Methods for the Spatial Analysis of Invasive Species and Ecosystem Fragmentation at Conservation Sites in Malta Using Drones*

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***Abstract*— Managing environmental conservation sites on the island of Malta is challenging due in part to pressures from urbanization and disruptions from changing land use patterns. Understanding the spatial and temporal context of these challenges through data visualization techniques is an important tool for conserving these ecosystems. This paper describes a set of approaches using aerial imagery collected by drones in support of ecosystem management for specific sites managed by a non-profit, non-governmental environmental organization working in the Maltese islands. Drone images were first taken using automated flight patterns to create high-resolution orthomosaic images. Data collected through fieldwork was combined with the orthomosaics for spatial analysis using GIS tools. The primary focus of the GIS analysis was to use the orthomosaics for the identification of invasive and endangered species and to monitor coastal erosion. These methods help enable efficient, periodic data updates and mapping by the site managers. Additional benefits of the approach described in the paper include helping site managers gain insights into ecosystem fragments from urban expansion and establishing a baseline to analyze future change. The maps created can help improve public awareness of each site and more broadly promote environmental awareness of different conservation sites throughout the islands.**

I. Introduction

Pressures from urbanization and disruptions from changing land use patterns can make managing environmental conservation sites challenging on the island of Malta. These pressures can create stress on ecosystems and lead to fragmentation of natural habitats of species. Non-profit, non-governmental environmental organizations such as Nature Trust Malta (NTM) manage a number of environmental conservation sites in Malta [1]. For organizations like NTM, certain kinds of data collection can be challenging due to constraints on human resources. Additionally, a lack of public awareness (a goal of NTM) about the sites and their ecosystems can hinder conservation and protections efforts.

This paper focuses on several specific sites managed by NTM located at Ballut ta' Marsaxlokk, Maghluq Natura ta' Marsaskala, and Chadwick Lakes. In addition to the challenges mentioned above, each site faces its own unique challenges related to environmental impact. For example, a challenge at Ballut ta' Marsaxlokk is coastal erosion and erosion control; Marsaskala requires monitoring and protection of the endangered killifish species; and Chadwick Lakes has excessive presence of invasive species of castor oil plants, balloon vine, cocklebur, narrow-leaved aster, prickly pear, and great reed.

The use of drones can assist in managing these sites through the collection of areal images and creation of maps that assist in spatial analysis. Recent drone models have embedded programs that allow for advanced mapping from aerial images without being overly complex, difficult to navigate, or costly as compared to traditional approaches. Advantages of this approach include the ability to regularly update data for each site and expand on specific data for emergent issues. This approach can also be useful for public awareness and communication to explain the importance of conservation at each site.

The motivation for this project was to support NTM in its overarching mission, by applying areal surveying techniques by drones. Additionally, the process for monitoring each site could be useful in other environmental conservation contexts.

II. Background and Related Research

Drones are commonly used for aerial mapping because they offer a cost effective, repeatable, and accurate approach to data collection. Additionally, the ability to create flights paths using integrated applications enables more accurate near-ground mapping where the high-resolution camera equipped with the drone can detect intricate details and changes with clarity [2]. Such features make drones ideal for mapping within wildlife monitoring and management, ecosystem monitoring, ecotourism, environmental management, and disaster response.

Drones allow for flexibility in how they respond to situations and how the maps they produce can be used to appropriately respond [3]. In terms of environmental monitoring, drone technology can be used to map and survey a variety of environmental factors such as land erosion, wildfire risk, invasive species growth, endangered species populations, and more. This data can then be used to make

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more informed decisions on how to best persevere and protect the environment and humans in some cases as well.

For the purposes of environmental mapping, LIDAR (light detection and ranging) and infrared imagery combined with aerial images and geolocation data can help in creating more accurate representations of the environment. This is important for environmental monitoring and can help by better informed decisions. Studies have found that drone-derived data is between 43% to 96% more accurate than human-collected ground counts and drones can mimic similar actions of LIDAR mapping by combining aerial images with geolocations [4]. This allows for drone technology to be essential in gathering accurate, actionable environmental information that can produce high-resolution maps through photogrammetric image processing software and creating digital elevation models. An additional benefit of using drones when working with fragile ecosystems is that drones can get into harder-to-reach places more easily allowing for improved data collection [5].

There are recent examples of similar approaches using drones for environmental applications. For example, a recent project by J. Barajas et al. used multispectral imagery collected from drones to "...[analyze] changes in algae levels in bodies of water as an indicator of eutrophication" [6]. Their paper details the usage of specific toolkits built into ArcGIS with Python that can be used to analyze multispectral images based on parameters set by the user. The toolkit allows for the analysis of three main values: Normalized Difference Vegetation Index (NDVI)[1], Mean Squared Error (MSE)[2], and Structural Similarity Index (SSIM)[3]. The use of these tools allowed for a process where the modeling of algae blooms allowed the user to have more control over what is identified and what information is relayed back. This informed the approach described in this paper, which focuses on creating maps to identify the presence of invasive species. It further informed how the general process might be approached and automated after the orthomosaic images had been created.

Another study conducted by S. Kentsch et al. used similar ArcGIS analysis tools on orthomosaic images taken by drones to identify invasive blueberry species in wetlands. This study focused on identifying specific features of the blueberry species which were imported into data analysis systems in ArcGIS. Quantification of the blueberry bush characteristics looked at the distribution and properties of the species. This was then used to analyze the spread of the pattern of the bushes through concentration, density, and spread. With the characterization and measurement of the invasive species defined using user-set annotations, kernel density, collect event, and optimized hotspot analysis, deep learning was then used for blueberry classification and localization. This allowed them to achieve an overall accuracy of 98.83% [7]. This methodology and analysis breakdown process provided the team with a more in-depth understanding of how the orthomosaic images acquired may be analyzed for desired results.

III. Methodology

A. Overview

The project goal was to utilize a drone to collect high-quality imagery that could be used to create maps of conservation sites in Malta. The drones used during this project were low cost, recreational drones widely available to the public. Two web-based software programs were used for flight path programming, imagery collection, and orthomosaic processing. This process involves using many photos with location data to create high resolution orthomosaics which can then be analyzed for conservation work purposes.

To accomplish the project goals, the team created a plan for capturing and processing the aerial images. The drones were flown using DJI Fly, DJI GO 4, and Map Pilot Pro applications on an iPhone. These applications allowed the team to create flight paths that the drone could follow along each site autonomously and take aerial imagery in regular intervals.

As aerials are taken, geographic data is collected which allows for the pictures to be input into Maps Made Easy – an online platform for stitching photos together to create a map. Once the final map is created, several types of maps such as 3D elevation maps and Digital Elevation Models (DEM) can be made to show geographic data for each site being surveyed. Finally, field data regarding erosion patterns and the presence of invasive and endangered species were input into the maps.

B. Drone Models Used

The project team used two different drone models, both were from the Company DJI which is a popular recreational and professional camera drone manufacturer. Aside from a few slight differences, these drones were able to do many of the same kinds of tasks. For this project, the team utilized the GPS and digital camera to conduct the project. The pilot in the team was able to control drones through smartphones connected to the remote control, and then connecting to the drone via WI-FI. In order to create accurate georeferenced images, pictures needed to be tagged with location data and these drones simplify that process. The first model was the DJI Mavic Air. This model was able to complete the first two conservation sites managed by NTM. The DJI Mini 2 model was later used to capture the data for the last site we visited.

Both drones feature very similar camera technology and were able to capture data at a pixel resolution necessary for mapping purposes. However, the Mini 2 proved to be the better of the two. This model was also proved to be more convenient and easier to fly due to its small size. More

[1] Which, in terms of agriculture, determines the greenness of an area and in turn the health of crops [6].

[2] "...[measurement] for how much algae has changed from the average amount recorded" [6].

[3] Which can quantify and measure differences between similar-looking images as well as use this process to model lost data [6].

importantly, the battery life of the Mini 2 was about 30 minutes compared to the 20-minute life of the Mavic Air. This extended battery life helped the team complete the project on time as it greatly improved efficiency. This consideration is especially important because it allowed the drone to complete the specified flight paths without landing. The team did not make any modifications to the drone for the project.

C. Image Processing

An orthomosaic is created by photogrammetrically piecing together many images of the same area from slightly different angles to improve the quality of the image. Once complete, the image can then be orthorectified for geographically accurate uses. Photogrammetry involves making measurements between points on overlapping photos to derive elevation and location data. This process is done using computer software to complete the calculations and produce the map products. The team used Maps Made Easy to manage the image processing which helped with time constraints, which was a different approach than originally planned.

D. Software

Map Pilot Pro was the drone flight automation app that the team used to program a custom flight plan for collecting suitable imagery for photogrammetry. This software is downloadable as an app onto the smartphones used to fly the drones. Several parameters are used when designing a flight path on Map Pilot Pro such as the flight path pattern, altitude, rotation, overlap of images, speed, image file type, and offset altitude from ground level. The altitude of the drone during data collection determines the pixel size on the ground of the images produced. Overlap is important when creating these maps because it provides more angles for the computer to calculate from. The drone's flight speed must be slow enough for the SD card to write the image before a new one is taken.

Image data was captured in a JPEG format because of the EXIF information stored about location, which is essential for accurate georeferencing. Setting an offset altitude from ground level allows the ground to remain at the same height while passing over elevation changes. Figure 1 represents the overlap report that is produced which helps the user assess the quality of their map. This is especially important when creating 3D map products. Figure 2 shows the designed path to cover the Ballut site in Marsaxlokk with irregular corners and lots of coverage. Chadwick lakes was a site that proved to be especially unique because it covered a long riparian zone with many curves around hills and private property. To complete this type of flight path, the plan was broken down into four different flights of shorter sections which is seen in Figure 3. This strategy enabled the team pilot to retain a strong WI-FI connection during the flight as well as increased spatial resolution. Flight path programming was essential during this project as it allowed us to streamline our data collection process and ensure the quality of our outputs.

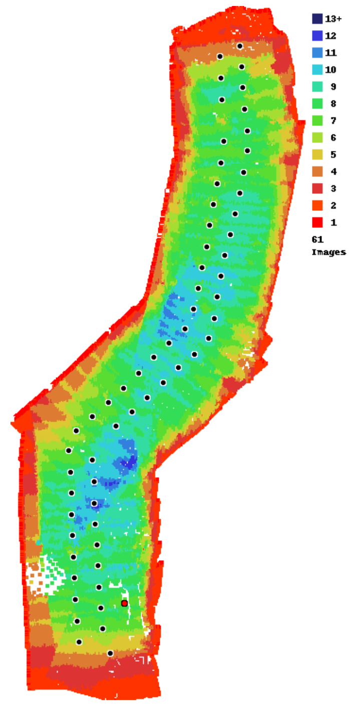

Figure 1: Image overlap report for a section of Chadwick Lakes.

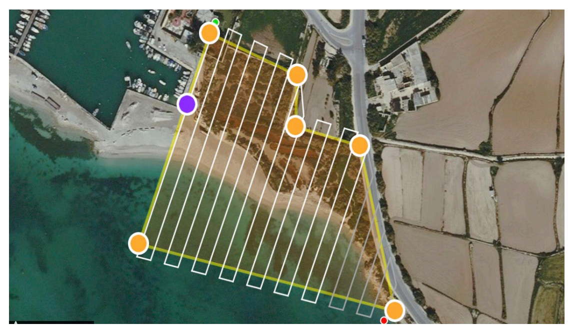

Figure 2: Map Pilot Pro automated flight path for Ballut.

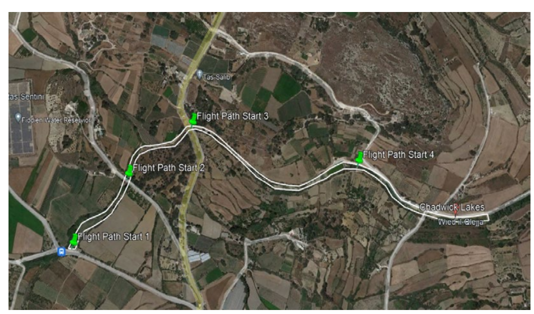

Figure 3: Imitation of Map Pilot Pro automated flight path shown on Google Earth due to the inability to access original flight plans through the application.

Maps Made Easy is the parent software of Map Pilot Pro. It is the website that was used to upload the data collected during the programmed flights made on Map Pilot Pro. After the flights were complete, the team connected the drone directly to a computer to upload the data into Maps Made

Easy.

A consideration in selecting the types of products to create (i.e., full resolution GeoTIFF and JPEG, DEM GeoTIFF and JPEG, 3D models in KMZ and OBJ formats, and shareable online models) is the time to creat the maps. For this project, the maps took approximately one hour per 100 photos. These images were shared via Google Drive with NTM site managers.

IV. Results

The NTM sites the team collected imagery and created maps for were Ballut in Marsaxlokk, Maghluq in Marsaskala, and Chadwick Lakes near Rabat. Each site had its own issue to focus on and the maps were able to showcase these issues. These maps met the project goal of creating recently collected, high-resolution representations of NTM sites.

A major focus on the map for Ballut in Marsaxlokk was to capture the changes in shoreline to demonstrate coastal erosion that has happened over recent years from disruptions to the ecosystem from development and commerce. The team created 3D maps to visualize the area with greater detail. Figures 4 and 5 show the high-resolution map as well as the DEM generated for Ballut using aerial images. The DEM did result in having some errors in elevation along the shoreline which was due to errors from reflection of light from the water.

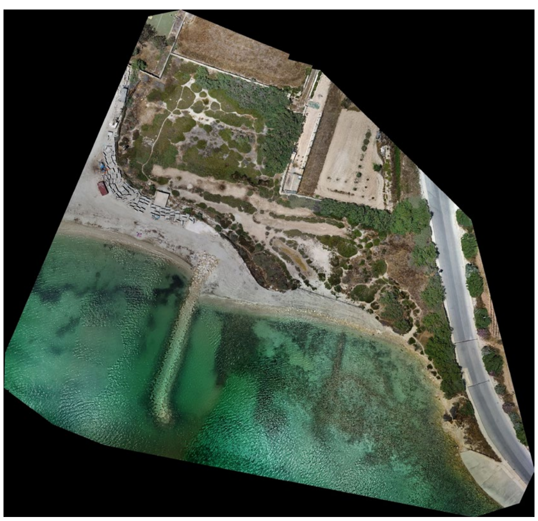

Figure 4: High-resolution JPEG of Ballut.

For Maghluq at Marsaskala, the goal was to create a high-resolution updated map of the site that the site manager requested. An updated map was requested since the previous one taken with a drone was not aligned appropriately and resulted in difficulty in seeing details at the site. Additionally, an updated image would allow for the development of algal blooms to be more easily observed. In contrast to other sites surveyed, 3D maps or DEMs of this area were not a focus and were therefore not created. This image is shown in Figure 6.

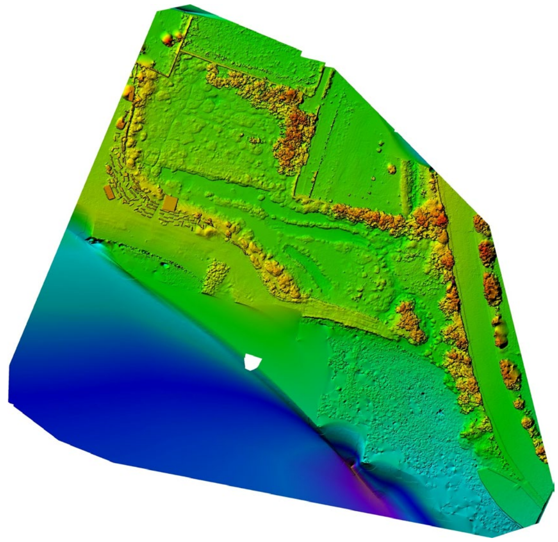

Figure 5: Colorized DEM of Ballut.

Figure 6: High-resolution JPEG of Maghluq.

The Chadwick Lakes site near Rabat covers about two kilometers of a narrow valley between private farmlands. The flight plan was split into four sections and only made two passes along each area. followed the streambed and made only two passes along the way. The main goal of this map was to get an updated map that can show current invasive species along with the entire site. The map created allowed another biogeography team to be more precise in mapping out the location of the individual invasive species. In turn, the hope is that this will allow for a more effective process when removing invasive species. For this to be achieved, the altitude was set lower to provide a higher resolution. Figure 7 shows our map of Chadwick Lakes.

Figure 7: High-resolution JPEG of Chadwick Lakes.

V. Conclusion and Future Work

An important aim of this project was to provide NTM site managers valuable information to support goals for each site and the overall mission of NTM. This project successfully generating maps for each of the project site: Ballut at Marsaxlokk, Maghluq at Marsaskala, and Chadwick Lakes. The high-quality pictures gave the team the chance to create different maps and charts that they could not have been able to previously. The hope is that this will assist the project partner gain data collection at each respective site to further their overall goal of environmental conservation and awareness. Additionally, the team created a process for creating and using orthomosaic images for environmental conservation to NTM.

There are many improvements that could be applied to further projects. Future work could involve the implementation of similar toolkits within ArcGIS as described by J. Barajas et al. to better identify invasive species at Chadwick Lakes and geographical changes to land at Marsaxlokk. Also, more work could be done to create a more comprehensive bathymetry map at Marsaskala that can be combined with eutrophication data within the area.

Although eutrophication was not initially recorded, it was an identified issue that could be added to help better understand the environmental issues within the area and how they might be resolved. Finally, although this project was designed for the needs of NTM, these applications can be applied to any similar projects looking at using drones and orthomosaic images for a variety of applications within environmental conservation.

Further development of these methods would allow for wider applications of such technologies. Although purchasing a drone can be a costly initial investment, they have the potential for savings in terms of time and data collection cost for environmental monitoring and conservation.

Finally, the maps created were also valuable to other teams working on related projects with NTM in parallel with this project. For example, the maps were valuable to the biogeography and mapping teams by providing accurate visual representations of their projects. These teams were able to use the images to create species identification maps with ArcGIS Pro. Maps Made Easy and Map Pilot Pro proved to be essential to this project by automating image collection and image processing.

An important consideration for this kind of project is ensuring that all regulations and requirements for flying a drone are followed. These can differ from country to country, as well as specific constraints and requirements for specific sights. The team spent significant time making sure these requirements were met. For this kind of project, it is important to budget time to understanding the process of being able to fly the drone and gaining experience with the software to develop flight patterns.

Acknowledgment

The team would like to thank the faculty and staff in the James Madison University Engineering, ISAT, and Geography departments for their support during this project. Additionally, the team would like to thank Nature Trust Malta and the site managers we worked with; Benjamin Camilleri, Martina Cutajar, James Gabarretta, and Tamsin Caruana for helping to create the project and providing awareness of environmental issues in Malta.

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