Assessment and Inventory of Palms in a Plantation by Template Matching of Unmanned Aerial Vehicle (UAV) Image

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Authors’ contributions

This work was carried out in collaboration between all authors. All authors conceptualized the research work. Author OSP designed the study, developed the procedures and wrote the first draft of the manuscript. Authors OSP and KAA managed the literature searches. Author OSP performs the field survey and the analysis. Authors KAA and ATS edited the manuscript and prepare relevant maps. All authors read and approved the final manuscript.

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ABSTRACT

The cost of acquiring real time, high resolution spatial datasets required for effective management of plantation has been a major challenge to farm management in developing country like Nigeria. But recent commercialization of Unmanned Aerial Vehicles (UAVs) has gradually made an affordable means of acquiring these spatial datasets available to individuals and small organizations.

This study counts the palm trees in a palm plantation by template matching of digital orthophoto produced by a low cost Unmanned Aerial Vehicle. An aerial survey was carried out at Obafemi Awolowo Teaching and Research Farm using Phantom II Vision quadcopter. Using a flying altitude of 100 m, the plantation, which covers a land area of about 56,000 m² and containing 663
mature palm trees, was surveyed using the UAV. An 11 cm Orthophoto and Digital Surface Model (DSM) were produced. Template Matching algorithm was used to extract individual palm tree stand unto a thematic vector layer. The palm tree distribution map was produced after errors have been corrected using the DSM.

The procedure shows that there are 572 palms present in the plantation with 86.27% accuracy in comparison with manual counting. The distribution of the palms in the plantation indicates underutilization of the plantation due to presence of empty and uncultivated area in the plantation. Also, there are presence of foreign trees in the plantation which might be competing with the palm trees for nutrients and thereby reducing the total yield of the plantation.

Keywords: Remote sensing; geographic information system; template matching; palm trees; plantation; inventory; farm management.

1. INTRODUCTION

Accurate and near-real time information is needed for a sustainable oil palm plantation management, especially on plant quality and health [1]. The use of traditional approach in managing farm plantation has proven to be ineffective and time consuming. In developing countries, various localized farm practices have resulted in lower yield from plantations. Although, various methods have been used to improve plantation management practices such as counting of trees, taking inventory and assessing plant health, the use of high resolution remote sensing products have proven to be effective in taking inventory of plantations as opposed the labour intensive and time consuming manual field-based method. For example, [2] uses high resolution satellite image to delineate tree crown of a mixed forest while [3] uses template matching of palm tree image objects of satellite images to estimate the number of palm trees in a palm plantation. Other complex examples exist in which remotely sensed data were used in plantation management practices. Usually, these processes use data that are expensive since they are usually of high resolution that are previously acquired by airborne remote sensing system carried by aircrafts but recent technological development has provided for the commercialization of unmanned aerial vehicles (UAVs), especially the development of low cost combined Global Positioning System/Inertia Positioning System (GPS/INS) systems, which are necessary to navigate flying electronic device over predefined points [4].

Unmanned Aerial Vehicles (UAV), otherwise known as Unmanned Aerial System (UAS), Remotely Piloted Aircraft (RPA) or simply a Drone can be described as unmanned, powered, free-flying platforms that vary greatly in their technical characteristics and photographic capabilities. They may be controlled by a pilot on the ground, who is in visual contact with the drone, or they may be programmed to fly along predetermined flight lines with the possibility of making repetitive measurements at specific points or at regular interval [4]. These devices, mounted with a commercially available camera payload can be used to produce highly accurate spatial datasets such as Digital Orthophotos, Contour lines, Elevation Models, Vector data, etc. [5]. The resulting effect is the deposition of a powerful tool in the hand of individual and small organizations with respect to its capability in collecting high resolution remotely sensed imageries. Over the years, more scientists are turning to the use of this technology in performing aerial survey especially over a relatively small area. With the attendant benefit of being able to collect high resolution spatial datasets at the required time and processing of the same within a rather short time. Therefore, high resolution orthophoto can be collected at will by users which can be processed and inserted into plantation management practices thereby increasing yield and productivity.

2. METHODOLOGY

2.1 The Study Area

The study was conducted at the Obafemi Awolowo University Teaching and Research Farm (Fig. 1) located between Longitude 4°31’ 55’’E and 4°34’ 40’’E and Latitude 7°31’ 51’’N and 7°34’ 27’’N. There were 663 mature palm trees in the plantation which covers a land area of approximately 56,000 square metres.

2.2 Flight Planning and Aerial Photographs Acquisition

The UAV used in this study is the Phantom II Vision quadcopter with a 14 Megapixel Digital
Fig. 1. Obafemi Awolowo University campus showing the teaching and research farms

Single Lens Reflex Camera on board. Four parallel flight lines whose length is 640 m and are 240 m apart was drawn over the study area using ArcGIS Desktop 10.1, consecutive and parallel aerial photographs should have overlap so as to produce digital orthophoto and digital surface models with no distortion and gaps, thus the 240 m apart flight lines ensures a minimum of 60% side overlap between aerial photographs [6]. The coordinates of the endpoints of each lines were collected to be inputted into the Vision App. Using a flight altitude of 100 m, flight speed of approximately 30 m/s and a 5 seconds camera shutter speed interval is used in order to ensure a minimum of 75% forward overlap between aerial photographs [6]. Excluding the take-off and landing images, 120 overlapping aerial photographs was collected in approximately 30 minutes at noon so as to minimize the effect of shadows.

2.3 Image Processing

The aerial photographs captured during the aerial survey were imported into Agisoft photoscan 1.0 where they were automatically aligned and processed to obtain the Digital Surface Model (DSM) and the orthophoto of the study area. The orthophoto was imported into ecognition developers 9.0. To determine the position and distribution of the palms in the plantation, palm tree templates, which is a grey-scale representation of a palm tree (i.e. a palm tree model), were created. To ensure optimal matching of template at palm tree locations, multiple palm tree templates were created by selecting palm centres in a test area, these were later cleaned up by the template cleaning tools. The identified palms in the test area were used to generate more templates using the test template tool in order to match different structure and appearance of palm trees. Then five templates group was created by rotating the template at different angles so as to match any palm tree orientation. Template matching algorithm was used to extract individual palm trees in the orthophoto by using the created template group to create the palm tree object layer [7,12]. The DSM was imported into PCI Geomatica 2016 where terrain editing tool was used to remove above ground feature to create a Digital Elevation Model (DEM). The Normalised Digital Surface Model (nDSM) was obtained using raster calculator in ArcGIS 10.3. Since the plantation has matured palm trees, the height information from the nDSM was used to remove palms that were matched at elevations lower than 8 m so as to remove any palm trees that were erroneously matched by the generated template in the plantation. The statistic of the remaining palm tree stands was collected and the palm tree distribution map was produced. Also, the location
of the unmatched palm tree was determined by visual examination.

3. RESULTS AND DISCUSSION

The Orthophoto and the normalized Digital Surface Model (nDSM) produced are as shown in Fig. 2 and Fig. 3 respectively. The spatial resolution of these spatial datasets is 11 cm which results from flying the UAV at a lower elevation of 100 m. The level of details obtained in the orthophoto clearly shows the individual palm tree stands with their characteristic star-shaped structure. This level of detail is higher than that of satellite images which can only be as high as 31 cm [8].

Although the palm tree can be identified individually and counted, the method will be cumbersome, time consuming and stressful as the size of the plantation gets larger. The procedure used in this study provides an automatic means of deriving the inventory of the palms in the plantation from which the extent, status and estimate of the yield and/or the performance of the plantation can be derived. The derived palm tree template is as shown in Fig. 4. Using this template, the total number of palms from the template matching classification algorithm derived a value of 572 palms in the plantation which is about 86.3% accurate in comparison with manual counting of the palm trees in the plantation. Although this result is lower than the 90% accurate estimation of palms using a high resolution multispectral image [9] [10], the use of purely optical orthophoto from a low-cost UAV is advantageous over the comparatively expensive satellite image. Furthermore, the spatial datasets used produces the result while eliminating the challenges faced by previous attempts of taking inventory of a palm plantation using satellite images in which the lower spatial resolution and shadow effects prevents optimal inventory of palm trees [3,11].

Fig. 2. 11 cm digital orthophoto of the palm tree plantation showing the level of details
The nDSM shows height values ranging from 0 m – for bare ground, to 32 m – for the tallest tree in the plantation. Although the average height of palm trees in the plantation is 15 m, the higher height values are associated with foreign tall trees in the plantation located at the west central part of the area.

The distributions of the palms in the plantation is as shown in Fig. 5, while the location of the uncounted palm trees was manually determined as shown in Fig. 6. The uncounted palm trees may be due to inability of the template to be matched with the palm. This may result from palms being covered partly by tree and imperfections in the image as shown in Fig. 7. The distribution shows lower utilization of the land area. There is presence of other trees species which will be competing with the palms for available resources such as sunlight and water. Also there are sizeable pockets of shrubs and grasslands at the west centre and north east part of the plantation which can be used for the development of more palms and thereby adding to the total production of the plantation as a whole.

The method employed in this study stresses further the advantages of using remotely sensed data in taking farm inventory which provides an inexpensive, fast and relatively accurate means of taking farm inventory. It has been shown that multispectral satellite images provide better delineation of vegetation edges [12], thus it is recommended that the inventory and assessments should be done with respect to the counting and determination of the health of each palm tree stands using a multispectral camera on board the UAV. Also, the flying height can be varied to determine the spatial resolution that will provide the highest accuracy for the inventory.
Fig. 5. Palm tree distribution map (Counted)

Fig. 6. Palm tree distribution map showing uncounted palm trees
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Fig. 7. Some uncounted palm trees; a: Palm tree partly covered by a foreign tree; b: Distortion in the orthophoto

4. CONCLUSION

The study thus concluded that the use of low cost UAV could be a cost effective way of creating very high resolution spatial datasets which provides means for effective management of available natural resources. The inventory of palm trees plantation using template matching of the UAV imagery could achieve an accuracy as high as 86.27%. Also, the product also provide means of determining the distribution and the level of yield derivable from the plantation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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