IIT Gandhinagar

Summer Research Internship 2023

Surveying, Mapping and Vegetation Analysis Using Drones

Submitted by:
Chirag Kotian, B.Tech in Electrical Engineering
Smit Mehta, B.Tech in Mechanical Engineering

Supervised by:
Prof. Vineet Vashista

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July 13, 2023

1 Introduction

1.1 What is Surveying and Mapping and it's Application:

Surveying and mapping is the process of collecting information on physical features of the Earth's surface, which are used to create maps and models by analysing and creating representations and depictions of it. These techniques have been deployed in various applications, including urban planning, infrastructure development, environmental monitoring, flood modelling, and risk assessment. In the agriculture domain, periodically accessing parameters such as crop health, soil fertility, water availability, etc, are important to be regulated. In this context, surveying and mapping provide an easy and useful technique to evaluate these parameters for maximising agricultural yield.

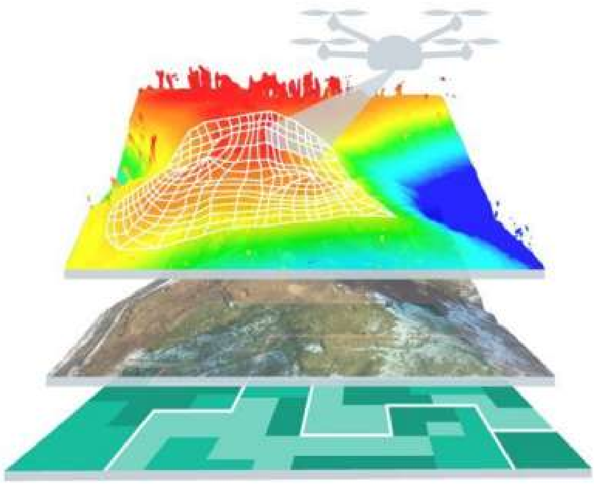

Figure 1: Surveying and Mapping Using Drones.[1]

1.2 History:

Over the time, mapping and survey methods have evolved significantly. It started with simple tools like compasses, chains which were used to measure azimuth and distances. Progressively, instruments such as transits and optical theodolites were used to measure azimuth and vertical angles; and tapes and other electronic distance-measuring instruments with relatively good accuracies were used. Currently, advanced technologies like satellite remote sensing systems, Global Positioning System (GPS), and Robotic Total Station (RTS) m instruments are utilised to perform large-scale mapping of the areas[1]. From being a tool of interest to a relatively narrow group of surveyors and instrument designers, the use of photography in surveying and mapping to determine measurements between objects, i.e., photogrammetry, moved into the mainstream during World Wars. Especially during World War 2, as the truly global nature of the conflict necessitated a huge investment in resources to create the

[1]*Image credits: https://ycspl.in/services/digital-survey/*

mapping needed to support military operations[2]. Structure from Motion (SfM)[3] technology in digital photogrammetry enables the extraction of detailed geometric and visual information to create 3D structures from images. Modern advancements in computation power have enabled the generation of dense 3D geometric information for real-world objects by combining two slightly different images with precise measurements and mapping of land.

Figure 2: Usage of theodolite for surveying.[2]

1.3 Aim of this Study:

This study aims to explore the use of unmanned aerial vehicles, such as drones, for surveying and mapping purposes. A custom-built drone equipped with an integrated GoPro camera is designed to capture images at predefined geo-locations. As a case study, multiple images of ravine areas and vegetable farms were collected. In order to extract useful information from these images, various software has been explored. Amongst them, Pix4D emerged as the standard tool to provide accurate results, which comes with the disadvantage of being very expensive. To overcome this problem, open-source software, such as Meshroom, was also explored, whose results were good, albeit with slightly reduced accuracy. The generated 3D models of the ravine are used to compute area and volume for the prediction of water flow and soil erosion. Moreover, to address the challenges of vegetation analysis, we investigated cost-effective alternatives by leveraging RGB images. Through a comparative analysis of the red, green, and blue channels, we successfully identified areas covered with vegetation, providing valuable insights like land utilisation without the need for expensive multi-spectrum imaging.

2 Research Methodology:

2.1 Learning About Drones:

The initial phase of the project focused on the development, calibration, and testing of small drones. This initial stage laid the foundation for future progress and performance. The basics of the components, such as flight controller, GPS, ESCs, etc., were learned.

[2] *Image credits: https://www.britannica.com/technology/theodolite*

2.2 Small Drone (Based on S500 Frame):

2.2.1 Setting-Up the Drone:

The small drone was carefully built to ensure the seamless integration and proper functioning of all vital components. Following assembly, the drone underwent calibration using Mission Planner software to fine-tune its flight performance and optimise control mechanisms. This involves careful adjustment of sensors such as accelerometers, magnetometers, gyroscopes, etc. The calibration process is critical to achieving stability and accuracy during flight.

2.2.2 Testing:

The small drone was operated in three flight modes: stabilise, loiter, and auto. The stabilise mode involved manual control of the drone using the radio transmitter/controller. In the loiter mode, the drone autonomously maintained its position by holding the current location, providing a safety measure in case of unforeseen risks. The auto mode employed the Mission Planner software to plan missions, guiding the drone along predetermined paths.

Note: *All the flights were done by taking all possible precautions and permissions for flight were obtained from Dr. Gaurav Srivastava, Dean of Campus Development, prior to the flight*

Figure 3: Small Drone Testing.

2.3 Configuring RC Transmitter:

After conducting test flights of the drones, it was determined that a self-centering throttle-based RC transmitter would be more preferable. Such a transmitter aids the pilot when the drone is in loiter or stabilize mode, providing better control and maneuverability. However, the available transmitters were of the standard position holding throttle type, which lacked the self-centering feature.

To address this issue, one of the existing transmitters was modified by incorporating parts salvaged from other transmitters. This modification allowed the conversion of the standard position holding throttle transmitter into a self-centering throttle transmitter. By repurposing components from different transmitters, the desired self-centering functionality was achieved, providing an improved flight experience for the pilot.

In summary, after realizing the advantages of a self-centering throttle transmitter during test flights, efforts were made to convert one of the available standard position holding throttle transmitters into a self-centering one. By utilizing salvaged parts, the modification enabled the desired self-centering throttle feature, enhancing the control and performance of the drone during loiter or stabilize mode.

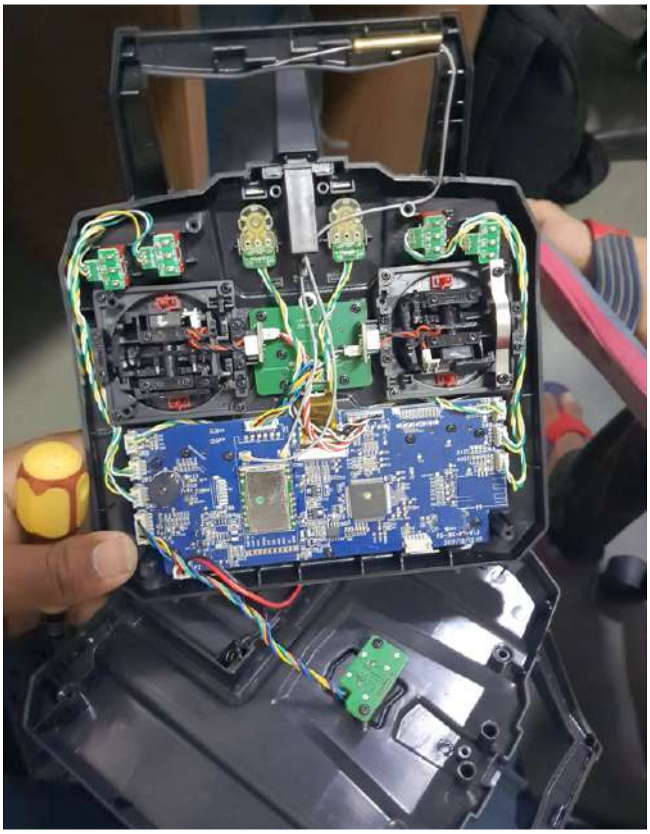

Figure 4: Configuring RC transmitter.

2.4 Big Survey Drone (Based on 690 Parrot Drone Frame):

2.4.1 Setting up the Drone:

Once a solid understanding of drone flight and control was established, attention shifted to the main drone(big drone). Similar to the small drone, the big drone underwent setup and calibration procedures. Additionally, a mount for the GoPro camera and battery was designed using 3D printing technology. The initial design underwent iterative improvements, incorporating lessons learned from previous flights and addressing any issues identified in earlier versions. The first test flight of the drone was conducted without attaching any accessories to check the CG balance, agility, and controllability of the drone. Unfortunately, the test ended in disaster as the drone crashed, resulting in broken propellers and damage to the main chassis. The flight log was analysed, revealing that the drone started oscillating furiously and crashed due to CG imbalance, troublesome parts, and weaker joints. The drone was rebuilt from scratch with upgrades, replacement of troublesome parts, and reinforcements to the main chassis. Special attention was given to the CG of the drone. A sturdy and lightweight 3D-printed mount was created to hold both the drone's battery and the GoPro camera.

Note: *All the flights were done by taking all possible precautions and permissions for flight were obtained from Dr. Gaurav Srivastava, Dean of Campus Development, prior to the flight*

Figure 5: Calibrating drone using Mission planner.

Figure 6: Big drone.

Figure 7: GoPro, GoPro mount and 3D printed battery and GoPro holder on weighing machine.

2.4.2 Integrating NodeMCU with the Flight Controller:

Integration of the NodeMCU with the PixHawk Cube Orange flight controller facilitated the control and triggering of the GoPro camera. The NodeMCU, equipped with Wi-Fi functionality, enabled connection to the GoPro camera's Wi-Fi network. Through this connection, the controller could send remote commands to trigger the GoPro camera. This integration proved essential in capturing images at specific waypoints during the mission.

Figure 8: Triggering GoPro Camera.

2.4.3 Test Flights:

The drone was recalibrated and tested. Its stabilising response was tested by manually tilting it in various directions while being held. Building upon the success of the previous test, the drone was flown in stabilise and loiter modes up to a height of 20m, initially without the camera and then with the camera, achieving successful flights. The camera trigger system was also tested. Subsequently, a simple line and square waypoint mission were performed using the drone. Finally, a trial survey was conducted, and all these tests yielded successful results.

Note: *All the flights were done by taking all possible precautions and permissions for flight were obtained from Dr. Gaurav Srivastava, Dean of Campus Development, prior to the flight*

Figure 9: Testing response of drone to artificial stimulation.

Figure 10: Image captured from onboard camera.

Figure 11: Area covered in test survey.

2.5 Survey Mission 1 (Ravine Area):

2.5.1 Data Collection in Ravine Area:

Once the big custom drone with the GoPro camera was ready, the data collection started with flying the drone near the research park ravines at an altitude of 30m. The purpose was to obtain sample photos and test the hardware's capabilities of the custom drone, such as battery time, stability with a camera, GPS accuracy, etc.

Note: *All the flights were done by taking all possible precautions and permissions for flight were obtained from Dr. Gaurav Srivastava, Dean of Campus Development, prior to the flight*

Figure 12: Entire ravine area(Marked in blue) was covered in two flights.

Figure 13: One of the photo taken from the onboard camera.

2.5.2 Geo-Tagging the Collected Data:

The GoPro camera comes with a built-in GPS feature that attaches geographical coordinates to images immediately upon capture, storing this information in the image's metadata. However, the GPS accuracy of the GoPro was quite limited compared to the HERE3 GPS system on the drone. To obtain better accuracy, the images were geotagged once again using the geotagging feature available on mission planner software. This feature geotags the images in a selected folder sequentially, utilising the log data from the flight controller, which records the location where the camera was triggered. By doing this, the geotagging process enhances the accuracy of the geographical information associated with the images. This information is used by the photogrammetry software to generate accurate 3D maps.

2.5.3 Processing and Analysis of the Collected Data:

After the data collection from the first survey, Pix4D software and Meshroom software was used to process and analyse the collected images. Pix4D provided very accurate results, hence this software was used for further analysis. Pix4D is a powerful tool that utilises advanced machine learning and computer vision techniques to extract features from images and generate precise 3D models.

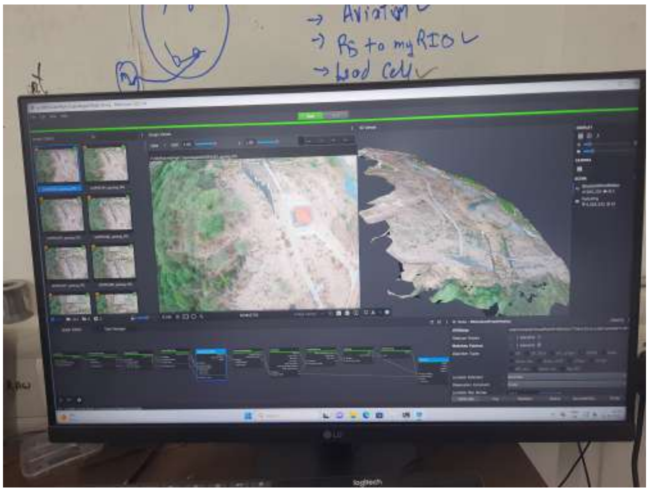

Figure 14: Processing images on Meshroom.

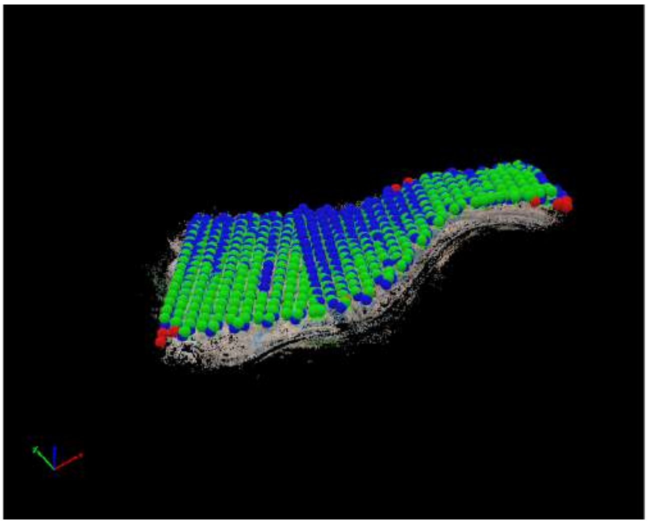

Figure 15: Processing images on Pix4D.

The first step in the Pix4D image processing operations is feature extraction. The software automatically detects and matches common features across overlapping images. This process allows accurate alignment and registration of the images. Certain adjustments happen to refine the camera positions and orientations for a precise reconstruction of the scene. Surface reconstruction algorithms are employed to generate a 3D representation of the scene. Finally, generated point clouds are converted into meshes by various algorithms and texture addition to create a detailed 3D model. While processing it in software, it was noted that there was inadequate image overlap in certain areas leading to inaccuracy in the model generated. To overcome this challenge, one more survey mission which consisted of two drone flights to cover the entire Ravine area was planned and conducted in a manner such that enough overlapping occurred, which led to more accurate 3D model generation.

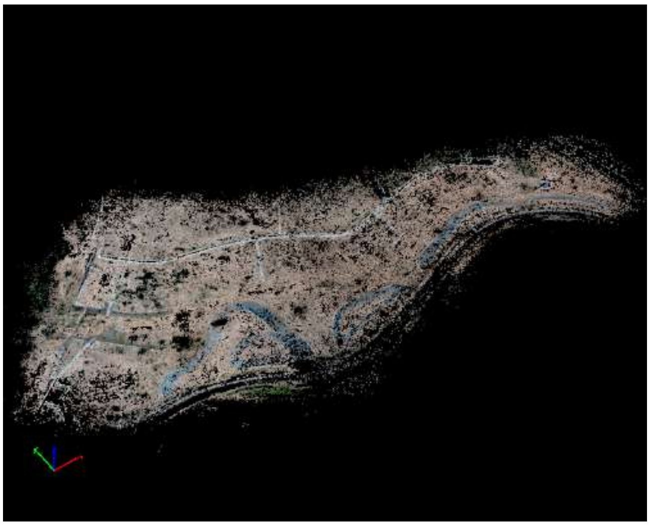

Figure 16: Point cloud generated on Pix4D.

2.6 Survey Mission 2 (Vegetable Garden):

2.6.1 Data Collection and Use of Data Collected:

In the last phase of our project, we conducted a final flight over vegetable garden to explore how this technology could benefit farmers. We selected two farms: one growing cotton and the other dedicated to vegetables. To ensure a thorough analysis, we covered both farms completely, capturing images at different altitudes. Using a GoPro camera mounted on the drone, we remotely triggered the camera to capture images from three different altitudes. In the cotton farm, we took images at heights of 2.5 meters, 4 meters, and 6 meters. For the vegetable farm, we captured images at 2 meters, 4 meters, and 6 meters. These images are incredibly valuable for farmers. They provide a clear and detailed view of their crops, allowing them to analyse and assess the health and growth patterns. By studying the captured images, farmers can gain valuable insights into their crops' condition and make informed decisions about irrigation, fertilisation, and pest control. This technology opens up new possibilities for farmers to understand their fields. By using drones to capture images from different altitudes, farmers can get a comprehensive view of their entire farm. This enables them to identify areas that need attention and optimise their farming practices accordingly. The benefits of drone-based imaging technology in vegetable farms are significant. Farmers can use these images to monitor their crops, detect any issues or challenges, and make necessary adjustments to ensure the best possible outcomes. This technology empowers farmers with a visual representation of their fields, enhancing their ability to manage their crops effectively and ultimately improve yields.

Note: *All the flights were done by taking all possible precautions and permissions for flight were obtained from Dr. Gaurav Srivastava, Dean of Campus Development, prior to the flight*

Figure 17: Areas covered in vegetable Garden.

Figure 18: Cotton farm and drone at takeoff position.

Figure 19: A photo taken from onboard camera.

Figure 20: Drone flying on fields, collecting data.

Figure 21: Flight 1 of drone in farms covering cotton farm at 2.5m and 4m altitude. **Note:** *The image shown here is an old satellite image of the site.*

Figure 22: Flight 2 of drone in farms covering cotton farm at 6m altitude. **Note:** *The image shown here is an old satellite image of the site.*

Figure 23: One of the images of cotton farm captured at an altitude of 2.5m.

Figure 24: One of the images of the cotton farm captured at an altitude of 4m.

Figure 25: One of the images of the cotton farm captured at an altitude of 6m.

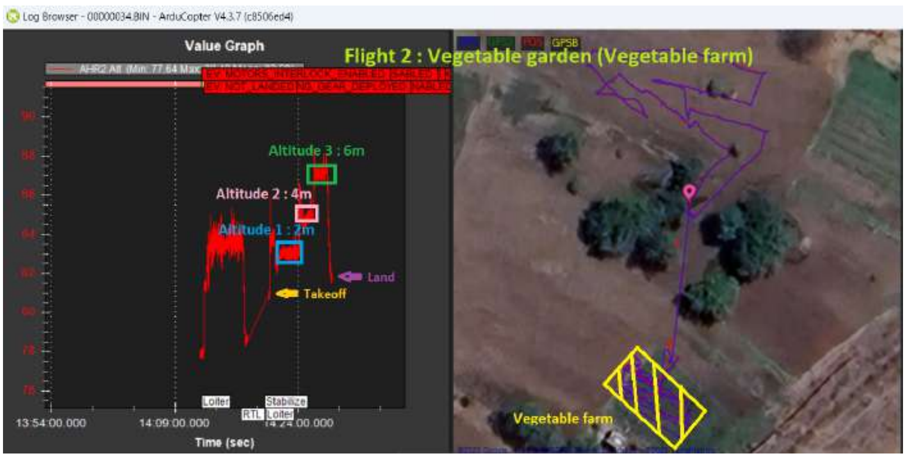

Figure 26: Flight 2 of drone in farms covering vegetable farm at 2m, 4m and 6m altitude. **Note:** *The image shown here is an old satellite image of the site.*

Figure 27: One of the images of vegetable farm captured at an altitude of 2m.

Figure 28: One of the images of vegetable farm captured at an altitude of 4m.

Figure 29: One of the images of vegetable farm captured at an altitude of 6m.

2.6.2 Analysing the Data Collected:

The images captured from the vegetable garden were processed using a Python script that utilized the OpenCV library. The script involved separating the R (Red), G (Green), and B (Blue) channels of the images. Next, the G channel was subtracted from the R channel and was mapped from 0 to 255 pixel by pixel to obtain an image in grayscale, representing areas with living leaves as darker tones and areas without or with dead leaves as lighter tones.

Further processing was performed on this grayscale image to convert it into a monochrome or binary image. By utilizing this processed image, the percentage of the farm area covered by living leaves was calculated. This calculation involved analyzing the distribution and density of the darker tones in the image to estimate the proportion of the area occupied by healthy vegetation.

In summary, the Python script using the OpenCV library was employed to extract useful information from the images of the vegetable garden. By analyzing the grayscale image derived from the R and G channels and performing additional processing, the script enabled the calculation of the percentage of the farm area covered by living leaves, providing insights into the health and vegetation density of the garden.

Figure 30: Input image of the cotton farm.

Figure 31: Output image of the cotton farm after subtracting G channel from R channel.

Figure 32: Input image of the vegetable farm

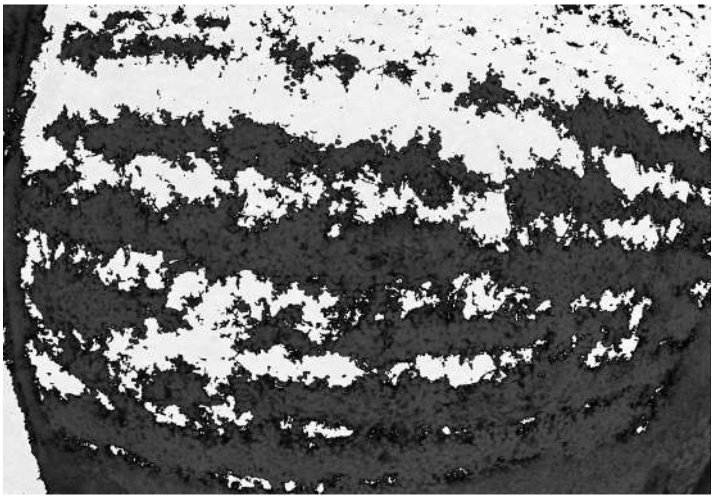

Figure 33: Output image of the vegetable farm after subtracting G channel from R channel.

3 Experimental Results

3.1 Comparing Photogrammertry Softwares:

Meshroom is an open-source photogrammetry software that can create 3D meshes, point clouds, and textured models using input images. It has a user-friendly nodal interface, which makes it easy to use. However, being open source, it lacks certain industry-oriented features such as survey area/volume calculations or the ability to generate R, G, and B indexes from regular camera images. If such features are available, their usage is not as straightforward as in commercial software like Pix4D.

In our comparison between the 3D map models generated by Pix4D and Meshroom, we found that Pix4D's map model closely resembled the actual survey site. On the other hand, Meshroom's 3D map had some missing features and did not accurately represent the survey area. Additionally, Pix4D processed the project faster compared to Meshroom.

In summary, while Meshroom is a convenient open-source option for photogrammetry, it lacks certain specialised features found in commercial software like Pix4D. Pix4D produces more accurate 3D map models and has faster processing speeds for similar projects.

3.2 Results Obtained from Pix4D:

Pix4D software was employed to investigate the generated 3D models further. The focus was on measuring the area and volume within these models. Such measurements offer valuable insights for improved agricultural planning and effective land management decision-making. By utilising Pix4D software, estimations of area and volume were obtained, providing essential information for agricultural planning. This data helps develop strategies for optimal water flow management, which helps reduce soil erosion and enhance agricultural productivity. Understanding the size and shape of specific areas allows for better resource allocation and more efficient land utilisation.

Specifically, the analysis revealed that the area at the ravine's base was 17,483.69m^2, while the area at the top of the ravine measured 55,645.13m^2. Additionally, the total volume enclosed within the boundaries of the ravine, including both the top and bottom areas, amounted to 3,21,807.42$\pm$1,391.98m^3. In summary, the utilisation of Pix4D software enabled advanced measurements of area and volume within the 3D models generated from the survey. These measurements contribute to improved agricultural planning, efficient water flow management, and informed decision-making regarding land management practices.

Figure 34: Bottom area of ravine area.

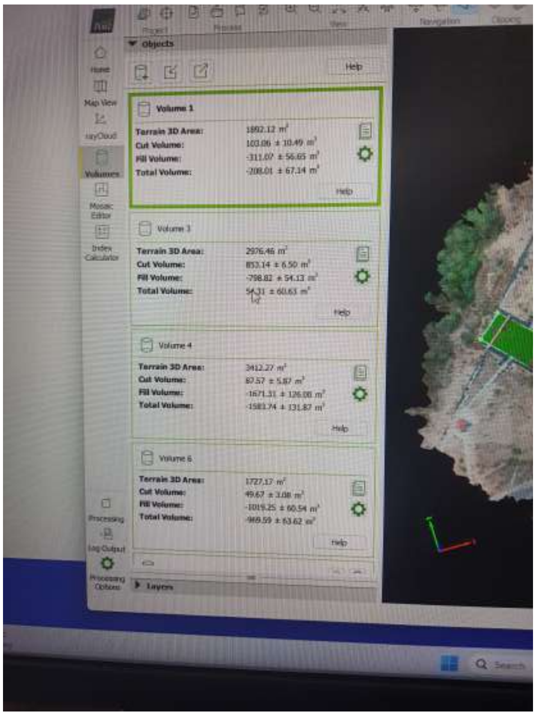

Figure 35: Values of areas of the bottom of the ravine in various sectors of ravine area.

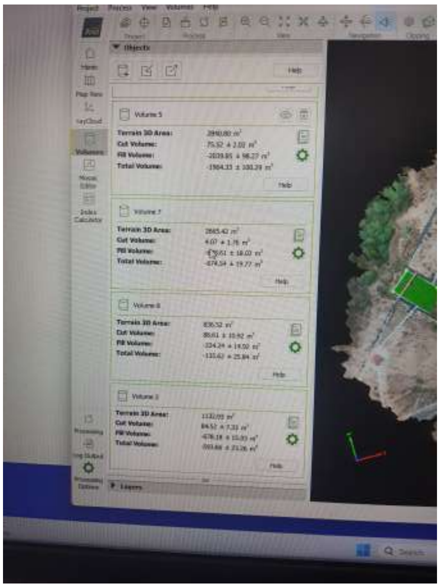

Figure 36: Values of areas of the bottom of the ravine in various sectors of ravine area (Total area is the addition of areas in all sectors).

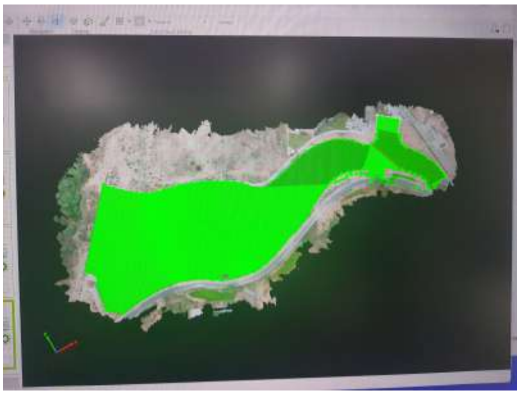

Figure 37: Top area of the ravine area.

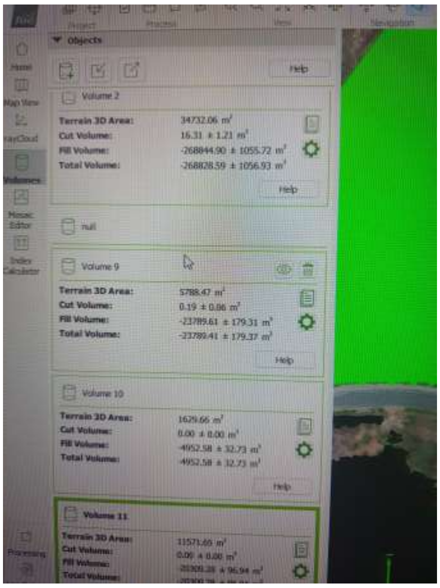

Figure 38: Values of areas of the top of the ravine and volume from top to bottom in various sectors of ravine area.

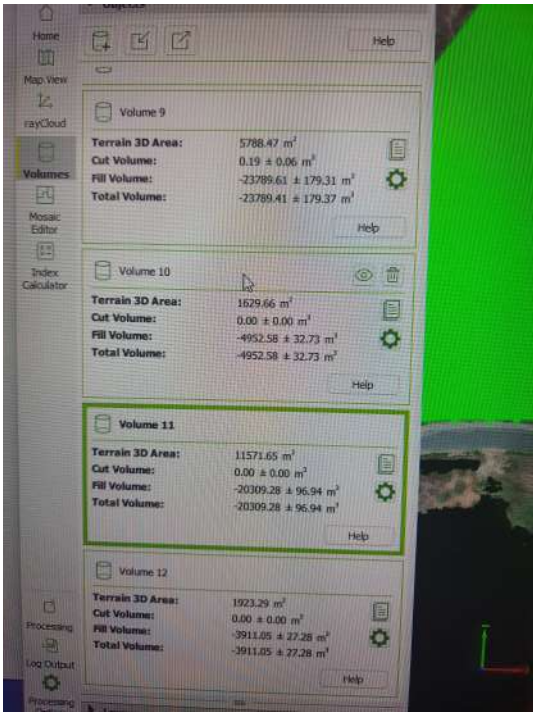

Figure 39: Values of areas of the top of the ravine and volume from top to bottom various sectors of ravine area (Total area and volume is the addition of areas and volumes, respectively in all sectors).

3.3 Vegetation Analysis Results of Vegetable Garden:

During the vegetable farm survey, RGB images were captured to assess the condition of the plants. By analysing these images, we could distinguish areas where plants were thriving and areas where plants were dead, or the land was barren. This analysis allowed us to determine the distribution of living plants and assess the overall health of the farm. Furthermore, using the RGB images, we calculated the percentage utilisation of land within the fields in terms of the greenery covering the area. This measurement provided valuable insights into the extent of vegetation cover and the efficiency of land utilisation.

In summary, through the analysis of RGB images obtained from the vegetable farm survey, we successfully identified areas with living plants and those without and calculated the percentage of land utilisation in terms of green coverage, which was 48.573% for cotton farms and 64.558%for vegetable garden. This information contributed to a comprehensive understanding of the farm's vegetation distribution and assessed land productivity.

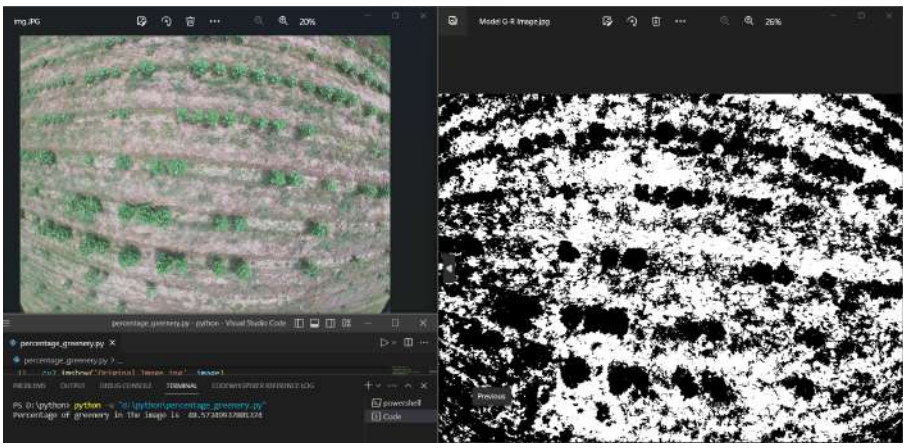

Figure 40: Input image, monochrome image and percentage greenery calculated for one of the images of the cotton farm.

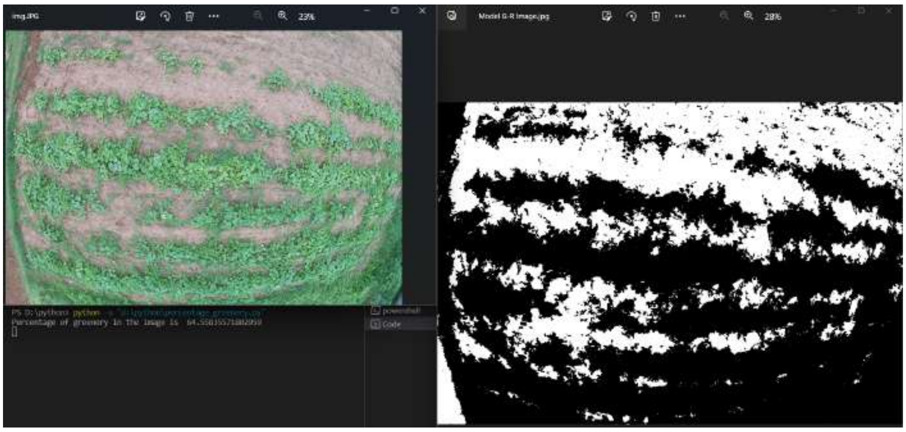

Figure 41: Input image, monochrome image and percentage greenery calculated for one of the images of the vegetable farm.

4 Discussions & Conclusions

4.1 Future Expansions to the Project:

This project has the potential for further advancements in agriculture, offering farmers the ability to gain deeper, more accurate, and timely insights. Farmers can capture images in various spectrums, such as red edge, red, green, blue, and near-infrared, by utilising multispectral cameras attached to drones. These images can be used to calculate different vegetation analysis indexes like NDVI, OSAVI, GNDVI, and NDRE, enabling the identification of problem areas in a field, such as sections experiencing stress due to disease, pests, water stress, dead vegetation, or nutrient deficiencies[3][4].

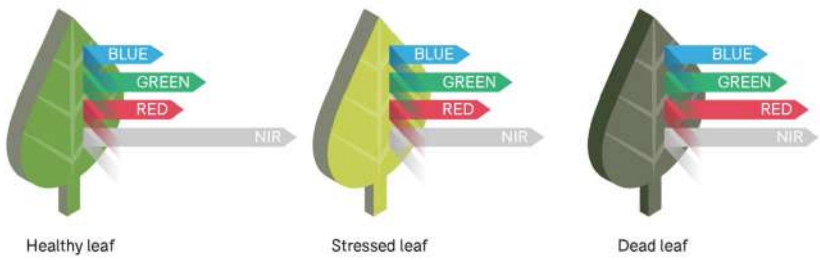

Figure 42: Light reflected by leaves.[3]

Additionally, this project could be expanded to assess the rate of soil erosion over time. By utilising the 3D maps generated from the images obtained from drones in areas prone to erosion, such as riversides and ravines, the difference in volume can be calculated to analyse soil erosion patterns. If this method proves to provide accurate data, it could be a game changer as drones offer a fast and cost-effective means of conducting this type of analysis.

4.2 Multirotors vs Fixed wings and Quick Survey Methods:

This project used a quadcopter, requiring multiple flights in the same area to cover a larger ravine area. Ample overlap in photos was necessary at junction points for accurate 3D mapping using specialised software. However, multi-rotors like quadcopters are relatively less efficient compared to fixed-wing drones. Fixed-wing drones are preferable for larger areas due to their higher payload capacities, longer flight times, and more stable flight characteristics. Multiple drones can be employed simultaneously to overcome time constraints in survey missions covering large areas. It is important to ensure that all

[3] *Image credits: https://www.heliguy.com/blogs/posts/multispectral-drones-benefits-and-applications*

drones use the same camera and properly geotag all the images to maintain uniformity in the collected dataset[6].

Figure 43: Multirotor vs Fixed wings.[4]

4.3 Selecting a Good Camera:

When selecting a camera to attach to the drones, certain parameters, such as shutter speed, ISO, camera resolution, and lens selection, should be considered. As aerial photography falls under motion photography, the shutter speed should be carefully chosen. A shutter speed of 1/250 sec is generally sufficient to freeze people walking, while 1/500 sec is better for subjects in slightly faster motion. For faster-moving objects like cars and birds in flight, preferred shutter speeds are 1/2000 sec, 1/4000 sec, or faster. In our case, we used the GoPro HERO7 Silver camera, which yielded mediocre results. Through thorough research, we discovered that a minimum shutter speed of 1/1000 sec, ISO ranging from 100 to 800 to strike a balance between sensitivity and noise, an ideal camera resolution between 24 to 36 MP, and a lens within the range of 18 to 50mm are recommended parameters. Unfortunately, our camera fell short or just met the bare minimum requirements, resulting in blurry images. This limitation forced us to conduct surveys at very slow drone speeds, limiting the area we could cover in a single flight. Additionally, since our camera was a regular RGB camera, the number of vegetation indexes we could calculate was also limited[7][8][9].

In summary, by combining the use of drones, multispectral cameras, and advanced analysis techniques, this project offers significant potential for providing farmers with valuable insights into their fields. However, careful consideration should be given to the choice of equipment, such as the type of drone, camera parameters, and the need for uniform data collection to ensure accurate and reliable results.

[4] *Image credits: https://www.applanix.com/news/fixed-wing-vs-multi-rotor*

Figure 44: Multispectral camera.[5]

4.4 Current Scenario:

4.4.1 Global Scenario:

The global scenario of surveying and mapping has remarkable advancements in technologies like drones, satellite imagery, LiDAR, and GIS(Geographic Information System). These technologies have revolutionized data collection, enabling more accurate and efficient mapping outcomes. Photogrammetry software solutions such as Pix4D, Agisoft Metashape, and Bentley ContextCapture play a crucial role in generating precise 3D models and extracting valuable information from aerial and ground-based imagery. These software solutions, backed by machine learning and computer vision techniques, have become dominant players in the global market, empowering industries across sectors with advanced mapping capabilities for decision-making, planning, and analysis.

4.4.2 Indian Scenario:

The current survey scenario in India is greatly influenced by the Indian government and private companies offering aerial mapping and services. The Indian government has given specific guidelines for aerial mapping and survey, as outlined in the document titled "Guidelines for Remote Sensing Data Acquisition and Geospatial Data Creation using Unmanned Aircraft Systems". These guidelines are the regulatory framework to ensure safety while using unmanned aircraft systems (UAS) for mapping and surveying purposes.The government's initiatives, such as the National GIS and the Digital India Land Records Modernization Program[10], have propelled the country towards comprehensive geospatial databases and efficient land management. The Survey of India[11] is a government agency that is responsible for mapping and surveying activities across the country. They are responsible for maintaining and updating the national geospatial database, conducting surveys, and creating accurate maps for various applications. Various private companies in India provide excellent services by utilising advanced technologies in surveying and mapping, like Aerial Photo, Drone Nation Solutions, and Aarav Unmanned Systems Private Limited.

[5] *Image credits: https://www.gim-international.com/content/news/wingtra-unveils-multispectral-camera-with-panchromatic-sensor*

Figure 45: Survey of India logo.[6]

4.5 Conclusion:

In conclusion, developing a cost-effective drone-based 3D mapping and surveying technology has effectiveness and potential in various applications. Accurate data collection, accurate 3D modelling, and valuable analysis were achieved using a custom drone equipped with a GoPro camera and using Pix4D software. The technology demonstrates scalability, adaptability, and cost-effectiveness, making it a viable solution in mapping and surveying. Continued progress in this area holds great promise for optimising decision-making processes, improving resource management, and promoting sustainable development in all sectors.

5 References

1. Wolf, Paul R. "Surveying and mapping: History, current status, and future projections." Journal of Surveying Engineering 128.3 (2002): 79-107

2. Collier, Peter. "The development of photogrammetry in World War 1." International Journal of Cartography 4.3 (2018): 285-295

3. Deliry, Sayed Ishaq, and Uğur Avdan. "Accuracy of unmanned aerial systems photogrammetry and structure from motion in surveying and mapping: A review." Journal of the Indian Society of Remote Sensing 49.8 (2021): 1997-2017

4. van der Merwe, Deon Burchfield, David Witt, Trevor Price, Kevin Sharda, Ajay. (2020). Drones in agriculture. 10.1016/bs.agron.2020.03.001.

5. https://www.heliguy.com/blogs/posts/multispectral-drones-benefits-and-applications

6. https://geonadir.com/fixed-wing-vs-multirotor-drones-which-is-better/

7. https://visionaerial.com/best-camera-for-photogrammetry/

8. https://medium.com/@EightyLevel/what-camera-should-you-use-for-photogrammetry-3a67864bd4eb

9. https://www.canon-europe.com/get-inspired/tips-and-techniques/capturing-motion

10. https://dilrmp.gov.in

11. https://www.surveyofindia.gov.in/