ARDHI UNIVERSITY

COMPARATIVE ANALYSIS OF NASADEM, SRTM DEM AND UAV DATA FOR TOPOGRAPHIC MAPPING

A Case Study of Williamson Diamond Limited

AKYOO, ERICK F

BSc Geomatics

Dissertation

Ardhi University, Dar es Salaam

July, 2023

COMPARATIVE ANALYSIS OF NASADEM, SRTM DEM AND UAV DATA FOR TOPOGRAPHIC MAPPING

A Case Study of Williamson Diamond Limited

AKYOO, ERICK F

A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geomatics (BSc. GM) of Ardhi University

CERTIFICATION AND COPYRIGHT

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled **"Comparative Analysis of NASADEM, SRTM DEM and UAV data for Topographic Mapping, a case study of Williamson Diamond Limited"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geomatics at Ardhi University.

………………………………… ……………………………..

Dr. Elifuraha Saria **Dr. Zakaria Ngereja**

(Main Supervisor) (Second Supervisor)

Date ……………………… Date ………………………

DECLARATION AND COPYRIGHT

I, AKYOO ERICK F hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

………………………………..

AKYOO, ERICK F

22777/T.2019

(Candidate)

ACKNOWLEDGEMENT

The completion of this undertaking could not have been possible without the participation and assistance of many people whose names may not all be enumerated. Their contribution are sincerely appreciated and gratefully acknowledged.

First of all, I am grateful to The Almighty God for enabling me to successfully complete this Research.

I wish to express my sincere thanks my research supervisors Dr. Elifuraha Saria and Dr. Zakaria Ngereja for their constant supervision and guidance throughout this research. Their dynamism, vision, sincerity and motivation have deeply inspired me.

Another grateful thanks goes to the staff members of School of Earth Science, Real Estate, Business and informatics of Ardhi University for their contributions during my entire studies which helped me to shape and successfully complete this research.

Last but not least, I would like to thank my classmates, fourth year students 2023 in Department of Geospatial Science and Technology (DGST) for their help and cooperation during my entire studies at Ardhi University.

DEDICATION

I dedicate this thesis to my parents, brothers, sisters, classmates and friends. without their patience, understanding, prayers, love, support and encouragement the completion of this work would not have been successful.

ABSTRACT

Topographic maps are detailed, accurate graphic representations of features that appear on the earth’s surface using contour lines. There are many methods for topographic mapping including terrestrial methods, photogrammetry method, Global DEM method which is a digital representation of land surface elevation with respect to reference datum. DEMs are used to determine terrain attributes such as elevation at any point. Also, Unmanned Aerial Vehicle, an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft and produces images with point cloud of high precision. This research analyses the difference of SRTM DEM and NASADEM with horizontal resolution of 30m datasets against UAV with resolution of 1.5m datasets at Williamson Diamond Mine. The DEMs were downloaded from Open Topography search engine while the UAV data was obtained from Williamson Diamond Mine, survey department. Softwares used were Global mapper, suffer. Since the reference datum of DEMs is different from that of UAV datasets, unification of datum was required whereby the vertical datum for UAV was in orthometric WGS84 while for the DEMs was orthometric EGM96 So, the UAV datum was converted to be the same as that of DEMs. The assessment parameters used in this research include Mean, Standard Deviation (SD), and Root Mean Square (RMS) of height differences between DEMs and the UAV datasets. The results show that the general performance of SRTM DEM in terms of SD and RMS is 7.58186m and 5.5495m respectively while the general performance of NASADEM for the same statistics is 7.8474m and 5.66024m respectively. Also, the assessment of how elevation appears in 3D surface presentation for both datasets as well as their differences. Therefore, this research has identified SRTM DEM as the best DEM in vertical performance compared to NASADEM for Williamson Diamond Mine. So, further vertical assessments of relative performances of DEMs should be done for other places in order to determine the best DEM for Tanzania in all land covers, which will have a wide range of applications and significantly reduce the cost of construction engineering tasks.

Keywords: NASADEM datasets, SRTM DEM datasets, UAV datasets and Topographic Maps

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATION

SRTM	Shuttle Radar Terrain Model
DEM	Digital Elevation Model
UAV	Unmanned Aerial Visual
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
RTK	Real Time Kinematics

CHAPTER ONE

INTRODUCTION

1.1 Background of the study.

Topographic maps are detailed, accurate graphic representations of features that appear on the earth's surface using contour lines. These features include roads, buildings, urban development, railways, airports, names of places and geographic features, administrative boundaries, state and international borders, reserves, lakes, rivers, streams, swamps, coastal flats. (Ghilani and Wolf, 2015). In topographic mapping it involves the acquisition of horizontal and vertical data to plot the change in terrain of specific area. Topographic surveys are used in Cartography and Mapping to create detailed and accurate maps that represent the natural and man-made features of a specific area, including elevation contours, rivers, roads, buildings, and vegetation. Engineering and Construction, topographic surveys provide critical data for engineers and architects when designing and constructing infrastructure projects such as roads, bridges, buildings, and drainage systems. Navigation and GPS, accurate topographic maps contribute to effective navigation, whether for outdoor enthusiasts, surveyors, or pilots.

There are several methods for producing topographical maps, including Aerial Photography, this involves capturing images of the ground from an elevated position, usually from an aircraft, satellite, or UAV (ASPRS Guidelines, Version 1.0, 2004). Aerial photography uses specialized cameras mounted on aircraft or UAVs to capture high-resolution images of the Earth's surface. The photographs are typically taken at predetermined flight paths, altitudes, and intervals to ensure coverage and accuracy. Aerial photographs can provide valuable information about terrain features, land cover, infrastructure, and other spatial data that are essential for mapping, analysis, and decision-making processes (ASPRS Guidelines, Version 1.0, 2004). Ground surveying technique, it involves determining the relative positions of points on or near the Earth's surface by means of measured horizontal distances, vertical distances, and angles between them, and by computations based on the principles of geometry and trigonometry. (American Society of Civil Engineers (ASCE), 2014). Ground surveying techniques can vary depending on the specific application, but they commonly involve the use of total stations, GPS (Global Positioning System) receivers, levels, and other surveying equipment. LiDAR technique, it is a Remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light. (United States Geological Survey (USGS), 2021). LiDAR works by emitting laser pulses from a sensor, typically mounted on an aircraft or ground-based platform. These laser pulses travel to the Earth's surface and bounce back when they encounter objects or the ground. The sensor then measures the time it takes for the laser pulses to return, allowing for the calculation of precise distances. By scanning the laser pulses across an area, LiDAR systems can create highly detailed point clouds, which represent the elevation and spatial characteristics of the terrain and objects. Unmanned Aerial Vehicle, an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft. (Federal Aviation Administration (FAA), 2021). UAVs typically consist of an aircraft body, propulsion system, onboard sensors, and a communication link with the operator or ground control station. They can be equipped with various sensors, such as cameras, LiDAR scanners, thermal sensors, or multispectral cameras, to capture imagery and data from the air. UAVs offer the advantage of accessing remote or hazardous areas, acquiring high-resolution aerial imagery, and collecting data in a cost-effective and efficient manner. Also, UAV has various dis advantage in topographic surveying, it has limited flight time due to battery constraints, it is highly affected by weather conditions, potential for technical malfunctions and it is expensive and it can sometimes pose risk to manned aircraft and require skilled operators for safe and effective use. Global Digital Elevation Models (DEMs) provide topographic data for the entire Earth's surface. They represent the elevation or relief of the terrain in digital format. Some popular global DEMs include SRTM (Shuttle Radar Topography Mission), ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer Global DEM), and ALOS World 3D (Advanced Land Observing Satellite World 3D). These datasets offer valuable information for various applications, such as geographic analysis, environmental monitoring, and infrastructure planning.Apart from the aforementioned methods for topographic surveying, Digital elevation models can also be used in topographic mapping.

Digital elevation model is a digital representation of land surface elevation with respect to reference datum. DEMs are used to determine terrain attributes such as elevation at any point, slope and aspect. Nowadays there are new technologies of radar interferometry and airborne laser scanning that are used to generate high quality of DEMs useful in a wide range of civil urban planning and military uses. Also, DEMs can be used for route planning in construction of highway and railways. DEMs are important factor in assessing in any process using digital topography analysis including slope, curvature, roughness and local relief that are its derivative attributes. The parameters are normally utilized in several applications such as flood simulation (Pakoksung and Takagi 2015), determination of land slide probability (Dhakal et al.2000), geological mapping, mineral exploration and water sources. Also in Geomatics field, DEMs are used to provide height information which used for precise gravimetric geoid determination (Abbak ,2014). DEMs has the following advantages coverage and consistency, data collection efficiency, safety and cheap, temporal analysis, automation and reproducibility and consistent and data format. UAV and DEMs methods used in topographic mapping, but UAV is expensive compared to DEMs. Hence there is a need to assess the accuracy between DEMs so as to obtain a DEM with highest accuracy that can be used as an alternative of UAV.

A study on Comparative Analysis of Unmanned Aerial Vehicle and Terrestrial Laser Scanner Data for Deriving Digital Surface Models and Extracting Vegetation Features, Authors, Nex, F., Remondino, F. Published: ISPRS Journal of Photogrammetry and Remote Sensing, 2014. This study compared UAV-based photogrammetry with terrestrial laser scanning (TLS) for generating digital surface models and extracting vegetation features. The authors assessed the accuracy and suitability of both techniques and discussed their strengths and limitations. A study on Accuracy Assessment of Digital Surface Models Derived from Unmanned Aerial Vehicle Imagery on Glaciated and Non-glaciated Landscapes, Authors: James, M.R., Robson, S. Published Remote Sensing, 2014. The study evaluated the accuracy of DEMs derived from UAV imagery on glaciated and non-glaciated landscapes. The authors compared the UAV-derived DEMs with reference LiDAR datasets and investigated the influence of various factors on the accuracy of the UAV-derived DEMs. A study on Comparison of UAV Photogrammetry and LiDAR Data for Digital Elevation Model Extraction in a Forested Area, Authors Khosravipour, A., Skidmore, A.K., Isenburg, M., et al. Published Remote Sensing, 2014.This study compared UAV-based photogrammetry and airborne LiDAR (Light Detection and Ranging) data for extracting digital elevation models in a forested area. The authors assessed the accuracy and suitability of both methods for generating DEMs.

In contrast to the current research, this study uses NASADEM and SRTM DEM datasets downloaded from Open Topography engine search and the UAV georeferenced datasets collected from Williamson Diamond Mine, survey department. The obtained DEM datasets were analysed with respect to the UAV datasets so as to acquire the best between them. Also, it involved the use of 3D surface representation of UAV against the DEMs so as to see their differences to validate with the obtained results and lastly come up with discussions and analysis on the best DEM to be used.

1.2 Statement of the problem

Ultimately, the choice between methods for topographic mapping depends on the specific requirements of the project, such as budget, area of interest, and required level of detail. Terrestrial survey method such as GNSS method can be nearly equal to UAV but it consumes time and high budget when it comes to large areas. The comparative analysis between GNSS data and the UAV data has already been studied and results showed that GNSS method had the best performance in terms of accuracy and precision. The Global DEMs such as NASADEM, SRTM DEM, CORPENICUS, FABDEM, TANDEM etc. also produce quality topographic maps with the advantages of coverage and consistency, data collection efficiency, safety and cheap, temporal analysis, automation and reproducibility and consistent and data format. The comparative analysis between UAV and DEMs in terms of requirements of the project, such as budget, area of interest, and required level of detail have not yet been done. Since UAVs provide high-resolution and accurate maps but with a high cost, skilled operator to use, high budget and highly affected by weather conditions This study covers the comparative analysis of NASADEM, SRTM DEM and UAV for topographic maps so as to assess the best DEM which can be used as an alternative of UAV and reach out to help the Survey and Mapping Division when in need to produce series of updated topographic maps.

1.3 Research Objectives

1.3.1 Main objectives

The main objective of this research proposal is to carryout comparative analysis of NASADEM, SRTM DEM and UAV data for topographic mapping and come up with a DEM which can be used as an alternative for UAV for different requirements.

1.3.2 Specific objectives

i) Compare the accuracy and resolution of topographic maps generated from NASADEM, SRTM DEM and UAV data.

ii) Evaluate the suitability of NASADEM and SRTM DEM for topographic mapping in different topographic landforms.

iii) Investigate the cost-effectiveness of using NASADEM and SRTM DEM or UAV data for topographic mapping.

1.4 Significance of the research

This study helps users such as consultants, engineers and surveyors to select appropriate methods in topographic mapping depending on the accuracy. To bring knowledge about remote sensing and application especially on the Digital elevation model. Compare the effectiveness of different remote sensing techniques for mapping topographic features and determine the most accurate method for future mapping applications.

1.5 Scope and limitations

The Williamson Diamond Mine (also known as the Mwadui mine) is a diamond mine 23 kilometers (14 miles) northeast of Shinyanga in Tanzania. Figure 1.1 shows the location of Williamson diamond mine. This study is limited in producing topographical maps, therefore the data collected from the two sources will be analyzed and compared. The results will lead into conclusion that based on accuracy for each method.

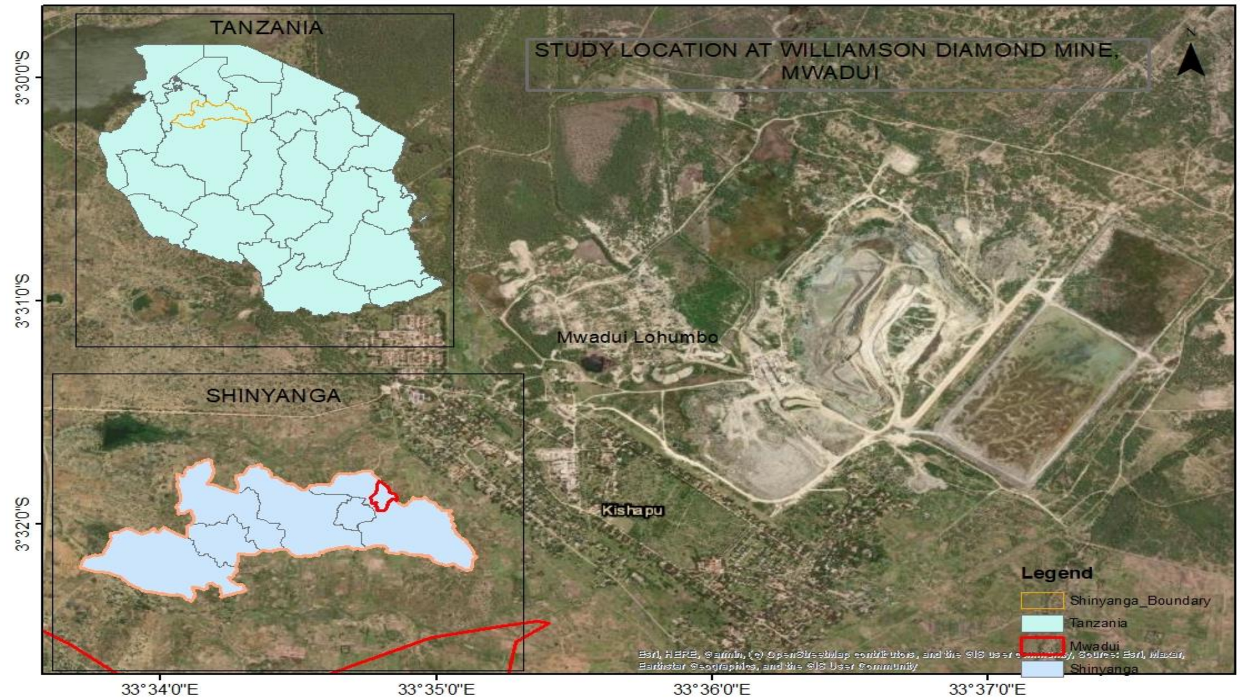

Figure1.1: Location of Williamson diamond limited

1.6 Dissertation outline

Chapter one provides a brief insight and history of the surveying equipment used. This chapter also contains the research problem statement, questions, aims, objectives, scope, contributions and significance, methodology, limitations, and the thesis statement. Chapter two seeks to give the reader more insight information on the topic. This section describes some of brief idea about the overall concept of precision and accuracy NASADEM, SRTM DEM and photogrammetric technique (UAVs) in for topographic mapping. Chapter three explains the methodological options available to be used and the reasoning behind choosing the best approach for this research, description of the site area, field study, procedures and research data analysis that will be used and to achieve specific objectives. Chapter four explains the analysis and discussion of the findings gathered from this research by constructing a comparative table that shows the differences of the results (vertical accuracy & precision) of using the UAV photogrammetric surveying method and compares the results obtained. Chapter five seeks to achieve the main objective which is concluding the research by recommending the better option for future research.

CHAPTER TWO

LITERATURE REVIEW

The primary focus of this literature review is to gather relevant information from previous studies about topographic map making using satellite images and shuttle radar topographic mission digital elevation model together with those made from photogrammetric technique (UAVs).

2.1 Topographic Map

Topographic map is a type of map characterized by large scale detail and quantitative representation of relief features usually using contour lines but historically using variety of methods. Traditional definitions require a topographic map to show both natural and artificial features. One of the most widely used of all maps is the topographic map. Topography comprises of two English words, namely 'topo' that deals with earth surface and 'grapho' that represents information (Moustafa, 2012).

A map is a model of part of the earth surface showing the shape and position of different countries, political borders, natural features such as rivers and mountains and artificial features such as roads and buildings. A map can also give a particular type of information about a certain area on the surface of the earth. A topographic map is a two-dimensional representation of a three-dimensional land surface. Topographic maps are differentiated from other maps in that they show both the horizontal and vertical positions of the terrain and a major distinction from the other maps is the presence of contour lines which depicts the elevation of points on the earth's surface (Costa & Diambra, 2005). The feature that most distinguishes topographic map from other types of maps is the use of contour lines to portray the shape and elevation of the land. Topographic map renders the three-dimensional ups and downs of the terrain on a two-dimensional surface (Starr, L. E., & Anderson, 1991). Given the diversity and heterogeneity of the natural and human altered landscape, it is obvious that the time-honoured and laborious method of ground inventory is inappropriate for mapping land use and land cover over large areas. A more synoptic vantage point, such as provided by remote sensing is required for effective detection, identification, classification, delineation, and analysis of landscape features (Caetano & Santos, 2008).

Maps became increasingly accurate and factual during the 17th, 18th and 19th centuries with the application of scientific methods. Many countries undertook national mapping programs. Nonetheless much of the world was poorly known until the widespread use of aerial photography following world war I. Modern cartography is based on a combination of ground observations and remote sensing. Maps are a universal medium for communication easily understood and appreciated by most people regardless of language or culture. Incorporated in a map is the understanding that it is a snapshot of an idea, a single picture and a selection of concepts from a constantly changing database of geographic information. Old maps provide much information about what was known in times past, as well as the philosophy and cultural basis of the map, which were often much different from modern cartography. Maps are one means by which scientist distribute their ideas and pass them on to future generations (F. Samadzadegan, A. Milanlak, & M.GH. Majdabadi, 2004).

All variety of maps can be classified as either real map or virtual map. Real maps are tangible product that has a permanent form and can be viewed directly. Examples are conventionally drawn or printed product, aerial photography products etc. Virtual maps are non-permanent, none physical and in some case none visible. Examples are temporary map image projected onto screen by the CRT, mental map etc. (Nkeki & Asikhia, 2014).

All components of a topographic map at a specified scale are of equal importance; water, terrain, communication, built up areas, vegetation etc. as well as the lettering of place-names and geographical and cultural features. Topographic maps use a wide variety of symbols to represent manmade and physical features for example highways, railroads, gravel pits, buildings, etc.
Ideally, all these features should appear on a map in their true proportion, position and shape. This is however, still not feasible because many of the features would be unimportant and others would be unrecognized because of their reduction in size. Furthermore, some symbols have to be created to represent the man-made and natural features. These symbols are as closely as possible to the real features themselves. If this is not possible, a new symbol is created that logically implies the feature(s) it portrays. For example, a campsite is represented by a small black triangular tent.

Symbols are positioned on a topographic map in such a manner that the center of the symbol remains its true location. However, an exception to this would be the position of a feature adjacent to an important road. If the width of the road has been exaggerated, then the feature is moved from its true position to preserve its relation to the road.

2.2 3D modelling

Is the process of creating a 3D representation of any surface or object by manipulating polygons, edges, and vertices in simulated 3D space (Wolf, Dewit, & Wilkinson,2014). (Rosnell,2012), tested the ability of different micro drone systems, digital cameras and photogrammetric software to generate 3D models. The study identified several areas of consideration when performing photogrammetric processes utilizing UAS systems. The first of which being poor image quality because of windy conditions. Objects with a thin profile such as light poles and trees as well as object with homogeneous surfaces such as roofs and large parking lots were also problematic.

2.3 NASA DEM

NASADEM is a modernization of the Digital Elevation Model (DEM) and associated products generated from the Shuttle Radar Topography Mission (SRTM) data. Interferometry SAR data from SRTM were reprocessed with an optimized hybrid processing technique in producing the data products. NASADEM data products were derived from original telemetry data from the Shuttle Radar Topography Mission (SRTM), a collaboration between NASA and the National Geospatial-Intelligence Agency (NGA), as well as participation from the German and Italian space agencies. SRTM's primary focus was to generate a near-global DEM of the Earth using radar interferometry. It was a primary component of the payload on space shuttle Endeavour during its STS-99 mission, which was launched on February 11, 2000, and flew for 11 days. NASADEM relied on Ice, Cloud, and Land Elevation Satellite (ICESat) Geoscience Laser Altimeter System (GLAS) ground control points of its lidar shots to improve surface elevation measurements that led to improved geolocation accuracy. Other reprocessing improvements include the conversion to geoid reference and the use of GDEMs and Advanced Land Observing Satellite Panchromatic Remote-sensing instrument for Stereo Mapping (PRISM) AW3D30 DEM, and interpolation for void filling. NASADEM are distributed in 1-degree latitude by 1-degree longitude tiles and consist of all land between 60° N and 56° S latitude.

This accounts for about 80% of Earth's total landmass. NASA DEM dataset referenced to horizontal datum WGS84 and vertical datum EGM96. (JPL, NASA DEM, 2021)

2.4 Shuttle Radar Topographic Mission Digital Elevation Model.

The Shuttle Radar Topography Mission obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of the Earth. SRTM consisted of a specifically modified radar system that flew onboard the Space Shuttle Endeavour during an 11- day mission in February of 2000. The radar system was based on the older space borne imagingradar- C/X- band synthetic aperture radar (SIR-C/X-SAR), previously used on the shuttle in 1994.

To acquire topographic data, the SRTM payload was outfitted with two radar antennas. One antenna was located in the shuttle's payload bay, the other – a critical change from the SIR-C/XSAR, allowing single-pass interferometry on the end of a 60m mast that extend from the payload bay once the shuttle was in space. The technique employed is known as interferometric synthetic aperture radar. The elevation models are arranged into tiles, each covering one degree of latitude and one degree of longitude, named according to their south western corners. The resolution of the raw data is one arc second (30m along the equator) and coverage includes Africa, Europe, North America, South America, Asia and Australia (Pantazis et al., 2005).

A derived one arc second dataset with trees and the other non-terrain features removed covering

Australia was made available in November 2011; the raw data are restricted for government use. For the rest of the world, only three arc second (90m along the equator) data are available. Each one arc second tile has 3601 rows, each consisting of 3601 16bit. The dimensions of the three arc second tiles are 1201 x 1201. The original SRTM elevations were calculated relative to the WGS84 ellipsoid and then the EGM96 geoid separation values were added to convert to heights relative to the geoid for all the released products. The elevation models derived from the SRTM data are used in geographic information systems. They can be downloaded freely over the internet. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). (Nkeki & Asikhia, 2014) demonstrated that GIS platform can effectively be used to map and previsualize topographical data with regard to SRTM DEM-based raster. Over the years, the application of GIS technique in landscape modeling has been embraced by contemporary researchers in the physical environment disciplines. Developing a geographic visual model of any topography is a complex task that requires complex state-of-the-art technology if the goal is to achieve accurate result. This is because geographic datasets are complex in nature due to it spatial and temporal characteristics.

Although, at the end of the nineteenth century, good quality topographic mapping existed for few regions of the world (part of Europe, North America, and India), the technology for producing such map could not meet the need of planners. Hence, there arise a need for technological advancement, and the adoption of new and promising methodology.

2.5 Overview of UAVs

2.5.1 The definition of UAVs

Unmanned Aerial Vehicles (UAV) are any form of aerial vehicle not being piloted by anyone on board, and not inevitably needed to be controlled remotely in any way. Another synonymous term to UAV is 'drones', but a drone is a UAV that is continuously being controlled remotely either by a person and/or a computer program (Simpson & Weiner, 2017). These broad categorization places UAVs in as air balloons and fixed wing.

2.5.2 The development of UAVs

The use of UAV technology started innocently back to the early 1800s in the form of blimps and hot air balloons, and their sole purpose is acquiring data on the earth upper atmosphere for weather predictions (Eisenbein, 2009). Then in the mid-1800s, the military industry recorded their first use of a significant adaptation of UAV technology by launching approximately 200 unmanned airships infused with self-detonating timer bombs over the city of Republic of San Marco, Venice, ending The First Italian War of Independence (Flagg, 1853).

2.5.3 UAVs Photogrammetric Surveying

Photogrammetry Surveying is the process of generating a 3D model called a digital elevation model (DEM) of the area from multiple 2D photographs of the same point from multiple angles (Constro,2018). The process is done by specialized software capable of displaying images based on a Ground Control Point (GCP) to triangulate the elevation point of the specific site. Usually, the higher the number of images taken the higher the accuracy of the 3D mesh model of the site, but it only increases ever so slightly, once it has reached a specific number of images required (Colomina and Molina, 2014). The use of having a base map of the area to conducting surface analysis in order to predict water flow for hydrology or mass movement such as landslides (Campbell, 2013).

2.5.4 The Capabilities of UAVs Photogrammetric Surveying

One of the pioneers in UAV research, concluded that UAV with the appropriate photogrammetric evaluation equipment is very much capable of conducting a photogrammetry survey. (Corrigon, 2018) Reported what (Manyoky & P., 2012) that UAV equipped with an intervalometer shutter on the camera is suitable to carry out 3D Mapping. (Gindraux, 2017) concluded that the data acquired from UAV are reliable enough to be used to create a DEM with minimum use of 3 GCPs.

2.5.5 There are two work flows in UAVs with the recent technological advancement

I. Ground control points based photogrammetric surveying

In this method you need a sufficient number of known points to verify and pin your imagery to the ground. Having multiple GCPs ensures survey accuracy, but they can be time consuming to set up on a large work site. Sometimes aero-points are used.

II. Post processing kinematics photogrammetric surveying

With the PPK capability the UAVs geotags, X, Y and Z coordinates to each image based on its GPS unit. While this happens, a base station or the CORS network on the ground is also recording positional information, but with much more accurate triangulation.

In this research the UAVs photogrammetry will be used based on the ground control points. And each GCP will be distributed evenly on the area of interest.

2.6 Error analysis

Error is the difference between a measured or calculated and the established value of a quantity. (Schofield,2007). In the case of this research the base value is the values determined through ground surveying that controls the detailed survey.

Errors in measurements stem from three sources: personal, instrumental, and natural. Any observation can contain various types of errors. Often some of these errors are known and can be eliminated or at least reduced by applying appropriate corrections. (Schofield, 2007). However, even after all known errors are eliminated, a measurement will still be in error by some unknown value. To minimize the effect of errors it maximizes the accuracy of the final results.

2.7 Accuracy

Accuracy is the degree of conformity of a measurement to its true value, (Anil,2005). Accuracy relates to the quality of the result. Small magnitude errors of each individual measurement may affect the quality of the final result by considerable large amount. Therefore, the final result may depend on the accuracy and precision from each individual measurement.

CHAPTER THREE

METHODOLOGY

This research deals with comparison analysis of SRTM DEM-1“and NASADEM-1” by the use of UAV data from Williamson diamond mine. First requirement is to compare the two DEMs over study area so as to assess their agreement at every point of intersection. Secondly, the DEMs are assessed using the UAV data available over selected area.

3.1 Office planning

Office planning involves the collection and the verification of useful information to enhance the smooth execution of the project. This involves the collection of information about the study area. This information includes NASADEM datasets and SRTM datasets both with resolution of 30m that covers the project area as well as the UAV georeferenced datasets with resolution of 1.5m. The DEMs are downloaded with the header information as dataset file, the header must be modified to resemble that of gravest package before it’s converted to surfer format where most of work is done.

3.2 Software requirements

Softwares used for data processing and analysis are;

i) Global Mapper version 23 Used to convert the grid file of DEMs to raster format (GeoTIFF)

ii) Golden surfer version 18.1 This used to convert the DEMs from surfer grid to DAT format (x, y, and z) for elevations extraction, grid data manipulations and Calculation of Mean, SD, RMS, maximum and minimum values

iii) Microsoft Excel This was used in writing report and performing computations. Programs which mostly used were Microsoft word for writing report and Microsoft excel for computing statistics attributes such as standard deviation, root mean square and the mean.

iv) Microsoft Word to write the research report.

3.3 Unification of datum

To achieve the objective of this research, the unification of datum for all data sets used to have the common reference system, whereby UAV data based on WGS84(orthometric) was converted into EGM96(orthometric) so as to coincide with the SRTM DEM and NASADEM.

3.4 Conversion of UAV data to EGM96 orthometric height

UAV data was converted to EGM96 so as to have the same format as the heights of NASADEM and SRTM DEM. Therefore, by using the geoidal height from EGM96, UAV data height was converted to orthometric height. This was done through equation h=H+N

$H_{84}^{UAV}=h_{84}^{UAV}-N_{84}$ ……………………………………………………………3.1

$H_{96}^{SRTM}=h_{96}^{SRTM}-N_{96}$ ……………………………………………………………3.2

From eqn..1

$h_{96}^{UAV}=H_{84}^{UAV}+N_{96}$ ……………………………………………………………3.3

$H_{96}^{UAV}=h_{96}^{UAV}-N_{96}$ ……………………………………………………………3.4

then

$H_{96}^{SRTM}=h_{96}^{SRTM}+N_{96}$ ……………………………………………………………3.5

$H_{96}^{UAV}=h_{96}^{UAV}+N_{96}$ ……………………………………………………………3.6

The same procedure is done for NASADEM-1" to be;

$H_{96}^{NASADEM}=h_{96}^{NASADEM}+N_{96}$ ……………………………………………………………3.7

Where; H_{84}^{UAV} is the orthometric height UAV data based on WGS84

h_{84}^{UAV} is the ellipsoidal height UAV data

N_{84} is the geoidal height of WGS84

h_{96}^{SRTM} is the ellipsoidal height of SRTM DEM-1"

H_{96}^{SRTM} is the orthometric height of SRTM DEM-1" based on EGM96

N_{96} is the geoidal height of EGM96

$H_{96}^{NASADEM}$ is the orthometric height of NASADEM-1" based on EGM96

$h_{96}^{NASADEM}$ is the ellipsoidal height of NASADEM-1"

3.5 Assessment of NASADEM, SRTM and UAV datasets

After resampling the data in every 30m, t NASADEM, SRTM DEM and UAV data points whereby relative height differences between the points were computed. To assess the difference in each DEM and UAV elevations, the dataset must be obtained and the evaluated on orthometric heights system made so as to compare with the UAV. The accuracy assessment of the DEMs is determined from the statistics of the differences in height. These statistics include mean, standard deviation, and root mean square as shown in the following equations;

a) Mean of height differences

Equation below used to compute the mean of height differences between DEMs and UAV data.

$$\Delta H_{mean}^{UAV,DEM} = \frac{1}{n}\sum_{i=1}^{n} \Delta\, H_{i}^{UAV,DEM} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Where: n is the number of UAV data used.

b) Standard Deviation (SD)

Standard deviation is the measure of amount of variation or dispersion of a set of values. A low standard deviation indicates that the values that the values tend to be close to the mean of the set while high standard deviation indicates that the values are spread out over a wider range. Equation below used to compute standard deviation of height differences between DEMs and UAV data.

$$\mathrm{SD} = \pm\sqrt{\frac{\sum_{i=1}^{n}(\Delta H_{i}^{UAV,DEM} - \Delta H_{mean}^{UAV,DEM})^{2}}{n-1}} \ldots\ldots\ldots\ldots\ldots..3.9$$

c) Root Mean Square (RMS) value of the height differences

RMS is a measure of the magnitude of a set of numbers. Equation below is used in this research

to compute the RMS value of height differences between DEMs and UAV data.

$$\mathrm{RMS} = \pm\sqrt{\frac{\sum_{i=1}^{n}(\Delta H_{i}^{UAV.DEM})^{2}}{n}} \ldots\ldots\ldots\ldots\ldots..3.10$$

3.6 NASADEM Dataset

NASADEM is a modernization of the Digital Elevation Model (DEM) and associated products generated from the Shuttle Radar Topography Mission (SRTM) data. NASA DEM dataset referenced to horizontal datum WGS84 and vertical datum EGM96. (JPL, NASA DEM, 2021). The datasets appeared on global mapper as shown in figure 3.1

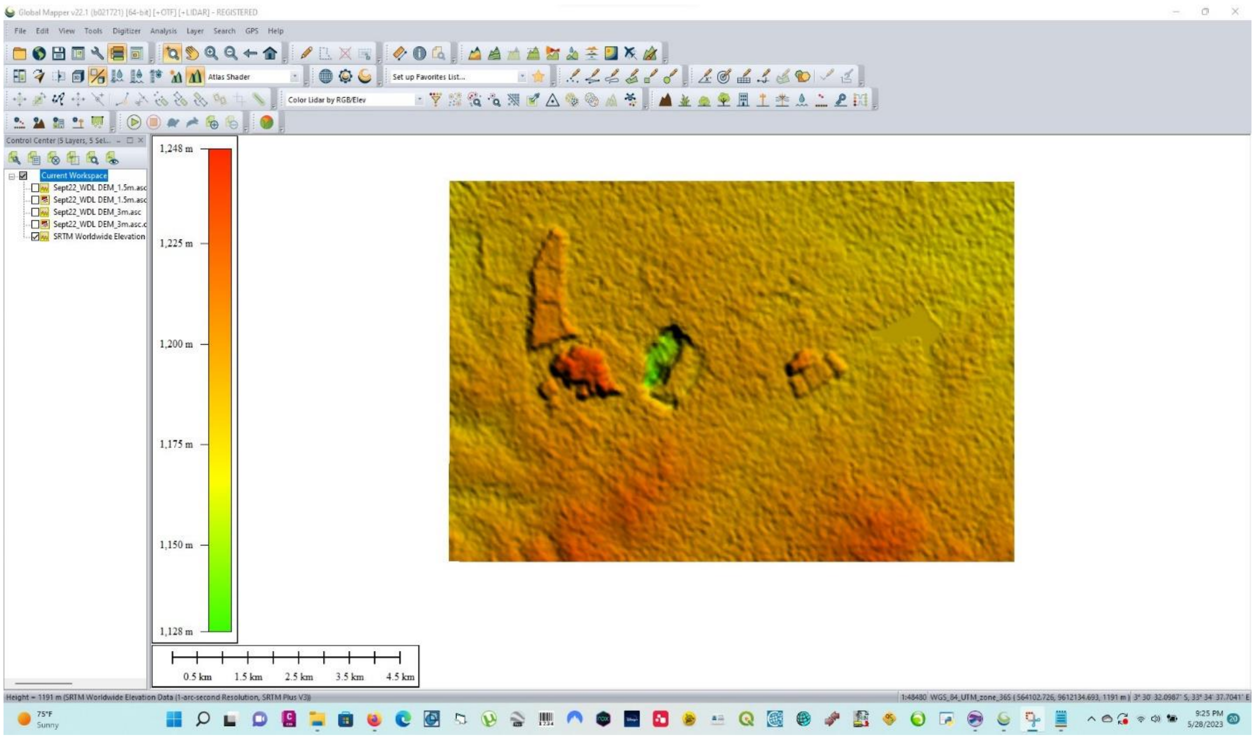

Figure 3.1: NASADEM cover for Williamson diamond mine

3.6.1 Procedures to download NASADEM

i. Fill in the links with the use of a search engine such as google.com

ii. Download the NASADEM-1” directly from Open Topography.

iii. Choose the region you want to download, then move the cursor to the area of interest and highlight it with a rectangle block.

iv. Once you have submitted your project, they will provide you information through email and allow you to start downloading the NASADEM-1”.

3.7 SRTM DEM Dataset

The Shuttle Radar Topography Mission obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of the Earth. The resolution of the raw data is one arc second (30m along the equator) and coverage includes Africa, Europe, North America, South America, Asia and Australia (Pantazis et al., 2005). After importing the datasets, they appeared as shown in figure 3.2

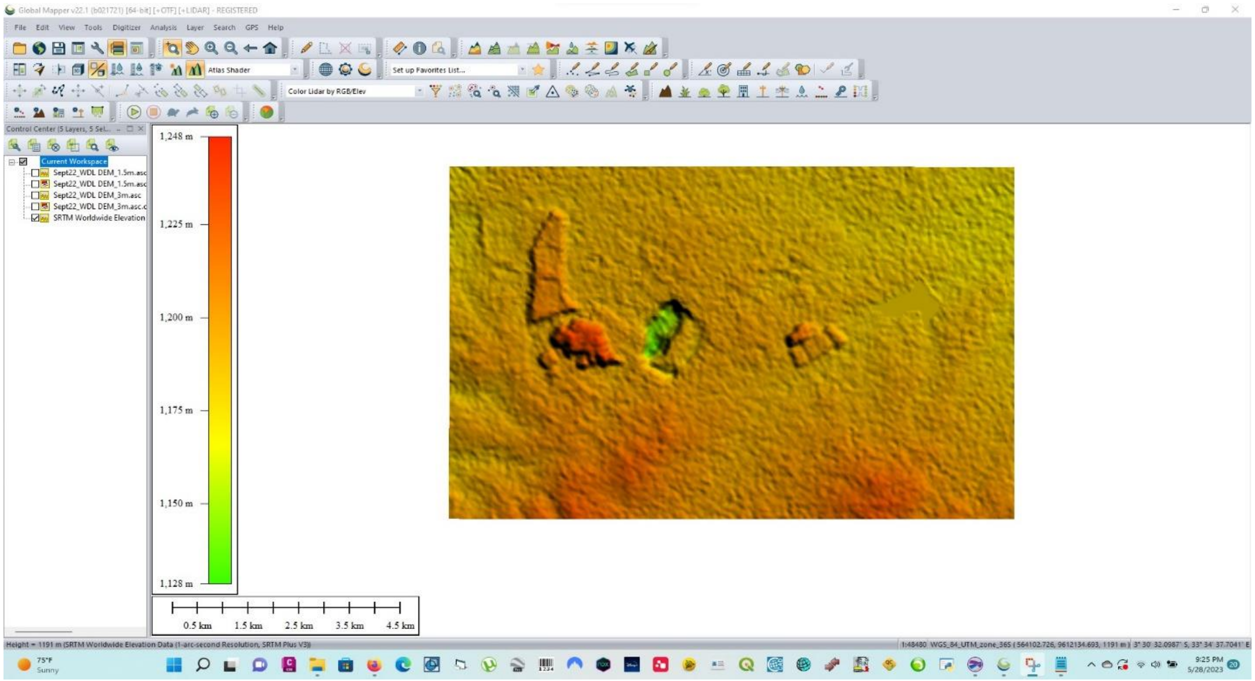

Figure 3.2: SRTM DEM cover for Williamson diamond mine

3.8 UAV dataset

Unmanned Aerial Vehicles (UAV) are any form of aerial vehicle not being piloted by anyone on board, and not inevitably needed to be controlled remotely in any way. Another synonymous term to UAV is 'drones', but a drone is a UAV that is continuously being controlled remotely either by a person and/or a computer program (Simpson & Weiner, 2017). Accuracy is the degree of conformity of a measurement to its true value, (Anil,2005). Accuracy relates to the quality of the result. The UAV data appeared as shown in figure 3.3

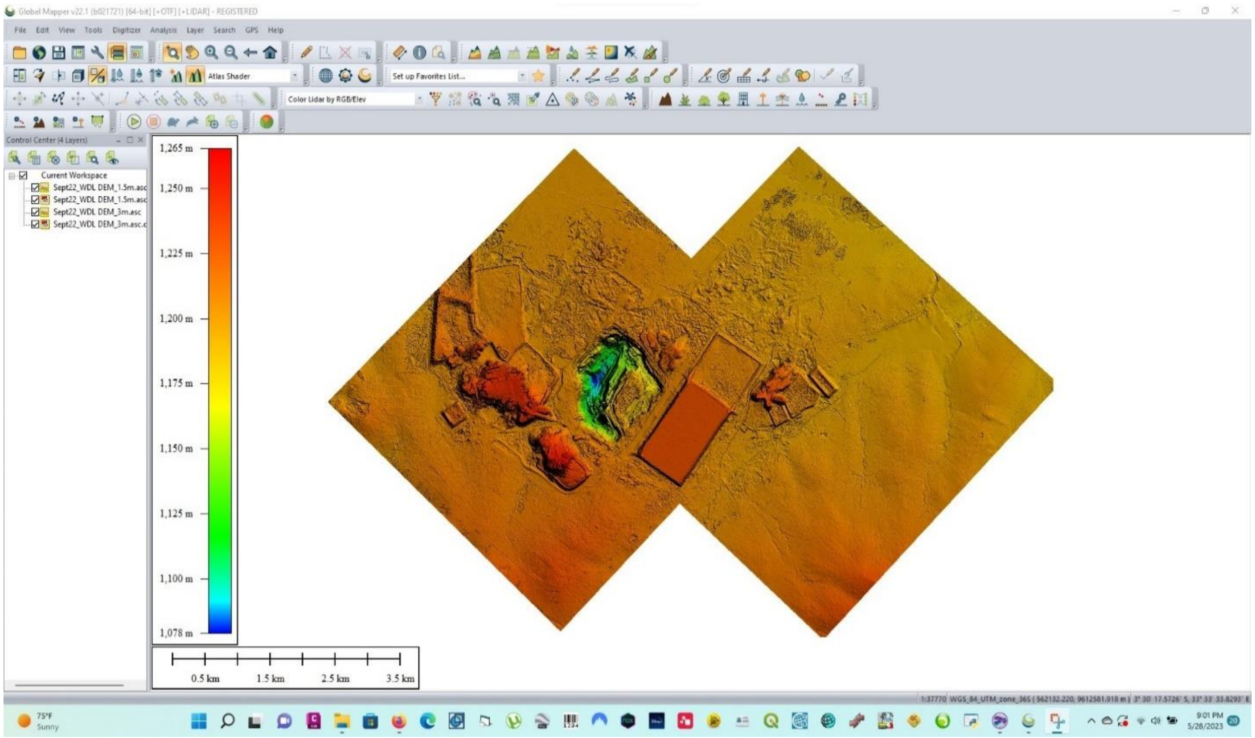

Figure 3.3: UAV cover for Williamson diamond mine

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

This chapter presents the statistics of the height differences between DEMs and the UAV datasets whereby the statistics calculated includes the number of values, minimum, maximum, mean, standard deviation and root mean square. Also, results from comparison of elevation profiles between DEMs and UAV datasets are presented. A discussion of all presented results is done and the Root Mean Square (RMS) is used as a measure of accuracy such that the lower the RMS the higher the vertical accuracy.

4.1 DEMs elevations with UAV datasets

The heights of all DEMs were extracted by using Surfer v-18.1 since the point's 2D positions dataset which obtained from UAV dataset were used. All DEMs are based in EGM 96 as vertical datum.

After importing SRTM DEM datasets with coordinate system of WGS84 and orthometric height as datum, the values appeared as shown in table 4.1

Table 4.1:Relative heights of SRTM DEM-1''

SN	NORTHINGS (m)	EASTINGS (m)	ELEVATION (m)
1	563363.941	9610969.897	1189.6055
2	563363.941	9610939.897	1190.8543
3	563393.941	9610999.897	1190.1071
4	563393.941	9610969.897	1190.7014
5	563393.941	9610939.897	1191.3303
6	563393.941	9610909.897	1192.0385
7	563423.941	9611029.897	1190.805
8	563423.941	9610999.897	1191.8202
9	563423.941	9610969.897	1192.3446
10	563423.941	9610939.897	1192.4976
11	563423.941	9610909.897	1192.7718
12	563453.941	9611059.897	1189.4623
13	563453.941	9611029.897	1191.0346
14	563453.941	9610999.897	1192.4967

After importing UAV datasets with coordinate system of WGS84 and orthometric height as datum, the values appeared as shown in table 4.2

Table 4.2:Relative height for UAV dataset

SN	NORTHING (m)	EASTING (m)	ELEVATION (m)
1	563363.941	9610969.897	1201.48
2	563363.941	9610939.897	1201.565
3	563393.941	9610999.897	1201.797
4	563393.941	9610969.897	1201.779
5	563393.941	9610939.897	1202.03
6	563393.941	9610909.897	1202.068
7	563423.941	9611029.897	1199.899
8	563423.941	9610999.897	1201.065
9	563423.941	9610969.897	1201.711
10	563423.941	9610939.897	1201.935
11	563423.941	9610909.897	1202.678
12	563453.941	9611059.897	1200.703
13	563453.941	9611029.897	1200.475
14	563453.941	9610999.897	1200.971
15	563453.941	9610969.897	1201.649

After importing NASADEM datasets with coordinate system of WGS84 and orthometric height as datum, the values appeared as shown in table 4.3

Table 4.3:Relative height for NASADEM-1"

SN	NORTHING(m)	EASTING(m)	ELEVATION(m)
1	563363.941	9610969.897	1190.415246
2	563363.941	9610939.897	1191.005601
3	563393.941	9610999.897	1190.781418
4	563393.941	9610969.897	1191.160914
5	563393.941	9610939.897	1191.540179
6	563393.941	9610909.897	1191.919093
7	563423.941	9611029.897	1190.274162
8	563423.941	9610999.897	1191.507546
9	563423.941	9610969.897	1191.833629
10	563423.941	9610939.897	1192.159687

4.2 Comparison of Relative Heights of Public DEMs against UAV dataset

In order to ensure a good statistical analysis results, the relative elevations obtained by taking the difference of Public DEMs from UAV data as standards for this research study. Each vertical point of UAV dataset was subtracted with the DEMs at the same point. The slight difference in height was calculated with coordinate system of WGS84 and orthometric height as datum, the values appeared as shown in table 4.4

Table 4.4:Relative change in height between UAV and DEMs

SN	NORTHING (m)	EASTING (m)	UAV-SRTM(m)	UAV-NASADEM(m)
1	563363.941	9610969.897	11.87452	11.064754
2	563363.941	9610939.897	10.71074	10.559399
3	563393.941	9610999.897	11.689912	11.015582
4	563393.941	9610969.897	11.077573	10.618086
5	563393.941	9610939.897	10.69974	10.489821
6	563393.941	9610909.897	10.029455	10.148907
7	563423.941	9611029.897	9.0939793	9.624838
8	563423.941	9610999.897	9.244779	9.557454
9	563423.941	9610969.897	9.366406	9.877371
10	563423.941	9610939.897	9.4373597	9.775313

The statistical results were obtained after calculating from equation 3.8, 3.9 and 3.10, the results are shown in figure 4.5

Table 4.5:The statistics of relative height difference of DEMs for analysis with UAV dataset

	SRTM DEM(m)	NASADEM(m)
Number of values	52778	52778
Sum	495895.23	510669.26
Minimum	-67.02016	-68.00904
Maximum	65.609352	65.319408
Mean	9.3958701	9.675798
Variance	57.48474	61.582661

Standard deviation	7.5818692	7.8474621
RMS	5.54956	5.66024

4.3 3D surface representation for NASADEM

After importing the gridded coordinates for the NASADEM data on suffer, 3D surface representation of features and elevations was shown in figure 4.1

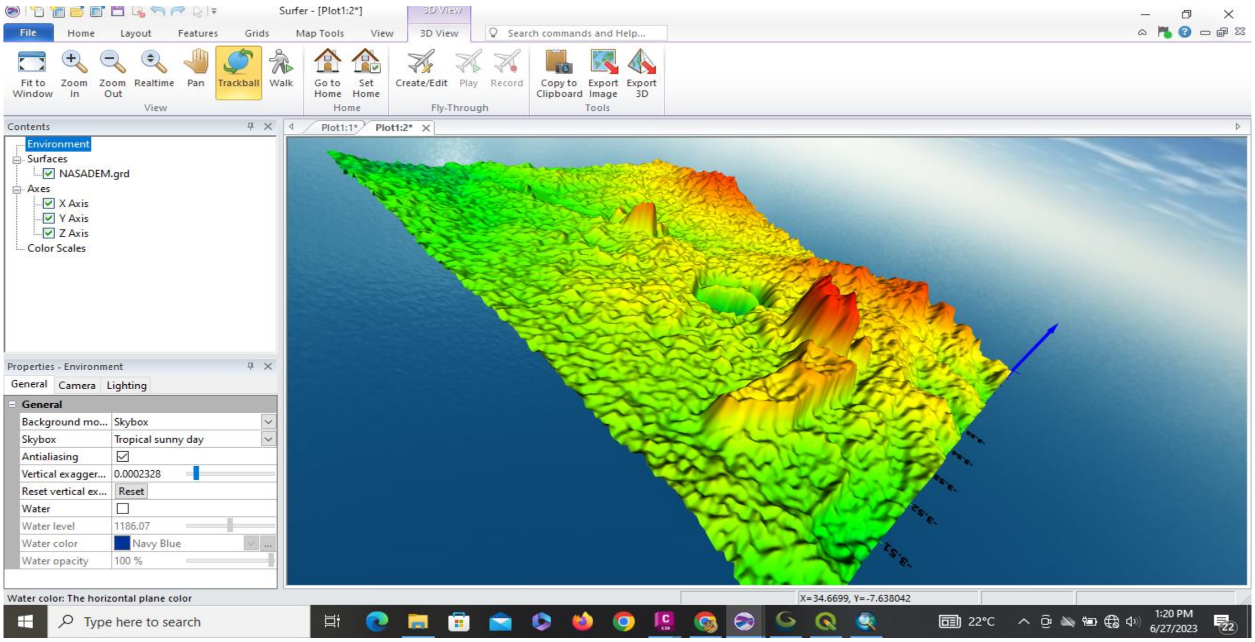

Figure 4.1:3D surface NASADEM presentation

4.4 3D representation for SRTM DEM

After importing the gridded coordinates for the SRTM DEM data on suffer, 3D surface representation of features and elevations was shown in figure 4.2

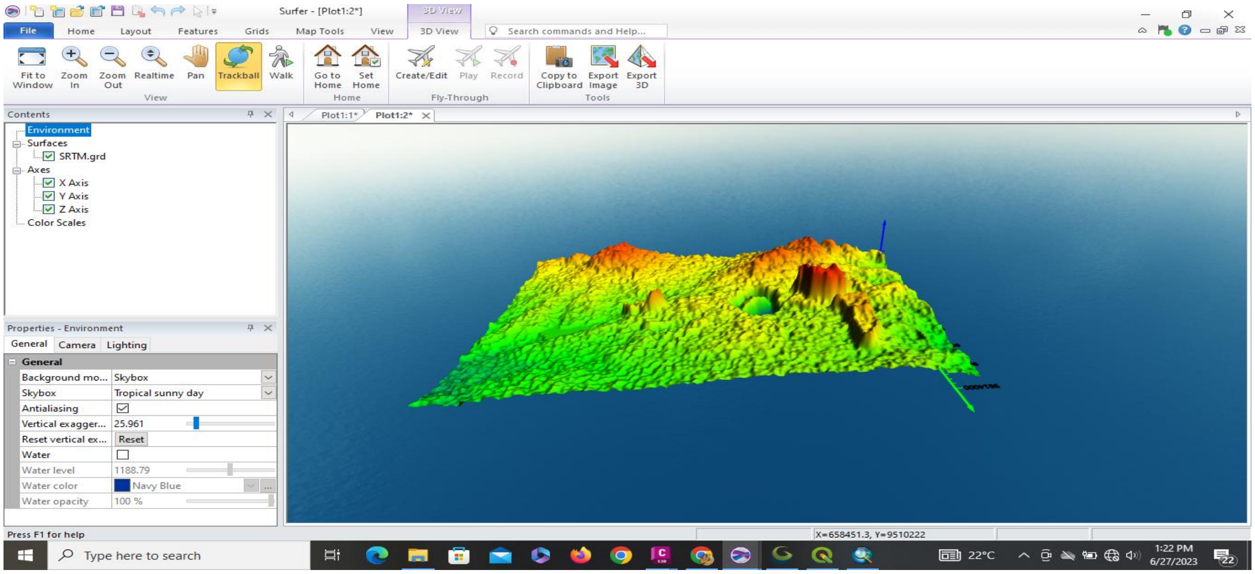

Figure 4.2:3D surface SRTM DEM presentation

4.5 3D surface representation for UAV

After importing the gridded coordinates for the UAV data on suffer, 3D surface representation of features and elevations was shown in figure 4.3

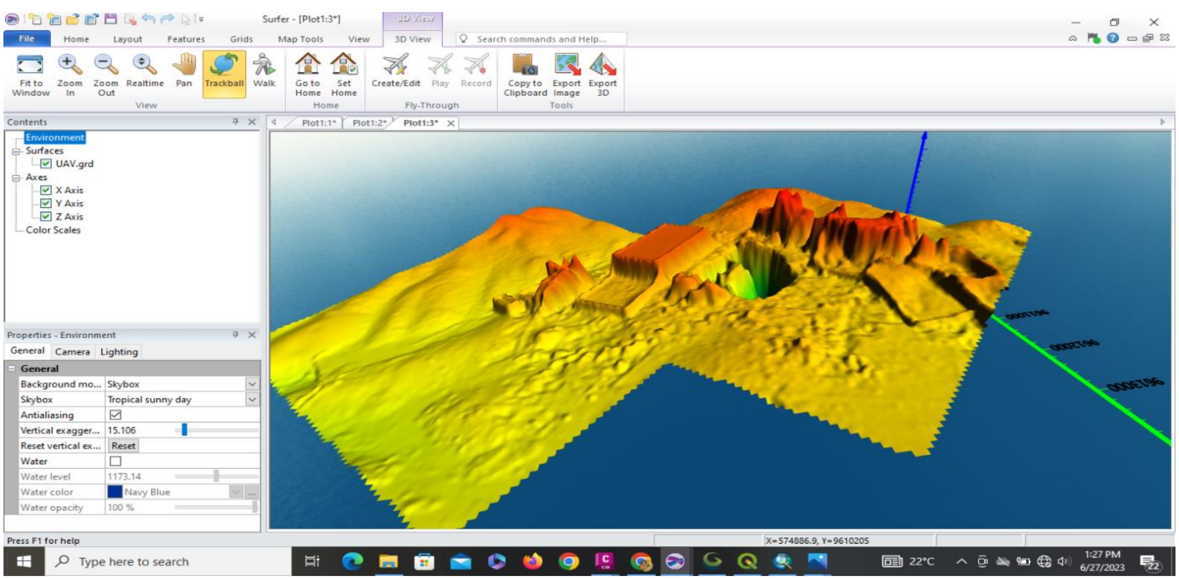

Figure 4.3: 3D surface UAV presentation

4.6 The differences of the 3D surfae figures

The differenes between UAV with respect to DEMs were obtained by taking the gridded coordinates of UAV minus that of DEMs. The 3D surface difference representation between UAV datasets with NASADEM is shown in figure 4.4

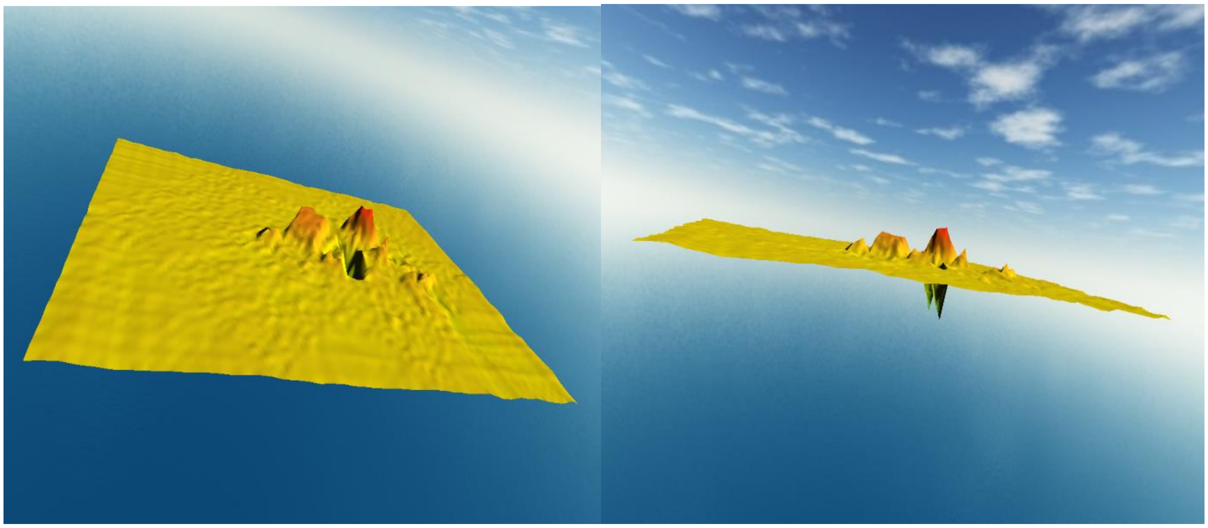

Figure 4.4: The 3D difference representation between UAV datasets with NASADEM

The 3D surface difference representation between UAV datasets with SRTM DEM is shown in figure 4.5

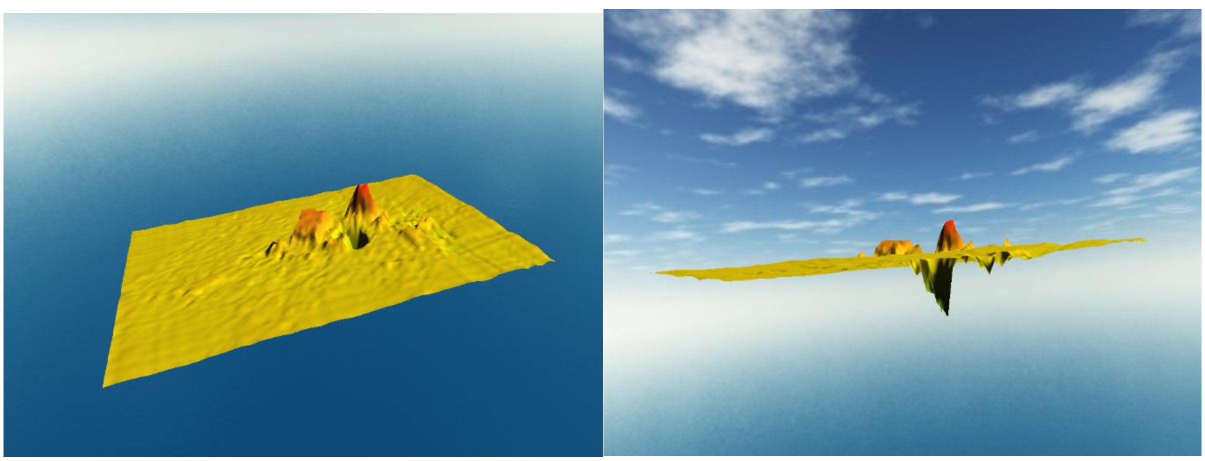

Figure 4.5: The 3D surface difference representation between UAV datasets with SRTM DEM

4.7 Comparison of elevation profiles between DEMs and UAV datasets

The elevation profile between the DEMs and UAV datasets was obtained by importing both datasets on the same sheet on global mapper then selecting a road of two kilometers. Thereafter the graph for elevation against distance was aquired. It is shown well in figure 4.6

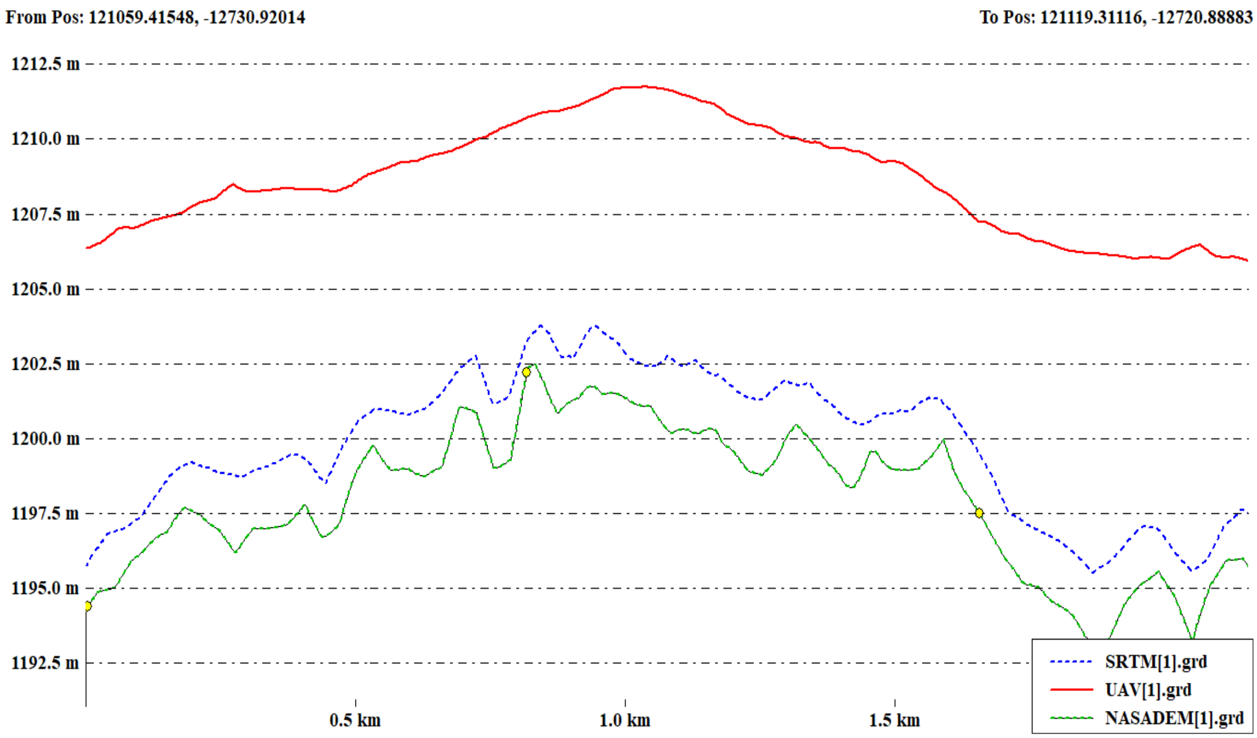

Figure 4.6: Elevation profile representation for DEMs and UAV

4.8 Discussion and Analysis

The discussion is based on the value of the mean, SD and RMS statistics. The DEM with the least value of the mean, SD and RMS is one which termed as the best DEM than the others. Results from Table 4.5, show the overall fit of DEMs and UAV dataset in the Area of Interest (AOI). From the table, SRTM DEM 1" with RMS of 5.54956m is the best followed by NASADEM- 1” with RMS of 5.66024m. From figure 4.1,4.2 and 4.3 illustrates that the DEMs have poor performance in taking stockpiles and TSF area, but also the bare land in UAV appear poor in DEMs. Also, the DEMs have poor performance in presenting buildings and trees in general compared to UAV.

Figure 4.4 and 5.5 shows the difference in 3D surface representation whereby they indicate those shown from table 4.4. Figure 4.6 presents the elevation profile for the three datasets whereby, SRTM appears to be a superior to NASADEM for this case.

Therefore, For the case of Williamson Diamond Limited SRTM DEM can be used as an alternative of UAV for some topographic maps based on cost and purpose of the map.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The main objective of this research was to assess the relative performances of SRTM AND NASADEM using UAV datasets. Results show that the general performance of SRTM-1" is more superior with a RMS of 5.54956m compared with NASADEM with RMS of 5.66024m.

Also, The DEMs show poor presentation of bare land, trees and buildings compared to UAV hence UAV remains to be superior.

Results from this research cannot provide a country wide ranking of SRTM-1"as the study area is too small to be a representative sample of the whole country, although a projection can be made with the current results. Validation studies performed in the country from previous years, SRTM-1" has shown a significant improvement in vertical accuracy in DEMs that suits the country generally in the AOI and in selected land covers.

5. 2 RECOMMENDATION

Based on the results obtained in Chapter 4 and the discussions in Section 4.4 it is recommended that;

i) Further vertical assessments of relative performances of DEMs should be done for a wider coverage in Tanzania, particularly in areas with terrain and land cover characteristics different from those covered in this research. In order to determine the best DEM for Tanzania in all land covers, which will have a wide range of applications and significantly reduce the cost of construction engineering tasks.

REFERENCES

Mostafa, Y. G., & Abdelhafiz, A. (2012). The Potentials of Satellite Images for Map Updating with Emphasizes on Egypt Sat-1 Images. *Civil Eng Dept. Faculty of Engineering*, Sohag University., (October 2016). https://doi.org/10.21608/jesaun.2012.114470

Moustafa, Y. G., Farrag, F. A., & Ahmed, A. (2012). Updating with emphasizes on Egypt SAT-1 images. *Mining and Metallurgy Eng. Dpt. Faculty of Engineering, Assiut University*., 40(4), 989–1003.

Costa, F., & Diambra, L. (2005). Topographical maps as complex networks. *Institute of Physics at Sao Carlos, University of Sao Paulo, Sao Carlos.*, (August 2004), 1–7. https://doi.org/10.1103/PhysRevE.71.021901.

Caetano, M., & Santos, T. (2008). Updating land cover maps with satellite images. Geoscience and Remote Sensing Symposium., 1–3.

F.Samadzadegan, A.Milanlak, & M.GH.Majdabadi. (2004). Geometrical Correction Of Satellite Images By Generic Models. Depertment of Surveying and Geomatics Engineering,Faculty of Engineering, University of Tehran.

Nkeki, N. F., & Asikhia, M. O. (2014). Mapping and Geovisualizing Topographical Data Using Geographic Information System (GIS). Department of Geography and Regional Planning, University of Benin, Benin City, Nigeria., 6(1), 1–13. https://doi.org/10.5539/jgg.v6n1p1

Athmania, D., & Achour, H. (2014). External validation of the ASTER GDEMs, GMTED2010 and CGIAR-CSI SRTM v4.1 free access digital elevation model in Tunisia and Algeria. Remote Sensing, 6(5), 4600-4620.

Balenovic, I., Marjanovic, H., Vuletic, D., Paladinic, E., Sever, M. Z., & Indir, K. (2015). Quality assessment of high density digital surface model over different land cover classes. PERIODICUM BIOLOGORUM. VOL. 117, No 4, 459-470.

Elkhrachy, I. (2018). Vertical Accuracy Assessment of SRTM and ASTER Digital Elevation Models. a Case Study of Najran City, Saudi Arabia. Ain Shams Engineering Journal, 9(4), pp.1807-1817 .

Hameid, N. A., & Kadhem, G. (2016). Absolute Surface Elevations Accuracies Assessment of Different DEMs Using Ground Truth Data Over Kingdom of Bahrain. J Remote Sensing & GIS 5: 166. doi: 10.4172/2469-4134.1000166.

Hirt, C. (2014). "Digital Terrain Models”. Encyclopedia of Geodesy: 1-6. doi: 10.1007/9783-319-02370-0_31-1.

Li, Z., & Zhu, Q. G. (2005). Digital Terrain Modeling: Principles and Methodology. CRC Press, Bocca Raton.

Mapunda, S. B. (2019). Comparison and Vertical Performance Assessment of SRTM-1"-v3, ALOS-1"-v2, MERIT-3" and TanDEM-X-3" Public Global DEMs in Tanzania Using GPS Ground Controls. Dar es salaam: a BSc. Dissertation of the Department of Geomatics, SGST, Ardhi University, Tanzania.

Marwa, G. (2017). Comparison and Vertical Accuracy Assessment of ALOSv2-1" and SRTMv3-1" global DEMs over Tanzania using GPS ground controls . Dar es salaam: : a BSc. Dissertation of the Department of Geomatics, SGST, Ardhi University, Tanzania

Azmi, S. M., Ahmad, B., & Ahmad, A. (2014). Accuracy assessment of topographic mapping using UAV image integrated with satellite images. *IOP Conference Series: Earth and Environmental Science*, 18, 012015. https://doi.org/10.1088/1755-1315/18/1/012015

Nkeki, N. F., & Asikhia, M. O. (2014). Mapping and Geovisualizing Topographical Data Using Geographic Information System (GIS). *Department of Geography and Regional Planning, University of Benin, Benin City, Nigeria*., 6(1), 1–13. https://doi.org/10.5539/jgg.v6

Charles.D. Ghilani & P.R. Wolf (2015), Elementary Surveying an Introduction to Geomatics *14th edition, upper saddle River, New Jersey, Pearson Education Inc*.

Kosian, M. (2010). Updating the maps of prehistoric landscapes by DEMs. National Service for Archaeology, Cultural Landscapes and Built Monuments (RACM), the Nertherlands.,1–12.

APPENDIX

UAV Grid Information

Tue Jul 25 15:03:12 2023

Grid File Name: C:\Users\Jairo\AppData\Local\Microsoft\Windows\INetCache\IE\WV9XF03E \UAV [1]. grd

Grid Size: 242 rows x 373 columns

Total Nodes: 90266

Filled Nodes: 52341

NoData Nodes: 37925

NoData Value: 1.70141E+38

Grid Geometry

X Minimum: 563338.35748438 X Maximum: 574498.35748438 X Spacing: 30

Y Minimum: 9607482.5489366 Y Maximum: 9614712.5489366 Y Spacing: 30

Univariate Grid Statistics

	Z
Count:	52341
1%-tile:	1149.08605957
5%-tile:	1189.38000488
10%-tile:	1191.66894531
25%-tile:	1197.54101563
50%-tile:	1203.73498535
75%-tile:	1211.46203613
90%-tile:	1222.18395996
95%-tile:	1229.71899414
99%-tile:	1243.38500977
Minimum:	1080.79296875
Maximum:	1265.49304199

Mean:	1204.74222549
Median:	1203.73498535
Geometric Mean:	1204.65198107
Harmonic Mean:	1204.56055899
Root Mean Square:	1204.83137412
Trim Mean (10%):	1204.84928446
Interquartile Mean:	1203.95367726
Midrange:	1173.14300537
Winsorized Mean:	1204.93093003
TriMean:	1204.11825562
Variance:	214.81428232
Standard Deviation:	14.6565440101
Interquartile Range:	13.9210205078
Range:	184.700073242
Mean Difference:	N/A
Median Abs. Deviation:	6.90502929688
Average Abs. Deviation:	9.70036047743
Quartile Dispersion:	0.00577874756018
Relative Mean Diff.:	N/A
Standard Error:	0.064063486225
Coef. of Variation:	0.0121657095601
Skewness:	-1.38135702872
Kurtosis:	13.9552017674
Sum:	63057412.8245
Sum Absolute:	63057412.8245
Sum Squares:	75979171239.4
Mean Square:	1451618.64006