Work Package 2: Technological Innovation for Sustainable Development

Deliverable T2.4.1: Project report

Guidance for local authorities on the use of drone technology for the sustainable development of the coastal zone

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SUSTAINABLE RESILIENT COASTS

Project Partners

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Executive Summary

Drone or Uncrewed Aerial Vehicle (UAV) technology is rapidly becoming an important tool across a broad range of coastal applications. Whether mapping local natural resources or digitally preserving natural and built heritage sites through 3D models, simple off-the-shelf drone technology has proven to be an affordable and accessible option for these and similar tasks. However, drone usage in local authorities is currently underutilised. There is an opportunity for local authorities to effectively manage and assess their regional resources by adopting simple and easy-to-use methodologies for the use of drones to support their decision-making processes.

This report aims to distil the findings, experiences, and recommendations from the previous reports on drone technology for sustainable development, into a simple guide for local authorities. Areas covered include training, equipment, applications and survey approaches, with a general info-graph to tie the different elements together and provide links to additional information.

The report has been produced as part of the European Regional Development Funded Sustainable Resilient Coasts (COAST) project, a collaboration between partners from Iceland, Finland, Ireland, and Northern Ireland focusing on the future challenges and development of coastal areas in Europe's Northern Periphery and Arctic (NPA) region. The project seeks to deliver practical guidance for coastal local authorities to support resilience building and coastal sustainability. This document is therefore intended to enable local authorities with limited experience but a desire to understand and use drone technology for the assessment and survey of coastal resources. Further project reports, such as Giannoumis (2021), Hayes *et al.,* (2021), Hayes (2022) and Kandrot and Holloway (2020), can be found at the COAST website: http://coast.interreg-npa.eu/

Acknowledgements

Thanks to the academic staff at UCC and the project partners for their insightful discussions in many of our online meetings.

Acronyms and Abbreviations

COAST	Sustainable Resilient Coasts
EASA	European Union Aviation Safety Agency
GDPR	General Data Protection Regulations
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IAA	Irish Aviation Authority
ICZM	Integrated Coastal Zone Management
INSPIRE	Infrastructure for Spatial Information in the European Community
LA	Local Authority
NPA	Northern Periphery and Arctic
RTK	Real Time Kinematic GPS
SDG	Sustainable Development Goal
SfM	Structure from Motion
UN	United Nations
UAV	Uncrewed Aerial Vehicles
VLOS	Visual Line of Site
VTOL	Vertical take-off and landing

1 Introduction

1.1 Introducing COAST

The aim of the COAST project is to build the resilience of coastal communities in the Arctic and northern periphery by providing a roadmap for protecting, promoting, and developing the cultural and natural heritage of sparsely populated and remote coastal communities. The sustainable development of coastal areas is imperative as these regions experience increased vulnerability largely due to climate change including the effects of sea level rise. At the same time, coastal regions also experience increasing socioeconomic pressures. To support coastal managers in achieving sustainable development in the coastal areas, COAST aims to provide guidance on using easy-to-use and inexpensive innovative technologies, such as drone technology, to enable the protection, promotion, preservation, and development of coastal and natural heritage.

1.2 Introducing partner regions

COAST is a joint collaborative project between Agricultural University of Iceland, Oulu University of Applied Sciences, Causeway Coast and Glens Heritage Trust, Mayo County Council, and University College Cork. The aim of the COAST collaboration was to draw out the lessons learnt from some of the case studies which include the Westfjords of Iceland, Hailuoto in Finland, Rathlin Island in Northern Ireland, and Clew Bay in County Mayo (Figure 1). Each case study offers unique experiences in their approach of sustainable development of the coastal area. There is a common challenge experienced across the regions which shows an opportunity to increase awareness around how coastal managers can utilise innovative solutions to enable the protection and development of the heritage.

As part of the second COAST work package, an extensive literature review was performed (Kandrot *et al.,* 2021) to identify coastal applications of drone technology and how these could contribute to the United Nations Sustainable Development Goals (UN SDG). Demonstration studies have been conducted in Clew Bay, Co. Mayo, Ireland (Hayes *et al.,* 2021) and on Rathlin Island, Co. Antrim, Northern Ireland (Hayes 2022). These case studies used affordable, off-the-shelf drones and standard processing methods and software, ensuring the methods and tools are accessible. This report takes on a broader perspective on how coastal managers and coastal communities can adopt easy-to-use and affordable innovative technologies to monitor and utilise their coastal marine resources.

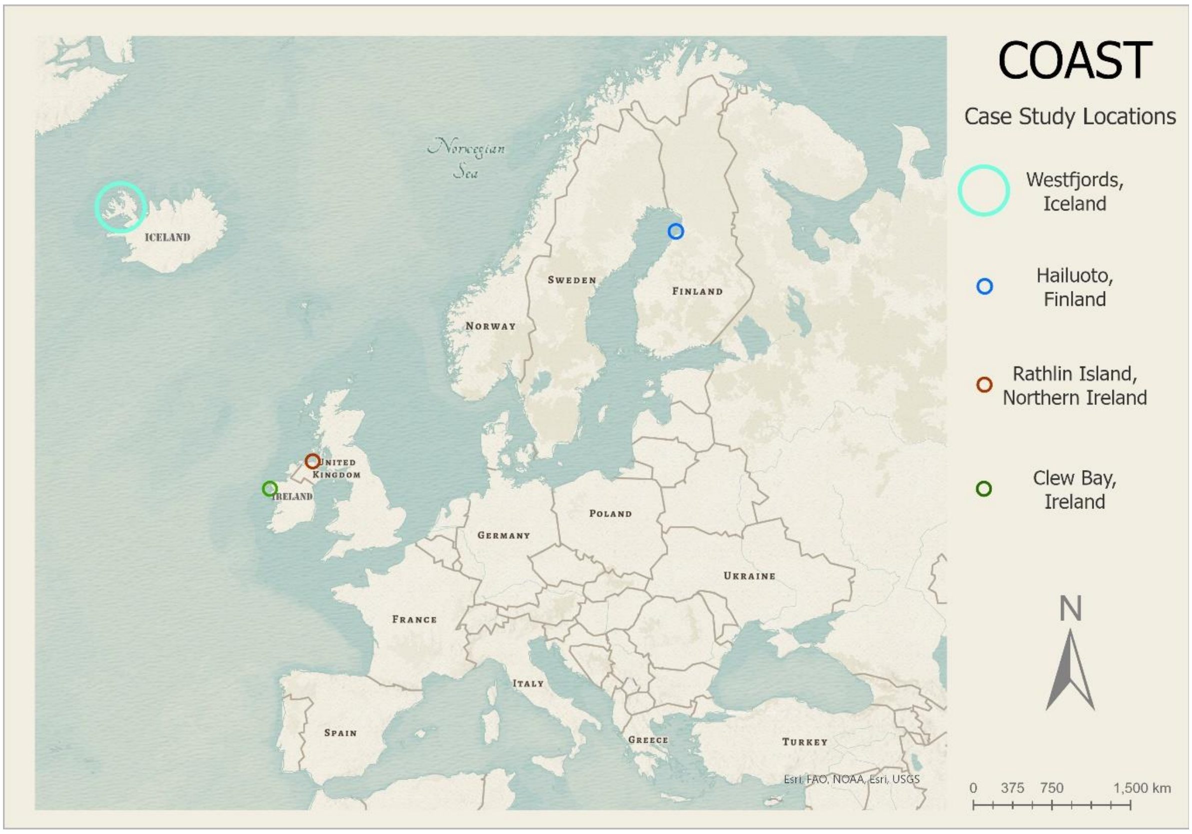

Figure 1: COAST case study locations. Turquoise circle indicating the case study region in the Westfjords, Iceland; blue circle indicating the study region in Hailuoto, Finland; red circle indicating the study region on Rathlin Island, Northern Ireland; and the green circle indicating the study region in Clew Bay, Ireland.

2 Applications of Drone Usages in Local Authorities

Drone technology may be used for a number of different applications. The COAST project set out to understand how local authorities in the partner regions currently utilise drone technology. Thus, a survey was produced to gain a deeper understanding on the use of drone technology and how drone technology is used to achieve the sustainable development goals. The survey would also be used to identify common challenges and opportunities within the coastal regions. The purpose of the survey was to identify if and how local authorities utilised drone technology. The main foci areas of the survey included:

1. the current use of drone technology within local authorities, i.e., using drone technology for monitoring and conservation, heritage documentation, risk management, emergency responses, among others
2. understanding whether local authorities use drone technology to support coastal zone management
3. to gain knowledge about local authorities using drone technology to support the Sustainable Development Goals (SDGs).

From there, several themes emerged that will be presented in the sections below.

2.1 Findings of Survey

Surveys of local authorities (LAs) within the four partner regions (Ireland, Northern Ireland, Finland and Iceland) were used to gauge if and how drones are employed, particularly in terms of coastal zone management and the UN SDG (Figure 2). The 17 SDGs address global grand challenges, such as global health, food security, inequality, environmental degradation, and climate change and provide decisionmakers with targets, indicators, and metrics to measure progress towards the overall goals.

SDG 14 – *Life below Water* – is an important SDG for coastal regions as this concerns the sustainable development of marine resources while ensuring the environmental protection of marine resources and increasing the wellbeing of coastal communities that derive direct and indirect benefits from the marine resources (https://sdgs.un.org/goals). Direct benefits include economic benefits among others, while indirect benefits may include the health of the marine ecosystem (Barbier, 2017). Understanding the wide range of application of drone usage can support LAs in meeting SDGs and supporting the direct and indirect benefits of marine ecosystems.

Figure 2: The 17 United Nations Sustainable Development Goals plus the four most closely related to the COAST project highlighted in blue

A total of 30 local authorities responded to the survey requests, with 18 of these from Iceland, and four each from Finland, Ireland and Northern Ireland. Of the respondents, 22 use drones in some manner, whether in-house or through external contracting, while seven have not used drones at all and one LA was not aware if drones were used (Figure 3A). A lack of consideration of what drone technology can be used for was the most common reason LAs had for not using drones (n = 6), while one claimed to not have one and another cited a lack of budget and education for drones (Figure 3B).

For those that did make use of drone technology, 15 of the 22 used drones for to meet at least one of the 17 UN SDGs – the most common being industry, innovation, and infrastructure, with half of the 22 responding in the affirmative. None of the LAs used drones for reducing poverty, for zero hunger nor for improving gender equality, while the remaining SDGs had between one and nine LAs attempting to address them with drone technology (Figure 4). Overall, local authorities appear not to have considered the potential of utilising drone technologies to support the sustainable development agenda in their coastal regions. SDG 14 – Life below Water – is an important SDG for coastal regions as this concerns the sustainable development of marine resources while ensuring the environmental protection of marine resources and increasing the wellbeing of coastal communities that derive direct and indirect benefits from the marine resources (https://sdgs.un.org/goals). Direct benefits include economic benefits among others, while indirect benefits may include the health of the marine ecosystem (Barbier, 2017).

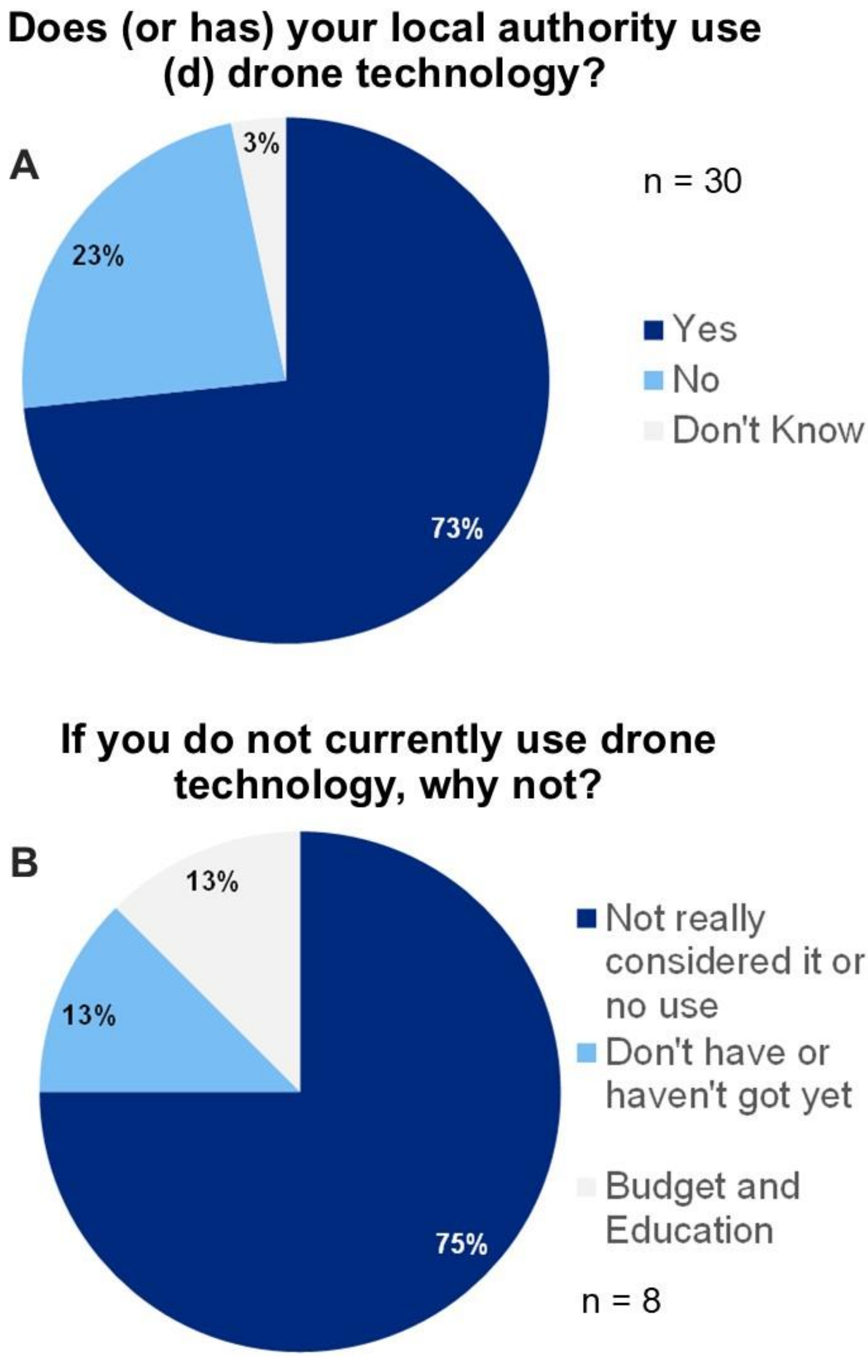

Figure 3: (A) Local authorities survey results on whether they use drones and (B) if not, why not?

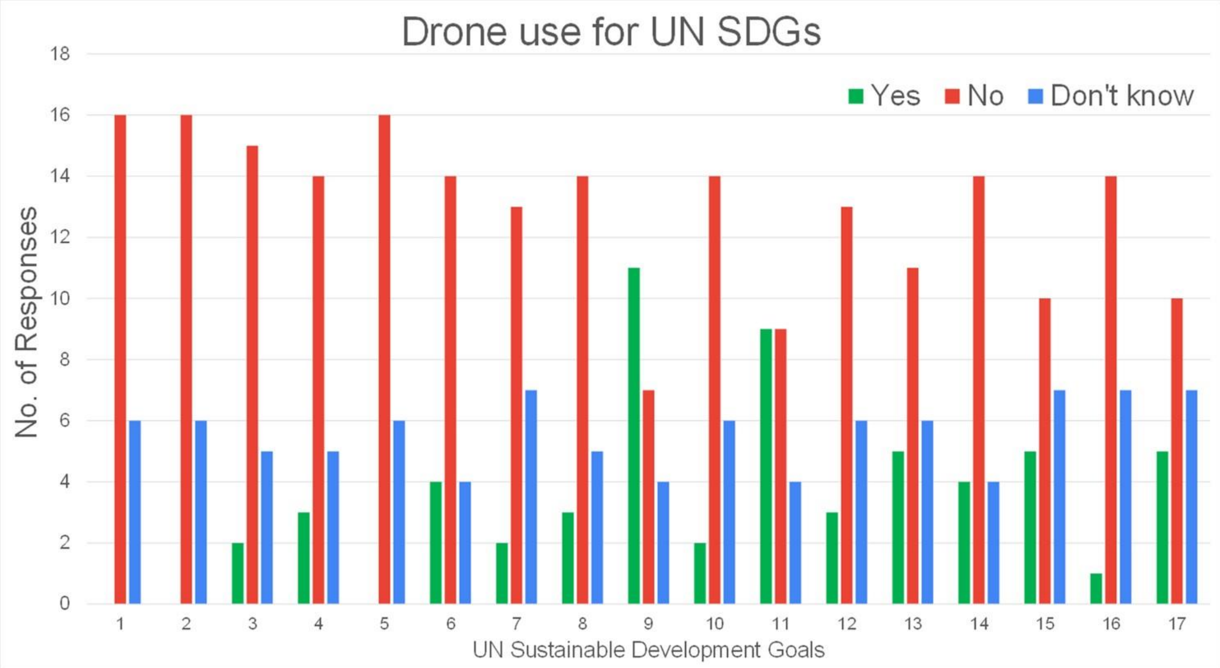

Figure 4: Responses from the local authorities that use drone technology regarding which, if any, UN sustainable development goals the drone technology contributes towards

As coastal resources, such as for example vulnerable bird populations or marine resources such as seaweed and kelp forests can be in difficult to reach terrain, drone technologies could offer a potential way to monitor and assess re Six of the 22 LAs (27%), use drones for some form of coastal zone management, seven do not and nine either did not know or offered a neutral response (Figure 5). sources with minimal impact on marine wildlife and resources. However, the survey indicated that local authorities have not yet availed of these opportunities.

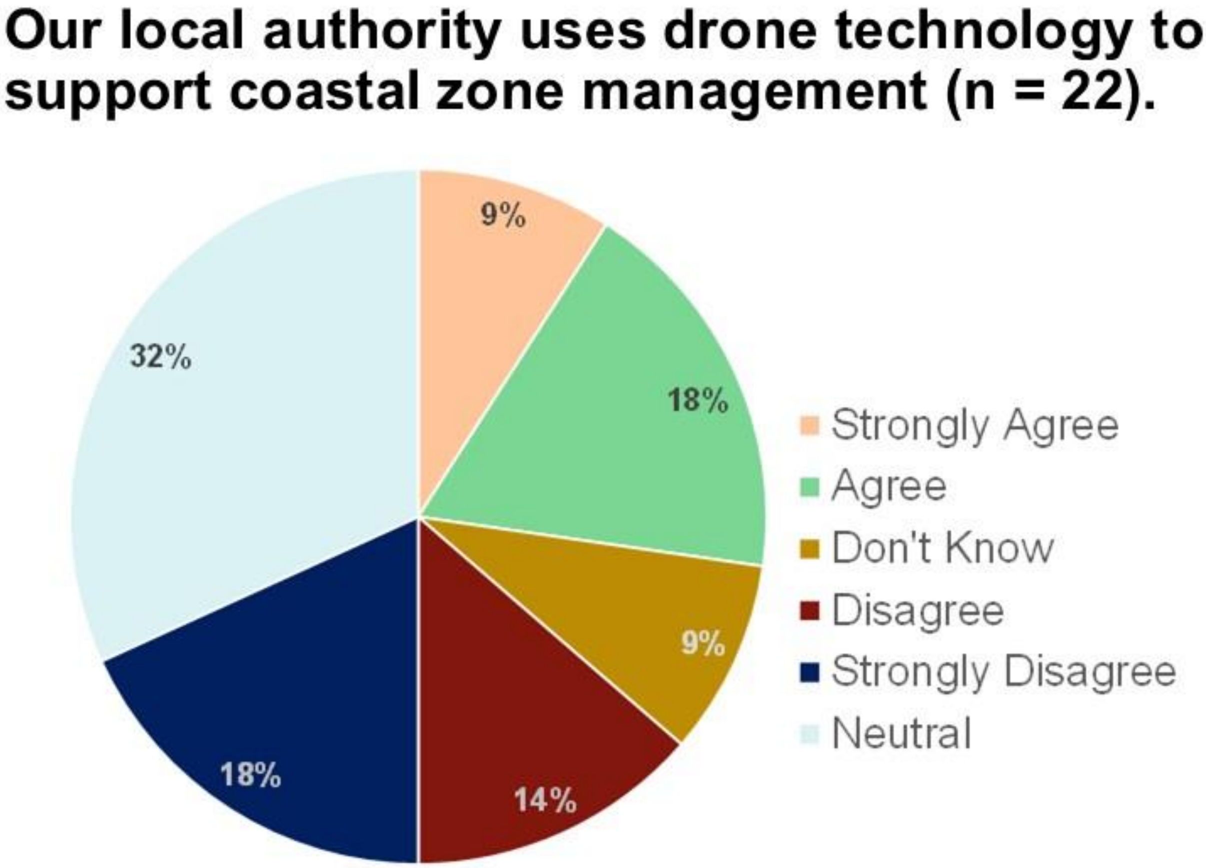

Figure 5: Local authority (that use drones) responses, regarding whether they use drones for coastal zone management

The survey showed that eight of the 30 respondents did not use or were not aware of the use of, drone technology within their LA. The majority of these (six) claimed that they had not considered drones or didn't think they would be of use. To address this, the next section will describe many of the coastal drone applications, how accessible they are and their relationship to many of the UN SDGs, based on an extensive literature review – hopefully demonstrating the broad utility of these tools. It is, however, encouraging to see that over two thirds of the respondents did use or were aware of drone use within their LA. That being said, 12 of the 22 LAs use contractors for all of their drone work – something that, while incredibly useful in many scenarios, can be costly and time intensive. This is particularly challenging when LAs could use drone technologies for emergency responses.

In addition to the drone applications discussed in the next section, this report will examine drone types, licensing and survey design, while also providing two examples of what can be achieved using simple, affordable, off-the-shelf drones and processing tools through two case studies – seaweed resources assessment in Clew Bay, Ireland, and digital documentation of built and natural heritage sites on Rathlin Island, Northern Ireland. It is hoped that this can highlight the ease and cost-effectiveness of doing in-house drone surveys to encourage local authorities to make use of these innovative technologies.

3 Applying Drone Technology – Practical Steps

Utilising drone technology is underpinned by several decision-making steps. The four practical steps include 1. drone applications, 2. drone technology and tools, 3. training and licensing, and 4. survey design. Each of these steps comes with a number of questions local authorities may ask themselves before using drone technologies. Figure 6 illustrates the four overarching steps and some of the key issues that need to be addressed in each step. The below sections will detail some of the issues.

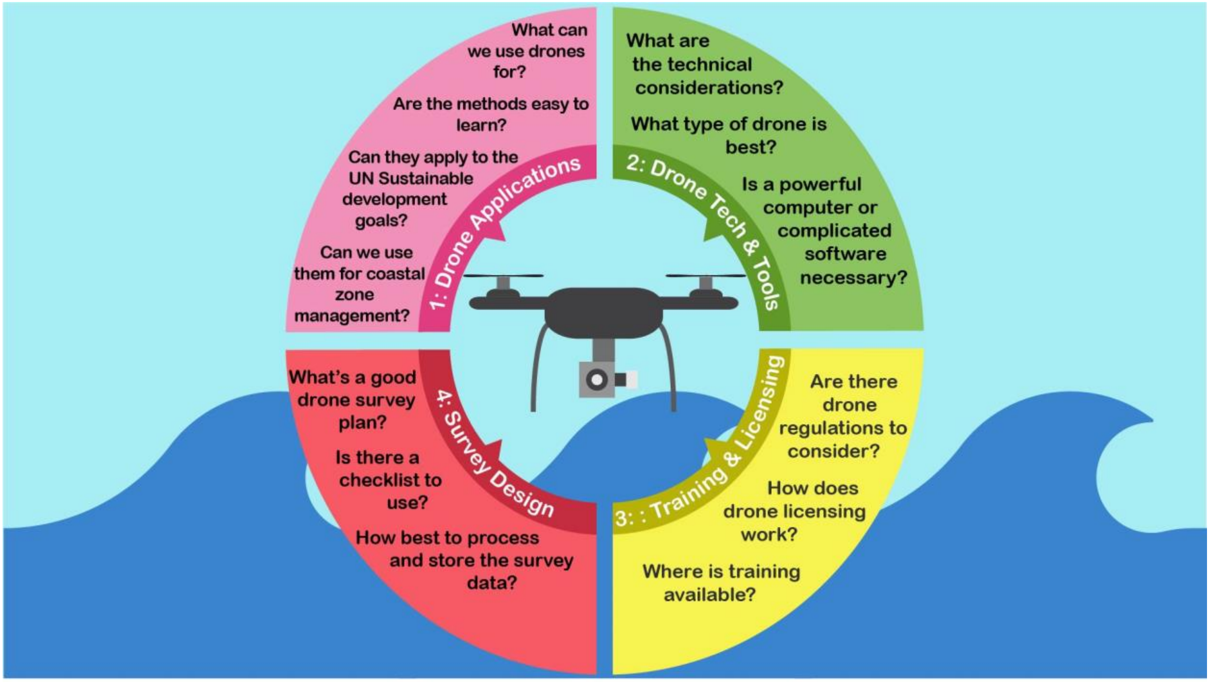

Figure 6: Basic steps and the questions that often arise when considering the use of drone technology

3.1 Drone Applications: Using Drones for the Sustainable Development of Coastal Zones

The range of coastal applications to which drones can be applied is already broad and is rapidly growing. The flight times have increased, capabilities expanded and tools and software capable of handling drone imagery has proliferated, allowing drones to become key technology for integrated coastal zone management (ICZM). Further, Kandrot *et al.,* (2021) found that drones could contribute to ten of the 17 United Nations sustainable development goals through activities such as capturing media for promoting tourism, post-storm damage and cost assessments, habitat mapping, detection of illegal fishing, pollution monitoring and much more (Figure 7).

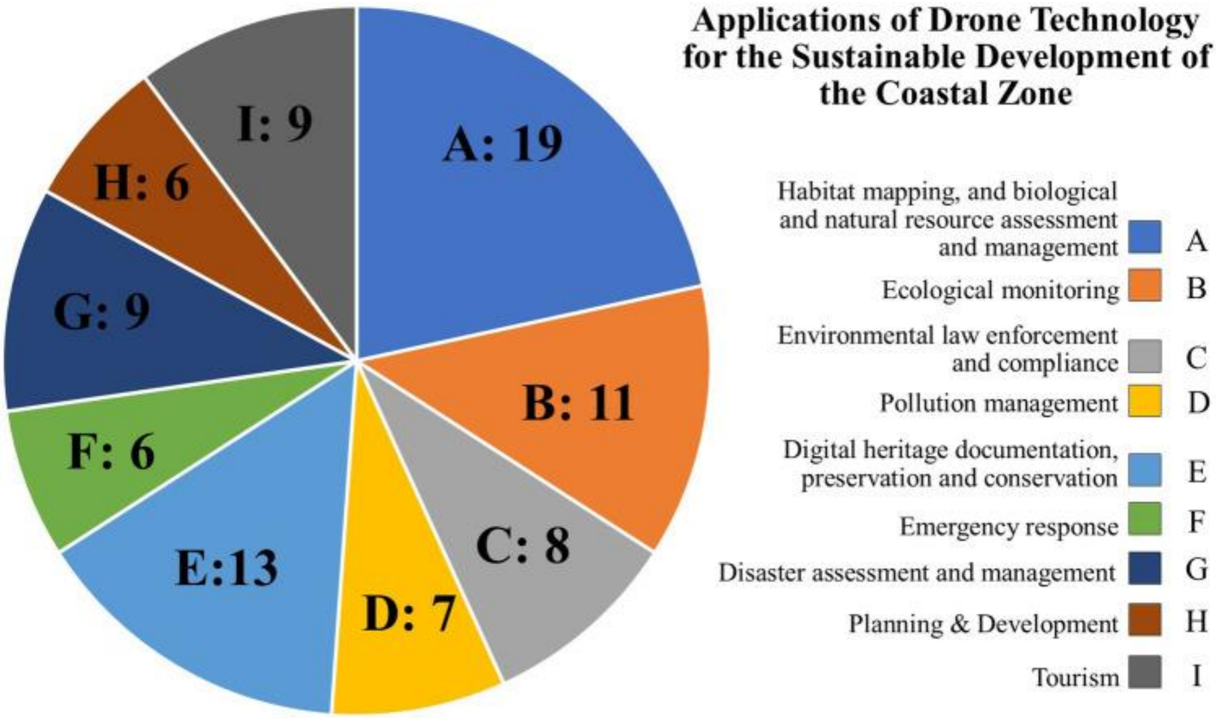

Figure 7: Drone coastal sustainability application areas and the number of studies conducted within each application area as found in Kandrot et al., (2021)

In Kandrot *et al.,* (2021), nearly 90 drone studies were reviewed and their applications categorised in terms of their cost, ease of use and maturity (how well established the methods are), to provide an overall assessment of how accessible different drone application areas are for coastal managers, where the higher the score, the more accessible they are (Table 1). Many application areas are highly accessible, using cheap drones and well established (mature) methods that are easy to learn and employ. These are most common in areas such as tourism, environmental law enforcement and compliance, and digital heritage documentation, preservation and conservation (Figure 8). On the opposite end, areas such as pollution management, and disaster assessment and management are slightly less accessible. This can be due to expensive drones or drones that are custom designed and built, requiring additional expertise and a large budget. Furthermore, the processing and analysis of some drone captured can require additional training and expertise, making some applications less accessible for local authorities. All that being said, each application area has examples that rate highly in terms of accessibility, showing that there are accessible drone survey options that can be employed across a large range of applications. Much more information on coastal drone applications can be found in Kandrot and Holloway (2021) and Kandrot *et al.,* (2021).

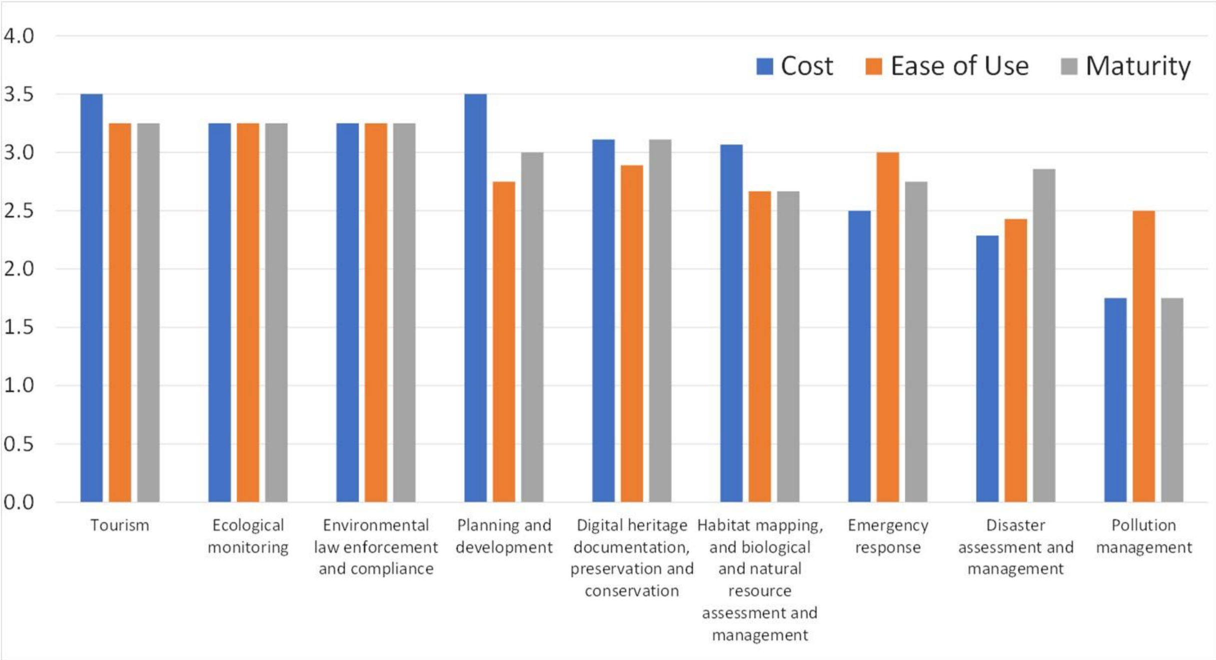

Figure 8: The different drone coastal sustainability application areas and their accessibility ratings in terms of (blue) cost, (orange) ease of use and (grey) maturity

Table 1: Criteria and descriptions used in assessing the cost, ease of use and maturity of drone applications. Adapted from Kandrot et al., 2021

RATING	COST	DESCRIPTION	EASE OF USE	DESCRIPTION	MATURITY	DESCRIPTION
4	Low	<€2,000	Very High	Simple off-the-shelf equipment for visual observation and simple tasks	Very High	Simple and commonly used tasks/equipment and a proven track record
3	Medium	€2-5,000	High	Some processing of imagery and advanced analysis but common software. Some more advanced sensors	High	Somewhat common, though less widespread with some mixed results
2	High	€5-20,000	Medium	Advanced image processing and use of a variety of different sensors. Larger more complex drones with custom elements	Medium	Partly experimental, but similar methods/equipment previously used in related projects
1	Very High	>€20,000	Low	Largely custom built or advanced equipment. Use of machine learning, AI and other advanced processing methods	Low	Mostly experimental/proof of concept for analysis and equipment

Given that numerous coastal drone applications are high accessible and have strong connections to the UN SDGs, there is great potential for LAs to begin or enhance their use of drone technology. The type of activity to which a coastal manager may wish to employ drone technology will come with many considerations, such as equipment, software, training and survey knowhow. These will be explored in the following sections, using the experience and knowledge gained as part of the COAST project thus far.

3.2 Drone Tech and Tools

While certain drone applications require little ancillary technology or software (such as taking pictures or videos to use for tourism), for many tasks related to coastal zone management, the technological element can involve much more than just the drone itself. To achieve cm scale accuracy when mapping with drones, for example, precise global positioning system/global navigation satellite systems (GPS/GNSS) devices are necessary to finely georeferenced objects or markers in the survey area. Similarly, for creating high-resolution digital models using structure from motion (SfM) photogrammetry, powerful computers may be necessary to avoid processing time running into multiple days or even weeks. This section will briefly describe some of the additional technological and software considerations related to drone-based surveying.

3.2.1 Drones

There are two main types of commercial drones (Figure 9):

A. Multi-rotor
B. Fixed wing

Multi-rotor systems are the most dominant within the consumer drone market. These systems have multiple motors each spinning propellors to provide lift. These types of drones have the ability to hover and offer the pilot fine control over their positioning. This is particularly advantageous when images of an object are required from multiple different angles, such as when creating 3D models using SfM or during infrastructure inspections. Multi-rotor systems range in price from a few hundred euros up to 10s of thousands of euros. The increased price brings additional features, such as longer flight times, the ability to carry heavy payloads with multiple or advanced sensors, more accurate GPS/GNSS, greater environmental resilience and more.

Fixed wing systems perform more like airplanes as the movement of air over the wings provide lift. They tend to be more costly than multi-rotor, with starting prices of over €10,000, but can be better suited to mapping large areas due to their higher speeds and longer flight times. Smaller fixed wing systems can be launched by hand, but larger models require runways or catapults to become airborne. With the added complexity, size and costs, fixed wing drones can be more difficult to fly, requiring additional training and expertise relative to multi-rotor systems.

There are a variety of different and less common drones. These include vertical take-off and landing (VTOL) systems, essentially a hybrid drone that uses propellors for take-off and landing, and fixed wings in flight. There are also flying submersibles, drones capable of operating both in the air and under water. These types of drones tend to be for more niche applications, are more expensive and require additional training. For most applications, multi-rotor and fixed wing drones are cheaper and more accessible. More information on drone types can be found in Kandrot and Holloway (2020).

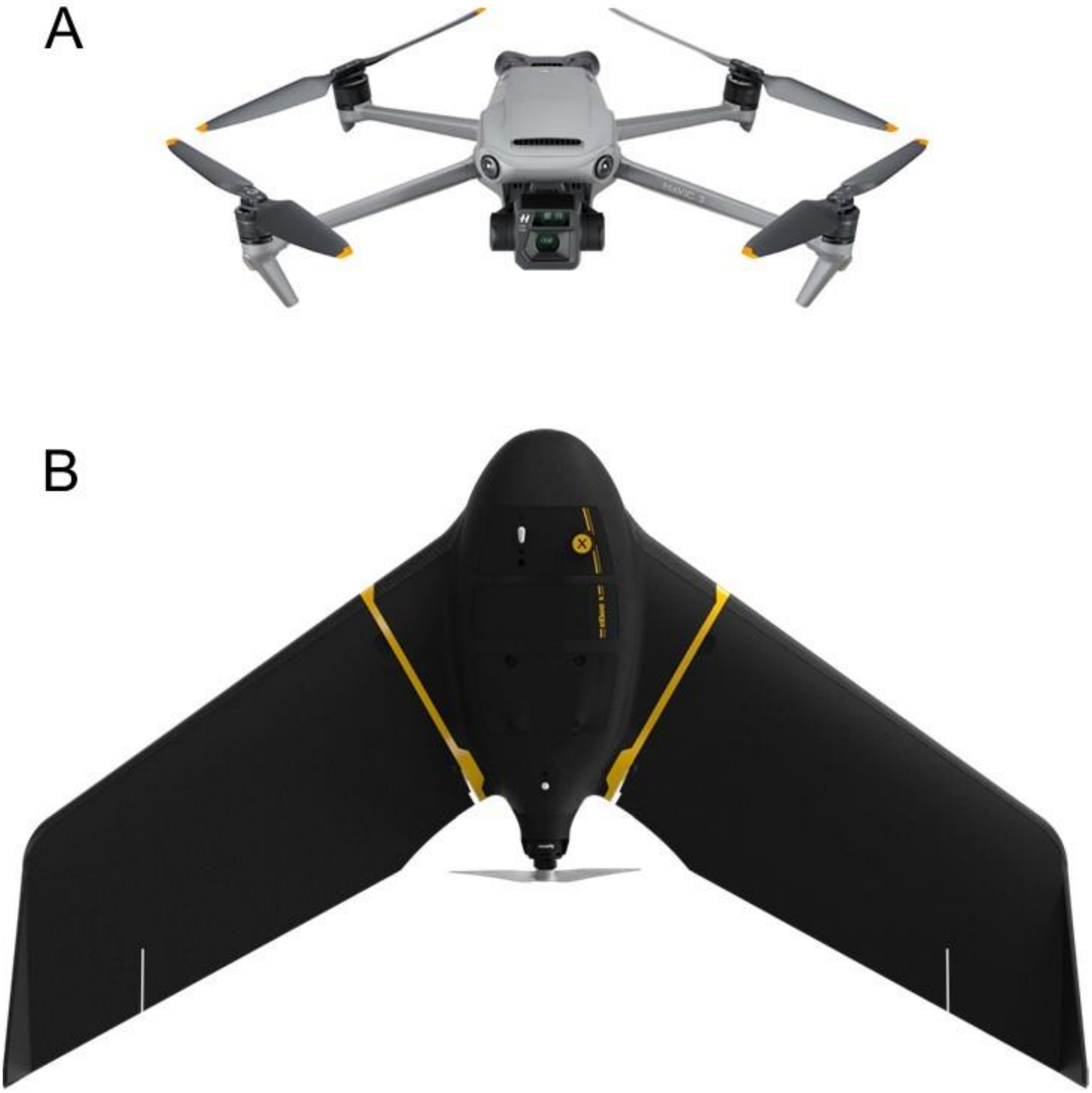

Figure 9: DJI Mavic 3 multi-rotor drone (A) and the Sensefly Ebee fixed wing drone (B)

Two case studies were carried out as part of the COAST project. The first, mapping seaweed cover in Clew Bay (Hayes *et al.,* 2021), used the DJI Mavic 2 Pro (https://m.dji.com/ie/product/mavic-2). The second case study, that involved creating digital models of two sites on Rathlin Island (Hayes, 2022), used the DJI Mavic Air 2s (https://www.dji.com/ie/air-2s). Both of these drones are consumer grade off-the-shelf systems costing under €1,200.

3.2.2 Hardware and Other Devices

Many drone applications require accurate georeferencing of the data captured, maps produced, or models created. This means that the positional or geometric accuracy of the final products are very high. While most modern drones come with in-built GPS/GNSS devices, these typically provide positional uncertainty of a meter or more. In order to get positional accuracy down to centimetres or less, additional devices such as real-time kinematic (RTK) GPS, are required. With an RTK system, markers or objects in the survey area can be accurately measured (Figure 10) and incorporated into the processing workflow, improving the positional accuracy of the final outputs. These devices can often cost over €10,000 and require additional training but are a worthy investment where survey outputs require fine positional accuracy.

Some of the processing of drone imagery can be intensive, such as SfM photogrammetry. The complex processes associated with constructing 3D models from potentially thousands of high-quality photos requires powerful computers to avoid processing time spanning weeks. For large projects, it may be worth considering investment in powerful computers with dedicated graphics cards, otherwise compromises will have to be made on the detail and accuracy of the outputs. For agisoft metashape, the most popular SfM software, a modern 4 to 8 core CPU, at least 16 GB of RAM and a dedicated graphics card are recommended for a basic set up (https://www.agisoft.com/downloads/system-requirements/).

Figure 10: An example of RTK set up and measurements from Zhang et al., (2019)

3.2.3 Software

Different software options are available at all levels of a drone survey, from data capture to processing and final analysis and editing.

Most drones will come with software that can be used on a phone, tablet or computer to control the drone, operate the camera/sensor and store the captured data. Some will allow for flight planning and automation of the survey flight and camera operations (Figure 11), but this option is not always available for cheaper drones. Third party apps can offer a broader range of capabilities, but at an additional cost. For photogrammetric operations (such as mapping and SfM), flight automation can improve the efficiency and repeatability of surveys by allowing the survey details to be saved and repeated, ensuring consistent and comparable data capture over time. Factors such as drone compatibility, flight features, cost and ease of use should all be assessed when considering what app is best suited to your survey needs.

Figure 11: Screenshot showing the DJI Pilot PE flight plan from Clew Bay (Hayes et al., 2021)

Depending on the types of survey and output requirements, a range of software options are available. To create digital 3D models or to combined multiple photos into one consistent, larger image, SfM photogrammetry software is required. Agisoft metashape (https://www.agisoft.com/) was used for the case studies (Figure 12) in this project (Hayes *et al.,* 2021; Hayes, 2022), but other options are available, such as ESRI's Drone2Map (https://www.esri.com/en-us/arcgis/products/arcgis-drone2map/overview), Pix4D (https://www.pix4d.com/) or free, open source software such as Open Drone Map (https://www.opendronemap.org/).

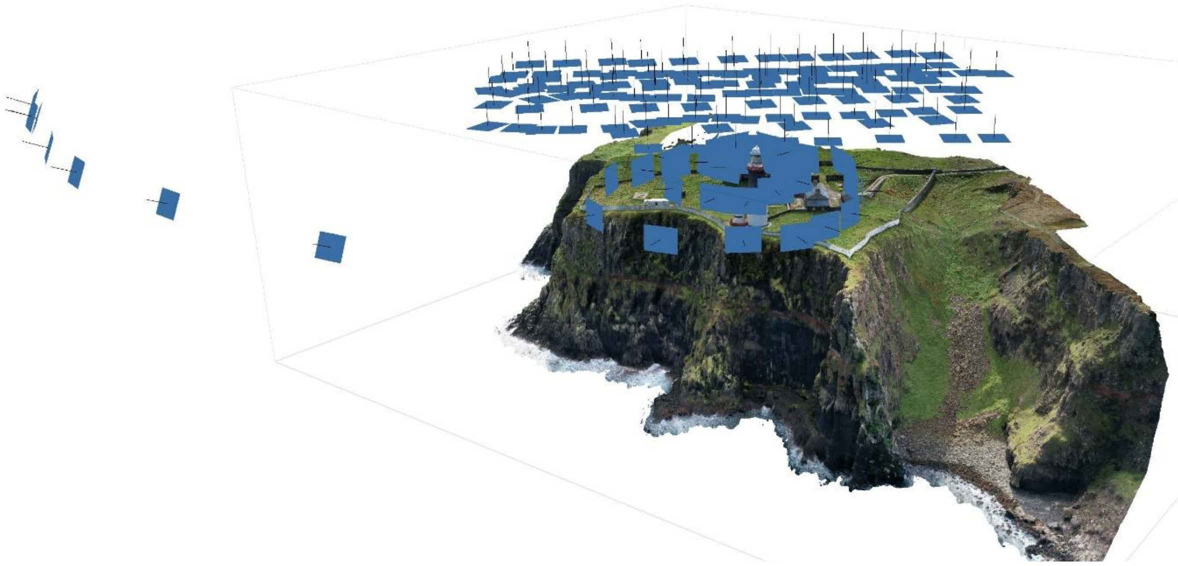

Figure 12: Digital model and drone camera positions and orientations for the East Lighthouse compound on Rathlin Island

A lot of processing and analysis will also occur within Geographical Information System (GIS) software (Figure 13), such as ArcGIS (https://www.esri.com/en-us/arcgis/products/index) or the free, open source QGIS (https://www.qgis.org/en/site/). GIS software can perform various forms of analysis (change detection, classification, combination with other data types such as vector) and are great for creating final products, such as finished maps. Remote sensing software has a lot of overlap with GIS software but is specifically designed with processing and analysis of satellite imagery. For data captured that extends beyond visible light (such as near infra-red or thermal), remote sensing software can offer options and speed of processing that exceed more general GIS programs. Some examples include ENVI (https://www.l3harrisgeospatial.com/Software-Technology/ENVI) and Open Drone Map (https://www.opendronemap.org/).

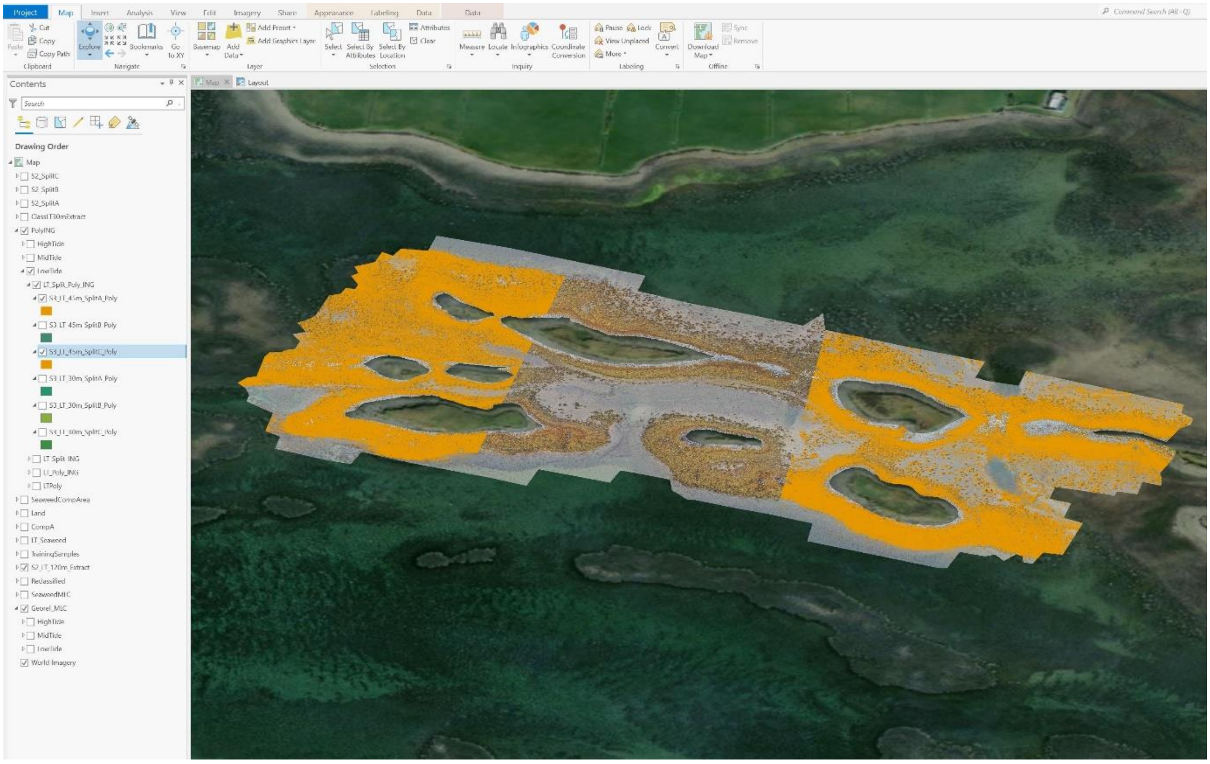

Figure 13: A partially classified seaweed map from Clew Bay, created using drone imagery within ArcGIS Pro

Finally, for editing of photos and videos there are also numerous options to choose from. The most common editing software for professionals is generally the Adobe creative cloud suite (https://www.adobe.com/ie/creativecloud.html), but many free alternatives to their software also exists, such as GIMP (free adobe Photoshop alternative: https://www.gimp.org/) or Shortcut (free Premiere Pro alternative: https://shotcut.org/).

More information of software can be found in Kandrot and Holloway (2020).

3.3 Training and Licensing

Drone regulations within the EU are dictated by the European Union Aviation Safety Agency (EASA). Regulations in the UK largely mirror that of the EU, but it is possible that these will diverge over the coming years. Within the EASA framework, any drone that is not classified as a toy (less than 250g and without a camera) requires the operator to obtain an appropriate license. Many drone operations are considered low risk and fall under the purview of the open category licenses, which can be split into three further sub-categories, the details of which can be seen in Table 2:

- A1: Can fly over people but not large groups
- A2: Can fly near people
- A3: Must fly far from people

Table 2: Current open category license requirements and regulations from EASA)

UAS	Operation		Drone operator/pilot		
Max weight	**Subcategory**	**Operational restrictions**	**Drone operator registration**	**Remote pilot competence**	**Remote pilot minimum age**
< 250 g	A1 (can also fly in subcategory A3)	— No flight expected over uninvolved people (if it happens, overflight should be minimised) — No flight over assemblies of people	No, unless camera / sensor on board **and** the drone is not a toy	— No training required	No minimum age
< 500 g			Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*
< 2 kg	A2 (can also fly in subcategory A3)	— No flying over uninvolved people — Keep a horizontal distance of 50 m from uninvolved people	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Remote pilot certificate of competency' for A2 'open' subcategory	16*
< 25 kg	A3	— Do not fly near or over people — Fly at least 150 m away from residential, commercial or industrial areas	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*

For more risky drone operations, such as flying out of visual line of site (VLOS), over urban areas, near airfields or above the 120 m elevation limit, to name some risk factors, more advanced licenses are required. This may be a specific category license, for activities that fall outside of the open category and so requires additional elements to be satisfied, such as carrying out risk assessments and securing approval from the local aviation authority. Certified category licenses are intended for the highest risk activities, such as international drone cargo transports, and requires additional steps and certification to be eligible. While the open category license requires a simple online test to acquire, the other licenses will require additional elements carried out with an instructor that's been approved by your national aviation authority, the details of which depend on the particular drone application and license requirements. Further details can be found in Giannoumis (2021) and at EASA (2021).

3.4 Survey Design

The survey design includes several steps necessary to ensure a safe drone operations. Careful planning will improve all phases of a drone survey, from clearly identifying all prerequisites needed to conduct the survey, to appropriate analysis and General Data Protection Regulations (GDPR) compliance. Much of this can be achieved by following some basic principles as outlined in Figure 14.

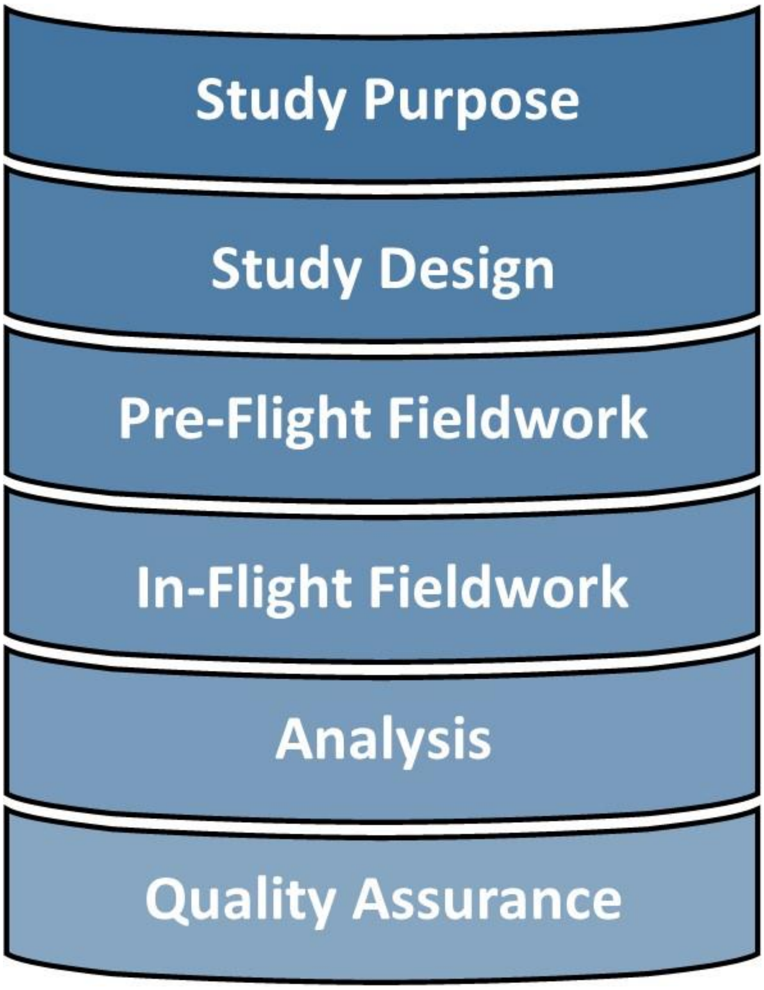

Figure 14: Simple survey design workflow from Hayes et al., (2021)

Study Purpose: Gather information of the topic of study to gain a basic understanding. Consult experts, stakeholders and potential end users to identify any knowledge gaps, needs or opportunities that can be filled. Formulate the end goals of survey outputs and familiarise yourself with the tools needed and the necessary training and licensing.

Study Design: Choose a region to conduct the survey and figure out the specific sensors and flight parameters needed (area to cover, flight height, speed, media type, etc). Select the correct equipment, hardware and software for the task. Ensure you have an appropriate license and training for the survey, analysis and outputs.

Pre-Flight Checks: Make sure to assess the survey area to determine any legal issues such as privacy concerns, obstacles, hazards, flight restricted areas and to find an ideal landing and take-off zone. Determine the flight parameters needed to plan and automate the flight, and place and/or georeferenced ground control points if needed. Monitor the weather conditions to ensure a safe flight (light winds and no precipitation).

In-Flight Checks: Ensure that flights are conducted in accordance with the local aviation authority regulations and within the limits set by your license. Make yourself and the landing/take-off areas visible and make sure to take detailed survey notes, such as drone used, battery conditions, weather, flight time, etc.

Analysis: Make sure the data are well organised and backed up as soon as possible. Use the appropriate software and tools to process and edit the data as needed, keeping in mind the desired outputs and end users. Meticulously document the steps taken so that it can be easily reproduced.

Quality Assurance: Back up all the outputs and store large files in a data repository if possible. Ensure all GDPR regulations are followed, such as removing any identifiable information from the outputs. Follow the Infrastructure for Spatial Information in the European Community (INSPIRE) directives where possible.

Each survey will have its own particular nuances that can't be covered by general guidelines but making the effort to properly plan and conduct your surveys will always prove beneficial. Further details on survey design can be found it Giannoumis (2021) and Tmušić *et al.,* (2020). The two case studies (Hayes et al., 2021; Hayes, 2022) also provide practical examples of the drone survey procedure, with step-by-step examples of the data collection, processing and analysis. The first case study involved mapping seaweed coverage in Clew Bay, Co. Mayo, Ireland with the DJI Mavic 2 Pro. It shows the flight planning (with a check list - Appendix A), data collection, processing of the imagery into classified seaweed maps the comparison of seaweed coverage based on flight height and tidal conditions. The second case study provides an additional step by step guide, describing the creation of digital models of a geological feature and a lighthouse compound on Rathlin Island, Co. Antrim, Northern Ireland, with the DJI Air 2s. These can both act as examples and overviews of the various steps involved in carrying out two different types of drone surveys.

3.5 Applying Drone Technology: Overview

While there is a lot to consider starting out, breaking drone surveys down into four categories (1. applications, 2. drone tech and tools, 3. training and licensing, and 4. survey design) can simplify the process and help focus on the necessary steps and considerations.

Figure 15 is an update of Figure 6, moving from the general questions to the specific options and considerations in each of the four areas.

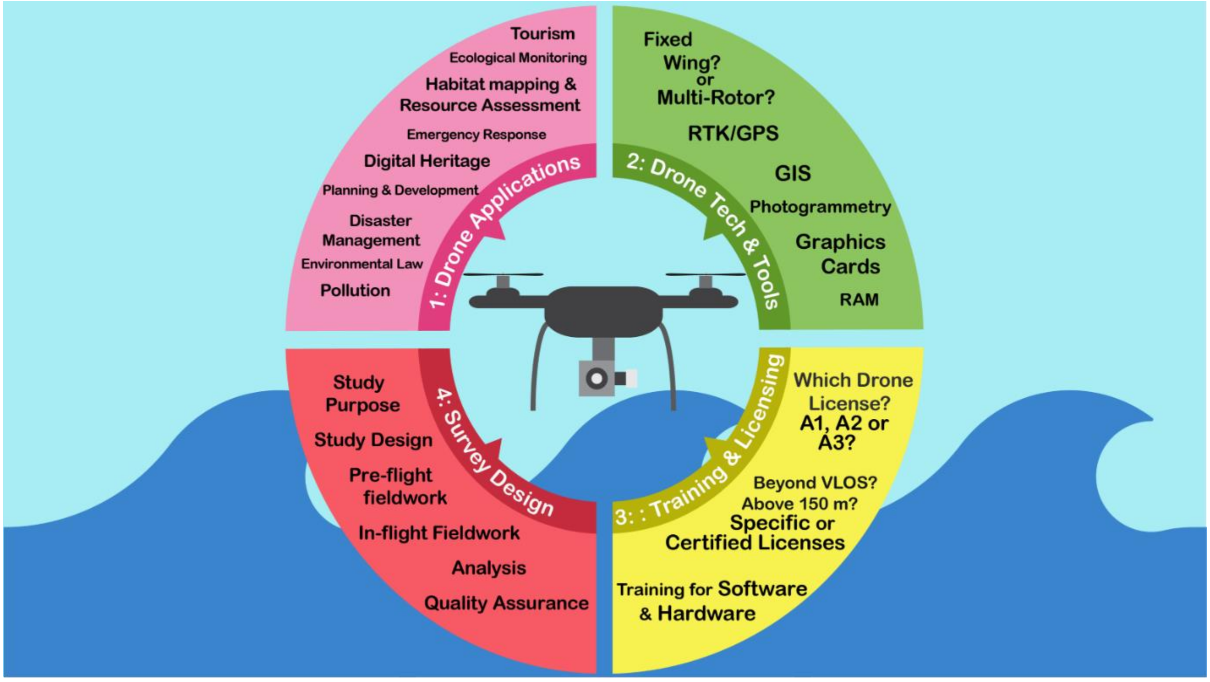

Figure 15: An updated version of Figure 6, with more specific considerations for carrying out drone-based survey work

3.6 Applying Drone Technology: Clew Bay

Application: Habitat mapping and resource assessment – To show how simple drones and standard software and processing can be used to successfully map seaweed coverage at high spatial resolutions

Drone Tech and Tools: A simple off-the-shelf multi-rotor drone, the DJI Mavic 2 Pro, with free flight automation software (DJI Pilot SE). Use Agisoft Metashape to combine drone photos into single large images for each survey and ArcGIS Pro to analyse them and extract seaweed coverage data (Figure 16).

Training and Licensing: The task requires only an A1/A3 license, obtained through an online exam with the Irish Aviation Authority. Experience and training had already been obtained in both Agisoft Metashape and ArcGIS Pro, so no training necessary

Survey Design: Map seaweed while also assessing the influence of tidal conditions and drone flight height. Select three primary test sites based on information from low resolution seaweed maps, then site visits to ensure seaweed presence and accessibility, and to minimse hazards and privacy concerns. Survey each site at three tide levels (low, medium and high) and five flight heights (30 m, 45 m, 60 m, 90 m, and 120 m). Three weeks of fieldwork to conduct surveys and minimise disruption from poor weather. Generate seaweed maps from each individual survey and compare and contrast their spatial coverage (Figure 17).

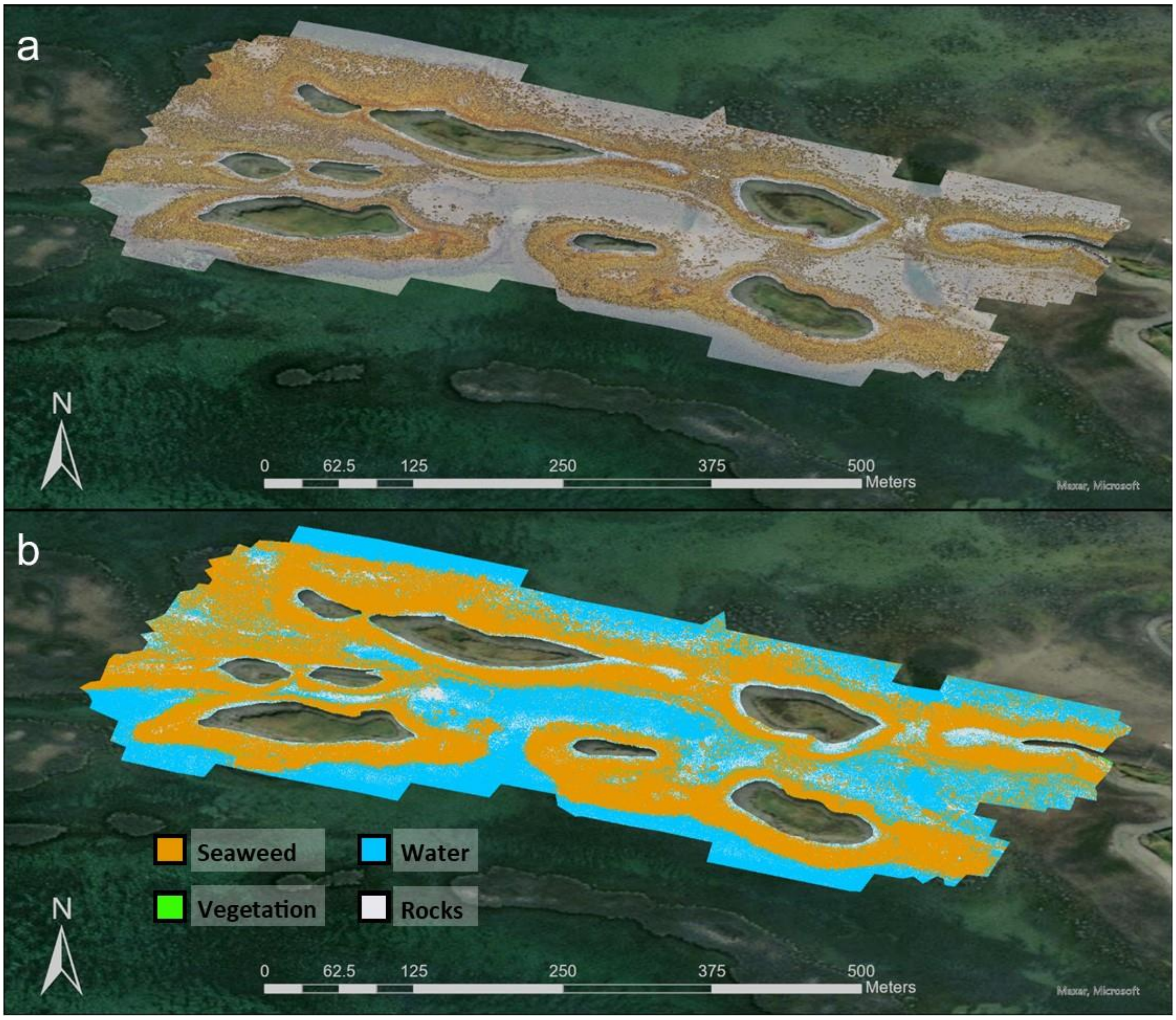

Figure 16: (a) Drone based high resolution image of a seaweed survey site in Clew Bay with the island clipped out and (b) a classified version of the image showing seaweed, vegetation, water and rocks.

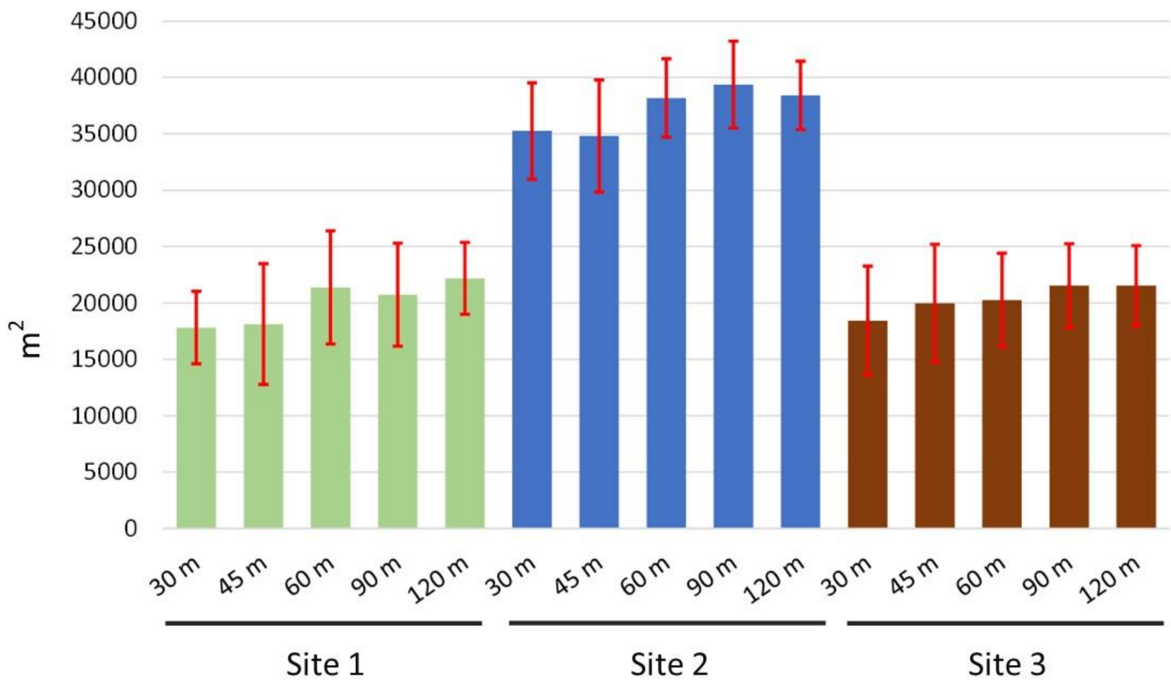

Figure 17: Seaweed coverage (bars) and standard deviation (red) from the three main Clew Bay survey sites at each of the five drone survey heights

3.7 Applying Drone Technology: Rathlin Island

Application: Protection and preservation of natural and built heritage sites – To show how simple drones and standard processing methods can be used to create 3D digital models of a natural geological formation and a lighthouse compound (Figure 18).

Drone Tech and Tools: Simple off-the-shelf multi-rotor drone, the DJI Mavic Air 2s. Use Agisoft Metashape to combine hundreds of images from each site into high-resolution 3D models

Training and Licensing: The task requires only an A1/A3 license, obtained through an online exam with the UK Civil Aviation Authority. Experience and training had already been obtained in Agisoft Metashape, so no additional training necessary

Survey Design: To create 3D models of both the East Lighthouse and the Doon Point geological site from drone photos. Permission sought and granted from the Commissioners of Irish Lights and the local landowners on Rathlin Island. Multiple field journeys planned to capture the needed data in Summer and Autumn 2021. Drone flown manually to capture both sites at variable angles and heights. Close up photos of important features for higher resolution modelling, distant and fewer photos of surrounding region for lower resolution. Combine high- and low-resolution models within each site for two complete models.

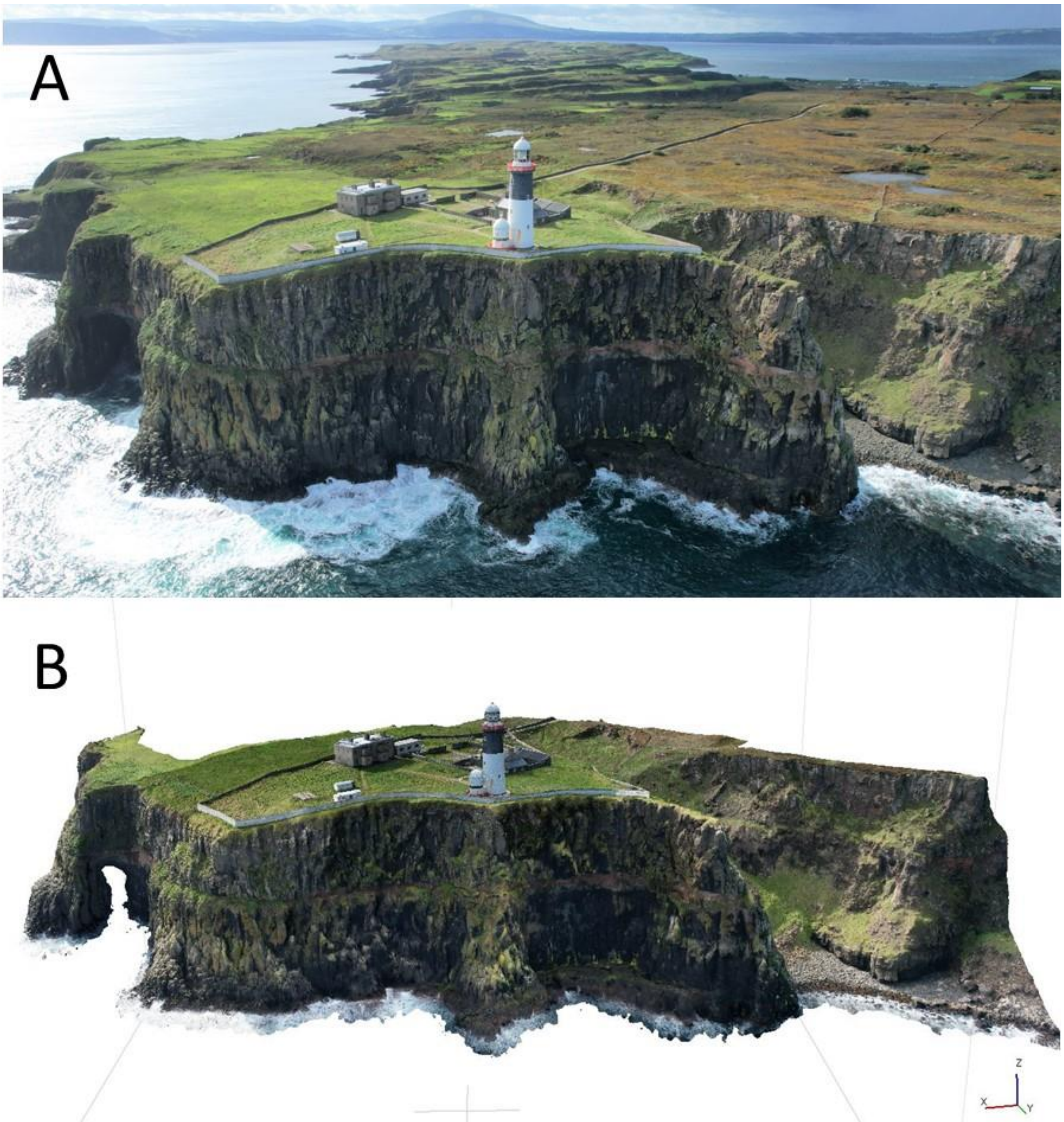

Figure 18: A comparison of the East Lighthouse on Rathlin Island as seen by (A) drone and (B) the SfM based digital model

4 Recommendations

Coastal regions are under serious threat and require immediate attention to ensure their sustainable development, and the preservation and protection of their natural and cultural heritage sites. The aim of the COAST project was to bring together a suite of tools to assist coastal managers in the decision-making process in how to sustainably develop their coastal regions. The following sections outlines recommendations for coastal managers and regional decision-makers to aid in identifying potential ways forward in utilising innovative solutions, such as drone technologies, to support the sustainable development.

4.1 Identify urgent needs on a short-term, mid-term, and long-term perspective

- Drone technologies can be applied in a wide range of contexts, including coastal management, environmental and ecological monitoring, digital heritage and tourism. Thus, coastal managers should identify potential regional specific opportunities in how drone technology can be used to support the sustainable development in their region.
- Drone technology is evolving rapidly, coastal managers should invest into adaptive strategies that ensure the maximisation of using drone technologies to meet regional needs.

4.2 Identify regional specific capacities and opportunities

- Coastal managers should invest into in-house training to ensure local knowledge and know-how in using drone technology over time. This way, local authorities would maintain the knowledge in-house and can therefore respond quicker to emergency responses.
- In-house capacity would also allow long-term monitoring strategies whereby the same survey design could be used over time as this allows an in-depth understanding of temporal and spatial changes. This also ensures that the surveys produce the same or similar outputs that can be compared over time.

4.3 Targeted coastal community involvement

- Coastal regions are often remote and difficult to reach. Targeted approaches to include coastal community involvement could therefore ensure a vested interest from the community to use drone technology.

- Providing drone technology training to the local communities could also provide employment opportunities for example through marine resource mapping projects or digital heritage projects.
- Coastal communities may also be quicker to respond to potential changes in nature and may therefore provide local authorities and coastal managers with the most up-to-date information and data on the marine resources.

5 Conclusions

Drone technology is underutilised within local authorities. However, from photos and videos that can enhance tourist promotions, to digitally preserving important heritage sites with 3D models and thermal imaging for search and rescue operations, drone technology offers an ever-expanding range of opportunities that are reducing in cost and becoming much simpler and more accessible.

It is hoped that this report can provide an access point that allows local authorities to assess how drone technology can be of use to them, answer many questions that coastal managers may have regarding drone surveying and provide links to further readings for more in-depth investigations, and ultimately, to enhance coastal reliance and sustainable development.

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Appendix A - Flight planning check list

Flight Check List	
Batteries & Controllers Fully Charged	☐
Firmware & Software Fully Up to Date	☐
Adequate Storage for Survey Data	☐
Propellors Securely Fit	☐
Damage Free & Gimbal Protector Removed	☐
Operator ID Visible	☐
Adequate Backup & Storage for Survey Data	☐
Pilot in High-vis Clothing	☐
Take off/Landing Area Clearly Demarcated	☐
No Obstacles Obscuring VLOS	☐
Flight & Weather Details Recorded	☐
Notes	

Figure 19: Some essential pre- and in-flight checks when conducting drone surveys