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Mapping of Nypa Palm Invasion of Mangrove Forest Using Low-Cost and High Resolution UAV Digital Imagery in The Niger Delta, Nigeria

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Abstract

The encroachment of nypa palm into mangrove forest is a major cause of the disappearance of mangrove forest in the Niger Delta. It was thus hypothesized that the palm is an invasive species and stressor to mangrove forest and will affect greenness and health of mangroves. The study was conducted in March, 2018 in a mixed forest (mangrove plus nypa palm) at Eagle Island. A DJI spark drone (300 g) was flown from different geo-referenced Ground Control Points (GCP) 25 m above the forest to record several images of tree canopies.Images from two clear flight paths were chosen and mosaicked using software called drone deploy. The visible atmospherically resistance index (VARI), which shows the greenness and health of the trees were analyzed from the mosaicked images using ESRI Arc GIS. Three Dimensional images (3D) were derived to show tree height. Result of mangrove forest 1 indicates that significant part of the mangrove forest was stressed because out of the VARI range of 0-1.93 (where 0=low and 1.93=high greenness) most of the forest fell below 1.0. Similarly, result for mangrove forest 2 show that in a range of 0-0.86 most of the forest fell below 0.5. This indicates that the mangrove forest is stressed by the presence of the nypa palm. However, other environmental factors such as hydrocarbon pollution may play key role, but the result indicate that the presence of the palms increased the stress level of the mangroves leading to decreased population. The stress level of the mangroves can be reduced through the removal of the invasive palms and the re-planting of mangrove propagules.

Keywords: Drone; Invasion; Nypa palm; Unmanned Aerial vehicle; Vegetation index

Introduction

Mangroves are a biodiversity hot spot that undergo carbon sequestration[1]. Mangrove forest is a rich source of carbon because it is a sink for carbon dioxide. The forest purifies the environment by removing carbon dioxide, which helps to reduce global warming effect. Carbon is found in living biomass of tree, underground vegetation, dead mass of litter, dead wood and soil organic matter. To control climate change different programs had been established globally in studying the impact of climate change such as Reducing Emissions from Deforestation and Degradation (REDD+) that adopts Measuring, Reporting and Verification mechanisms (MRV) [2]. Tree biomass is important in monitoring forest, and is often estimated by measuring tree height and Diameter at Breast Height (DBH) by the use of destructive method i.e. tree cutting and weighing. But this method is discouraged globally because it is counterproductive due to its reduction in the number of tree stands at different geographical locations.This is because the reduction of trees harms the environment by not reducing the effectsof atmospheric pollution, flooding and erosion. A non-destructive method is rather preferred and known as allometric method, which involves the use of direct measurement of the tree height and the DBH. Previous studies had used this method to estimate Above Ground Biomass (AGB) of mangrove *Rhizophoraracemosain* the Niger Delta [3].This method employed the Model 1 (diameter-height-wood density) mangrove biomass regression[4-6].

Remote sensing is currently being used in forestry [7,8]. It deploys small drones orUnmanned Aerial Vehicle (UAVs), which is less expensive and less time consuming to study different kinds of forest. Remote sensing is the knowing, analyzing and capturing of information from a distance (RS). It is an art used to

interpret images and is a form of science, which involves the use of mathematical models. It also involves the use of different sensor technology. In the past low optical resolution such as MODIS and land sat [9], and high optical resolution such as Geo eye and World view-3 hadall been used to study AGB.These methods measure horizontal, but not vertical forest structures. However, LiDAR, an airborne sensor measures vertical structure. There are various sensor types, the active and the passive. The active generates their own energy and collect reflections of their own energy on earth. Examples areRADAR (Radio Detection & Ranging) and LiDAR (Light Detection & Ranging) whereas the passive collects and records electromagnetic energy through optical lens. Example is digital cameras and infrared sensors that are loaded on drones. They orbit space and collects data. Nevertheless, there are some problems that are associated with satellite-based research such as cloud cover which is a major problem in tropical regions such as Niger Delta where rain falls from January to December [9]. There is also the problem of having a suitable revisit time. For instance, Landsat revisit time is 16 days. Similarly, satellite-based research has low resolution scenes, which mean they get small images from space. There is also the problem of poor understory information due to low resolution of images and high cost of scene.

The drones have therefore come to the rescue by producing high resolution and low cost images. They are called Unmanned Aerial Vehicles (UAV). They are light weight aircraft platform that operates from the ground. They were originally initiated in 2006-2007 for military purpose, but are now used for civilian purpose for resource application such as forest monitoring, surveillance, mapping and 3D modeling amongst others. They fly manually with the use of remote control or are preprogrammed. Drones have been used in precision agriculture [10-12], vegetation monitoring in range land [13-15], biodiversity monitoring [7,16], habitat monitoring [17,18], study of soil properties [19,20], environmental monitoring [21,22], mapping and monitoring fires [23-25], forestry [7,8], pest and disease detection [26-28] and tropical forest conservation [29]. But out of all these studies there is a limited use of drones in the study of mangroves in the Niger Delta region, where no known studies had been conducted.

There are three main kinds of drones according to their design and flight mode. They include various

a. Balloons, blimps, kites, and paragliders.

b. Rotary-wing aircraft.

c. Fixed-wing aircraft.

The UAV has both rotary and fixed wing aircrafts.The DJI Spark Drone used for this study is a rotary-wing aircraft.The drone has several advantages as compared to the satellite-based system. These includes high spatial resolution for single tree identification, high temporal resolution for time series analysis, no problem of cloud cover effect, where it is used to generate Digital Elevation Model (DEM), reduction of use of ground plot, operational ease, low price for drone images, quick data acquisition, enhanced monitoring of illegal activities such as deforestation and artisanal refining of crude oil, access to inaccessible or remote areas, and potential environmental benefits. Despite these advantages, there are some disadvantages of the use of drones, these includes small payloads, low spectral resolution, poor geometric and radiometric performance, low software automation, sensitivity to atmospheric condition such as wind effect, short flight endurance e.g. the DJI spark drone flies for only 16 minutes and needs the battery to be charged before reuse, possibility of collisions since it flies at the range of ground objects, potential problems for repairs and maintenance, need for flying licenses in some regions, which is not a problem in the Niger Delta, safety and security issues, potential social impacts and ethical issues.

There are different vegetation indices used to determine plant health such as Normalized Difference Vegetation Index (NDVI), Near Infra-Red (NIR) and VARI, but the significance of the NDVI is that it monitors seasonal and inter-annual changes in vegetation. For instance, lack of chlorophyll may be due to invasion pressure or pollution effect. It determines species health, climate change and pollution effect. It ranges between -1 to +1, where negative means less or no vegetation while positive means more vegetation. NDVI is equal to near infra-red minus red divided by near infrared plus red [30]. i.e.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

The VARI also uses similar principle to the NDVI, they are both ratio based index. In this study the VARI was used to determine the greenness and health of the mangrove forest at Eagle Island. We thus hypothesized that small drones (i.e. DJI spark drone) can be used to study the invasion of nypa palm (*Nypa fruticans*) in mangrove forest in the Niger Delta by checking the greenness and health of trees.

Materials and Methods

Description of Study Area

The Niger Delta has a tropical monsoon climate with two seasons, dry and wet seasons. Dry season occurs from November to January while wet season occurs from February to October each year. But in some year's rainfall occurs from January to December. The zone has an average annual rainfall of 1246 m. Its mangrove forest is estimated to cover an area of 5,000 to 8,500 km^2 [31]. Mean monthly temperature ranges between 26-30 ˚C. The soil is swampy and grades from red to brown as a result of iron deposition [32]. The soil compaction ranges from 0.25-0.75 tones

cm^{-1}, while the pH ranges from 5.0-7.0. The study area is called Eagle Island in the Niger Delta region of Nigeria (Figure 1). It was an exclusive mangrove forest some 30 years ago but because of human activities invasive nypa palms had been introduced leading to the formation of mixed forests. It is close to a river channel that separates several small local indigenous communities. But because of population pressure and accommodation issues in the city people had migrated into the mangrove forest area to build and live. They cut the trees, dredged and sand filled large portions of the forest to build houses. Because of the intrusion of people, the mangrove forest had been converted to a mixed forest that has a combination of palms and grass species.

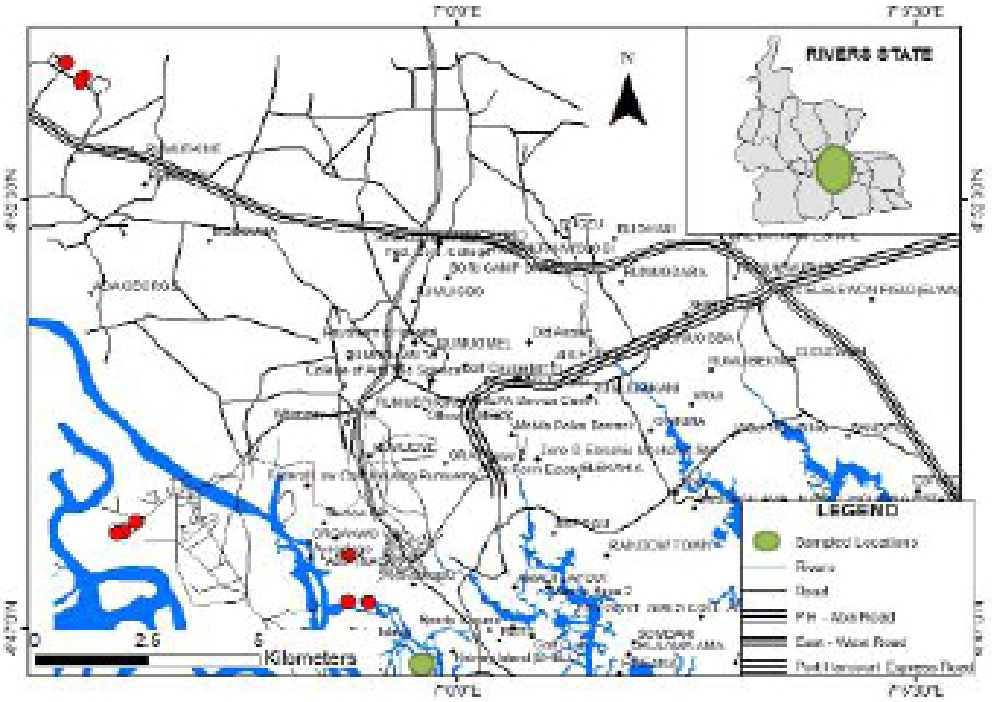

Figure 1: Map of study area, Eagle Island Niger Delta Nigeria.

Anthropogenic activities such as building, establishment of industries, maritime transportation and trading in the locality had worsened the situation by further opening up the forest to invasion by other alien species. The traditional swampy mangrove soil had been converted to hard soil that is made up of a mixture of sand and waste material. The specific area of study measures 20 m x 20 m and includes a mixture of red (*Rhizophora racemosa*) and white (*Avicennia germinans*) mangroves and nypa palms (*Nypa fruticans*). The location is bound by river at the southern part, a tarred road separating a boundary of an institution (Rivers State University) on the northern part, a sand-filled area on the western part and a sewage processing company at the eastern part.

Specification of The DJI Spark Drone

The DJI spark drone used for this study weighs 300 g, has a dimension of 143 x 143 x 55 mm and has a maximum speed of 31 mph. It uses a 3 D sensing system. It has an altitude range of 0-26 ft (0-8 m), an operating range of 0-96 ft (0-30 m). It has propellers and motor; and the gimbal system adjusts the camera view during flight. The camera sensor is 12 megapixels. It takes videos and photographs. It has a charger and flies for 16 minutes [33].

Data Acquisition

The DJI spark drone was used for data acquisition in an area that was an exclusive mangrove forest that was invaded by nypa palm. Some Ground Control Points (GCPs) markers were established at the edge of the forest with boards that were painted black and white.The different GCP were geo-referenced with Garmin GPS (USA) (Table 1). Several drone flight missions were conducted across the locations at strategic points at the edge of the river at different time intervals from 5th to 30th March, 2018. In all eight images were taken, and two clear images were specifically

chosen for data processing. These two areas are mangrove forest sites 7 and 8 (Table 1).The aim was to derive temporal resolutions (daily, weekly & monthly). Images were taken both automatically and manually through the use of the remote controller. Several pictures were taken at 25 m at the zenith with 50% overlap to enable smooth mosaickingof images.

Sites	Class Name	Forest type	Coordinates of GCP	Clarity	Acquisition date
1	Mang_UAV1	Mixed	N4˚47.406'; E6˚58.600, Elev. 2m	Not clear	5/3/2018
2	Mang_UAV2	Mixed	N4˚47.292'; E6˚58.726; Elev. 48m	Not clear	9/3/2018
3	Mang_UAV3	Mixed	N4˚47.230'; E6˚58.558; Elev. 15m	Not clear	13/3/2018
4	Mang_UAV4	Mixed	N4°47.385'; E6°58.612; Elev. 12m	Not clear	16/3/2018
5	Mang_UAV5	Mixed	N4˚47.225'; E6˚58.680; Elev. 43m	Not clear	19/3/2018
6	Mang_UAV6	Mixed	N4˚47.329; E6˚58.575; Elev. 20m	Not clear	26/3/2018
7	Mang_UAV7	Mixed	N4˚47.315'; E6˚58.548; Elev. 10m	Clear*	30/3/2018
8	Mang_UAV8	Mixed	N4˚47.346'; E6˚58.617; Elev. 5m	Clear*	30/3/2018

Table 1: Coordinates of Ground Control Points (GCP) and acquisition dates for different flight session using the deployment of DJI Spark drone at Eagle Island, Niger Delta Nigeria. Mixed forest is a combination of mangrove and nypa palms (*Nypa fruticans*) forest.

Data Processing

The images were first mosaicked with a software called drone deploy. This software joins each of the RGB images to make a single multiband image showing the whole pictures of the area covered during a single flight session (Figure 2). The mosaicked images were then used to calculate the Vegetation Atmospherically Resistance Index (VARI), which provides information on vegetation greenness and health status of the forest. It also provided images of the native mangrove forest and the invasive nypa palms (Figure 2). Color patches were used to identify the health of both species and to indicate areas with higher chlorophyll level.

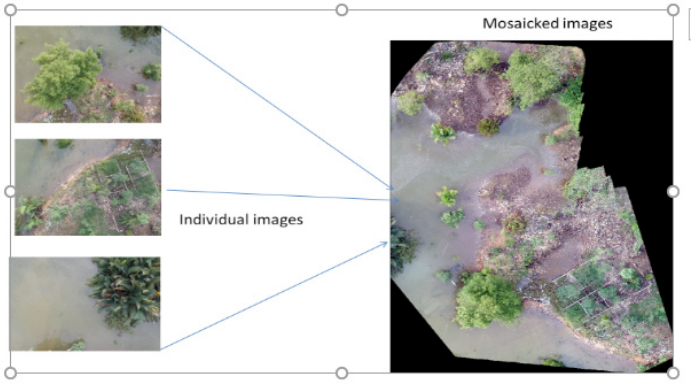

Figure 2: Mosaicked image of nypa palm (*Nypa fruticans*) encroachment in a mangrove forest at Eagle Island water front, Niger Delta, Nigeria.

ESRI Arc GIS 9.3 [34] was used for image pre-processing to generate the 3D images from where the Above Ground Biomass (AGB), NDVI, tree height and plant health were measured. In this study the mosaicked image was processed with Visible Atmospherically Resistance Index (VARI). Where

$$VARI = = \frac{G-R}{G+R-B} \quad (2)$$

VARI represents vegetation greenness and health to some extent. The higher the value, the greener and healthier the mangrove and nypa palm trees. Stress of invasion can reduce the greenness.

Results

The vegetation greenness/health value at mangrove forest site 7 ranges from 0-1.93; where 0 represents low greenness and poor health while 1.93 represent highest greenness and healthy trees (Figure 3a). Similarly, at site 8 the vegetation greenness/health value ranges from 0-0.86; where 0 represents low greenness and poor health while 1.93 represent highest greenness and healthy trees (Figure 4a).

The mosaicked images are shown in Figures 3a and Figure 4a while the processed images using VARI is given in Figures 3b and Figure 4b. Similarly, the 3 dimensional (3D) images of tree canopy are given in Figure 5, and show the canopy height.

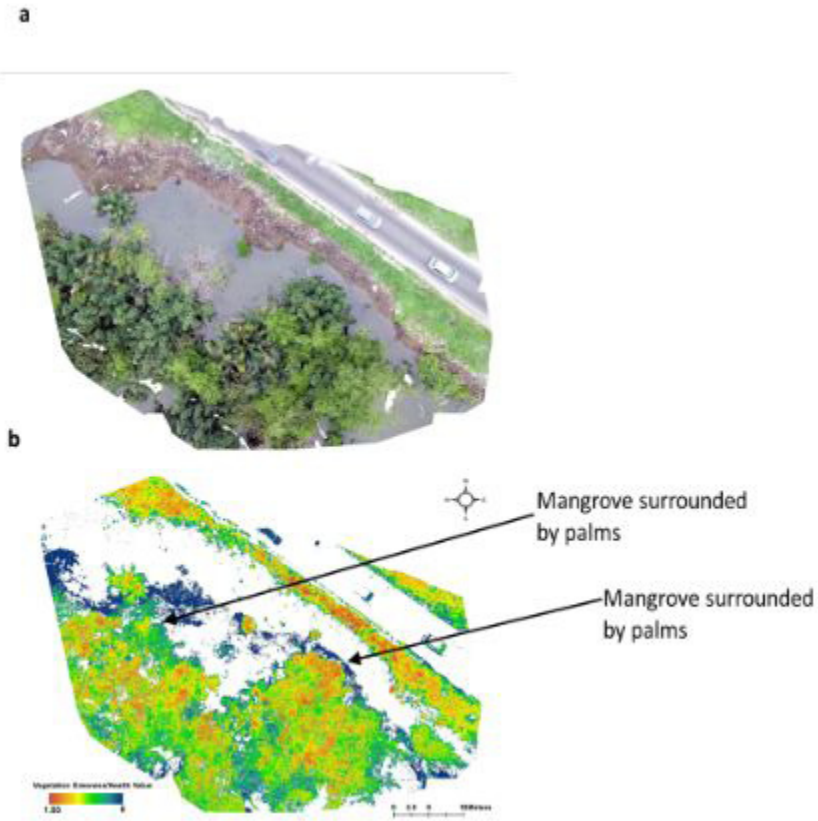

Figure 3: Mangrove forest images at site 7, showing **(a)** RGB imagery of mosaicked mangrove forest; **(b)** Mosaicked image of mangrove forest processed with Visible Atmospherically Resistance Index (VARI) at Eagle Island, Nigeria. Green and yellow color indicates signs of stress whereas red color indicates healthy or less stressed forest.

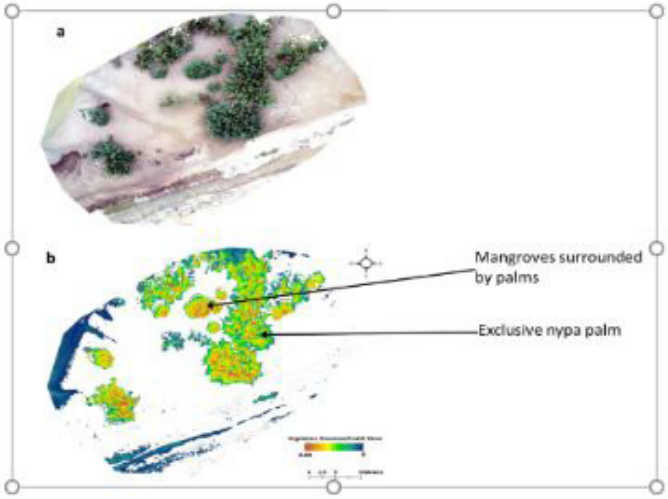

Figure 4: Mangrove forest images at site 8 showing **(a)** RGB imagery of mosaicked mangrove forest; **(b)** Mosaicked image of mangrove forest 8 processed with Visible Atmospherically Resistance Index (VARI) at Eagle Island, Niger Delta Nigeria. Green and yellow color indicates signs of stress whereas red color indicates healthy or less stressed forest.

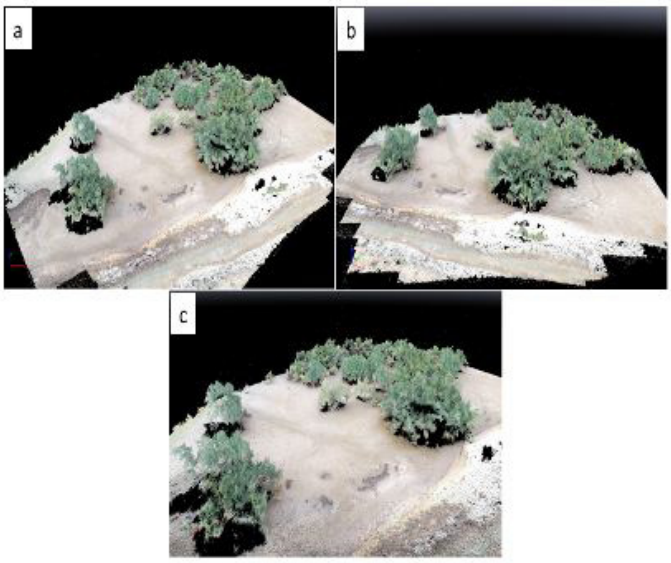

Figure 5: 3 D reconstruction of tree canopy of mangrove forest showing the depth and height of trees at Eagle Island, Niger Delta, Nigeria. Spatial distribution of mangrove forest due to deforestation activity.

Discussion

The result of this study indicates that the state of health of the mangroves is poor because of the large presence of nypa palms. Mangroves face a lot of environmental stressors such as pollution, invasion, salinity and herbivory [35]. But this study used the drone image to show that areas of mangroves invaded by the palms have less greenness due to stressors from the presence of the palms while areas away from the palmsshow more greenness (Figure2). The simple reason is that the palms compete with the mangroves for nutrients, and utilize the nutrients better and faster than the mangroves due to the configuration of their root system [36]. In figures 3a and 4aindividual mangrove stands are surrounded by large number of nypa palm trees, thus increasing the reduction of greenness of the mangroves, which shows high stress level.

The mangroves and the nypa palm forest face similar environmental stressors such as high salinity, hydrocarbon pollution, tidal surge and other anthropogenic effects. But in addition to these problems the mangroves have the nypa palms as one of their stressors. The study location is close to a jetty where marine craft transports people across the sea. These sea going crafts deposit engine oil in the sea which are carried into the mangrove forest. It is thus inundated with human activities which contribute to the overall degradation of the mangrove. The cutting of the trees for the purpose of fire wood had resulted in the decimation of mangroves from this location. The drop in the population of mangroves had further exacerbated the entry and colonization of mangrove forest by opportunistic nypa palm [37]. The use of drones to study invasion provides more holistic information on the health status of the mangroves. This is better than the collection of data from the ground alone. Therefore, as ameasure of conservation the nypa palms need to be removed and transplanted in a different environment from the mangroves. This will give the mangroves the breathing space to recover and grow healthier and survive for alonger period of time. Already the mangroves are a resilient plant that can grow in highly polluted location without dying as observed in the Niger Delta mangroves. But their biggest challenge apart from oil and gas exploration is invasion [37].

Conclusion

Landscape studies are better done using GIS and satellite data. But small unmanned vehicles (drones) have proven to be very effective in retrieving aerial images at high resolutions. In many locations around the world drones had been deployed to study agricultural crops, tropical trees and other types of vegetation. This is because drone images provide wider and clearer view of tree canopies. The result of this study has shown that drones can be deployed in studying mangrove forest, which is an improvement on the previous use of only allometric data. Drones can also be used to study the impact of urbanization and pollution. It can also be used to derive better carbon stock and biodiversity data. Future study will consider the use of drones to study canopy height and wider areas of mangroves forest to determine other stress indices such as salinity, hydrocarbon pollution and urbanization.

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