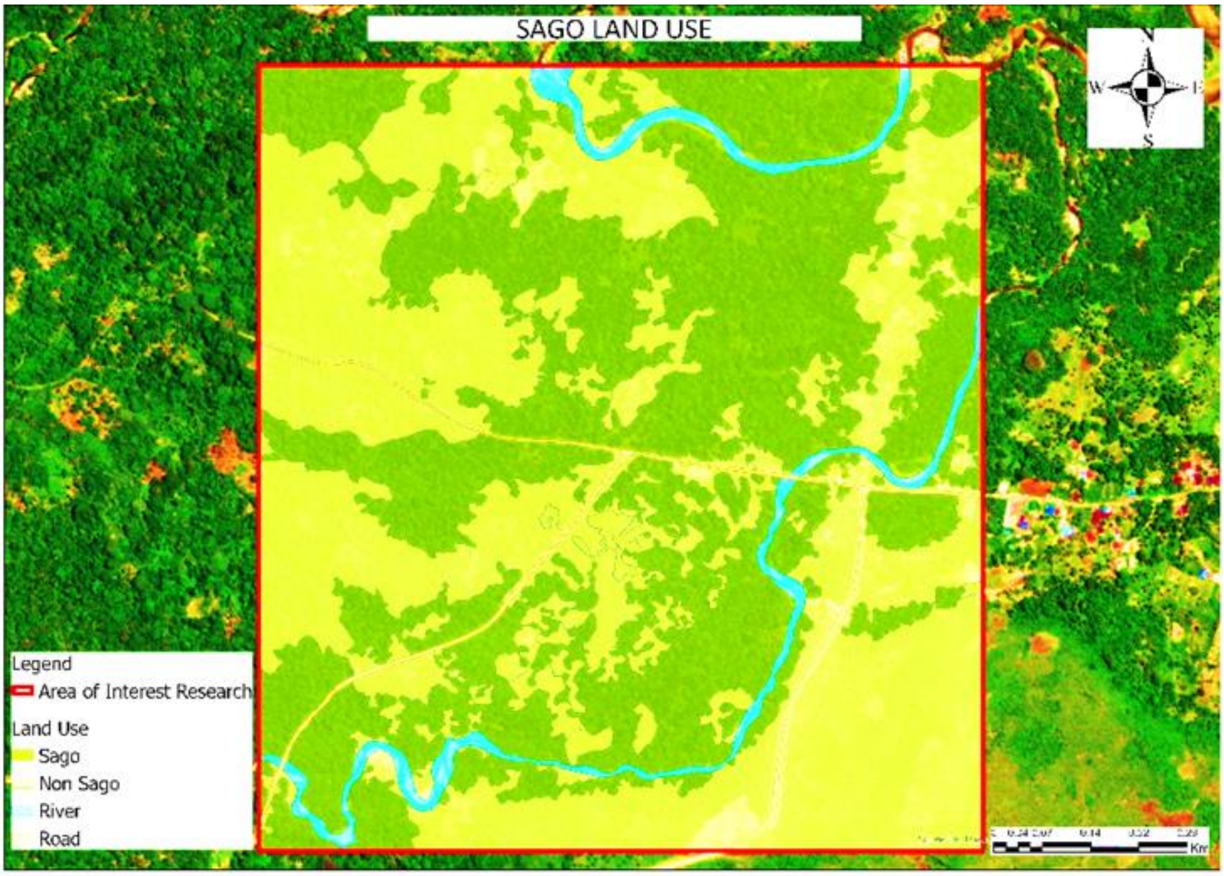

Figure 5. Orthomosaic raster map.

The results of the orthomosaic map of the research site were used to determine land use and cover through an on-screen digitization/delineation process. This led to the classification of sago and non-sago land use cover, as shown in Table 1, Figure 6, and Figure 7. Figure 3 shows the results of identifying the distribution of sago plants for growth rates at the tree level based on the appearance texture display that is clear and evenly distributed at the study site. This condition matches the results of field identification related to the distribution of sago plant species at the tree level, and saplings have clear differences in plain sight to distinguish physical characteristics [25]. Compared with the results of the interpretation of the cover that has been delineated or digitized on the screen, the results of air shooting generally show that all types of sago have a texture appearance that can generally be said to be the same, and there is almost no difference.

Tabel 1. Site for land use research.

No	Land Use	Area (ha)	Percentage (%)
1	Sago	0.24	47.50
2	Non-Sago	1.49	48.48
3	River	3.90	3.07
4	Street	1.20	0.95
Total		126.83	100.00

Figure 6. Results of digitization and deliniation on screen.

Figure 7. Location of the sago land use map study.

According to data from the identification of sago plants at the research location, three types of sago dominate the study area, namely, two types of spiny sago, namely tuni sago (*M. rumphii Mart.*), Ihur sago (*M. sylvestre Mart.*), and one type of non-thorny sago, the molat sago (*M. sago Rottb*). The dominant distribution of sago species in the study location was tuni sago type. Types of sago ihur and sago molat are not widely found but are still found unevenly and are associated with the type of tuni sago [26]. When viewed physically that the distribution of sago plant species occupies water basin areas where these locations are watery lowlands called swamps as the location where they grow. Based on sago land use map data obtained from the onscreen delineation analysis process, it is known that the distribution of sago plant area reaches 60.24 ha or 47.50% of the second term when compared to non-sago land use in the first order, with an area of 61.69 ha or 48.48%. The third place is occupied by river land use with an area of 3.90 ha or 3.07%, and finally, road land use with an area of 1.20 ha or 0.95%. From this explanation, it is clear that sago growth is evenly distributed on a stretch of land. Based on aspects of growing places (edafis) and biophysical factors of land in Tulehu Country, the distribution pattern of sago is very adaptive to the condition of swampland or flooding.

Sago plants on Seram Island in Maluku Province, according to Botanri et al. [27], grow and develop in four different habitat types: dryland habitat, nonpermanent flooded fresh water, flood nonpermanent brackishwater, and permanently flooded. According to Pranata et al. [28], Sago plants are a type of plant that typically grows in wetland or permanently flooded conditions and survives on flat terrain. The sago plant, which is a palm plant when grouped with other plant species, thrives and is extensively distributed in tropical areas, including Maluku and Papua. To ensure the expansion of sago plantations, a sago land cover assessment can be planned at a minimum using adequate coverage tools to support decisions that help strategies for land use change (LUC). Therefore, this study used a mathematical model of mixed integer linear programming (MILP) to plan for the expansion of sago plantations to determine whether sago plantation expansion is necessary to maintain the diversity of sago plants displaced by land-use change [29].

Identification of Sago by High Strata

Sago plants grow in a diverse range of habitats, including flat areas, basins that are often sloping, and humid. The macro-relief of sago plants can grow in all landforms, from the lands to mountainous regions, while the micro-relief of sago plants grows in sunken, flat, and sloping areas with water conditions that are relatively constant throughout the season. The results of the sago plant identification in Tulehu Village, Salahutu District, Ambon Island were based on land cover classes using DSM data, and the method of determining the distribution of sago plant growth rates was carried out using on-screen delineation techniques for each sago plant tree based on the appearance of height strata from the orthomosaic data, as shown in Table 2, Figure 8, and Figure 9.

Table 2. Data classification in strata of sago staple crops.

No	Types of strata	Height (m)
1	Seedling	0–6
2	Sapling	6–12
3	Poles	12–18
4	Trees	>18

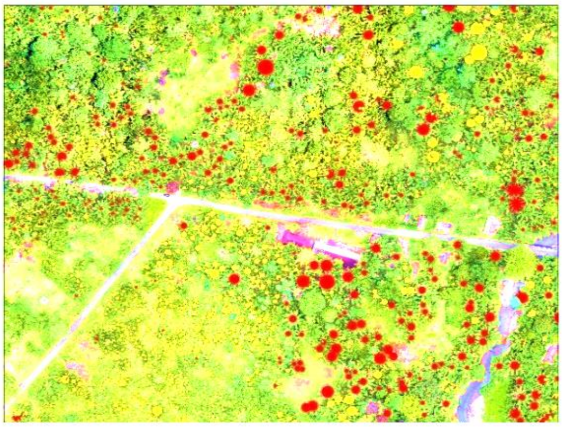

Figure 8. Identification of sago staple crops (data digitasi onscreen).

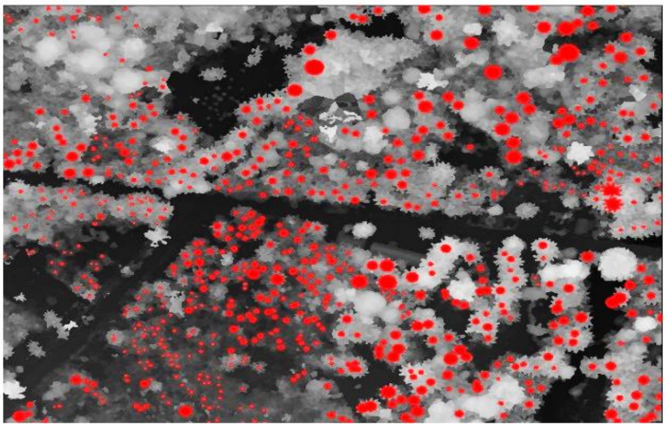

Figure 9. Identifying of sago staple crops (data DSM).

Based on the presence of sago plants in Maluku, the spatial distribution of sago plants on Ambon Island has an area distribution of 86.44%, with the majority of them being found in two areas, namely Leihitu District (238.81 ha) with a 50.71 basis point area distribution and Salahutu District (168.27 ha), with a distribution of 35.73% and 35.74% [20]. Especially at the study site of Tulehu Village, Salahutu District, Ambon Island, the results of the identification of sago staple plants based on the distribution of altitude levels were obtained using the interpolation method. Then, according to the high-class strata of sago staple crops, extraction of DSM data was carried out and is depicted in Table 3 and Figure 10.

According to Table 3 and Figure 10, onscreen digitization data analysis and data from the DSM reveal that the distribution of sago plant height strata is quite variable. The findings indicated that there were 100 or 10.81%, seedlings in seedling strata, 818 or 88.43%, saplings in sapling strata, 3,332 or 0.36%, stands in polishes, and 3,709 or 4.30%, stands in trees. Directly using DSM data to derive contour lines and spot height is one technique that is available. The prerequisite is that the DSM height error value should not be higher than the scale's required precision. Based on a comparison of the shooting analysis data, found that for capturing aerial images at a flying height of 50 m, the average number of photos was 376, which was more than 100 m and 150 m in altitude.

Table 3. Results of sago staple crops strata classification.

No	Sago Classification	Height (m)	Sum (individual)	Precentage (%)
1	Seedling	0–6	100	10.81
2	Sapling	6–12	818	88.43
3	Poles	12–18	3,332	0.36
4	Trees	> 18	3,709	0.40
	Total		925,041	100.00

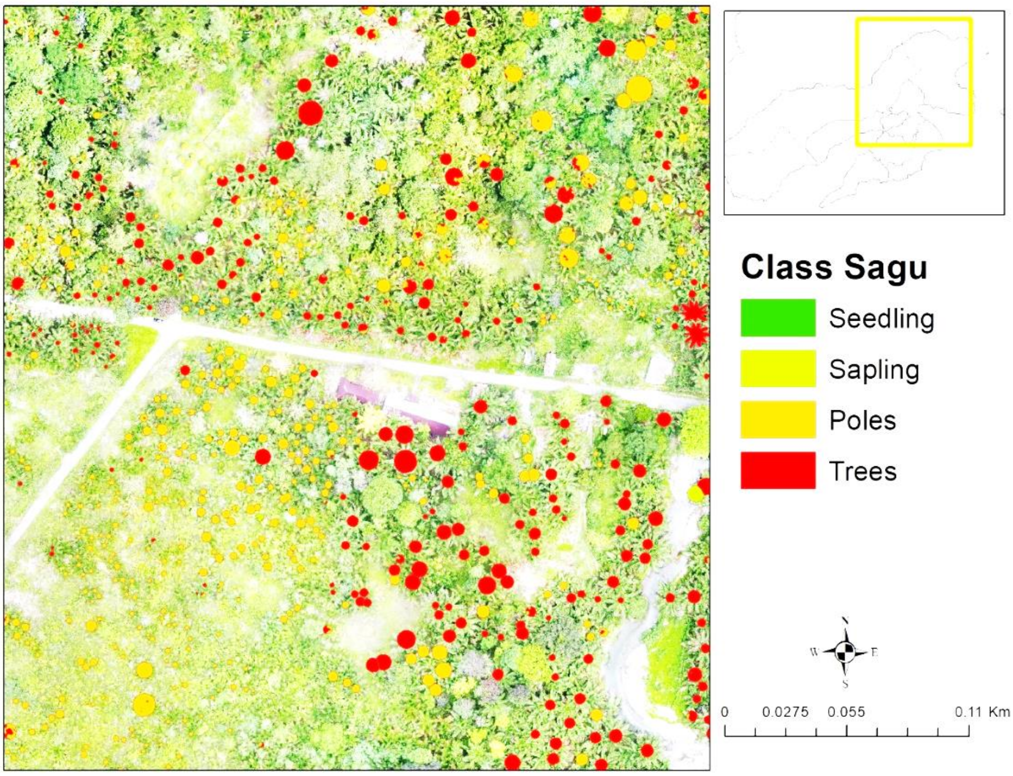

Figure 10. Results of sago staple crops strata classification.

Conclusion

The results of the identification of sago plants in Tulehu Village, Salahutu District, and Ambon Island were based on land cover classes using DSM data. To determine the potential and distribution of sago plant species that can be produced per area in the sago forest area, the sago land area was mapped using drone aircraft to cover the sago land area, and then the diameter and height class of sago plants were determined. The results of mapping sago land using unmanned aircraft (UAV) produced very high-resolution authomosaic data that could be used to identify sago land use at the study site. In addition, these results can also be analyzed using DSM and DTM data, where the extraction results from DSM and DTM data. The information revealed that there were 100 seedling strata, 818 sapling strata, 3,332 polishing stands, and 3,709 tree stands. For the difference in digitization of the sample area and distance, it can be said that the average requirements related to height accuracy and shooting calculations for sago staple plant element objects are appropriate or significant with the height of coverage of onscreen digitization data analysis results and DSM data analysis results for high-class strata data of sago staple crops based on classification results.

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