DRONES4BLUECARBONSEAGRASS: A Capacity-Building Program for Mapping Seagrasses using Unmanned Aerial System (UAS) Technology in the Philippines

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Abstract:

Coastal blue carbon ecosystems, such as mangrove forests and seagrass meadows, are important for various environmental functions, serving as habitats, food sources, and carbon sinks. Despite their importance, seagrass ecosystems are experiencing global decline due to numerous stressors, including anthropogenic activities. To address this, effective monitoring and management strategies are crucial. Traditional in situ surveys for seagrass monitoring are labor-intensive and time-consuming. Alternatively, remote sensing technologies, particularly satellite imagery, offer a more efficient means of mapping seagrass distribution over large areas. However, accurately assessing seagrass cover at a local scale remains challenging with satellite data alone. Recently, unmanned aerial system (UAS) technology has emerged as a promising approach for seagrass mapping. With its fine resolution and flexibility for image acquisition, UAS can provide more precise estimates of seagrass cover, complementing satellite data. This integration enhances accuracy assessments and expands data availability for training and validation purposes. Under the BlueCARES Project, a drone training program was developed to equip stakeholders with the skills needed for cost-effective UAS-based seagrass mapping. The drone training program encompasses lectures on UAS basics, flight planning, and image processing. Beyond training, collected data are used to create seagrass maps and assess seagrass density. This initiative not only advances seagrass conservation but also fosters collaboration between government agencies, academia, and local communities to achieve sustainable management of blue carbon ecosystems.

1. Introduction

Coastal blue carbon ecosystems, such as mangrove forests and seagrass meadows, play an important role in providing numerous environmental functions. They serve as habitats, refuges, and food sources for a variety of marine organisms, while also acting as nurseries for them. Additionally, they enhance soil stability, regulate nutrient cycle, and water turbidity, and protect coastlines. Moreover, they play a significant role in sequestering large amounts of carbon from the atmosphere (Macreadie et. al., 2019). Among these blue carbon ecosystems, the seagrasses stand out for their remarkable ability to sequester organic carbon in sediments on a global scale, with estimates reaching up to 19.9 petagrams (Pg) (Ricart, et. al., 2020). Despite providing these ecosystem services, seagrass ecosystems are facing significant decline worldwide. This decline could be attributed to various stressors such as rising sea levels, increasing sea surface temperatures, natural disasters, and mechanical damage. At the local scale, anthropogenic disturbances play a predominant role in the decline of seagrasses. Activities such as seaweed farming, dredging, and land modification, contribute substantially to this decline (Short and Wyllie-Echevarria, 1996; Ceccherelli et. al., 2018; Saunders, et. al., 2013). The decline and loss of seagrasses globally and locally has highlighted the need to monitor and identify threats and implement evidence-based management strategies to conserve and restore these blue carbon ecosystems.

In situ surveys, encompassing activities like diving, snorkeling, and sampling-based methods, have been widely applied in seagrass monitoring efforts; however, they are characterized by their labor-intensive, expensive, and time-consuming nature. In contrast, remotely sensed data, such as satellite optical imagery, have emerged as effective tools for mapping seagrass and evaluating its spatial distribution. The use of mid-resolution satellite imageries such as Landsat (30 m) and Sentinel 2 (10 m) are advantageous as they can capture the spatial extent and distribution of seagrass meadows over large geographic areas efficiently (Hossain et. al., 2015; Phinn et. al., 2018). However, with this approach, determining the seagrass percentage cover at a local scale may be more challenging and difficult (Kutser et. al., 2020).

Because of its flexibility for image acquisition and finer resolution, unmanned aerial system (UAS) technology has recently emerged as a potentially effective approach for mapping seagrasses. It can effectively capture information down to the level of individual shoots due to its centimeter-level resolution. Provided that the drone imagery is free from glint and wave artifacts, there is a potential to obtain more precise estimates of seagrass cover within a satellite pixel. This integration of drone and satellite data not only enhances accuracy assessments but also expands the quantity and coverage of data available for training and validation (Carpenter et. al., 2022). The high potential of UASs’ implementation into mapping seagrass ecosystems has been tested and evaluated, establishing it as a proactive, and efficient technology poised for widespread adoption within local communities, academe, and corresponding government agencies.

Characterized by its low-cost, timely, cloud-free, and very high spatial resolution imagery, UAS technology is gaining popularity across a wide range of stakeholders, ranging from grassroots community organizations to academic researchers. However, as UAS technology becomes more widely embraced by diverse groups, it also presents a range of challenges that warrant consideration (Yang et. al., 2020).

As part of a collaborative effort under the Comprehensive Assessment and Conservation of Blue Carbon Ecosystems (BlueCARES), a drone training program was created with the objective of developing a comprehensive set of guidelines for coastal and benthic habitat mapping focusing on seagrasses. The drone training program is designed specifically to equip stakeholders with the necessary skills to utilize a cost-effective UAV solution for seagrass mapping. Furthermore, the training program endeavors to engage beginner users in the operation of UAVs, not only to facilitate the seagrass mapping and monitoring activities but also to extend support for the exploration and assessment of other coastal environments. This approach ensures that participants are equipped with the knowledge and skills required to leverage UAS technology for the conservation and management of blue carbon ecosystems.

While the BlueCARES Project ended in 2022, the initiative of introducing the UAS technology for mapping blue carbon ecosystems was later done by the Philippine Space Agency (PhilSA) under the PhilSA Integrated Network for Space-Enabled Actions towards Sustainability (PINAS) Project. The PINAS Project is envisioned to be an active network of institutions and people working together towards sustainability using space data and information. One of the goals of the PINAS Project is to capacitate Local Government Units (LGU) in the collection of ground data and field measurements using different methods including the use of UAVs. Through this project, there is a continuous flow of information dissemination and capacity building.

To achieve the goals of the project, the initial focus was on the implementation of UAS methods for mapping blue carbon ecosystems, especially seagrasses. These steps include lectures on the basics of UAS, preparing, and examining air space law/regulations set by the Civil Aviation Authority of the Philippines (CAAP), preparing, planning, and realizing flight plans, and lastly processing and analyzing the imagery. Beyond the training activities, the data collected were used to develop maps of seagrass and seagrass density.

2. The BlueCARES Project

The Japan International Cooperation Agency (JICA) initiated the “Comprehensive Assessment and Conservation of Blue Carbon (BC) Ecosystems and their Services in the Coral Triangle” Project, known as BlueCARES. This project pioneered collaborative research on blue carbon ecosystems to develop conservation strategies at local and national levels. The Blue Carbon Strategy, which will be based on the project’s research findings, will serve as a guide for stakeholders in conserving and managing blue carbon ecosystems (JICA, 2022).

In addition to field surveys, the project aims to incorporate advanced technologies such as Remote Sensing, Geographic Information System, and Unmanned Aerial System (UAS) to enhance the formulation of strategies for conserving and managing blue carbon ecosystems. Moreover, it has gathered diverse stakeholders, including government agencies, local government units, academic institutions, and non-governmental organizations, to establish a Blue Carbon Network (BC) in the Philippines. Through capacity-building initiatives, the project aims to empower these stakeholders to sustainably conduct field surveys, conservation efforts, and implement blue carbon strategies even after the project concludes (The BlueCARES Project; JICA, 2023).

3. Aligning UAV Training with the BlueCARES Project

As part of Project BlueCARES’ initiatives, different stakeholders are being equipped with skills in utilizing Remote Sensing and Geographic Information Systems (GIS) to effectively conserve and manage blue carbon ecosystems. A key aspect of this capacity-building involves establishing standardized procedures for the acquisition, processing, and analysis of unmanned aerial vehicle (UAV) data, particularly focusing on mapping and surveying seagrass beds.

The training sessions, facilitated by a team of three, took place from January to February, coinciding with the period typically characterized by the lowest tides in the Philippines. This was also chosen strategically to leverage optimal conditions for capturing high-quality images of seagrass beds. During this season, there tends to be reduced cloud cover, favorable lighting conditions, and fewer weather disturbances, making it ideal for UAV-based mapping.

The trainers involved in the program possess drone license certificates and extensive experience in utilizing UAV technology for mapping and surveying purposes. Through these capacity-building initiatives, stakeholders are empowered to employ advanced techniques and technologies in their conservation and management efforts, contributing to the sustainable protection of blue carbon ecosystems.

3.1 Study Area and Design

A three-person UAV team implemented the training course with local research partners of the BlueCARES Project. Three training sites with seagrass beds were chosen for the training program, one in Miag-ao, Iloilo, one in New Washington, Aklan, and one in Zamboanga City. Over 15 participants from partners and stakeholders were trained including undergraduate and graduate students, faculty members, and research staffs.

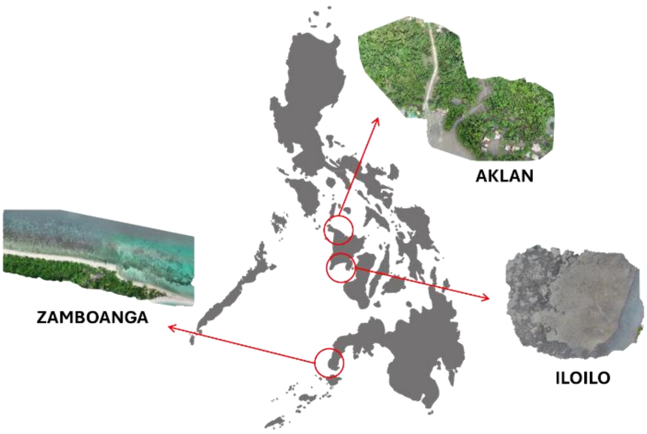

Figure 1. Orthomosaics generated by the participants from the three training sites (Aklan, Iloilo, and Zamboanga)

In each of the training sites, the trainers developed a comprehensive three-day drone training program in collaboration with the research partners and stakeholders. Throughout the duration of the training activity, participants engaged in a structured series of lectures and hands-on activities designed to provide them with the necessary skills and knowledge in drone mapping and surveying. The training sessions began with lectures covering fundamental concepts related to UAV, emphasizing their different applications in various fields. Additionally, participants were introduced on the safety and regulatory considerations set by the Civil Aviation Authority of the Philippines (CAAP) to ensure compliance with airspace laws. Following these initial lectures, the training shifted to practical aspects, offering participants hands-on experience with drone technology. Participants learned to set up drone equipment and software, with

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guidance on how to conduct flight operations both manually and autonomously. This hands-on approach provided valuable insights into the logistics and technical requirements of drone mapping. As the training progressed, the focus moved to data collection and analysis. Participants worked with drone-generated products such as orthomosaics and digital elevation models (DEMs). These exercises gave them a deeper understanding of how to interpret and analyze the data produced by drones.
Ensuring a structured learning experience, the drone training program was divided into four modules (Figure 2), each tailored to address specific aspects of drone mapping. By implementing a comprehensive curriculum and providing practical field experience, the training program aimed to equip the participants with the necessary skills to effectively utilize UAV technology for mapping and monitoring of blue carbon ecosystems.

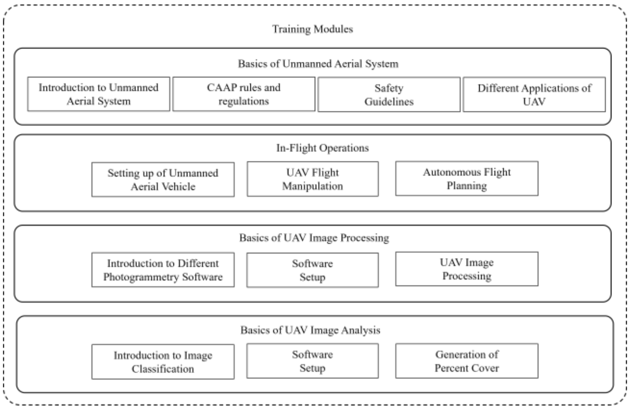

Figure 2. Training modules for UAV mapping and surveying workflows

3.1.1 Basics of UAV: The first training module covered a wide range of topics important for understanding unmanned aerial vehicles. Participants received lectures introducing UAV technology, along with an overview of the rules and regulations set by CAAP. Safety guidelines were also emphasized to promote responsible usage of drones. Furthermore, the module explored the different applications of drones across various fields highlighting their versatility and potential. A practical demonstration of flying a drone was also conducted to provide participants with insight into its capabilities.

During the training session, the DJI Phantom 4 Pro V2 was utilized as the primary drone model, chosen for its impressive capabilities and user-friendly features. This consumer-level quadcopter is known for capturing high-quality images, making it ideal for various applications. It offers a wide range of functionalities, including multiple flight modes, advanced obstacle sensor avoidance, and an automatic return-to-home function for enhanced safety. The drone is beginner-friendly, allowing new users to operate it with ease while still providing advanced options for more experienced pilots. Additionally, its long battery life (20-30 mins) and long-range transmission capabilities, reaching up to 2 km, make it exceptionally well-suited for conducting extensive aerial mapping and data collection tasks. These features of DJI Phantom 4 Pro V2 collectively ensure efficient and effective performance during the training session.

Figure 3. DJI Phantom 4 Pro V2 units were used for the BlueCARES drone training.

In addition to technical lectures on the fundamentals of drones and their applications, the training program dived into crucial aspects of safety and regulatory compliance outlined by the CAAP. Participants were briefed on pre-flight planning measures, emphasizing the importance of conducting checks on equipment and identifying suitable take-off and landing sites.

During the flight operations, emphasis was placed on adhering to safety protocols, such as maintaining a visual line of sight, avoiding populated areas, or flying outside the 10-km buffer on an airport to ensure the safety of the individuals as well as the equipment. Participants were also educated on CAAP regulations on drone licensing and operator certificate requirements.

Given the training program’s specific focus on seagrass mapping, additional procedures were discussed to optimize data collection. This included specifying the recommended flying for drones (between 30 – 40 meters) and identifying optimal timeframes for data acquisition (between 8 am to 10 am and 2 pm to 4 pm). By incorporating these guidelines, participants gained a comprehensive understanding of both technical and regulatory aspects necessary for safe and effective drone mapping of seagrasses.

3.1.2 In-Flight Operations: Following the overview of the drone fundamentals, its operation, and application, the participants engaged in practical flying sessions supervised by trainers. Participants engaged in manual flying to gain hands-on experience and familiarity with basic control such as takeoff, landing, flight adjustments, and camera/video settings. Throughout these exercises, participants focused on honing their skills in drone control, maintaining a visual line of sight, and navigating through potential hazards.

Following the manual operation, the participants proceeded to an autonomous drone mapping activity. Recognizing the efficiency and comprehensiveness offered by autonomous mapping, the training utilized an automatic flight planning application called Pix4D Capture. This free and open-source flight planning mobile application facilitated the planning and execution of autonomous flights, allowing participants to adjust flight parameters for optimum coverage. Considerations for autonomous flight parameters are as follows: (1) Spatial resolution and coverage, (2) Camera angle and positioning to minimize sun glint, (3) optimization of flight direction and capture, and lastly (4) side laps and front overlaps. Trainers provided guidance and troubleshooting support as participants navigated the setup and execution of automated flights using the Pix4D Capture application. Figure 4 shows a sample flight plan created in Pix4D Capture.

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Figure 4. Flight plan conducted by participants in New Washington, Aklan to demonstrate execution of autonomous flight planning.

3.1.3 Data Processing: After completing field-based training modules, participants were trained to process drone-captured data obtained during the practical training. This data processing module encompassed several key steps: (1) software setup, (2) stitching of drone imageries, and (3) generation of products (orthomosaics, digital elevation models, etc.). Prior to image processing, the participants were first introduced to the photogrammetric processes involved in drone image processing software as well as the importance of visually inspecting the captured data to identify and exclude low-quality images that could compromise the processing. Since most of the participants are from academic institutions, a free and open-source software solution was instead introduced for data processing module. With this, the Open Drone Map (ODM) emerged as a suitable choice due to it being free and open source. The ODM serves as an open ecosystem of solutions tailored for processing, analyzing, and displaying aerial drone data. Leveraging ODM, participants gained access to a comprehensive toolkit designed to handle drone image processing. The generated products of this process will be accessible for free (under the request) by academe, government institutions, etc.

Figure 5. Open Drone Map graphical user interface for processing drone images

3.1.4 Data Analysis: In concluding the training module, participants were introduced to the basics of image analysis and classification techniques customized to align with the research goals and objectives of the project. This session provided an overview of the basics of remote sensing, GIS, and image classification methods relevant to the project's scope. Participants were introduced to the potential applications of the products derived from orthomosaics and digital elevation models. Specifically, the focus was on seagrass classification and seagrass percent cover. These derived datasets will serve as vital inputs for modelling nationwide seagrass cover, contributing to a broader understanding of seagrass distribution and dynamics across the country.

4. Results and Data Products

4.1 Implementation of Drone Training Program

Drone surveys were carried out at each study site (Aklan, Iloilo, and Zamboanga) utilizing the Phantom 4 Pro V2, specifically targeting large areas of seagrass beds within the areas. While the training modules were standardized across regions, the trainers ensured the adaptability of the program by tailoring its content to accommodate the varying environmental conditions spanning from Visayas Regions to Mindanao. Additionally, localized rules and regulations concerning drone operations were considered incorporated to ensure compliance and safety throughout the training process.

(a) (b)

Figure 6. Hands-on drone operation for (a) Aklan State University – New Washington Campus participants, and (b) University of the Philippines Visayas – Miagao Campus participants

To ensure the seamless generation of data products from the collected drone imagery, lectures and data processing activities were conducted within the computer laboratories of partner academic institutions. Comprehensive manuals (Figure 7) were prepared and distributed to participants, serving as step-by-step guides for installing the required software and executing data processing tasks. These manuals were created to provide clear instructions and troubleshooting tips, ensuring that participants could navigate the software installation process with ease and confidence. The provision of detailed manuals served as valuable reference materials, enabling participants to reinforce their understanding of software installation procedures and data processing workflows. This approach not only enhanced participants' technical proficiency but also promoted self-sufficiency in utilizing software tools for future data processing endeavors.

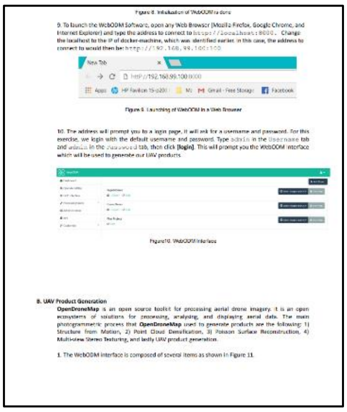


Figure 7. Screenshot of drone image processing manual provided to the participants.

Figure 8. Drone image processing and analysis done in a computer laboratory of Aklan State University

4.2 Data Products from the Drone Training Program

As a crucial part of the project’s objectives, comprehensive sets of drone images capturing seagrass habitats, along with other derived products, were generated across each study site. These images, alongside other relevant derived products, were collected and stored. The primary purpose of these drone image collections was to serve as datasets for the development and refinement of AI models geared towards the comprehensive assessment of the seagrass extent and percent cover on a nationwide scale. Figure 9 shows an example of an orthomosaic generated by the trainers in Masinloc, Zambales. The flying height of the drone was set to 40 meters and the images were captured at around 3 pm. On the other hand, figure 10 highlights the outcomes of the drone training program, featuring some of the orthomosaics generated by the participants from Aklan State University and Ateneo de Zamboanga University. These images effectively capture seagrass habitats and various associated features, with all images accurately geo-registered for spatial referencing and analysis purposes.

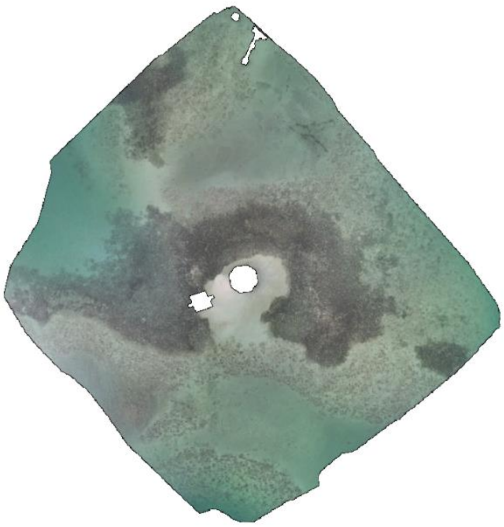
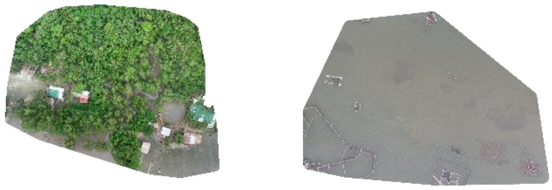


Figure 9. Orthomosaic of seagrass beds found in Masinloc, Zambales captured by DJI Phantom 4 Pro V2



(a)

(b)

Figure 10. Sample orthomosaic produced by the participants, (a) New Washington, Aklan, and (b) Great Sta. Cruz Island, Zamboanga City

The site-level orthomosaics show the difference of seagrass beds from other benthic covers such as corals, algae, sand, and rubble in terms of spatial patterns. At 1-3 cm spatial resolution, the textural difference of seagrass from other benthic covers is clear and well-captured.

After processing the drone-captured images into orthomosaics, additional data products were derived by the trainers to further analyze the seagrass habitats. Utilizing GIS software, QGIS, and a cloud-based remote sensing platform, Google Earth Engine, seagrass percent cover was extracted from the orthomosaic datasets. First, the orthomosaics were classified into seagrass and non-seagrass classes using K-means, an unsupervised classification algorithm. The generated binary classifications were then processed using QGIS to extract seagrass percent cover. A fishnet derived from the spatial resolution of Sentinel-2 was used for the calculation of seagrass cover statistics. These derived percent cover serve as crucial metrics for quantifying the density as well as the extent of the seagrass beds within the study area. The seagrass percent cover values derived from the analysis and processing will later become inputs for artificial intelligence (AI) models aimed at generating nationwide seagrass percent cover maps.

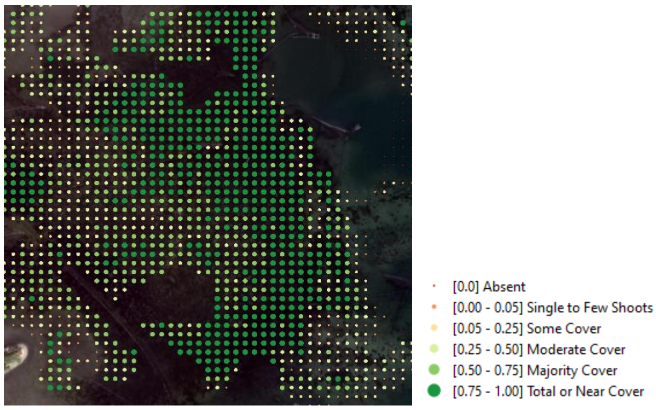


Figure 11. Seagrass percent cover derived from one of the generated orthomosaic of the participants.

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5. Discussion

The use of drones for mapping seagrasses in the Philippines has been limited due to a lack of widespread understanding and application of drone technology in coastal mapping. To address this gap, one of the main goals of the project was to create a methodology and toolkit for generating aerial imagery datasets of seagrass habitats. This effort aims to provide essential support for conserving and managing blue carbon ecosystems across the country.

By improving access to high-resolution imagery datasets, the project aims to contribute to existing seagrass mapping efforts in the Philippines. However, some challenges were encountered during the implementation of the drone training program. A significant hurdle was the cost associated with starting drone operations. To mitigate this, we opted to use a consumer-level drone and an open-source and free software; thereby, reducing the initial financial burden on our partner institutions. While it was demonstrated that consumer-level drones can capture high-quality RGB images at a finer detail, using them for more advanced features like multispectral requires a more expensive camera and drone system. This would also entail a steeper learning curve since the use of multispectral drones is more complicated than drones with RGB cameras (Yang, et. al., 2020).

Furthermore, both the trainers and participants encountered significant challenges in mapping seagrass using drones. The primary difficulties included are dealing with turbid waters, which can obscure the visibility of seagrass beds, and managing sun glint, which can create reflections on the water surface that interfere with image clarity. Additionally, varying environmental conditions, such as changes in weather, tides, and water clarity, posed an obstacle to consistent and accurate data collection. These factors collectively complicated the process, highlighting the need for specialized techniques and adaptive strategies in drone-based seagrass mapping. As a result, the focus of the drone training program was to explore the workflow and use of RGB-based drones in combination with artificial intelligence for mapping seagrass habitats. This strategic approach aimed to align the training program with the current capabilities and resources available, ensuring effective utilization of the equipment and maximizing learning outcomes for participants.

Providing drone training to our partner institutions represents a significant milestone in capacity-building efforts related to seagrass mapping. The knowledge and skills acquired by participants during the training sessions will not only support the project's objectives but also establish a foundation for future initiatives, enabling sustained efforts in seagrass conservation and management. Moreover, the significance of the training program extends beyond its immediate impact. It serves as a blueprint, providing a structured framework and guidelines for mapping seagrasses using drones. This blueprint encapsulates best practices, methodologies, and lessons learned from the training sessions, offering valuable insights and resources for future endeavors in seagrass mapping. Importantly, the training program serves as a blueprint for mapping seagrasses, laying the groundwork for broader adoption and implementation by the Philippine Space Agency and other relevant stakeholders.

6. Conclusion

Through this study, a significant step has been made towards the nationwide mapping of seagrasses in the Philippines. By harnessing the potential of Unmanned Aerial Vehicle (UAV) technology coupled with Remote Sensing and Geographic Information System (GIS) techniques, we have developed a comprehensive training program tailored for individuals or institutions lacking prior experience in these fields. The outcomes of this study not only underscore the efficacy of UAS technology in mapping seagrass at a local scale but also lay the groundwork for broader applications.

In addition to paving the way for nationwide seagrass mapping, the training program establishes a framework of practices and guidelines for leveraging drone technology in coastal and marine science research. This initiative aims to bridge the gap between traditional in-situ survey methods and innovative technologies, empowering stakeholders with the knowledge and skills necessary to harness the full potential of UAS technology.

By equipping participants with expertise in UAV operation, data processing, and analysis, the training program facilitates the integration of drone technology into coastal and marine research initiatives, especially in seagrass mapping research. Furthermore, it fosters collaboration and knowledge exchange among different stakeholders, facilitating the adoption of standardized practices and methodologies across the field.

Ultimately, this study not only advances the understanding and conservation of seagrass ecosystems but also contributes to the broader discussion surrounding the integration of emerging technologies in coastal research and management and other fields. Through concerted efforts and capacity-building initiatives, we can continue to leverage innovative tools and approaches to address pressing environmental challenges and pave the way for sustainable coastal and marine resource management.

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