UAV-Based Imaging for Environmental Sustainability - Flash Floods Control Perspective

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Key words: UAV, ES, High resolution camera, Flash floods, Topographic map.

SUMMARY

The problem of environmental sustainability (ES) of which flooding is one of the main causative agents is a global issue with significant global alert on the need to conserve the earth's atmosphere. The trends and focuses of researchers on ES are dynamics with emphasis on preservation of both renewable and non-renewable resources. For effective ES, aerial photographs of higher resolution usually achieved through the use of optical satellite imagery, aerial photograph, and land based platforms. These methods are terrifically expensive and do not provide better resolution due to high altitude of satellite and aircraft hence the need for the use of Unmanned Aerial Vehicle (UAV). UAV is a newly developed technology system which provides alternate solution for small aerial mapping with higher resolution. It does not require pilot, reduces weights, cost, eminent of danger and highly flexible. This paper focuses on the use of a high resolution UAV as a data acquisition method, which takes aerial photographs of flooded area to generate topographic map for the control of floods. The use of UAV for topographic mapping does not restrict to the any area. Therefore, it can be used for mapping of any small area. This could be achieved through proper pre-flight operation planning, setting of appropriate inertial measurement unit (IMU) for navigation and high resolution sensor camera for exposure along the flight lines. Auto pilot takes coordinates of the exposure points along the flight line. As the IMU moves, three computer – controlled accelerometers updated its location. The accelerometer platform orient north – south, east – west, and plumb by means of three computer controlled gyroscopes. Data processing achieved using Agisoft professional processing software and ArcMap10 software to obtain the final results. For image rectification, we applied terrain correction by considering the highest and lowest points so that terrain could be treated flat for better accuracy. Conversion of the coordinates to UTM would be accomplished using WSG 84 projection system. The flight mission took almost 60 minutes to cover 1.3km^2 at accuracy of 0.3cm. Hence, the result of this research could be used for the control of flash floods for environmental sustainability by considering the possible protective flood barriers: Dams, Lakes, Ponds, Levees, and Floodwalls.

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1. INTRODUCTION

1.1 Background

Flood is abnormal high flow of water over land or coaster area. Floods are of different categories with different behavioral characteristics. Examples are Flash flooding; Seasonal flooding Regional flooding; Tidal flooding, and Flood due to Dam mismanagement. Flash flooding- occurs as a result of heavy rains in hilly areas for a shorter term and will increase both local and small rivers volume to an unsafe level of water; Seasonal flooding- occurs during the rainy season and is due to heavy rain for several hours. It will systematically increase the volume of water to a dangerous level, thereby causing severe flooding of the extensive area and claiming lives and damaging properties; Regional flooding- results from heavy rains of almost 90mm or greater, and can cause severe damage. Because the volume of water flowing will surpass the width and depth of the drainages meant to conveying the water, to designated area; Tidal flooding- is as a result of tropical disturbances, causing serious violence rotating windstorm along the coastal areas. This may extend to several miles and has annihilating effects; Flood due to Dam mismanagement- occurs when the dams constructed for the storage of water poorly managed or damaged. This would result to the failure of the dams and emergency flooding of the entire area.

The utmost interest of this research is 'Flash flooding' control using UAV for environmental sustainability. Control of flooding is necessary and requires all practicable measures to attenuate the detrimental effects of floods. The useful materials needed to achieving this are digital orthophoto map, digital surface model, aspect data, slope map, and contour map, which could be obtained through Photogrammetry methods. In the past years, the tasks of obtaining topographic mapping started from traditional methods to satellite images and aerial photos. These methods are not free from deficiencies; events that called for the use of UAV.
Photogrammetry is a division of Geoinformation science, and it can be defined as the art science and technology of obtaining reliable information about the physical objects and the environment through the process of recording, measuring and interpolating photographic images and patterns of electromagnetic radiation imagery and other phenomena (Wolf, 1983)
Unmanned aerial vehicle (UAV) is an aircraft with its aircrew removed and replaced by a computer system and a radio-link (Austin,2010). Perry and Ryan (2011), stated that unmanned aerial vehicles include fixed-and-rotary-wing aircraft that flown without a Pilot in its cockpit.

America Institute of Aeronautics and Aerospace (AIAA) committee of standards, Lexicon of UAV/ROA defines UAV to be an aircraft which designed or modified, not to carry a human pilot and operated through an electronic input initiated through the flight controller or by an on-board autonomous flight management control system that does not require flight controller intervention.

We live in a fast changing world, what we perceived are processes, circumstances and events that happen or occur in the real world. The known conventional models of the real world are maps; these are always being the result of any successful field's observation and the first tool useful for planning and decision-making. The process of obtaining maps ranges from platform to coverage area.

Long tradition of unmanned aerial vehicle could be better traced to military science as a target for shooting practice, as a platform for reconnaissance and launching of offensive attacks to the enemies. Also in the field of military science and industrial uses are Unmanned Undersea Vehicles (UUVs). These vehicles were capable of mapping the sea- bed without having a pilot in their cockpits. The first fixed-wing unmanned aircraft was the Ruston Protector Aerial Target developed by Archibald Low as a guided weapon during World war 1 (Newcome, 2004).

Thereafter, unmanned aerial vehicles were able to gain popularity and started using as platforms for serious conflicts coverage globally. Unmanned aircraft finds application in mapping purposes Example of this was after the second world wars, where the first pigeons and airplanes used for mapping of battle fields (Jonal et al; 2012).
Civilian applications of UAVs have increased significantly in recent years to their greater availability and the miniaturization of sensors, GPS, inertial measurement units, and other hardware (Lamberts et al; 2007; Zhou and Zang; 2007; Patterson and Brecia; 2008; Rango et al 2008; Nagai et al; 2009). Mapping with airborne and space borne have greater benefits, but they remain underutilized in the mapping of small islands area due to high costs and required specialized personnel and equipment.

UAV application in the range land monitoring is a welcome development and appears to be remarkably suitable because of the aloofness and low population density of rangelands. It is extremely easy to obtain permission to fly from the land management agencies compared to density populated area. Land management agencies such as the U.S Bureau of Land Management (BLM) U.S Natural resources conservation services (NRCS) have a need to monitor and access millions of acres of rangelands, a task that is not feasible with ground monitoring techniques alone. Using UAVs, there is a likelihood of obtaining imagery data quickly for rangeland inventory, assessment, and monitoring by aerial and terrestrial photogrammetry, and also introduces new (near) real time application and low-cost alternatives to the traditional manned aerial photogrammetry (Eisenbeiss,2009).

The United States defence Advanced Research Project Agency (DARPA), sponsored challenges for Unmanned Ground Vehicles in 2004, 2005, and 2007 and came out with the technical analysis that, not a single vehicle was able to run more than 8 mile in 2004; five teams were able to complete the 131.6 mile course, of which four of them in less than 10 hours in 2005. The agency also saw several cars drove autonomously in simulated urban traffic in 2007, with six completing the 60 mile course (DARPA,2007).

UAV is the latest technology in the field of mapping and has since been given different names by the researchers around the world (i.e Unmanned Aerial Vehicle, Uninhabited Aerial Vehicle, and Autonomous Aerial Vehicle). The aircraft (UAV) is different from model aircraft and drones. A model aircraft itself is unmanned but has to be within sight of ground based Pilot. Drone is almost the same with UAV in operation, if not because of its Zero intelligent. Once launched the drone, it does not communicate with the Pilot on the ground and the result of the mission will not be received until the mission successfully completed.

UAV has greater advantages over manned or conventional satellite mapping because of its capability to acquire data in unaccessible or parlous area. Aside from using manned or piloted methods for mapping are Unmanned Aerial Vehicle (UAV), Unmanned Undersea Vehicle (UUV) and Unmanned Ground Vehicle (UGV). The global trends and focuses of researchers around these vehicles for different applications are overwhelming. This research focused on UAV alone.Unmanned aerial vehicles proffers solution in disaster management and sustainability. The data acquired from these instruments can be further processed and analyzed using remote sensing methods to produce hazard maps, dense surface models, detailed building renderings, detailed elevation models, and other disaster area characteristics.

The use of UAV imagery for post–disaster assessments explored in the capacity of both automatic and manual imagery assessments (Adams et al, 2010). The research was on post-disaster studies with UAV as data collection platform.

Applications of photogrammetry and remote sensing are relying on capturing, processing, interpretation and analysis of aerial photographs and satellite images to create different maps for different applications of which topographic mapping inclusive. Detailed topographical survey played a key role in many geomorphological research questions.

Beyond the scope of memory, is the use of traditional methods of obtaining topographical information, and are by far tedious and time consuming especially in a large area. It is also difficult to measure complex morphologies in a steep hilly area. Measurements complicated by vegetation cover, uneven and steep terrain, and difficult accessibility (Nitsche et al,2010). Satellite imagery and aerial photograph that should have been helpful, for obtaining geomorphologies information are of low resolution due to higher altitude, and too expensive for small area mission.

In the regions characterized with complex terrain, Lidar system or terrestrial laser scanners are difficult to use in those regions because they need line of sight elevated positions and good aerial or road access. Terrestrial laser scanning under good conditions (TLS) is a rapid, precise and expensive survey technique to measure fluvial topography (Hodge et al, 2009). However, the fine mechanical scanning devices can make it difficult to use laser scanner under hazardous environmental conditions (Marszalec et al, 1995).

For stereo photogrammetry, good contrast needed in order to identify features in two dimensional images and to measure their displacement. In addition, the stability of the ambient light level and spatial distribution of target reflectivity have an impact on the performance of those systems (Sackos et al, 1996). Major overriding factor acting as a set-

back for civilian applications of unmanned aerial vehicles is due to unfamiliarity of the Federal Aviation Administration (FAA) concerning UAV operations in the National Airspace (NAS). The regulations (FAA,2008) stated that a public operator (i.e. federal, state, or local agency.) needs to acquire a certificate of authorization (COA). This document provides guidelines for operator qualifications, UAV airworthiness, UAV Maintainance, flying altitudes, communication with air traffic control, visual line of sight, and observer requirements.
This research presents step-by-step procedures for data acquisition and data processing of an unmanned aerial vehicle system, and the main objective was to provide an alternative solution to the problem of environmental sustainability'.

2. **FLOOD MANAGEMENT**

Management of floods is essential to mitigate the adverse impact of floods. Adequate control of floods, centered on three main factors such as, nature of floods, the extent of damages and the local conditions. Therefore, control of floods could either be short- term or long- term methods. Short- term method - consist erection of embankment, construction of upraised platform, dewatering of flooded area using pumping mechanism, erection of floodwall at every nook and cranny of the cities, and incessantly evacuation of drainages at both swarming and remote areas. Long- term method includes construction of storage dam and reservoir to regulate the flow of water along the stream's current.

3. **FLOODS CONTROL**

Avoidance of losses and provision of relief materials due to flooding could be ensured by strictly controlling subjected area to flooding. Adequate control of floods require various methods, but structural method in line with the UAV's products is the research's attention. Structural method involves treatments of the catchment to enabling holding of water, construction of dams and reservoirs for temporary storage and regulating flow of water, construction of more channels to enhance the carrying capacity of a river water and also for easily flowing of water that could cause flooding of the coastal area, and construction of levees, embankments, and flood walls to protect area prone to flooding.

4. **COMPONENT OF SYSTEM**

UAV is just a system comprises of a number of sub-systems like aircraft, control station (CS) payload, communication, aircraft recovery, transport, and support equipment. This sub-systems formed an essential component for dynamic observational roles in image acquisition. Below flow chart describes UAV component as sub-systems of autonomous aerial vehicle.

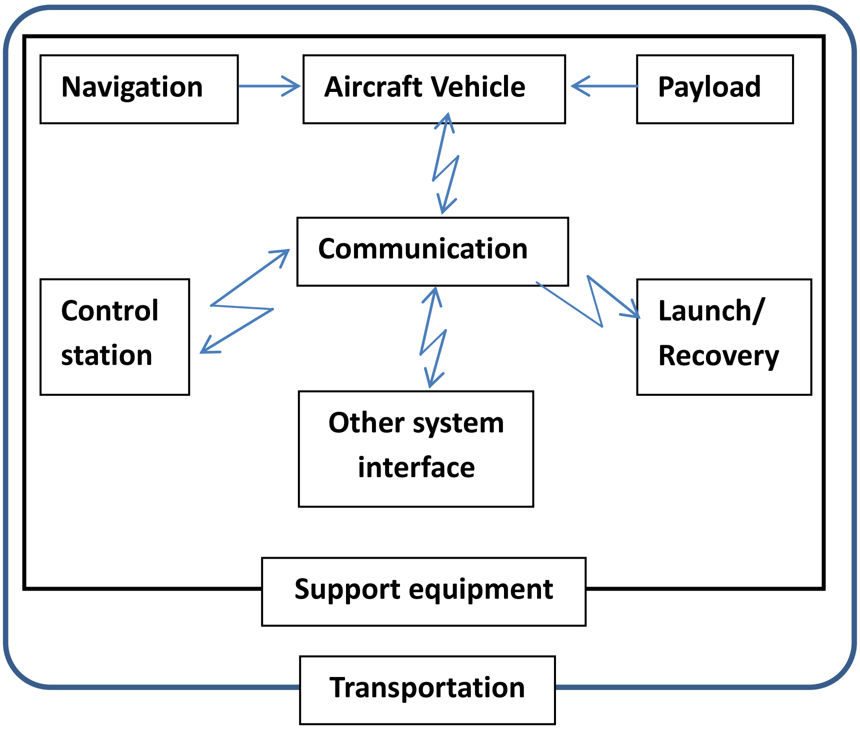

Figure 1 UAV system component

From the above figure, aircraft vehicle will carry the payload to the mission area and navigates through the use of Global Positioning system (GPS) so that the ground based operators will be able to know the position of the aircraft during flight. For fear of the GPS blocked or nonautonomous operation, additional sub-system known as direct tracking or radar tracking needed for use. Via communication, the aircraft receives the signal and provide data links (up and down) between central station and the aircraft. It sends the signal for launching and landing. Control stations hold the planning unit of the whole system and sometimes called mission planning control stations (MPCS). It also up links and down links the information and images to the operators on the ground via communications, a function that makes UAV differs from drone. System interface indicates how sub-system interact with each other. Although some of the system can work uniquely or collectively, but in this context, they must work together, and interact to make a complete system. It is a program that controls a display for the operators (usually on a computer monitor) and allows operators to interact with the system. Launch and recovery needed for vehicles which does not have a vertical and horizontal flight (VHF) capabilities. It does these by receiving signals from control stations via communication.

Support equipment houses other sub- systems including tools and kits. UAV systems often need to be mobile, therefore, transportation provides means of conveying the system to the mission area.

5. **IMAGE ACQUISITION**

5.1 **Preamble**

We acquired the images on the 22nd October,2012 using Fixed- wing UAV and Pentax 12.1mp digital Camera as the platform and sensor respectively. Also used to obtain the images are 320km above the terrain as the altitude, and 61km/ hour as the velocity with 60% side overlap.
The brain has processed the optical signals received through the eyes and mind and may go further to define the attributes of the features and their potentials to change with time. This explains the process of data acquisition, which may be transferred through appropriate data processing into information for planning and decision making. Therefore, geospatial information and geographic information are synonymous and exist in the real world in terms of space and time (Akinyele et al, 2003).
Image acquisition means the process of obtaining primary data, below figure is a flow chart describing how UAV images can be acquired.

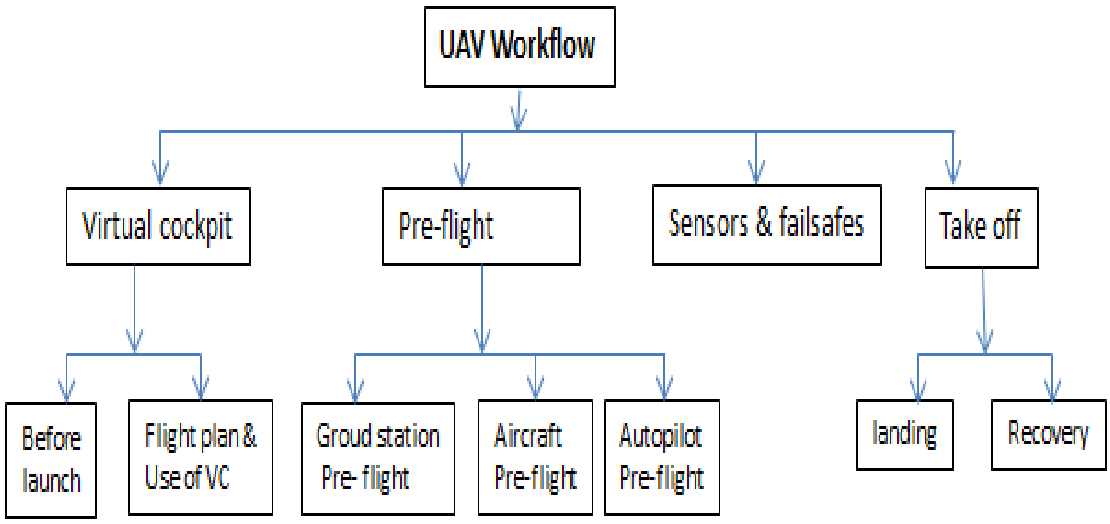

Figure 2 Unmanned Aerial Vehicle workflow.

Extract from figure figure 2 above are virtual cockpit, pre- flight check, sensors and failsafes, and take off, and would be sequentially discussed:

1. Virtual cockpit(VC) - Two settings consist of system set up and system check needed to be carried out before launching the UAV. For flight plan and use of VC, set agent list(address, comm, altitude, velocity, Rccheck box), check heads up display information, check window messages, and check pe-flight buttons. Also need existing map of the study area for flight plan preparation, recovery and landing points uploaded and initiate flight plan set up to at least 4 waypoints.

2. Pre- flight check- UAV pre-flight and ground control station checks needed to be carried out before the flight. It is necessary to set-up the system, open the serial port, boot up the laptop, attach USB game pad to the laptop, power up the commbox and ensure that the wireless modem is working. Launch the virtual cockpit by starting and run the cockpit.

3. Sensors and Failsafes – Sensors and failsafes procedures include pressing the “zeropress” button, set GPS home position button, sensors check button, open failsafe window button to prevent loss of communications, loss of GPS, and low battery. It is necessary to add at least 4 waypoints and ascertained tracking of minimum of 5 satellites, and also verify if sensors are within the range. If not, sensor calibration would be required by pressing “zeropress” button to start the calibration, and this can be carried out before or after the flight using manual and automated techniques. Verification of wireless range is necessary and needed to be done periodically to ascertain proper function of the wire. It is necessary to ensure that the manual mode button turns green for autopilot to take full control of the UAV. Before launching the UAV, set take off mode, ensuring that the voltage did not drop and allowing its propeller to clear off the obstacles.

4. Launch and Landing – It is necessary to hold the aircraft by the throw hole and switch the UAV mode to take off waypoints. The autopilot will control the aircraft to fly towards the takeoff waypoints and switch to navigation mode after take off circle has completed. When the mission completed the autopilot will control the aircraft to landing via communication and turns switch off mode for safety.

a) 


b)


c)

d)


e)

Figure 3 (a, b, c, d, e) : UAVsub-system.

Figure 3 above shows Battery, digital Camera, GPS, Ground control station, and UAV respectively, and were the equipment used for the acquisition of the images.

6. **IMAGE PROCESSING**

Image processing refers to the set of programs that orchestrate and manipulate data, this is required when dealing with large volume of data. The quality of the acquired images was unsatisfactory due to adverse weather, which lead to another flight mission. High profile desk top hardware configurations such as windows 7, 8GB RAM, 1-5-2500 CPU at 3.30GHZ needed due to the nature of UAV's images The generic workflow of image processing involves: block definition, aerial triangulation, elevation model, orthophoto mosaic and stereo mapping, and performed using Agisoft Professional software. ArcMap10 software used to obtain aspect slope, slope map, and contour map with barriers from digital surface model. Although, it also requires human interventions in the area of selecting camera parameter such as pixel size, focal length and principal points coordinates. The camera needs to be calibrated either before or after the flight mission. In this case, the Camera calibration obtained before the flight mission. Ground control points were established for projecting the result into local coordinate system using (RTK-GPS). To rectify images, terrain correction was applied by considering highest and lowest points so that terrain could be treated flat for better accuracy. For the conversion of the coordinates to UTM,WGS84 projection method applied.

7. **RESULTS**

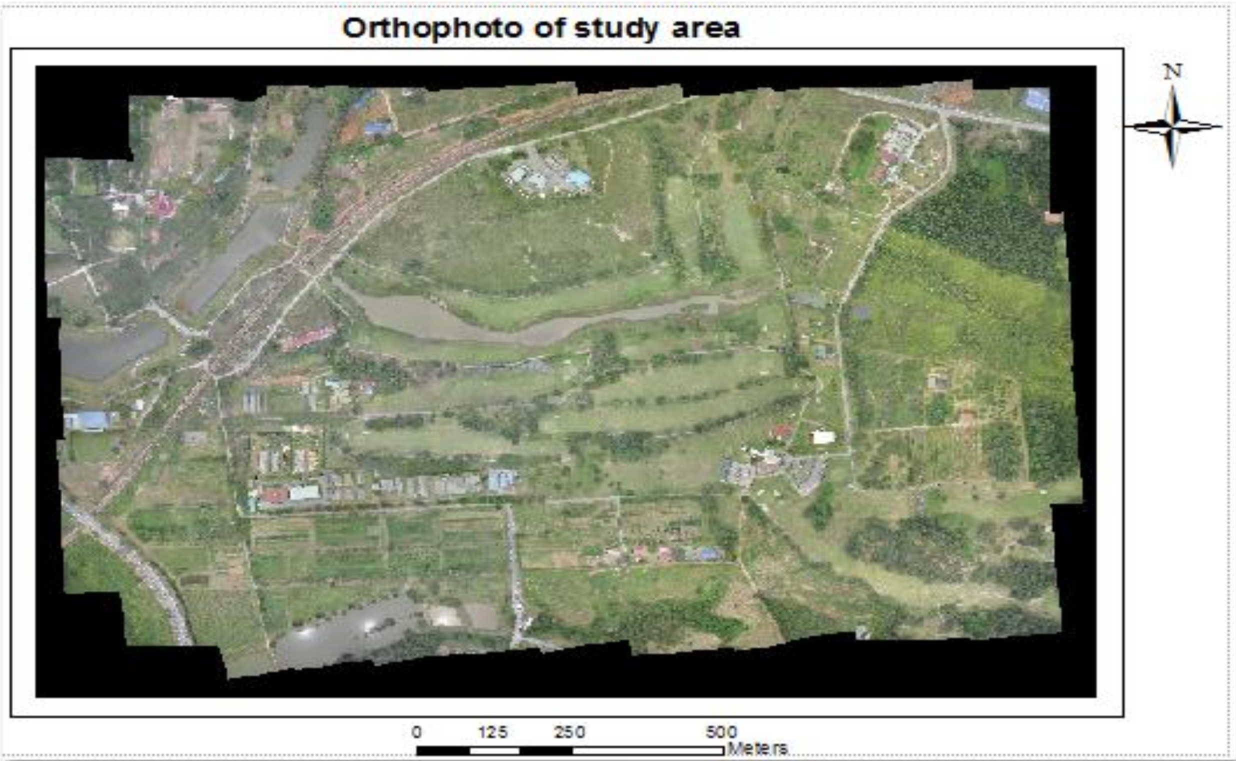

Figure 4 orthophoto mosaic.

Figure 5 contour map with barriers.

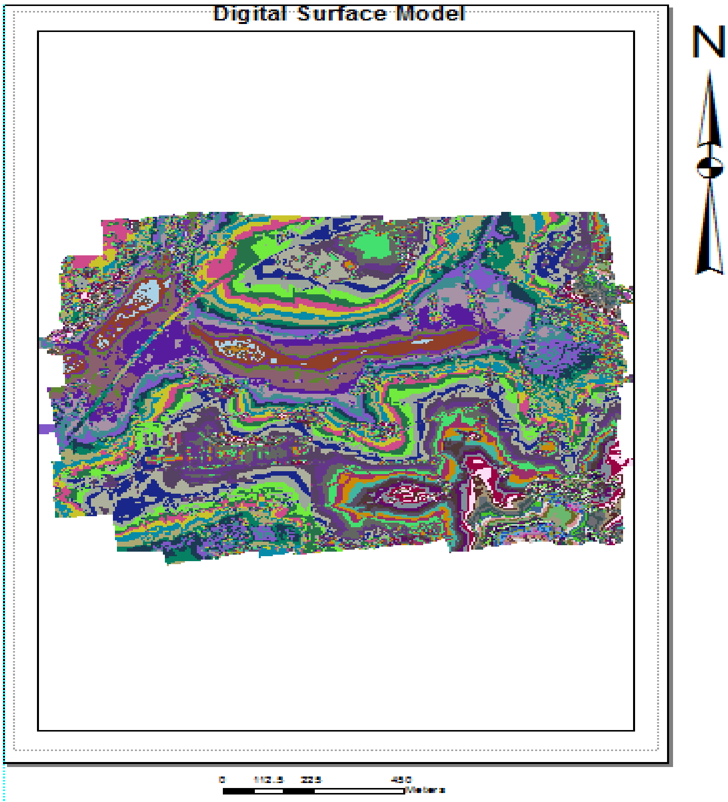

Figure 6 digital surface model.

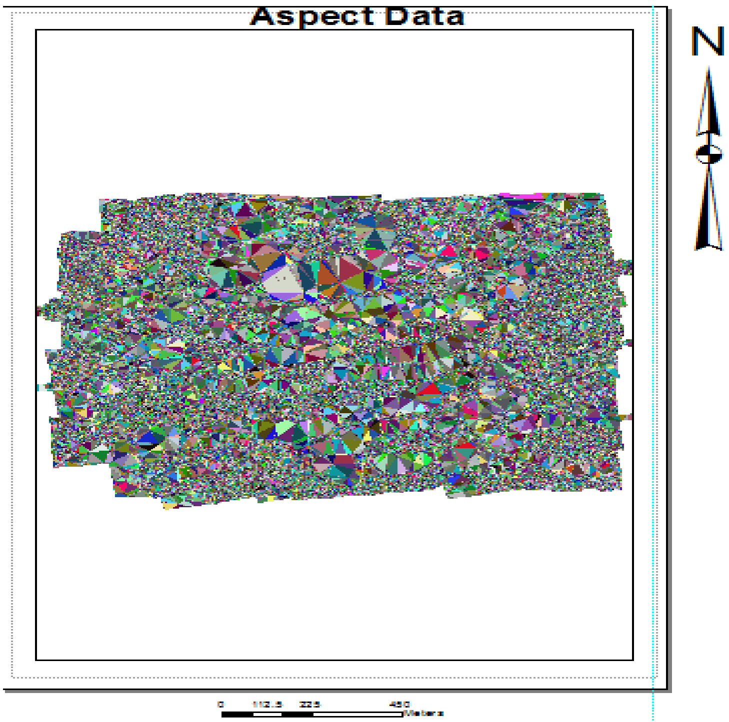

Figure 7 aspect map.

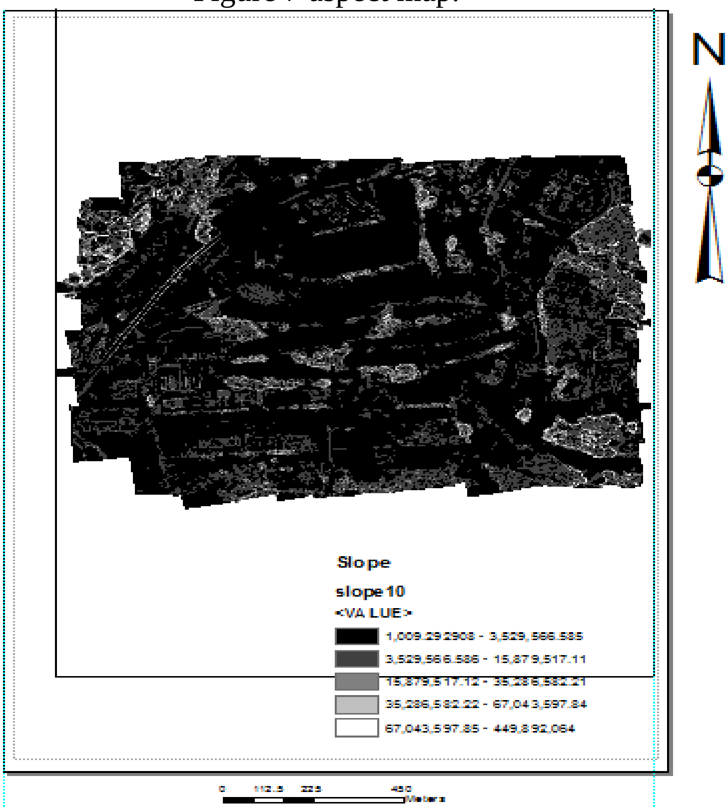

Figure 8 slope map.

Figure 4 – 8 above are products extracted from the UAV imagery acquisition.

8. **DISCUSSION AND CONCLUSION**

Digital orthophoto mosaic obtained from digital terrain model for the terrain rectification of the raw UAV's images and can also be used as guidelines for studying risks before the occurrence of flood disaster. In a likelihood manner, damages caused by the landslide can be easily examined and zoomed to a larger extent for qualitative analysis. These are some of the useful examples of digital orthophoto mosaic.

Digital surface model offers the possibility of generating aspect data, slope map, and contour map. These are useful materials for controlling and predicting floods inundation. Evidence from contour map above indicates that the gentle slopes are the areas prone to flooding and any increase in the water level can cause serious flood disaster to the environment.

Recall that the focus of this research based on the structural aspect of 'flash flood' (construction of levees, dams, embankment, reservoirs, lakes, ponds, floodwalls). Therefore, the above UAV's products are useful materials for engineers for the construction of the structural safety floods barriers, hence justify the use of an UAV as a solution for environmental sustainability.

Obviously, UAV system is not without any challenges despite the fact that it provides several opportunities for mapping of small area, inaccessible area, mapping of the disaster area, and many more. The nature of its data required the use of complex imagery processing software. Often, the quality of images, the accuracy of the on- board GPS/IMU data, and the use of calibrated sensors speak more about the UAV's accuracy. Therefore, the main bottleneck of UAV is about the restriction in securing flight permission which will soon be historical.

Also, UAV system often operated at lower altitude with higher resolution a feature that extinguished the use of classical methods of mapping. More research needed to improve on the orthometric height so that it can become an excellent tool for Surveyors and Engineers.

From the foregoing, it had shown that UAV as a new technology proffers striking solution for environmental sustainability due to its versatility, time saving, less expensive with better resolution when compare with optical satellite, manned aircraft, and terrestrial based platforms.

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