CANARI

Government of the Republic of Trinidad and Tobago

MINISTRY OF AGRICULTURE, LAND AND FISHERIES

TOBAGO HOUSE OF ASSEMBLY

Tech4CoastalResilience Project

Participatory Drone Mapping for Environmental Monitoring

FINAL REPORT

Trinidad & Tobago
December 2024

MARINE SPATIAL INFORMATION SOLUTIONS

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ACKNOWLEDGEMENTS

Special thanks are extended to the Caribbean Natural Resources Institute (CANARI) as well as the Fisheries Division, Ministry of Agriculture Land and Fisheries, Trinidad and the Department of Maine Resources and Fisheries, Tobago House of Assembly in organizing this training initiative. It has enabled participating national agencies and community-based organisations across Trinidad and Tobago to explore the use of drone mapping technologies for monitoring and participatory management to improve the resilience of coastal communities against climate change.

The "Integrating Digital Technologies and Participatory Tools to Support Coastal Community in Trinidad and Tobago (Tech4CoastalResilience)" Project is supported through the Harnessing Innovative Technologies to Support Resilient Settlements on the Coastal Zones of the Caribbean (HIT RESET Caribbean) programme. It is funded by the ACP Innovation Fund - Research and Innovation Programme, which is implemented by the Organization of African, Caribbean, and Pacific States (OACPS) with financial contributions from the European Union (EU).

CITATION

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TECH4COASTALRESILIENCE PROJECT IN TRINIDAD AND TOBAGO

PROJECT OVERVIEW

The "Integrating Digital Technologies and Participatory Tools to Support Coastal Community Resilience in Trinidad and Tobago (Tech4CoastalResilience)" project, led by the Caribbean Natural Resources Institute (CANARI), was implemented in collaboration with the Fisheries Division, Ministry of Agriculture, Land and Fisheries and the Department of Marine Resources and Fisheries, Tobago House of Assembly. Supported by the "Harnessing Innovative Technologies to Support Resilient Settlements on the Coastal Zones of the Caribbean (HIT RESET Caribbean)" program and funded by the ACP Innovation Fund, OACPS Research and Innovation Programme, and the European Union (EU), this project aimed to build the resilience of vulnerable coastal communities in Trinidad and Tobago (T&T) against climate change impacts.

Central to the Tech4CoastalResilience Project was a comprehensive drone training programme designed and delivered by Dr. Kim Baldwin. This training aimed to build the capacity of community-based organizations (CBOs), environmental non-governmental organisations (NGOs), and coastal management agencies to apply drone technology and participatory mapping for environmental monitoring, data collection, and informed decision-making in coastal resilience efforts. Participants included representatives from vulnerable coastal communities in T&T and key government agencies, enhancing their abilities to integrate both local and scientific knowledge for resilient coastal management (Figure 1).

DRONE TRAINING PROGRAMME STRUCTURE

A blended training approach was adopted, combining virtual sessions, in-person workshops, and continuous technical support to ensure long-term capacity building. This training was structured as a cohort-based programme, with 16 participants split between Trinidad and Tobago, forming five drone teams across the two islands. Over five months, the program progressively built participants' skills in drone safety, Participatory Uncrewed Aerial Systems (P-UAS) mapping techniques, and environmental monitoring strategies through field exercises and digital mapping tasks. Participants applied their training in real-world scenarios at 10 selected coastal sites, utilizing a customized curriculum to develop and execute monitoring plans aligned with the Tech4CoastalResilience Project's objectives.

Each trainee was therefore equipped with hands-on experience in drone flight, ecosystem-based mapping, and monitoring using five procured Uncrewed Aerial Systems (UAS) kits and DroneDeploy mapping software, setting a new standard in environmental management in T&T. First, participants underwent a 5-day practical "Drone Mapping and Environmental Monitoring" bootcamp and then completed an additional 3-month virtual training course through the **Dr. Kim Baldwin Training Academy.**

TRAINING OBJECTIVES

The drone training programme sought to strengthen environmental monitoring capabilities among national agencies and local community groups in T&T through the P-UAS approach (Baldwin et al. 2021). These included: Equipping participants with practical drone and geospatial analysis skills for coastal ecosystem management; and empowering trainees to develop tailored P-UAS coastal marine mapping and site monitoring strategies to support coastal community resilience initiatives in T&T.

In alignment with the Tech4CoastalResilience Drone Mapping & Environmental Monitoring Training Objectives, the following key deliverables have been provided to the CANARI over the course of this Project (June-October 2024). Key Project deliverable milestones were achieved throughout the P-UAS Training Programme (Table 1).

Figure 1. Overview of the Tech4CoastalResilience in Trinidad and Tobago Project.

CANARI

MINISTRY OF AGRICULTURE, LAND AND FISHERIES

Integrating Digital Technologies and Participatory Tools to Support Coastal Community Resilience in Trinidad & Tobago

The Caribbean Natural Resources Institute (CANARI), Fisheries Division – Ministry of Agriculture, Land and Fisheries and Department of Marine Resources and Fisheries, Tobago House of Assembly are implementing this 2-year project from 2023-2024 to enable inclusive and evidence-based decision-making to build the resilience of vulnerable coastal communities in Trinidad and Tobago.

Objectives

1. Innovative digital technologies and participatory tools refined/developed in collaboration with key agencies to support inclusive and evidence-based planning and decision-making for coastal community resilience

2. Increased use of innovative digital technologies and participatory tools by key agencies and community stakeholders to support prediction, planning and management for coastal community resilience

Target Stakeholders

National fisheries authorities

Other **coastal management agencies** and government entities working on climate change, coastal zone planning and management and local area planning in Trinidad and Tobago

10 TARGET COASTAL COMMUNITIES

Trinidad
- Blanchisseuse
- Matelot
- Carli Bay
- Mayaro
- Moruga
- Icacos

Tobago
- Castara
- Scarborough
- Roxborough
- Speyside

Project Approach

employing digital technologies (e.g., GIS, video and drone technology) using participatory approaches to improve capture of local knowledge

helping to resource and build the capacity of key management agencies for uptake of digital technologies and participatory tools and integration of the local knowledge generated from these.

Key Results

At least **3 suitable digital technologies** and **2 participatory tools** identified for prediction and coastal planning and management

At least **4 coastal management agencies** and **10 community groups** engaged in piloting and demonstrate enhanced knowledge and skills in use of digital technologies and participatory tools

This project is funded through the ACP Innovation Fund, OACPS Research and Innovation Programme. This programme is implemented by the Organization of African, Caribbean and Pacific States (OACPS), with the financial contribution of the European Union (EU).

For more info, visit https://canari.org/technologies-4-resilience-tt/

Table 1. Project Outputs and timetable for the Tech4CoastalResilience Drone Training Component.

Deliverables	Due Date	Project Outputs
Tech4CoastalResilience Training Project Workplan	May 31, 2024	Inception Report (Workplan)
D1a: A 5-day in-person bootcamp training workshop in Tobago on coastal monitoring using drones with a total of 8 persons from partner agencies, CSOs and local communities conducted	June 30, 2024	Course Evaluations and Certificates
D1b: A 5-day in-person bootcamp training workshop in Trinidad on coastal monitoring using drones with a total of 8 persons from partner agencies, CSOs and local communities conducted	July 31, 2024	Report (Training)
D2: Report of in-country Bootcamp in-person training workshops on coastal monitoring using drones		Specifications List; Delivery of Equipment and Software
D3: A nine-week virtual training workshop on participatory mapping and unmanned aerial systems conducted for 16 persons from partner agencies, CSOs and local communities in Trinidad and Tobago	September 30, 2024	PUAS Mapping & Environmental Monitoring Virtual Course Delivery and Tech Support for Teams
D5: Technical support provided for drone monitoring in up to 10 target coastal communities in Trinidad and Tobago	October 31, 2024	UAS Mapping and Monitoring Strategy
D4 & D6: Final Project Report of virtual training workshop and baseline site results on Participatory UAS mapping conducted in each community in Year 2	November 15, 2024	Final Report & Presentations of UAS Mapping and Monitoring Plans by Trinidad and Tobago Drone Teams

Drone Mapping & Monitoring Training Inception

The Tech4CoastalResilience Drone Training Kick-Off Meeting on 22 June 2024 provided an introductory overview of the upcoming drone training programme designed to support coastal resilience efforts in T&T. The virtual session included drone training participants from various governmental and community-based stakeholders. The discussion emphasized the objectives to empower community-based organisations and enhance the capacity of local and national agencies to use drone and digital technologies for coastal resilience. Participants were introduced to operating DJI drones, ecosystem mapping, vulnerability assessments, and integrating data into national databases. Additionally, compliance with aviation regulations, maintaining at least 80% attendance, and completing assignments for successful certification was discussed. Practical instructions for blended course delivery, including upcoming bootcamp sessions, as well as a review of usage of online support tools like the Dr. Kim Baldwin training academy and learning resources were also provided. This kick-off meeting underscored the project's goal of establishing drone monitoring sites to create mapping and geospatial data, reinforcing the role of local engagement for effective coastal planning and management decisions. A recording can be found at: **Tech4CoastalResilience Inception Meeting**

Identified UAS Applications for Environmental Management

Based on responses from a Tech4CoastalResilience Drone Training Pre-Assessment Survey and feedback given at the Drone Training Kick-Off Meeting, the participants expressed five specific needs in environmental mapping and applications that were used to develop the objectives for the Tech4CoastalResilience Drone Flying and Environmental Mapping and Monitoring training course. These included:

- Climate Vulnerability & Disaster Management – assessment of impacts & coastal communities' vulnerability
- Mapping Critical Coastal Marine Habitats – quantifying biodiversity and management of coastal ecosystems
- Wildlife Monitoring and Tracking – coastal marine species, including birds, sea turtles, whales and sharks

- Marine Spatial Planning – space-use mapping for understanding ecosystem dynamics and development
- Sargassum, Fisheries Monitoring & Management – improving sustainable fisheries and coastal livelihoods

Drone Training Participants

The final Trinidad and Tobago Drone Team Members included participants from six government agencies (47%) and seven NGOs (53%) across T&T, resulting in a total of 16 enrolled drone pilots. Participants comprised of 8 (50%) women and 8 (50%) men (Table 2).

The Pre-Training Knowledge and Skills Assessment provided a baseline for evaluating the 16 trainees' drone-related proficiency. Most participants had either little or no previous drone flying experience (93%), with one person reporting advanced proficiency in conducting drone mapping surveys. Three of the agencies already owned mapping drones (i.e. IMA, ODPM, TEMA), while the other agencies/organisations did not. All trainees unanimously expressed willingness to contribute to the Tech4CoastalResilience Project and required coursework, offering to develop drone mapping strategies that could be applied nationally and help manage logistics, coordination, and data collection.

Table 2. List of drone training participants categorized by island, name, agency, position, and email address.

Island	Name	Agency	Position	Email
Trinidad	Marc Bejai	Fisheries Division	Fisheries Officer	mbejai@gmail.com
	Recardo Mieux	Fisheries Division	Senior Fisheries Officer	rmieux@gov.tt
	Rayna Sookdeo	Institute of Marine Affairs (IMA)	Geomatics Technician	rsookdeo@ima.gov.tt
	Ryan Mannette	SpeSeas	GIS Specialist	ryan@speseas.org
	Curmira Gulston	Office of Disaster Preparedness and Management (ODPM)	Hazard Mitigation Specialist	cgulston@mns.gov.tt
	Evana Douglas	Future Fishers	Technical Coordinator	evana@futurefishers.org
	Aaron Peter	Caribbean Natural Resources Institute (CANARI)	Junior Technical Officer	aaron@canari.org
	Candice Ramkissoon	Caribbean Natural Resources Institute (CANARI)	Senior Technical Officer	candice@canari.org
Tobago	Jenise Kirk	Department of Marine Resources and Fisheries, THA	Fisheries Officer	fso.dmrf@gmail.com
	Esther Tobias	Department of Marine Resources and Fisheries, THA	Marine Parks Officer	marinepark08@gmail.com
	Howard Robin	Coastal Zone Management Unit (CZMU), THA	Head, CZMU	hwrdrobin@gmail.com
	Dayreon Mitchell	Tobago Emergency Management Agency (TEMA)	GIS Officer	gis.tema365@gmail.com
	Shanice Mark	Environmental Research Institute, Charlotteville (ERIC)	Marine Ecologist	ericecologist@eric-tobago.org
	Mark Hamilton	Environment Tobago	Member	marc.a.hamilton@gmail.com
	Kerry Walcott	Roxborough Police Youth Club	President/Member, Turtle Village Trust	thomassilverd64@gmail.com
	Allison Thomas	Tobago United Fisherfolk Association (TUFA)	Secretary	tufafisherfolkassociation@gmail.com

Drone Flying and Mapping Training Bootcamp

Two 5-day in-person drone training bootcamps were conducted to provide tailored training and focused skill development for two distinct cohorts within T&T. The comprehensive Drone Flying and Mapping Bootcamp, held in Trinidad and Tobago (Appendix I), covered essential topics such as drone policy, UAS licensing and national regulations, commercial operating procedures, UAS components, safety and emergency protocols,

site feasibility assessments, weather considerations, flight planning, standard operating procedures, and data management protocols.

The initial cohort of eight participants convened from June 24 to 28 in Tobago, followed by a second cohort of eight participants from July 8 to 12 in Trinidad. Aligned with the Tech4CoastalResilience Project's goal of utilising drone mapping and geospatial technologies to enhance coastal and marine ecosystem monitoring, trainees were guided to plan and execute large-scale ecosystem mapping flight surveys at designated demonstration sites.

The drone mapping and monitoring site surveys involved post-processing aerial data, developing mapping products, and creating multimedia content. Participants were introduced to web-mapping analysis tools, especially DroneDeploy, which facilitated the preparation of monitoring site reports and seamless data sharing across diverse audiences.

To enhance communication and support throughout the training programme, a dedicated Slack channel for Tech4CoastalResilience was established. This platform serves as a centralized hub for participants to engage in discussions, share valuable learning materials, and seek assistance, fostering a collaborative and supportive learning environment. All collected drone and geospatial data and course materials—including the training agenda, presentation slides, handouts, and additional resources—are accessible electronically via www.drkimbaldwin.com, ensuring trainees have easy access to essential references for ongoing learning (Figure 2).

Summary of In-Person Drone Mapping Boot Camp Accomplishments

During the course's in-person boot camp, participants successfully conducted comprehensive drone mapping across two sites in Trinidad and Tobago, resulting in detailed geospatial products and significant environmental insights. These initiatives provided valuable data for environmental monitoring, disaster preparedness, and habitat assessments, aligning with the course's goal of training participants in practical drone applications. For more detailed results, refer to the previous Tech4Resilience midterm training report (Baldwin, 2024).

The selected Tech4CoastalResilience PUAS mapping sites for the bootcamps included Little Rocky Bay and Scarborough Waterfront in Tobago, as well as Carli Bay in Trinidad (Figure 3).

Carli Bay (Trinidad)

- 14 flight surveys, including 8 mapping surveys and 3 panoramic captures.
- Complete ecosystem map created, covering 119 hectares with high-resolution imagery (443 images).
- Mapping applications: mangrove health, fisheries infrastructure, coastal erosion, and habitat monitoring.

Little Rockly Bay (Tobago)

- 12 flight surveys with 10 mapping surveys and 1 panoramic capture.
- Complete ecosystem map spanning 155 hectares capturing over 900 images.
- Applications: habitat mapping, sargassum assessment, coastal erosion, and pollution monitoring.

Scarborough Waterfront (Tobago)

- 10 flight surveys with 5 distinct mapping plans, covering 11.3 hectares with 102 high-resolution images.
- Focus on coastal vulnerability, pollution, and infrastructure management.

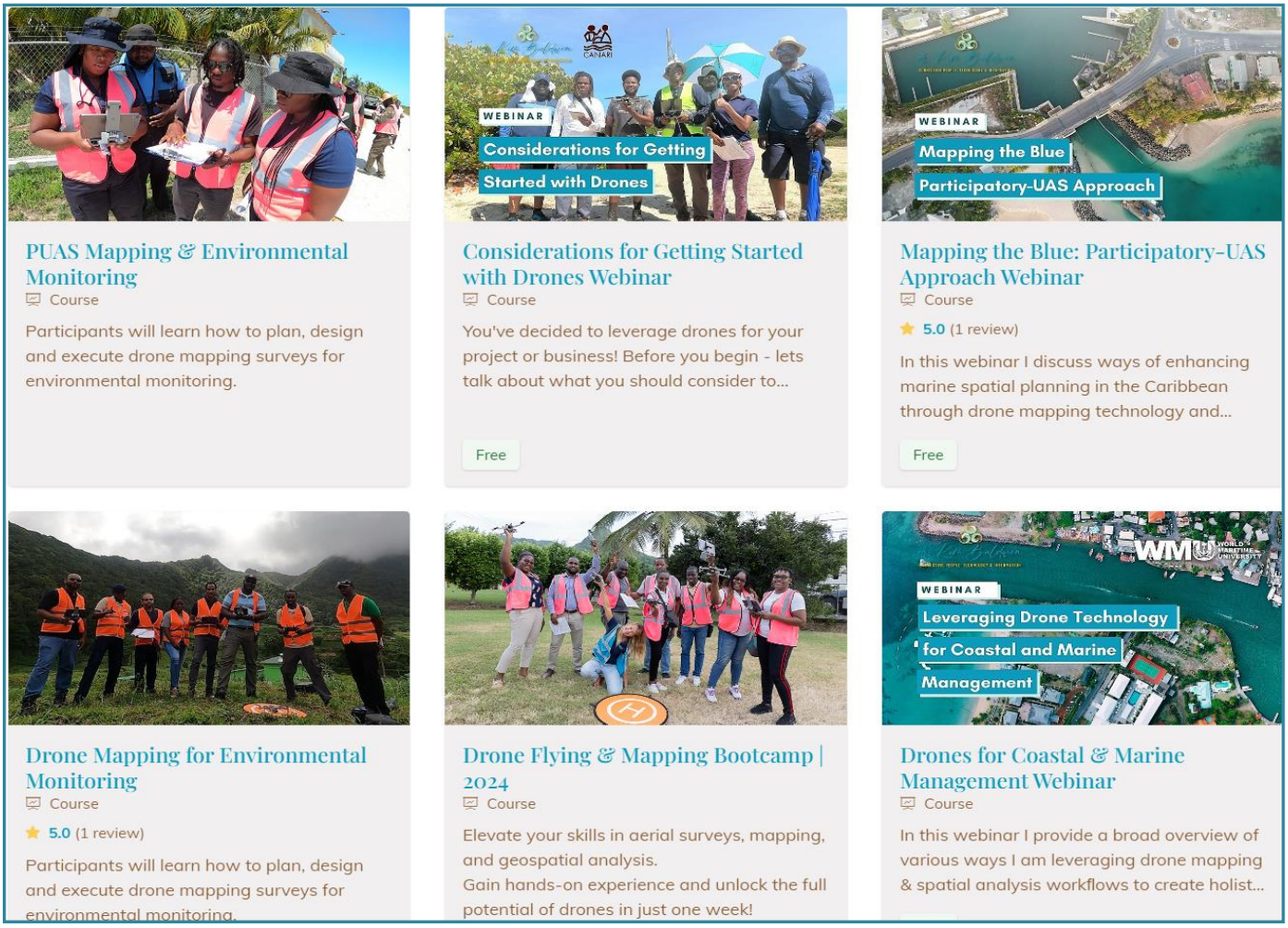

Figure 2. Courses available as part of the Tech4Resilience Training Bundle via Dr. Kim Baldwin Training Academy

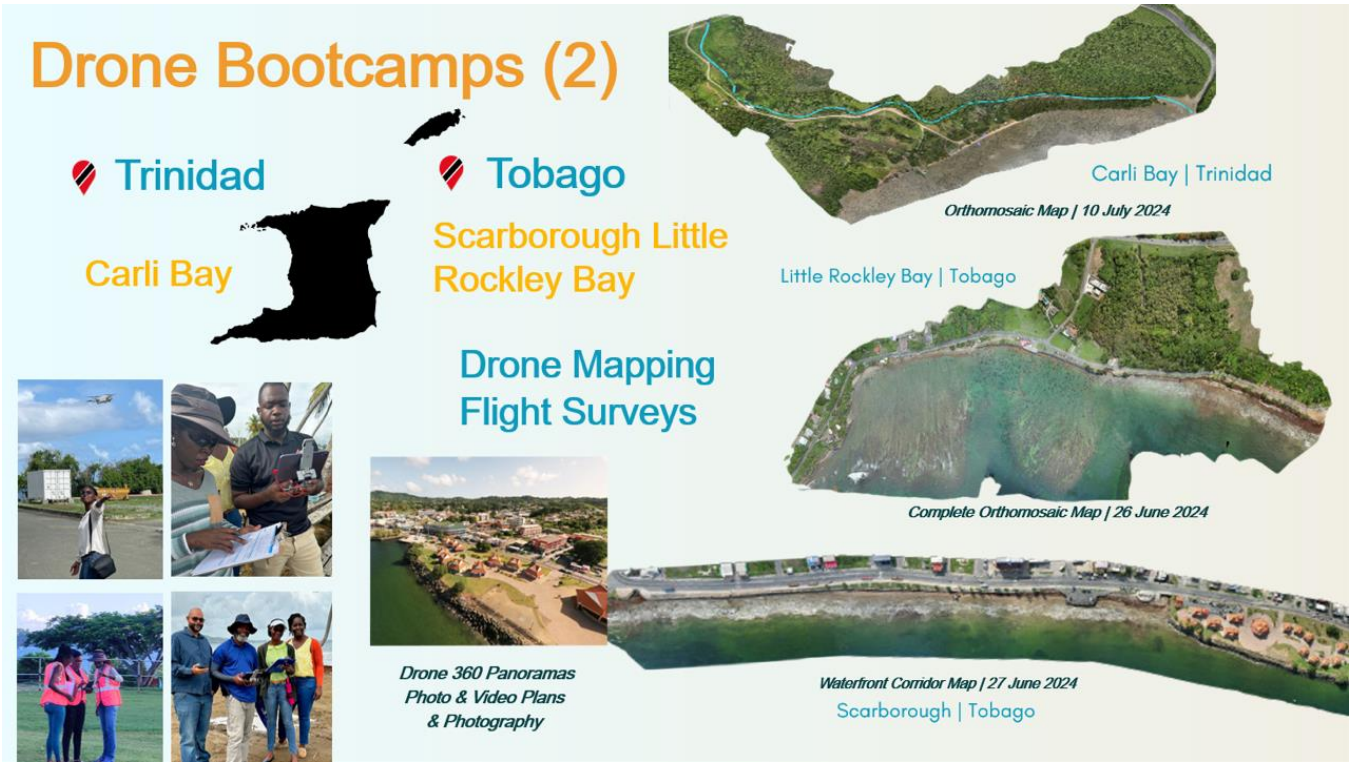

Figure 3. Samples of the drone mapping results from the bootcamp, along with photos of participants during the session.

P-UAS Mapping and Evironmental Monitoring Course

Following the in-person drone bootcamps, a comprehensive **P-UAS Mapping and Monitoring Course** was delivered to enhance participants' skills in drone technology for environmental management. The course consisted of **56 lessons** and **10 hours of video content**, covering essential topics related to drone operations and applications (Figure 4). Five live training webinars were also conducted to facilitate interaction and discussion via Zoom. Participants engaged in several 'DroneWork' assignments designed to develop their mapping skills, alongside quizzes for each module to reinforce their understanding (see Appendix II for the Course Outline).

Moreover, a tailored *Drone Mapping and Monitoring Guidebook* was produced to support teams during virtual component of the project, serving as a valuable course resource. Additional materials, such as links to relevant videos and files, were provided to further enhance participants' knowledge and skills, supporting them in applying their learning effectively in real-world scenarios.

The primary goal of the course was to empower participants to master drone technology for aerial surveys, precise mapping, and geospatial analysis, thereby enhancing their environmental management workflows. Designed for beginners to intermediate drone flyers, the course equipped participants with the skills needed for safe commercial drone operation and experience in conducting automated mapping surveys.

Key highlights included:

- **Professional Survey Techniques:** Knowledge and skills to conduct aerial flight surveys professionally.
- **Accurate Geospatial Data Capture:** Mastery in capturing precise geospatial data for effective environmental monitoring.
- **Ecosystem-Based Environmental Insights:** Generation of ecosystem-based information to support decision-making and collaborative management.
- **Effective Communication of Information:** Presentation of unique pilot projects to demonstrate drone skills and enhance communication of findings.

The course distinguished itself through its structured, hands-on teaching approach, combining comprehensive online learning materials with weekly practical exercises. Each week, participants were presented with foundational theory and informational resources, such as video demonstrations, course worksheets, and curated YouTube playlists. They were then guided through step-by-step practical assignments, starting from scoping and site assessments to developing detailed flight plans, conducting missions, analyzing results, and ultimately communicating their findings in a final webinar.

This progressive structure ensured that participants gained confidence and competence in completing every critical phase of a drone mapping mission. By systematically building on each week's learning outcomes, participants were not only able to grasp theoretical concepts but also apply them in real-world scenarios under expert guidance, developing best practices for safe and efficient drone operations.

Recognizing the importance of data management and geospatial analysis, the course emphasized essential skills for handling, storing, and processing drone-acquired data using platforms like DroneDeploy. Participants learned how to create a variety of geospatial data products, including:

- **Orthomosaics:** High-resolution aerial images stitched together to form a detailed and accurate map of a specific area. These maps are essential for environmental planning and monitoring.
- **Elevation Point Clouds:** 3D representations of the terrain, capturing the height and features of land. These models help in understanding the landscape, identifying areas at risk of flooding, or planning construction projects.

- **Digital Surface Models:** A map of the Earth's surface that includes objects such as buildings and trees, providing critical insights for habitat analysis or urban planning.
- **Annotations for GIS:** Participants used DroneDeploy's analysis dashboard to create detailed annotations that could be exported as JSON shapefiles for GIS platforms or as KMZ files for visualisation in Google Earth or web-based mapping tools. These outputs provided versatile options for sharing data and integrating it into existing workflows.

These outputs are highly relevant for environmental monitoring and decision-making, enabling participants to generate actionable insights and reports that can inform better resource management.

By bridging theoretical knowledge and hands-on application, the **Participatory UAS Mapping and Monitoring Course** successfully equipped participants with the tools needed to utilize drone technology for environmental monitoring and management within their respective fields. The step-wise design not only established a strong foundation but also ensured that participants could make meaningful contributions to their organizations through actionable insights and enhanced workflows.

Figure 4. Summary of the Course Curriculum for the P-UAS Mapping and Monitoring Course.

RESULTS | P-UAS MAPPING & MONITORING SITES

The following sections provide a summary the T&T training cohort's ten PUAS demonstration monitoring sites, outlining the mapping parameters, corresponding results, preliminary analysis and monitoring recommendations. These sites included all 10 of the communities that are part of the Tech4CoastalResilience project. The review highlights the potential P-UAS applications, drone mapping methodologies employed, demonstrating the skills acquired by the Tech4CoastalResilience T&T drone teams during the final phase of this P-UAS training programme. See each of the P-UAS Site Monitoring final presentation slides (Appendix III). The recorded presentation is available for viewing at: **Tech 4 Coastal Resilience Project Final Presentation | CANARI**. Timestamps are added within the recording for easy navigation directly to each of the following P-UAS site presentation for quick access.

BLANCHISSEUSE | TRINIDAD

Blanchisseuse is a coastal village with a mix of natural habitats—beaches, rocky coastlines, and forested areas—as well as urban developments including villas and resorts. The area is vulnerable to coastal erosion and extreme weather, making it essential to monitor both natural and built environments. Key applications of this mapping effort include coastline monitoring, vulnerability assessments, hazard identification, and spatial planning, particularly to protect sea turtle nesting areas.

The P-UAS mapping project at Blanchisseuse, Trinidad, comprised four drone flights over 63 minutes using a DJI Air2S, capturing 437 images across 923 acres. Flown at 120 meters above ground level (AGL), this project produced an orthomosaic map at a resolution of 3.4 centimeters per pixel and an elevation resolution of 13.6 centimeters per pixel, with an RMSE accuracy of +/- 2 meters. A 360-degree panorama of the river mouth and nine fixed photo plans were completed to assess potential impacts of coastal development on sea turtle nesting sites. A total of 27 measurement annotations were created to document key observations at the site.

Recommendations for future site monitoring include quarterly UAS flights to capture seasonal changes and identify any emerging threats. A participatory UAS mapping approach with local stakeholders is advised to enhance data accuracy and encourage community involvement. Extending the photo coverage across the entire beach, establishing high-accuracy ground reference points, and conducting annual PGIS exercises are recommended to improve positional accuracy and expand understanding of this critical coastal area.

Table 3. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Blanchisseuse Village.

UAV (Model & Payload)	DJI Air2S
Altitude (AGL)	120 meters
Images Captured	437
Orthomosaic Map	**Blanchisseuse Complete Map TA (120 m) | 1 October 2024 A2S**
Total Mapped Area	923 hectares
Orthomosaic Resolution	3.4 centimeters per pixel
Elevation Resolution (DEM)	13.6 centimeters per pixel
Accuracy (RMSE)	2 meters RMSE
Mapping Applications	Coastline monitoring, vulnerability assessments, hazard identification, spatial planning
360 Site Panoramas	**River Mouth Pano (60 m) | 1 October 2024 A2S**
Fixed Photo and Video Plans	**Nesting Beach Photo Plan | 20 m (5 m) | A2S**

Figure 5. Orthomosaic of Blanchisseuse monitoring site map flown at 120m AGL.

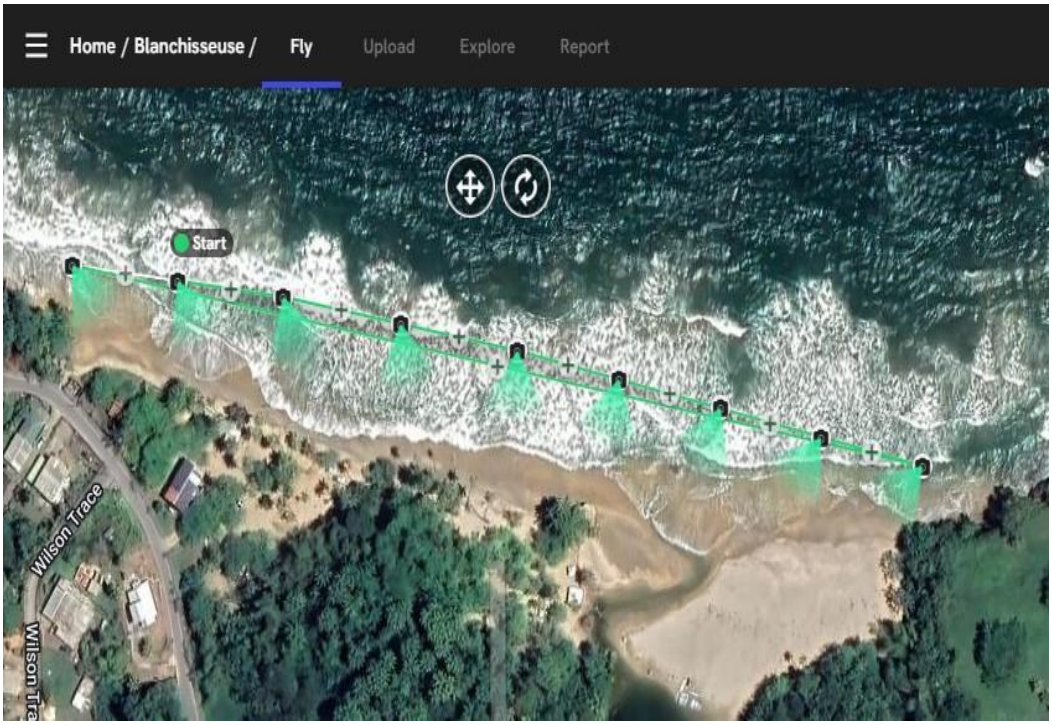

Figure 6. Nesting Beach fixed photo plan flown at 20 meters AGL

MORUGA | TRINIDAD

Three drone flights over 46 minutes at 120 meters AGL were conducted with a DJI Air2S, mapping 115 hectares of the Moruga coastline in Trinidad. The survey captured 420 images and created a high-resolution orthomosaic map (3.5 cm/pixel) and elevation model (1.4 cm/pixel), along with a 360-degree panorama and a fixed photo plan. The mapping focused on essential infrastructure and natural features, including fisheries, shoreline protection, mangroves, community areas, and monitoring of sargassum influxes.

A total of 23 annotations documented erosion, protection structures, mooring areas, and fishing vessels. Quarterly mapping to monitor erosion and mangrove health, especially at varying tides, is advised. Additional data collection, such as monthly sargassum tracking, corridor mapping along Grand Chemin River, and vessel census activities, is recommended to enhance coastal management and support sustainable use of the coastline.

Table 4. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Moruga Coastline.

UAV (Model & Payload)	DJI Air2S
Altitude (AGL)	120 meters
Images Captured	420
Orthomosaic Map	**Moruga Coastline Complete Map TA (120 m) | A2S**
Total Mapped Area	115 hectares
Orthomosaic Resolution	3.5 centimeters per pixel
Elevation Resolution (DEM)	1.4 centimeters per pixel
Accuracy (RMSE)	2.5 meters RMSE
Mapping Applications	Fisheries infrastructure, shoreline protection infrastructure, moored commercial fishing vessels, recreational and mangrove areas, community infrastructure, sargassum influxes
360 Site Panoramas	**Beach Pano (30 m) | A2S**
Fixed Photo and Video Plans	**Shoreline Photo Plan 20 m | (A2S)**

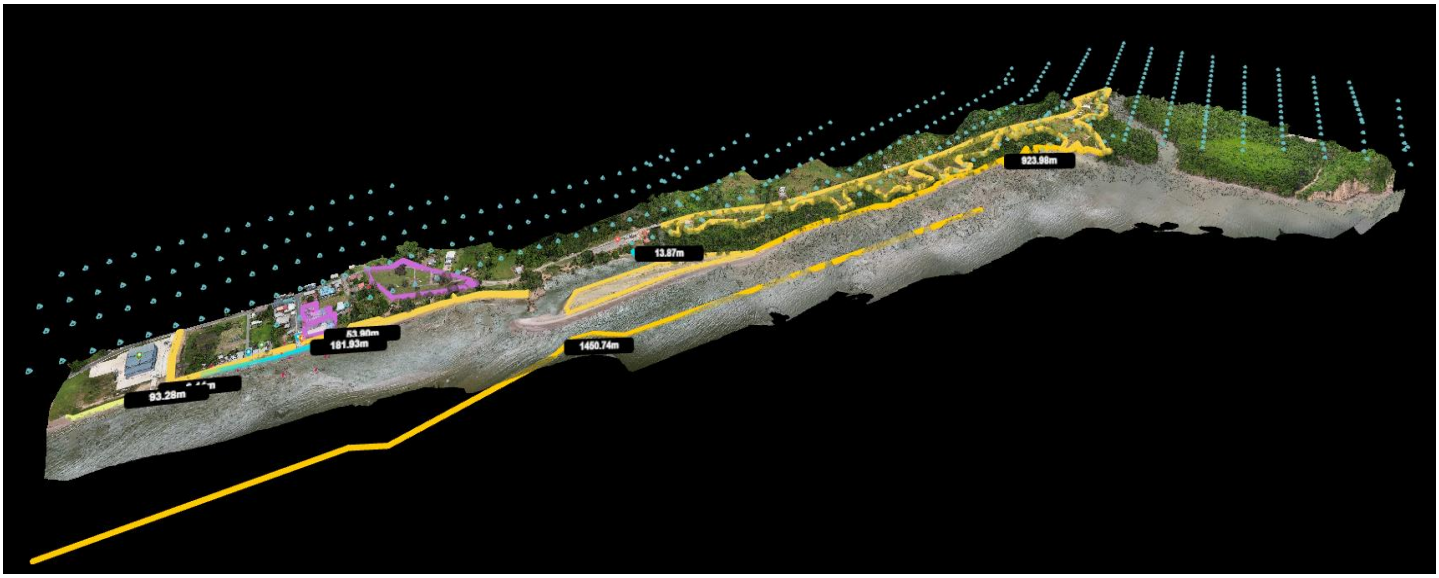

Figure 7. Orthomosaic of the Moruga coastline complete map, featuring annotation measurements and a total of 420 ensembled images.

MATELOT | TRINIDAD

Matelot is a remote village adjacent to the 9,000-hectare Matura Forest Reserve and Environmentally Sensitive Area, where local livelihoods rely on fishing, farming, and ecotourism. The mapping focused on assessing infrastructure damage, vulnerability, land use, and coastline conditions. Key features identified include three schools, three emergency shelters, a fishing center, and various critical infrastructures.

Seven drone flights totaling 69 minutes were conducted at 120 meters AGL over Matelot Village, mapping an area of 130 acres. This effort yielded 500 images, two 360-degree panoramas, and an orthomosaic map with a resolution of 3.6 centimeters per pixel and an accuracy of +/- 3 meters RMSE. Sixteen significant issues were noted, including damage from hazardous seas, infrastructural issues, and erosion affecting accessibility.

Yearly monitoring is recommended to track changes and assess damage post-weather events, with active community engagement for updated data needs. Ground-truthing surveys should also be conducted to document inaccessible damages, and the ecosystem map should expand to include Grande Riviere. Additionally, 3D models of vulnerable areas can improve understanding of infrastructure stability and landscape changes.

Table 5. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Matelot Village.

UAV (Model & Payload)	DJI Air2S
Altitude (AGL)	120 meters
Images Captured	500
Orthomosaic Map	**Matelot Community Complete Map (120 m) | A2S) | 19 September 2024 A2S**
Total Mapped Area	130 hectares
Orthomosaic Resolution	3.6 centimeters per pixel
Elevation Resolution (DEM)	14.3 centimeters per pixel
Accuracy (RMSE)	3 meters RMSE
Mapping Applications	Infrastructure damage assessment, vulnerability and capacity assessment, land-use mapping, coastline monitoring
360 Site Panoramas	**Matelot Pano (110 m) | 19 September 2024 A2S** **Matelot Pano (30 m) | 19 September 2024 A2S**

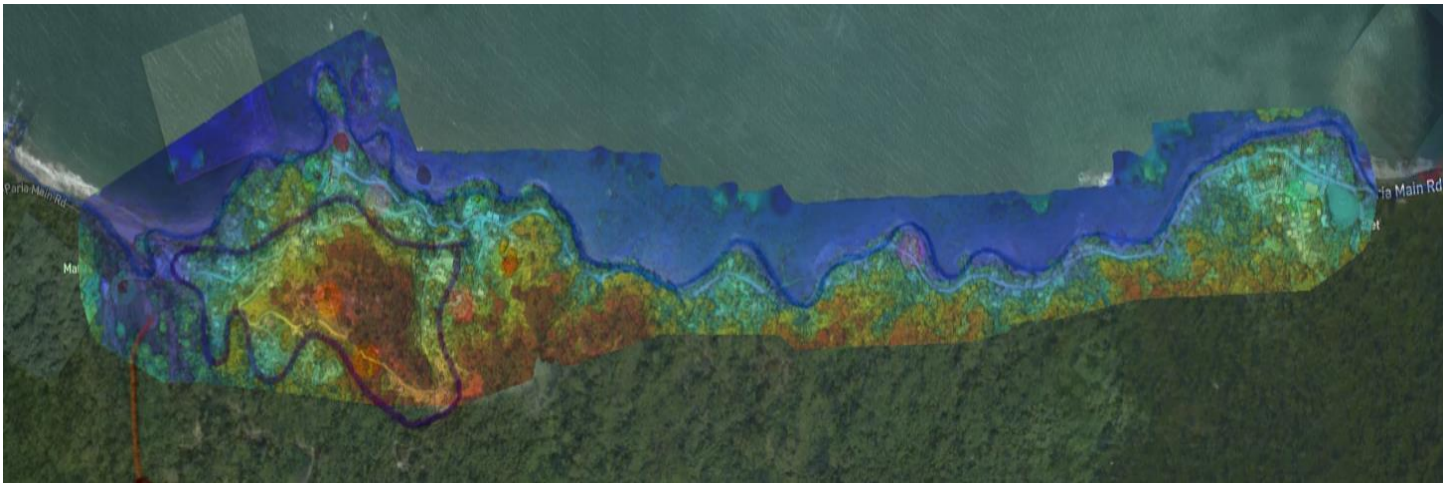

Figure 8. Digital Elevation Model and PGIS overlay produced for Matelot site map.

MAYARO / TRINIDAD

Key mapping applications at Mayaro are coastal mapping, hazard and vulnerability assessment, wetland and wildlife monitoring, and fisheries management, supporting sustainable community practices and resilience. Essential habitats include—rivers, beaches, mangroves, and sandbanks—sustain local fishing, agriculture, and recreation, with Mayaro's resources impacted by seasonal changes and coastal erosion.

A total of six drone flights (1 hour and 7 minutes) were conducted at 120 meters AGL using DJI Air2S to map 98 hectares of the Mayaro Community. The mapping produced an orthomosaic resolution of 3.6 cm/pixel and an accuracy of 1.9 meters RMSE, with 415 images captured. Deliverables included one 360-degree panorama, two photo plans, and two video plans, along with 15 annotation reports that identified key features and two main issues.

Seasonal monitoring, especially at low tides, is recommended to capture sandbank shifts and maintain safe river mouth access for fishers. Additional surveys along the river corridor and expanded PUAS mapping across the Mayaro-Manzanilla coastline and Nariva Swamp are also advised. Engaging fishers and farmers in participatory GIS (PGIS) could further enrich site-specific data for the Ortoire community.

Table 6. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Mayaro Community.

UAV (Model & Payload)	DJI Air2S
Altitude (AGL)	120 meters
Images Captured	415
Orthomosaic Map	**Mayaro Community Complete Map TA (120 m) | 20 September 2024 A2S**
Total Mapped Area	98 hectares
Orthomosaic Resolution	3.6 centimeters per pixel
Elevation Resolution (DEM)	14.5 centimeters per pixel
Accuracy (RMSE)	1.9 meters RMSE
Mapping Applications	Coastline monitoring, hazard and vulnerability monitoring, wetland and wildlife monitoring, fisheries monitoring and management
360 Site Panoramas	**Mayaro Community Pano (60 m) | 20 September 2024 A2S**
Fixed Photo and Video Plans	**Mayaro Community Photo Plan | 20 September 2024 A2S** **Mayaro Near Recreation Photo Plan | 20 September 2024 A2S** **Mayaro Vegetation Loss Video Plan | 20 September 2024 A2S** **Mayaro Ortoire Community Video Plan | 20 September 2024 A2S**

Figure 9. Orthomosaic of Mayaro Community monitoring site map flown at 120m AGL.

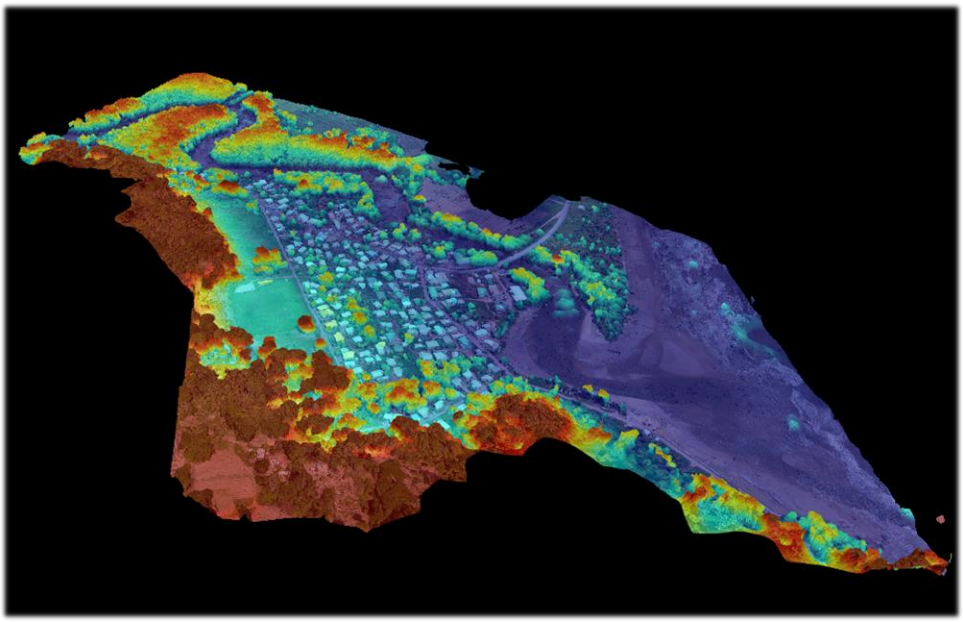

Figure 10. Digital Elevation Model produced for Mayaro Community monitoring site map.

ICACOS | TRINIDAD

The P-UAS mapping in Icacos aimed to support vulnerability assessments and adaptation planning for this coastal fishing community. Two UAV flights (22 minutes total) were conducted using a DJI Air2S at 120 meters AGL to create an orthomosaic map of Icacos' west coastline, covering 94 hectares with a resolution of 3.2 cm/pixel and an RMSE accuracy of 1.5 meters. Mapping focused on critical assets and vulnerable areas, identifying key features such as a health center, gas station, and landing site, along with 78 coastal buildings and 39 fishing boats.

Regular UAV monitoring is recommended seasonally or yearly to track coastal changes, particularly erosion and flooding. Further participatory GIS (P-GIS) is suggested to involve community members in continuing to assess local vulnerabilities, updating basemaps, and refining and implementing action plans based on evolving conditions.

Table 7. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Icacos Coastal.

UAV (Model & Payload)	DJI Air2S
Altitude (AGL)	120 meters

Images Captured	125
Orthomosaic Map	**Icacos West Coastline Map (120 m) | 24 October 2024 A2S**
Total Mapped Area	94 hectares
Orthomosaic Resolution	3.2 centimeters per pixel
Elevation Resolution (DEM)	12.6 centimeters per pixel
Accuracy (RMSE)	1.5 meters RMSE
Mapping Applications	Coastal community vulnerability monitoring, coastal and wetland ecosystems monitoring
Additional Mapping Surveys	**East Coastline Map TA (120 m) | 24 October 2024 A2S** **Corral Point Corridor Map TA (75 m) | 24 October 2024 A2S** **Punta del Arena Corridor Map TA (75 m) | 24 October 2024 A2S**

Figure 11. Orthomosaic of Icacos' western coastline monitoring site map captured at 120 meters AGL.

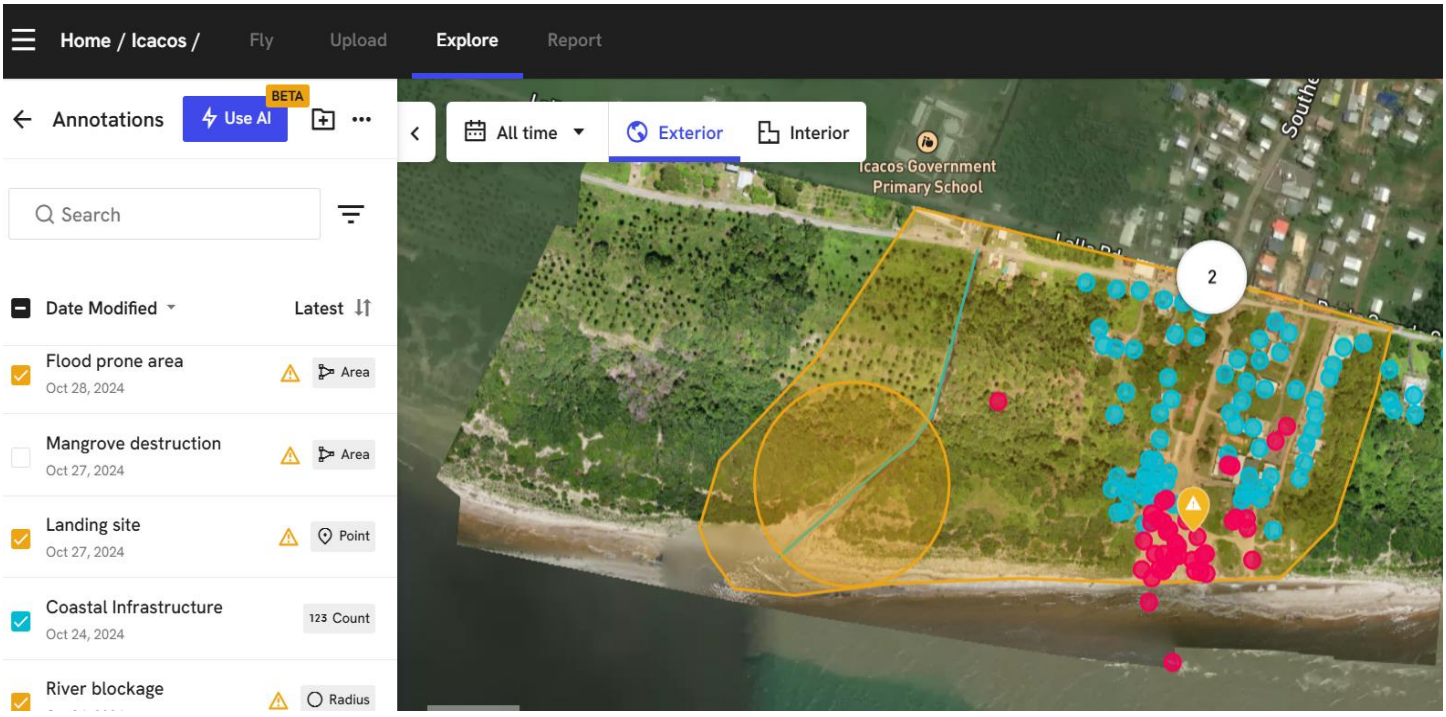

Figure 12. Icacos West Orthomosaic Map with featured annotation measurements.

SPEYSIDE | TOBAGO

P-UAS mapping applications identified at Speyside, which is located in the NE Tobago UNESCO Man and the Biosphere Reserve, include coastal erosion, sargassum, and sea turtle nesting monitoring. Speyside's mapped features include schools, a recreational ground, a sea turtle nesting beach, coral reefs, and the historic Speyside Estate ruins.

Four drone flights over 93 minutes with a DJI Air2S mapped 105 hectares of Speyside at 120m AGL, capturing 437 images with a resolution of 3.6 cm/pixel (RMSE 2.4 m). A corridor plan was also flown to map and monitoring sargassum beaching events.

Key annotations noted 36 fishing vessels, coastal erosion (465 m), and algal bloom. The proposed monitoring strategy includes bsiannual mapping, with post-storm surveys for erosion, monthly corridor checks for sargassum in peak seasons, and regular reef health and nesting beach monitoring during relevant seasons.

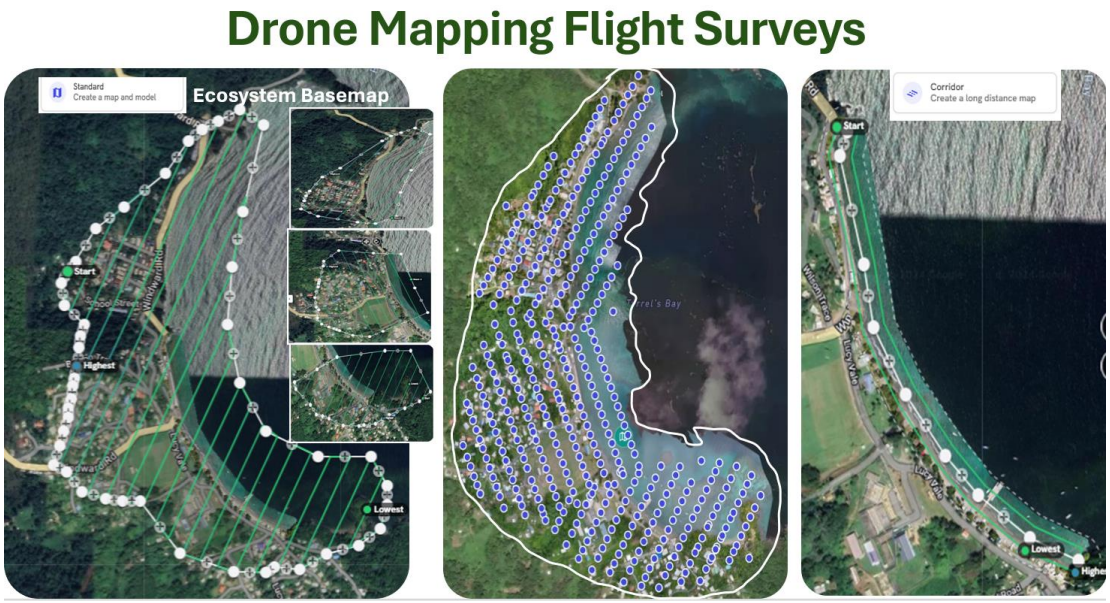

Figure 13. Drone mapping surveys conducted for Speyside monitoring site featuring 437 captured images and photo plans.

Table 8. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Speyside.

UAV (Model & Payload)	DJI Air2S (RGB Payload)
Altitude (AGL)	120 meters
Images Captured	437
Orthomosaic Map	**Speyside Complete Map TA (120 m) | 18 October 2024 A2S**
Total Mapped Area	105 hectares
Orthomosaic Resolution	3.6 centimeters per pixel
Elevation Resolution (DEM)	14.2 centimeters per pixel
Accuracy (RMSE)	2.4 meters RMSE
Mapping Applications	Coastal erosion, sargassum monitoring, sea turtle monitoring
Additional Mapping Surveys	**SG Corridor Map TA (70 m) | 18 October 2024**

SCARBOROUGH | TOBAGO

Scarborough Watershed

The Scarborough Watershed encompasses the main town, harbor, and fish port, situated on reclaimed low-lying coastal land at the mouth of Crooks River. P-UAS site mapping applications focused on fisheries infrastructure, sanitation, vessel mooring, climatic vulnerability and impacts, particularly focused on coastal erosion, storm surge, flooding and sargassum influxes.

Six drone flights were conducted over a total duration of 66 minutes using a DJI Air2S to map the Scarborough Watershed. An orthomosaic map was created, capturing 166 images that covered 30.7 hectares at an altitude of 120 meters AGL. The orthomosaic map generated a resolution of 3.5 cm per pixel, with a root mean square error (RMSE) of +/- 3.8 meters. Additional mapping surveys were conducted over the Fish Port, which included three 360-degree panoramas and one fixed photo plan.

The additional 360° panoramas and corridor surveys of the fish port were used to further support infrastructure inspections and environmental assessments. Moving forward, it is recommended to conduct monthly or bi-monthly monitoring. Additionally, a feasibility study should be considered for potential relocation of facilities at high risk from coastal erosion, in alignment with the Scarborough Urban Redevelopment Project.

Table 9. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Scarborough Watershed.

UAV (Model & Payload)	DJI Air2S (RGB Payload)
Altitude (AGL)	120 meters
Images Captured	166
Orthomosaic Map	**Scarborough Watershed Up SBoro Map TA (115 m) | 1 October 2024 A2S**
Total Mapped Area	30.7 hectares
Orthomosaic Resolution	3.5 centimeters per pixel
Elevation Resolution (DEM)	14.1 centimeters per pixel
Accuracy (RMSE)	3.8 meters RMSE
Mapping Applications	Fisheries infrastructure assessment, sanitation assessment, vessel mooring, climate impact assessment
Additional Mapping Surveys	**Sboro Fish Port TA (60 m) | 1 October 2024 A2S** **Sboro Fish Port Corridor TA (60 m) 75 m | 1 October 2024 A2S**
360 Site Panoramas	**Sboro Pano (70 m) | 1 October 2024 A2S** **Sboro Pano (50 m) | 1 October 2024 A2S** **Sboro Pano (30 m) | 1 October 2024 A2S**
Fixed Photo and Video Plans	**Sboro Fish Port Photo Plan (50 m) | 1 October 2024 A2S**

Figure 14. Orthomosaic of Scarborough Watershed monitoring site map flown at 120 meters AGL.

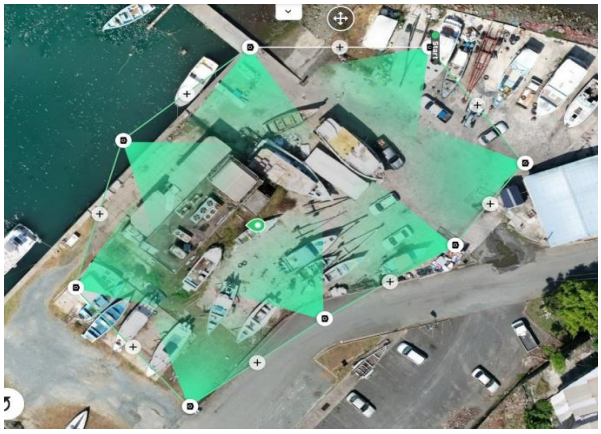

Figure 15. Fixed Photo Plan of Scarborough Fish Port taken at 50 m AG using DJI Air2S.

Lambeau to Scarborough Coastline

The coastline encompassing Lowlands to the west, Signal Hill to the north, and Scarborough to the east presents a diverse blend of residential, commercial, and state-owned properties. Natural features enhance the area's significance, including scenic coastlines, secluded coves, and the lower segment of the Lambeau River. This region supports a variety of essential community facilities, including schools, recreational spaces, and the Shaw Park Cultural Complex, a central hub for cultural activities. It also includes the only coastal road providing an alternative route to the Claude Noel Highway, contributing to critical infrastructure redundancy.

Three drone flights lasting 35 minutes were conducted at Lambeau Scarborough with a DJI Air2S at 120 meters AGL, capturing 256 images over 52 hectares. The orthomosaic produced has a resolution of 3.6 cm per pixel and an elevation resolution of 2.3 cm. A photo plan and 360-degree panoramas were also created to enhance mapping efforts. The P-UAS mapping applications address coastal erosion, sargassum monitoring, and road condition assessments. Significant coastal erosion has affected a secondary road, leading to road failure from land slippage. Sargassum accumulation threatens local aquatic life and community health.

Monitoring recommendations include improving data capture timing, extending flight plans, conducting ground truthing for land stability, and scheduling flights every six months, particularly after severe weather events. Engaging with stakeholders using P-UAS is recommended for additional data gaps and field surveys.

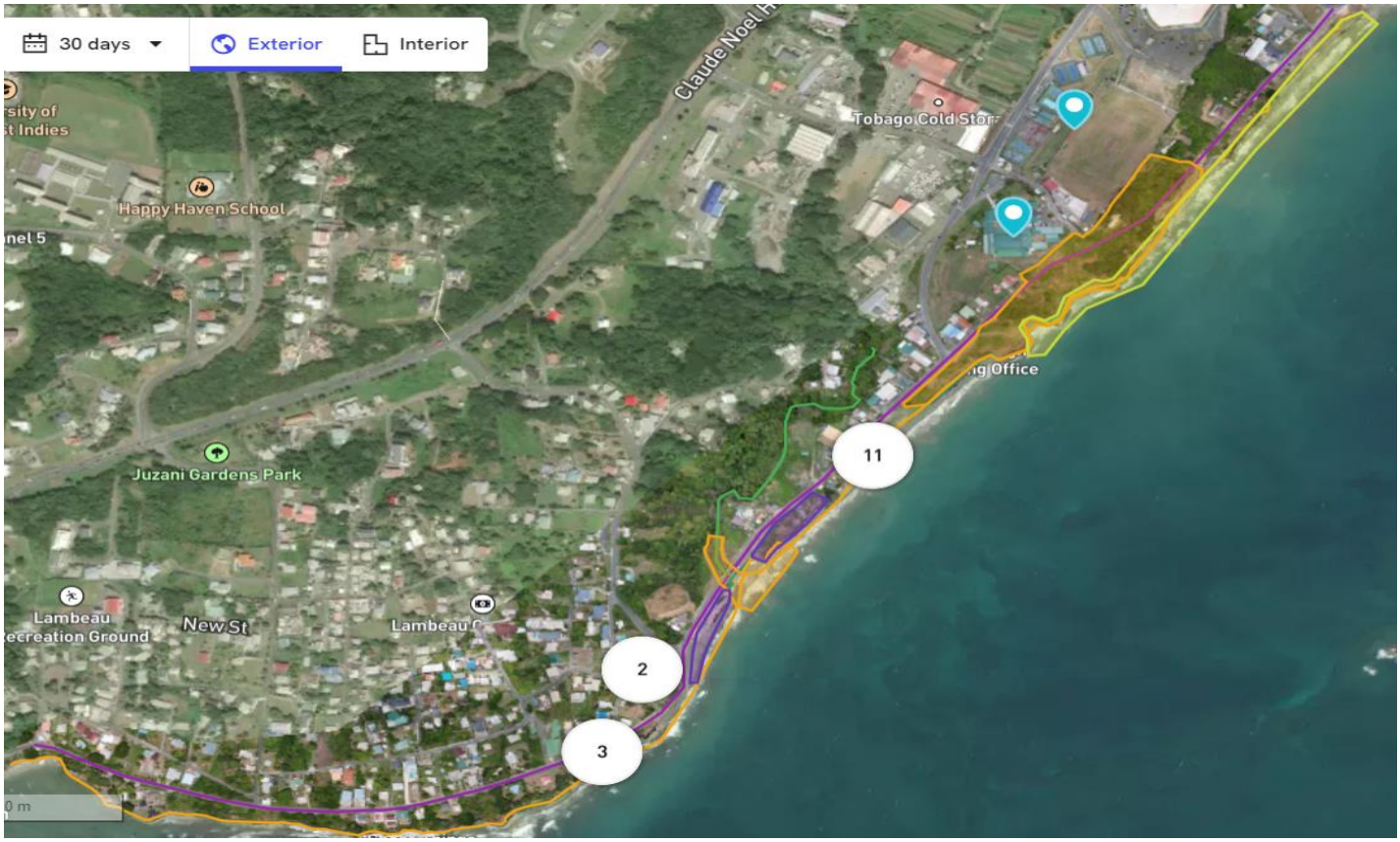

Figure 16. Lambeau to Scarborough Coastline Orthomosaic Map with featured annotation measurements.

Table 10. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Lambeau to Scarborough Coastline.

UAV (Model & Payload)	DJI Air2S (RGB Payload)
Altitude (AGL)	120 meters
Images Captured	256
Orthomosaic Map	**Lambeau Scarborough BaseMap (120 m) | 4 October 2024 A2S**
Total Mapped Area	52 hectares
Orthomosaic Resolution	3.6 centimeters per pixel
Elevation Resolution (DEM)	2.3 centimeters per pixel
Accuracy (RMSE)	14.4 meters RMSE
Mapping Applications	Coastal erosion monitoring, sargassum monitoring, environmental impact analysis, road condition assessment
360 Site Panoramas	**Lambeau Scarborough Pano (50 m) | 4 October 2024 A2S**
Fixed Photo and Video Plans	**Lambeau Scarborough Photo Plan (50 m) | 4 October 2024 A2S**

CASTARA | TOBAGO

Castara, located on Tobago's leeward side, is a biodiverse area with coastal, wetland, and coral reef ecosystems that support fishing, diving, and eco-tourism. These habitats are critical for local wildlife, including fish, birds, and marine species. Mapping applications include community infrastructure assessment, coastal and inland erosion monitoring, vulnerability analysis, and urban planning.

Three drone flights lasting 22 minutes were conducted at the Castara site using a DJI Air2S at 120 meters AGL, capturing 343 images across 53.2 hectares. The resulting orthomosaic has a 3.7 cm per pixel resolution and an elevation resolution of 14.7 cm, with an RMSE accuracy of +/- 6.5 meters. Additionally, a corridor map and a video survey of the fish facility at 70 meters AGL were conducted.

Regular P-UAS monitoring is recommended seasonally (every six months in wet and dry season) to track river changes and monthly for erosion-affected areas, especially before and after adverse weather. Stakeholder

involvement in development and land management is essential. Recommendations include ground-truthing field surveys and continued training for local participants.

Table 11. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Castara.

UAV (Model & Payload)	DJI Air2S (RGB Payload)
Altitude (AGL)	120 meters
Images Captured	343
Orthomosaic Map	Castara Complete Map TA (120 m) | 7 October 2024 A2S
Total Mapped Area	53.2 hectares
Orthomosaic Resolution	3.7 centimeters per pixel
Elevation Resolution (DEM)	14.7 centimeters per pixel
Accuracy (RMSE)	6.5 meters RMSE
Mapping Applications	Community infrastructure mapping, coastal and inland erosion monitoring, infrastructure vulnerability assessment, urban development planning
Additional Flight Surveys	Castara Corridor Map (90 m) | 7 October 2024 A2S
Fixed Photo and Video Plans	Fish Facility Video (50 m) | 7 October 2024 A2S

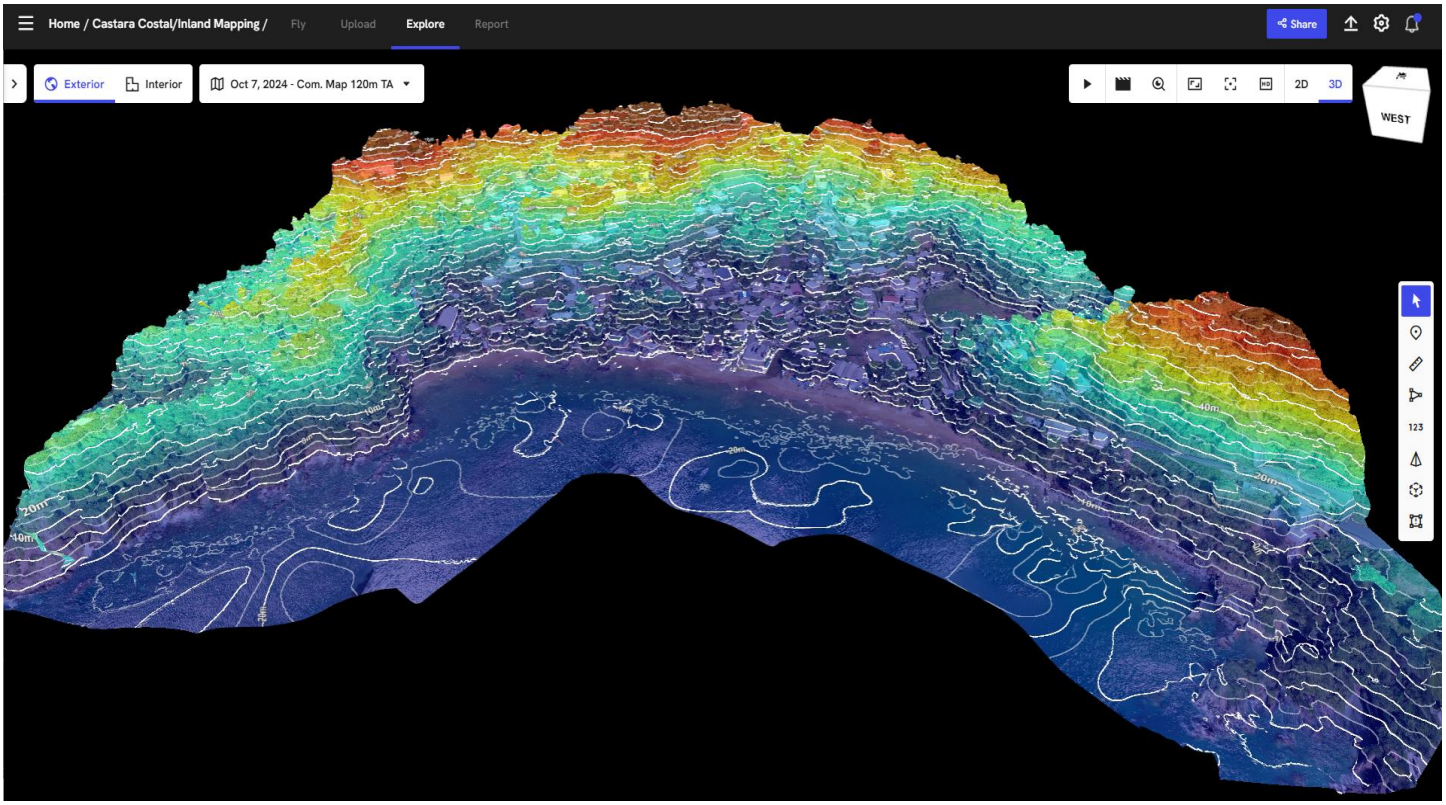

Figure 17. Digital Elevation Model showing contours produced for Castara monitoring site using DJI Air2S

ROXBOROUGH | TOBAGO

Roxborough is a coastal community vulnerable to flooding, erosion, and severe weather impacts. The site P-UAS mapping applications include coastal vulnerability monitoring, flood risk mapping and hazard identification. Nine critical features were annotated, including critical infrastructure (high school, hospital, police station, fire station, and gas station), urban development sites (housing scheme, construction site, and drainage), and natural features (river and beach).

Drone mapping surveys using a DJI Matrice 300 RTK were flown at 120 meters (AGL) for a total flight time of 14 minutes to create an orthomosaic map of Roxborough's critical disaster-related infrastructure. The map covered 38.8 hectares, with a 4.9 cm/pixel resolution and elevation model resolution of 19.6 cm/pixel with a map accuracy of +/- 3.1 meters RMSE obtained.

Regular monthly or bi-monthly mapping and pre/post-storm surveys are recommended, with focused video documentation in high-risk flood and erosion zones. Additional data collection should include thermal imaging to identify moisture and temperature variations, especially near the construction site, and ground-based surveys for precise risk assessment. Expanding the photo plan to cover the full study area is advised.

Table 12. Drone model and overview of drone mapping survey conducted for Roxborough Critical Infrastructure site.

UAV (Model & Payload)	DJI Matrice 300 RTK
Altitude (AGL)	120 meters
Images Captured	383
Orthomosaic Map	**Roxborough Critical Infrastructure Complete Map (120 m) | 2 October 2024 A2S**
Total Mapped Area	38.8 hectares
Orthomosaic Resolution	4.9 centimeters per pixel
Elevation Resolution (DEM)	19.6 centimeters per pixel
Accuracy (RMSE)	3.1 meters RMSE
Mapping Applications	Coastal monitoring, flood risk mapping and hazard identification

Figure 18. Orthomosaic of Roxborough monitoring site map flown at 120m AGL using DJI Matrice 300 RTK.

ROXBOROUGH | TOBAGO

Roxborough Bay is located on the south east coast of Tobago and is also part of the North East Tobago UNESCO Man and the Biosphere Reserve, functioning as a developing business hub and main access route to northeastern villages on the island. Coastal erosion poses a critical threat to both infrastructure and local residences.

Using the DJI Air2S, P-UAS mapping focused on coastal erosion monitoring and identifying areas needing infrastructural support. Two drone flights, comprising of 23 minutes of flight time, were flown at 120 meters AGL to create a complete orthomosaic map of Roxborough Bay. The P-UAS site basemap covered 27 hectares, and an additional corridor map survey was also completed. Mapping revealed severe erosion impacts: five homes face a first-degree threat from erosion, and seven are less severely threatened. Significant issues include two critical wave-undercutting areas and extensive seawall undermining over a 523-metre stretch. Several erosion prevention measures, like stone revetments, have been implemented but need further support.

Quarterly PUAS mapping is recommended, with additional seasonal assessments. Monthly adjustments to the corridor plan, using a camera angle of 30-50 degrees, will capture coastline and infrastructure changes. Long-term recommendations include relocating vulnerable structures, investing in resilient coastal support (e.g., breakwaters), and engaging in community mapping initiatives for ongoing monitoring and awareness.

Table 13. Drone model and overview of drone mapping surveys and other additional flight surveys conducted for Roxborough Bay.

UAV (Model & Payload)	DJI Air2S (RGB Payload)
Altitude (AGL)	120 meters
Images Captured	143
Orthomosaic Map	**Roxborough Bay Complete Map (120 m) | 3 October 2024 A2S**
Total Mapped Area	27 hectares
Orthomosaic Resolution	3.9 centimeters per pixel
Elevation Resolution (DEM)	15.4 centimeters per pixel
Accuracy (RMSE)	3.4 meters RMSE
Mapping Applications	Coastal erosion monitoring, infrastructure management
Additional Mapping Survey	**Roxborough Bay Corridor Map (90 m) | 3 October 2024 A2S**

Figure 19. Orthomosaic of Roxborough Bay monitoring site map flown at 120m using DJI Air2S.

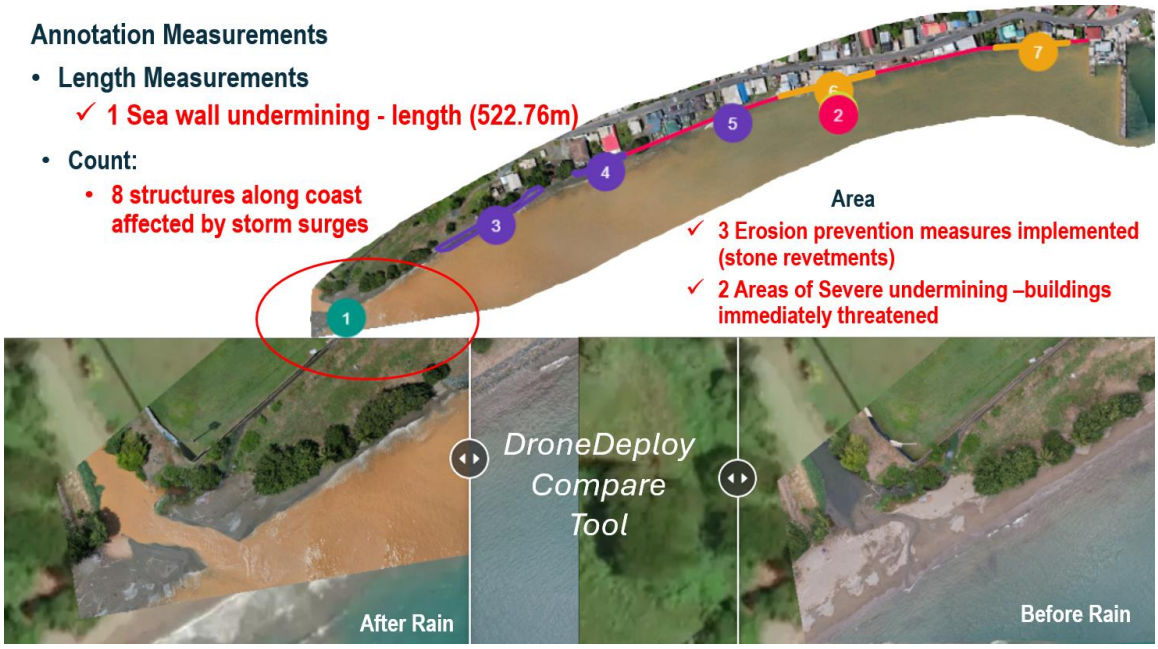

Figure 20. Roxborough Bay monitoring site annotations and an example of the compare tool of the site - before and after rain event.

COURSE EVALUATIONS

DRONE TRAINING BOOTCAMP EVALUATIONS

All 16 participants from the Trinidad and Tobago cohorts provided overwhelmingly positive evaluations of the bootcamps (see Baldwin 2024 for details). Participants agreed that the agenda and objectives were clear, and the sessions were highly effective in meeting both personal and workshop goals. The practical exercises, which introduced them to drone applications in environmental management, were particularly valued for enhancing their understanding and skills.

While most participants found the allocated time sufficient, several suggested that an extended bootcamp would allow for more hands-on practice and in-depth experience with drone mapping. Instructor evaluations were uniformly excellent, with high praise for their knowledge, presentation skills, and approachability. The learning resources and overall organization were also well-received, though some recommended more time for reviewing preparatory materials.

Both cohorts expressed interest in further training, specifically in advanced topics like high-accuracy mapping and flight skills. Overall, the bootcamp was considered a success, with participants eager to apply their new skills and continue into the virtual component of the course.

FINAL COURSE EVALUATIONS

The Mapping & Monitoring Course Evaluation indicates a highly positive response from participants regarding the effectiveness of the course in addressing drone mapping surveys and environmental monitoring techniques (See Student Insights, Figure 21). The majority rated the course highly, with most respondents giving a score of 5, reflecting a strong consensus on its relevance and quality. Participants appreciated the depth of content covered, indicating that the course met their expectations and needs.

Instructor effectiveness also received favorable feedback, with ratings primarily in the 4 to 5 range. Respondents noted Dr. Kim's ability to explain complex concepts, such as drone mapping and flight surveys, effectively. Her teaching style, which combined theoretical knowledge with practical applications, was highlighted as a key factor in facilitating learning. The practical bootcamp session, in particular, was noted for its hands-on approach, allowing participants to gain confidence in conducting their own drone operations.

Participants reported a solid understanding of drone photogrammetry software, flight planning, and mapping techniques by the end of the course, with many expressing appreciation for the planning phase. This aspect emphasized the importance of preparation in maximizing data collection efficiency. Additionally, the flexibility of the course structure was appreciated, as it accommodated individual schedules and allowed for self-paced learning, enhancing the overall experience.

The course's practical components, such as mission planning and flight surveys, were instrumental in skill acquisition. Clear instructions and effective learning resources contributed to participants' confidence in applying the techniques learned. The collaborative environment fostered through group activities and communication platforms further supported knowledge sharing and teamwork.

Feedback on potential course adjustments was minimal, with most participants satisfied with the course design and structure. Suggestions for minor improvements included extending the course duration for better comprehension and enhancing communication through a single platform. Overall, participants expressed a high level of satisfaction, highlighting the course's comprehensive nature and its alignment with their professional needs in the field of drone mapping and environmental monitoring. The final course evaluations responses can be viewed at CANARI Mapping & Monitoring Course Evaluations.

Summary of the CANARI Tech4CoastalResilience' Drone Mapping for Environmental Monitoring Course Training Pre- and Post- Assessments

The pre- and post-training surveys reflect significant improvements in participants' knowledge, confidence, and practical application of drone technology. Below is a concise summary of key findings from the trainees' assessments.

Knowledge of Drone Technology

1. Before the training, most trainees had minimal knowledge of drones, with limited or no experience in drone mapping or operations.
2. After the training, participants reported a solid understanding of drone photogrammetry software, flight planning, and mapping techniques, showcasing significant knowledge growth.

Confidence in Drone Usage

1. Pre-training surveys revealed low confidence levels in conducting aerial mapping surveys, with most participants feeling unprepared for practical applications.
2. Post-training feedback highlighted increased confidence, especially after hands-on mission planning and flight exercises, enabling trainees to independently plan and execute surveys.

Practical Application of Skills

1. Initially, many participants aimed to use the training for broad goals, such as GIS enhancement or environmental monitoring, without clear implementation strategies.
2. Post-training, trainees expressed specific and actionable plans for using drones in fisheries management, coastal erosion monitoring, and environmental conservation, indicating the practical utility of the course.

Familiarity with Drone Tools and Software

1. Prior to training, most participants were unfamiliar with specialized tools for drone mapping and data analysis.
2. Following the course, trainees noted how tools like DroneDeploy streamlined their workflow, making data collection and analysis significantly faster and more effective.

Use of Training for Future Applications

1. Initially, participants viewed the course as a means to enhance their current skill set without specific future applications in mind.

2. Afterward, trainees were enthusiastic about applying their knowledge to specific projects, such as risk mapping, community participatory mapping, and environmental management.

Student Insights

Students expressed profound growth in both technical and personal aspects throughout the course. Many shared that the hands-on training significantly boosted their self-confidence in operating drones, allowing them to see their capabilities expand. Participants also highlighted the practical nature of the course, noting that the opportunity to engage with real-world applications like environmental monitoring and disaster management was both rewarding and motivating. They also appreciated the collaborative nature of the course, stating that working alongside peers with different skills and perspectives enriched their overall learning experience. Overall, feedback indicated that the course not only enhanced their technical skills but also provided a greater sense of purpose in using drone technology for meaningful, impactful work.

The transition from pre-training to post-training reveals significant improvements in both technical skills and professional mindset among participants. The hands-on experience and the practical application of drones in real-world scenarios were key factors in enhancing participants' confidence, knowledge, and readiness to apply their new skills in diverse professional settings. Overall, the course not only elevated their technical expertise but also transformed how they approach drone technology in their work, fostering a greater sense of purpose and direction in their future projects.

Student Insights

The practical bootcamp session was extremely helpful and useful. Compared to other courses that comprises a theory, I believe that the bootcamp was much more effective, it definitely prepared me to confidently go out on my own.

A program like this takes more than just skill & knowledge. I believe the energy & passion from Dr. Kim was contagious and it made learning fun & meaningful. The course was perfect & comprehensive - simple to understand for persons who may not have GIS background.

- Evana Douglas, Future Fishers

Student Insights

What we got in this workshop is much more than just flying. We learned the applications and learned how to do actual mapping using drones. Now we can use our knowledge to go out in the field to do species and coastal zone monitoring.

The mapping of areas using drones will be a great asset to our organization as we will be able to more quickly ascertain the conditions of the field and use the information to assist in environmental management, monitoring & policy planning moving forward

- Ryan Mannette, SpeSeas

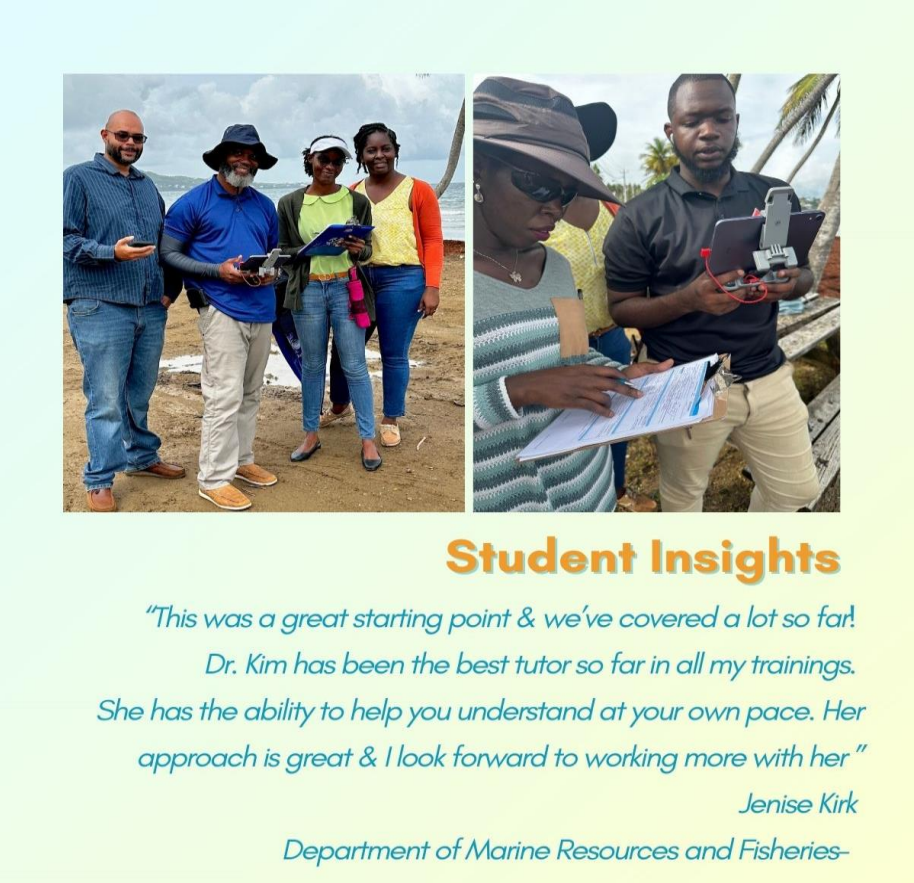

Figure 21. Three of the student insights from the final course evaluation surveys.

OUTREACH AND EDUCATION

To aid outreach education and support for the training initiative, social media posts have been made on multiple social media platforms including Instagram and LinkedIn. Public presentations and interactive sessions were recorded and available for viewing YouTube for knowledge sharing and across a wider audience (Table 14)

Table 14. Social media posts hyperlinked and listed by platform, title, source, and date.

Category	Title and Source (Hyperlinked)	Date
Zoom Presentation (Posted on YouTube)	CANARI Tech 4 Coastal Resilience | Project Final Presentation	1 November 2024
	CANARI Tech 4 Coastal Resilience | Virtual Course Info Meeting	6 August 2024
	CANARI Tech 4 Coastal Resilience | Participatory-UAS Training Inception Meeting 2024	24 June 2024
	CANARI Tech 4 Coastal Resilience Project | Drone Training Requirements & FAQs	17 June 2024
LinkedIn	Project Final Presentation Announcement | Event	28 October 2024
	Drone Mapping Results | Video	9 August 2024
	Drone Training Bootcamp | Photos	17 July 2024
	Drone Training Bootcamp | Photos	17 July 2024
	Drone Training Project Introduction | Photos	10 July 2024
Instagram	Drone Mapping Results | Video	9 August 2024

ACCOMPLISHMENTS & NEXT STEPS

The *Tech4CoastalResilience* Drone Training Programme has successfully achieved and exceeded its initial objectives, fostering widespread collaboration and empowering stakeholders in Trinidad and Tobago to utilize participatory

drone and geospatial technologies. The project has provided substantial training and technical support, equipping participants with the knowledge and skills needed to independently conduct drone mapping and environmental monitoring across 10 coastal communities identified by CANARI.

Project Deliverables and Accomplishments

Although the specific deliverables (D3–D6) were met in slightly different formats than originally outlined, the extended deliver of a blended course and field coaching proved even more beneficial.

Key accomplishments include:

- Conducting a comprehensive virtual training workshop (D3 & D4), which extended beyond two days to eight weeks of robust learning including four in-person live webinars and time allotted for office hours.
- Providing continuous technical support, chat messages and video coaching to participants during their planning and conduction of drone mapping and monitoring analysis of 10 target coastal communities (D5).
- Trainees delivering P-UAS site monitoring reports and communicating results and skills learned through the conduct of final presentations that detailed the results of each community's drone mapping efforts (D6).

Collaborative Efforts and Government-Civil Society Synergy

One of the project's unique strengths has been its ability to facilitate collaboration between government agencies and civil society organizations (CSOs). Key agencies, such as the Fisheries Division, the Institute of Marine Affairs (IMA), the Office of Disaster Preparedness and Management (ODPM) and Tobago Emergency Management Agency (TEMA), worked alongside CSOs like SpeSeas, Future Fishers, Environment Tobago and the Caribbean Natural Resources Institute (CANARI). This intersectoral approach brought together diverse expertise to strengthen the technical capabilities of the trainees while fostering teamwork, shared learning, and a stronger network of stakeholders committed to improving coastal community resilience.

Blended Learning Approach

Following the in-person bootcamp, trainees were enrolled in an online Training Academy to allow access to review a variety of learning resources and time to reinforce skills. Then they were enrolled in an eight-week *Participatory UAS Mapping and Monitoring Virtual Course*, which included 56 lessons, including several live training webinars and over 10 hours of recorded video content. The virtual component covered essential topics such as site selection, feasibility and safety assessments, flight planning, data handling, participatory-UAS mapping and an introduction to analysis and reporting. The hands-on drone flight planning and fieldwork that accompanied this virtual training allowed participants to independently map all ten (10) *Tech4Resilience* sites, producing valuable baseline mapping results.

Participants praised the course's structure, practical fieldwork, and the continuous support provided by Dr. Kim's technical coaching sessions and communication via SLACK messages. As a result, all trainees now possess the skills to conduct drone-based environmental monitoring and geospatial analysis, independently applying these tools to address a wide range of coastal and marine challenges, such as habitat mapping, erosion monitoring, and fisheries management.

Conclusion and Future Steps

The Tech4CoastalResilience Project has successfully established a solid foundation for the long-term integration of drone and geospatial technology for environmental management in Trinidad and Tobago. By empowering local stakeholders through advanced training, fostering collaboration, and equipping participants with the necessary tools and resources, this project has now created a capable and self-sufficient environmental mapping and monitoring network of drone pilots. This new CANARI drone team network is well-positioned to support accurate geospatial data collection to aid informed and collaborative decision-making to support coastal community resilience in T&T.

One of the Drone Training Programme's key strengths is that each of the five Project Partner 'sub-teams' now owns their own drone equipment and iPads, along with one year of Drone Deploy software access and DJI aircraft 'hull'

insurance—an invaluable asset for ensuring ongoing UAS mapping and operational capabilities. Additionally, the creation of a strong network of trainees across various government agencies and CSOs provides a unique support system that allows for continued collaboration and resource sharing moving forward. This new 'CANARI Drone Team' network is an important benefit that will aid in maintaining the momentum of the Project.

However, it is essential to note that continued UAS practice and skill refinement are crucial for the long-term success of these teams. While this training provided a strong foundation, it is recommended that advanced training be offered, particularly in more complex geospatial analysis and integration with ArcGIS Online for enhanced environmental applications. Furthermore, specialized training in more advanced 'coastal and marine' mapping techniques will also strengthen their ability to apply these tools in practical, high-impact coastal marine mapping scenarios.

A critical next step is to address the limited timeframe of the DroneDeploy mapping and analysis software 'Teams' license, which was acquired by CANARI at a discounted non-profit rate for one year. To prevent the loss of this valuable tool, it is highly recommended that plans be made now to ensure that the licensing can be maintained beyond the initial period. Maintaining access to this software will be key to the teams' continued long-term success in producing high-quality data and further developing their PUAS mapping and monitoring applications.

Additionally, the trainees are strongly encouraged to continue practicing and applying their new drone skills, especially through regular field missions and collaborative efforts. Maintaining the CANARI Drone Team partnerships built during the course will be vital, as peer support and shared experiences will help solidify their knowledge and encourage continuous learning and improvement moving forward.

Further, the trainee organisations and other relevant stakeholders that have a specific role and interest in ongoing coastal mapping and monitoring of these 10 sites will be able to leverage the drone flight plans and site monitoring plans that have been developed under the course and support monitoring on a bi-monthly, quarterly, half yearly and yearly basis as recommended based on these initial efforts. Where sites are not currently being monitored, the mapping under the project can serve as a valuable baseline for further monitoring.

The P-UAS Training has achieved its' objectives by building a well-equipped team of 16 new drone operators. As participants continue to grow in their expertise and apply these skills, the Tech4CoastalResilience Project serves as a model for future initiatives aimed at integrating digital technologies to enhance coastal resilience and environmental conservation. Moving forward, ongoing practice, advanced training, and strategic planning for software and resource sustainability will ensure that this Project's impact grows and endures.

APPENDICES

APPENDIX I. COURSE OUTLINE FOR THE 5-DAY DRONE FLIGHT BOOTCAMP IN-PERSON TRAINING WORKSHOP.

dr. Kim Baldwin
CONNECTING PEOPLE, TECHNOLOGY & INFORMATION

INTRODUCTION TO DRONE FLYING AND MAPPING METHODS

Provides an detailed overview of drone policies, regulations & flight safety procedures and practical experience conducting drone flight survey mapping methods using internationally-accepted commercial standard operating procedures

Overview of Applications

- Description of UAS Components
- Aerial Surveys, Mapping & Geospatial Analysis
- Industry Applications & Case Studies
- Mapping Methods, Flight Surveys & Data Outputs
- Data Processing, Spatial Analysis & Reporting
- Exporting, Creating & Sharing Information

UAS Policy and Procedures

- UAS Policy and Operational Protocols
- Safety and Risk Management Strategies
- National Drone Rules and Regulations
- Commercial Standard Operating Procedures
- Flight Feasibility and Safety Assessment
- Crew Roles, Coordination and Support Duties
- Maintenance Logs and Repair Procedures

Processing Data and Information

- Data Handling, Storage and File Management
- Post-Processing and Outputs (Orthomosaics, Elevation Point Cloud, DSM, DTM)
- Analytic Dashboards: Web-Mapping, 3D Measurements and Annotation Tools
- Reporting (Accuracy, Annotations and Site Progress)
- Data Exporting, Conversion & Integrations (GIS, JPEGS, KMZ, PDF, Contours, URLs)
- Data Sharing & Web-based Mapping Platforms

UAS - Ground / Theory (classroom)

- Assembly & Care of UAS Components
- Handling of System Components & Batteries
- Ground Control Station: Transmitter Review, Operating Frequencies & Limitations
- Flight Controls, Sound & Light Signals
- Manual and Auto-Pilot Flight Modes
- Crew Management, Roles & Responsibilities
- Pre-flight Inspections & Safety Checks
- Mission Planning and Site Assessments
- Conduction of Flight Surveys
- Flight procedures (Pre & Post Mission)
- Problem Solving, Fault Analysis & Repairs
- Maintenance, Repairs, Warranties & Insurance

UAS - Flight Exercises (practical skills)

- Safety Features (automated & manual) Protocols
- Range, Signal & Flight Control Checks
- Take-off & Landing Procedures
- Practical Flight Exercises (manual control)
- Practical Flight Surveys (automated control)
- Camera Operations (settings and options)
- Non-normal & Emergency Procedures
- Issues, Threats & Error Management
- Commercial Standard Operating Procedures

APPENDIX II. PARTICIPATORY-UAS MAPPING & MONITORING VIRTUAL COURSE CURRICULUM

- *56 lessons, 5 live Training webinars, 10 hours of video content*

1. **Welcome Aboard** 🚀
    a. Course Introduction
    b. What To Expect
    c. Prerequisites & Required Resources
    d. Review & Drone Work

2. Site Selection 🎯
    a. Module Overview
    b. Participatory-UAS Ecosystem Approach
    c. Environmental Monitoring Strategies | Coastal Marine Applications
    d. Required Resources
    e. Drone Work | Site Selection
    f. Learning Check

3. Feasibility & Safety Assessment 🦺
    a. Module Overview
    b. Determining Your Site Extent
    c. Mission Planning | Flight Feasibility and Safety Assessment
    d. Demo | San Dieguito Lagoon FSA
    e. Drone Work | Feasibility & Safety Assessment
    f. Learning Check

4. Flight Planning & Data Capture 📸
    a. Module Overview
    b. UAS Mission & Flight Planning
    c. Drone Work | Create Flight Plans
    d. Office Hours - Flight Planning | CANARI 2024.09.09 REPLAY
    e. Copy of Aerial Capture Basics | DroneDeploy Academy
    f. Flight Prep & Logistics
    g. Demo | Pre-Flight Checks
    h. Demo | Site Safety Briefing
    i. Demo | Conduct Flight Surveys
    j. Post-Mission Flight Checks
    k. Learning Check

5. Data Handling 📁
    a. Overview Importance of Data Management
    b. Demo | Storage & Naming Conventions
    c. Demo | Processing with DroneDeploy
    d. Uploading Multiple Flight Data - Complete Map | Drone Deploy*
    e. Demo | Reviewing Results
    f. Demo | Exporting Data
    g. Data Management Review
    h. Learning Check

6. Participatory-UAS Analysis & Reporting 📑
    a. Module Overview
    b. Demo | Web-Mapping Dashboard & Analytic Tools
    c. Bonus Lesson| Importing Overlays & Software Integrations
    d. Bonus Lesson: Isolate Beached Sargassum - (Classification using Plant Health Tool)
    e. Drone Work | Mapping & Monitoring Strategy
    f. Reporting Tools
    g. Participatory-UAS Mapping Approach* | Course Wrap Up
    h. Learning Check

7. Review & Next Steps 👣
    a. Module Overview
    b. Spreadsheet for Drone Mapping & Monitoring Sites
    c. Final Assignment | Guidelines & Tips
    d. Demo | Final Presentation of San Dieguito Lagoon Case Study
    e. Course Assessment & Feedback
    f. Learning & Continuing Education
    g. Thanks & Next Steps

8. Additional Course Resources 📚
    a. Drone Mapping for Environmental Monitoring Guidebook | 2024
    b. Drone Mapping Resource Links | 2024
    c. Participatory-UAS Ecosystem Approach | Baldwin et. al 2021
    d. Dr. Kim's Drone Mapping & Monitoring | YouTube Playlist
    e. DroneDeploy's Ultimate How to Guide | DroneDeploy 2021
    f. Guide to Drone Mapping | GeoNadir 2021
    g. WWF Conservation Drones | 2020

APPENDIX III. FINAL PROJECT REPORT PRESENTATIONS

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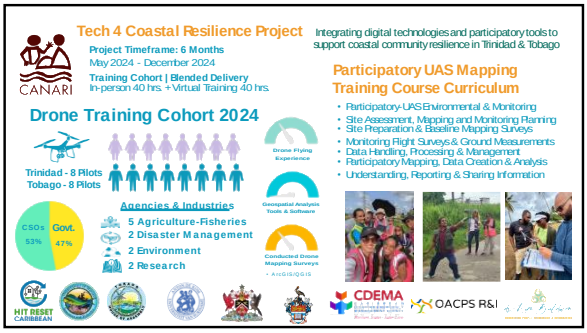

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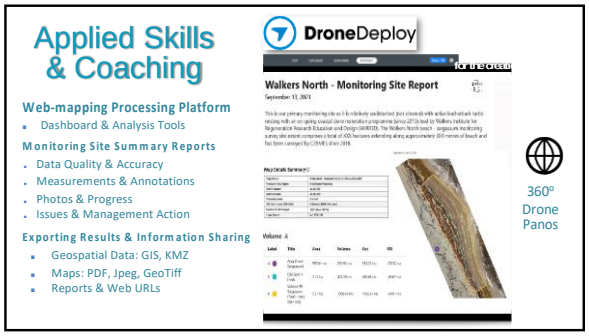

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Links to final drone site presentations by training participants.

TRINIDAD	TOBAGO
Blanchisseuse	Castara
Carli Bay	Roxborough Bay Roxborough community (TEMA)
Icacos	Scarborough watershed Lambeau to Scarborough coastline
Matelot	Speyside
Mayaro	
Moruga	

View Drone Team P-UAS Course Certificates here.

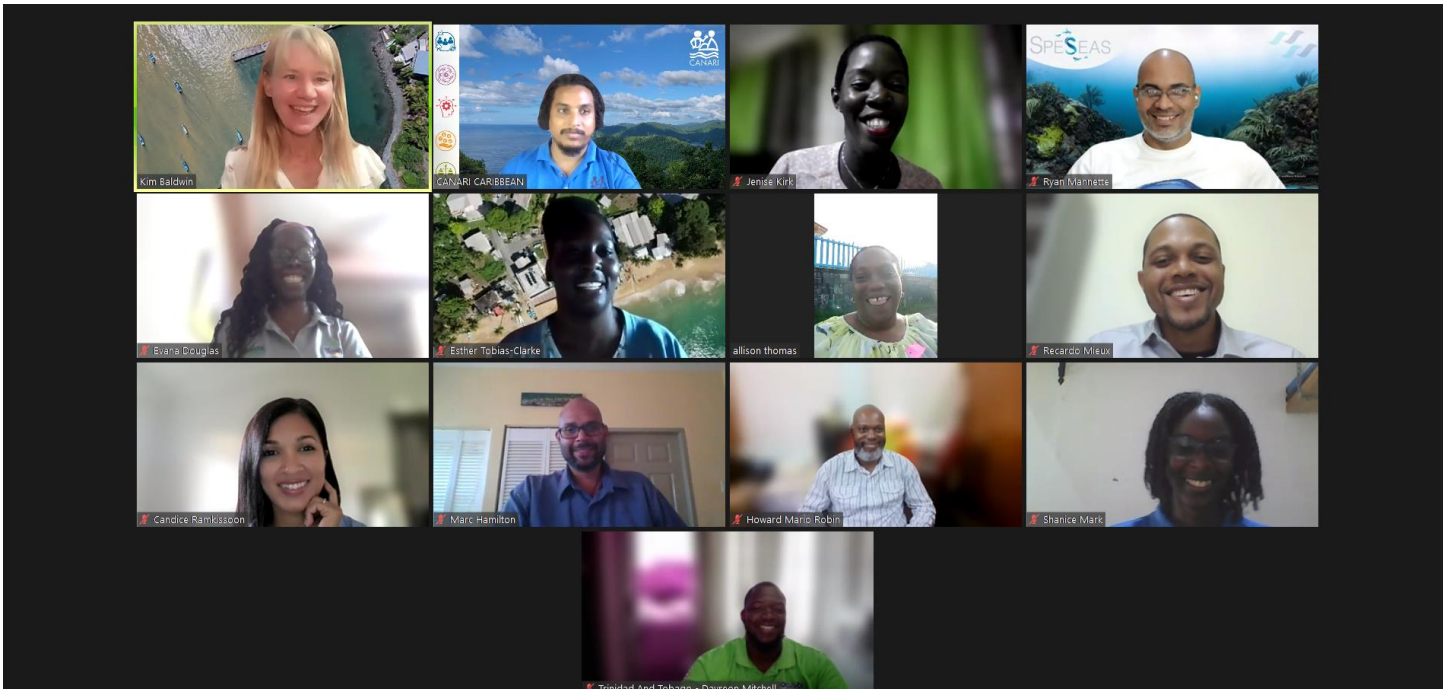

Photo 1. Drone training participants at final presentation session.