Assessing Crisis Damage: A Comparative Study of Satellite and Drone Orthophotography

Muhannad Al-Nadabi, Mohammed Al-Harthi, Amol Ganesh Deshmukh

[1]Geomatics Engineering Department, Military Technological College, Muscat, Oman
2116013@mtc.edu.om
[2]Geomatics Engineering Department, Military Technological College, Muscat, Oman
mohammed.alharthi@mtc.edu.om
[2]Geomatics Engineering Department, Military Technological College, Muscat, Oman
amol.deshmukh@mtc.edu.om

ABSTRACT

Aerial imagery-derived orthophotos for evaluation purposes, for example, in the event of any destruction, are used to assess the change in the built environment. This study seeks to assess the impacts of severe storms in the town of Shinas by comparing pre-storm and post-storm orthophotos to examine their impacts and support the region during recovery. The National Survey Authority (NSA) provided the tools and the drone to do this project. Orthophotos taken before the storm were also used to provide a detailed baseline of the town's structures, networks, land-use features, and the strength of the valleys. High-resolution orthophotos of the storm-accredited areas were then developed from drone-captured imagery after the storm. I used these pre-post datasets, placing one on top of the other, to compare them and identify collapsed structures, flooded areas, fields of debris, and other changing features of the city landscape. The comparative study showed extensive damage caused in Shinas by hundreds of residential and commercial buildings and transport utilities, drowning many low-lying coastal regions. The comparison analysis demonstrated the substantial damage inflicted on hundreds of residential and commercial structures, transportation infrastructure, and low-lying coastal districts, resulting in their drowning. These results influenced the design of emergency responses, directed the distribution of resources for rehabilitation, and assisted in the creation of community-wide long-term resilience plans. Following the storm, the integration of pre- and post-event orthophotos has proven to be an effective tool for timely damage assessment and well-informed decision-making.

KEYWORDS

Orthophotos, UAV, Aerial imagery, GIS, Emergency response

1. INTRODUCTION

1.1. Background

Unmanned aerial vehicles (UAVs) are becoming a widely used tool in many different industries as a feasible platform for low-altitude aerial photography. The aggressive support of this expansion has come from national agriculture and remote sensing organizations. Compact size, cheap operating costs, high-resolution pictures, ease of use, mobility, and wide applicability are just a few benefits of UAV-based aerial photography. This method is an effective complement to satellite-based remote sensing, offering a viable alternative. UAVs are ideal vehicles for low-altitude aerial imaging because they have high-definition sensors that can record detailed ground-level data. UAV-captured photography produces images with more resolution and detail than high-altitude aerial footage from manned aircraft. Notably, low-altitude UAV operations are not impacted by cloud cover, allowing the gathering of centimeter-scale, high-definition aerial data [1].

1.2. Problem Statement

Big spring and summer storms cause huge damage to the built environment and present significant challenges for disaster response, recovery, and community resilience planning. Assessment of impacts using the traditional protocols can sometimes be slow and expensive, limiting the ability to rapidly appraise the implications and focus recovery efforts. In this study, data collected from aerial reconnaissance was used to investigate the use of pre- and post-storm orthophotos generated from aerial drone data, which could be instrumental in the fast and effective damage analysis of a severe storm. Changes to important infrastructure, buildings, and landscape features can be determined by comparing high-resolution orthophotos, therefore informing emergency response, resource allocation, and community resilience measures. The findings will help to better appreciate the value of integrating geospatial datasets for early damage assessment and decision-making after natural catastrophes.

1.3. Project Question

- What is the baseline condition of the town's structures, infrastructure, land use features, and topography as captured in the pre-storm orthophotos provided by the Department of Geographic Information Systems (GIS) in NSA?
- How can high-resolution post-storm orthophotos generated from drone-captured aerial imagery be used to identify and quantify changes to the built environment, such as collapsed structures, flooded areas, debris fields, and other landscape alterations?
- What insights can be gained by overlaying and comparing the pre-storm and post-storm orthophotos, and how can these insights be used to guide emergency response efforts, inform the distribution of recovery resources, and support the development of long-term community resilience plans?
- To what extent has the integration of pre-event and post-event orthophotos proven to be an effective tool for timely damage assessment and well-informed decision-making following the severe storm in Shinas?

1.4. Project Aims

- The aim of this project is to use pre-storm orthophotos to establish a detailed baseline of Shinas' buildings, infrastructure, land use, and topography.
- Moreover, utilizing high-resolution post-storm drone orthophotos to identify and quantify changes like collapsed structures, flooded areas, and debris. Also, to evaluate the effectiveness of integrating pre-event and post-event orthophotos for timely damage assessment and decision-making.
- Gain hands-on experience producing orthophotos using drone technology, contributing to understanding how aerial imagery can rapidly assess disaster impacts.

1.5. Project Objectives

- Establish a detailed baseline of the town's-built environment using pre-storm orthophotos.
- Identify and quantify changes to the built environment, such as damaged structures and landscape alterations, using post-storm orthophotos.
- Conduct a comparative analysis of pre-storm and post-storm orthophotos to gain insights for informing emergency response, recovery resource allocation, and community resilience planning.
- Evaluate the effectiveness of integrating pre-event and post-event orthophotos for timely damage assessment and decision-making following the severe storm.

1.6. Project Motivations

The motivation for this study is to leverage aerial orthophotos to assess the impacts of a severe storm on the built environment in Shinas. The project aims to establish a baseline using pre-storm data, quantify changes using post-storm drone-captured aerial imagery, and gain insights to inform emergency response, recovery efforts, and community resilience planning. The study also evaluates the effectiveness of integrating pre- and post-event orthophotos for timely damage assessment and decision-making. Additionally, I will gain hands-on experience in producing orthophotos using drone technology. As a student of photogrammetry, I recognize the immense value and importance of these aerial images, and I am eager to apply my skills to help the people of Shinas through this project. The images are very impactful and useful, and I wish to assist the people affected by this severe storm.

1.7. Project Outline

Chapter 1 provides the background, problem statement, project questions, aims, objectives, and motivations for the study.

Chapter 2 examines the use of orthophotos derived from aerial imagery for assessing crisis damage through relevant literature.

Chapter 3 describes the study area, data sources, and the process of generating and analyzing pre- and post-storm orthophotos.

Chapter 4 entails the comparative analysis of the orthophotos presented, including the identified changes and limitations.

Chapter 5 gives the findings of the study along with conclusions, recommendations, and potential future project directions.

2. Literature Review

Past projects have established the utility of various remote sensing technologies for gathering critical data in the aftermath of natural disasters. This study aims to build upon these established methods and techniques.

Recent Developments in the Field of Risk and Crisis Management towards Realization of the Sustainable Development Goals was studied [2]. The study investigated the contributions of 3-D models and orthophoto maps to aerial disaster assessment separately for field reconnaissance and damage assessment. The results showed signs of success with quicker decisions and better damage estimates, although some areas needed further improvement. One significant finding was the substantial increase in data processing time for 3D and orthophoto products compared to the standard evaluation technique. Some of this time burden could be relieved by logistical maneuvers, but further projects are required to streamline the technical workflow. The study also demonstrated that the solutions were effective to varying degrees in different types of assessments. While 3D and orthophoto maps are helpful for damage evaluation, there is a need for more improvement and optimization of the needs recognition through the disaster management spectrum. The study helps us understand these new technologies' application in a disaster context. However, for these solutions to be widely adopted and maximize their impact, solution providers need to collaborate more closely with end-users to ensure that the design of new tools aligns with the constraints and requirements of disaster management practitioners. Continued experimentation and iterative improvement will be crucial for realizing the full potential of these tools in enhancing disaster resilience and supporting global sustainability goals.

A Case Study of Post-Mining Sites in Indonesia considering Advantages of UAV Photogrammetry for Landscape Analysis Compared with Satellite Data was performed [3]. The use of remote sensing data, along with GIS methodologies, has transformed how we perceive and analyze environmental conditions, situations, and changes at various scales. While satellite-based sensors provide a wide view, they frequently have constraints such as cloud cover and low ground resolution, which might limit the amount of information necessary for certain applications. This study examines the potential of adopting drone-based photogrammetry as an alternative approach to improve the analysis of complex landscapes, using post-mining sites in Indonesia as a case study. By comparing the capabilities of SAR and UAV-based techniques, the study highlights the advantages of drone photogrammetry in gathering comprehensive local-scale information, which may be critical for strategic land-use management and environmental restoration. This project investigates the benefits of using drone-based photogrammetry to gather comprehensive local landscape information, in contrast to the limitations of satellite photography, especially in fast-changing situations. The study focuses on post-mining areas on Belitung Island, where human activity has dramatically altered the terrain. While satellite-derived data, such as SAR imaging, can offer a broad picture of land-use and land-cover (LULC) changes, the fine-scale analysis necessary for informed decision-making is sometimes beyond their capabilities. In contrast, drone-based Structure-from-Motion (SfM) photogrammetry provides more precise data, such as comprehensive Ortho imagery and terrain information, which are critical for determining local LULC distribution and topography. This strategy can aid in focused land-use planning, development, and project in areas with complex, quickly changing landscapes.

3. METHODOLOGY

3.1. Introduction

Using the remarkable capabilities of drones, this chapter gives a thorough account of the exact process utilized to produce a detailed image and map of a particular area within the Shinas Wilayat.

3.2. Study Area

The study area is situated in Shinas, in Abu Baqara located at the Latitude of 24°45′N and Longitude of 56°28′E. This area was chosen as the study site on purpose because of the terrible damage that recent storms had inflicted there. The goal was to leverage comparative analysis of historical satellite imagery and the newly captured high-resolution drone orthophotos to identify the specific areas that have been most severely impacted and degraded by the intense precipitation events. Furthermore, assessing the amount of valley growth over time in this highly afflicted area would provide critical information for developing mitigation plans and remedies to the neighborhood's environmental challenges. The multi-source data method provided a full assessment of landscape changes, which served as the foundation for developing successful plans to rebuild damaged regions and manage the increased water flows that caused valley development [4].

Figure 1. Study Area selected for this work

3.3. Methodology Process

The method shown includes creating flight plans, analyzing kinematic data, utilizing a UAV drone to acquire aerial pictures, and then downloading and processing the data with specialist software. This optimized approach allows for rapid data gathering and analysis to meet project objectives.

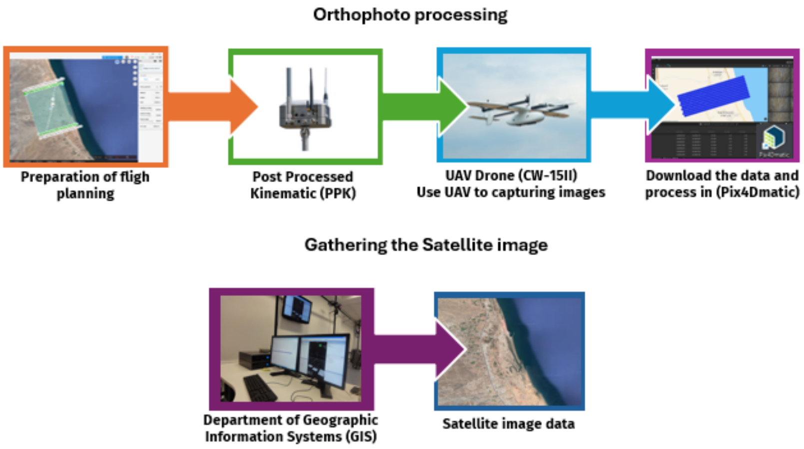


Figure 2. Methodology process

3.4. Data Source and Data Collocation

3.4.1. Drone Selection

The CW-15II drone has been used in this project, which appears to be a good fit because it has characteristics that can help with data collection. The drone's ease of use and capacity to thoroughly plan the mission ahead of time are key features, allowing for optimal aerial coverage and image overlap to suit the project's objectives. Furthermore, the CW-15II's support for post-processed kinematic (PPK) technology is a considerable advantage. PPK allows for more accurate positioning of captured imagery by merging the drone's GNSS data with a reference station, boosting the overall quality and precision of photogrammetric outputs such as point clouds, Digital Surface Models (DSM) and orthomosaics [5].

Figure 3. Picture of Drone (CW 15-II)

3.4.2. Flight Parameters

Software called FlightSurv is used for flight planning for the Shinas wilayat in the Abu Bakra area. Next, the mission mileage approximately 222.0 km and paths were established, and the following conditions were fed as input into the FlightSurv software:

- Forward overlap = 80%
- side lap = 70%
- flight speed = 17.0 m/s

Then, the UAV flight was performed under autonomous control according to the preset path.

The flight time depends on the missions and the route mileage. The data capture was divided into three missions.

- For the first mission, the time taken was 1h16m11s and the route mileage was 77.7 km
- For the second mission, the time taken was 1h17m32s and the route mileage was 79.1 km
- and for the last mission, the time taken was 1h3m55s and the route mileage was 65.2 km

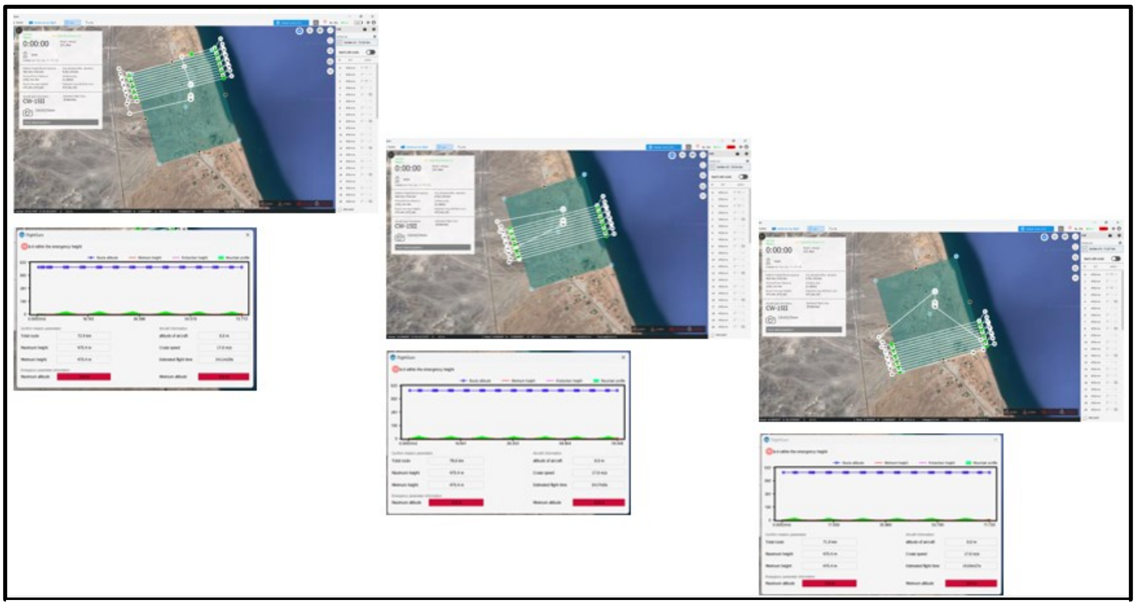


Figure 4. FlightSurv missions

3.4.3. Data Collection

This project's extensive data collection procedure included strategically deploying drone technology throughout the selected study area. To gather high-resolution aerial imagery, skilled pilots flew a succession of drones under ideal weather conditions while adhering to tight safety measures. The drone's GPS capabilities guaranteed that each photograph was precisely georeferenced, documenting the location and altitude data required for flawless imagery integration and alignment throughout the subsequent data processing stage. Ground Control Points (GCPs) were also set up at 6 spots over the study area through Post Processed Kinematic (PPK). The UAV photogrammetry models were geospatially referenced based on these GCPs, enhancing the geolocation information of the land surface. Employing technology tools was meant to provide a more comprehensive data gathering process which was essential for the identification of the present landscape conditions that served as the basis for comparison with historical satellite information. Additionally, satellite image for 2023 from the Department of GIS was collected for the same area.

3.4.4. Data Review

To achieve the highest level of data quality and consistency for this project, a thorough review procedure was created following the completion of aerial surveys. This rigorous evaluation included a thorough visual review of the collected images, with an emphasis on detecting any instances of blurriness, distortion, or other anomalies that might jeopardize the correctness and dependability of the final orthophotos and maps. Any images discovered to be of low quality or have significant faults were immediately removed from the collection. This rigorous purging step was important to maintaining the data's integrity and consistency, providing the groundwork for the subsequent processing processes. By meticulously eliminating the problematic photographs, the project team was able to maintain a high-quality dataset, opening the way for the development of precise and dependable orthophotos and maps that completely meet the project's specifications. The attention to detail and commitment to data quality displayed throughout this post-collection review phase highlight the project team's commitment to generating high-quality outputs while limiting the chance of mistakes or inaccuracies in the final deliverables.

3.5. Data Analysis Method

3.5.1. Processing Image

Specialized software Pix4Dmatic was used to apply advanced image processing algorithms to the captured aerial imagery. The purpose of this thorough data processing approach was to create extremely precise and detailed orthophotos that would serve as the project's fundamental mapping deliverables, graphically depicting the project region and the impacts of a recent storm. A complicated processing pipeline using the Pix4Dmatic platform's famous photogrammetric capabilities, which included aerial triangulation, bundle correction, and dense point cloud production was established. Orthophotos are developed that accurately caught the genuine ground conditions, were devoid of distortions and geometric inconsistencies, and effectively displayed the storm's consequences on the terrain. The resulting high-quality orthophotos are significant allowing project stakeholders to do precise spatial analyses, make educated decisions, and create detailed mapping products that match their individual needs. The team's ability to use cutting-edge photogrammetric software and methods was critical to the successful generation of these orthophoto outputs, which serve as the foundation of the project's geospatial data infrastructure and provide visually accurate depictions of the study area, including the effects of the most recent storm.

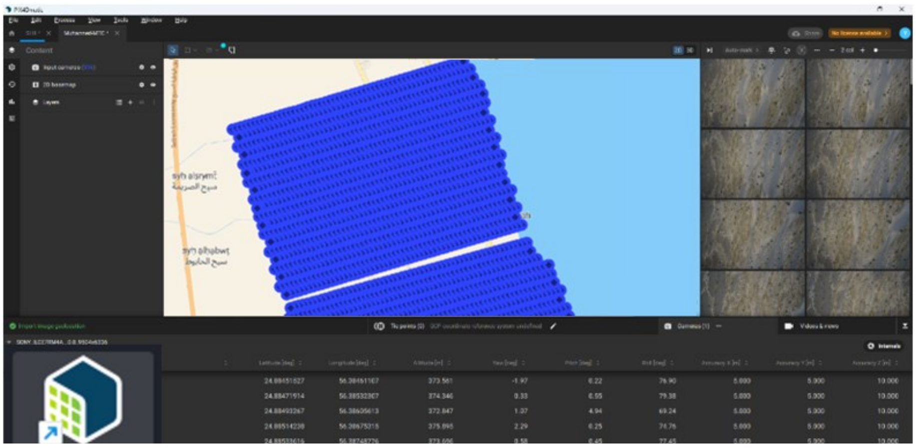


Figure 5. Pix4Dmatic Interface

The processing was carried out as per the following steps:

Create a new Pix4Dmatic project in the selected folder path.

Load the images as shown in following figure.

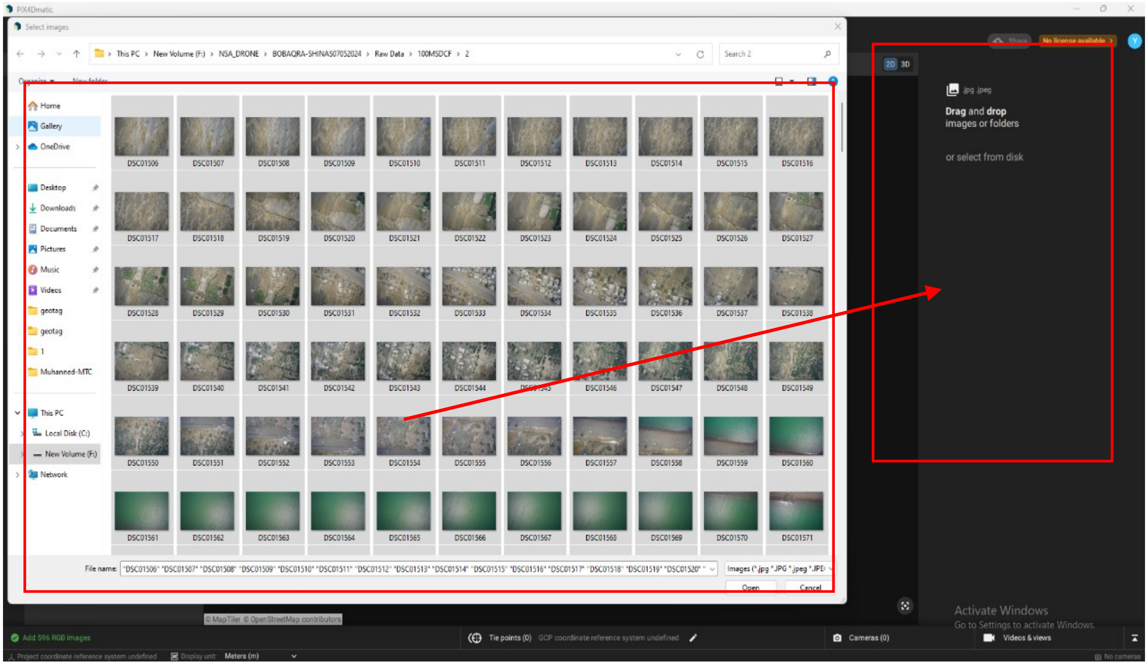


Figure 6. Loading the images in Pix4Dmatic

The images will be displayed as follows:

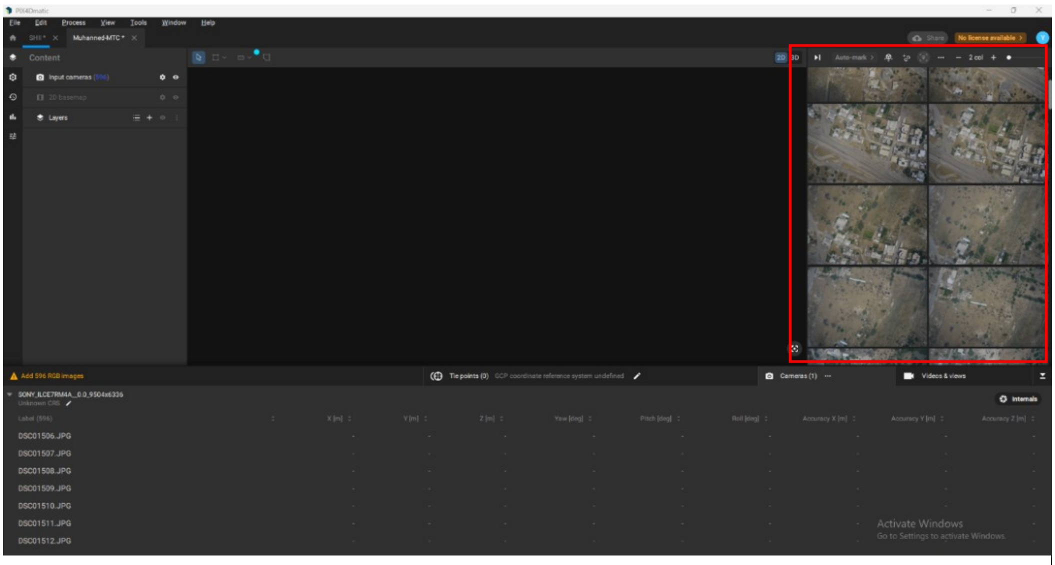


Figure 7. Image display interface

Import image geolocation and orientations from the folder as follows:

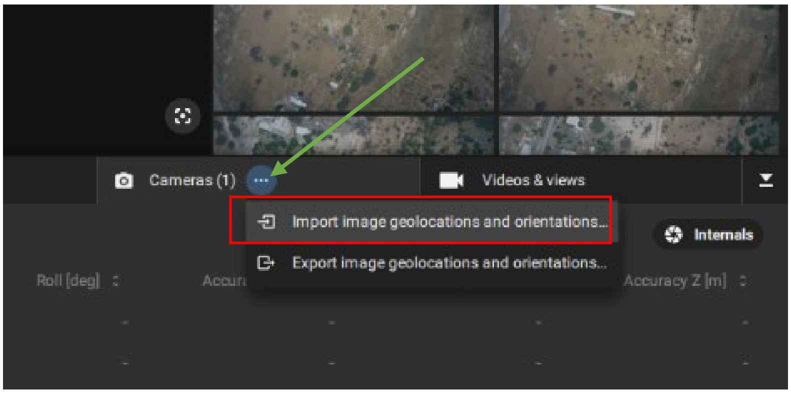


Figure 8. Image geolocation

Set the Horizontal coordinate reference system as World Geodetic System 1984 (WGS84) with European Petroleum Survey Group (EPSG) ID as 4326

Set the vertical coordinate reference system as Earth Gravitational Model 2008 (EGM2008) for height with EPSG ID as 3855

The Geoid will be by default EGM2008 and click apply

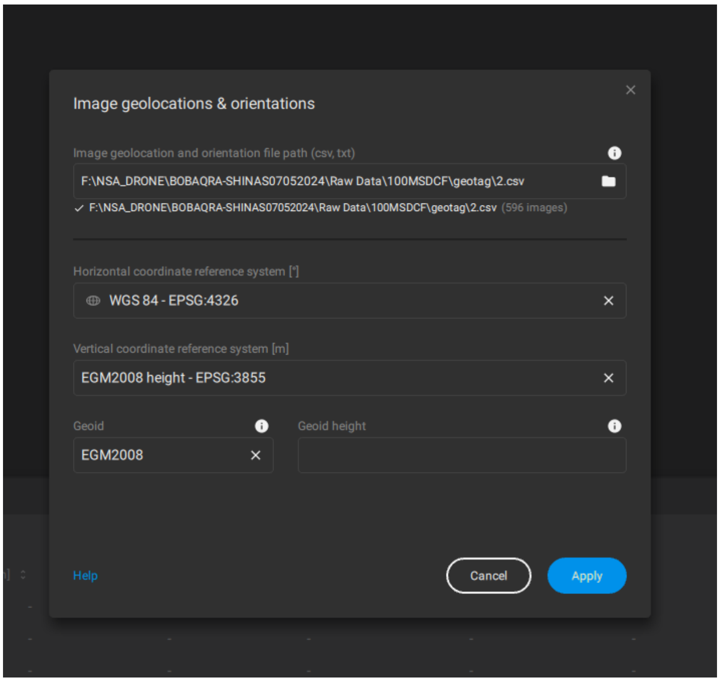


Figure 9. Details of Horizontal and Vertical Coordinate systems

After applying it the path will appear as shown in the following image and then select Calibration, Dense point cloud, Image pre-processing, DSM, Orthomosaic etc.

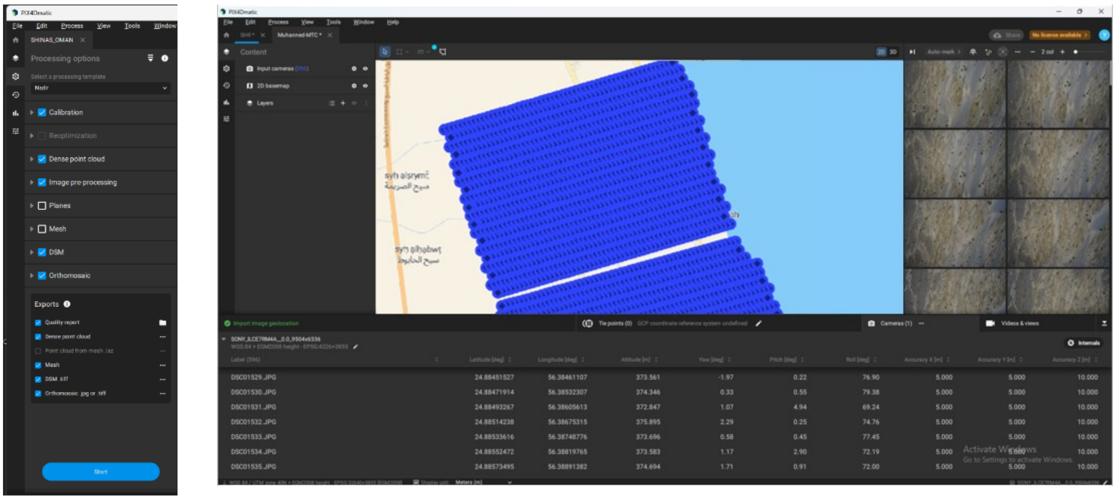


Figure 10. Processing section

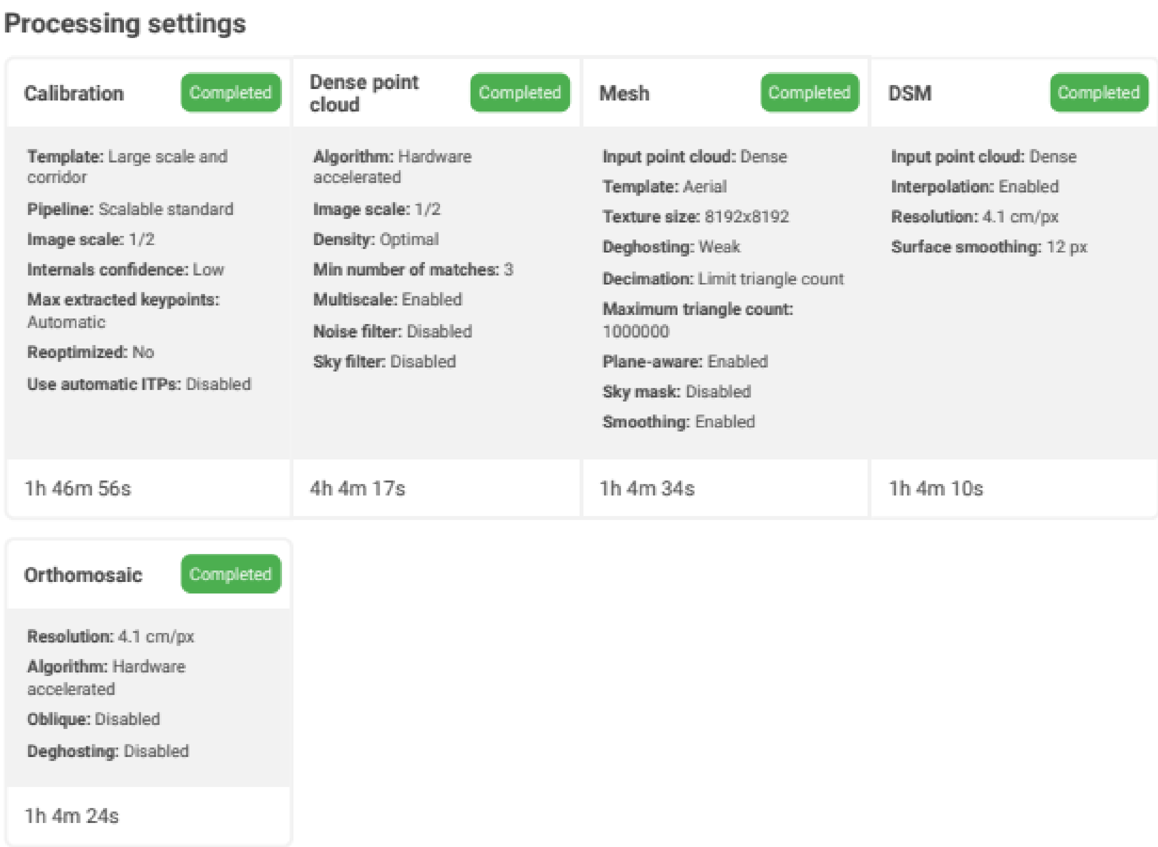


Figure 11. Processing settings

3.2. Orthophoto Generation

These comprehensive orthophoto outputs were built on the high-resolution drone images, corrected with ground control points. The photos were corrected to accurate, distortion free orthographic projections at 4.1 cm pixel resolution for detailed spatial analyses and change detection.

Figure 12. Orthomosaic of the study area

3.3. Comprehensive Map Analysis

After creating the high-quality orthophoto, I compared it to satellite images to identify the exact characteristics or elements that were impacted by the severe weather conditions in the study region. Using ArcGIS Pro's sophisticated capabilities, you were able to extensively study and map the characteristics that had been influenced by the climatic conditions. This integrated technique, which included comprehensive orthophotography and satellite data, allowed you to precisely determine and assess the individual characteristics that had been degraded or altered by unfavorable weather occurrences. The use of GIS software allowed for the smooth integration and display of these various geographical datasets, giving you significant insights into the scope and nature of the study's climate-induced consequences. The following steps are:

- Open ArcGIS Pro software
- Load the Orthomosaic image
- Load the satellite image
- Creating a shapefile for each feature that gets damaged to digitizing it

3.4. Digitizing the features from Satellite Image

The wadis were digitized as shown in red color. The image on the left shows satellite image and the image on the right shows satellite image with digitized wadi feature.

Figure 13. Satellite image with Digitised Wadi

The orthophoto generated through this project as shown below shows the area after the storm event has occurred. The red line now delineates the changed route or path of the same wadi as depicted above, indicating it has expanded or shifted compared to the previous image. Within the outlined blue rectangle, there appear to be damaged walls or structures, suggesting the storm has caused physical impacts to buildings and infrastructure in this region.

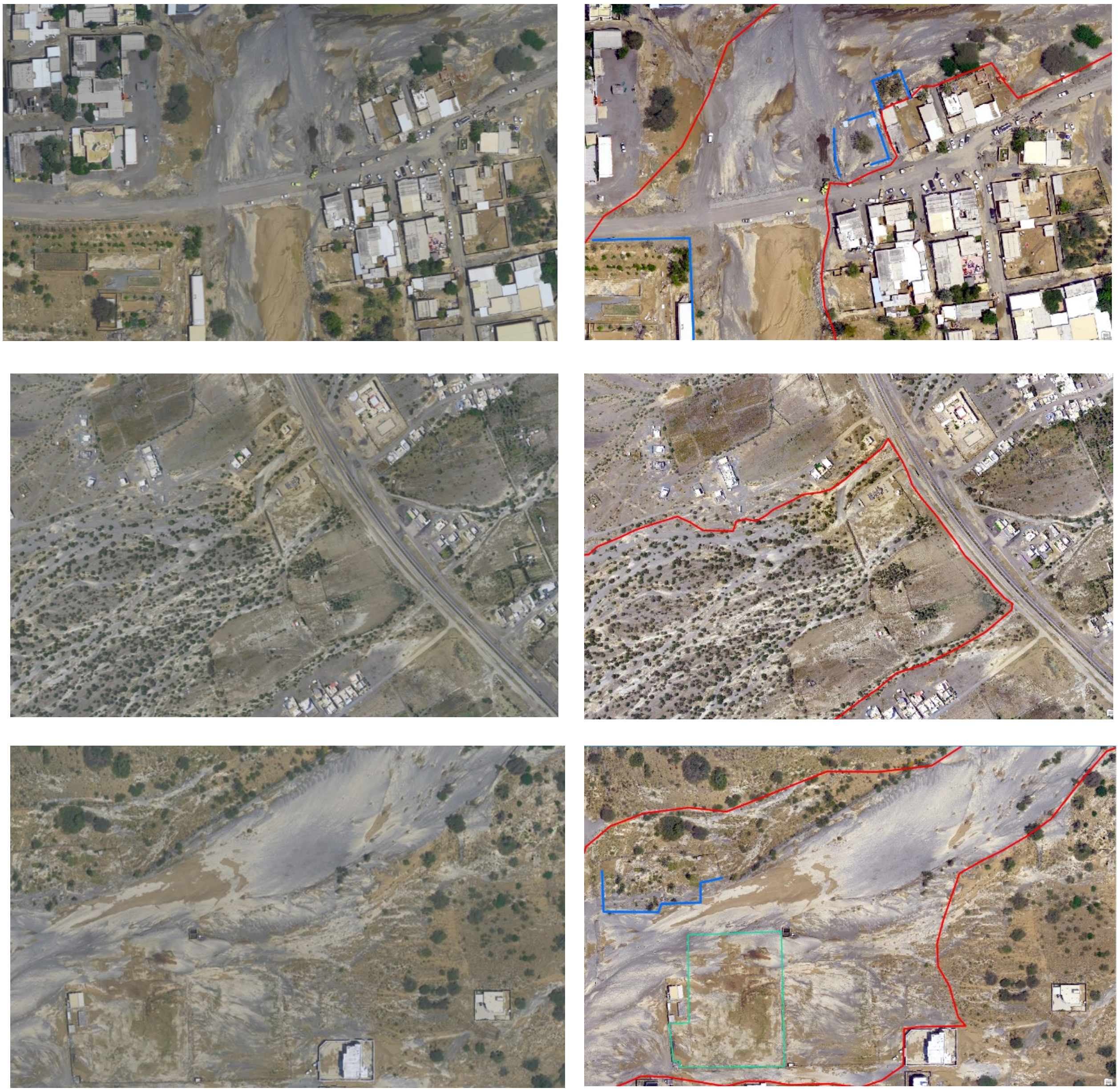


Figure 14. Orthophoto with digitized Wadis

3.5. Conclusion

The project's comprehensive methodology used an integrated approach, combining varied geographical information and powerful GIS tools to perform a full examination. By merging orthophotography, satellite imaging, and other data, the project provided useful insights into climate-induced consequences. The workflow, which included everything from site selection to analysis and mapping, featured specialist technologies such as PIX4DMATIC and ArcGIS Pro, which enabled robust data processing and the effective attainment of objectives, as well as informative maps to aid decision-making

4. Results and Analysis

4.1. Introduction

In the present chapter, results & discussion of using drone device to be capturing photos and generating maps for Shinas area with spotlight on the location of Abu Baqarah is shown. These results provide important knowledge about the efficiency of drone-platform methods for high-resolution image capture, output photograph accuracy and mapping product quality. This chapter starts with a brief explanation of the data processed and dataset used for analysis. It further breaks down these results and what these findings mean in a fuller analysis and interpretation segment. In sharing this extensive reporting, readers gain a useful understanding of how drones can perform and what they are suitable for in producing photographs and maps. The knowledge gained about the usage and benefits and in return the improvements in drone-based approaches for a case example surely reiterates that we are on the right way with this project.

4.2. Result

The main goal of this project is to create high-resolution orthophotos for Shinas, including highly dense Abu Baqarah locations, by applying drone-based aerial feature extraction. I did this by flying a CW-15II drone platform and took larger photos from these surveys. After this, the images were processed to undergo steps such as georeferencing, aerial triangulation, and orthophoto generation for creating the final orthophoto product using Pix4Dmatic software. The product is an orthoimage with a highly accurate Ground Sample Distance (GSD) of 4.1 cm that well depicted both terrain, infrastructure, and land cover features in substantial detail. I used this high-resolution orthophoto to delineate areas that had been disturbed by or influenced by storm events. I mapped the changes in landscape made by water erosion and landsliding through multi-spectral analysis of drone-derived orthophotos along with high-resolution satellite images. By comparing these differences through the analysis of ArcGIS Pro software, a detailed picture emerges, understanding how it has affected local valleys and other topographic features in the area that could be useful for disaster response, infrastructure planning, and environmental management in this region. To conduct this comparative evaluation, I captured the exact features and locations that were damaged in ArcGIS Pro. This detailed investigation was used as the foundation for creating an orthophoto.

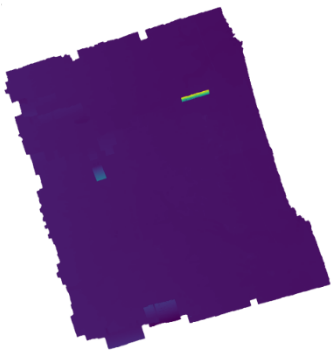
Orthophoto	Digital surface model (DSM)	Mesh
		

Figure 15. Outputs derived from this project

4.3. Limitations And Challenges

Availability and quality of historical satellite images for Shinas area is the first big constraint this study suffered from. While the new fine spatial resolution drone orthophotos provided highly accurate flooding map delineations of post-storm conditions, adequate archival satellite data were not available or could yield only with low-to-moderate spatial resolutions constraining overall evaluation across all locations through time. Moreover, variability in cloud cover and various atmospheric conditions during a given satellite overpass could also make change detection more uncertain. Another problem was being able to conduct airborne surveys in the days immediately following large storms, when weather or damaged infrastructure might prevent the deployment of drones. Despite these limits, i were able to integrate geographic data from several sources to gain significant insights that might improve disaster response, recovery planning, and long-term resilience measures for the Shinas community.

4.4. Conclusion

This study highlights the effectiveness of drone-based aerial images and geospatial analysis in high-resolution mapping and environmental evaluation. The 4.1 cm orthophoto captured detailed images of Shinas, including Abu Baqarah. Integrating drone and satellite data observed landscape changes and identified regions damaged by rainfall, providing critical insights for disaster response and preparation. Drone integration is critical for effective geospatial monitoring.

5. Discussion and Conclusion

5.1. Introduction

This study used pre- and post-storm orthophotos to estimate the considerable damage caused by the strong storm in Shinas. Geospatial analysis aided disaster response, recovery, and community resilience activities.

5.2. Summary

The objective of the study was to determine damage incurred by the town of Shinas post-severe storm after processing pre- and post-storm orthophotos. Orthophotos taken before the storm provided a comprehensive snapshot of existing structures and infrastructure in town, land use features, topography etc. These include post-storm orthophotos of high resolution, obtained from aerial imagery collected by drones to detect changes such as collapsed structures, flooded regions and debris fields. The study overlaid and compared the pre- to post-storm orthophotos, which yielded invaluable information applicable for future emergency response guiding recovery resource allocation as well as input relation strategies directed toward long term community resilience planning. The findings illustrate the successful outcome of incorporating geospatial datasets into post-natural disaster rapid assessment and decision support. Using the tools and expertise of the National Survey Authority, this study was able to create such a panel database which provided these invaluable comparative insights that inform crisis response identification.

5.3. Findings

The comparative analysis of pre- and post-storm orthophotos revealed extensive damage to the built environment in Shinas, including the collapse of hundreds of residential and commercial buildings, as well as significant impacts on transportation infrastructure and low-lying coastal regions. The integration of these geospatial information proved to be an excellent tool for assessing damage in real time, informing emergency response methods, allocating resources for rehabilitation and reconstruction activities, and assisting with the creation of long-term community resilience plans. The National Survey Authority (NSA) was instrumental in providing me with the tools, experience, and drone technology I needed to acquire and analyze orthophotos.

Finally, comparing satellite and drone orthophotography has shown to be a significant tool for assessing crisis damage and organizing catastrophe responses. Practitioners may make educated judgments to optimise their damage appraisal procedures and speed up disaster relief operations by knowing the distinct strengths and limits of each remote sensing technique. The primary findings of this study will contribute to the community's long-term resilience in the event of future natural disasters.

5.4. Recommendation

The results presented in this paper unequivocally show that drone-based orthophotography is a better methodology than satellite imagery for quickly assessing crisis damage. Drone-based aerial surveys provided high-resolution spatial and timely data to map the collapsed structures, inundated zones, debris fields in Shinas. This helped in letting the disaster response team allocate resources swiftly, set recovery efforts as top priority and build resilient strategies for long-term. For the future, we highly suggest disaster management agencies to invest in drone technology and geospatial analysis capabilities for a quicker damage evaluation and decision support process.

5.5. Scope for Future Work

But in the case of drone orthophotography for disaster damage assessment, this study shows that there is still a lot to be discovered. Further exploration of how we might optimize data collection, processing, and analysis workflows may reduce the turnaround time even more. Additionally, exploring novel AI change detection methods that use artificial intelligence to automatically detect affected areas can increase the scalability of these approaches. Combining drone photography with other remote sensing data sets, e.g., from satellite or ground-based sensors, could give novel insights for improving disaster response planning.

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Authors

Muhanned is a L4 student at the Military Technological College (MTC) in Oman in the department of Geomatics Engineering. His primary areas of interest include Surveying, particularly with the use of Total Stations and GNSS (Global Navigation Satellite Systems), and data processing using Geographic Information Systems (GIS).

Mr. Amol Ganesh Deshmukh is a Geomatics Lecturer and Course Leader at the Military Technological College (MTC) in Oman, specializing in GIS, Database Management, Geodesy, Applied Surveying, and GNSS. He contributes to module assessments, student evaluations, and mentoring while being part of the MTC research team. His leadership played a pivotal role in obtaining the Geomatics program a dual diploma certification from the University of Portsmouth. Recognized for his technical paper on "CO_2 Emission Heat Map for GCC using Python for GIS," he has over a decade of experience at the National Survey Authority, Ministry of Defence, Oman. Mr. Deshmukh is a certified PMP with published research from IIT Bombay.

Mr. Mohammed is a Geomatics Assistant Lecturer at the Military Technological College (MTC) in Oman, specializing in Remote Sensing and Surveying. He contributes to module assessments, student project evaluations, and personal mentoring.