



DELIVERABLE 7.7

A Blueprint for European Environmental Intelligence



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Innovative modelling approaches for predicting Socio-environmental evolution in highly anthropized coastal LAGOONS

Deliverable 7.7

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Abstract

SMARTLAGOON Project benefits from the financial support of the Horizon 2020 programme of the European Union within the framework of an Innovation Action. The progress of the project activities as well as the key results are documented by the members of the SMARTLAGOON consortium in a series of deliverables released throughout the project duration (48 months).

The present deliverable D7.7 is the third version of the “Blueprint for a full-fledged system for environmental intelligence” according to the inter-project Collaboration Agreement between the FET projects (see Annex). The deliverable is jointly prepared by the projects funded under the H2020 FET Environmental Intelligence call: I-Seed, SMARTLAGOON, WatchPlant, RAMONES and ReSET.

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Introduction

This document is the third iteration of a collaborative Blueprint for European Environmental Intelligence (EI) and is produced jointly by five projects of the Horizon2020 Future and Emerging Technologies (FET), called Environmental Intelligence: I-Seed, RAMONES, ReSET, SMARTLAGOON and WATCHPLANT.

Environmental Intelligence gathers key innovative scientific and technological components needed to better address environmental challenges in Europe and beyond. Specifically, the purpose of environmental intelligence is to improve environmental sustainability through policy or management endowing nature with technology. Since the first blueprint document, the five projects involved in this action have identified a series of technological, economic and societal challenges to be addressed. Specifically, the challenges include aspects for: Hardware; Software; Networks; People, Training and Engagement, and Policy.

- **Hardware.** This represents the computing, the communication and the data collection hardware that provides, processes, and communicates the derived intelligence. It also includes the physical “body” of the technology and system used to collect certain data: the body of a robot and its physical components (sensors, actuators, batteries/energy suppliers). The EI challenge should always be addressed with green technologies to reduce the environmental footprint of the ICT itself. For example, the use of biodegradable or zero-impact materials and alternative sources of energy.
- **Software.** It involves the code running on data collection, data processing and communication infrastructure that forms part of the environmentally intelligent system.
- **Networks.** This represents the soft networks of people, institutions, and stakeholders, as well as the hard networks for data collection, data processing and communication of outcomes.
- **People, training, and engagement.** This represents the people involved in the collection, processing, and analysis of data (including model results), as well as those impacted by the environmental problem, asking the questions, assessing the proposed solutions, and implementing investments, policies or regulations.
- **Policy.** It covers the policy context and policy levers available to facilitate change given intelligence on what needs to be done, but also the demand for evidence and effectiveness assessment that in-turn creates the need for environmental intelligence.

In addition to these topics in distant disciplines, Environmental Intelligence needs multidisciplinary approaches and a clearly integrative methodology to move environmental research in a more solution (rather than problem identification) focused direction. It is a logical extension of recent developments in data science, coupled with the increased need for high-quality, question-focused evidence to support sustainability interventions in unsustainable systems.

Finally, considering the joint multidisciplinary efforts to contribute to social good in terms of Environmental Intelligence, technical challenges in Environmental Intelligence identified are updated in this third version of the environmental intelligence blueprint. Moving forward with the advancements of the projects, we have included the challenge of advancing the TRL of innovation and the

identification of new market opportunities available or created. This additional challenge discusses the opportunity of founding start-ups, and exploiting innovation actions to develop in this field.

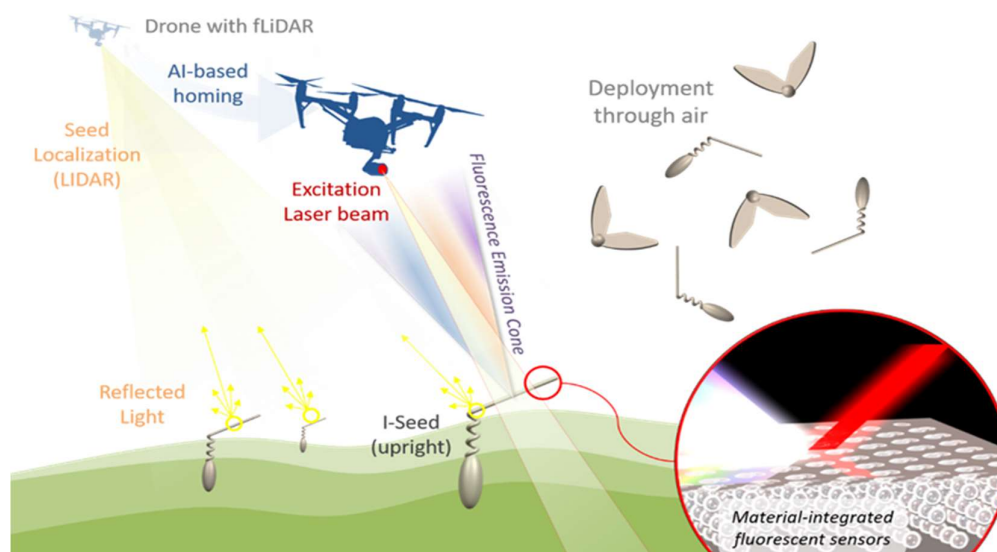
Technical challenges in Environmental Intelligence. Year 3 FET projects developments

In this section, the main topics addressed by the Environmental Intelligence group have been reviewed from the first and second blueprint 2022. Specifically, the challenges and advances in each topic carried out by the projects under a multidisciplinary approach have been updated.

Key information

I-Seed

The EU FET Proactive Environmental Intelligence project “I-Seed” targets towards the development of a radically simplified and environmentally friendly approach for analysing and monitoring topsoil and air. Specifically, I-Seed aims at developing a new generation of self-deployable, zero-impact and/or biodegradable soft miniaturised robots, inspired by the morphology and dispersion abilities of plant seeds, able to perform a low-cost, environmentally responsible, and in-situ detection. I-Seed robots are conceived as unique in their movement abilities because they are inspired by passive mechanisms and materials of natural seeds, as well as in their environmentally friendly design because they are made of biodegradable components. Sensing is based on a chemical transduction mechanism in a stimulus-responsive sensor material with fluorescence-based optical readout, which can be read via one or more drones equipped with fluorescent LiDAR technology and software able to perform a real-time georeferencing of data.



The I-Seed scenario

Following a focused study of plant seed materials and biomechanics, we have developed the first series of biodegradable seed-like robots (Cecchini et al., 2023; Cikalleshi et al., 2023) able to measure environmental parameters, and a system for the detection of such artificial seed-like objects from a drone (Bomantara et al., 2023). We are currently in the phase of technology integration, during which we will optimise the integration of the chemical sensors in the robots, the I-Seeds-Drone LIDAR-based system will be integrated with the data driven flight control and the data readout will be optimised to be transferred to a remote station for further data analysis.

RAMONES

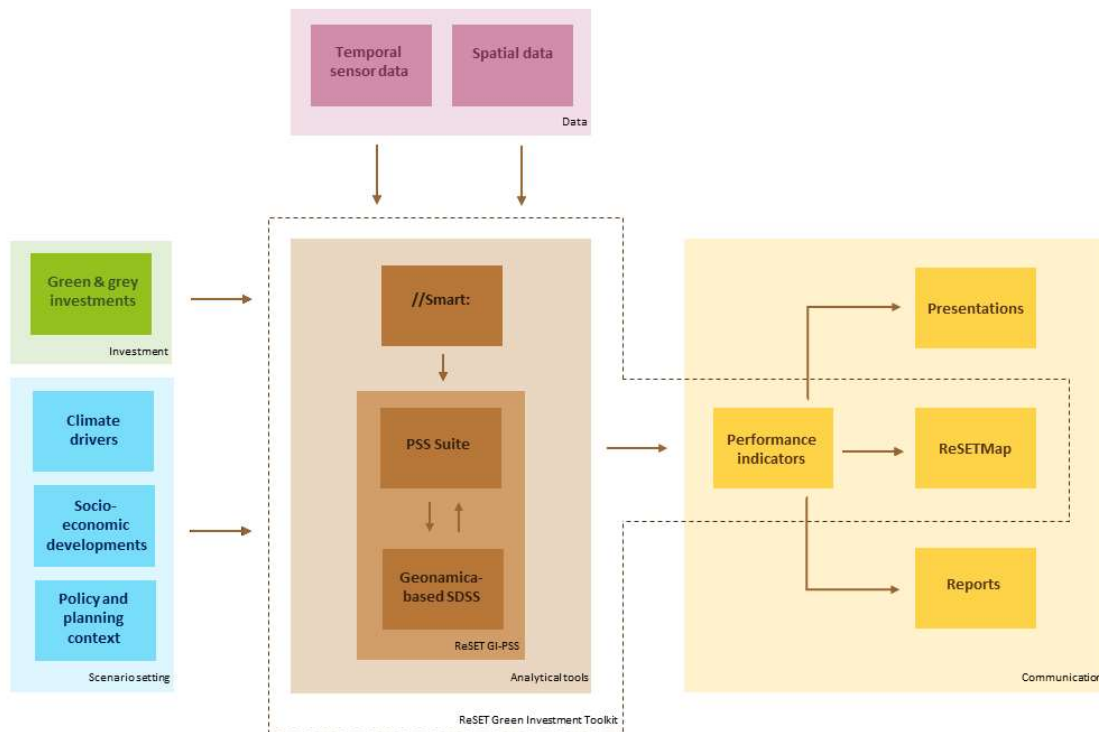
ReSET

The EC H2020 ReSET project (Restarting Economy in Support of Environment through Technology), brings together environmental scientists, social scientists, informatics specialists and stakeholders from five European countries to develop state-of-the-art green investment policy support systems. These combine the best available earth observation, crowd-sourced and field-monitored data with sophisticated spatial policy support systems for biophysical and social processes. Harnessing combined machine and human intelligence, we seek to understand best-bet options for 'build back better' investments that maximise environmental, economic and employment benefits of green investments. We focus on both urban and rural green investments throughout Europe including those addressing air pollution, flood, drought, heatwave, noise, and light pollution.

The project has developed a toolkit bringing together a range of tools in analysis pipelines to provide decision support for a range of green investors in sustainable agricultural- and urban- land use and management. The ReSET Investment Toolkit (ReSET-IT) consists of three key tools:

- ReSET Green Investment Policy Support System (GI-PSS) to provide spatial intelligence for effective green investment on employment, environment and economy comprising spatial modelling tools including WaterWorld, Co\$tingNature and Metronamica..
- //Smart: to collect, visualise and analyse data from open-source design, low-cost Internet-of-Things connected monitoring equipment.
- ReSETMap to show the location of green investments in relation to proposed grey infrastructure and a simple visualisation of other components of the ReSET Investment Toolkit.

In addition to the toolkit, the project has developed approaches for its use, which have been trialled in the demo sites and improved along with the tools based on stakeholder feedback. An overview of the ReSET-IT is provided in the next figure. It shows the toolkit's main components in the middle (in brown), the input data required to populate these components (in pink), the investment options that can be assessed (in green) and the scenario context under which the options can be assessed (in blue). This is complemented with the communication options, including both the type of information and the way the information is presented (in yellow).



Overview of the ReSET Investment Toolkit showing how the individual components fit within their use context.

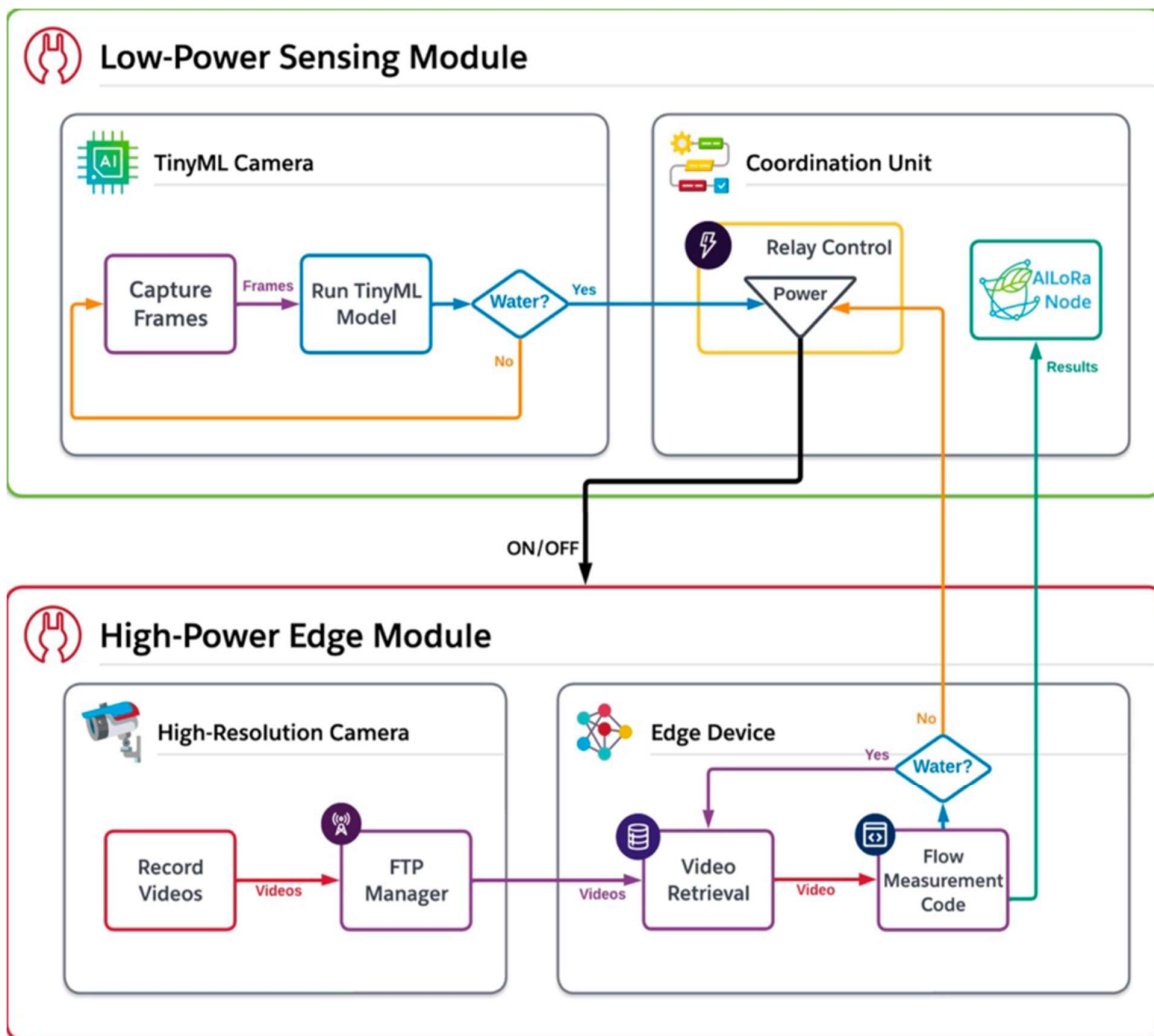
SMARTLAGOON

Effective environmental monitoring is crucial for managing global environmental challenges and providing the necessary data for Environmental Intelligence (EI). This discipline involves the integration of data from various sources to gain a comprehensive understanding of specific regions or processes. In SMARTLAGOON, we introduce BODOQUE, a hardware-software infrastructure to monitor water flows in ephemeral streams where the water rarely flows with great force. BODOQUE uses a low-power TinyML-based camera to detect the presence of water, activating a more complex system to measure flow only when the water flows, thereby optimizing energy consumption. This device is being deployed in the Segura basin, Murcia, Spain. This work focuses on the power-saving capabilities of BODOQUE, comparing the energy consumption of different edge devices running the code that measures water flow in the streams. Our goal is to determine the optimal hardware setup for the system based on our experiments, which involve performance and energy consumption tests. The results provide valuable information for future environmental monitoring systems, considering the best balance among the device's cost, performance, and energy consumption.

Our prior solution for monitoring ephemeral streams in the Segura Basin employed a system that combined an outdoor high-performance network camera and a small single-board computer (SBCs). The system was designed to transmit videos to a server only upon detecting rainfall in the surroundings, a determination made by consulting weather stations. While this approach was practical, it

was burdened by several limitations. The system's continuous operation led to high power consumption, with the SBC requiring, on average, 2.53 W and the network camera around 12 W. Moreover, the system's dependence on transferring large volumes of data to a remote server for processing posed efficiency challenges.

The conception of BODOQUE was led by the need to develop a more efficient and sustainable solution for monitoring ephemeral streams. The system now operates bimodally, leveraging a low-power sensing module and a high-performance edge module, a design that allows for significant energy savings and increased operational efficiency. This bimodal operation allows the system to conserve energy by keeping the more complex and power-consuming part of the system inactive when not needed. The Edge Device, as a single-board computer, provides the necessary computational power for processing the video data, while the high-resolution camera captures high-quality video of the ephemeral streams. Combining these components in the high-performance edge module enables the BODOQUE system to perform its monitoring tasks effectively while optimizing energy consumption.



Low-Power Sensing Module

The low-power sensing module of the BODOQUE system consists of a low-power TinyML-based camera, a coordination unit, and a relay. This module is designed to be energy efficient and primarily serves to detect the presence of water in the streams and control the activation of the high-performance module. The low-power TinyML-based camera is the primary sensor in this module. Upon detecting the presence of water, it sends a signal to the coordination unit. The coordination unit plays a crucial role in the system. It is connected to a relay that controls the power supply to the components of the High-Performance Edge Module. When the coordination unit receives the signal from the low-power TinyML-based camera, it activates the relay, powering on the Camera and the Edge Device.

The coordination unit is also connected to the Edge Device. This connection allows the Edge Device to provide the coordination unit with the processing results, which the coordination unit then sends using a low-power, long-range and mesh-capable communication protocol based on LoRa (namely, AllLoRa protocol) which is another result of the SMARTLAGOON project, to a gateway for further processing and analysis. Moreover, the coordination unit receives a signal from the Edge Device when the processing is complete, and no more water is left to measure the streamflow. Upon receiving this signal, the coordination unit waits until the Edge Device is off and then deactivates the relay, powering off the High-Performance Edge Module's components. This action restarts the process, with the low-power TinyML-based camera resuming its monitoring for the presence of water.

While the high-performance edge module is off, the coordination unit continues to send the results. It can store them, eliminating the need to keep the more power-consuming part of the system active while the results are being transmitted. This bimodal operation allows the system to conserve energy by keeping the more complex and power-consuming part inactive when not needed.

High-performance Edge Module

BODOQUE's high-performance edge module is a more complex subsystem that includes a high-resolution camera and a single-board computer (SBC) serving as the Edge Device. This module is activated only when the low-power sensing module detects the presence of water. The Edge Device runs a discharge measurement code (see below) that measures water flow in the streams. The data collected is then transmitted to the coordination unit, which sends it over LoRa using the AllLoRa protocol to a gateway for further processing and analysis. When the system detects no more water flowing in the ephemeral stream, it stops requesting videos from the camera. After finishing the transfer of all the results to the coordination unit (for it to store them and transmit them later using the AllLoRa protocol), the Edge Device signals the coordination unit that it can be deactivated. The coordination unit waits for the Edge Device to turn itself off before shutting down the relay, halting the high-performance edge module.

Discharge measurement code

The discharge measurement code, central to our system, is based on the principles of image-based methodologies for discharge measurements. Over the past two decades, various methods have been developed, e.g., Large-Scale Particle Image Velocimetry (LSPIV), Particle Tracking Velocimetry (PTV), Space Time Image Velocimetry (STIV), among others. Herein we used a system that is based on a cross-correlation image velocimetry technique but overcomes some of the known factors that compromise LSPIV performance, such as glare, shadows, and lack of traceable features in the flow. First, a short video must be acquired, captured by the High-performance Edge module's camera. The frames are subdivided into interrogation windows, and the cross-correlation algorithm is applied to each window, yielding a displacement field. Erroneous vectors due to wrong matching patterns are filtered out, and a surface velocity profile is fitted to the stream-wise components of the velocity vectors. The discharge is then calculated by estimating the bulk velocity based on the surface velocity.

Initially developed for traditional computing architectures, the code has been successfully adapted in this study to run on devices powered by ARM processors, enabling the system's deployment at the edge. This adaptation opens up new possibilities for using energy-efficient and cost-effective appliances in environmental monitoring systems.

WATCHPLANT

WatchPlant project proposes a novel approach of developing a biohybrid system technology for in-situ monitoring of undersampled parameters and new dynamics based on plant physiology. To this aim, the project aims to create smart biohybrid organisms by the use of wearable sensors for plants. It include not only new sensing technologies but also AI components and technological interfaces, resulting in the creation of "smart biohybrid organisms" for environmental monitoring. Therefore, the main goal is to develop, deploy, and perform an experimental validation of this new biohybrid system technology to address the in situ monitoring of environmental context focused on pollution, together with living plants, primarily in urban scenarios using undersampled parameters in plants, multiparametric data collection and interpretation together with air quality as a study case, in order to establish a relation to human health.

Currently, there are a lot of monitoring approaches and sensors already developed to obtain information about the environment. However, there is a lack of information on the data obtained. Watchplant projects aim to explore new dynamics in the parameters and correlate them with the environment. Thus, it would be possible to detect plant stress and establish the reason, which could have an effect in early-stage actions. Additionally, it is also key to access new valuable information based on undersampled parameters to obtain new information about plant status. Afterwards, environmental models are very useful and will be one of the targets of the WatchPlant project in the upcoming years to obtain a better understanding of the environment. Is not only about measuring but deciding what to measure while understanding the obtained data properly.

In this third year, we have developed the separate components of the biohybrid system for tracing the indicators in the plant that correlates with environmental conditions related to air pollutants. During this year different algorithms have been used, considering plants as black boxes and applying statistics and machine learning to automatically interpret measured signals and classify them for a given use case into the way to obtain valuable key information.

Hardware Challenges

I-Seed

One of the first challenges was to define the methodology to translate the biological principles of some selected plant seeds and their dispersal strategies in the design and fabrication of environmentally responsive seed-like soft robots made of multi-functional biocompatible and biodegradable materials. With the I-Seed objective to perform measurements above soil and topsoil, two groups of natural seeds have been identified and analysed to extract biological specifications for the artificial systems: (1) self-burying seeds able to passively penetrate the soil fractures. Crawling and burying occur thanks to the seed awn unit, which has hygroscopic characteristics and responds to variations of external humidity by changing its configuration; (2) flying seeds - which use their morphology and structural features to be carried by the wind and dispersed over great distances. We have systematically collected, for the first time together, the morphological, structural, biomechanical, and aerodynamic information from selected plant seeds relevant to take inspiration for the engineering design of soft robots, and discussed potential future developments in the field across material science, plant biology, robotics and embodied intelligence (Mazzolai et al., 2021). Motion and dispersion of the seeds can be obtained by using the natural combination of sensing and actuation through material computation, with which it is possible to obtain a passive mobility (with no need of any internal energy source), exploiting their morphology, structure, and biomechanics/aerodynamics.

Some of these seed-inspired robots, have been endowed with sensing abilities, envisioned as simple and low-cost tools to be used for collecting environmental data in-situ aimed to high spatial and temporal resolution across large remote areas where no monitoring data are available, and for extending current environmental sensor frameworks and data analysis systems.

Starting from the identified biological principles, we focused on the fabrication of artificial seed-like robots with biodegradable/environmentally-friendly materials able to provide structural support and dynamically respond to several environmental stimuli. With this in mind, we have fabricated:

- self-burying robots responsive to humidity variations made with biodegradable polycaprolactone and cellulose materials using different manufacturing techniques (i.e., two-photon lithography, bioprinting, electrospinning) (Fiorello et al., 2022; Cecchini et al., 2023a).

- a bioinspired nanocomposite actuator driven solely by humidity and sunlight through a photothermal-hygroscopic effect. The actuator is fabricated in PDMS through casting coupled with direct ink writing (DIW) of cellulose (Mariani et al., 2023a)
- a bioinspired and biodegradable soft actuator based on photothermal expansion of biodegradable polymers (polycaprolactone and lignin). The actuator is fabricated through direct ink writing (DIW) techniques (Cecchini et al., 2023b).
- a flying biodegradable seed robot bioinspired to *Ailanthus altissima*. The seed is fabricated through direct ink writing (DIW) of cellulose acetate and leaching techniques for the creation of an ultralight porous seed with the same flying performance of the natural one (Cikalleshi et al., 2023a).
- a flying biocompatible seed robot bioinspired to *Acer campestre*. Fluorescent materials were embedded into biodegradable polylactic acid (PLA) and a fluorescent filament was produced via an extruder (insert reference Cikalleshi et al. 2023b). The fluorescent filament is then 3D-printed through Fused Deposition Modeling (FDM) to create sensor I-Seeds with the flying and dispersal performance of the natural one (Cikalleshi et al., 2023b).

RAMONES

ReSET

ReSET has encountered and focused on the following hardware challenges:

- **Challenge:** discontinuation of Particle IoT lines. Some of the microprocessors that we are working with have been discontinued by their manufacturers as a result of COVID related supply chain challenges.
- **Solution:** This has meant that we have had to develop Generation 3 FreeStation designs based on more readily available microprocessors: the ubiquitous ESP32. This has meant adapting PCBs, code and web systems to handle these new devices. Whilst this has been time consuming, it has opened up to a much greater range of microprocessor hardware.

SMARTLAGOON

In the pursuit of developing resilient and efficient IoT infrastructures for the SMARTLAGOON project, we have encountered several hardware challenges, particularly due to the remote and aggressive environmental conditions of the Mar Menor region and its watershed. These challenges are primarily in the domains of continuous computing for energy conservation, ensuring robust security, and maintaining reliable connectivity in such adversarial settings.

Continuum Computing and Energy Savings: The need for continuous monitoring and data processing in remote areas necessitates a computing continuum from the edge to the cloud. This poses a significant challenge in energy management, as these IoT devices must operate on limited power while performing computationally intensive tasks. The integration of edge computing has been a

step towards mitigating this issue, allowing data processing to occur on-site, which reduces the need for continuous data transmission to a centralized cloud and thus saves energy. However, ensuring these edge devices can operate efficiently, handle the computational load, and maintain prolonged uptime with minimal energy consumption remains a critical hurdle. To address this, we are exploring energy-harvesting technologies that can leverage renewable sources, such as solar or wind power, which are abundant in the Mar Menor region. Additionally, we are developing low-power algorithms and energy-efficient communication protocols that reduce the energy footprint of each device within the network.

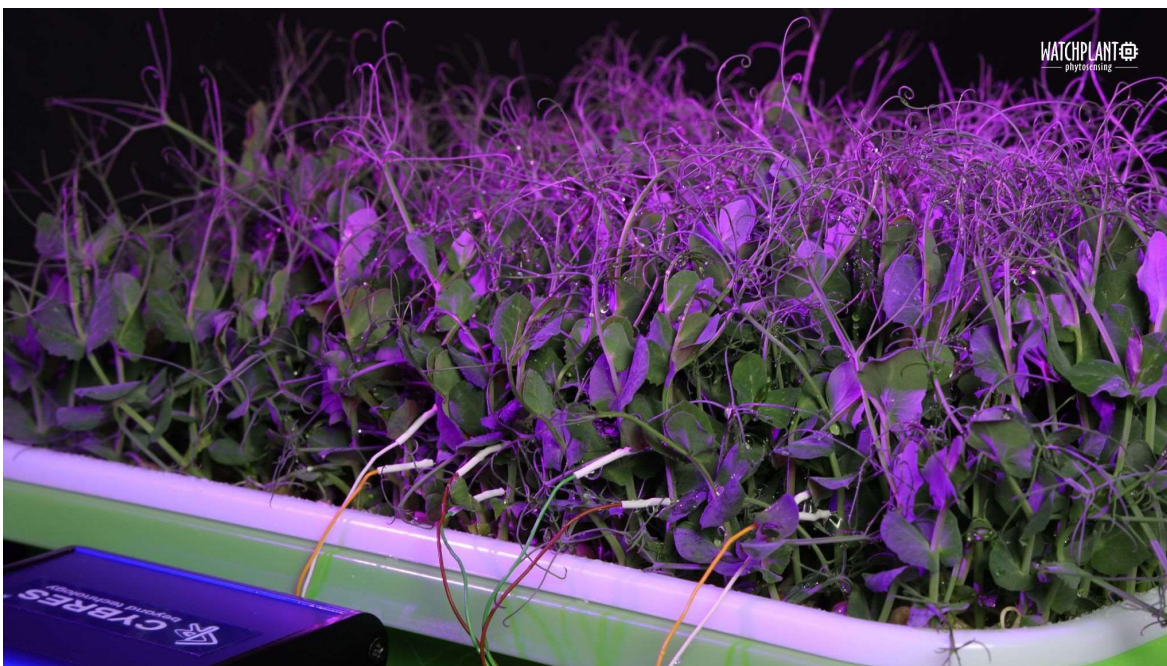
Security Challenges: The deployment of IoT devices in isolated locations increases vulnerability to physical and cyber threats. Physical security is a concern as devices are exposed to the elements and are at risk of tampering or theft. Cybersecurity is equally critical, as the data transmitted must be protected against interception and unauthorized access. We are implementing robust encryption methods for data at rest and in transit, and employing secure boot and firmware update processes to protect against cyber threats. Physically, we are designing rugged and tamper-evident casings for devices to withstand environmental aggressors and deter unauthorized access.

Connectivity with LoRa: Connectivity in remote areas is a significant challenge, especially where traditional cellular networks are unreliable or nonexistent. LoRa (Long Range) technology has emerged as a promising solution, providing long-range, low-power wireless communication that is well-suited for transmitting small amounts of data across vast distances. The use of LoRa enables our IoT devices to transmit environmental data even from the most isolated parts of the watershed. However, challenges with LoRa include signal interference, bandwidth limitations, and the need for careful planning of network topology to ensure optimal coverage and data integrity.

WATCHPLANT

Hardware challenges in WatchPlant are primarily related to biosensing applications, compatibility with biological organisms, in-situ information processing as well as with such typical hardware aspects as long-term energy supply and durability in outdoor applications. Current solutions are based on measuring the electrophysiology, photosynthetic activities, and hydrodynamic parameters of plants: they provide enough information for monitoring physiological parameters depending on environmental conditions and can be applied to different developmental stages – from young seedlings, see next figure, up to adult plants.

In this sense, new hardware challenges since the last report are:



Phytosensing physiological parameters of plants at different developmental stages for detection of environmental pollutants and contaminants.

- **Challenge: Electromagnetic Interference (EMI).** The measurements of the electrical potential are sensitive to EMI as the wires of the electrodes can act as antennas. Solution. To reduce possible EMI, we placed the PhytoNode in an aluminum housing and used coaxial cables for the electrodes. This shields most of the hardware and only the tips of the electrodes are uncovered.
- **Challenge: Providing power and communication infrastructure for distributed sensing in remote outdoor environments.** The natural environments relevant to plant sensing such as parks and forests mostly lack the proper infrastructure to build a continuously operational sensor network for environmental monitoring. Various types of wired and wireless sensors are needed to cover the full spectrum of measurements, each with its different abilities and limitations. There is a need for a hardware solution that can operate autonomously and act as a central hub for energy storage and data acquisition in sub-networks of these various devices. Solution: We have designed a simple-to-use, portable, weather-proof, and autonomous data collection system consisting of a waterproof enclosure, battery, and solar panels for off-grid power supply. The system includes a Linux-based mini-PC for data collection and local processing and can communicate wirelessly using three different technologies: Wi-Fi, BLE, and Zigbee. It also provides power and communication infrastructure to specialized wired phytosensing devices.

Software Challenges

I-Seed

Sensing in artificial seeds is obtained via transduction-based sensor materials, which challenge the advancement of in-situ sensing technology based on chemical transduction mechanisms. This goes beyond the current sensor network by using materials that react to environmental parameters, such as temperature or humidity, or to certain chemical analytes by changing optical properties. The reading of the signal is based on optical signalling and fluorescence by the Active Laser Fluorescence (ALF) Imaging technology. The challenge focuses on the design and development of a multi-wave-length fluorescence LiDAR system capable of detecting several excitations in one observation. This will extend the presented laser-induced fluorescence principle as evaluated for vegetation to other materials being part of the I-Seeds.

The ALF imaging prototype consists of several modules that serve various purposes for validation and read-out of the fluorescence signal from the I-Seed sensor. The current design consists of following modules: 1) Laser Excitation module; 2) Area-scan spectroscopy module; 3) Hyperspectral Imaging Module; 4) Triangulation module; 5) RGB Imaging module; 6) Verification module; and 7) Computation module. Starting point for the development of the ALF Imaging System prototype was to build it on Commercially Off-the-shelf (COTS) optical components. From the physical dimensions and the spatial positioning of the COTS elements, the casing and mounts were designed in CAD software.

In this design, we employed an excitation module providing the required excitation power and wavelength for laser-induced fluorescence. This module consists of the 980 nm laser head, laser power supply and cylindrical lens for shaping the output laser beam from rectangular to line shape. The detection of the fluorescence signal is based on the Hyperspectral Imaging Module which provides the localization and spectroscopic response of the I-Seed sensor. Customized wrapper software has been prepared to support the operation of the imaging system, setting measurement parameters and store the acquired data-streams for the different modules.

The timestamp of the GNSS onboard the ALF imaging system will be adopted to align with the GNSS timestamp for achieving georeferenced data. The ALF imaging data post-processing and drone flight controller are necessary to design and implement a “smart” flight controller based on deep learning architecture, with a software able to read and process in real-time the data stream and a desktop software to do post-processing and export georeferenced data of the location and calibrated reading from the I-Seed sensors in the field.

RAMONES

ReSET

ReSET has encountered and addressed the following software challenges:

- **Challenge: analysis of large deployments of sensors.** Several of the ReSET demo sites have deployments in excess of 20 dataloggers with multiple sensors on each. Analysis of data from such deployments requires a system capable of flexible and sophisticated data summary.
- **Solution: the FreeStation Data API.** In 2023 we have developed the FreeStation Data API as a means of interrogating large numbers of loggers and providing spreadsheet compatible results that can facilitate analysis of large deployments.
- **Challenge: visualisation of results.** For large deployments it is important that sophistication visualisation capability is available.
- **Solution:** in 2023 we have developed a new visualisation interface to FreeStation data at <https://analytics.policysupport.org/freestation/analyse>, which allows more sophisticated visualisation of single and multi-station data than is possible from the standard FreeStation visualisation tools.

SMARTLAGOON

To date SMARTLAGOON is addressing the following software challenges:

- **Challenge: End-to-End communication system for data visualization and model training.** **Solution:** Once the data has been captured, at the software level, the challenges of sending this data in near-real time to the cloud for further analysis and visualisation are posed. In addition, this data must be analysed, sanitised and connected with the models developed to make short-, medium- and long-term predictions.
- **Challenge: Clearly define the outputs of the digital twin of the Mar Menor.** **Solution:** The concept of the digital twin is applied in SMARTLAGOON to the socio-environmental intersections of an ecosystem such as the Mar Menor. These interactions are innumerable and growing in the future, making it difficult to establish a static model. Therefore, it must be established, dynamically, which interactions are most relevant to the context of the Mar Menor, in order to be able in the future to determine and/or amplify new relevant information that our digital twin should produce.
- **Challenge: Social impact measurements in real time.** **Solution:** In order to measure the social impact of the economic and environmental context of our digital twin, it is essential to know people's opinions in real time. We are designing a social monitoring tool to identify people's main concerns on social networks and to be able to respond to this in real time.

WATCHPLANT

To date the challenged addressed by Watchplant related to software are:

- **Challenge: Real-world data.** Measurements performed in real-world scenarios pose various challenges, such as noise, uncontrolled mixture of stimuli, redundancy or high dimensional-

ity. This can cause machine learning or statistical approaches to become unnecessarily complicated or even fail as each new dimension increases the complexity of our models and the signal may be too noisy. **Solution:** Post-processing operations on the data are helpful and include, for example, filters to suppress noise or certain frequency components. However, there is a risk that valuable information about the plant physiology is stripped away by filtering given that the underlying electrophysiological signal is not well understood. Therefore, post-processing must be kept to a minimum so that as little information as possible is lost.

- **Challenge: Efficient software design.** Our low-power sensor nodes, called PhytoNodes, are capable of running deep neural networks on board (Buss et al., 2022). However, it only contains a microcontroller with limited computational capabilities and storage. The challenge is to design software that is as efficient as possible to constrain computational complexity. **Solution:** One solution is to use as short programs as possible so that most of the memory can be used to buffer valuable plant physiological data until it is transmitted. This can be achieved by finding the smallest architecture of an artificial neural network, e.g. by using explainable AI to prune the network.
- **Challenge: Aggregating and understanding measurements from heterogeneous sensors.** Gathering accurate data about plant physiology requires the use of multiple specialized sensors that operate efficiently with limited energy. However, this results in data from various sources that must be systematically organized to form a complete picture of the environment. **Solution:** The data from each source can be labeled uniquely and organized in a systematic way to facilitate aggregation into large open-source datasets. These datasets, along with carefully collected metadata about the experiment location and other conditions, can be used to efficiently apply machine learning models for building environmental intelligence.

Network Challenges

I-Seed

The collection of environmental data and their analysis target the filling of geographical gaps to improve ongoing monitoring networks in areas where no monitoring infrastructures are available with low investment and management costs. I-Seed scenario challenges to increase the spatial resolution of monitoring points/sites developing a low-cost technology allowing to execute continuous field campaigns in contaminated sites/emission regions to cross-check the effectiveness of remediation measures adopted to restore ecosystems quality.

RAMONES

ReSET

ReSET has encountered and addressed the following challenge:

- **Problem:** whilst reliable, 3G connectivity will be switched off by 2033, with some companies starting as early as next year.
- **Solution:** As part of the move over to new hardware we have also moved from 2G/3G connectivity to 4G connectivity (NB-IoT and CAT-M). Challenges remain: both of these technologies are relatively new and at various stages of maturity throughout Europe. Different providers use different of these two and their coverage is not necessarily overlapping. Many international SIM providers do not have access to these technologies in certain countries.

SMARTLAGOON

To date SMARTLAGOON is addressing the following network challenges:

- **Challenge: Development of low-power, long-range communication systems in remote environments.** The deployed oceanographic buoy is located about 12 km off the coast. SMARTLAGOON has developed a LoRa-based communication system to connect the oceanographic buoy with the Spanish Institute of Oceanography (IEO) in Murcia, located on the shore of the Mar Menor. In this way, the processes of collecting and sending data through this protocol are being optimised. In addition, a Mesh-based protocol is being designed to scale the protocol with multiple devices and allow greater coverage range.

WATCHPLANT

The challenges explored by Watchplant during 2023 according to network are:

- **Challenge: Distribution of energy consumption.** Wireless communication proves to be costly due to higher energy consumption when sending and receiving data compared to local processing. Excessive connections and data transfers at individual sensor nodes accelerate their energy consumption. If such a node is the only connection between node clusters or between the central data sink and the rest of the network (i.e., bottleneck without options for routing), the network may experience a partial or complete failure, known as a single point of failure. The primary challenge lies in the distribution of energy consumption across all nodes and over time within the WSN. Solution: One approach involves establishing adaptive connections to prevent nodes with limited energy from sustaining numerous connections and data transmissions, thereby mitigating the problem.
- **Challenge: Network reliability.** The performance objective of remote sensing units relies on building a sustainable sensor network. Therefore, the network should allow the dynamic deployment/relocation of sensor nodes to enable reinforcing the network and repairing broken/weak links on the fly. Here, the challenge is to modify existing routing protocols to allow the detection of such necessity, then indicate locations for manual (i.e., by human operators)

or automatic replacement/deployment. However, the automatic deployment is extra challenging because the attachment process of electronics to plants is not trivial. Solution: A solution for the challenge of dynamic network reconfiguration and resilience to broken or weak links is a distributed method for network topology control published in (Griparic et al., 2022; Krizmancic et al. 2022). Furthermore, it is possible to use modern communication protocols such as Zigbee that have self-reconfiguration and self-healing features built into the protocol by default.

- **Challenge: Adaptive communication network.** WatchPlant faces the challenge of developing both hardware and software components for a multi-protocol network that will ensure interoperability between heterogeneous nodes with different capabilities and provide effective and efficient data acquisition and processing under all conditions. Solution: Based on our research of the strengths and weaknesses of various radio communication protocols for this application (e.g., GSM, LoRa, WiFi, Bluetooth), we have developed a prototype of a heterogeneous sensor network. This network uses BLE for efficient data transmission from sensor nodes, Zigbee for a self-reconfiguring backbone for data sharing between the nodes, WiFi for high-throughput upload of data to the cloud, and GSM (SMS) and LoRa to enable access to the network from remote locations with limited infrastructure.

People, training and engagement Challenges

I-Seed

During the third year, I-Seed has engaged with different communities through:

- **Communication.** Raising awareness of the I-Seed project mission, challenges and results using the project website, social media, press releases at national and international level, addressing popular newspapers, magazines, participation in radio and TV programs, in fairs, and organisation of “scientific café”.
- **Dissemination.** Dissemination of project results towards the scientific community and industrial representatives via scientific publication in peer-reviewed journals and international conferences; flyers, posters, presentations; organisation of special tracks, workshops, special sessions to present results and technologies in national and international conferences
- **Environmental sustainability and community building.** Leverage the cross-disciplinary connection of the community of biorobotics and environmental science to support the evaluation of the effectiveness of measures undertaken in the implementation of environmental policies; and to promote eco-innovation initiatives through citizens’ involvement for raising awareness on critical environmental issues.
- **Training.** Use of master classes, dedicated workshops, scientific tours, and summer schools, with the goal of educating a new generation of roboticists, material scientists, biologists and environmental scientists with the multi-disciplinary expertise for the creation of new environmentally-friendly technologies for the environment.

- Exploitation. Use of presentations of I-Seeds prototypes, in their different phases, and meetings with potential customers and stakeholders

RAMONES

ReSET

ReSET has encountered and addressed the following challenges:

- **Challenge:** The need to simplify and clarify our offering. The tools that we provide are many (FreeStation, //Smart:, Co\$tingNature, WaterWorld, Metronamica, ReSETMap, ReSET toolkit).
- **Solution:** careful communication and training. We have had to ensure that each tool as well as the tool results, are communicated simply and effectively to the relevant audiences through the various communication channels: the ReSET website h2020reset.eu, the websites of the individual tools, the user documentation and training, and the stakeholder interaction during workshops.

We have developed demo-specific web pages and stakeholder-group specific documentation, for example for teachers through our EduStation materials and for investors, consultants and policy makers through infographics and brochures. For the latter group we also developed policy briefs on 'Environment, employment, economy triple-win green investments' (D6.9) and 'Employment, economy and environment trade-offs' (D6.10).

Information on tools presented was developed by the modelling partners and next reviewed and questioned by the non-modelling partners to ensure a clear communication to a non-technical audience and to avoid the use of jargon. In addition, we have been working on a guidance document to facilitate potential users in selecting and combining the most relevant combination of tools for their questions and intended use.

SMARTLAGOON

To date SMARTLAGOON is addressing the following People, training and engagement challenges:

- **Challenge: Disseminating new findings and involving stakeholders potentially interested and able to benefit from them is not an easy task. Solution:** Raise awareness through communication activities and direct engagement through co-design and co-creation. We have begun awareness raising of the SMARTLAGOON project using social media #SMARTLAGOON @SMARTLAGOON, web www.smartlagoon.eu, participation at events, and presentation at conferences. Moreover, we organized workshops and meetings with stakeholders to make them aware of what we can provide and to understand their needs, capacities and priorities, and eventually, co-design and co-create our solutions with them.
- **Challenge: Gathering the support of the different stakeholders involved in the environmental problems of the Mar Menor is the greatest social challenge of the project. Solution:**

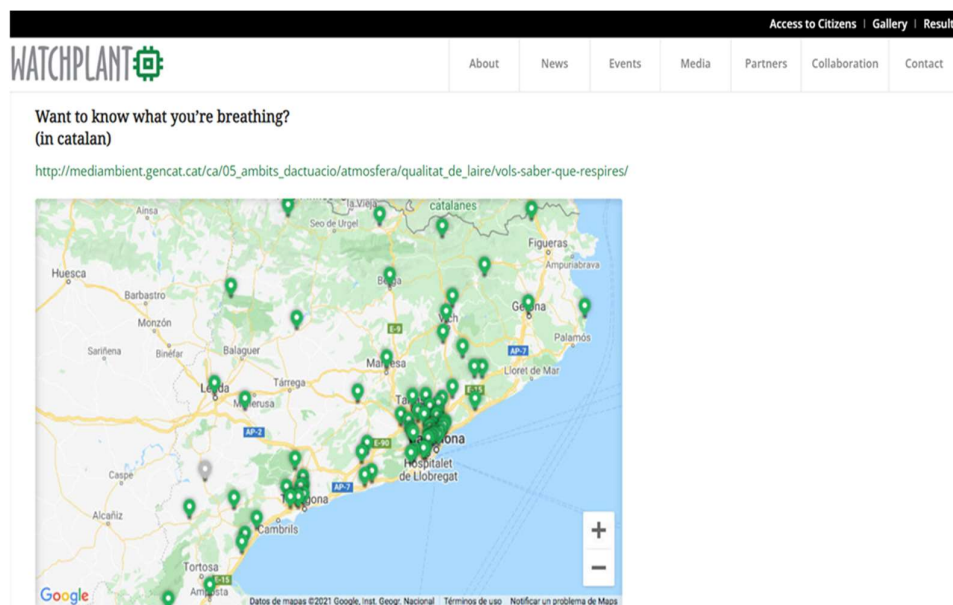
Maintain a clear communication strategy based on the scientific documents generated as a consequence of the tasks carried out during the project. The clear politicisation of the social problem derived from the environmental crisis of the Mar Menor has led to a very tense working climate in which SMARTLAGOON has to keep out of the political interests of the different stakeholders. This neutral position must be based on a clear communication of the scientific documents of the project.

WATCHPLANT

To date Watchplant is addressing the following people, training and engagement challenges:

- **Available and accessible data for citizens / enabling citizens to interact with the sensor network.** Watchplant project is committed to achieve one of the main motivations for Environmental Intelligence, providing people with tools for better and more meaningful environmental data acquisition. The interaction with the citizens to increase their engagement should start at the data collection level, continue at the hardware and software levels, but also at a step further. Specifically, the challenge lies in identifying simple and effective methods to rapidly distribute the key environmental parameters measured to the general public, as well as encouraging their participation in collecting, processing and distributing data within the sensor network using their smartphones or wearable devices. **Solution:** To achieve those challenges, Watchplant promotes actions to provide the information collected by the biohybrid system to the citizen, such as to upload the data to the project web page to enable free and open access to the data; and to participate in divulgation events and conferences to discuss about the benefits and contributions of Environmental Intelligence.

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Watchplant web page (<https://watchplantproject.eu/access-to-citizens/>) with the real-time data of environmental parameters related to air pollutants..

Policy Challenges

I-Seed

To date I-Seed has focused on the following policy challenge:

- **Challenge: Policy makers and implementing agencies.** An important component of dissemination and outreach strategy of I-Seed is the involvement of international convention secretariat and expert groups supporting the policy implementation at national, EU and UN levels (i.e., UNEP, UNIDO, UNITAR), considering that I-Seed project could help to face challenges related to UN Sustainable Goals (i.e. 13 - Climate Action; 15- Life on Land). The evaluation of the effectiveness of measures undertaken by governments to achieve the objectives of an environmental policy depends primarily on the availability of monitoring data that may show the improvement of environmental quality over time. To leverage the ongoing monitoring programs with low-cost monitoring technologies would allow nations to promote nationwide monitoring programs and be an active part of the policy implementation.

RAMONES

ReSET

ReSET has encountered and addressed the following policy challenge:

- **Challenge: large variation in user interest.** When applying our tools in practice in the various demo sites, it became evident that there was a large variation in what stakeholders were interested in (use purpose, types of questions, complexity of the tools, etc) and as a result what tools would be relevant and which combination of tools would be preferred. Developing one hard-wired toolbox that would fit all users and use cases was therefore not seen as a meaningful way forward to have the tools applied in practice.
- **Solution: development of a more flexible framework.** We have developed the ReSET-IT as described in the first section, offering users the flexibility to select their tools of relevance rather than having it imposed on them to use the entire toolkit. To facilitate this process we are developing a guidance document illustrated with examples of using (combinations of) tools in the various demo sites.

SMARTLAGOON

To date, SMARTLAGOON has focused on the following policy challenges:

- **Challenge: Legislation updating through collaboration with regional and national administrations.** In recent years, both the regional and national governments have published various regulations specifically related to the Mar Menor coastal lagoon. These regulations include a broad list of

measures that are not prioritized among them. As can be seen in Lopez-Ballesteros et al. (2023), SMARTLAGOON has evaluated the effectiveness of the different measures incorporated in existing laws and has transmitted these results to both regional and national governments so that they can be taken into account in future updates of these laws.

WATCHPLANT

No additional challenges related to Policy had to be addressed in the third year of Watchplant project.

Basic science and technology facing innovation. Challenges in Environmental Intelligence

Environmental Intelligence faces the challenge to unify multidisciplinary innovation in the fields previously exposed in the direction of benefit social good. This is supposed to be easily translated into an interest in investment from target companies in the related fields. Thus, Environmental Intelligence objective is focused on multiply the impact of the proposed solutions and prepare the transition towards medium-range TRL developments, together with preparing the ground for future industrial and commercial uptake, to fully achieve the expected impact. In this section, the needs of society have been identified for each field and linked to associated technology and target markets. Additionally, challenges in founding start-ups from low TRL technology or in context in which there is not a market developed yet will be pointed in this section.

Market Opportunities

I-Seed

The market opportunities for I-Seed technologies are being defined thanks to a continue discussion with environmental scientists and innovators.

Reduced environmental footprint for environmental ICT: Made of biodegradable materials and with no need for internal power supply, I-Seed robotic systems are conceived to avoid the dispersal of new e-waste and no-need of retrieval actions for the devices themselves. New multi-functional materials and fabrication processes will be investigated and implemented for the development of the I-Seed series, paving the way for a new generation of environmentally benign technologies.

Availability of reliable data and models at multiple levels of granularity for environmental policy-making: The proposed I-Seed technology would provide three key contributions to the current monitoring capabilities that would represent an advantage for the implementation of environmental policies at any geographical scale, which include: (i) the possibility of filling geographical gaps to improve ongoing monitoring networks in areas where no monitoring infrastructures are available,

with low investment and management costs; (ii) the increasing of the spatial resolution of monitoring points/sites with a technology that is cost-effective, robust over time, remotely controlled, and that allows monitoring our selected parameters in the top soil, and air above the top soil (air-top soil interface). This is crucial information for reducing the range of uncertainty in numerical atmospheric modelling evaluation aimed to assess spatial patterns of contaminants' concentrations and exchange fluxes over terrestrial receptors with changing emission regimes and meteorological conditions; and (iii) the development of a low cost technology that would allow to execute continuous field campaigns in contaminated sites/emission regions to cross-check the effectiveness of remediation measures adopted to restore ecosystems quality.

RAMONES

ReSET

Our key societal challenge is that huge investment in urban and rural restoration of nature will be made in the next decade to avoid existential challenges associated with (a) increasing exposure to floods, droughts, heatwaves, wildfire (b) the mass extinction of biodiversity and (c) the collapse of nature's contributions to people which underpin food, energy, water and financial security. These investments require evidence to ensure that they are effective, cost-effective and socially just, but there is a lack of supply of integrated knowledge systems for:

- 1) Effectiveness assessment to learn from already-made land management and restoration investments.
- 2) Strategic spatial planning of what restoration investments to make where, for low-cost, socially-just and environmentally sustainable outcomes.

Current approaches are often without social dimension, fragmented, time-consuming, lacking evidence base, difficult and not solution-focused. ReSET's environmental intelligence brings together advanced remote sensing, sophisticated spatial modelling and low-cost, in-situ, IoT sensing to provide locally specific evidence for green investment. We have world-leading environmental and socio-economic modelling (Co\$tingNature, Metronamica); prototype sensors and sensor networks (FreeStation); excellent understanding of environmental policy and regulatory landscape, decision support needs and metrics for environment, economy, employment and leading work on multi-stakeholder processes (CNR, ICA, RIKS).

We consider the market for our technology to include all public and private sector investors and planners that will have obligations to invest in nature to ensure: carbon net-zero by 2050 (or earlier); nature positive (by 2030) and management of climate and nature-related risk in their portfolios. This systemic transformation of business models and practice towards sustainability will be the greatest challenge most public and private sector organisations have ever faced. The ESG consulting market will more than triple this decade, to support this transformation & investment.

Producing a sustainable business model for such a broad range of technologies as ours is challenging but could include:

- 1) Consultancy: use the improvements made to our technologies under ReSET to expand the existing consultancy market of the 3 SMEs in the project
- 2) Platform economy: Build systems for use by other environmental consultants, under affiliate licence, including some Freemium.
- 3) End user software licensing: for well understood environmental investment scenarios, market direct to end-users e.g. company ESG departments, urban and rural green investors, planners and implementers.

At the end of the third year, our tools vary from TRL 2/3 for those newly developed in ReSET to TRL 5/6 for those existing tools improved under ReSET. Further investment beyond ReSET will be needed to achieve a transition from TRLS 2/3 and 5/6 to TRL 8/9 and thus to grow societal impact by entering new markets. This investment would be put to professionalising the software and systems in addition to continued testing of their relevance through application to real-world cases and improving them based on stakeholder feedback. This would enable us to go beyond ReSET, towards an investment-ready proposition, supporting a socially-just, multistakeholder, nature-positive transition for sustainability.

SMARTLAGOON

SMARTLAGOON's market opportunities are diverse and span across several industries and sectors. Capitalizing on these opportunities requires strategic planning, a deep understanding of the target markets, and a clear value proposition that aligns with the needs and challenges of potential customers.

Environmental Monitoring Solutions:

The technologies developed for real-time monitoring of lagoons and watersheds are highly transferable to other regions and ecosystems. This opens up a market for environmental monitoring solutions in various sectors, including agriculture, urban planning, and natural resource management. Organizations and governments worldwide are seeking advanced monitoring systems to better understand and manage environmental risks, particularly in the face of climate change.

IoT and Edge Computing Hardware:

The project's advancements in IoT devices and edge computing are valuable to industries that require robust, low-power, and efficient computing in remote locations. This includes sectors such as agriculture for precision farming, logistics for tracking goods in transit, and even disaster management where real-time data is crucial.

Data Analytics Services:

Data collected from the SMARTLAGOON project can be utilized to offer analytical services to stakeholders interested in environmental data. This encompasses data processing, pattern recognition, and predictive analytics, which are in high demand for evidence-based decision-making in environmental policy, conservation efforts, and urban development planning.

Citizen Science and Engagement Platforms:

The citizen science aspect of SMARTLAGOON has the potential to be adapted into various platforms that engage communities in data collection and monitoring efforts. Such platforms can be marketed to educational institutions, non-governmental organizations (NGOs), and government agencies looking to increase community involvement in scientific and environmental initiatives.

Consultancy for Environmental Regulation Compliance:

With the increasing complexity of environmental regulations, there is a growing market for consultancy services that help businesses and governments comply with these regulations. The expertise developed within the SMARTLAGOON project could be leveraged to provide guidance on compliance with environmental laws, particularly in the European context.

Smart Water Management Systems:

The integrated water management solutions developed can be marketed to water utilities, irrigation districts, and flood management agencies. These systems offer a way to optimize water usage, predict flooding events, and manage water resources more effectively.

Technology Licensing and Partnerships:

Intellectual property generated from the project, such as software algorithms, sensor designs, and data processing methodologies, could be licensed to other companies or used to form strategic partnerships. This would enable the project to penetrate markets that the core team may not have the resources to address directly.

Educational and Research Collaborations:

Developing training programs and educational materials based on the research and technologies developed in SMARTLAGOON can address a market need for up-to-date environmental science education. Research institutions and universities could be potential customers for these educational services.

Sustainability and Climate Change Mitigation:

Lastly, companies and organizations looking to enhance their sustainability practices or contribute to climate change mitigation may find the technologies and methodologies developed in SMARTLAGOON to be of particular interest. This could open up opportunities in the corporate social responsibility (CSR) sector.

WATCHPLANT

The main goal of WatchPlant is to develop, to deploy and to perform an experimental validation of new biohybrid system technology to address the in-situ and remote monitoring of environmental context. This system would have a great impact in the field of sensing technologies including portable and wearable technologies for in situ and decentralised plant analysis.

Additionally, different stakeholders with a powerful tool for decision-making could be aware of this technology in real-time based on the real status of the environment for cities management. However, during the three years of project execution Watchplant has detected interest from other markets such as the agro food industry. This is in line with the trend of decentralised monitoring, but the technology still requires overcoming some barriers to reach market and private sectors. This involved aspects such as stability and outdoor data collection, limited resource uses, time-consuming and costly methods or materials, and also energy efficiency systems to be well accepted for the target markets or to be profitable enough for new companies' generation.

ENVIRONMENTAL INTELLIGENCE TARGET MARKETS

According to the previously described challenges, the target markets for each project has been summarized in Table 1 according to the main field of technology challenges.

Table 1. Environmental Intelligence contributions to target markets in the key fields

Field	Available technology	Non-available technology		Target market	Target segment	Actor
		New product, service, process	IIPR			
Key information	Spatial decision support models	ReSET Investment Toolkit	varies	Consultants, green investors, sustainability departments	Consultants, green investors	ReSET
						RAMONES
	Distributed and optical measurement of air/soil parameters	Biodegradable/biocompatible fluorescent robots sensitive to environmental parameters.	Patents; licenses; industrial know-how	Green investors. Public institution, private companies	Farmers and producers/ Sensors manufacturers companies	I-Seed
	On-demand data of socio-environmental interactions.	Mar Menor's digital twin	varies	Public institutions	Policy-makers	SMARTLAGOON
	On-demand measurements of physical and chemical parameters.	Sensors development for under-sampled chemical parameters. Ecophysiology to understand obtained data in a combined manner	Patent/ Industrial and Commercial Secrecy	Private companies	Farmers and producers/ Sensors manufacturers companies	WATCH-PLANT
Hardware challenges	Spatial distribution of the I-Seed robots and reading of the fluorescent signals by UAV/LIDAR technology	Biodegradable/biocompatible I-Seed robots dispersible by wind and humidity changes. Fluorescent materials sensitive to environmental parameters (e.g., Temperature, Humidity, CO ₂ and Hg). LIDAR on board of UAVs for fluorescence stimulation and reading.	Patents; licenses; industrial know-how	Green investors. Public institution, private companies	Farmers and producers/ Sensors manufacturers companies UAV producers.	I-Seed
						RAMONES
	Battery monitoring	New on PCB battery monitoring	varies	FreeStation users		ReSET

	Low-power and ubiquitous measuring systems	Edge computing artificial vision device to measuring flows	varies	Public institutions	River basin agencies	SMARTLAGOON
	Non-combined sensors and clean energy harvesting strategies	Miniaturised, integration of a net of physical and chemical sensors and power supply	Patent/ Industrial and Commercial Secrecy	Private companies	Farmers and producers/ Sensors manufacturers companies	WATCH-PLANT
Software challenges	Management and maintenance of large deployments	Software for data analysis and data-driven flight control	varies	Users of FreeStation	Farmers and producers. UAV producers	I-Seed
	Communication of results		varies	users fo FreeStation and ReSET-IT		RAMONES
	Management and maintenance of large deployments		varies	Users of FreeStation	Consultants, teachers, scientists	ReSET
	Social impact measurements	Social sensing tool to measure people's concern in real time	varies	Public and private institutions	Local, Regional and national governments, Medium-big companies	SMARTLAGOON
						WATCH-PLANT
Network challenges	Distribution models, environmental data management and validation	Data architectures, Data calibration and validation	Patents	Green investors. Public institution	Sensors manufacturers companies, Farmers and producers, UAV producers	I-Seed
						RAMONES
	No additional					ReSET
	Low power and long range communication protocols in rural areas	LoRa-based Mesh protocol	varies	Private companies	IoT-based companies	SMARTLAGOON
		Minimise energy consumption		Private companies	Sensors manufacturers companies	WATCH-PLANT

Dissemination and exploitation

I-Seed

During the third year, the consortium has continued to present the project at several international conferences in the fields of robotics (e.g. the 2023 IEEE International Conference on Soft Robotics “RoboSoft”; the 2023 Living Machines conference), material science (e.g. the 2023 Complex Active and Adaptive Material Systems GRC - Gordon Research Conference and conferences dedicated to photoluminescence materials such as Spectral SHapIng For Biomedical and Energy Applications (SHIFT) or the International Conference of Luminescence (ICL) to raise the awareness of the community towards novel applications), and environmental science, just to mention a few.

Particularly relevant during this year, was the contribution of I-Seed as exhibitor at the 2023 Living Machines Conference, the 12th edition of the International Conference on Biomimetic and Biohybrid Systems. This conference is held annually, and it is dedicated to research on new technologies inspired by the scientific investigation of biological systems (biomimetics) and the research that seeks to interface biological and artificial systems (biohybrid systems). This year, the conference aimed to focus on sustainability and the environment, a highly relevant topic to showcase the results of I-Seed during the exhibition and the poster sessions.



I-Seed at Living Machines 2023 during the exhibition (left) and poster sessions (right).

I-Seed was also part of the exhibition “Reverse Biology” at the Genova Science Festival, from October 24 to November 3, 2023. The exhibition is an immersive experience in the world of bioinspired robotics, with the aim to illustrate the importance of the “imitation of nature”, of taking inspiration to natural organisms, to better understand them and to design innovative technologies and machines that can help to better protect our environment and live in a more sustainable way.

RAMONES

ReSET

With more of our outputs becoming available, dissemination of ReSET activities and results has increased in the third year of the project. The www.h2020reset.eu website remains the main gateway to all information about ReSET and outlines the aims, activities and progress of the project. The site contains a link to all our public outputs and details of what we are doing and where we are working. In addition a set of leaflets and brochures has been developed for the overall toolkit and our tools, and where relevant these have been provided in the local language as well. There has been active interaction with stakeholders in all demo sites, which included the presentation and discussion of the tools and (preliminary) monitoring and modelling results, thus facilitating a feedback loop between stakeholders and tool developers to finetune the work and enhance the usability of the tools.

In 2023 the work has been presented at various conferences, amongst which Adaptation Futures (Montreal), World water week, SIWI Seminar (Stockholm), CUPUM (Montreal), Congreso LIFE Vía de la Plata (Salamanca), British Ecological Society (Belfast) and EGU (Vienna). Published and accepted publications include Van Delden et al., 2023 and Senent-Aparicio and Mulligan, 2024 (an inter-project publication).

As the ReSET project is coming to its end, a strategy for project exploitation for the final 6 months and beyond the duration of the project has been developed (D6.11) that focuses on the final dissemination of the work in the demo sites, at conferences and through scientific publications, but also presents plans for commercial, academic and public sector and government exploitation.

SMARTLAGOON

Members of the SMARTLAGOON consortium have organised together with the ReSET project a special session on Digital twins to support strategy and effectiveness assessment for nature-based solutions for adaptation at the ECCA 2023 (European Climate Change Adaptation Conference 2023) where SMARTLAGOON and ReSET are meeting and presenting the results of their projects. The progress of the project has been disseminated not only in high impact scientific journals (López-Ballesteros et al., 2023; Cecilia et al., 2023) but also in different media such as television, newspapers and radio. In addition, members of SMARTLAGOON have also participated in the Digital Ocean Forum 2023 organised by the European Commission.

WATCHPLANT

During the third year of the project, WatchPlant has been present in several events to promote Environmental Intelligence to society. In the field of robotics a newsletter has been launched to reach general population and introduce the field of smart biohybrid organisms from the point of view of AI and robotics (About intelligent plants, robots and the subjectivity of time | campus.kn (uni-konstanz.de)) or Youtube video distributed in social media about advances in sensing technologies for plants developed in the project, in the way to create autonomous systems for a better nature understanding WatchPlant Project Progress - YouTube.

Additionally, different events in universities have been organised as “open days” to introduce Environmental Intelligence topics in the academic field. In addition to it, open access scientific publications have been published in the field of robotics and sensing in a way to enhance the understanding of nature-technology relationship.

Additionally, and in order to reach the industry WatchPlant attends regularly to different events in regional companies’ clusters, workshops, networking events, universities and national media and radio in the countries of the partners involved. Thus, the project continues contributing to the Environmental Intelligence topic using diffusion and communication activities to enhance the technology awareness by social citizens and companies. Specifically, about the power of new valuable information and their understanding in the context of environmental surveillance for conservation and management. In this sense, patents are under discussion in the project to provide a new tool

for exploitation of the technology in the industry, that could obtain a great benefit from the technology developed in the project in higher Technology Readiness Levels.

Overall Conclusions

Environmental Intelligence aims to provide nature with technologies to create autonomous methods for monitoring and maintenance. It is a challenging mission since it involves a multifactor approach including a wide range of disciplines in very action- and product-focused research and development. The diversity found in environmental intelligence projects funded by the H2020 FET call have several challenges in common, relating to hardware; software; networks; people, training and engagement and policy contexts. These have been addressed in different ways by the projects as best suits their specific objectives but with the same vision for environmental intelligence profit.

After analysing the inputs, challenges and proposed solutions of the different projects to the key fields, several conclusions can be stated. It provides reliable information, not only from the technological point of view but from the purpose of the data obtained.

Providing reliable and useful information are key aspects to applying new policies and early stage actions, especially currently, in the era of data, where there is a lot of information available, it is essential to focus on obtaining the key information about environmental phenomena. The challenge of obtaining reliable information is based on a better understanding of current available data either by the use of models or new information based on undersampled parameters or new information obtained from data dynamics analysed in a combined manner. In this sense, advances in remote and autonomous sensing technologies together with statistics and artificial intelligence have a key role in the upcoming years.

Additionally, the good use of resources and energy are still key challenges to more efficient energy systems by software developments, autonomous materials and sensors including reusable solutions or biodegradable materials in the context of sustainability.

This document represents an update on the December 2022 II Blueprint for European Environmental Intelligence and will be further updated in December 2024.

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