Drone 4HER

SAVE THE HISTORIC GARDENS' HERITAGE USING DRONES

Drone4HER

Manual

How to use drones for gardening

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drone4her.eu

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The elaboration of the manual has been written by the partners of the Drone4HER project. The content of the manual was designed based on the needs analysis of the gardeners working in the historic gardens that was carried out as a previous phase of this project, so that it responded to what is expected by them and allowed for the adequate creation of the subsequent online course on how to use drones for historic gardens management and maintenance, contemplated within the Drone4HER project.

The Drone4HER project's partners would like to thank Mr. Lukasz Przybylak, acting president of the European Route of Historic Gardens, for his precious contribution to the introductory section of the manual, where he presents the current challenges of historic gardens maintenance and management.

The Drone4HER project's partners would also like to thank the specialists who have assisted in writing the manual as well as the European Route of Historic Gardens' managers and representatives who have provided pictures for the manual.

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1. Background and Innovation

1.1. Purpose and Scope of the Manual

The utilization of drones in historic gardens represents a groundbreaking innovation that seamlessly blends technological advancements with the preservation of cultural heritage. This innovative approach transcends traditional methods of garden management, offering a transformative way to monitor, protect, and showcase these cherished landscapes. By embracing drones, historic gardens adopt a forward-looking strategy that harmonizes technology and tradition, ensuring their legacy preservation for generations to come while adapting to the ever-evolving needs of the present. Additionally, the development process of the present manual itself is innovative, involving co-creation with historic gardeners and managers. By incorporating their insights and needs, the resulting manual and online course become tailored solutions, ensuring a symbiotic fit between the project's outputs and the expectations of the very users it aims to empower. This holistic approach seamlessly intertwines technological innovation with collaborative creation, fostering a dynamic transformation in historic garden preservation practices.

The purpose of this manual is to serve as a reference guide for the online course of the project. With that purpose, the manual provides detailed and practical content on how to integrate drone technology for the maintenance and management of historic gardens. Historic gardens, with their cultural significance and architectural beauty, require the gardeners to be able to use innovative solutions to overcome the challenges of preservation and sustainability. By harnessing the power of drones, gardeners and managers of historic gardens can efficiently address these challenges and ensure the preservation of these cherished landscapes for generations to come.

The scope of this manual covers various aspects related to drone operations in historic gardens. It begins with an exploration of the fundamental understanding of drones, including the types of drones available under the categories recommended for operation in historic gardens and their key components and features. Building upon this foundation, the manual goes through the practical implementation of drone technology in historic gardens.

The manual presents the development of new skills and competences specific to historic gardens to leverage drone technology effectively. This includes acquiring data from mapping flights, conducting thermography inspections, utilizing photogrammetry for accurate 3D models, and applying precision agriculture techniques for efficient gardening.

Safety and compliance are critical in any drone operation. Therefore, the manual provides guidelines for safe and effective drone usage, including legal requirements and regulations for operating drones over historic gardens. Additionally, maintenance and storage procedures are explored to ensure the longevity and optimal performance of drone equipment.

The manual highlights the benefits of using drones in historic garden maintenance, emphasizing their applications in water monitoring, health assessment, risk management, maintenance identification, and assessment of hard-to-reach areas.

Moreover, the manual explores the marketing potential of drones in historic gardens, providing tips for effective promotion and enhancing the tourist experience through drone technology.

Recognizing the importance of digital upskilling for the labor force, the manual and the online course provide innovative and digital learning resources for historic garden staff and emphasize the advantages of online learning.

By embracing drones' technology, gardeners and managers can enhance garden management and preservation, promote garden's historical significance, and foster a sustainable and thriving future for these culturally significant landscapes.

1.2. Challenges of Historic Gardens Maintenance and Management, by Lukasz Przybylak[1], acting president of the European Route of Historic Gardens

The challenges facing the restoration of historical gardens are increasing proportionately to social changes, including the development of tourism, but also legislative and environmental changes. The basic factor valorising the nuisance of a specific category of challenges in relation to contemporary restoration and management of garden heritage is the legal affiliation of the site. The form of legal ownership of a site is closely linked to the funding opportunities for care and conservation activities. In conjunction with public procurement law, it also has a direct (usually adverse) impact on the smooth implementation of conservation projects.

It has to be underlined as well that the time of the COVID-19 pandemics didn't pass without the influence on the management of historic gardens too. In fact, this global crisis has speeded the results of more than 50% of the historic gardens issues.

FIGURE 1
A historic garden's worker is fixing the ground

Source: Santa Clotilde Gardens

The group of major challenges identified today among the historic gardens and cultural landscapes can be divided into:

1. Methodological challenges,
2. Legislative challenges,
3. Technological challenges,
4. Administrative challenges,
5. Social challenges,
6. Environmental challenges,

The last ones include a group of factors with which garden heritage is confronted every day and every year in an increasingly violent way. Intensification of natural phenomena unfavourable for the substance of the historic gardens has been observed since at least the beginning of the current century, with particular intensity in the last decade.

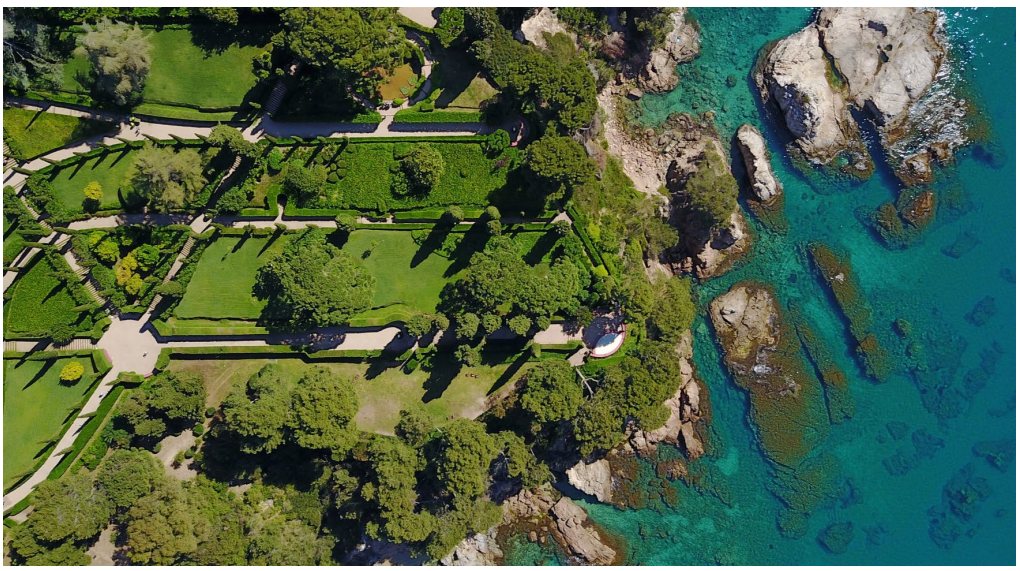
[1] Lukasz Przybylak is a PhD in Landscape Arquitecture, Chair of history of landscape architecture and preservation of garden monuments (Dresden Technical University). He is adviser on historical gardens to the Chancellery of the President of the Republic of Poland & Co-Founder of the Eduard Petzold European Centre for Garden Art.

The extent to which climate change is advancing (both globally and locally) means that actions to address these challenges can be divided into preventive and adaptive measures. It should be stressed, however, that the scale of changes affecting the natural environment (including historical gardens) redefines the concept of prevention. Prevention is no longer about preventing a phenomenon from occurring as a whole. It concerns the development of an efficient model of management in the field of minimizing (if it is allowed by the nature of the factor) the extent of the impact of the threat already identified within the boundaries of the garden on the other components of its layout and structure.

With prevention defined in this way, any tools to help area-based identification of phenomena that threaten historic gardens are invaluable. The use of remote-controlled drones, for instance, can serve as an example. Devices equipped with video and photographic instruments can be used, for example, to monitor the spread of visually identified flora diseases. Drones equipped with scanning devices can also be invaluable for more precise monitoring of the state of the vegetation as well as the identification of its specific characteristics.

Extensive historic gardens complexes located within the boundaries of dynamically developing urban agglomerations take on an additional role of a specific ecosystem reservoir. It gives the fauna and flora, naturally occurring in the area, a chance to survive. This, in turn, results in an increase in the level of conservation and nature responsibility, thanks to which the site, which is shaped according to the rules of garden art, must be partly adapted to the needs of plants and animals. The adaptation of the historic garden to the requirements of the natural environment should, however, take place with full respect for the historically documented layout and structural specificity of the site. In the context of the aforementioned factors, for example, the belief in the legitimacy of continuing to cultivate gardens representing the broadly defined Baroque style also needs to be redefined. These spaces are already unfamiliar to us not only in cultural terms (i.e. in terms of ceremonial, symbolism) but, in the face of contemporary challenges, are also natural-cultural phenomena impossible to maintain in the spirit of legendary authenticity.

FIGURE 2
Aerial view of Santa Clotilde Gardens in Spain



Source: Santa Clotilde Gardens

Global events in the first half of the 21st century demonstrate emphatically that we are facing a necessary revision of the current doctrine of dealing with historic gardens and cultural landscapes. The slogan 'sustainability' is no longer just a neat term to make conservation projects and plans more attractive. Conservation action in harmony with the natural world is now a duty and fulfilling it with

the support of high-tech technology and the simultaneous remembrance of traditional craftsmanship is a necessity.

1.3. Overcoming Challenges of Introducing Drones in Historic Gardens

1.3.1 Developing new roles in historic gardens

Developing new roles for drone operations in a historic garden can greatly enhance the efficiency and effectiveness of the drone program. With specialized expertise and site-specific considerations in mind, these new roles ensure that the drone operations team is well-equipped to address the unique challenges presented by the garden's historical significance and architectural intricacies. By incorporating experts in historical preservation, cultural heritage, and other relevant fields, the team can conduct drone operations with a keen understanding of the garden's value and importance. These new roles contribute to more informed decision-making, improved data interpretation, and better integration of drone-captured content into preservation efforts and promotional materials. Ultimately, the addition of new roles strengthens the overall management of drone operations in the historic garden, enhancing its conservation, visitor experience, and appreciation of its rich cultural heritage.

To establish effective drone operations in historic gardens, several roles should be developed to ensure safe, responsible, and successful drone usage as shown in figure 3.

FIGURE 3[2]
Roles related to successful drone operations

Source: Project partner ERHG (2023)

- **Drone pilot**

Trained and licensed drone pilots are essential for operating the drone safely and capturing high-quality footage. They should be skilled in drone flight, navigation, and adhering to aviation regulations. The drone pilot is responsible for planning flights, ensuring proper drone maintenance, and operating the drone during filming.

[2]Drone U (2023, June 7). *Drone Pilot Jobs Guide: Exploring Opportunities for UAS Jobs*. https://bit.ly/3DutlM2
Pilot Institute (2022, January 25). *What Kinds of Jobs Can Drone Pilots Do?* https://bit.ly/3pYxxRr
DJI (2022, April 8). *Enterprise. Roles for drone operators across industries*. https://bit.ly/451Ti1l

- **Visual observer or camera/sensor operator**

When large drones are operated from the subcategory A3 of the European categorization system for drones, often it is necessary to have more than one person operating the drone. Even if it is not needed legally, but in terms of safety and quality control, it is a better practice. Moreover, many commercial drones support dual-control mode where a second pilot can operate cameras and sensors while the other pilot focuses on flying.

- **Safety officer**

A safety officer oversees the drone operations to ensure compliance with safety protocols and regulations. They monitor the flight area, manage crowd control during drone operations, and take necessary precautions to minimize risks to visitors, garden structures, and the drone itself.

- **Videographer and editor**

A professional videographer and video editor are responsible for producing high-quality marketing materials using the drone footage. They will handle post-production work, including editing, color correction, and adding music or narration to create captivating marketing videos.

- **Legal and regulatory compliance officer**

This role ensures that all drone operations comply with local and national regulations governing drone flights. They handle obtaining necessary permits, permissions, and any required clearances for drone operations in historic gardens.

Besides these roles, there will be need of a person responsible for public relations and marketing aspects of the drone operations. This person will ensure that the captured footage aligns with the garden's branding and messaging and oversee the dissemination of promotional materials featuring the drone-captured content. This new role is called Communications Coordinator.

Also, to study images from drones for inspecting structures in historic gardens, reading vegetation mapping, thermography and photogrammetry data, there are additional roles that need to be created in historic gardens. Figure 4 presents these additional roles that are explained below.

- **Civil engineer**

A civil engineer can assist in evaluating the building's foundation, drainage systems, and overall site conditions.

- **Remote sensing specialist**

A remote sensing specialist is skilled in analyzing data collected from aerial or satellite sensors, which provide the raw imagery used for vegetation mapping. They understand the technical aspects of the sensors and the process of image acquisition.

- **Thermographer or an infrared thermography expert**

The specialist who reads thermography data from drones. These experts are skilled in capturing and interpreting thermal images using infrared cameras and sensors to analyze temperature variations in objects, surfaces, or environments.

- **GIS analyst**

A Geographic Information System (GIS) analyst is responsible for processing and organizing the vegetation mapping data within a GIS platform. They create maps, analyze spatial patterns, and interpret the vegetation data in a geospatial context.

- **Drone 3D modeler or mapper**

This specialist is responsible for creating 3D maps and models from high resolution images received from a drone using a special photogrammetry software platform.

- **Data analyst**

A data analyst plays a crucial role in processing and interpreting the raw data collected for vegetation mapping. They perform statistical analyses, evaluate the accuracy of the data, and generate reports based on their findings.

- **Landscape architect**

A landscape architect contributes their understanding of landscape design and planning principles to interpret the vegetation mapping data in the context of the garden's layout and overall aesthetics.

- **Conservation biologist**

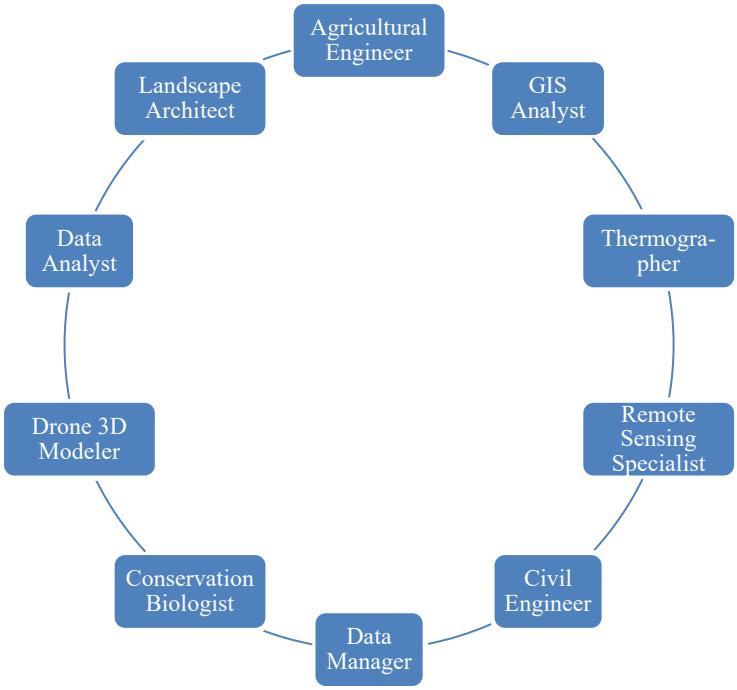
A conservation biologist provides insights into the ecological significance of different vegetation types and their importance in supporting biodiversity and habitat conservation efforts.

- **Data manager**

The data manager handles the storage, organization, and security of the drone-captured footage and associated files. They ensure that data is backed up and easily accessible for future marketing or research purposes.

FIGURE 4

Main roles related to data analysis and interpretation of drone operation in historic gardens



Source: Project partner ERHG (2023)

By developing these roles and assembling a competent and coordinated team, historic gardens can implement drone operations in a manner that showcases their beauty and cultural significance while prioritizing safety, preservation, and compliance with regulations.

1.3.2 Addressing the lack of digital skills among gardeners

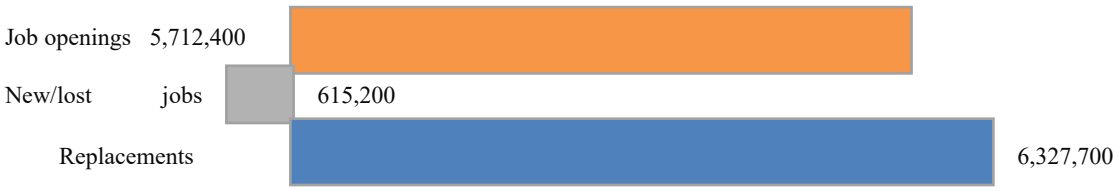
Automation, technology, climate change, and the green transition along with the coronavirus pandemic are reshaping the European labour market. There is an urgent need of creating specific professional roles, able to quickly bridge the gap between the application offered by new technologies and the traditional practices and methodologies. Gardening is one of these practices and gardeners need to be upskilled.

FIGURE 5
Use of drones in historic gardens

Source: Creative Commons copyrights free (2023)

As it can be seen in table 1, from 2018 to 2030, it is estimated that around 6.3 million people will leave their jobs as farmworkers and gardeners, and they will need to be replaced.

TABLE 1
Future jobs opening as farmworkers and gardeners (2018-2030)[3]



Source: Cedefop (2020)

This fall in employment is not as pessimistic as it might first appear. The upshot of this is that there will be around 5.7 million job openings that will need to be filled by 2030 and to be ready for these new jobs opening the gardeners needs to understand different technologies and be able to apply analytical methods and tools. For instance, just to name a few, gardeners need to know how to map and monitor water resources, and pest diseases, be able to apply precision irrigation and identify the risks through constant monitoring of the status of the historic gardens' vegetation and artefacts.

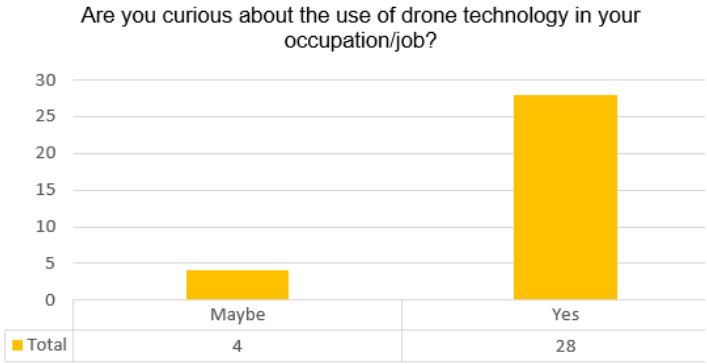
The results of the data collected from 32 gardeners, researchers and garden managers in the initial phase of this project provide a unique and realistic understanding of the gardeners' situation related to the new trend in the labour market and reveal a clear vision of the digital skills they need to deal with the challenges of a technology-driven world.

As it can be seen in tables 2 and 3, the results of the research show a high level of curiosity and interest among the 32 respondents in the use of drone technology.

[3] Cedefop (2020, January 30). *Farmworkers and gardeners: skills opportunities and challenges (2019 update).* https://tinyurl.com/4f2h5aj6

TABLE 2

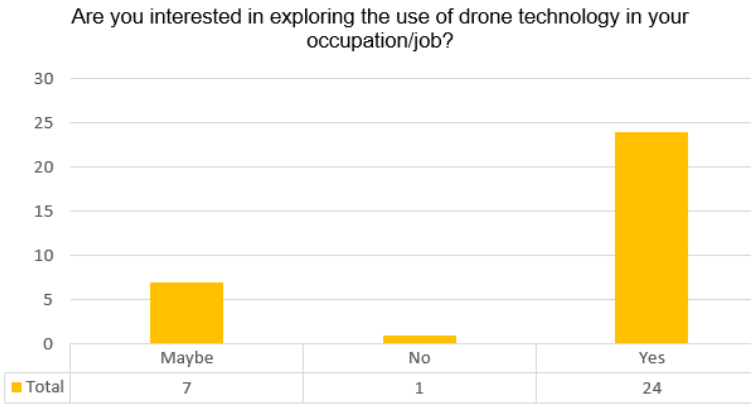
Level of interest in drone technology among gardeners[4]



Source: Project partner STC (2023)

TABLE 3

Level of interest in using drone technology



Source: Project partner STC (2023)

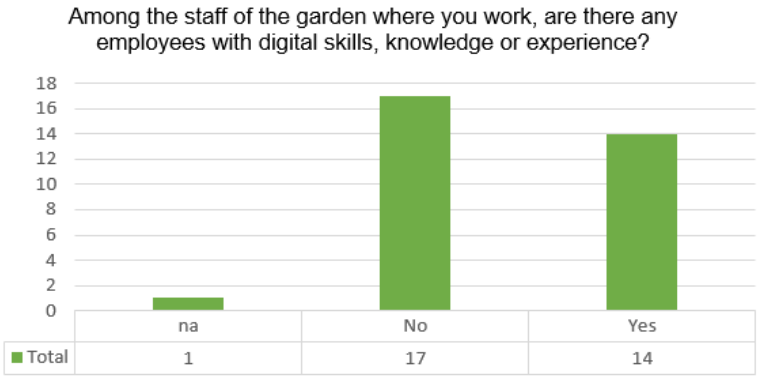
Additionally, the use of technical tools by the respondents was valued as essential and helpful in improving their work conditions and careers. On the contrary, there is a very low percentage of gardeners with digital skills and very few historic gardens are equipped with robotic tools and with humidity and temperature sensors. See table 4.

The data collected during the Drone4HER initial survey match most of the key facts identified by Cedefop [5] the European Center for the Development of Vocational Training and the last statistical data published by Eurostat where among the tasks and skills of farmworkers and gardeners are reported the skills related to the use of technology. See Table 5, where the use of ICT refers to the ability to understand and operate a wide range of technology software, and the use of machines refers to the ability to use machine and digital technology to collect data, take better decisions and be more creative and faster.

[4] Graph 4, 5 and 12: Laurelli C., Lizama Fuentes L.A., Lizama Gonzales J.M. & Moreno Garcia A.R. (2023). Drone4HER Mapping Analysis Report. Sviluppo Turistico Collodi, pp 7-12. https://tinyurl.com/mr2arrpp

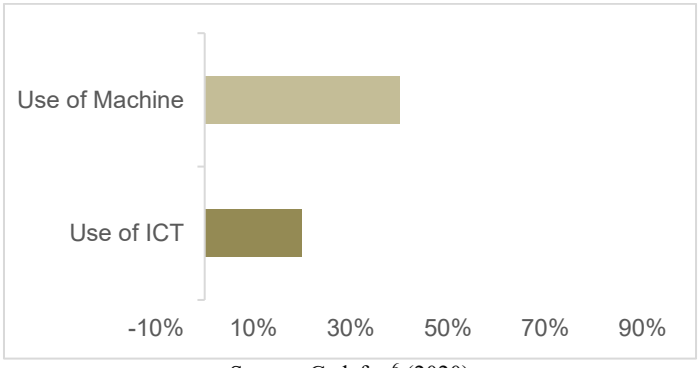
[5] Cedefop, *Digital, greener and more resilient: insights from Cedefop's European skills forecast*. Publications Office, 2021. *https://data.europa.eu/doi/10.2801/154094*

TABLE 4
Employees with digital skills among the staff of the garden



Source: Project partner STC (2023)

TABLE 5
Tasks and skills of farmworkers and gardeners related to the use of technology



Source: Cedefop[6] (2020)

To sum up, individuals and professionals working in the sector of gardening need to take into consideration these future trends, acquire digital skills and improve their confidence in the use of technology in their daily work.

FIGURE 6
Digital skills and technology needed in the sector of gardening

Source: Creative Commons copyrights free (2023)

[6] Cedefop (2020, January 30). *Farmworkers and gardeners: skills opportunities and challenges (2019 update).* https://tinyurl.com/4f2h5aj6

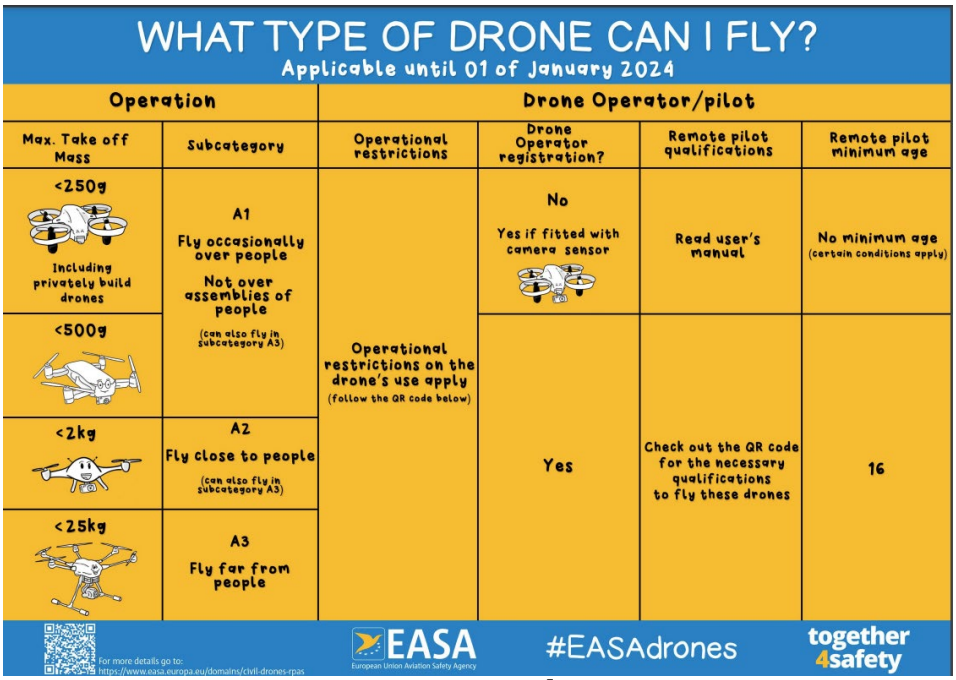
1.3.3 Staying up to date with legal requirements and regulations

Starting from January 1st, 2024, operations in the open category must be conducted either with a drone bearing a C0 to C4 class identification label or being privately built or even without class identification label but only if purchased before December 31st, 2023.

A transitional period applies until December 31st, 2023. Until that date, a special drone to operate in the 'open' category is not needed, provided it weighs less than 25 kg.

Depending on the actual weight of the drone, different requirements apply to operate them (see table 6). Privately built' means that a person built the drone for his/her own personal use; it does not refer to UASs assembled from sets of parts placed on the market as a single, ready-to-assemble kit.

TABLE 6
Type of drones allowed flying with A1-A3 license 01 January 2024



Source: EASA[7]

In table 7 we provide some resources where you can find information to stay up to date with legal requirements.

TABLE 7
Resources to stay up to date with legal requirements

Name	**Resource**	**Additional information**
How to operate drones in the open category in Europe	https://www.easa.europa.eu/en/domains/civil-drones/drones-regulatory-framework-background/open-category-civil-drones	After 01.01 2024, information on "How to operate drones in the open category" are available on this page.

[7] EASA. *What types of drones can I fly?* https://tinyurl.com/4ndckwp2

Latest news from EASA about drones' operations in Europe	https://www.easa.europa.eu/en/light/topics/drones?page=1a	For updates and getting notifications from EASA and EASA Light via email alert. EASA Light shares information also on operating a drone safely, in a sustainable and environmentally friendly manner and shows you how your privacy is ensured.
EASA Light – platform with information about safe drone operations	https://www.easa.europa.eu/en/light/topics/easa-light-stay-informed	Stay informed and up to date with EASA Light. This website is available in all the European languages.
EASA legislation news	https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu	Easy Access Rules for Unmanned Aircraft Systems (drones).

Source: Project partner STC (2023)

1.4. Benefits of Using Drones in Historic Gardens Maintenance

Using drones in historic gardens maintenance brings forth a number of benefits that significantly enhance the preservation and management of these culturally significant landscapes. One of the primary advantages lies in improved control and awareness of the garden's condition. Drones provide a unique bird's-eye view, allowing custodians and garden managers to assess the entire garden's layout, identify potential risks, and monitor changes in vegetation and structures over time. This enhanced perspective enables a comprehensive understanding of the garden's health and aids in making informed decisions for its long-term preservation.

Safety is paramount in historic gardens, and drones offer a non-invasive and safe means of conducting inspections and monitoring. By deploying drones for tasks such as structural assessments and tree inspections, personnel can avoid physically accessing potentially hazardous or hard-to-reach areas, reducing the risk of accidents and ensuring the safety of staff and visitors.

Additionally, the use of drones increases efficiency in responding to issues that may arise within the garden. Prompt data collection through drone flights provides real-time insights, enabling quicker detection and assessment of problems like leaks, pest infestations, or structural deterioration. With this timely information, garden managers can take swift action to mitigate risks and carry out necessary maintenance, preventing further deterioration and preserving the garden's integrity.
Moreover, drones aid in efficient management of resources and operations within the garden. By optimizing irrigation through aerial data analysis, gardeners can water plants more precisely, conserving water and promoting environmental sustainability. Drones equipped with thermography sensors can identify areas with uneven heat distribution, allowing for targeted heating or cooling measures to maintain an optimal microclimate for delicate plant species.

Furthermore, the use of drones enhances public awareness of the garden's cultural and natural significance. Captivating aerial footage and imagery from drone flights offer captivating marketing material, attracting visitors and fostering a deeper connection with the garden's history and beauty. By showcasing the garden from a unique perspective, drones contribute to promoting tourism and appreciation for these timeless landscapes.

Overall, the integration of drones in historic gardens maintenance optimizes control, safety, and efficiency, enabling informed decision-making, timely responses to issues, and sustainable management

practices. By leveraging this transformative technology, custodians can embrace a proactive approach to preservation, safeguarding these treasured landscapes for future generations to cherish and enjoy.

2. Understanding Drones

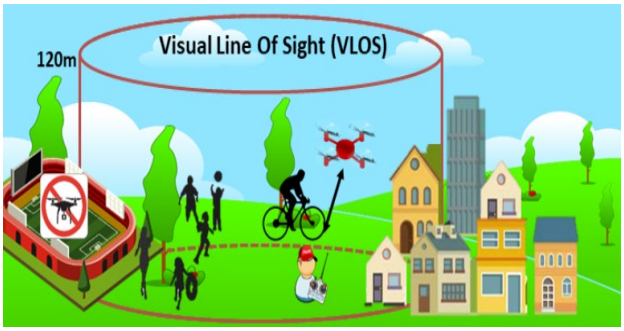
2.1. Types of Drones Recommended

The subcategories of drones that are recommended for operation in historic gardens are the ones that fall under the 'open' subcategories A1-A3, which are summarized following figures 7 and 8.

A1: Open category – Subcategory A1 can fly over people but not over assemblies of people. These drones are expected that no uninvolved person is overflown. In case of unexpected overfly over uninvolved persons, the remote pilot shall reduce as much as possible the time during which the unmanned aircraft overflies those persons.

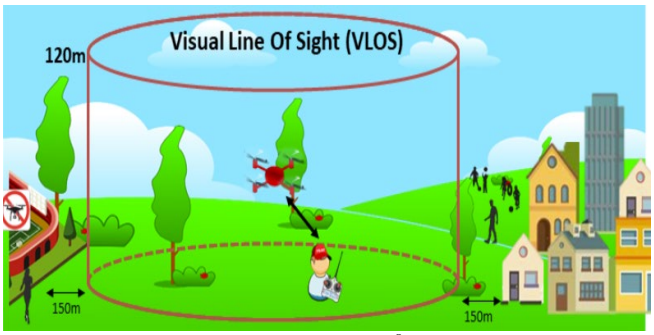
A3: Open category – Subcategory A3 can fly far from people. These drones can be conducted in an area where the remote pilot reasonably expects that no uninvolved person will be endangered within the range where the unmanned aircraft is flown during the entire time of the UAS operation.

FIGURE 7
Subcategory A1



Source: EASA[8]

FIGURE 8
Subcategory A3



Source: EASA[8]

Types of drones in the subcategory A1 [9]

In the subcategory A1 of the European categorization system for drones, the maximum takeoff weight is 250 grams or less. Drones in this category are typically lightweight and have a low level of risk to people on the ground. Below are the types of drones commonly available in this weight range and that can be used for management and preservation of historic gardens.

[8] EASA. *What are the requirements under the subcategories of the 'open' category?* https://tinyurl.com/mzv59y2c
[9] EASA. *Open Category - Civil Drones*. https://tinyurl.com/bddt52dj

Mini Quadcopters: These are small, compact quadcopters that are popular among hobbyists and beginners. They usually come with basic features, such as altitude hold, headless mode, and basic camera capabilities for aerial photography or video.

The average weight of Mini Quadcopters can vary depending on the specific model and its features. However, as a general guideline, Mini Quadcopters typically fall within the weight range of 100 grams (g) to 250 grams (g).

Some Mini Quadcopters may be at the lower end of this range, around 100 to 150 grams, while others may be closer to the upper limit of 250 grams. The weight of the drone is influenced by factors such as the size, construction materials, battery capacity, and additional features like cameras or sensors.

In table 8 we present some of the most popular drone models available in this category.

TABLE 8
Drone models available in the Mini Quadcopters subcategory[10]

Drone model	Description
Autel Evo Nano+	Autel Evo Nano+ is a small and a very affordable drone that has all the features of a more expensive drone in the same category. This drone features a very good quality of video with 8k resolution and it has an HDR imaging feature that increases the colors and the depth of the image.
DJI Mavic Mini	This compact drone from DJI is lightweight and portable. It features a stabilized camera for capturing photos and videos and offers flight features such as GPS positioning, altitude hold, and intelligent flight modes.
Ryze Tello	The Ryze Tello is a small and affordable drone that offers a fun flying experience. It comes with a 720p camera, stable flight controls, and programmable features. It's often used for recreational purposes and learning basic drone piloting skills.
Hubsan X4	The Hubsan X4 series includes various models, such as the H107L and H107D. These drones are small, agile, and suitable for both indoor and outdoor flights. They come with basic features like altitude hold, headless mode, and different flight modes.
Holy Stone HS series	Holy Stone offers a range of mini quadcopter models, such as the HS210, HS160, and HS170. These drones are compact and user-friendly, with features like altitude hold, one-key takeoff/landing, and various flight modes.
Syma X5 series	The Syma X5 series includes models like the X5C and X5SW. These drones are affordable and popular among beginners. They typically have a camera for aerial photography or video recording and offer stable flight controls.

Source: Project partner ERHG (2023)

Micro Quadcopters: Micro drones are even smaller than mini quadcopters. They are typically characterized by their small size and lightweight design. The average weight of Micro Quadcopters generally falls within the range of 20 grams (g) to 80 grams (g).

However, it's important to note that the weight can vary depending on the specific model, features, and components. Some micro quadcopters may be lighter, closer to 20 grams, while others might be slightly heavier, reaching around 80 grams.

The lightweight nature of Micro Quadcopters allows for increased agility and maneuverability, making them suitable for indoor flying and close-range outdoor flights. It's important to comply with local regulations and guidelines regarding drone weight and categorization, as they may vary based on the specific region or country.

[10] B&H. *The Best Mini Drones of 2023*. https://tinyurl.com/3ct4xfsz
Droneller. *7 Best Drones Under 250 Grams 2023*. https://tinyurl.com/mrpys82n

When considering purchasing a Micro Quadcopter, it's recommended to check the product specifications provided by the manufacturer to obtain accurate information on the weight of a particular model.

FIGURE 9
DJI Mavic drone from the Mini Quadcopters subcategory

Adobe Stock: Mashita

In table 9 we present some of the most popular drone models available in the Micro Quadcopters subcategory.

TABLE 9[11]
Drone models available in the Micro Quadcopters subcategory

Drone model	Description
Blade Inductrix	The Blade Inductrix is a popular micro quadcopter known for its durability and agility. It is often used for indoor flying and comes in various versions, including FPV (First Person View) options.
Eachine E010	The Eachine E010 is a small and affordable micro quadcopter suitable for beginners. It features a lightweight design, stable flight controls, and offers an enjoyable flying experience.
Tiny Whoop	The Tiny Whoop is a term used to describe micro quadcopters that are typically built on a Blade Inductrix or similar platform but modified and customized by enthusiasts. These drones are often used for indoor racing and acrobatic flying.
BetaFPV Meteor65	The BetaFPV Meteor65 is a popular micro quadcopter designed for indoor racing. It offers a lightweight frame, brushless motors, and customizable options to suit racing enthusiasts' needs.

[11] Buzzflyer. *Micro Quadcopter Drones*, https://tinyurl.com/xfx3ffem
European Union Aviation Safety Agency. *Open Category - Civil Drones*, https://tinyurl.com/bddt52dj
Agencia Estatal de Seguridad Aérea. *Operations UAS/Drones — Open Category (Subcategories A1, A2 and A3),* https://tinyurl.com/rua383za

Mobula6	The Mobula6 is another well-known micro quadcopter designed for indoor flying and acrobatics. It features a lightweight frame, brushless motors, and an FPV camera for an immersive flying experience.

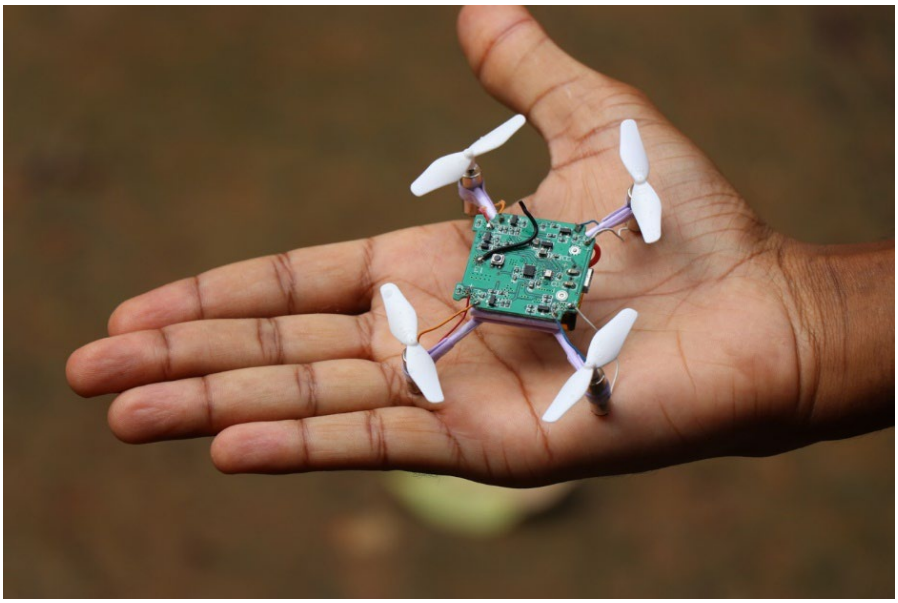
Source: Project partner ERHG (2023)

FIGURE 10
Tiny Whoop drone with FPV (First Person View) glasses from the Micro Quadcopters subcategory

Adobe Stock: Jarp

Nano Drones: Nano drones are the smallest category of drones, usually fitting in the palm of your hand. Due to their diminutive nature, the average weight of nano drones typically falls between 10 grams (g) to 30 grams (g).

FIGURE 11
A nano drone on the hand of a person



Adobe Stock: Pixel

Since nano drones are designed to be lightweight and easily maneuverable, they prioritize portability and agility over carrying heavy components or advanced features. The lightweight construction allows for indoor flying, close-quarters maneuvering, and often makes them safe to use around people or delicate objects.

However, it's important to note that the weight of specific nano drone models can vary. Some models may be closer to the lower end of the weight range, while others may reach the upper end. To get precise weight information for a particular nano drone model, it is advisable to consult the specifications provided by the manufacturer.

In table 10 a few examples of popular nano drone models are described.

TABLE 10
Drone models available in Nano Drones subcategory

Drone model	Description
Blade Nano QX	The Blade Nano QX is a well-known nano drone that offers stability and agility. It is often used for indoor flying and learning basic drone piloting skills.
Cheerson CX-10	The Cheerson CX-10 is a tiny nano drone that fits in the palm of your hand. It is lightweight and offers basic flight features, making it a popular choice for beginners or casual flying.
Hubsan Q4 H111	The Hubsan Q4 H111 is another nano drone option known for its compact size and stable flight performance. It is suitable for both indoor and outdoor flying.
Eachine E010 Mini	The Eachine E010 Mini is a nano-sized drone that is often used for indoor flying or close-range outdoor flights. It is durable, agile, and suitable for beginners.
Syma X12 Nano	The Syma X12 Nano is a nano-sized quadcopter with basic flight features. It is compact, lightweight, and often used for recreational flying.

Source: Project partner ERHG (2023)

Types of drones in the subcategory A3 [12]

In the subcategory A3 of the European categorization system for drones, the maximum takeoff weight is above 250 grams (g) up to 25 kilograms (kg). Drones in this category are typically larger and can carry more payload. In table 11 we present some examples of the types of drones that can fall into the A3 subcategory.

TABLE 11 [13]
Drone types available in the A3 subcategory of the European categorization system for drones that can be used in historic gardens

Drone Type	Description
Professional Photography Drones	These drones are designed for professional aerial photography and videography. They often have high-resolution cameras or gimbals for stabilized footage. Examples include the DJI Inspire series, Freefly Alta, or Yuneec Typhoon H Pro.
Industrial Inspection Drones	Drones in this category are used for various industrial applications, such as infrastructure inspection, power line inspection, or surveying. They may have specialized sensors, thermal imaging cameras, or LiDAR systems. Examples include the DJI Matrice series, senseFly eBee, or Intel Falcon 8+.
Agricultural Drones	These drones are specifically designed for agricultural purposes, such as crop monitoring, spraying, or mapping. They often have advanced imaging systems or payload capabilities for precision agriculture. Examples include the DJI Agras series, Yamaha RMAX, or PrecisionHawk Lancaster.
Heavy-lift Multirotors	These drones are built to carry heavy payloads for specialized applications like lifting equipment or scientific instruments. They are often used in research, engineering, or industrial sectors. Examples include the Freefly Alta 6, Gryphon Dynamics X8, or VulcanUAV Black Widow.

Source: Project partner ERHG (2023)

[12] EASA. *Open Category - Civil Drones*. Open Category - Civil Drones | EASA (europa.eu) j
[13] JOUAV, Unmaned aircraft systems. *Different Types of Drones and Uses (2023 Full Guide)*. https://tinyurl.com/2p88whhk UAV Coach. *The Top Professional Drones for Serious Commercial UAV Pilots, Updated with New Drone Models for 2023*. https://tinyurl.com/3vrn6mm6

It's important to note that the specific models and features of drones in the A3 subcategory can vary based on the intended use and manufacturer. Also, these drones must be designed based of the need that the historic garden wants to cover. First, sensors or cameras must be selected, and then, depending on the weight, the drone corresponding to the weight. Always refer to the manufacturer's specifications and consult local regulations to ensure compliance with weight and licensing requirements for drone operations.

2.2. Drone Components and Features

Drones basic components

Drones consist of several basic components that work together to enable their flight and functionality. These components are mainly the same in all drone categories. But there are also some specific components for each drone category that will be described later in this part.

In figure 12 we present the fundamental drone components. It's important to note that the specific features can vary among different small drone models, and additional features such as built-in cameras, FPV capabilities, or advanced obstacle avoidance may be available in certain models.

Figure 13 shows the basic drone components available in the A1 subcategory of the European categorization system for drones. Larger drones from the A3 subcategory have the same components, but at a larger scale. Also, they can carry additional sensors and cameras that will be describes later in this part of the manual.

There are some drone components that are specific to the A3 subcategory of drones that can carry weight up to 25 kilograms. The types of UAVs typically require more advanced components to handle the larger size and weight. In table 12 we present some specific drone components commonly found in the A3 subcategory.

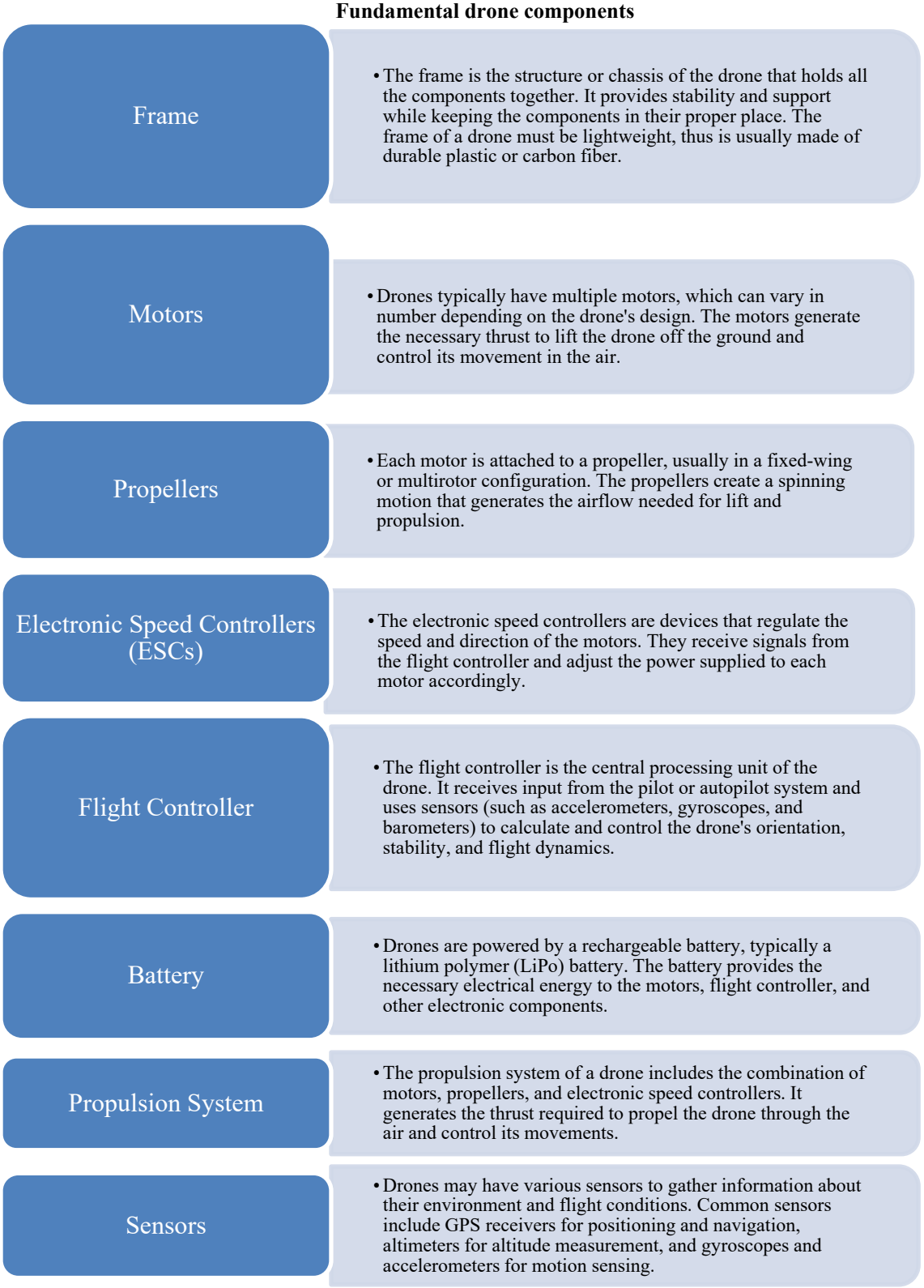
TABLE 12
Drone components commonly found in the drones that can carry weight up to 25 kilograms

Drone components specific to the A3 subcategory[14]	**Description**
Payload Mounting System	A3 drones often have a more robust and versatile payload mounting system to accommodate various payload options. This can include mounting plates, gimbals, or specialized connectors for attaching cameras, sensors, or other equipment depending on the specific tasks the drone is designed for.
Advanced Navigation Systems	A3 drones may incorporate advanced navigation systems, such as GPS (Global Positioning System) or GNSS (Global Navigation Satellite System), to enable precise positioning, autonomous flight, and navigation features.
Telemetry and Communication Systems	A3 drones typically include advanced telemetry systems that provide real-time data on flight parameters, battery status, and other critical information. They also feature robust communication systems for reliable control and communication between the drone and the ground station.
Safety Features	Drones in the A3 subcategory may include additional safety features, such as redundancy in critical systems (e.g., dual flight controllers or redundant power systems), fail-safe mechanisms, and emergency landing options.
Collision Avoidance Systems	Some A3 drones may include collision avoidance sensors or systems to help detect and avoid obstacles in their flight path. These sensors use various technologies such as ultrasonic, infrared, or computer vision to provide an added layer of safety during autonomous or manual flights.

Source: Project partner ERHG (2023)

FIGURE 12[14]

Fundamental drone components



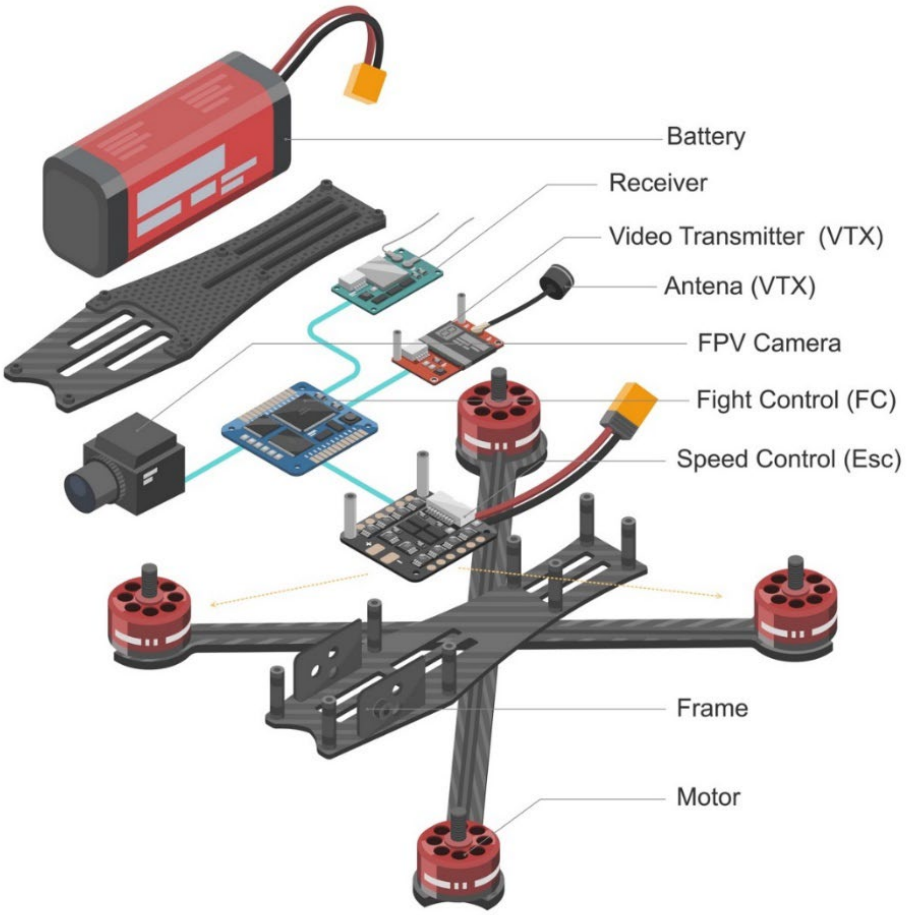
[14] CFD. *Flow Engineering, Working Principle and Components of Drone*. https://tinyurl.com/4xbrk6u8
SPACE.com. *What are FPV drones.* https://tinyurl.com/mskemxmk

Fundamental drone components (cont.)

Remote Controller	• The remote controller is the handheld device used by the pilot to control the drone's movements. It typically communicates wirelessly with the drone, sending commands and receiving feedback.
Communication System	• Drones may utilize wireless communication systems, such as radio frequency (RF) or Wi-Fi, to establish a connection between the drone and the remote controller. Those include a Radio Transmitter that sends the radio signal to ESC to pilot to control motor speed and a Radio Receiver that receives the signal from the pilot.
FPV (First-Person View) Cameras	• These cameras enable pilots to have a real-time, immersive view of the drone's flight from a first-person perspective. By providing a live video feed of the drone's surroundings, FPV cameras enhance situational awareness and allow pilots to navigate through obstacles, perform precise maneuvers, and capture stunning aerial footage. The video feed from the FPV camera is transmitted wirelessly
Camera (optional)	• Some UAVs mostly in the Mini Quadcopters from A1 and A3 subcategories of drones come with built-in cameras or camera mounts to attach action cameras. These cameras capture photos or record videos from an aerial perspective with a high resolution image. These cameras are specifically designed to capture stunning photos and videos from the sky, providing professional-grade results.
Gimbal or Camera Stabilizer (optional)	• Gimbals play a crucial role in stabilizing cameras mounted on drones, allowing for smooth and steady thus professional-grade footage even in turbulent flight conditions. This components are mostly used on larger drones as they carry professional cameras for a steady image during flight. By employing a system of motors and sensors, gimbals actively compensate for unwanted movements, such as tilting, rolling, or yawing, to keep the camera stable and oriented in the desired direction.

Source: Project partner ERHG (2023)

FIGURE 13
Main components of a small drone from the A1 subcategory[15]



Shutterstock: Allahfoto

Drone basic features

Typical drone features can vary depending on the specific model and intended use. However, some common features that most drones have are presented in table 13.

TABLE 13[16]
Drones features available on most of drones

Drone features	Description
GPS Positioning	Drones equipped with GPS can accurately determine their position and enable features like autonomous flight, waypoint navigation, and return-to-home functionality.
Altitude Hold	This feature allows the drone to maintain a consistent altitude, making it easier for pilots to control the vertical position and focus on other aspects of flight.
Follow Me Mode	In this mode, the drone tracks and follows a designated target, typically the pilot or another moving subject, allowing for dynamic aerial footage or capturing action sequences.

[15] EASA. *Open Category - Civil Drones*. https://tinyurl.com/bddt52dj
[16] AltiGator Unmanned Solutions. *Features of our drones*. https://tinyurl.com/2pzbny4e

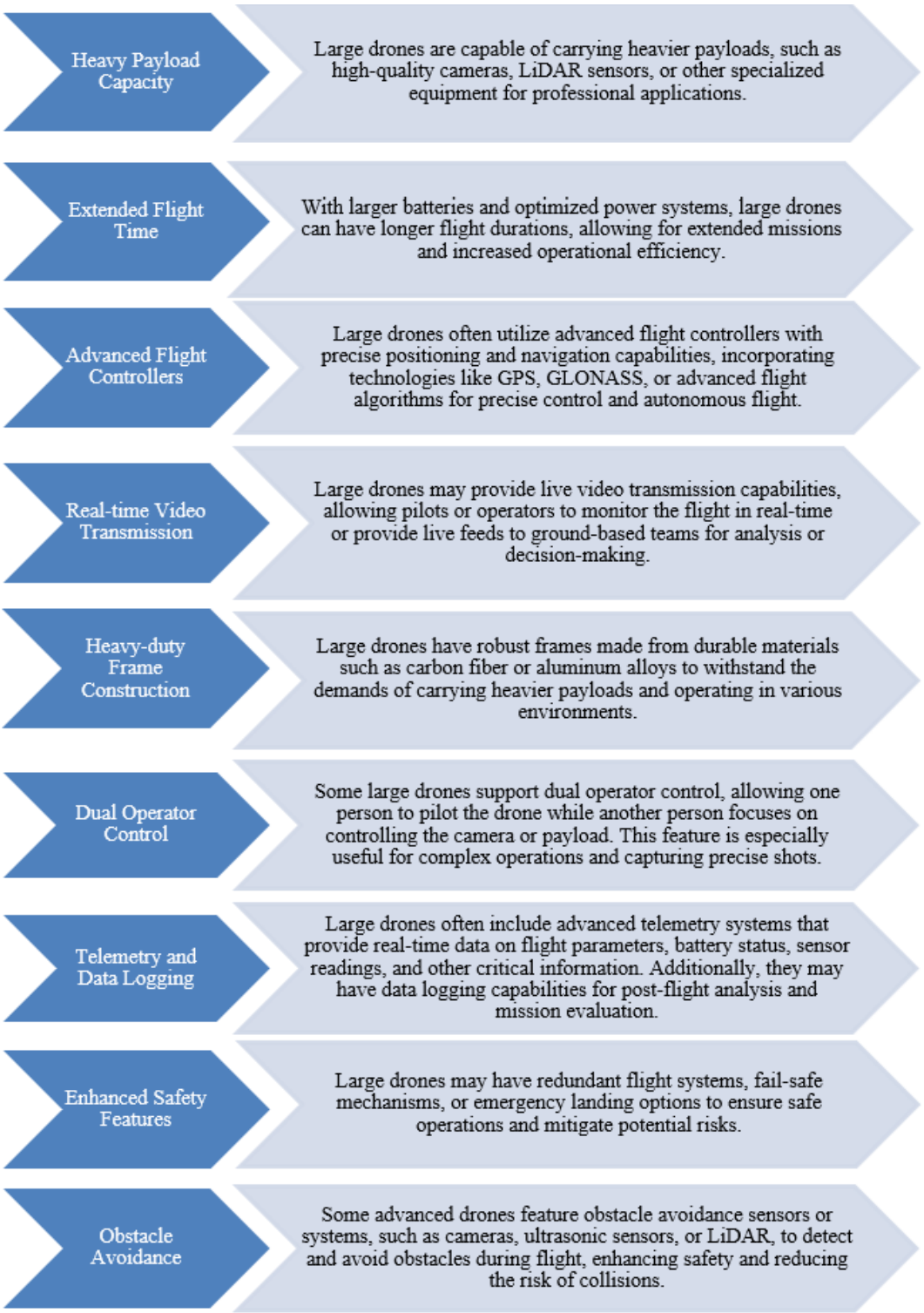
Auto Return-to-Home	With this feature, the drone can automatically return to its takeoff location with the push of a button or in case of low battery or lost connection.
Intelligent Flight Modes	Drones may offer various intelligent flight modes, such as orbit mode (circles a specified point of interest), waypoint mode (flies along predetermined flight path), or gesture control (responds to specific hand gestures for control) or object tracking, allowing for automated flight paths and dynamic tracking of subjects or points of interest.
Stabilization Systems	Drones may incorporate stabilization systems, including gyroscopes and accelerometers, to improve flight stability, reduce vibrations, and maintain smooth footage.
Mobile App Integration	Many drones offer companion mobile apps that allow pilots to control the drone, access flight telemetry, adjust camera settings, and even edit and share captured footage directly from their smartphones or tablets.
Flight Telemetry	Drones often provide real-time flight telemetry data, including battery status, altitude, speed, distance from home point, and other flight parameters, which can help pilots monitor and optimize their flights.
Hover	This feature enables the drone to hover in place steadily without user input, allowing for stable footage and precise control.

Source: Project partner ERHG (2023)

Figure 14 shows the drone features that are available in the A3· subcategory.

It's important to note that the specific components and features of drones in the A3 subcategory can vary depending on the manufacturer, intended use, and customization options.

FIGURE 14[17]
Drone features available in the A3 sub-category



Source: Project partner ERHG (2023)

[17] UAV Systems International. *Heavy Lift Payload Drones.* https://tinyurl.com/4u2m29st
DJI. *MATRICE 200 Series V2*. https://tinyurl.com/5h4aemd5

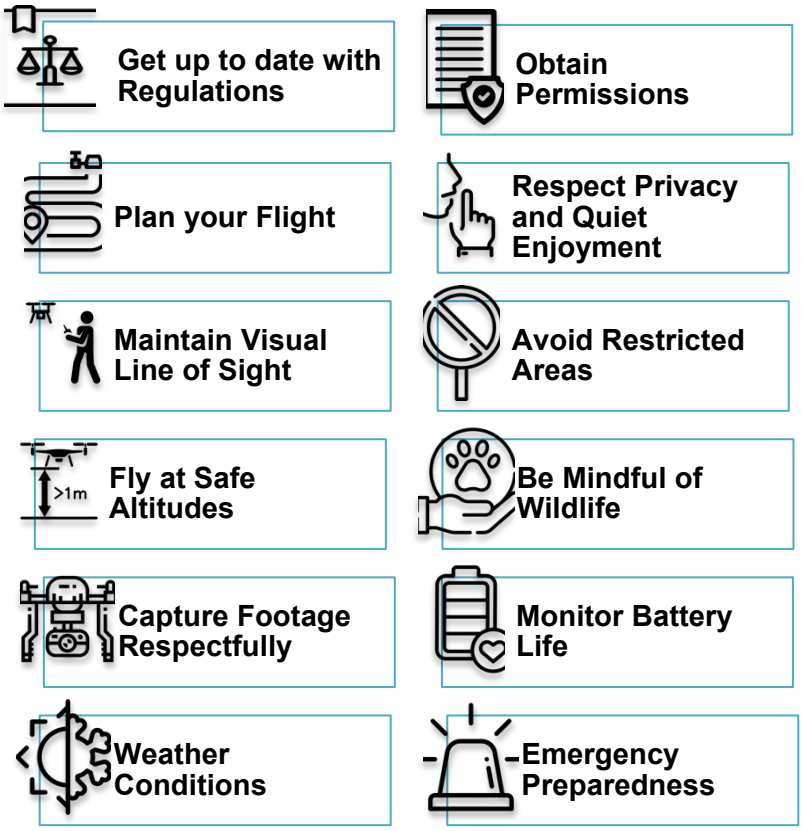
3. Drones Operations in Historic Gardens

3.1. Guidelines for Safe and Effective Drone Operation in Historic Gardens

When operating a drone in historic gardens, there are important things to consider. First, make sure you have permission from the authorities or property owners to fly the drone in the garden. Look for any specific rules or permits you might need. Before taking off, carefully plan your flight and be aware of any potential hazards or fragile areas in the garden like historic buildings, sculptures, and fountains. Be aware of people and delicate plants and respect their privacy and peaceful enjoyment of the space. Always keep the drone in sight and avoid restricted areas. Fly at a safe height, giving yourself a clear view and avoiding obstacles like trees or buildings. Be mindful of wildlife and avoid disturbing their habitats. Lastly, capture footage in a respectful way, highlighting the garden's beauty without intruding on its cultural or historical value.

By following these guidelines, you can operate your drone safely in a historic garden.

FIGURE 15[18]
Important aspects of safe and effective drone operations in historic gardens



Source: Project partner ERHG (2023)

[18] Federal Aviation Administration, Small Unmanned Aircraft Systems (UAS) Regulations (Part 107), https://tinyurl.com/488udc26
European Union Aviation Safety Agency, Civil drones (unmanned aircraft). https://tinyurl.com/2u79fzc2

- **Get up to date with regulations**

Understand and adhere to the local regulations and laws governing drone operations in the area. Familiarize yourself with any specific guidelines or restrictions related to flying drones in historic gardens. Restricted areas may include delicate structures, architectural features, or heritage buildings. Also, historic gardens often have unique and protected plant species or wildlife habitats.

It is important to respect these areas and avoid flying drones in close proximity to them to prevent any disruption or harm to the natural environment. In addition to that, areas within the historic garden that attract a large number of visitors, such as entrances, pathways, or popular viewpoints, should be avoided for drone flights. Flying drones over crowded areas can pose a safety risk and may cause discomfort or intrusion on the visitors' experience. Or it is necessary to plan the flight during the least crowded periods of time or off time of the operation of a historic garden.

- **Obtain permissions**

Seek permission from the appropriate authorities in the area where the historic garden is located or property owners to operate a drone in the historic garden. Some locations may have specific rules or permit requirements for drone use.

- **Plan your flight**

Conduct thorough pre-flight planning by assessing the surroundings, identifying potential hazards, and determining safe takeoff and landing areas.

The takeoff area must be in an open space. Look for a clear and open area that provides sufficient space for takeoff and landing. Avoid areas with tall grass, loose debris, or uneven terrain that could interfere with the drone's propellers or landing gear. Consider the presence of people, fragile structures, or delicate flora in the garden.

- **Respect privacy and quiet enjoyment**

Drones can be quite noisy and disturbing to people. Be mindful of the privacy and tranquility of visitors and residents in the area. Avoid flying over or near individuals without their consent and aim to minimize noise disturbances.

- **Maintain visual line of sight**

Keep the drone within your visual line of sight at all times during the flight. This ensures you can monitor the drone's position and respond to any unexpected situations promptly. Which means that it is important to measure and plan in advance the takeoff location from the area that will need to be inspected in a historic garden.

- **Avoid restricted areas**

Stay away from restricted or sensitive areas within the historic garden. Respect any signs or barriers indicating off-limits zones or areas of cultural or historical significance.

- **Fly at safe altitudes** [19]

Maintain a safe altitude that allows for a clear view of the surroundings and provides a buffer between the drone and any structures, trees, or other objects in the garden. For larger drone from the subcategory

[19] European Union Aviation Safety Agency, Open Category - Civil Drones. https://tinyurl.com/3pb9dz2f

A3 that can carry a heavy payload, maintain a minimum clearance of at least 10 meters above the tallest tree or structure in the vicinity.

For smaller drones in the subcategory A1 with a takeoff weight of up to 250 grams, keep a minimum clearance of at least 5 meters above the tallest tree or structure in the vicinity. This provides a buffer to account for any unexpected obstacles or variations in elevation.

FIGURE 16
The drone pilot maintains a line of sight with the aircraft while piloting

Shutterstock: Raullazaro

- **Be mindful of wildlife**

Make sure not to disturb or harm wildlife inhabiting the garden. Avoid flying too close to nesting sites, roosting areas, or natural habitats of birds and other animals.

- **Capture footage respectfully**

If capturing photos or videos, do so in a way that showcases the beauty of the garden without intruding on the privacy or sanctity of the space. Consider the artistic and cultural value of the location and capture images in a respectful manner. Consider that some people might not like to be on the video or photographs you are taking with a drone. Thus, avoid areas with people or seek for permissions from people if you would like to have them on your media.

- **Monitor battery life**

Keep track of the drone's battery life and plan flights accordingly. Ensure you have enough power to safely return the drone to the designated landing area without risking a low battery situation.

- **Weather conditions**

Check weather conditions before flying and avoid operating the drone in adverse weather, such as high winds, heavy rain, or low visibility, which can compromise flight stability and safety. The exact maximum wind speed that a small drone can handle will depend on factors such as its size, weight, design, and specific manufacturer guidelines. It's crucial to refer to the drone's user manual or specifications provided by the manufacturer to determine its recommended operational limits, including wind speed.

When using your drone at high outdoor temperature above 40°C(104°F), make sure that the battery's temperature does not get above 65°C(149°F). If the battery's temperature reaches this level, land your drone immediately.

You can fly during daylight (30 minutes before official sunrise to 30 minutes after official sunset, local time) or in twilight if your drone has anti-collision lighting.

- **Emergency preparedness**

Be prepared for emergencies or unexpected situations. Maintain a clear plan for dealing with issues like signal loss, equipment failure, or emergency landings to minimize any potential harm or damage.

Remember, responsible drone operation in historic gardens not only ensures safety but also helps preserve the beauty and integrity of these cultural and natural spaces. Always prioritize the well-being of the environment, wildlife, and the people who may be present in the area.

3.2. Maintenance and Storage of Drones in a Historic Garden

When it comes to maintaining and storing drones in a historic garden, there are several considerations to ensure proper care and minimize any impact on the garden's integrity, as shown in figure 17.

FIGURE 17[20]

Important pillars to consider for drone maintenance and safe storage in historic gardens

Source: Project partner ERHG (2023)

[20] Drone blog (n.d.). *9 Tips for Proper Storage and Maintenance of Your Drone*. https://tinyurl.com/yuvkvt4v
COPTER.BG (2020, December 21*). Proper drone maintenance and storage*. https://tinyurl.com/36ndt6h9

Here are some guidelines:

- **Regular Maintenance**

Schedule regular maintenance checks for your drone to keep it in optimal condition. This includes visual inspection of drones and cleaning the propellers, checking the battery, ensuring firmware updates are up to date, and inspecting the overall structure for any signs of wear or damage.

- **Storage Location**

Choosing an appropriate storage location for a drone is essential to ensure its safety and longevity. Ideally, the storage area should be clean, dry, and free from environmental hazards that could damage the drone or its components.

A temperature-controlled environment (generally between 10 to 25 degrees Celsius) is beneficial to prevent extreme heat or cold, which can adversely affect battery performance and overall drone functionality. Additionally, the storage location should offer protection against dust, moisture, and direct sunlight and be far from any sources of magnetism, as these elements can potentially cause damage or deterioration.

Using a dedicated storage case or bag further shields the drone from potential impacts or accidental damage. It's important to keep the drone away from areas with high foot traffic or where it could be knocked over, ensuring that it is stored securely to prevent unauthorized access. Thus, the best places to store a drone are a closet or a cupboard, as long as the said conditions are met. By selecting an appropriate storage location, you can prolong the lifespan of their equipment and ensure it remains in optimal condition for future flights (see figure 18).

FIGURE 18
Remote control drone stored in a hardcase for storage

Shutterstock: Lukassek

- **Respect historic structures**

When storing the drone, ensure it is placed away from any delicate historic structures or artefacts to avoid any accidental collisions or disturbances. The storage location should not obstruct pathways or impede the movement of visitors.

- **Battery care**

Follow the manufacturer's guidelines for proper battery care. Store batteries in a cool and dry place, away from flammable materials. Avoid leaving batteries fully charged or completely discharged for extended periods, as this can affect their longevity.

In table 14 we present some examples from DJI manufacturer's guidelines for battery use [21].

TABLE 14
Examples of temperatures for battery use from different drone models

Temperature for Battery Use	Products
-20° to 40°C (-4 ° to 104°F)	Inspire 2
-10° to 40°C (14 ° to 104°F)	Mavic Pro, Inspire 1 Series, Phantom 3 Series
0° to 40°C (32 ° to 104°F)	Spark, Phantom 4 Series

Source: Project partner ERHG (2023)

To ensure the batteries longer usage life, avoid charging the batteries right after the flight because the battery's temperature might be too high. For the best batteries' maintenance, check-up with the drone's manufacturer for the charging temperature range like the one in the table 15 below.

TABLE 15
Examples of charging temperature range from different drone models

Charging Temperature Range	Products
0° to 40°C (32 ° to 104°F)	Inspire 1 Series, Phantom 3 Series
5° to 40°C (41 ° to 104°F)	Spark, Mavic Pro, Inspire 2, Phantom 4 Series

Source: Project partner ERHG (2023)

After charging is complete, disconnect the battery from the charger and regularly examine the charger for any damages in the plug, cord, enclosure, or other parts.

When the aircraft and the batteries will be stored for more than 3 months, store them at around 25°C (77°F) in a dark shadowed place and fully charge and discharge the battery once every three months to maintain battery health. Also, discharge the battery to 40% to 65% before storage. Storing a battery with full power or low power for a long time may lead to permanent damage.

- **Noise considerations**

Drones can generate noise, which may disrupt the tranquility of the historic garden. When storing the drone, choose a location that minimizes noise impact on visitors and nearby structures.

[21] DJI Support. *Drone Maintenance Checklist*. https://tinyurl.com/stxnksj5

- **Security measures**

Ensure the storage area is secured to prevent unauthorized access or potential theft of the drone. Consider using additional security measures such as locks or surveillance systems if necessary.

- **Compliance with regulations**

Stay updated with the local regulations regarding the storage and operation of drones. Adhere to any specific guidelines or restrictions related to drone storage within the garden premises.

- **Visitor awareness**

If the storage area is visible to visitors, consider placing signs or information to raise awareness about the presence of drones and highlight the responsible use and respect for the historic garden environment.

By following these maintenance and storage guidelines, you can ensure the longevity of your drone while respecting the historical value and tranquility of the garden. Always prioritize safety, compliance with regulations, and the preservation of the garden's integrity when dealing with drone maintenance and storage in a historic setting.

3.3. Legal requirements for drone operations

The U-space[22] Regulation establishes and harmonises the necessary requirements for manned and unmanned aircraft to operate safely in the U-space airspace.

FIGURE 19
U-space

Source: EASA[23]

Regulations for drone operation in Europe are set by the European Union Aviation Safety Agency (EASA).[24]

[22] Set up in 2013 the U-Space is such an unmanned aircraft traffic management solution that allows the scaling up of the volume of drone operations that are complex, in environments that are challenging. They are intended to facilitate the efficient and safe use of drones especially in urban areas.
[23]EAS. *U-space*. https://tinyurl.com/46fec2yz
[24] EASA. *Drones (UAS).* https://tinyurl.com/ymvk43rd

As of December 31st, 2020, the European Regulations 2019/947 and 2019/945[25] set out the framework for the safe operation of civil UAS/drones in the European skies and affect all drones regardless of their use and size. The EU Regulations adopt a risk-based approach, and as such, do not distinguish between leisure or commercial civil drone activities. What they consider is the weight and the specifications of the civil drone and the operation it is intended to conduct.

The Regulations use the term UAS, Unmanned Aircraft System, to refer to a drone, its systems, and all the other equipment used to control and operate it, such as the command unit, the possible catapult to launch it, and others.

RPAS (Remotely Piloted Aircraft Systems) is a subcategory of UAS, which includes both RPAS and fully autonomous UAS. Fully autonomous UAS fly completely by themselves without the need for any pilot intervention.

3.3.1 European regulations and national laws

The EU drone regulation is an act that became immediately applicable in all EU Member States since December 31st, 2020 superseding national regulations and making them not applicable anymore.

However, the Member States can develop National Acts to define certain aspects such as:

1. Minimum age for a remote pilot
2. Conversion of certificates issued before the applicability of the EU regulation
3. Authorisation of model clubs and associations
4. Fines when breaching the regulation
5. Use of geographical zones

3.3.2 Drone operation categories

EU Regulation 2019/947 caters to most types of operations and their levels of risk. It does so through three categories of operations: the 'open', 'specific' and 'certified' categories. This manual presents only the drone regulations for the 'open' subcategories A1-A3.

The subcategories A1-A3 cover flights with drones which pose a low risk and therefore do not require authorization to operate, and safety is ensured provided the civil drone operator complies with the relevant requirements for its intended operation. These subcategories A1-A3 are particularly relevant for private drone pilots.

Wherever a pilot is flying, it is likely that he/she also needs to think about the safety of any people in the area. As a general rule, when a pilot operates in the 'open' category, he/she is not allowed to fly over people who are not involved in the drone flying/activity. This means the right distance needs to be kept from people and property. This is both for their own safety and to respect people's privacy.

3.3.3 Drone protocol

We provide hereby with the necessary protocol steps you must follow to operate a drone.

1. All users or organizations owners of a drone and intending to fly a drone must register as operators on the website of the National Aviation Authority (NAA) or to another organization recognized and authorized by the NAA and should obtain the operator number according to European regulations (UAS Operator Registration section).

[25]EASA. *Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and (EU) 2019/945*). https://tinyurl.com/2x3k9krh

2. Once the operator number has been obtained, this number should be visibly included/attached to the drone.

3. The drone pilot needs to complete the necessary online training offered by the National Aviation Authority, pass a pilot exam and get an official EASA valid remote pilot competency certification before flying a drone weighing 250 grams or more.

4. The UAS certificate/license is valid for 5 years If the revalidation is conducted before the certificate expires, the remote pilot may attend a seminar provided by the National Aviation Authority or by an entity recognised by it, otherwise, competencies need to be re-demonstrated[26].

5. An insurance policy covering civil liability against third parties for damages that may arise during and for the execution of each flight carried out, both for recreational and professional purposes, must be contracted.

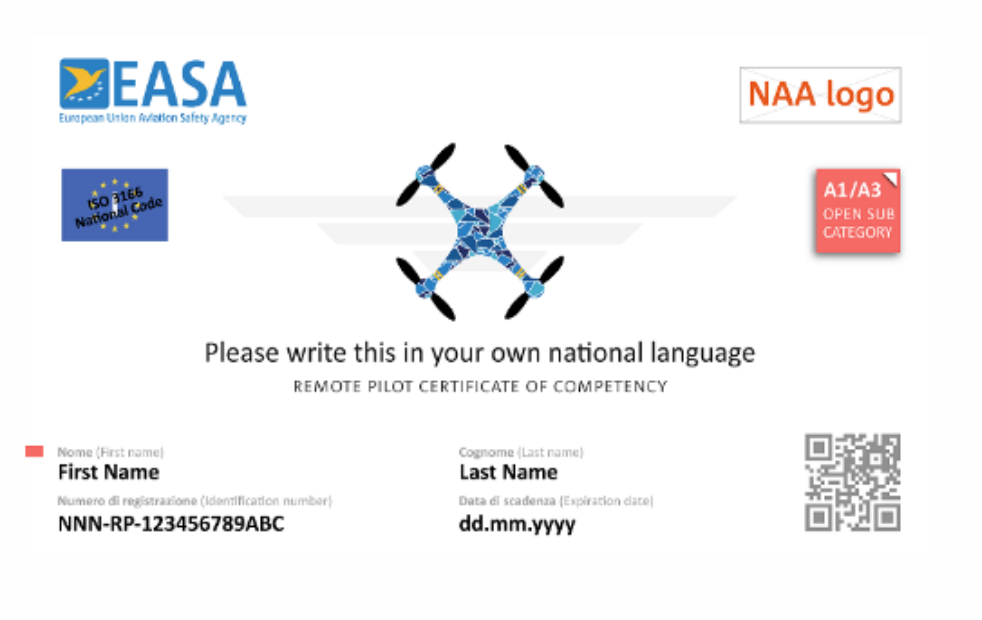
6. Drones equipped with cameras must be equipped with parachutes or an automatic landing system that allows them to land safely if they lose power.

7. The pilot must be at least 16 years old.

8. Flights are allowed only during the daylight period (UDP).

9. The only category of drones that are allowed to fly close to people is a drone with a C class 2 marks or under category A2.

FIGURE 20
Example of UAS certification/ license A1-A3



Source: DRONEAIR[27]

[26] *Regulatory reference: DRONE.OPEN.070 (1) of EU regulation 2019/94*
[27] DRONEAIR, Certificato EASA Drone A1/A3 + A2 + Pratica A2. https://tinyurl.com/8t6x7zd5

Tables 16, 17 and 18 extend on useful details related to drone protocol.

TABLE 16
Difference between a pilot and operator for UAS category known as 'open' category

	**A drone operator** is any person, or organisation, who owns or rents one or more registered drones. Drone manufacturers and/or retailers don't register drones. The owner needs to take the initiative to register with the National Aviation Authority, in the country of residence or main place of business. It is possible to be both a drone operator and a remote pilot if it is the same person who actually flies the drone. However, it is possible to be a remote pilot without being a drone operator, if, for example, you are a pilot working for a company which provides services with drones. In that case, the company is the drone operator and you are the remote pilot. In case a person bought a drone to fly in his leisure time, this person is both the drone operator and the remote pilot. In case a person bought a drone to give away as a gift, the person who will receive the gift and then fly the drone will be the drone operator and the remote pilot.
	**A drone pilot i**s the person actually flying the drone, without necessarily owning or renting the drone.

Source: EASA[28]

TABLE 17
UAS/Drone operator responsibilities

Insurance	The drone operator needs to have the right insurance in place, even if the drone is piloted by someone else. For insurance refers to the National Aviation Authority of the country where the drone is registered. By having drone insurance, you provide coverage for the operator's liability in case of damage to third-party property or injury to other people as a result of your drone operation. Getting drone insurance is not only a good idea and it is mandatory if the drone is above 20kg. If the drone is below 20 kg, there is no specific requirement for insurance. However, most EASA Member States mandate third-party liability insurance also if you are operating a lighter drone. Specific information is available on the national authority websites and https://www.easa.europa.eu/en/light/topics/drone-insurance.
Registration	For drones in the open category, the drone operator needs to register with the National Aviation Authority. The registration number is valid in all other EASA Member States. It is not possible to register twice. (*Regulatory reference: article 14 of EU regulation 2019/947).*
Registration ID Number	Once a person is registered as a drone operator he/she will receive a registration ID number. The ID number must be fixed on the drone/drones that the person owns.
Pilot certificate	Before handing over any drones, it would be good to check that the designated pilot/s has done the necessary online pilot training, has passed the online pilot exam and has a valid pilot certificate.

Source: Project partner STC (2023)

TABLE 18
How to register as a UAS/Drone operator in Spain and in Italy

[28] *EASA, Drone operator and drone pilot – what is the difference? https://www.easa.europa.eu/en/light/topics/drone-operators-pilots*

Registration of UAS/Drone operator in Spain	In Spain, all drone operators must be registered (registration is free) with the Spanish Civil Aviation Authority (AENA) before using a drone. Registration is free and can be done through the following link**.** This procedure will be automatic and immediate if a digital certificate is used. More, it is illegal for anyone other than AENA to operate a drone weighing more than 25kg at an altitude above 120m unless they have obtained special permission to do so. Drones must only be flown during daylight hours and there is no night flying allowed.
	More information: Spain Aviation Agency Section Drone Spain registration as operator Spain UAS/drone training general information Spain UAS/drones training entity for open category
Registration of UAS/Drone Operator in Italy	To be recognized as a UAS operator, a person/organization must successfully register on the d-flight portal and acquire the unique and personal European identification code, in QR code format, to be affixed to each of the UAS (drone) with which the person operates. In Italy registration of a UAS operator is mandatory: 1. For all operators who use drones weighing equal to or greater than 250 g unless they are classified as toys and comply with the European Directive 2009/48/EC on the safety of toys. 2. For operators of drones weighing less than 250 g with high-speed characteristics (in the event of an impact they can transfer kinetic energy greater than 80 Joules to the human body) and/or who install a camera.
	Travelling abroad: if an Italian operator intends to operate a UAS in EU/EASA countries, he must refer to the instructions contained in the EASA website page "Travelling with Drones". For non-EU / non-EASA states, the operator must refer to the page of the competent authority of the destination state.
	More information: Italian Aviation Agency Section Drone Italian registration as drone UAS operator Italian UAS/drones training

Source: Project partner STC (2023)

3.3.4 Consolidated European legislation

1. Consolidated Implementing Regulation (EU) 2019/947 including changes to Implementing Regulation (EU) 2020/639, Implementing Regulation (EU) 2020/746, Implementing Regulation 2021/1166 and Implementing Regulation (EU) 2022/425. (link to the standard).

2. Consolidated Delegated Regulation (EU) 2019/945 including changes to Delegated Regulation (EU) 2020/1058. (link to the standard).

3. EU Regulation 2019/945 defines requirements for the design and manufacture of unmanned aircraft systems ("UAS") intended to be operated under the rules and conditions defined in Implementing Regulation (EU) 2019/947 and of remote identification add-ons.

4. EASA management resolution approving national standard scenarios (STS-ES) for UAS operations in the 'specific' category under an operational declaration in accordance with Implementing Regulation (EU) 2019/947. (link to the standard).

3.4. Documentation for Drone Operations in Historic Gardens: Ensuring Preservation, Compliance, and Safety

Operating drones in historic gardens requires careful planning, adherence to regulations, and consideration of the environment and stakeholders. It is crucial to emphasize the significance of

effective management and maintenance of documentation, as it plays a vital role in meticulous planning and ensuring strict adherence to guidelines. This is especially important for safeguarding the preservation and safety of invaluable cultural treasures within historic gardens.

The following table 19 presents a comprehensive set of documents recommended for effectively working with drones in historic gardens. Each document serves a specific purpose in ensuring the safe and responsible use of drones while maximizing their potential for garden management and conservation. From regulatory compliance to risk assessment, environmental impact evaluation, and emergency response planning, these documents provide guidance for establishing well-structured and organized drone operations.

Furthermore, the table 19 highlights the importance of continuous learning and improvement by incorporating documents for capturing valuable insights and lessons learned from past operations. Stakeholder communication and community engagement plans are also essential to foster transparency, address concerns, and maintain positive relationships with local communities and authorities.

FIGURE 21
Checking necessary documentation

Source: Song_about_summer

TABLE 19
Recommended Documentation Content

Document	Description	Recommended Content
Regulations and Policies	This document should encompass all relevant regulations and policies pertaining to drone operations in historic gardens. It is essential to review and update this document periodically to ensure compliance and adapt to any necessary changes.	• Local regulations governing drone operations. • Required permits or authorizations. • Specific policies and guidelines established by the management or governing body of the historic garden. • Restrictions on flying in historic areas: Restrictions on flight altitude; Restrictions on flight paths;

		Restrictions on operational hours; Restrictions on near landmarks.
Risk Assessment	This document should include specific information tailored to the unique characteristics of the historic garden. It is imperative to regularly update this document in response to any changes in the garden's environment.	• Potential risks or hazards in the historic garden: trees, buildings, statues, fountains, delicate vegetation, visitor foot traffic. • Weather conditions: wind speed, precipitation, visibility. Set of emergency procedures: Drone malfunction, Loss of control, other unforeseen circumstances. • Historic Garden Map with No-Fly Zones.
Environmental Impact Assessment	An Environmental Impact Assessment evaluates the potential environmental effects of drone operations in the historic garden. It helps identify and mitigate any adverse impacts on the flora, fauna, and surrounding ecosystem.	• Assessment of potential effects on wildlife and vegetation. • Evaluation of noise and disturbance levels to nearby residents or wildlife. • Recommendations for minimizing environmental impact during drone operations. • Plans for habitat restoration or conservation, if applicable. • Monitoring protocols to ensure ongoing compliance with environmental guidelines.
Drone Operations Plan	This foundational document should outline a comprehensive list of pre-flight plans specific to the historic garden in question. The purpose of this document is to facilitate efficient planning for repetitive operations, streamlining the process for future flights.	• Equipment and Personnel. • Drone and Payload Specifications. • Maintenance and Inspection Procedures. • Operator Qualifications and Training. • Support Team Roles and Responsibilities. • Flight Procedures: Launch and Landing Protocols, In-Flight Operations, Altitude and Flight Path Considerations, Communication Protocols, Data Collection, and Storage Procedures. • Post-Flight Operations: Data Analysis and Processing, Post-Flight Equipment Maintenance, Report Generation, and Documentation, Data Privacy and Security Measures. • Continuous Improvement and Revising and Updating the Operations Plan. • Drone Operations Checklist. • Contact Information for Authorities and Stakeholders.
Drone Operational Procedures Manual	This essential document serves as a baseline guide that outlines the procedures for conducting drone operations in a historic garden. It provides clear instructions on how the drone operation should be carried out, ensuring adherence to best practices and safety protocols.	• Pre-flight checklist: inspecting the drone for any damage; calibrating the sensors; ensuring that all software and firmware are up to date. • Operation team: operator; visual observer. • Flight restrictions specified by the historic garden's policies and guidelines. • Safe distance from delicate structures, vegetation, and areas of cultural significance. • Safety of garden visitors during drone operations. • Establish clear boundaries or restricted areas. • Prevent unauthorized access or potential accidents. • Specific data requirements and capture protocols. • Privacy concerns related to visitors or neighboring properties.
Issue Register	This document serves as a comprehensive record for capturing any incidents that may occur.	• Incidents that take place during drone operations in the historic garden, ensuring a detailed account of any noteworthy occurrences. • Anomalies discovered during routine maintenance and inspections of the drone equipment, highlighting any irregularities or deviations from expected performance, any problems or challenges that were not anticipated in the initial risk assessment. These unexpected issues are crucial to consider and review when revisiting the drone operations plan, enabling necessary adjustments and improvements.
Lessons Log	The Lessons Log serves as a repository for capturing valuable insights and	• Lessons Learned and Feedback: any lessons learned from practical experience that contribute to

	lessons learned to enhance the utilization of drones in historic gardens. It is regularly updated whenever new lessons are acquired.	improving the use of drones in historic gardens. It encompasses valuable knowledge gained through past operations. • Any lessons learned regarding the optimal utilization of the information gathered by the drone for the maintenance of the historic garden. It focuses on extracting meaningful insights from the collected data and leveraging it effectively.
Flight Log	The Flight Log provides a detailed account of each drone flight conducted in the historic garden. It serves as a valuable record for monitoring flight patterns, ensuring adherence to regulations, and analyzing the data collected during each flight operation.	• Date and time of each flight. • Drone identification number and model. • Purpose of the flight (e.g., survey, monitoring). • Flight duration and distance covered. • Specific locations and flight paths taken. • Data collected during the flight (e.g., images, videos, sensor data). • Any incidents or issues encountered during the flight.
Drone Safety and Emergency Procedures Manual	This document outlines safety protocols and emergency response procedures to ensure the safe operation of drones in the historic garden.	• Emergency response procedures for drone crashes, injuries, or equipment malfunctions. • Designation of responsible personnel and their roles during emergency situations. • Communication protocols to alert relevant authorities or stakeholders during emergencies. • Coordination with local emergency services if required.
Data Management Plan	This document outlines the procedures for collecting, storing, managing, and securing the data gathered from drone operations in the historic garden. It ensures compliance with data privacy regulations and establishes protocols for data backup and sharing with relevant stakeholders.	• Data collection methods and instruments used. • Data storage locations and backup strategies. • Data retention and archiving policies. • Data access controls and permissions for authorized personnel. • Data sharing protocols with relevant authorities or stakeholders. • Data disposal or deletion procedures when data is no longer needed.
Data Analysis and Reporting Plan	This plan outlines the procedures for analyzing the data collected during drone operations in the historic garden and creating reports based on the findings. It ensures efficient data processing and meaningful insights to support decision-making and future planning.	• Data collection methods and instruments used. • Data storage locations and backup strategies. • Data retention and archiving policies. • Data access controls and permissions for authorized personnel. • Data sharing protocols with relevant authorities or stakeholders. • Data disposal or deletion procedures when data is no longer needed.
Stakeholder Communication Plan	The Stakeholder Communication Plan details the communication strategies and channels for engaging with various stakeholders, including garden visitors, local authorities, and conservation organizations. It fosters transparency and collaboration throughout the drone operations.	• Identification of key stakeholders and their interests in drone operations. • Communication channels (e.g., website, social media, newsletters) to update stakeholders on drone activities. • Coordination with local authorities to address any concerns or comply with regulations. • Feedback mechanisms to gather input from stakeholders.
Training and Education Plan	The Training and Education Plan outlines the training programs and educational initiatives for personnel involved in drone operations. It ensures that the team is equipped with the necessary skills and knowledge to operate drones safely and effectively.	• Training curriculum and topics covered for drone operators and support team members. • Training frequency and ongoing professional development opportunities. • Educational resources and materials for promoting drone safety and best practices. • Certification or licensing requirements for drone operators, if applicable.
Drone Inventory and Asset Management	This document maintains a comprehensive inventory of all drones, equipment, and accessories used in the historic garden. It aids in tracking assets,	• List of all drones and their specifications (e.g., model, serial number). • Inventory of drone accessories (e.g., batteries, propellers) and their conditions.

	managing maintenance schedules, and ensuring sufficient resources are available for operations.	• Asset management system to track the allocation of drones for different operations. • Maintenance history and schedules for each drone.
Budget and Resource Allocation	This document outlines the budget and resource allocation plan for managing drone operations in the historic garden. It ensures the availability of adequate funds and resources to sustain safe and effective drone use over time.	• Budget breakdown for drone procurement, maintenance, and training expenses. • Resource allocation for ongoing data management and analysis efforts. • Contingency plans for unexpected expenses or resource needs. • Monitoring of expenses to ensure cost-effectiveness.

Source: Project partner Telewander ApS (2023)

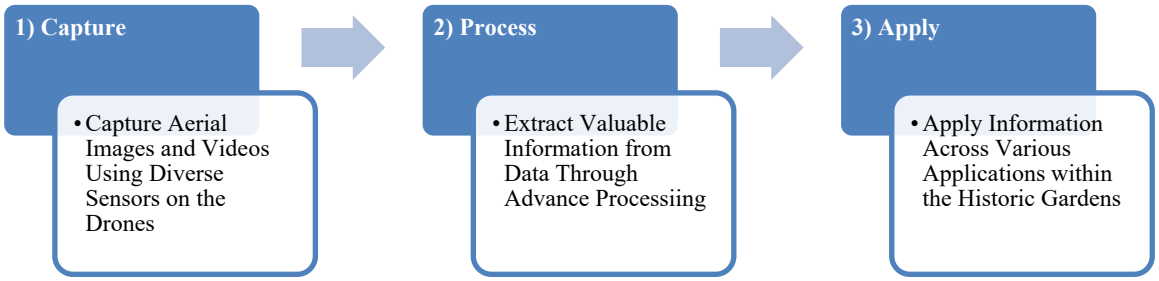
By utilizing these recommended documents, garden managers, conservationists, and drone operators can streamline their efforts, enhance safety measures, and effectively contribute to the preservation and sustainable management of historically significant gardens for future generations to enjoy.

Please note that the suggested documents provided are merely recommendations. It is crucial to customize the content and structure of these documents to align with your specific needs and requirements. It is important to emphasize that the suggested documents do not serve as substitutes for any legally mandated documentation. As drone operators in historic gardens, it is your responsibility to create any mandatory documentation necessary for drone operations in your local country and in accordance with the requirements of the historic garden.

4. Retrieving Useful Information from Drone Camera and Sensors

To maximize drone operations' utility and efficiency, a systematic approach is crucial. Capture high-quality aerial images and videos using diverse sensors on the drones, then extract valuable information from this data through advanced processing and apply it across various applications within the historic garden.

FIGURE 22
A systematic approach to working with drones in historic gardens



Source: Project partner Telewander ApS (2023)

4.1. Capturing Aerial Photographs and Videos

The use of drone photography and video in historic gardens offers numerous advantages that enhance our understanding, appreciation, and preservation of these cherished spaces.

Drones provide a unique aerial perspective that allows us to capture stunning visuals of the gardens, showcasing their architectural grandeur, intricate designs, and breathtaking landscapes. This bird's-eye view enables us to document and monitor the condition of historic structures, vegetation, and pathways, facilitating maintenance and restoration efforts.

FIGURES 23 & 24
The palace and garden complex in Wilanów with the Morysin nature reserve and the Sobieski Canal at Wilanów - autumn season-, Poland

Source: Archives of the Museum of King Jan III's Palace at Wilanów

Drone imagery also serves as a valuable educational tool, enabling us to create interactive experiences, virtual tours, and educational resources that bring the garden's history and cultural significance to life. Furthermore, drone footage can be used for promotional purposes, attracting visitors, promoting tourism, and generating support for conservation initiatives. By leveraging the advantages of drone photography and video, we can explore and appreciate historic gardens from new perspectives, preserving their beauty and heritage for future generations to enjoy.

4.2. Extracting information from photos, videos, and other drone sensors

FIGURE 25
Information received from a drone

Source: Scharfsinn

Drones equipped with advanced sensors can capture a wealth of valuable data, allowing experts to gain unprecedented insights into the condition and dynamics of these cherished cultural landscapes.

In the table 20, we present an overview of the data collected by various sensors commonly used on drones for monitoring historic gardens. Each sensor serves a unique purpose, capturing specific types of information that contribute to the comprehensive understanding and effective conservation of these precious heritage sites.

TABLE 20
Data from drone sensors

Sensor	Type of Data	Data Format	Applications/Uses	Advantages
RGB Cameras	RGB imagery and video	Image files (e.g., JPEG, PNG) and Video files (e.g., MP4)	Detailed visual records of garden layout and architecture	Basic and commonly used, providing visible light images like human eye
Multispectral Sensors	Multispectral data	Image files with multiple bands (e.g., TIFF)	Assessing vegetation health and stress	Captures multiple spectral bands, including infrared for plant analysis
Thermal Cameras	Thermal imagery	Image files (e.g., TIFF)	Assessing surface temperatures and heat signatures	Detects temperature differences, useful for identifying issues

LiDAR	3D terrain maps	Point cloud data (e.g., LAS)	Precise mapping of topography and landscape features	Provides highly accurate 3D maps through laser-based technology
Gas and Chemical Sensors	Gas and chemical data	Numeric data (e.g., ppm for gases)	Monitoring air quality and detecting pollutants	Identifies specific gases and pollutants, assessing environmental risks
Global Positioning System (GPS)	Geolocation data	Geospatial data (e.g., GPS coordinates)	Accurate mapping and change detection	Enables precise positioning and navigation during flights

Source: Project partner Telewander ApS (2023)

RGB Cameras, the most fundamental and widely employed sensors, provide high-resolution images in visible light, akin to what the human eye perceives. Meanwhile, Multispectral Sensors expand beyond the visible spectrum to detect specific wavelengths, enabling experts to assess vegetation health, nutrient levels, disease presence, and more. Thermal Cameras, capable of capturing thermal radiation, aid in identifying temperature variations and potential issues in garden structures. LiDAR sensors offer highly accurate 3D maps, revealing topography and subtle landscape features critical for erosion analysis and restoration planning. Gas and Chemical Sensors contribute to environmental monitoring, identifying pollutants and potential risks. Finally, GPS sensors ensure precise geolocation data, essential for accurate mapping and integration with other spatial datasets.

To extract valuable information from the vast amount of data collected by the sensors in historic gardens, experts employ advanced image processing techniques, machine learning algorithms, and specialized software. These technologies enable efficient data analysis, providing deeper insights into the garden's condition while optimizing time and resources.

Computer vision algorithms play a crucial role in automatically analyzing images and videos captured by drones, facilitating the identification of specific features such as architectural elements, historical artifacts, or invasive species. Moreover, these algorithms possess the capability to detect changes in vegetation density, color variations, or structural anomalies, effectively flagging areas that necessitate further investigation or intervention.

The software examples presented in the table 21 are essential tools that assist in processing and analyzing the collected drone sensor data. From advanced image editing and photogrammetry software to Geographic Information Systems (GIS) and video editing tools, these software solutions play a crucial role in generating actionable insights, supporting historical research, enhancing visitor experiences, and informing decision-making processes in the conservation and management of historic gardens.

TABLE 21
Data Applications and Software Solutions for Historic Gardens

Data Input	Data Output	Software Examples	Description
RGB imagery and video	Documentation and Imagery Enhancement	PS (Adobe Photoshop), GIMP, Corel PS Pro	Accurate visual records of garden layout and architecture. Basic and commonly used, providing visible light images like the human eye.
Multispectral data	Studying condition and ecological aspects	AM (Agisoft Metashape), Pix4D, DroneDeploy	Assessing vegetation health and stress. Captures multiple spectral bands, including infrared for plant analysis.
Thermal imagery	Landscape Planning and Design	AM (Agisoft Metashape), Pix4D, DroneDeploy	Assessing surface temperatures and heat signatures. Detects temperature differences, useful for identifying issues.

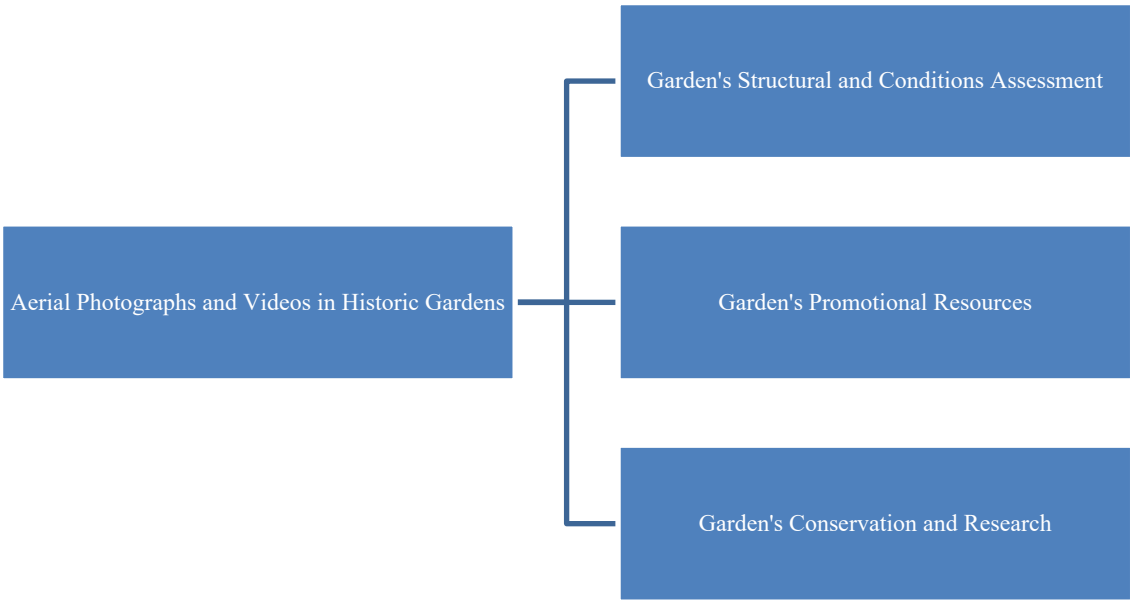
3D terrain maps	Condition Assessments and Maintenance	AM (Agisoft Metashape), Pix4D, DroneDeploy	Precise mapping of topography and landscape features. Provides highly accurate 3D maps through laser-based technology.
Gas and chemical data	Research and Analysis	ArcGIS (Esri), QGIS, Global Mapper	Monitoring air quality and detecting pollutants. Identifies specific gases and pollutants, assessing environmental risks.
Geolocation data	Site Mapping and Change Detection	ArcGIS (Esri), QGIS, Global Mapper	Accurate mapping and change detection. Enables precise positioning and navigation during flights.
RGB imagery and video, Multispectral data, Thermal imagery, LiDAR, Gas and chemical data, Geolocation data	Visitor Experience Enhancement	Premiere Pro, Final Cut Pro, DaVinci Resolve, 3DVista	Premiere Pro, Final Cut Pro, DaVinci Resolve, 3DVista

Source: Project partner Telewander ApS (2023)

4.3. Types of applications of aerial photos and videos

All types of aerial photos and videos that can be used in historic gardens for maintenance and management can be divided into three main categories.

FIGURE 26
Types of applications of photographs and videos from drones in historic gardens



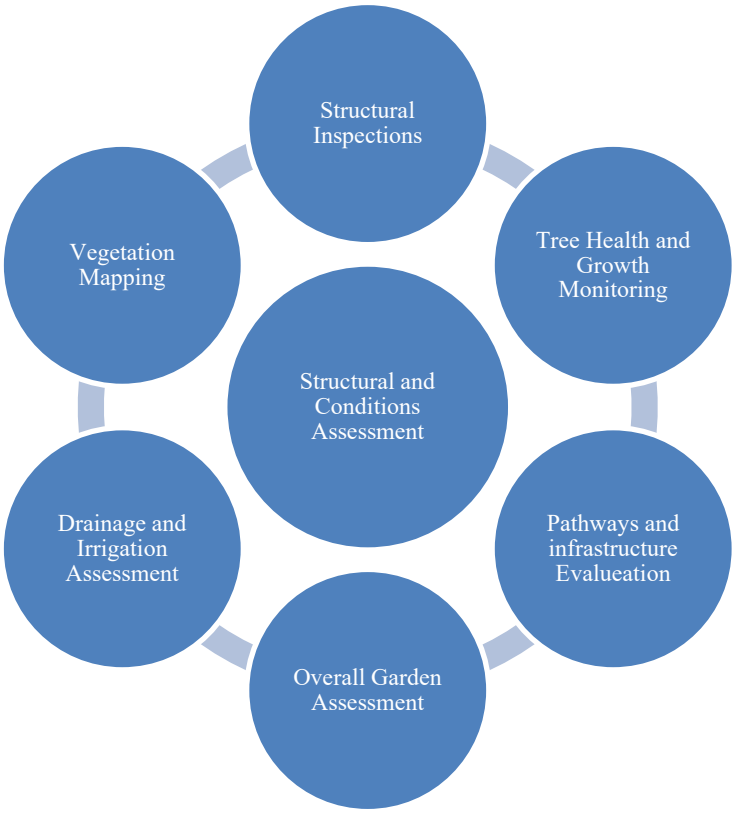
Source: Project partner ERHG (2023)

Garden's Structural and Conditions Assessment

Structural and conditions assessments in historic gardens help identify potential structural issues or vulnerabilities in structures within the garden, enable the identification of safety hazards and provide valuable data for research and historical documentation purposes. Additionally, structural and conditions assessments contribute to the development of comprehensive conservation plans. The

category Garden's Structural and Conditions Assessment includes the following six applications of drones.

FIGURE 27[29]
Usage of drone for structural and conditions assessment of historic gardens



Source: Project partner ERHG (2023)

- **Overall Garden Assessment**

Capture aerial shots that provide an overview of the entire garden. This helps identify any large-scale issues, such as areas that need restoration or maintenance, drainage problems, or changes in vegetation patterns.

- **Structural Inspections[30]**

Use aerial photography to inspect the roofs, facades, and other hard-to-reach areas of historic structures within the garden. High towers, spires, statues and steeples are extremely difficult and dangerous to reach for a person - not to mention sensitive. Aerial photography can help detect signs of damage, degradation, or the need for repairs. If you need to approach a structural element or some vegetation closer, it is recommended to use smaller drones from the subcategory A1 as they are lightweight and have lower risks of damaging any parts of the historic garden.

[29] Visual Skies (2023, May 23). *3D History: Drone Scanning for Heritage Preservation*. https://tinyurl.com/5ecv565j Historic England, (2015, April 1). *Drones for Heritage Uses*. https://tinyurl.com/4txp2may
[30] Engineers with drones (n.d*). Historical Building Inspection.* bit.ly/3YbXOIv

FIGURE 28
Historic sculptures and facade elements on the exterior of Miramare castle in Trieste, Italy

Shutterstock: Mauro Carli

- **Tree Health and Growth Monitoring**

Aerial imagery allows for monitoring the health and growth of trees in the garden. Photos and videos can reveal signs of disease, stress, or encroachment on other garden elements, assisting in timely interventions and tree management.

- **Pathways and Infrastructure Evaluation**

Document the condition of pathways, bridges, and other garden infrastructure elements from above. It helps identify areas that require maintenance, such as cracks, uneven surfaces, or signs of wear and tear. Drones help make this work faster by detecting problems in a matter of minutes, thus, accelerate the repair time of the garden meaning the better maintenance of historic gardens.

- **Drainage and Irrigation Assessment**

Aerial footage can be used to evaluate the effectiveness of drainage systems and irrigation networks within the garden. Detecting issues such as blockages, pooling water, or uneven distribution becomes easier from an aerial perspective.

- **Vegetation Mapping**

Create aerial maps and images that highlight the distribution and density of vegetation within the garden. This information can aid in garden planning, identifying invasive species, or monitoring the growth of specific plantings.

FIGURE 29
Vegetation mapping by a drone showing the field health maps for normalized difference vegetation index in the field

Shutterstock: Zapp2Photo

Garden's Promotional Resources

Creating promotional materials for historic gardens is important as it helps raise awareness, generate interest and attract visitors to these unique and culturally significant spaces. There are four main applications of drones that can be taken into account in the gardens' promotional resources category. See figure 29.

- **Promotional Materials**

Capture stunning aerial footage to create promotional videos or brochures showcasing the beauty and unique features of the historic garden. These visuals can attract visitors, promote tourism, and highlight the garden's historical significance.

- **Event Documentation**

Document special events, festivals, or gatherings held within the historic garden from an aerial perspective. Aerial photos and videos can capture the scale, ambiance, and visual impact of these events, creating memorable records for organizers and participants.

- **Visitor Experience Enhancement**

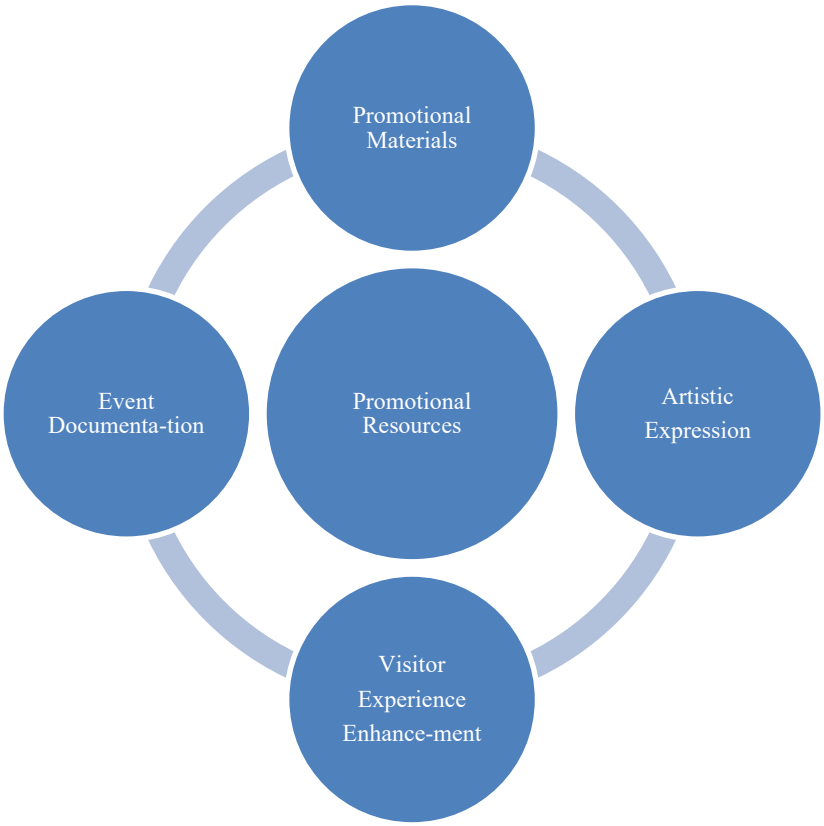
Enhance the visitor experience by providing interactive maps or virtual tours of the garden using aerial footage. Visitors can explore different sections of the garden, view historic structures, and learn about points of interest through immersive online platforms or mobile applications. This will attract even

more interest and future visitors to the gardens even if they are not able to come and visit it personally yet.

- **Artistic Expression**

Encourage artists, photographers, and filmmakers to explore the historic garden through aerial photography and videography. These creative works can capture the garden's aesthetic beauty, evoke emotions, and inspire new perspectives on its historical and cultural significance as well as spread the word about the garden among their followers.

FIGURE 30
Usage of drone for creating promotional resources for historic gardens



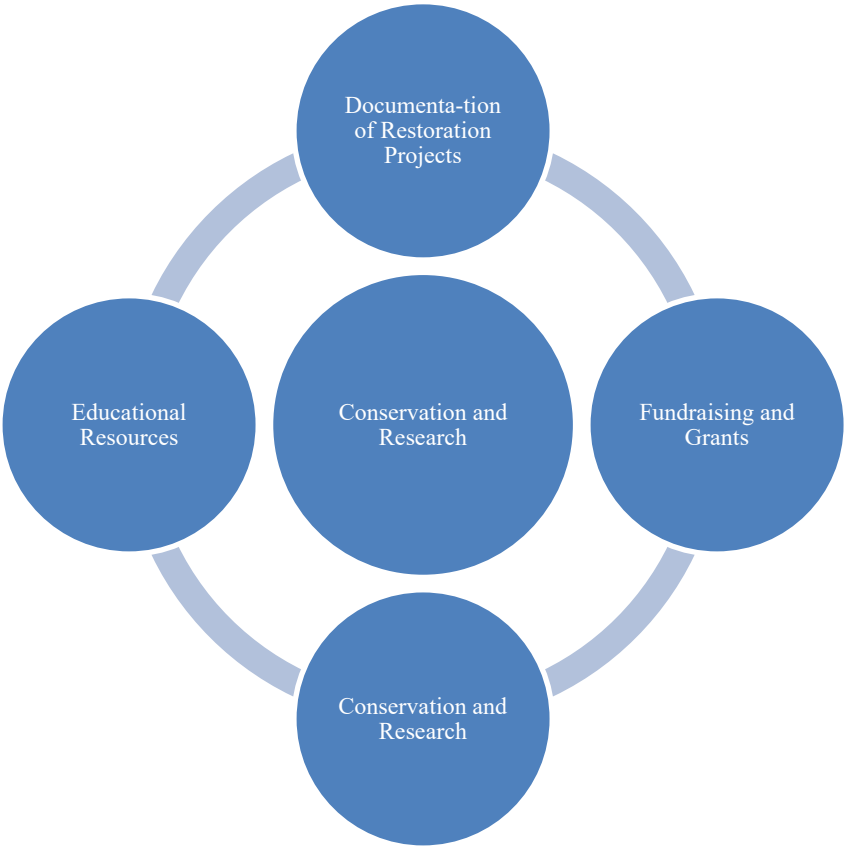
Source: Project partner ERHG (2023)

Garden's Conservation and Research

Conservation and research in historic gardens are crucial for preserving their cultural and historical significance. By engaging in conservation efforts, we can safeguard these invaluable treasures, protecting them from deterioration, environmental impacts, and the passage of time. Research plays a vital role in understanding the garden's history, identifying original design intentions, and informing restoration projects.

Four main drone applications can be emphasized in this category as seen in figure 31.

FIGURE 31[31]
Usage of drone for conservation and research purposes of historic gardens



Source: Project partner ERHG (2023)

- **Documentation of Restoration Projects**

Aerial photography and videography are valuable tools for documenting the progress and results of restoration projects within the historic garden. They provide a comprehensive view of the changes made and can be used for historical records and future reference. See figure 32.

- **Conservation and Research[32]**

Aerial imagery can assist in conservation efforts and research projects within the historic garden. Use drone photos and videos to monitor changes in vegetation, track biodiversity, study wildlife habitats, or document archaeological features that may be present.

- **Fundraising and Grants**

[31] Krátký, V. & Petráček, P. (2021). Safe Documentation of Historical Monuments by an Autonomous Unmanned Aerial Vehicle. *ISPRS International Journal of Geo-Information,* 10 (11), 738. https://doi.org/10.3390/ijgi10110738; Bentkowska-Kafel, A., & MacDonald, L. (Eds.). (2017). *Digital Techniques for Documenting and Preserving Cultural Heritage*. Arc Humanities Press: York, United Kingdom, 2017. bit.ly/3DuHWr9

[32] Bacco, M., Barsocchi, P., Cassará, P., Germanese, D., Gotta, A., Leone, G.R., Moroni, D., Pascali, M.A. & Tampucci, M. (2020). Monitoring Ancient Buildings: Real Deployment of an IoT System Enhanced by UAVs and Virtual Reality. *IEEE Access,* 8, 50131–50148. https://ieeexplore.ieee.org/abstract/document/9034055

Utilize high-quality aerial visuals to support fundraising campaigns or grant applications for preservation and restoration projects. Compelling drone footage can help stakeholders and funding organizations understand the importance of the garden and its conservation needs.

When using drones for photo and video applications in historic gardens, it is essential to prioritize safety, respect visitor experiences, and comply with local regulations. Working in collaboration with garden authorities, historians, and experts can help ensure that the drone imagery serves the intended purpose while preserving the garden's authenticity and integrity.

- **Educational Resources**

Use aerial imagery to develop educational resources about the garden's history, architecture, and landscape design. Combine drone footage with historical information to create engaging and informative presentations or interactive displays.

FIGURE 32
Restoration process of a historic building structure

Shutterstock: tomeqs

5. Applications of Drones for Historic Gardens Management and Preservation

5.1. Regular Surveying Monitoring and Inspection of Historic Gardens Using Drones

Under the pressure of climate and socio-economic changes, the management, including surveying, monitoring and inspection of historic gardens is experiencing a period of strong change and evolution due to new technologies and technical advances.

Indeed, to make the management of historic gardens concretely sustainable both from an economic and environmental point of view, it is necessary to rationalize the use of both human and natural resources. The use of drone technology shows all its potential for supporting the management and maintenance activities of green spaces, paving the way for progressive automation and virtualization of daily procedures and tasks of operators working in historic gardens where it is especially important to gather baseline information that allows ongoing monitoring and ad hoc inspections that are needed to continuously refine management techniques.

Drones used for rapid surveys and map areas create a series of still orthographic images which are then processed post-flight and stitched together, detecting identical points, to create a 3D point cloud from which ortho mosaics are taken. Ortho mosaics are mosaics of multiple aerial images that together form a dataset. These data are useful for building information modelling (BIM) workflows and can be used as a basis for cut-and-fill calculations and grading, amongst many other computational processes (Cureton, 2020)[33]. Drones may also be used to gain an aerial perspective of a site for a client, to make a documentary video of the area…" [34]such as flooding or infrastructure inspection.

With regards to vegetation monitoring and inspection, drone technology has an important role in historic gardens and historic landscapes: Using drone technology gardeners have the possibility to map trees, architectural art crafts, flowers and all garden vegetation.

Drones allow operators to survey individual trees growing in open areas (Scher et al., 2019)[35] and have the potential to record when each plant is leafing out and flowering and to monitor the structure, photosynthetic rate, and temperature of trees. In just a few hours, a drone could fly over hundreds or thousands of plants and take detailed digital images of all of the plants. Using images from successive days and weeks, it might be possible to determine the detailed phenology of all of the plants in a collection, though matching plants from one flight to the next remains a significant challenge. Similarly, fixed digital cameras have the potential to automate observations of flowering and leafing out (Chen et al., 2019)[36].

More drones can assist with irrigation monitoring, scheduling and topography mapping[37] and support gardeners to preserve historic gardens and there are endless opportunities for growth as gardeners if they are open to the idea of learning and working with technology. Using a drone for gardening can improve and make safer daily work.

Table 22 provides with details on how drones can support historic garden management and table 23 explains the benefits of using drones for surveying historic gardens.

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[33] Cureton, P. (2020). *Drone Futures: UAS in Landscape and Urban Design*, Oxon: Routledge, NY

[34] Cureton P., Shilton M. & Schroth, O. (2022) *Drones in Landscape Practice* (2nd ed.), Landscape Institute, Technical Information Note of 22/02/2022. https://tinyurl.com/3625vupa

[35] Scher, C. L., Griffoul, E., & Cannon, C. H. (2019). Drone-based photogrammetry for the construction of high-resolution models of individual trees. *Trees*, 33, 1385-1397

[36] Chen, B., Jin, Y. & Brown, P. (2019). An enhanced bloom index for quantifying floral phenology using multi-scale remote sensing observations. *ISPRS Journal of Photogrammetry and Remote Sensing*, 156, 108-120

[37] Hashem, A., & Hamilton, M. (July 2020*).* UAV imagery offers multiple irrigation applications. *Irrigation Today.* https://tinyurl.com/4k79dck2

TABLE 22
Drones and historic garden management

How drones can support historic garden management	
Surveying	Recording of qualitative or quantitative biological data using easily repeatable standardised techniques over a restricted period without preconceptions of the results.
Monitoring	Checking continuously for the purpose of control in order to react quickly to change and it the comparison of repeated surveys. It is critically important that initial (baseline) surveys are done to a standard, described method and that the results are fully documented so that they can be repeated.
Inspection	Assessing for changes or deviations to the anticipated or required results.

Source: Project partner STC (2023)

FIGURE 33
The Labyrinth, Garzoni Garden in Collodi, Italy

Source: Project partner STC (2023)

TABLE 23
Main benefits of drone surveys

Benefits of using drones for surveying historic gardens	
Efficiency	Drone surveys can cover large areas quickly and efficiently, reducing the time and cost of traditional survey methods. By conducting drone surveys, you can cover vast territories quickly and effectively, which ultimately minimizes the expenses and time consumed by conventional survey techniques.
Accuracy	Drones can capture highly detailed images and data, providing accurate measurements and 3D models of a site.
Safety	Drones can access hard-to-reach areas, reducing the need for workers to climb scaffolding or use heavy equipment
Flexibility	Drones can be used in a variety of settings, including urban areas, remote locations, and hazardous environment

Source: Project partner STC (2023)

Drones used for surveying/monitoring and inspection are equipped with onboard cameras that take photos of the ground from different points in the air. Images are tagged with geo-coordinates that are captured by a GNSS sensor on the drone indicating exactly where that image is located in space

For accurate, efficient and cost-effective data collection using drones, there are several methods available. Understanding these methods can be useful for selecting the most suitable technique for the work to carry out. See table 24.

TABLE 24
Most common types of methods for surveying using drones

Drone Survey Type	Description	Applications
Aerial Photogrammetry	During a drone survey with a digital a camera, the ground is photographed several times from different angles, and each image is tagged with coordinates. A series of overlapping images to generate measurements and models and elevation data. Photogrammetry is the process of measuring, recording and interpreting photographs to create a spatial model and 2D and 3D maps. In digital photography, the most significant factor is the sensor size which determines the quality of the results.	Commonly used to create topographical maps it is useful also for: • Cultural heritage • Monitoring gardens • Infrastructure inspection • Land use • Commercialization
Sensing	A sensing survey collects data in the form of light and color by detecting different wavelengths of radiation	• Pest Monitoring
3D Modeling	Create highly detailed 3D models of structures, landscapes, or objects using photogrammetry or LiDAR techniques.	• Cultural heritage • Architecture, • Disaster management • Urban planning
Topographical	Collect data on the contours, elevations, and features of a given area to create detailed topographic maps.	• Terrain mapping • Vegetation mapping • Construction • Land development • Environmental studies
Multispectral sensors	Unlike traditional RGB (Red, Green, Blue) sensors found in consumer cameras, multispectral sensors can detect and record data in specific wavelengths beyond what is visible to the human eye. These sensors can capture information in the infrared (IR) and ultraviolet (UV) ranges, as well as other narrow or broad spectral bands.	Environmental and garden monitoring: • Monitor forests • Wetlands • Water bodies. • Detect changes in land cover. • Analyze water quality and chlorophyll content. • Plant health analysis • Pest monitoring
LiDAR[38]	Use laser light to measure distances and create detailed 3D representations of an area in the form of point clouds.	• Forestry (plants information) • Flood • Risk assessment
Thermal Imaging		• Thermographic control

[38] Airborne laser scanning is a technology used for topographical surveying and mapping, e.g. hydrological mapping, construction and forestry. This method employs a light detection and ranging (LiDAR) scanner and is based on time of flight measurements of emitted laser pulses from surfaces on or near ground, measuring the distance to the object from the sensor. The main output from a LiDAR survey is a 3D point cloud. The purpose of the survey, and the required density of the point cloud will determine the specification of the sensor. LiDAR surveys are capable of mapping extremely narrow objects, such as overhead electricity lines, subject to the resolution employed.

Drone Survey Type	Description	Applications
	Use infrared sensors to detect temperature differences in objects, revealing heat signatures, moisture content, and energy loss.	• Water • Pest and diseases • Environmental factors • Forestry inspection • Wildlife monitoring • Building inspection

Source: Project partner STC (2023)

Drone surveys generate a variety of data formats and deliverables that can be used across different applications and industries. These deliverables provide valuable insights and support decision-making processes. We present these deliverables on table 25.

TABLE 25
Drone survey deliverable

Drone Survey Deliverable	Description	Applications
Orthomosaic Maps	High-resolution, georeferenced images are created by stitching together multiple aerial photographs.	Land development, agriculture, environmental monitoring
Digital Elevation Models (DEMs)	3D representations of the terrain's elevation data, displaying the surface's shape and features.	Flood risk assessment, land use planning, infrastructure design.
Digital Surface Models (DSMs)	Similar to DEMs, but include elevation data of all objects on the surface, such as buildings, vegetation, and infrastructure.	Urban planning, line-of-sight analysis, telecommunications network planning
Digital Terrain Models (DTMs)	Represent the bare earth surface by removing any above-ground features, such as vegetation and structures.	Civil engineering, geology, hydrological studies
Point Clouds	Collections of 3D points representing the surveyed area's shape and features.	3D model creation, volumetric calculations, structural integrity assessment
Contour Maps	Display elevation data as a series of contour lines representing points of equal elevation.	Land development, construction planning, resource management
3D Models	Detailed representations of structures, landscapes, or objects derived from point clouds or photogrammetry data.	Architecture, engineering, urban planning
Inspection Reports	Detailed reports for various structures, including high-resolution images, thermal data, and structural assessments.	Maintenance, repair, safety planning for buildings, bridges, pipelines
Vegetation Indices	Indices such as the Normalized Difference Vegetation Index (NDVI) providing insights into plant health, growth, and stress.	Agriculture, environmental monitoring, resource allocation
Volumetric Measurements	Calculation of volumes and areas, such as stockpile volumes, excavation sizes, or water body extents.	Mining, construction, waste management

Source: Project partner STC (2023)

5.2. Water Monitoring: Thermographic Control to Detect Areas with Excess/Lack of Water[39]

Thermal or Multispectral images have been introduced as an affordable tool for plant water status monitoring[40], especially in regions where water availability is the main limiting factor. In this section, we analyse:

- Thermal imaging technology.
- Use of the thermal image for water monitoring in historic gardens.
- Cases of thermal drone inspection in gardening.

FIGURE 34
Thermal image

Source: Wikimedia commons

- **Thermal Imaging technology**

Also known as infrared thermography (IRT), thermal imaging is the process of using thermal cameras to capture images of objects by using the infrared radiation (heat) emitted by these objects. The resulting thermal images (also known as thermograms) depict the spatial distribution of temperature differences in the scene captured by the thermal cameras.

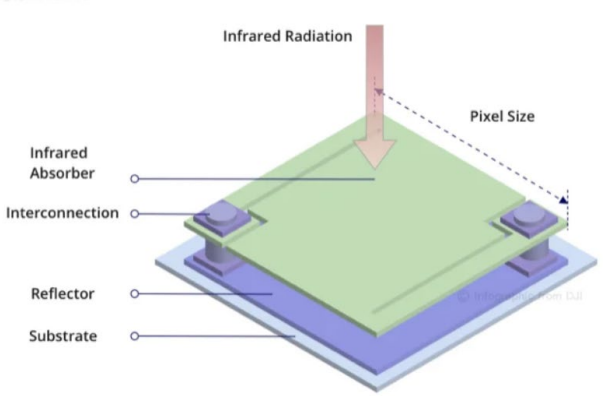
In recent years, thermal imaging cameras have been integrated with commercial drones in order to perform a wide variety of tasks. Thermal drones equipped with cutting-edge thermal imaging systems can capture different types of images simultaneously because generally carry two cameras: a thermal imaging camera and a standard imaging system.

Since infrared radiation (IR) is emitted by all animate and inanimate objects with a temperature above absolute zero, thermal imaging makes it possible to perceive one's environment even if there is insufficient lighting. Since the amount of IR emitted by an object increases with temperature, thermal imaging allows one to see variations in temperature.

[39] Workswell (n.d.). *Detection of water stress cereals crops with thermal camera UAV*. https://tinyurl.com/mpkm8ffh
[40] Stoll M., & Jones H. G., (2007). Thermal imaging as a viable tool for monitoring plant stress. *OENO One*, 41(2), 77–84. https://doi.org/10.20870/oeno-one.2007.41.2.851

To capture temperature variations, thermal cameras are equipped with sensitive heat sensors that can pick up minute differences in temperature. Thermal cameras are sensitive to wavelengths ranging from approximately 1,000 nanometers to about 14,000 nanometers.

FIGURE 35
Diagram of a thermal sensor (microbolometer)



Source: DJI Enterprise (2022)[41]

Thermal camera, thermal images and water monitoring

Thermal cameras, also known as infrared cameras, can detect temperature differences which can be indicative of water stress. Consequently, thermal images can be used for regular monitoring of gardens throughout the growing season to track changes in temperature and detect water stress early and/or can be an effective tool for water monitoring by detecting water stress that occurs when there is a deficiency of water supply, either due to inadequate irrigation or natural factors. The use of thermal cameras allows gardeners to constantly monitor water stress and take corrective actions, such as adjusting irrigation schedules, to mitigate risks and minimize vegetation losses.

- **Use of thermal camera and thermal images for detecting water stress in vegetation**

A thermal camera can capture the infrared radiation emitted by plants, which is influenced by their temperature. When plants are under water stress, they tend to have higher temperatures compared to well-hydrated ones. This is because transpiration, the process by which plants lose water through their leaves, is reduced under water stress, leading to higher leaf temperatures.

Thermal imaging can be also used to detect the moisture content of soil and create land maps, both of which can assist in optimizing irrigation systems. This will improve the efficiency of irrigation, reducing water wastage and preventing vegetation failures.

Temperature analysis: The thermal images captured by the camera can be analyzed using specialized software (please indicate the software) that can generate temperature maps or thermal indices. These maps can help identify areas of the garden that are experiencing higher temperatures, indicating potential water stress.

Comparison with baseline: The thermal images can be compared to baseline data of well-hydrated plants to identify temperature anomalies a water-stressed plant/vegetation in the garden would exhibit higher temperatures in specific areas or patches.

[41] DJI Enterprise (2022, August). *A quick look at how thermal imaging technology paired with the maneuverability of a drone can benefit your enterprise.* https://tinyurl.com/2dhynypc

Ground truth validation: Thermal imaging findings can be validated with ground truth data, such as soil moisture measurements, plant physiological measurements, and visual assessments of vegetation health. This can help confirm the presence of water stress and provide more accurate results.

Timely monitoring: Thermal cameras can be used for regular monitoring of gardens throughout the growing season to track changes in temperature and detect water stress early. This can allow gardeners to take corrective actions, such as adjusting irrigation schedules, to mitigate water stress and minimize vegetation losses.

- **Selected Use Cases of Thermal Drone Inspection**

Plant stress: Thermal images can be useful as a first line of detection to determine the onset of plant stress due to changes in stomatal aperture. This approach can give reliable and sensitive indications of leaf temperature and hence to calculate stomatal conductance.[42]

Monitoring water availability: Thermal imagings can be used to evaluate the water status of young and mature sweet cherry trees (Prunus avium L.) submitted to water stress. Two treatments per plot were assayed: (i) a control treatment irrigated to ensure non-limiting soil water conditions; and (ii) a water-stress treatment.[43]

FIGURE 36
A drone pilot flying a drone

Copyrights free 123RF: Sergey Mironov

5.3. Health Monitoring: Pest and Diseases Control

Plant diseases are one of the major threats to parks and gardens. Efficient monitoring and detection of plant pathogens allow early outbreak detection and treatment applications for effective pest management before pests are well-established and allow decisions that limit the spread of the disease and reduce the cost of pesticides.

[42] Jones, H.G., Leinonen, I. (2003). Thermal Imaging for the Study of Plant Water Relations. *Journal of Agricultural Meteorology*, 59 (3), 205-217. https://doi.org/10.2480/agrmet.59.205

[43] Blaya-Ros, P. J., Blanco, V., Domingo, R., Soto-Valles, F., & Torres-Sánchez, R., (2020). Feasibility of Low-Cost Thermal Imaging for Monitoring Water Stress in Young and Mature Sweet Cherry Trees. *Applied Sciences,* 10 (16), 54-61. https://doi.org/10.3390/app10165461

Traditional, molecular, and serological methods that are widely used for plant disease detection are often ineffective if not applied during the initial stages of pathogenesis when no or very weak symptoms appear. Moreover, they are almost useless in acquiring spatialized diagnostic results on plant diseases.

Instead, drones are able to provide early warning of plant diseases and play a pivotal role in the monitoring of plant pathogen spread. For instance:

1. Biotic stress, such as herbivory by arthropod pests, elicits physiological defense responses in plants, leading to changes in leaf reflectance that can be detected by imaging technologies.
   .
2. Acquired and processed canopy reflectance data obtained with sensing drones could potentially be transmitted as a digital map to guide a second type of drone, actuation drones, to deliver solutions to the identified pest hotspots, such as precision releases of natural enemies and/or precision-sprays of pesticides.

The advantages of drone technology include high spatial resolution (as several sensors are carried aboard), high efficiency, usage flexibility, and more significantly, quick detection of plant diseases across a large area with low cost, reliability, and provision of high-resolution data.

In this manual, we focus specifically on the use of small drones which are here defined as remotely controlled, unmanned flying robots that weigh more than 250 g but less than 25 kg, including payload. These types of drones typically have flight-times of a few minutes to hours and limited ranges. We will also briefly discuss the larger drones that are typically used for pesticide sprays. Discussion of larger drones is beyond the scope of this manual, but see Watts et al. (2012)[44], and Anderson and Gaston (2013)[45] for more information.

Drones used for the detection of pest hotspots are here referred to as sensing drones, while drones used for the precision distribution of solutions are referred to as actuation drones:

- Sensing drones reduce the time required to scout for pests.

- Actuation drones reduce the area where pesticide applications are necessary and reduce the costs of dispensing natural enemies.

Both types of drones could communicate to establish a closed-loop IPM solution. Importantly, the use of drones in precision pest management could be cost-effective and reduce harm to the environment. In table 26 we showcase the different imaging techniques that are used to acquire plant morphological information.

TABLE 26
Acquisition of plant morphological information through different imaging techniques

Imaging technniques	Description	What it does
Sensing drones, drone-based aerial imaging	One of the most significant and beneficial data types. These Remote Sensing (RS) approaches rely on the detection of any variation in the optical properties of plants.	In other words, they essentially detect any change in the plant physiology that, due to biotic or abiotic stresses, transpiration rates, morphology, plant density, and changes in solar radiation between plants, determines measurable variations in plants optical output. Furthermore, the movement of plant pathogens or their products can be

[44] Watts, A. C., Ambrosia, V. G., & Hinkley, E. A. (2012). Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use. *Remote Sensing*, 4 (6), 1671–1692. http://dx.doi.org/10.3390/rs4061671
[45] Anderson, K. and Gaston, K.J. (2013). Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Frontiers in Ecology and the Environment,* 11 (3), 138-146. https://doi.org/10.1890/120150

		traced from tens to hundreds of meters above crop fields, and numerous plant disease images can be captured directly and in real time, allowing the application of algorithms to monitor the occurrence of specific plant diseases.
Thermographic sensors	Non-intrusive solution for finding pests. Thermographic sensors capture infrared radiation emitted from the plant surface.	It utilizes infrared technology to detect and locate pest and disease problems. In case of a pathogen infection, the plant surface temperature will increase due to the transpiration reduction. Based on the change in temperature, the sensor can analyze disease's presence before it even appears however cannot detect the type of infection or disease. The precision of this type of control is influenced by the change of environmental conditions during measurement.
LiDAR[46]	Lidar sensors are a key component in autonomous vehicles, providing a high-resolution 3D view of their surroundings	LiDAR calculates the distance from the sensor to ground objects to measure their position; its beams can pass through the canopy and send back information about its structure, plant density, and the ground surface.
Structure-from-Motion (SfM) photogrammetry	Method that can detect diseases in the fields, monitor crop vigour, estimate biomass and yield, and detect symptoms of both abiotic and biotic stresses. Digital cameras can detect one or a few broad near-infrared (NIR) bands[47], while hyperspectral cameras (tens to hundreds of spectral bands) measure narrow bands; despite having been reduced for drone utilization, the latter requires extra space and payload capacity	SfM collects images from multiple perspectives as drones fly over the fields; it utilizes high-resolution digital cameras from which images can be used to measure such phenotypical characteristics of the plant population as individual height, lodging, and developmental stages.
Reducing Pest Population Sterile Insect Technique	A potential new area for use of drones in pest management is the release of sterile insects.	Pilot programs to release sterile insects with drones have been successful in controlling codling moth populations in New Zealand, Canada, and drone-released sterile insects proved effective for control of these pests in the United States[48]. The sterile insect technique (SIT) produces sterile or partially sterile insects through irradiation. After mating with wild insects, there is either no offspring or the resulting offspring is sterile, resulting in reduced pest populations. SIT is environmentally friendly, species-specific, and compatible with other management methods such as biological control, making it an

[46] Christiansen, M.P., Laursen, M.S., Jørgensen, R.N., Skovsen, S. & Gislum, R. (2017). Designing and testing a UAV mapping system for agricultural field surveying. *Sensors*, 17, 2703. https://tinyurl.com/586b6xe4

[47] Yang, C., Westbrook, J.K., Suh, C.P.-C., Martin, D.E., Hoffmann, W.C., Lan, Y., Fritz, B.K., & Goolsby, J.A. (2014). An airborne multispectral imaging system based on two consumer-grade cameras for agricultural remote sensing. *Remote Sens,* 6, 5257–5278. https://tinyurl.com/52za59kn

[48] Animal and Plant Health Inspection Service (2017, October 20). *PPQ Explores the Tantalizing Promise of Unmanned Aircraft Systems.* https://tinyurl.com/mubhzsuu

		important IPM tool[49]. Drone release of sterile insects may be cheaper and faster than ground release.

Source: Project partner STC (2023)

5.4. Risk and Prevention Management: Fire Prevention

Drones allow the transmission of images in real-time and consequently an accurate assessment of the outbreaks and their intensity and a speed response. They can be used to spot fires in inaccessible areas, or the remote sensing capabilities can be used to provide information on soil moisture levels, wind direction, and other environmental conditions that can help predict the potential for a fire. In table 27 we present the main uses of drones in fire prevention.

Drones with RGB cameras[50] are a versatile and easy-to-use tool, which improves situational awareness and helps teams work faster and smarter. The introduction of aerial thermal cameras promises greater visibility and a more complete view of the spread and speed of the fire and lower risks for the persons.

FIGURE 37
Drones and fire prevention

Source: Pinterest

TABLE 27
The main uses of drones in fire prevention

Use of drones	Description
Information collection	A pilot can cover a large area and identify the hottest spots using thermal camera drones.
Monitoring a fire's progress	By providing real-time data, drones can help to quickly detect and respond to any changes that may occur as a result of the fire and control that the fire is contained within its designated boundaries

[49] Simmons, G.S., Suckling, D.M., Carpenter. J.E., Addison, M.F., Dyck, V.A., & Vreysen, M.J.B. (2010). Improved quality management to enhance the efficacy of the sterile insect technique for lepidopteran pests. *Journal of Applied Entomology*, *134* (3) 261-273. https://doi.org/10.1111/j.1439-0418.2009.01438.x

[50] The term RGB refers to the color model in which the red, green, and blue primary colors of light are added to create different colors that we perceive. An RGB camera is used to deliver colored images of people and objects by capturing light in red, green, and blue wave lengths.

Help and protection	Knowing about fire spread and direction in a fire is vital. With a drone, teams can easily monitor from afar and ensure everyone is safe, as well as get data on fire spread.
Capture and Mapping	Using drone technology, it is possible to identify unseen critical points and increase the safety of operations. Thermal image capture can be used to support operations before and during the fire spread. Captured images can also be transformed into 3D maps assisting post-incident work.
Real-time situational awareness	Drone data can help ensure that decision-makers have the same information. The isothermal technology used by drones allows the operator to highlight certain temperature ranges and highlight them in real-time. In a fire, situational awareness is needed for planning. Drones fly over the area to collect data and thus plan and bring help to the scene and control the situation.

Source: Project partner STC (2023)[51]

5.5. Identification of Maintenance or Repair Work Needed and Assessment of Hard-To-Reach Areas

Drone inspections are particularly useful when conducting visual inspections in hard-to-reach parts of a garden or of an artifact can be dangerous.

For the operators involved in the preservation and conservation of these sites, the drones provide a cost-effective aerial view of places that can be difficult to access, allowing for detailed, up-to-date information to be collected. Drone provides also detailed aerial surveys, rapid data collection, and cost-effective data storage.

Using drones equipped with thermal and high-resolution cameras to conduct inspections of hard-to-reach areas allows to detect defects that would otherwise remain invisible. Examples are moisture inside of walls, water leaks, faulty wiring, canopy, and historic tall trees.

FIGURE 38
Villa Garzoni, Collodi, Italy

Source: Garzoni Garden

[51] HPDrones (2023, May 5). *Fire Prevention Using Drones*. https://tinyurl.com/27b22n8j

Drones equipped with high-resolution cameras allow to get a quicker analysis of the site, identify changes over time and allow a better understanding of the site's development. Drones have the ability to survey sites in a timely manner and eliminate the need for labor-intensive, time-consuming survey methods. This can help to identify potential risks or threats so that the site can be protected or restored more quickly and monitor the condition of the site and identify areas that need attention, especially the areas that may be difficult to see from the ground or difficult to reach.

Using drones there is no necessity to climb trees or roofs and prevents falling from height accidents and serious problems in the future. With early detection, repairs can be made before systems begin failing, so that conditions of the inspected never become unsafe, and money is saved over the long run. For this reason, the use of drones for monitoring and mapping of historical gardens and cultural sites is increasingly popular and it is beneficial for both the preservation of the site and for the identification of the maintenance work to be planned.

6. Application of Drones for Marketing in Historic Gardens

6.1. Tips for Marketing the Use of Drones in Historic Gardens

Using drones for marketing in historic gardens offers a multitude of benefits that can greatly enhance promotional efforts. Firstly, drones provide a unique aerial perspective, allowing for breathtaking visuals that capture the grandeur and beauty of the gardens from a new and captivating angle. This aerial imagery not only showcases the gardens' architectural splendor and landscape design but also highlights their historical significance and cultural value. Furthermore, the dynamic footage and immersive experiences created through drones help to engage and captivate audiences, generating excitement and curiosity about the gardens. By incorporating drone-captured content into marketing materials, historic gardens can effectively convey their unique offerings, attract visitors, and create a lasting impression. Drones also facilitate the documentation and preservation of the gardens, enabling the monitoring of changes over time and providing valuable historical records. Overall, the use of drones in marketing historic gardens opens up a world of possibilities, enabling the audience to experience these remarkable spaces in a way that is both visually stunning and deeply informative.

TABLE 28[52]
Drone footage tips for marketing purposes

Drone Footage Tips	Description
Plan Your Shots	Before taking off, have a clear vision of the shots you want to capture. Plan the angles, compositions, and movements to ensure you capture the most visually appealing footage.
Choose the Right Time	Lighting plays a crucial role in creating beautiful footage. Aim to film during the golden hour (early morning or evening) when the sunlight is soft, providing warm, flattering tones and long shadows that add depth to your shots.
Use Manual Settings	Familiarize yourself with the manual settings of your drone's camera, such as exposure, ISO, and shutter speed. Adjust these settings to control exposure and get the best results in various lighting conditions. Select the highest camera resolution available like 4K, 5.2K or 6K. Also, select HDR (High Dynamic Range) and RAW image if available in the camera settings installed on drone.
Select Shooting Mode	By selecting different shooting modes on the drone's camera, you can create creative and attractive images that you can use for marketing. For example, select a higher shutter speed, more than 60 fps, and create stunning slow-motion aerial videos to show all the beauty and details of the garden. Also, you can select to shoot a sequence of photos from which you can create a time-lapse to show the garden during the day and night or during different seasons, for example.
Avoid Harsh Movements	Smooth and controlled movements are essential for professional-looking footage. Use slow and steady camera movements to avoid jerky shots that can be disorienting to viewers.
Frame Your Shots	Compose your shots carefully to create visually engaging content. Incorporate leading lines, symmetry, and natural framing elements to guide the viewer's eye and draw attention to the garden's beauty.
Capture Diverse Perspectives	Experiment with different heights, angles, distances, and flight paths to capture a variety of shots. Showcase the garden from various viewpoints to give viewers a comprehensive view of its grandeur.
Showcase Seasonal Changes	Capture footage throughout the year to showcase the garden's seasonal beauty and transformations. Highlight the colorful blooms in spring, lush greenery in summer, vibrant foliage in autumn, and serene landscapes in winter.
Use ND Filters	Neutral Density (ND) filters can help control exposure in bright conditions and reduce overexposed areas in your shots, ensuring balanced lighting and more cinematic footage.
Post-Production Enhancement	After capturing footage, use video editing software to fine-tune your clips. Adjust colors, contrast, and saturation to enhance the visual appeal. Add subtle transitions and music to create a polished and captivating marketing video.

Source: Project partner ERHG (2023)

[52] DJI Guides (2017, May 12). *6 Photo Modes Every Aerial Photographer Needs to Know*. bit.ly/47928wk
K&F Concept (2023, June 21). *How Good are the Cameras On Drones?* https://bit.ly/454KEz4

By applying these tips, you can capture stunning footage from your drone, showcasing the beauty and uniqueness of the historic garden to create compelling marketing content that engages and attracts viewers.

6.2. Using Drones to enhance the Tourist Experience

Drones can be utilized in various ways to enhance the tourist experience in historic gardens. Here are some ideas on how to leverage drones effectively:

FIGURE 39[53]

Drones' applications to increase the tourist experience in historic gardens

Source: Project partner ERHG (2023)

- **Aerial Tours.** Offer guided aerial tours of the historic garden, allowing visitors to experience a bird's-eye view of the entire landscape. Drones can capture live footage streamed to screens or virtual reality headsets, providing an immersive and interactive tour experience.

- **Virtual Reality (VR) Experiences.** Create virtual reality experiences that allow visitors to explore the garden virtually through drone-captured imagery. With VR headsets, visitors can navigate through different sections of the garden, providing a realistic and immersive experience even from a remote location.

- **Interactive Maps and Apps, 3D models.** Integrate drone footage into interactive maps or mobile applications dedicated to the historic garden. Users can explore the garden virtually, accessing drone-captured imagery at specific points of interest, and gaining a comprehensive understanding of its layout and features. Utilize drone imagery to create interactive 3D models of the historic garden. These

[53] TS2 Space (2023, February 20). *Drones for Tourism: Enhancing Safety and Communication for Travelers* https://bit.ly/3Qa4RiV

Ilkhanizadeh S., Golabi M. & Rjoub H. (2020). The Potential Use of Drones for Tourism in Crises: A Facility Location Analysis Perspective. J*ournal of Risk and Financial Management*, 13 (10) bit.ly/3O9Us4a

models can be embedded on websites or used in virtual reality experiences, allowing viewers to explore the garden in a realistic and immersive manner.

FIGURE 40
Aerial view from a drone of Alhambra and Generalife Gardens in Granada, Andalusia, Spain

Shutterstock: Songquan Deng

- **Interactive Displays at Visitor Centers.** Create interactive displays at visitor centers or information kiosks within the garden. Incorporate touchscreen monitors or tablets that allow visitors to explore drone-captured imagery, historical facts, and multimedia content about the garden's significance.

- **Educational Interpretation.** Use drones to capture detailed imagery of specific features, architectural elements, or historical artifacts within the garden. Incorporate these visuals into educational displays or interactive exhibits, providing visitors with an in-depth understanding of the garden's history, design, and cultural significance.

- **Augmented Reality (AR) Enhancements.** Integrate augmented reality technology into the visitor experience. By overlaying drone-captured imagery onto physical structures or locations within the garden, visitors can use their smartphones or tablets to see how the garden looked in the past or to reveal hidden details and historical information.

- **Multimedia Presentations.** Create multimedia presentations that incorporate drone footage, historical narratives, and storytelling. These presentations can be shown in visitor centers, theaters, or outdoor screenings, providing visitors with a visually engaging and informative experience that brings the garden's history to life.

FIGURE 41
A female museum visitor is looking at an interactive map

Source: Shutterstock, Albina Matveytseva

- **Social Media Integration.** You can offer to capture photographs of visitors at a historic garden from a drone and encourage visitors to share their photos and videos on social media platforms using specific hashtags or geolocation tags. This user-generated content can create a sense of community and excitement, showcasing diverse perspectives of the garden and encouraging others to visit.

- **Touristic materials with drone footage.** Tourists coming to visit a place love a bring a piece of it to their home. Create materials for tourists with stunning imagery from drones like postcards, magnets, booklets, books, posters, tote bags, etc.

- **Garden Exploration Guides.** Develop drone-assisted exploration guides that visitors can access through smartphones or tablets. These guides provide information about specific garden features or hidden treasures, guiding visitors to different areas using drone-captured images or videos as visual references.

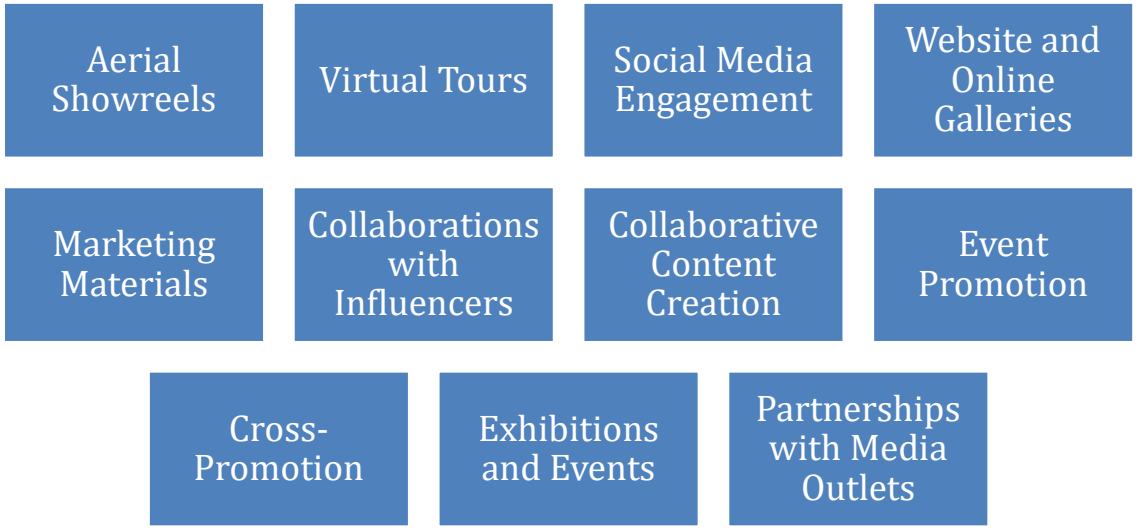
- **Nighttime Light Shows.** Utilize drones equipped with LED lights to create captivating light shows against the backdrop of the garden during evening or nighttime events. Choreographed drone formations and patterns can enhance the magical ambiance and provide a memorable experience for visitors.

By leveraging drones to enhance the tourist experience in historic gardens, visitors can engage with the gardens in new and immersive ways. These innovative approaches allow for deeper exploration, interactive learning, and an increased appreciation of the garden's historical and cultural value.

6.3. Using Drones to Promote Historic Gardens

Drones can be utilized in various effective ways to promote historic gardens and generate interest among potential visitors. In figure 41 we showcase some the best ways to use drones for promotional purposes.

FIGURE 42[54]
Drones' applications for promotional purposes in historic gardens



Source: Project partner ERHG (2023)

- **Aerial Showreels**

Create captivating aerial showreels that highlight the key features, architectural details, and scenic beauty of the historic garden. These short, visually stunning videos can be shared on social media platforms, websites, or during promotional events to give viewers a glimpse of the garden's charm and entice them to visit.

- **Virtual Tours**

Develop virtual tours using drone-captured footage, allowing people to explore the garden from the comfort of their homes. These interactive tours can be embedded on websites or shared as standalone experiences, enabling visitors to navigate different sections of the garden, view historical points of interest, and learn about its cultural significance.

- **Social Media Engagement**

Utilize drones to capture and share captivating images and videos on social media platforms. Regularly post high-quality content that showcases the unique aspects, seasonal beauty, and historical significance of the garden. Encourage user-generated content by running contests or challenges, inviting visitors to share their own drone-captured photos and videos using specific hashtags.

- **Website and Online Galleries**

Enhance the garden's website with dedicated sections or galleries featuring drone-captured visuals. Showcase stunning aerial photos, interactive maps, and immersive videos that provide visitors with a comprehensive digital experience of the garden. Keep the content updated and regularly refreshed to maintain visitor interest.

- **Marketing Materials**

Incorporate drone-captured imagery into brochures, flyers, posters, and other print materials. Use these visuals as captivating covers or centerpieces that immediately grab attention and convey the beauty and

[54] Alaska Adventure Charters (2019, October 4). *How Drones are Emerging as a Great Marketing Tool for Tourism Industry*. bit.ly/44UWz2I

uniqueness of the garden. Complement the visuals with concise and engaging descriptions to pique curiosity.

FIGURE 43
A woman is taking a virtual tour wearing a virtual reality headset

Source: Shutterstock, V_Lisovoy

- **Event Promotion**

Use drone footage to promote special events, festivals, or activities happening within the historic garden. Showcase the scale and ambiance of the events through aerial shots, capturing the energy and excitement that visitors can expect. This helps create a buzz and encourages attendance.

- **Collaborations with Influencers**

Partner with drone photographers, travel bloggers, or influencers who specialize in promoting unique destinations. Invite them to capture and share their experiences at the historic garden through drone-captured visuals. Their content and endorsements can help reach a broader audience and generate interest in visiting the garden.

- **Collaborative Content Creation**

Engage with local filmmakers, photographers, or content creators to produce collaborative projects that showcase the garden's beauty and historical significance. Collaboratively develop visually compelling narratives, short films, or documentaries that highlight the unique features and stories behind the garden.

- **Partnerships with Media Outlets**

Collaborate with local or national media outlets to feature drone-captured footage in articles, documentaries, or television programs. Such partnerships can raise awareness about the garden and its unique offerings, attracting visitors and fostering interest in its history and preservation.

- **Cross-Promotion with Tourism Organizations**

Collaborate with local tourism boards, travel websites, or tourism influencers to feature the historic garden as a must-visit destination. Provide them with exclusive access to drone-captured footage,

interviews, or behind-the-scenes experiences, allowing them to showcase the garden to their audiences effectively.

- **Exhibitions and Events**

Organize exhibitions or events that feature drone-captured visuals of the historic garden. Create immersive installations or displays that utilize large screens or projections to showcase the beauty and historical significance of the garden from aerial perspectives. These experiences can attract attention and generate interest among visitors.

By leveraging the capabilities of drones for promotional purposes, historic gardens can effectively reach and engage with a wide audience, showcasing their uniqueness and inviting visitors to experience their beauty and heritage first-hand.

7. Historic Garden Staff Training and Skill Development in Drone Operation and Maintenance

FIGURE 44
A man is preparing for his training

Source: fizkes

In the following pages, we will delve into the specific skillset required, emphasizing the importance of each skill in contributing to the successful implementation of drone technology in historic gardens. Additionally, we will explore the advantages of online training, which provides flexible learning opportunities, accessible resources, and the freedom to learn at one's own pace. This mode of learning empowers garden staff to acquire the necessary expertise effectively, enabling them to identify maintenance needs, track changes over time, and develop conservation strategies to safeguard the heritage of these cherished historic gardens.

To ensure continuous improvement and skill development, we will also provide valuable information on where to find relevant online resources for further training. You will discover tips and recommendations on how to best approach learning these new skills online, making the process both engaging and efficient. By the end of this section, you will be equipped with the knowledge and tools necessary to make the most of drone technology in preserving and enhancing the beauty and historical significance of these exceptional gardens.

7.1. Skills for Successfully Utilize Drones in Historic Gardens

To unlock the complete potential of these aerial tools, garden staff must possess a diverse skillset that empowers them to effectively utilize drones for a wide range of applications. In the following chart, we have identified eight essential skills that are crucial for harnessing the capabilities of drones.

FIGURE 45
Essential Skillset for Garden Staff to Successfully Utilize Drones

Source: Project partner Telewander ApS (2023)

The first four skills, namely "Drone Software Proficiency," "Drone Hardware Knowledge," "Drone Piloting and Flight Planning," and "Documentation Control," serve as the foundational pillars for effective drone utilization. The skill of "Historic Garden Preservation through Drones," a main focus of this manual, highlights the pivotal role of drones in preserving the historical significance and beauty of these gardens. Additionally, we assume that staff in historic gardens already possess knowledge about "Biodiversity Care in Historic Gardens," a key aspect of maintaining the ecological balance within these cherished locations. Furthermore, marketing and multimedia skills play a crucial role in leveraging drone technology to attract more visitors to the gardens.

The table 29 provides a comprehensive and detailed description of the key skills that garden staff should develop to navigate the world of drone technology successfully. Each skill represents a crucial aspect of drone usage, contributing to efficient operations, data analysis, and conservation strategies for these beloved historic gardens. Understanding the importance of these skills will empower the staff to make informed decisions, optimize drone capabilities, and play a significant role in preserving the heritage and beauty of these cherished locations.

TABLE 29
Skills Description

Skills	Description	Importance
Drone Software Proficiency	Proficiency in drone software for flight planning, image processing, and data visualization. Analyzing collected data for maintenance, tracking changes, and conservation strategies.	Essential for effectively utilizing drone capabilities and making informed decisions.
Drone Hardware Knowledge	Knowledge of drone hardware components, functionality, and troubleshooting techniques for basic maintenance and issue identification.	Enables smooth drone operations and reduces downtime due to technical problems.

Drone Piloting and Flight Planning	Understanding flight principles, limitations, and risks, planning optimal flight paths and mapping specific areas of interest. Knowledge of weather conditions, airspace regulations, legal and ethical considerations, and emergency preparedness	Ensures safe, compliant, and efficient drone operations in the historic garden.
Documentation Control	Effective record-keeping of drone flights, maintenance logs, and data analysis results for accurate historical records and future reference.	Ensures organized data for analysis, reporting, and compliance with regulations.
Multimedia Editing	Proficiency in multimedia editing software to enhance and present aerial imagery and videos in an appealing and informative manner.	Helps create engaging content for various purposes, including presentations and marketing.
Marketing	Basic knowledge of marketing to create purposeful media tailored to the target audience.	Helps promote the historic garden's drone-related initiatives and engage visitors effectively.
Biodiversity Care in Historic Garden	Knowledge about biodiversity care in the historic garden.	Helps integrate drone data with gardening practices for better conservation efforts.
Historic Garden Preservation through Drones	Training on how drones can aid in historic garden preservation efforts.	Utilizing drones for preservation and monitoring purposes to protect the garden's heritage.

Source: Project partner Telewander ApS (2023)

7.2. Advantages of Online Training

Online training offers numerous advantages for historic garden staff seeking to develop their skills in drone operation and maintenance.

1. Cost-Effective: Online training programs are often more affordable compared to traditional in-person training. This cost-effectiveness makes it accessible for organizations with limited budgets, allowing them to provide training opportunities to a larger number of staff members. For example, the Drone4HER online learning materials are available free online.

2. Easy to Scale: Online training materials, such as the Drone4HER program, can be easily scaled and used worldwide. The accessibility of online platforms enables historic garden staff from different locations and backgrounds to access the training materials and develop their skills in drone operation and maintenance. This scalability ensures that a larger number of staff members can benefit from the program's resources and contribute to the preservation and management of historic gardens globally.

3. Flexible Learning: Online courses offer flexibility in terms of scheduling and pacing. Staff members can learn at their own convenience, allowing them to balance their training with their regular work responsibilities. Online modules, video tutorials, and learning materials can be accessed anytime and from anywhere, empowering staff to learn at their own pace and revisit content as needed. This flexibility eliminates the need for staff to travel or attend specific training sessions, making it convenient for those working in remote or geographically dispersed locations.

4. Diverse Course Options: The online training landscape provides a wide range of courses and resources tailored to different skill levels and specific areas of drone operation and maintenance. Staff members can choose programs that align with their needs, interests, and career goals. For instance, the Drone4HER course offers modules covering various aspects of drone operation and maintenance, allowing staff members to select the specific topics that are most relevant to their roles in historic garden management.

5. Interactive Learning: Many online training platforms incorporate interactive elements to enhance engagement and facilitate a comprehensive understanding of the subject matter. Quizzes, simulations, and forums encourage active participation and practical application of knowledge. Staff members can engage in discussions, share experiences, and learn from others in the online community.

The Drone4HER program, for example, includes interactive quizzes and practical exercises to reinforce learning and ensure a hands-on approach to skill development.

6. Enhance Curriculum: Online training materials, such as the Drone4HER program, are designed to complement the education staff members receive in drone flight courses. By integrating online training into the curriculum, historic garden professionals can enhance their knowledge and skills in specific areas of drone operation and maintenance.

Overall, online training is a highly advantageous option for historic garden staff, offering cost-effectiveness, scalability, flexibility, diverse course options, and interactive learning. An exemplary representation is the Drone4HER online course, providing comprehensive training materials in various aspects of drone operations, including data analysis, data privacy, and drone regulations.

To address the need for practical experience in drone piloting, garden staff can effectively use advanced drone simulators like the DJI Flight Simulator and Liftoff Simulator. These simulators offer an immersive and realistic environment, enabling staff to practice piloting skills, flight maneuvers, obstacle navigation, and emergency responses without risking expensive equipment or visitors' safety.

Combining online resources with drone simulators provides a well-rounded approach to skill development. Garden staff can gain theoretical knowledge through online courses while receiving invaluable practical training, ensuring a comprehensive understanding of drone technology and its applications. This approach empowers staff to make informed decisions and contribute effectively to the preservation and advancement of historic gardens.

7.3. Available Training Programs and Resources

The table 30 presents a compilation of valuable resources for enhancing the knowledge and skills of historic garden staff in the domain of drone technology. It showcases various examples of sources of online training, industry webinars and workshops, collaborative learning platforms, and drone manufacturer resources, all aimed at empowering garden staff with insights and practical knowledge related to drone operation and maintenance.

TABLE 30
Sources and Examples of Online Training for Historic Garden Drone Operations

Source	Description	Examples
Online Training Platforms	Platforms offering courses on drone operation and maintenance.	European Drone Academy: Provides a wide range of drone-related courses, including piloting, regulations, and data analysis. Drones for Europe (D4EU): Offers courses on drone technology, aerial photography, and surveying for diverse applications. Udemy: Provides various drone-related courses, including piloting, aerial mapping, and photography and videography. Coursera: Offers courses from top universities and institutions on drone technology, aerial robotics, and data analysis using drones.
Industry Webinars and Workshops:	Webinars and workshops hosted by industry associations and conservation organizations.	AUVSI Webinars: Expert insights and practical guidance on drone technology. European Association of Remote Sensing Laboratories (EARSeL): Organizes webinars on drone applications in environmental monitoring and remote sensing. Historic England: Offers workshops on the use of drones in historic garden preservation and conservation. D-site conference: International conference dealing with the use of drones in the field of Cultural Heritage
Collaborative Learning	Online communities and forums for connecting with professionals and sharing experiences	DroneDeploy Community, DJI Forum, and Reddit's r/drones: Spaces for drone enthusiasts and professionals to connect, share experiences, ask questions, and learn from one another. European Drone Forum: A platform for drone enthusiasts and professionals to connect, exchange knowledge, and learn from one another. Drone Community Facebook Group: Allows knowledge exchange, resource sharing, and networking with European drone experts.

	within the drone community.	
Drone Manufacturer Resources	Online resources, instructional videos, and user manuals from drone manufacturers	DJI Educational Resources: Online tutorials, product guides, and tips for drone operation and maintenance. Autel Robotics: Offers resources for understanding their drone models. - Parrot: Provides instructional videos for their drones. Yuneec: Offers user manuals for their specific drone models within the European market.

Source: Project partner Telewander ApS (2023)

These resources offer a diverse array of courses, webinars, and online communities that cater to different skill levels and interests within the European Union. By exploring these resources, garden staff can bolster their capabilities, contribute more effectively to heritage conservation, and take full advantage of the benefits that drone technology brings to the world of historic gardens.

7.4. Tips for Effective Online Learning

As the landscape of technology and solutions evolves, providing historic garden staff with an effective process for online learning becomes essential. To optimize their training experience, consider the following tips:

- Stay Updated: Encourage staff to stay informed about drone regulations, industry trends, and technological advancements through industry newsletters and reputable online sources.

- Set Clear Goals: Help staff establish specific learning objectives, such as drone pilot certification or mastering aerial mapping techniques, and break them into milestones for tracking progress.

- Create a Structured Learning Schedule: Allocate dedicated time for online training, establish milestones, and use reminders or scheduling apps to ensure consistency.

- Engage in Practical Application: Encourage staff to practice drone operations in controlled environments, collaborate on pilot projects, and participate in field exercises to solidify their skills.

- Seek Feedback and Collaboration: Encourage seeking feedback from peers, supervisors, and experienced professionals through online discussion forums and social media groups focused on drones and historic garden management.

- Maintain Discipline and Motivation: Remind staff of the importance of training, celebrate milestones, and set personal targets or rewards for maintaining motivation.

Network and Attend Virtual Events: Encourage participation in virtual events, conferences, or webinars related to drones and historic garden management for networking and exposure to new ideas and best practices.

8. Conclusion

The present manual looks into the integration of drone technology for the maintenance and management of historic gardens, offering a wealth of knowledge and practical insights for historic gardens' gardeners and managers. With a strong focus on the unique challenges faced in preserving these culturally significant landscapes, the manual presents drones as powerful tools to overcome such obstacles. Beginning with the foundational understanding of drones, it progresses to explore their varied applications, including data collection, thermography, photogrammetry, precision agriculture, and marketing. Emphasizing safety, compliance, and staff training, the manual equips readers with essential guidelines and resources to ensure successful drone operations in historic gardens.

The use of drones in historic gardens yields a number of important and positive consequences, leading the way into a new era of preservation and management. One of the significant benefits lies in the efficiency and accuracy of data collection. Drones enable the capture of detailed aerial photographs and thermal imagery, allowing custodians to identify hidden structural issues, monitor vegetation health, and detect potential hazards. This enhanced data empowers informed decision-making, leading to timely interventions and targeted maintenance, ultimately safeguarding the garden's historical integrity and reducing the risk of irreversible damage. Additionally, the application of precision agriculture techniques using drones optimizes water usage, minimizes pesticide application, and enhances plant health, fostering a sustainable and eco-friendly approach to gardening. Furthermore, the use of drones enhances marketing efforts, captivating visitors with breathtaking aerial views and immersive experiences, enticing them to explore and appreciate the garden's unique charm. Embracing drone technology in historic gardens not only facilitates efficient operations but also promotes greater public engagement, ensuring these cherished landscapes continue to be cherished, protected, and celebrated for generations to come.

By adopting drones, we can revolutionize the way we address challenges, streamline maintenance efforts, and enhance the overall garden experience. Let us take the initiative to develop new roles and competences, empowering our teams to leverage drones for mapping flights, thermography inspections, photogrammetry, and precision agriculture. By adhering to the guidelines for safe and effective drone usage, we ensure seamless integration into our preservation strategies. With drones as our allies, we can embark on a journey of water monitoring, health assessment, risk management, and maintenance identification like never before.

Moreover, by embracing this innovative technology, we unveil new horizons for marketing and enhancing the tourist experience, inviting visitors to explore and appreciate the magnificence of our historic gardens. Through drone technology, we can bridge the gap between past and present, preserving the heritage and beauty of these timeless landscapes while embracing a sustainable and forward-looking approach. Today, we extend a resounding call to action - seize the opportunity, embrace drone technology, and begin the transformation of our historic gardens into sustainable havens of cultural heritage and natural beauty. Together, let us forge a legacy that stands the test of time, inspiring generations to cherish and protect these invaluable landscapes for centuries to come. By acting today, we ensure that our historic gardens continue to thrive as living testaments to history, culture, and nature's splendor.

List of acronyms

AENA - Aeropuertos Españoles y Navegación Aérea
AR - Augmented Reality
CEDEFOP - European Centre for the Development of Vocational Training
CFD - Computational Fluid Dynamics
DEMs - Digital Elevation Models
DSMs - Digital Surface Models
DTMs - Digital Terrain Models
EASA - European Aviation Safety Agency
ERHG – European Route of Historic Gardens
FPS - frames per second
FPV - First-person View
GIS - Geographic Information System
GLONASS - Global Navigation Satellite System
GNSS - Global Navigation Satellite System
GPS - Global Positioning System
HDR - High Dynamic Range
ICT - Information and Communications Technology
IPM - Integrated Pest Management
IR – Infrared Radiation
IRT - Infrared Thermography
ISO - International Standards Organization, is the sensitivity to light as pertains to either film or a digital sensor.
LAS – LASer File
LED - Light-Emitting Diode
LiDAR - Light Detection and Ranging
NAA - National Aviation Authority
ND - Neutral Density Filter
NIR - Broad Near-Infrared
RAW - file format used to save unprocessed, uncompressed images on a camera
RGB - Red, Green and Blue
RPAS - Remotely Piloted Aircraft System
RS - Remote Sensing
SfM - Structure-from-Motion Photogrammetry
SIT - The Sterile Insect Technique
STC - Sviluppo Turistico Collodi s.r.l.
UAS – Unmanned Aircraft System
UAV - Unmanned Aerial Vehicle
UDP - Uniform Daylight Period
UV – Ultraviolet
VR - Virtual Reality
2D - Two-dimensional
3D – Three-dimensional
4K, 5.2K or 6K - horizontal resolutions of around 4.000, 5.200 or 6.000 pixels, respectively

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