Application of Unmanned Aerial System in Shoreline Mapping

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Abstract*—Unmanned Aerial System (UAS) is an aspect of close range remote sensing and photogrammetry method that provides excellent and timely spectral and spatial services for rapid identification of details due to the low altitude of flight and identification of a clear water surface, topographic mapping and analysis, vegetation monitoring, land use change analysis, shorelines and river bank level monitoring, etc. Therefore, while comparing the imperative costs of the UAS and its major components (UAV, Ground Controller and Radio Communication) with the cost of multispectral and thermal cameras which are still very expensive alongside their end products as compared to visible cameras of UAV and the end products for cost effective and maximal applications in environmental surveying and modelling. However, this research shows how a commercially available middle-classed Quadcopter UAV/DRONE which is affordable even for the individuals to acquire was flown over the study area in accordance to pre-planned flight in Drone Deploy to collect data inform of images only in the visible region of the spectral bands i.e RGB, these images were then processed and mosaicked to obtain the Orthophoto using the Agisoft Metashape. In ArcMap, the orthophoto was used to calculate and generate different spectral vegetation indices. These indices were further visualized, analyzed and interpreted for different applications as it relates to identification and mapping of shoreline and vegetation including the clear water and the results includes NDI, CIVE, VDVI, VARI etc. which clearly shows the Shoreline, clear water and the vegetation better than the true colour image.

***Indexed Terms*—DRONE, Mapping, Remote Sensing and Photogrammetry, Spectral Image, UAS.**

I. INTRODUCTION

The term Unmanned Aerial/Aircraft System (UAS) is frequently used in the Engineering, Computer Science, Robotics and Artificial Intelligence, Photogrammetry and Remote Sensing world. Besides names like Remotely Piloted Vehicle (RPV) which was first used in 1970, Remotely Operated Aircraft (ROA) or Remotely Piloted Aircraft (RPA) are used by various authors and researchers (Olagoke et al., 2017).

The word 'DRONE' (Dynamic Remotely Operated Navigation Equipment) has been commonly used to mean UAV. Such act is misleading because high levels of technology were not required in drones' operation. The existence of drone was dated back to 1800 when the Austrian army used balloons filled with bombs to attack Venice. However, these drones have no advanced piloting controls to predetermine their destination and may as well be destroyed with the missiles in the cases of decoy use unlike UAV which can be controlled to return home pilotedly/manually or autonomously. American Army also used drones in 1900s when they were used for training purposes. By 1930s, there was technological advancement in drone operation when more of UAV emerged during World War II. They were used both to train antiaircraft gunners and to fly attack missions. Nazi Germany produced and used various UAV aircraft during the war (Okegbola et al., 2019; Gbiri et al., 2019; Bulletin of Defense Research and Development Organization, 2010; Watts et al., 2012; Federal Aviation Administration, 2007; Jitka and Pavel, 2018).

The early focus on UAS supporting the so-called “three Ds” (i.e., dull, dirty, or dangerous missions in which human pilot operations would be at a disadvantage or at high risk) highlighted the natural niche for UAS. Improvements in reconnaissance and guidance capabilities during the Cold War spurred interest among the scientific community in utilizing UAS for science missions in which pilotless aircraft provided similar advantages and risk mitigation. The US National Aeronautics and Space Administration (NASA) developed unmanned aircraft for high-altitude atmospheric sampling during the “Mini-Sniffer” program of the 1970s–1980s, but with limited success, and little follow-on activities. NASA’s Environmental Research Aircraft and Sensor Technology (ERAST) program in the 1990s marked the first major steps towards developing the protocols and capabilities for employment of UAS supporting scientific research. However, the military pedigree of most unmanned aircraft systems yielded a dichotomy in the nature of most systems: UAS capable of carrying powerful and accurate sensors tended to be large and very expensive, while small platforms lacked payloads to deliver precision data. The latter group of UAS was better suited to budgets or logistical demands of many research organizations, but had been designed for situational awareness as opposed to survey-grade data delivery. One of the major findings of the ERAST program and subsequent UAS science community workshops was the need for sensor miniaturization to allow the use of smaller-class (and affordable) UAS platforms (Okegbola et al., 2019).

An unmanned aerial vehicle (UAV) like receivers in GPS is just a component of a system called Unmanned Aircraft System (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. UAV is therefore a high-tech drones or aircraft without a human pilot aboard. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers (Anita et al., 2018; Ambrosia et al., 2003; Perry et al., 2008; Bulletin of Defense Research and Development Organization, 2010; Watts et al., 2012; Jakub, 2018).

United States Air-Force deployed UAV during Vietnam War between 1959 and 1964 but did not disclose the usage until later in 1973. Other nations such as Israel in 1973 (Yom Kippur War) and between 1967 (War of Attrition) deployed UAV against Syrian defense. Also, the use of UAVs were limited to military deployment with little commercial usage until in 2013 when the Amazon CEO, Jeff Bezos announced that they were testing the use of drones as a method of delivery. Since then, the commercial sector has been sensitized with the endless opportunities UAVs can create. Classification of UAS platforms for civil scientific uses has generally followed existing military descriptions of the platforms based upon characteristics such as size, flight endurance, and capabilities among others (Blakeslee et al., 2003; Hunt et al., 2010).

UAVs, in contrast to manned aircraft systems have some major advantages. UAV can be used in high risk situations without endangering human lives and in inaccessible areas even at low altitudes and at flight profiles close to the objects where manned systems cannot hover (Olagoke et al., 2017).

Based on latest technology in remote sensing and photogrammetry in the area of data acquisition, DJI Company has produced a DJI Phantom 4 Professional UAV (Figure 1) among other series and models which had been invented with the capability to generate the following major survey deliverables namely Point Cloud Map (Raster Elevation), Digital Surface Model (DSM), Digital Elevation Model (DEM), Orthomosaic or an Orthophoto (Olagoke et al., 2017) that can give an accuracy of up to centimeters and sub-centimeters depending on the accuracy of the Ground Control Points (GCP) when used, typically with the GPS on-board the Phantom 4 Pro, accuracy can range from 2.5m to 5.5m when the image is processed without GCP and some other conditions.

However, in aerial photogrammetry and remote sensing, orthophoto generation, topographic maps and other map deliverables have been produced from the aerial photograph acquired using large format metric cameras and of recent some satellite sensors can now give us multispectral and even hyperspectral images i.e. image with several bands. So the cost of acquiring the aerial photograph is very high either through the traditional means such as using manned aircraft which was used in Nigeria at FCT, Lagos and Oyo etc. to capture the states orthophotos or that of the recent technology using satellite images that can give centimeter to millimeter accuracy. Aside the cost, these methods mentioned either involve a very high technical planning or rigorous algorithm.

Image indices are images that are computed from multiband images, these images emphasize a specific phenomenon that is present, while mitigating other factors that degrade the effects in the image. For instance, a vegetation index will show healthy vegetation as bright in the index image, while unhealthy vegetation has lower values and barren terrain is dark. The clear water will also be clearly shown brightly while the unclear water will also be shown with lower brightness values of water colour in the index image depending on the band combination. Since shading from terrain variation (e.g hills and valleys) affect the intensity of images, the indices are created in ways that the color of an object is emphasized rather than the intensity or brightness of the object. These indices are often built by combinations of adding and subtracting bands, thereby making various band ratios. They are tied to specific bands that are in specific parts of the electromagnetic spectrum. As a result, they may only be valid for certain sensors or classes of sensors and it is critical that the proper bands are used in the index calculation (Qi et al., 1994; Hamuda et al., 2016; Ponti, 2013; Meyer and Neto, 2008).

However, this research shows how a commercially available middle-classed and multi rotor (Quadcopter) UAV/DRONE (DJI Phantom 4 Professional with built – in and fixed camera), which collects data only in the visible region of the spectral bands and also affordable even for the individuals, can simply be used to calculate different colour spectral indices to identify shoreline, vegetation and clear water, various color based vegetation indices, which are based only on red, green and blue bands were calculated and these include CIVE, ExG, GRVI, ExR, VARI, VDVI, ExG - ExR, ExR – ExG, R/G, G/R, GRVI and NDI.

Figure 1: Phantom 4 Professional UAS (Complete System)

II. AIM AND OBJECTIVES OF THE STUDY

This paper is aimed at showcasing the application of Unmanned Aerial System (UAS) (figure 1) in Spectral image mapping of part of Erelu dam shoreline and vegetation index pattern in Oyo, Oyo State.

The objectives set and painstakingly pursued in order to achieve the aim of the study include Flight planning, Image Acquisition, Image Processing, Vegetation index calculation/generation, Presentation and Analysis of results.

LOCATION OF THE STUDY AREA

The study area (figure 2) is part of Erelu Dam behind Emmanuel Alayande College of Education in Atiba Local Government Area, Oyo State, Nigeria. It lies approximately between Latitudes 07 52’ 52.596” N, 07 52’ 56.513” N and Longitudes 03 53’ 44.330” E, 03 53’ 48.893” E.

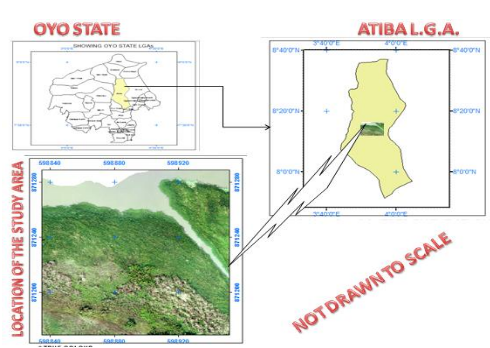


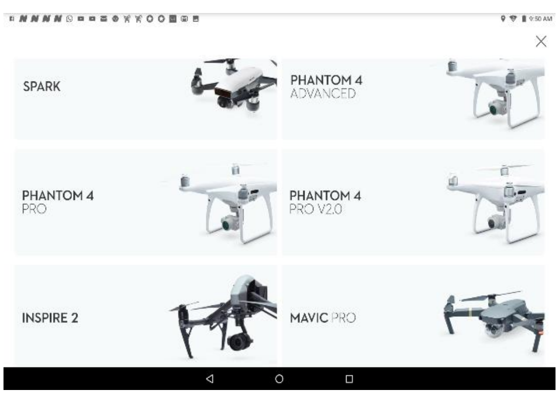
Figure 2: Location of the study area

III. RESEARCH METHODOLOGY

- Initial Flight Planning

Data was captured on 19th November, 2019 but before then the initial flight planning of the study area was carried out in DroneDeploy software (Figure 4) but the type/model of drone was initially selected in DJI GO 4 (Figure 3), it has the google map and imagery tiles embedded which shows the locations by search or navigation once online and this was used to define the flight boundary which otherwise brings a default flight lines including the front and side overlap values which was later changed to desired values and this planning was sent and uploaded to the drone. Altitude of 100m was selected for the flying height, front/side overlap was 75/65% respectively and the drone flew according to the plan. It took approximately 11 minutes to cover the study area of 18 Hectares with a total number of 147 images planned on eleven (11) main flight lines on an average speed of 10m/s using one (1) battery and the ground resolution was 2.89cm/pixel on a pixel size of 2.61 x 2.61µm. For sample camera locations and image overlaps/error estimates (See figures 7 and 8).

Though, a suitable leveled ground was selected close to the site for save vertical takeoff and landing of the autonomous flight and having considered all the necessary precautions and flight controls, the UAV was flown as earlier planned.



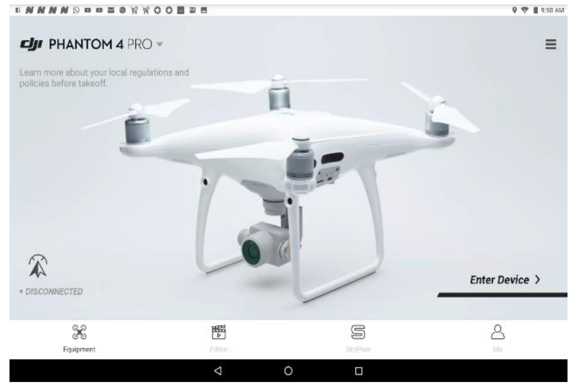


Figure 3: Selecting Type of drone used in DJI Go 4 Software (Phantom 4 Pro)

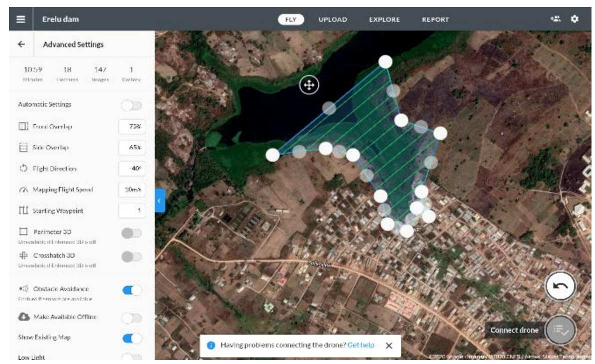


Figure 4: Flight Planning in Drone Deploy Software showing Settings configured for the flight

- Data Collection/Image Acquisition

A single flight was used to cover the study area and the wind direction was automatically considered and an angle of 40 degrees was used. Take-off and landing position was defined close to the study area at a relative clear and levelled surface. In preparation of the flight the Ground Remote Controller (GRC) was switched on and later the UAV, when the communication has been established, then the DJI GO 4 was launched to select the type of drone to be used i.e Phantom 4 Pro and then the software displayed "CONNECTED" once the drone is detected and seen the software was then minimized and DRONEDEPLOY software was launched then once the drone is detected and the connection is established "Drone Connected" is displayed" and the Erelu Dam Project which has been earlier planned (Figure 4) was opened and "Start preflight checklist" was clicked and while the software carry out some checks (see figure 5) the flight plan is uploaded into the drone and the "Start flight" was clicked for the "Autonomous flight" (see figure 6), the drone then take off and register the take off point by taking a camera position of the point then fly to the specified flight height and then horizontally fly to the starting point before it finally fly through the predefined flight lines to capture all the images/camera positions considering the pre-configuration parameters like the overlaps, speed etc.

Finally, after all the lines had been flown the drone returns and lands approximately on same take-off point and it was switched off.

Figure 5: Preflight checks in DroneDeploy

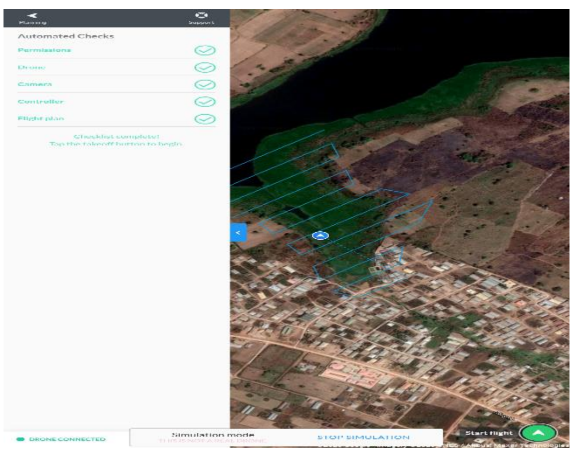


Figure 6: Taking off for autonomous flight in DroneDeploy (Start Flight)

- Image/Data Processing

Two software were used for this purpose and they include Agisoft Metashape and ArcGIS for Desktop 10.1. The captured image using the drone was downloaded and added in Agisoft Metashape from DJI for further processing, above all for a mosaic building to generate the Orthophoto (see table 1) for image properties as extracted from the processing reports. The mosaic imagery was imported into ARCGIS10.1 environment for visualization and further processing, the software was used to generate, analyze and visualize different colour indices like NDI, CIVE, and VDVI among others to choose which one could best be used for visualization in terms of differentiating some blended land uses for shoreline and vegetation mapping. Table 2 shows different kinds of formula used in obtaining vegetation indices using the raster calculator of the Image algebra from the Spatial Analyst Tool.

Table 1: Image Data Properties

Item	Description
Image dimension (Pixel)	4864 x 3648
Pixel Size (µm)	2.61 x 2.61
Ground Resolution (per pixel)	2.89cm
Image Format	Tiff
Ground Dimension of the image	26,517 x 26,057
Number of images Acquired	147

Table 2: Sample calculation formulas used to calculate vegetation indices

NDI	Normalized Difference Index	(Green-Red) / (Green+Red)
VDVI	Visible-Band Difference Vegetation Index	(2*Green-Red-Blue)/ (2*Green+Red+Blue)
VARI	Visible Atmospherically Resistant Index	(Green-Red)/ (Green+Red-Blue)
ExG	Excess Green	(2*Green-Red-Blue)
ExR	Excess Red	(1.3*Red-Green)
ExG - ExR	Excess Green - Excess Red	(2*Green-Red-Blue)-(1.3*Red-Green)
CIVE	Colour Index Vegetation Extraction	(0.441*Red)–(0.81*Green)+ (0.385*Blue)+ 18.78745

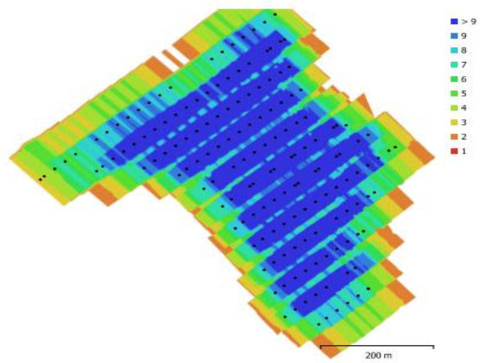


Figure 7: Camera locations and image overlap

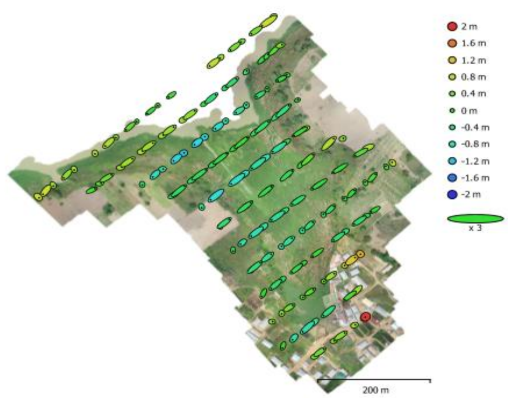


Figure 8: Camera locations and error estimates

IV. RESULTS AND INTERPRETATION

- Results

Based on the Visual interpretation in ArcGIS, after which several vegetation indices were calculated the following colour indices (Figure 9) were chosen as the most suitable ones: NDI, VDVI, VARI, ExG – ExR and CIVE.

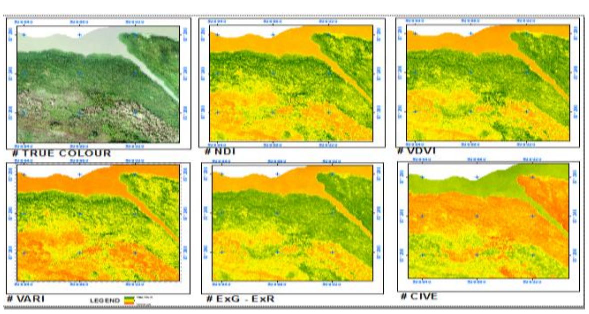


Figure 9: Calculated Vegetation Indices of the area of interest

- Interpretation of Results

(i) The ordinary water surface is highlighted by NDI, ExG – ExR (pink in both indices) and VDVI, VARI (Dark Pink in both indices). Therefore, the water surface can be distinctively distinguished from the seasonally flooded area and the green area along the shoreline, while the shoreline is clearly defined with yellow line in all indices.

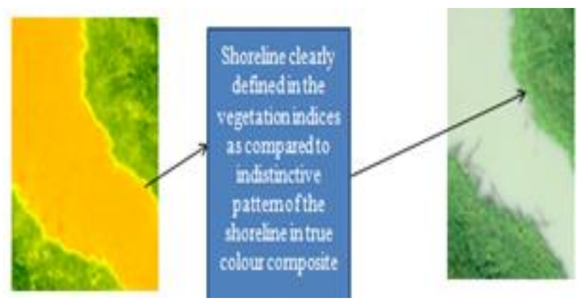


Figure 10: Calculated Vegetation Indices clearly showing Shoreline in Yellow

(ii) Green vegetation is more clearly shown by NDI, VDVI and ExG – ExR indices (Green)

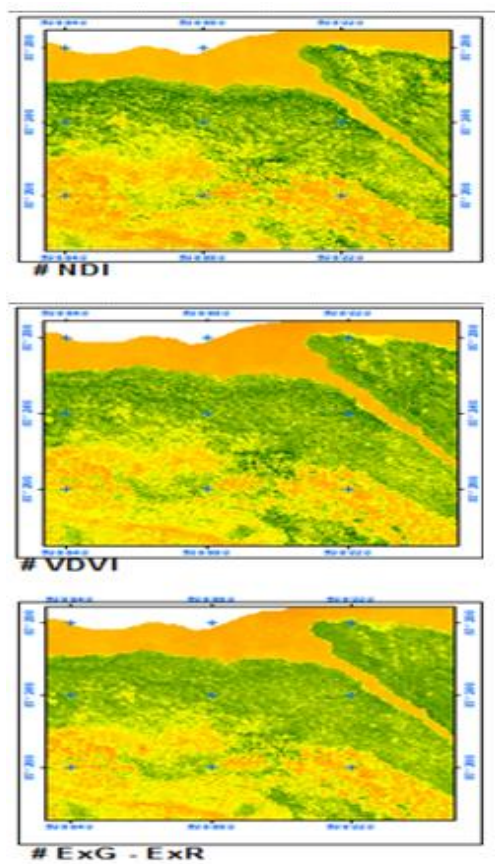


Figure 11: Calculated Vegetation Indices clearly showing Vegetation in Green

(iii) CIVE better shows sparse/dry vegetation, flooded area with bare lands (Yellow)

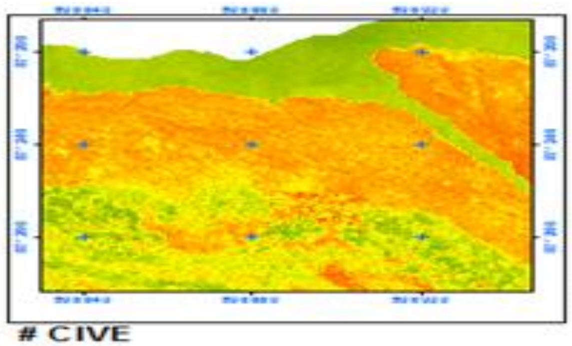


Figure 12: Calculated Vegetation Index clearly showing sparse vegetation, flooded area with dry grasses/bare lands in Yellow

(iv) And finally the trees are well shown by NDI, VDVI, VARI and ExG – ExR

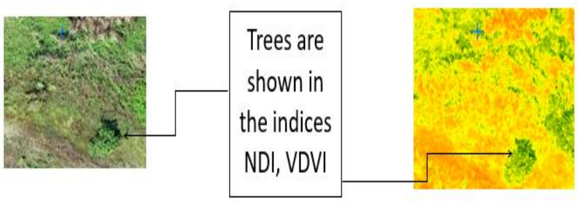


Figure 13: Calculated Vegetation Indices clearly showing tree

- Comments on the Indices

The ExG-ExR difference makes it a possibility to distinguish all vegetation from the clear water surface. CIVE is a useful index for differentiating a green vegetation from the dry one or bare lands. NDI and VDVI clearly highlights the trees even from the green vegetation.

CONCLUSION

In this research, monitoring, mapping and clear definition of vegetation and Shoreline was examined with a middle classed UAV equipped with a camera recording only in the visible spectral bands which provides up-to-date data with a very high spatial resolution because of the altitude of flight which is closer to the objects of concern, other projects can be executed in accordance to client's demand and this will be at an affordable cost unlike the imageries from the satellites which might be very costly with a lower spatial resolution. Inaccessible terrains which are waterlogged or overgrown can be mapped and easily monitored as well.

Specific land cover types can be easily distinguished by visual interpretation of the presented indices using simple RGB bands that can be used to calculate vegetation index and the indices can be further combined for further calculations on purpose. The vegetation indices based on the visible spectral bands enhanced the visual interpretation and they quickly highlight vegetation, seasonally flooded vegetation and clear water surface to enable identification of shoreline and vegetation. Hence, the research hereby recommends that the use of medium commercial UAVs be employed in the execution of projects of this nature instead of incurring larger costs on acquiring satellite imageries and that researcher should venture more into other indices that can be used for this purpose from UAV orthophoto.

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