Advancing Blue Carbon Knowledge: Leveraging Geomatics for Capacity Building through the BlueCARES Project

Kayziel Martinez[1], Ariel Blanco[1,2] , Ayin Tamondong[1], Christian Candido[2], Kazuo Nadaoka[3]

[1] Department of Geodetic Engineering, University of the Philippines – Diliman, Quezon City, Philippines
- (kpmartinez1, acblanco, amtamondong)@up.edu.ph
[2] Space Information Infrastructure Bureau, Philippine Space Agency, Quezon City, Philippines
- (ariel.blanco, christian.candido)@philsa.gov.ph
[3] School of Environment and Society, Tokyo Institute of Technology, Tokyo, Japan
- nadaoka.k.aa@m.titech.ac.jp

Keywords: Blue Carbon Ecosystems, Mangroves, Seagrass, Capacity Building, Drone, Google Earth Engine

Abstract

Mangrove forests and seagrass meadows, collectively termed as blue carbon ecosystems (BCEs), play a pivotal role in carbon sequestration and climate mitigation. Blue carbon research enables advancing scientific knowledge and gaining insights into their current state, which is crucial for making informed decisions on its conservation and management practices. The Japan International Cooperation Agency (JICA) launched the “Comprehensive Assessment and Conservation of Blue Carbon (BC) Ecosystems and their Services in the Coral Triangle” or BlueCARES to pioneer joint research on blue carbon ecosystems and formulate conservation strategies at local and national levels. BlueCARES aims to establish a robust Blue Carbon Strategy and initiate the establishment of the Blue Carbon Network (BCnet), convening various stakeholders, including government agencies, local government units, academic institutions, and non-governmental organizations. BCnet organizes summits, workshops, and conferences to facilitate collaboration. Through capacity development initiatives, the project empowers stakeholders to actively engage in field surveys, conservation efforts, and the implementation of the Blue Carbon Strategy, even after the project concludes. This paper narrates the capacity-building engagements made by the Geomatics team, leveraging remote sensing and geospatial technologies to foster sustainable blue carbon management practices and ensure the long-term resilience of BCEs in the country.

1. Introduction and Rationale

Mangrove forests and seagrass meadows are vital providers of ecosystem services, notably coastal stabilization, carbon sequestration, and climate mitigation. Collectively termed as blue carbon ecosystems (BCEs), they play a pivotal role in mitigating the impacts of increasing atmospheric carbon dioxide levels. Through photosynthesis, mangroves, seagrass meadows, and tidal marshes absorb carbon dioxide from the atmosphere and surface waters, storing it as organic carbon in their biomass and soil. BCEs have the capacity to sequester carbon for a millennium. If these ecosystems are destroyed, they release the carbon they have stored back into the atmosphere, contributing to an increase in greenhouse gases. Hence, the protection and conservation of these ecosystems can significantly reduce greenhouse gas emissions and mitigate climate change. (Quevedo et al., 2020,. Quiros et al., 2021, Beaumont et al., 2014, Crooks et al., 2017).

In the Philippines, mangrove and seagrass ecosystems have been subjects of study for many years; however, research focusing on their blue carbon storage capacity has only recently garnered attention (Corcino et al., 2023). Understanding the current state of blue carbon research in the Philippines is imperative for making informed decisions regarding conservation and management practices and for furthering scientific knowledge of these invaluable ecosystems.

The Japan International Cooperation Agency (JICA) launched the “Comprehensive Assessment and Conservation of Blue Carbon (BC) Ecosystems and their Services in the Coral Triangle” or BlueCARES as pioneered efforts on joint research on blue carbon ecosystems to form a conservation strategy at both local and national levels. BlueCARES represents a trilateral joint project involving Japan, Indonesia, and the Philippines, with participation from numerous research institutions in these countries. It is funded by the Science and Technology Research Partnership for Sustainable Development (SATREPS) and operates in close collaboration and consultation with the Japan Science and Technology Agency (JICA, 2022). Initially approved for a 5-year period in April 2017, the project was later extended until March 2023.

BlueCARES endeavors to establish conservation actions by formulating a robust Blue Carbon Strategy. This strategy hinges on a thorough evaluation of blue carbon ecosystem services, facilitated by nationwide monitoring and change detection initiatives. Integrated with socioeconomic data, these assessments will inform predictive models to identify optimal policy measures for effective blue carbon conservation. Moreover, the Blue Carbon Strategy will serve as a guiding framework for stakeholders, with the goal of safeguarding blue carbon ecosystems and fortifying their resilience through time. (The BlueCARES Project; JICA, 2023).

The project encompasses research on mangrove forests and seagrasses. This includes performing field surveys to collect samples and metrics for bio-analysis; mapping extent and coverage through remote sensing technologies; and identifying the ecological conditions of these ecosystems. Furthermore, the project initiated the establishment of the Blue Carbon Network (BCnet) which convenes various stakeholders including government agencies, local government units, academic institutions, and non-governmental organizations. BCnet organises summits, workshops, and conferences to facilitate collaboration. Through capacity development initiatives, the

project aims to empower these stakeholders to actively engage in field surveys, conservation efforts, and the implementation of the Blue Carbon Strategy, even after the project concludes.

The Philippine team of the BlueCARES Project is broken down into four (4) groups namely the Ecology Group, the Geochemistry Group, the Social Science Group and the Integrated Modelling and Geomatics (IMG) Group with the latter having sub-units of the Modelling Team and Geomatics Team. This paper will primarily focus on the efforts and engagements made by the Geomatics team toward capacity building through collaborative workshops, equipment training, and field demonstrations for remote sensing technologies.

2. Methods and Engagements

The capacity-building engagements initiated by the Geomatics Team are summarised in Figure 1.

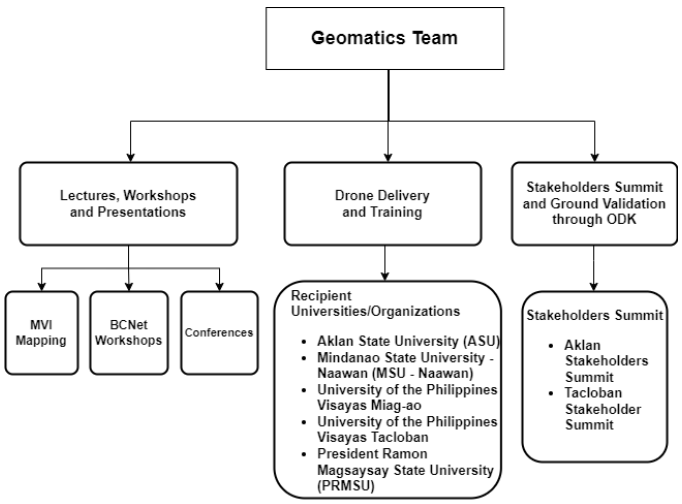

Figure 1. Overview of capacity-building efforts and engagements made by the Geomatics Team

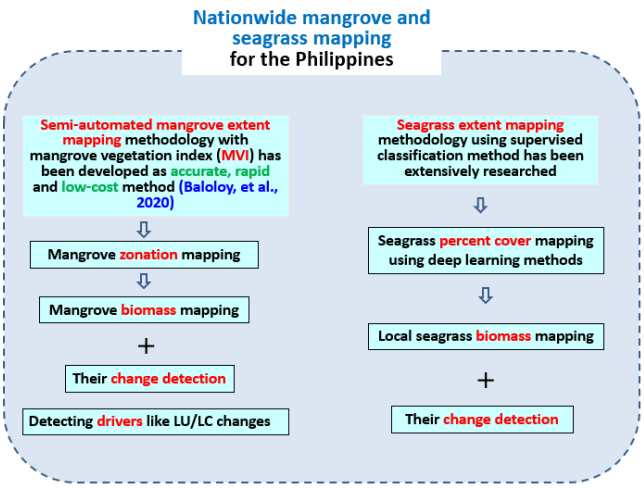

Figure 2. The Geomatics team’s methodological framework for the Nationwide Mangrove & Seagrass Mapping in the Philippines, presented at the Blue Carbon Regional Symposium 2023 by Dr. Tamondong

2.1 Lectures, Workshops and Presentations

The Geomatics team specializes in leveraging remote sensing, geographic information systems (GIS) and machine learning. By integrating these technologies, the team creates maps that visualize spatiotemporal dynamics and conducts technical analyses to assess the carbon stocks of blue carbon ecosystems. Figure 2 illustrates the framework of the Geomatics team’s goal to perform a nationwide mapping of mangrove and seagrass ecosystems from a technical perspective. This mapping methodology, along with developed products, are shared with the public through lectures, workshops, and presentations. These efforts aim to inform the public about the significance and existence of such technologies and to empower them with the knowledge to utilize these tools independently.

2.1.1 MVI Mapping

A significant achievement of the team was the creation of the Mangrove Vegetation Index (Baloloy et al., 2020). This formula uses the satellite's spectral bands to rapidly delineate mangrove forests at any location in the Philippines and at any time that the user would prefer. This index is implemented in Google Earth Engine (GEE), a cloud-based, open-source geospatial platform used for visualizing and analyzing satellite images. GEE eliminates the need for data downloads as users can directly retrieve the satellite images in the platform, therefore streamlining the process and conserving memory resources. Additionally, the team developed accessible scripts for implementation, ensuring that individuals, even those without a programming background, can also utilize the platform. Furthermore, the scripts are customizable and inclusive of proper documentation with simplified explanations to enhance understanding for the users and encourage exploration, fostering inclusivity to a diverse audience.

2.1.2 Blue Carbon Network (BCnet) Workshops

The Blue Carbon Network (BCnet) Philippines was established to foster collaboration among institutions, agencies, and citizen scientists in blue carbon research. Its mission is to conduct, promote, and provide research, technical assistance, and education services to support partner institutions and agencies in natural and socioeconomic blue carbon resource assessment and conservation. BCnet Philippines comprises three clusters—Luzon, Visayas, and Mindanao—and includes Provincial and Local Government Offices, National Government Agencies, State Universities and Colleges, Non-Governmental Organisations, and People's Organizations from various sectors such as environment, education, tourism, business, culture, social, energy, and legal. Together, the network members collaborate on activities and initiatives aimed at advancing blue carbon research in the country.

Before the pandemic, BCnet members engaged in various face-to-face activities that included comprehensive data collection surveys. These activities involved gathering detailed metrics on mangrove ecosystems, assessing seagrass cover percentages, conducting hands-on drone operations, and performing intricate GIS analyses. However, in response to the challenges posed by the pandemic, BCnet adapted to the new normal by transitioning to online meetings and virtual workshops. These virtual workshops served as a pivotal platform for BCnet members, featuring lectures delivered by diverse resource speakers. Additionally, the workshops included practical, hands-on tutorials focused on utilizing Multispectral Vegetation Indices (MVI) within the Google Earth Engine (GEE) platform.

2.1.3 Conferences

Capacity-building involves sharing knowledge across diverse sectors, and conferences serve as an effective avenue for this purpose. The Geomatics Team actively participates in conferences, where they present the products and analyses derived from their research and fieldwork. In addition to their participation, team members also contribute to organizing committees, thereby facilitating opportunities for knowledge exchange. BlueCARES has organized both the 1st and 2nd National Blue Carbon Symposiums (NBCS). The inaugural symposium was held in September 2018 at Subic Bay, Philippines, while the second symposium took place online in May 2022 due to COVID-19 restrictions.These symposiums bring together experts and practitioners from the Coral Triangle Region (CTR) and beyond for plenary sessions, parallel discussions, and panel talks. The focus is on addressing current scientific, social, and policy issues related to blue carbon (BC) amidst climate change and tropical coastal conservation efforts. They serve as vital platforms for information exchange, activity highlights, partnership building, and shaping the future direction of this critical field

2.2 Drone Delivery and Training

For the Geomatics Team, JICA supplied drones (Unmanned Aerial Vehicles) to enhance the monitoring of blue carbon ecosystems with higher resolution capabilities. Specifically, the DJI Phantom 4 Pro V2 units serve as validation sources for remote sensing outputs and enable rapid assessments over extensive areas at any preferred time.

Initially, team members conducted extensive research using these drones to develop effective methodologies for mapping blue carbon ecosystems. They experimented with various data collection, processing, and analysis techniques to establish a reliable and efficient workflow. This involved testing different flight patterns, camera settings, and post-processing software to optimize the accuracy and resolution of the data collected. Once the team had refined their approach and developed a robust structure for using the drones, they began sharing these techniques with BCnet members. The knowledge transfer included practical training sessions and demonstrations, ensuring that other members could replicate. Some of the drones were donated to various BCnet members, accompanied by comprehensive training on their use and post-processing techniques. The training included the use of OpenDroneMap and QGIS, both open-source tools utilized to produce high-resolution orthophotos and 3D models, as well as to analyze them.

The training sessions encompass lectures on fundamental concepts, as well as safety and regulatory considerations set by the Civil Aviation Authority of the Philippines (CAAP) to ensure compliance with airspace laws. Following the initial lectures, participants receive hands-on experience with drone technology, including guidance on conducting flight operations both manually and autonomously. Participants then work with drone-generated products such as orthomosaics and digital elevation models (DEMs), gaining a deeper understanding of how to interpret and analyze the data produced by drones. These exercises are designed to inform stakeholders of the entire process, from data collection to analysis, enabling them to acquire the skills needed to effectively utilize drone technology for blue carbon ecosystem monitoring. The training sessions are divided into modules to ensure clear and effective communication of each aspect of the process.

2.3 Stakeholders Summit and Ground Validation through ODK

The summit's objective is to unite stakeholders to discuss research outcomes and the roles of communities and stakeholders in the blue carbon (BC) strategy and engage them in the process. In January, the project facilitated the signing of a Memorandum of Understanding among Aklan stakeholders, forming the "Aklan Rivers, Bays, and Coasts Integrated Management Council." Similarly, in February, a Blue Carbon Stakeholders Summit along with a BCNet Training-Workshop was held in Eastern Samar, furthering the collaborative efforts in blue carbon conservation and capacity building. The summit typically includes representatives from all BlueCARES Philippine groups, presenting each group’s research outcomes as well as the gaps in between to which communities may assist in their way. The geomatics team underscores their presentation of their mapping results, mentioning the need as well for ground validation. The team explores the solution of having a citizen science validation approach through the Open Data Kit (ODK), which enables individuals to log observations on blue carbon ecosystems using mobile phones. As long as their location is turned on, these observations will be geotagged, making it easier to pinpoint specific areas of concern. This innovative approach not only significantly enhances the monitoring and assessment of these ecosystems but also empowers communities to contribute directly to conservation efforts. Furthermore, it allows individuals to utilize this information for their purposes, such as making informed decisions about their local environment and contributing to community-based conservation projects.

3.Results and Discussion

3.1 Lectures on MVI Mapping and BCnet Workshops

The BCnet Workshops, led by the Geomatics Team during the pandemic, are summarized in Table 1. These workshops focused on a variety of topics, all revolving around Mangrove Mapping, as the implementation of the Multispectral Vegetation Index (MVI) Mapping was shared among the network and other collaborators interested in learning and participating.

BCnet Workshop	Title/Topic	Date
2nd BCnet - Luzon	Mangrove Zonation Labelling & Validation with Citizen Science	July 2021
3rd BCnet - Luzon	Mangrove Extent Mapping, Modules 1 & 2	October 2021
1st BCnet -Mindanao	Mangrove Extent Mapping, Modules 1 & 2	November 2021

Table 1. (Virtual) BCnet Workshops led by the Geomatics Team

The workshops were designed to ensure comprehensive knowledge transfer, covering both theoretical and practical aspects of Mangrove Mapping. Participants were introduced to the fundamental principles of remote sensing and GIS, followed by detailed instructions on the use of MVI for accurate mapping of mangrove ecosystems. The Geomatics Team provided step-by-step guidance on data collection, processing, and analysis using the scripts prepared in Google Earth Engine. Figure 3 demonstrates some of the results achieved by the participants from various regions and organizations across the country. These results highlight the participants' understanding of the technical workshops and their ability to apply the learned techniques effectively.

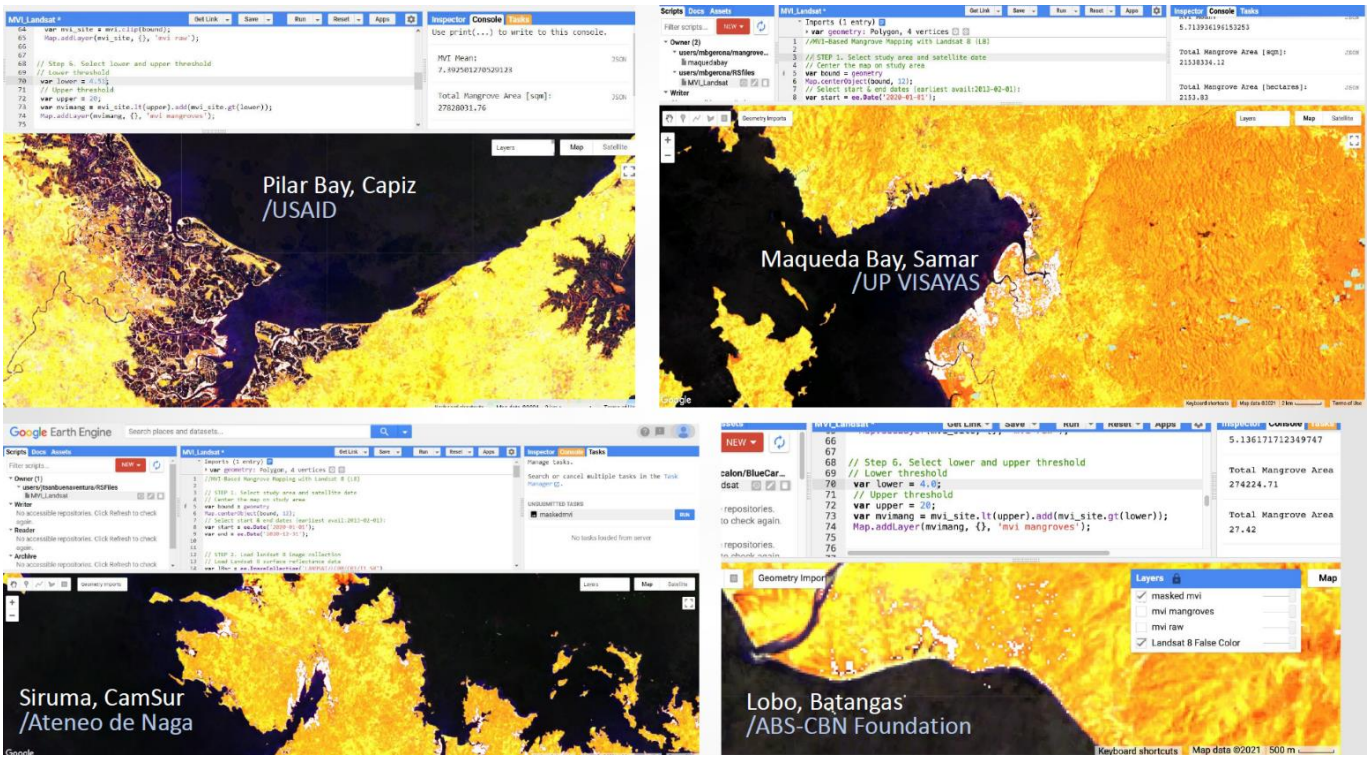

Figure 3. Results of the application of MVI in GEE made by different participants of the BCnet Workshop

The diversity of the participants' backgrounds and the quality of their outputs demonstrate the success of the workshops in fostering a collaborative learning environment.

The workshops not only equipped participants with valuable technical skills but also encouraged knowledge sharing and collaboration among different organizations. By engaging with a wide array of stakeholders, including academic institutions, NGOs, and local government units, the workshops facilitated the dissemination of best practices in mangrove mapping and the broader field of blue carbon ecosystem monitoring.

Overall, the BCNet Workshops played a crucial role in building capacity within the network, empowering participants to utilize advanced geomatics techniques in their own projects. The shared knowledge and collaborative efforts have strengthened the network's ability to monitor and manage blue carbon ecosystems more effectively, contributing to the broader goals of environmental conservation and climate change mitigation.

3.2 Conferences and Publications

The Geomatics Team has actively participated in conferences, showcasing members’ research projects primarily focused on developing methodological frameworks to improve the mapping of blue carbon ecosystems. Figure 4 illustrates one of the member's research on change detection, presented at the most recent National Blue Carbon Symposium (NBCS 2022). This research aligns with the technical structure's goal of enhancing monitoring capabilities.

Additionally, the presentations at conferences often lead to subsequent publications. The Geomatics Team also achieved a significant milestone with the publication of a book chapter titled "Mapping Multi-decadal Mangrove Forest Change in the Philippines: Vegetation Extent and Impacts of Anthropogenic and Climate-Related Factors." The findings in this paper was presented at the 4th World Symposium on Climate Change Adaptation (WSCCA-2021) in November 2021 and later published by Springer, as part of the book Climate Change Strategies: Handling the Challenges of Adapting to a Changing Climate.

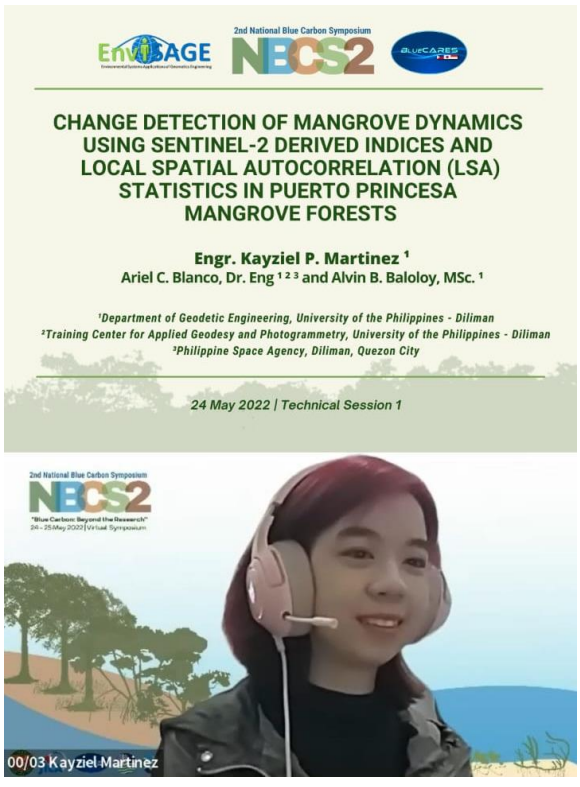

Figure 5. Research on mangrove change detection presented virtually at the 2nd National Blue Carbon Symposium by Engr. Martinez

3.3 Drone Delivery and Training

Drone-acquired orthophotos provide higher resolution data essential for visualizing, mapping, and analyzing blue carbon ecosystems. The Geomatics Team conducted extensive research to develop effective methodologies for integrating drones into blue carbon ecosystem mapping. Specifically, the team initiated data acquisition using drones at selected priority sites identified by the project. Subsequently, they developed and implemented specialized workflows tailored for drone-based mapping.

This effort included experimenting with flight altitudes to determine optimal resolutions for seagrass mapping, as seagrasses are challenging to capture in remote sensing due to their small size, emphasizing the importance of higher resolution data, as illustrated in Figure 6. Similarly, they identified optimal methods for generating Digital Elevation Models (DEMs) in mangrove-rich sites, depicted in Figure 7.

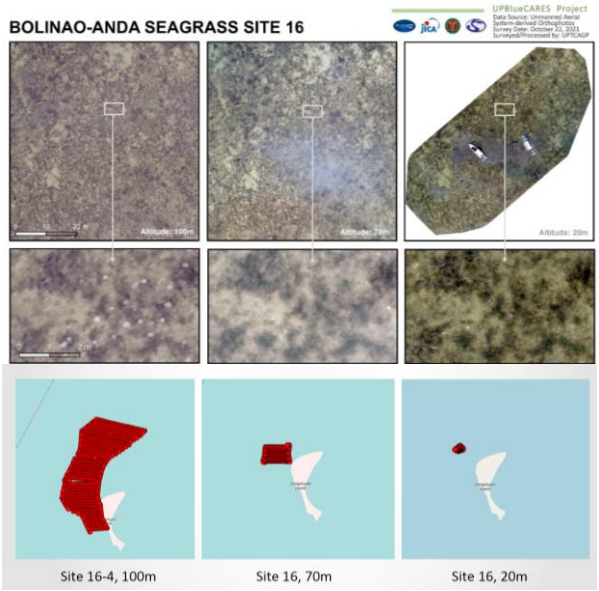

Figure 6. Orthophotos and DEM generated from drone imagery in Samar site made by Geomatics Team

Figure 7. Orthophotos and DEM generated from drone imagery in Samar site made by Geomatics Team

After completing exploratory mapping exercises, the Geomatics Team undertook training sessions for BCNet members in drone operation and data processing using the optimal techniques identified. The methodologies and training materials developed by the team are designed for scalability and replication in other regions. While the training modules were standardized, the trainers ensured flexibility by customizing the program’s content to suit diverse environmental conditions at different site locations.

These sessions have empowered BCNet members and other stakeholders with essential skills to independently utilize drone technology, crucial for the sustainable monitoring of blue carbon ecosystems and pivotal for the long-term success of conservation efforts. Figure 8 illustrates (left) hands-on drone training for University of the Philippines Visayas (UPV) Miag-ao members and (right) post-processing training of processed drone images for Aklan State University (ASU) members

Figure 8. (Left) Drone operations training for UPV Miag-ao members; (Right) Post-processing training of the process drone images for ASU members

3.4 Stakeholders Involvement and Significance of ODK

The stakeholders' summit serves as a pivotal platform for uniting various stakeholders to discuss research outcomes, the roles of communities, and stakeholders in the blue carbon (BC) strategy, with the aim of actively engaging them in the conservation process. Figure 9 illustrates the discussion session of the summit, where individuals from different sectors voiced their insights and concerns. The summits in Aklan and Eastern Samar successfully convened diverse sectoral representatives, as seen in Figure 10, which shows the participants of the Eastern Samar Summit.

During the summit, the implementation of the Open Data Kit (ODK) was introduced as a citizen science validation tool that can be easily taught and used by locals. Both summit participants were receptive to this idea and engaged enthusiastically in the hands-on training sessions. The implementation of ODK not only enhances the monitoring and assessment of blue carbon ecosystems but also empowers communities to actively contribute to conservation efforts.

Figure 9. Discussion session at the stakeholders' summit, where participants from various sectors shared their insights and concerns regarding the blue carbon (BC) strategy
(Photo Source: JICA Philippines)

Figure 10. Participants of the Eastern Samar Summit representing diverse sectors (Photo Source: JICA Philippines)

4. Conclusion

This paper highlights the extensive capacity-building efforts undertaken by the BlueCARES Philippines Geomatics Team to enhance sustainable blue carbon management and ensure the country's resilience of blue carbon ecosystems (BCEs). The team has effectively engaged various stakeholders through various avenues by leveraging advanced remote sensing and geospatial technologies.

The Geomatics Team has conducted a series of lectures and workshops and actively participated in national and international conferences. These engagements have facilitated the dissemination of knowledge and expertise on remote sensing and geospatial technologies, thereby enhancing the capabilities of a diverse audience and cultivating a collaborative environment conducive to advancing blue carbon research

Furthermore, through the distribution of drones and comprehensive training for BCNet members, the team has equipped stakeholders with the necessary skills to independently deploy drone technology, thereby enhancing the efficiency and accuracy of BCE monitoring efforts.

Lastly, by organizing and participating in summits and introducing the Open Data Kit (ODK), the Geomatics Team has facilitated meaningful community involvement in the monitoring and assessment of BCEs. This inclusive approach fosters a shared responsibility and commitment to conservation efforts among local stakeholders.

Through these multifaceted engagements, the Geomatics Team has not only built the capacity of various stakeholders but also promoted sustainable practices and long-term resilience for blue carbon ecosystems. Their efforts underscore the critical role of technology and community involvement in advancing environmental conservation and management; paving the way for a sustainable future where blue carbon ecosystems thrive under the stewardship of informed and empowered communities.

References

Baloloy, A. B., Blanco, A. C., Sta. Ana, R. R. C., & Nadaoka, K. (2020). Development and application of a new mangrove vegetation index (MVI) for rapid and accurate mangrove mapping. ISPRS Journal of Photogrammetry and Remote Sensing, 166, 95-117. https://doi.org/10.1016/j.isprsjprs.2020.06.001.

Beaumont, N., Jones, L., Garbutt, A., Hansom, J., & Toberman, M. (2014). The value of carbon sequestration and storage in coastal habitats. Estuarine, Coastal and Shelf Science, 137, 32–40.

Corcino, R. C., Gerona, M. E., Samoza, S., Fraga, J. K., & Salmo, S. (2023). Status, limitations, and challenges of blue carbon studies in the Philippines: A bibliographic analysis. Regional Studies in Marine Science, 62, 102916. https://doi.org/10.1016/j.rsma.2023.102916.

Crooks, S., von Unger, M., Schile, L., Allen, C., & Whisnant, R. (2017). Understanding strategic blue carbon opportunities in the seas of East Asia. Report by Silvestrum Climate Associates for Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), Conservation International and The Nature Conservancy, with support from the Global Environment Facility and United Nations Development Program; Partnerships in Environmental Management for the Seas of East Asia (PEMSEA): Quezon City, Philippines.

Japan International Cooperation Agency (JICA). (2022, July 4). Japanese and Filipino scientists see ocean of opportunity to fight climate change via coastal resource conservation. Retrieved from https://www.jica.go.jp/Resource/philippine/english/office/topics/news/220704.html

Japan International Cooperation Agency (JICA). (2023, April 4). Philippines, Indonesia and Japan lead efforts in blue carbon conservation to address climate change. Retrieved from https://www.jica.go.jp/Resource/philippine/english/office/topics/news/230404.html

Quevedo, J. M. D., Uchiyama, Y., Muhmad Lukman, K., Kohsaka, R. (2021). How blue carbon ecosystems are perceived by local communities in the Coral Triangle: Comparative and empirical examinations in the Philippines and Indonesia. Sustainability, 13(1), 127. https://dx.doi.org/10.3390/su13010127

Quiros TEAL, Sudo K, Ramilo RV, Garay HG, Soniega MPG, Baloloy A, Blanco A, Tamondong A, Nadaoka K and Nakaoka M (2021). Blue carbon ecosystem services through a vulnerability lens: Opportunities to reduce social vulnerability in fishing communities. Frontiers in Marine Science, 8, 671753. doi: 10.3389/fmars.2021.671753

The BlueCARES Project. Retrieved from https://www.bluecaresproject.upd.edu.ph/about-us