ClimaMED

Project Number: CCM/GR/000087

Coordinating Institution	BENAKI PHYTOPATHOLOGICAL INSTITUTE
Coordinator	Dr. Maria K. Doula
Address	St. Delta Str., n° 8, 145 61, Kifissia, Attica, Greece
Telephone No	+30 210 8180321
Fax No:	+30 210 2842 129
E-mail:	mdoula@otenet.gr; m.doula@bpi.gr
Project web site:	https://life-climamed.eu/

Innovative technologies for climate change mitigation by Mediterranean agricultural sector	
Project number	CCM/GR/000087
Title of the Deliverable	Official Edition of ClimaMed results
Action/task	Action E2
Action Leader	ENVITECH LTD
Task Leader	ENVITECH LTD
Responsible Beneficiary	The beneficiary develops the deliverable
Scientists involved	
Contributing Beneficiaries	
Foreseen submission date	
Actual submission date	
Final version date	
Document type	Report
Distribution	Select one or more: partnership, public, coordinator, EC
Summary	

Contents

1. Introduction

The LIFE ClimaMed (LIFE17 CCM/GR/000087) project is an ambitious initiative focused on creating and implementing innovative, reliable, and cost-effective technologies to measure CO_2, CH_4, and N_2O emissions and Soil Organic Carbon (SOC) stock changes from agricultural fields in real time. These technologies aim to support scientists, public authorities, and policymakers by providing accurate data for assessing and reporting greenhouse gas emissions and SOC changes in the Mediterranean agricultural sector. The project also has the potential to expand its application to other sectors such as forestry, tourism, and livestock farming. ClimaMed's impact could significantly benefit local and national economies through job creation, economic growth, and societal prosperity.

Key objectives of the project include:

- Developing and demonstrating a methodology for real-time GHG measurement using an innovative LIDAR device.
- Creating a methodology to detect SOC stock changes through the combined use of multispectral cameras and soil/crops analyses.
- Developing a GIS-based web platform (a Center of GHG Monitoring and Management, CMM) to collect, process, and map GHG and SOC data from agricultural fields at the national level. This platform aims to enhance the use of spatially-explicit data to monitor land use changes and establish a network of monitoring systems across the Mediterranean and the EU.

2. Aim of the report

The ClimaMED project also aimed to:

i. Enhance the reporting of GHG emissions and SOC changes by developing GHG/SOC measurement protocols based on real-time spatial data collection, improving upon the existing Tier 1 accounting methodology,

ii. Establish an Operational Center at the Greek Ministry of Rural Development and Food to monitor GHG emissions and SOC changes from agricultural fields,

iii. Draft legislative proposals, including one for the Greek Parliament to adopt ClimaMED's recommendations and outputs, as well as three legislative proposals for Italy, Spain, and Cyprus,

iv. Analyze the relationship between agricultural practices and GHG emissions and SOC stock variations, focusing on key Mediterranean crops such as olive trees, grapes, cereals, pistachios, and vegetables,

v. Develop and implement a certification system (e.g., green certificates, low-carbon certificates) for products with a reduced carbon footprint, enabling the recognition of "green farmers" based on real-time measurement data,

vi. Encourage and support behavioral change at the local and regional levels by offering additional incentives to farmers through the Greek Ministry, promoting the transition to low-emission agricultural practices.

3. Project Achievements

During the implementation of the project, the objectives initially set were largely achieved, and overall, they are considered effective, making the project successful. This indicates that the project's planned goals were successfully recognized, with a high degree of accomplishment throughout its various phases. The development of innovative technologies and methodologies, along with the establishment of a robust monitoring system, has greatly contributed to its success. The results align with the expected outcomes, demonstrating the project's capacity to deliver on its promise of improving GHG emissions and SOC stock measurement and reporting. Furthermore, the implementation of the GIS-based platform and the collaboration with governmental bodies ensure that the project's impact will continue beyond its completion, potentially influencing policy and agricultural practices across the Mediterranean region. The successful achievement of these goals underscores the project's relevance and effectiveness in addressing critical environmental challenges

3.1 LIDAR DEVISE

The LIDAR Device (Figure 1) is a ground-based, integrated path, differential absorption (IPDA) light detection device capable of measuring multiple GHG species in the atmosphere was developed to monitor greenhouse gas concentrations in small-scale areas with high emission activities. It is equipped with two low optical power tunable diode lasers in the near infrared spectral range for the atmospheric detection of carbon dioxide, methane, nitrous oxide and water vapors (CO_2, CH_4, N_2O and H_2O). The device was tested with measurements of background concentrations of CO_2 and CH_4 in the atmosphere (Crete, Greece). Accuracies in the measurement retrievals of CO_2 and CH_4 were estimated at 5 ppm (1.2%) and 60 ppb (2.5%), respectively. A method that exploits the intensity of the recorded H_2O absorption line in combination with weather measurements (water vapor pressure, temperature, and atmospheric pressure) to calculate the GHG concentrations is proposed. The method eliminates the requirement for measuring the range of the laser beam propagation. Accuracy in the measurement of CH_4 using the H_2O absorption line is estimated at 90 ppb (4.8%). The

values calculated by the proposed method are in agreement with those obtained from the differential absorption LiDAR equation (DIAL).

Figure 1. The LIFE ClimaMED greenhouse gas measurement system, consisting of the LIDAR measurement device, meteorological station, and solar panel.

The device comprises three low-power Differential Absorption LiDAR (DIAL) lasers, operating in the near-infrared spectrum to measure the three gases with high accuracy (Figure 2).

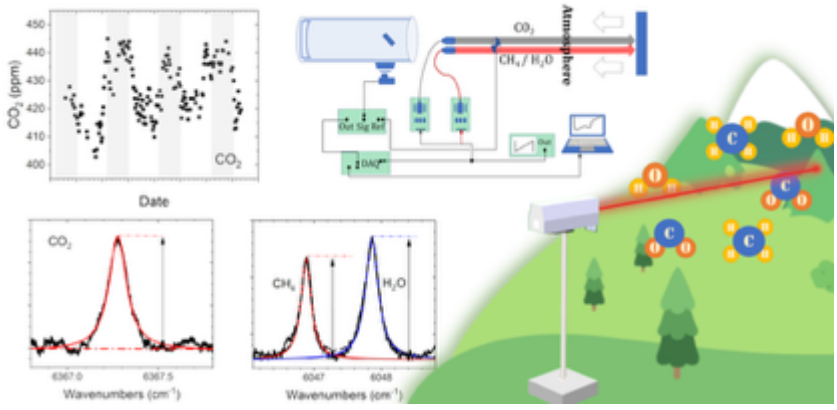

Figure 2. Operating and CO_2, CH_4 and H_2O measurement processing

For N_2O, detection is possible when its concentrations exceed the detection limit of the device, which is 3 ppm, as in cases of emissions from agricultural activities (e.g., use of nitrogen fertilizers). Under normal conditions, the concentration of N_2O in the atmosphere is around 337 ppb, which is below the device's detection threshold. However, when increased emissions occur due to agricultural activities, N_2O concentrations are expected to surpass this threshold and can be detected accurately.

Ten (10) technically validated and calibrated LIDAR devices have been constructed for the measurement of CO_2, CH_4 and N_2O concentrations in the atmosphere. Only six (6) of these devices continued to monitor the greenhouse gases until the end of the project (Figure 3).

Figure 3: the six LIDAR Devices in Greece continued to monitor the greenhouse gases until the end of the project

During the development process and after installation of the device's issues have been identified and solved with the optimal way, concerning budget demands. Main problems that occurred during the field operation are listed below:

- Invalid installation location
- Optical line interference
- Mis-alignment due to handling
- No Internet connectivity
- Power supply quality
- Optical component contamination

3.2 IoT Telemetry System

The team of ClimaMED project has developed an effective telemetric system, which satisfies the need for seamless collection and transfer of data from different sources in an effective manner. Its effectiveness could be evaluated against the criteria of:

- easy to be installed,
- easy to use,
- minimum requirements for maintenance,
- extensibility and connectivity,
- interoperability,
- cost of operation.

As part of the project, Green Projects has developed an IoT Core Platform that enables cloud-based data management, data access control, visualization, alerts, and reporting. The platform also includes APIs that ensure interoperability with all systems developed within the project and third-party applications. To support the telemetry network, a LoRa infrastructure has been established, with 16 gateways installed, ensuring extensive area coverage, including locations in Italy (Figure 4).

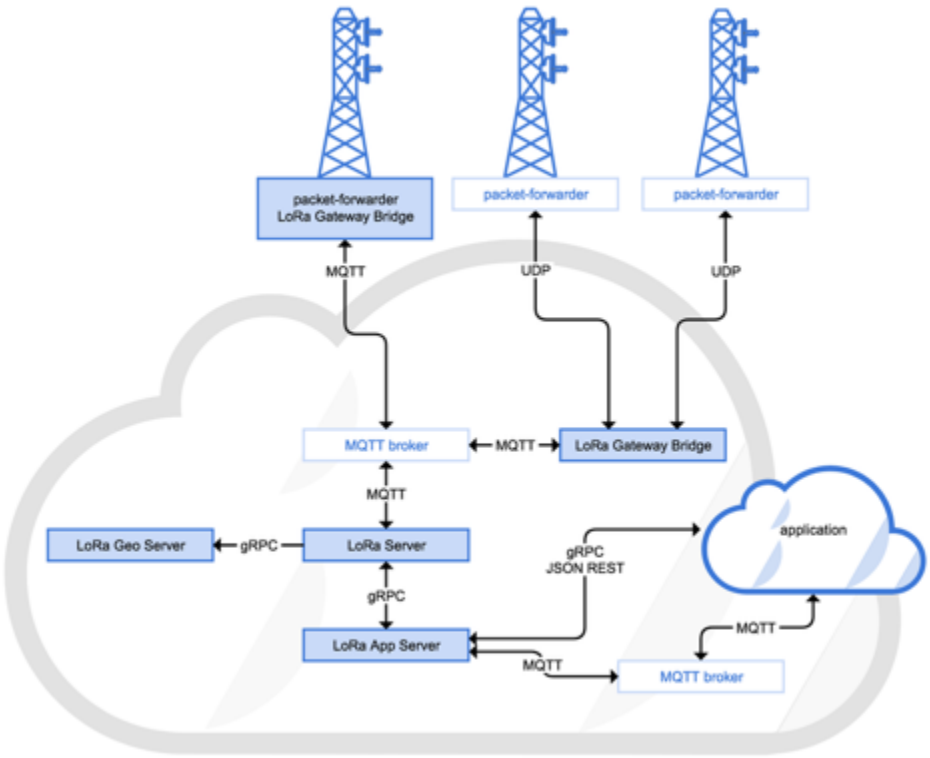

Figure 4: Lora Infrastructure

IoT technologies play a crucial role in managing power consumption and collecting meteorological data. IoT meteorological stations have been deployed to continuously monitor weather conditions (Figure 5). The IoT Telemetry Platform comprises several key features, including a mapping system for visualizing nodes and gateways, real-time node management, data representation through charts and graphs, gateway monitoring, and automated process support.

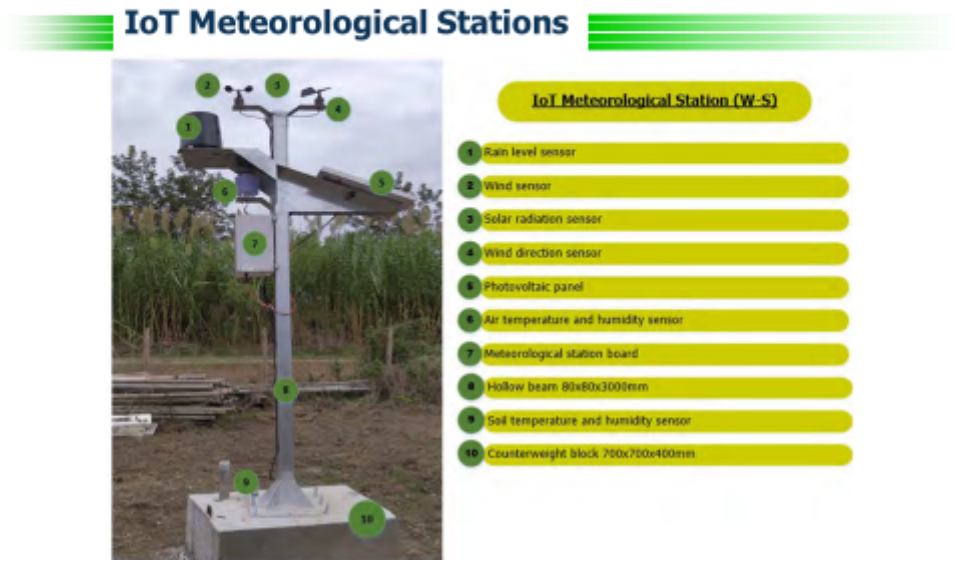

Figure 5: IoT meteorological stations

Based on the results of pilot testing, new features were introduced to enhance the safe operation of the LiDAR system. These features have been integrated into the telemetry system under a new category called the "Process Engine." The Process Engine includes modules such as Rules, which validate conditions between different events; Events, which allow applications to generate triggers for actions; External Events, which allow users to define and trigger external application events; and Event Attributes, which enable users to specify rule parameters. Additionally, Triggers are conditions that initiate actions, while the Trigger Results section logs instances when triggers were activated. The Actions module allows system-defined responses, and the Action Results section records executed actions.

For LiDARs to operate safely, certain environmental conditions must be met. Specifically, the wind speed must not exceed 4 m/s, there must be no rain, the air temperature must remain between 5°C and 35°C, and air humidity should not exceed 95%.

The system also includes monitoring and logging of LiDAR performance, ensuring operational efficiency. Updates on new installations and replacements of meteorological stations are recorded to maintain an optimal monitoring environment.

This comprehensive telemetry system enables real-time monitoring, data analysis, and automated decision-making to support the overall objectives of the LIFE+ ClimaMED project.

3.3 PLATFORM

The Center for Greenhouse Gas Monitoring and Management platform was designed and developed to provide a comprehensive solution for tracking, managing, and reporting GHG emissions from agricultural activities (Figure 6). The platform was conceived as a centralized hub offering to users a powerful and intuitive way to monitor data emissions, thus empowering stakeholders to make data-driven decisions and support sustainable agricultural practices.

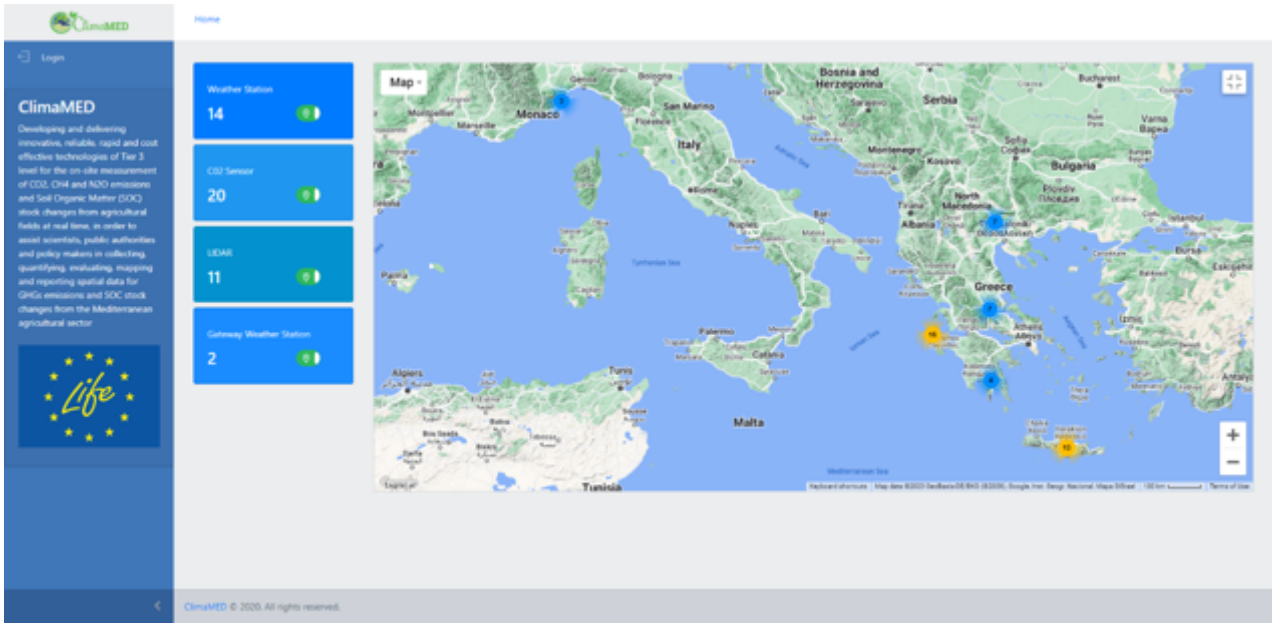

Figure 6: Operational Center development - ClimaMED platform (CMM)

The development of the platform combined technical excellence with user-centric design. These aspects were guided by the principles of scalability, modularity, and high performance. The architecture of the system was carefully structured into distinct layers: the presentation layer (user interface), the application layer (business logic), and the data layer (database and storage). This approach ensures the flexibility, straightforward maintenance and the support of future enhancements and expansions.

The combination of industry-leading tools and frameworks provided the technical foundation to build the platform. The backend of the platform was developed using PHP, which provides a reliable foundation for handling complex data processing tasks, user authentication, and secure access control. On the frontend, the platform leverages HTML5, CSS3, JavaScript, Bootstrap, and jQuery to create a responsive, user-friendly interface that delivers a consistent experience across different devices, including desktops, tablets, and mobile phones.

One of the key technical components of the CMM platform is its interactive mapping and data visualization capabilities (Figure 7). The platform uses the Leaflet library to deliver a highly interactive map interface that allows users to visualize GHG emissions data in a geographical context. The map displays real-time device locations and provides the ability to drill down into specific regions or devices to access detailed measurement information. The functionality of interactive mapping is crucial to aid users identify trends, pinpoint emissions hotspots, and gain deeper insights into emissions patterns.

Figure 7: Visualization and management services

The platform's data management system was designed to handle large volumes of real-time data from a variety of sources, including IoT devices, LiDAR sensors, and gateway connectivity. A critical aspect of the development process involved the integration of these diverse data sources into a cohesive system, capable of processing incoming data streams with high accuracy and reliability. To achieve this, the CMM platform leverages the CoreIoT API, which facilitates real-time communication and data exchange between the platform and remote sensors deployed in the field. The CoreIoT API ensures seamless data integration, enabling the platform to provide real-time updates and analysis to end-users.

The CMM platform employs a series of automated data processing workflows designed to validate, categorize, and manage incoming measurements from IoT and LiDAR devices. These workflows ensure that measurements are checked for accuracy, inconsistencies are flagged for review, and validated data is used to generate emissions reports and visualizations. The data can be analyzed over defined time periods, enabling users to explore daily, weekly, monthly, or custom date ranges. Users can also download measurements in various formats for further analysis outside the platform.

The platform's analytical tools allow users to compare GHG emissions trends across different timeframes, identify patterns, and examine specific events that may influence emissions levels. In addition, the system offers features for managers to validate measurements and filter out data based on specific criteria, such as measurement accuracy thresholds or the determination coefficient value. This ensures that only high-quality data is used for reporting and decision-making.

The CMM platform is deployed on a dedicated server in the premises of the Institute for Mediterranean Studies (IMS) of the Foundation for Research and Technology Hellas (FORTH). The configuration of the is able to support the high availability, performance, and security requirements of the platform. The hosting of the platform on-premises, the IMS-FORTH maintains full control over data privacy and system security, ensuring compliance with institutional and regulatory standards. The dedicated server provides a stable environment for real-time data processing, storage, and analysis, supporting the platform's continuous operation and scalability.

Throughout the development process, a strong emphasis was placed on user-centric design to ensure that the platform is intuitive and easy to use for individuals with varying levels of technical expertise. The user interface was designed to provide a clean and organized layout, with key features such as the dashboard, interactive charts, and device management tools easily accessible from the main navigation menu. The dashboard presents a clear overview of emissions data, with dynamic visualizations that allow users to filter information by gas type (CO_2, CH_4, N_2O) and time period, facilitating in-depth analysis. The use of jQuery enhances the interactivity of the user interface, enabling smooth navigation, dynamic content updates, and improved user experience.

To enhance security and usability, the CMM platform incorporates role-based access control (RBAC). This system ensures that different user roles—such as administrators, managers, and general users—have access only to the data and tools relevant to their responsibilities. This approach enhances security and simplifies the user experience by presenting each user with a personalized interface tailored to their specific needs.

A core design principle of the platform included its future scalability. The modular architecture allows for the seamless integration of new features, such as additional data sources, more specialized analytical tools, and expanded reporting capabilities. This adaptability ensures that the platform can continue to meet the evolving needs of stakeholders and remain relevant in a rapidly changing environmental landscape.

The development process of CMM platform can be summarized as follows:

1. Backend Development: The backend was implemented using PHP, ensuring reliable performance for data processing, authentication, and secure access control.
2. Frontend Development: The frontend was built using HTML5, CSS3, JavaScript, Bootstrap, and jQuery to create a responsive and visually engaging user interface with enhanced interactivity.
3. Mapping and Visualization: The Leaflet library was used to deliver interactive mapping functionality, enabling users to visualize emissions data geographically.
4. Telemetry Integration: The CoreIoT API was integrated to facilitate real-time communication and data exchange with remote sensors.
5. Data Processing and Validation: A set of automated workflows were developed to validate incoming measurements, flag anomalies, and ensure that high-quality data is used for emissions reporting and decision-making.
6. Deployment and Hosting: The platform is hosted on a dedicated server located at the IMS-FORTH, ensuring high availability, robust performance, and compliance with data security standards.

By providing a centralized and comprehensive solution for GHG monitoring and management, the CMM platform empowers stakeholders to make informed decisions that promote sustainable agricultural practices. Its combination of robust technical infrastructure, user-centric design, and practical analytical capabilities makes it a valuable tool for addressing the challenges of climate change and supporting efforts to achieve environmental sustainability.

.

3.4 Final Legislative Proposal

As part of Action E1, the Ministry, after consultations with all relevant stakeholders in Greece, as well as in Spain, Italy, and Cyprus, has prepared the draft law, which aims to create a system for monitoring greenhouse gas emissions in a specific sector, allowing the Ministry of Rural Development and Food to collect data on the amounts CO_2, CH_4, and N_2O released from agricultural activities (Figure 8). This will allow the development of a national policy for mitigating climate change within the agricultural sector.

The purpose of this section is to adopt the greenhouse gas emissions recording system developed during the implementation of the LIFE 17 CCM/GR/000087 project titled 'Innovative Technologies for Climate Change Mitigation in the Mediterranean Agricultural Sector' (LIFE ClimaMED) as a tool for the automated monitoring of greenhouse gas emissions from a specific agricultural area in real time, and for calculating the number of emissions within any required time frame, without human intervention.

Each farmer who installs a greenhouse gas emissions measurement device will have access to the emissions recording system and will be able to monitor in real-time the fluctuations of greenhouse gas emissions from the agricultural area where the measurement device has been installed, for which a certificate will be issued by the competent authority to verify the amount of greenhouse gas emissions from a specific agricultural area. The ultimate goal is for farmers to move from the cultivation methods they have been using until now to new, more sustainable practices in order to reduce greenhouse gases.

The draft law prepared by the Ministry has been sent to the relevant ministries in Spain, Italy, and Cyprus to prepare the corresponding draft law in each of these countries.

Figure 8: Meetings with stakeholders from Greece, Spain, Italy and Cyprus for draft law preparation and documentation

3.5 Dissemination Results

As part of Action E2 of the program, which focuses on the dissemination of results, a well-designed and targeted communication strategy has been created from the very first day of the program's beginning until its completion (1/7/2018 – 31/12/2024). The goal of this action is the continuous updating of people who are interested not only in the objectives and results of the program but also in the developments in sustainable agriculture and livestock farming. Dissemination activities play a crucial role in ensuring that the knowledge, results, and innovations developed during the project reach the intended audiences and have a lasting impact. These activities go beyond simply sharing information; they are designed to maximize awareness, foster engagement, and promote the adoption of findings both during and after the project's completion.

One of the project's most significant achievements was the organization of the '***Open EARTH 2024 Conference: Bridging Science and Society'*** which is a continuation of at the first Open EARTH conference in 2020.

The '***Open EARTH 2024'*** conference, which focuses on climate change and sustainable development, was hosted in Rethymno, Grete from November 26 to 28, 2024 (Figure 9). The goal of the conference was to highlight the contribution of agriculture to climate resilience and raise awareness about sustainable management strategies for the Mediterranean region and the planet. The conference featured leading scientists, representatives from various organizations, and experts from the agricultural sector, aiming to exchange knowledge, highlight innovative solutions and tools for adapting the agricultural sector to the climate crisis, and enhance the sustainability of the agricultural environment. The program was held under the supports of the Greek Ministries of Rural Development and Food and Education, Religious Affairs and Sports, as well as the Region of Crete (https://openearth.life-climamed.eu).

Figure 9: *Open EARTH 2024* Conference

Furthermore, as part of the strategic plan, various initiatives were implemented, including the creation of a website and the promotion of the program through social media. Additionally, efforts focused on developing informational and educational materials, participating in international conferences, publishing articles in high-impact journals, and organizing events, workshops, and other related activities (Figure 10).

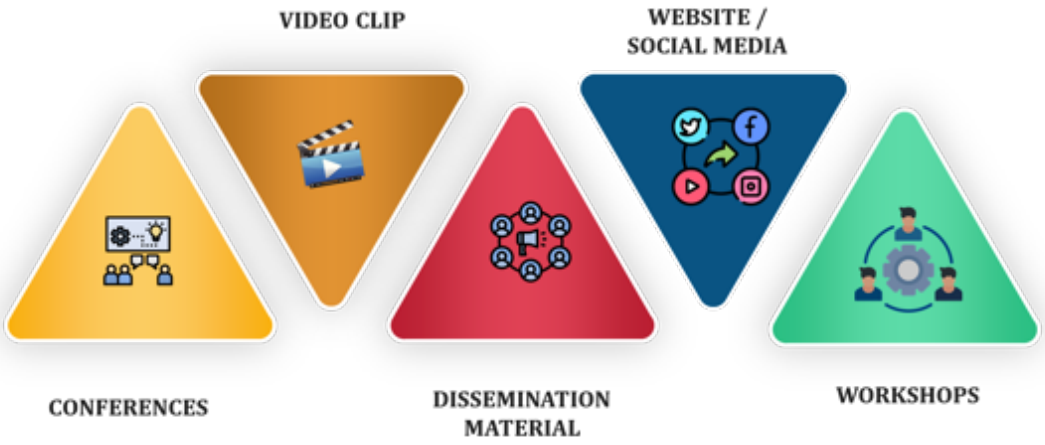

Figure 10: Dissemination Activities

4. Conclusions

LIFE ClimaMED is a project focused on agriculture, but its results can also be applied to other productive sectors, with appropriate adaptations. For instance, a LIDAR device was successfully installed on a cow farm, producing very encouraging results. These kinds of innovative technologies not only help to monitor GHG emissions more accurately but also assist in optimizing resource management and ensuring more sustainable practices across various industries. The project's tools also provide significant benefits for national authorities, helping them improve the precision of emission reporting and facilitating the development of GHG reduction policies. The implementation of a centralized system for monitoring GHG emissions, coupled with the acquisition and installation of relevant devices, supports more informed decision-making at the national level. This contributes to better planning and governance on climate action. For farmers' cooperatives and producer groups across the four participating countries, the platform's ability to collect, manage, and analyze GHG data is an invaluable resource. It empowers these organizations to enhance transparency, improve traceability, and demonstrate the carbon footprint of their products to consumers. By showing a clear environmental commitment, they can improve their market competitiveness and access to environmentally-conscious consumers and markets. Ultimately, LIFE ClimaMED's impact reaches beyond climate action alone, offering a wide range of economic, environmental, and social benefits. These include increased operational efficiency, stronger collaboration between stakeholders, and the facilitation of a sustainable transition toward more eco-friendly agricultural and production practices.