Alliance for IoT
and Edge Computing
Innovation

Webinar • 23 May 2023

Presentation of Role of IoT and Edge Computing in addressing biodiversity and environmental monitoring

AIOTI

Opening and Welcome

Luis Perez-Freire, AIOTI WG Agriculture Chair (Gradiant)

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Agenda

Agenda

15.00	**Opening and Welcome (10 min)**
	Luis Perez-Freire, AIOTI WG Agriculture Chair
15.10	**Presentation of the paper and recommendations**
	Luis Perez-Freire, AIOTI WG Agriculture Chair
15.25	**Presentation of the use cases (45 min)**
	Christopher Brewster (TNO) - Overview of IoT for biodiversity monitoring
	Marcin Plociennik (PSNC) – Use Cases on pollination monitoring and phenology observation
	Alan O'Riordan (Tyndall) – Use Case on soil nutrients monitoring
16.10	**Questions from the audience (15 min)**
16.25	**Wrap up and end of Webinar (5 min)**
	Luis Perez-Freire, AIOTI WG Agriculture Chair

About
AIOTI WG Agriculture

Luis Perez-Freire, AIOTI WG Agriculture Chair (Gradiant)

Agriculture

Chair
Luis Pérez Freire
Gradiant

Co-Chair
Max Schulman
COPA-COGECA

Vision: Unlock the full potential of IoT (technologies, solutions, services, ecosystem, and infrastructure) for supporting future-proof, sustainable agri-food and forestry value chains in the Green Deal era

Scope: EU policies and standards, collaborative research and innovation, key technological developments and gaps

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Highlights

Relevant facts

76 member organisations

104 participants

Main achievements

1. Close cooperation with demand side: representatives of farmers and cooperatives, representatives of agriculture machinery
2. Relevant voice and visibility through position papers and workshops/webinars. Some examples:
    1. Organisation of workshop on the role of IoT in agroecology
    2. Co-organisation and participation in preparatory workshops for defining the Common EU Agricultural Data Space
    3. Active participation in consultations on Reference Testing and Experimentation Facilities for Agrifood (Digital Europe programme)
    4. White paper and webinar on the role of IoT in addressing the agroecological focus of the Green Deal
    5. White paper on the role of IoT and digital technologies for monitoring of the new CAP
    6. White paper on IoT data marketplaces for the agri-food sector
3. Facilitating the creation of consortia for collaborative research projects. First successful project in Horizon Europe.
4. Position agriculture as a relevant vertical for research in next-generation networks and services (SNS JU)

Priorities 2023

1. Increase engagement with external (esp. demand side) stakeholders in the food value chain
2. Promote cooperation of WG members in collaborative research projects esp. Horizon Europe programme
3. Define frameworks for the IoT contribution to help fulfil environmental and biodiversity objectives under the EU Green Deal and CAP
4. Increase the public exposure of WG results
    - Position papers
    - Active dissemination towards agri-food policy makers (EC, MS) and rural development networks
    - Public workshops and events (IEEE World IoT Forum, IEEE COINS, Digital with purpose)

Presentation of the Paper and Recommendations

Luis Perez-Freire, AIOTI WG Agriculture Chair (Gradiant)

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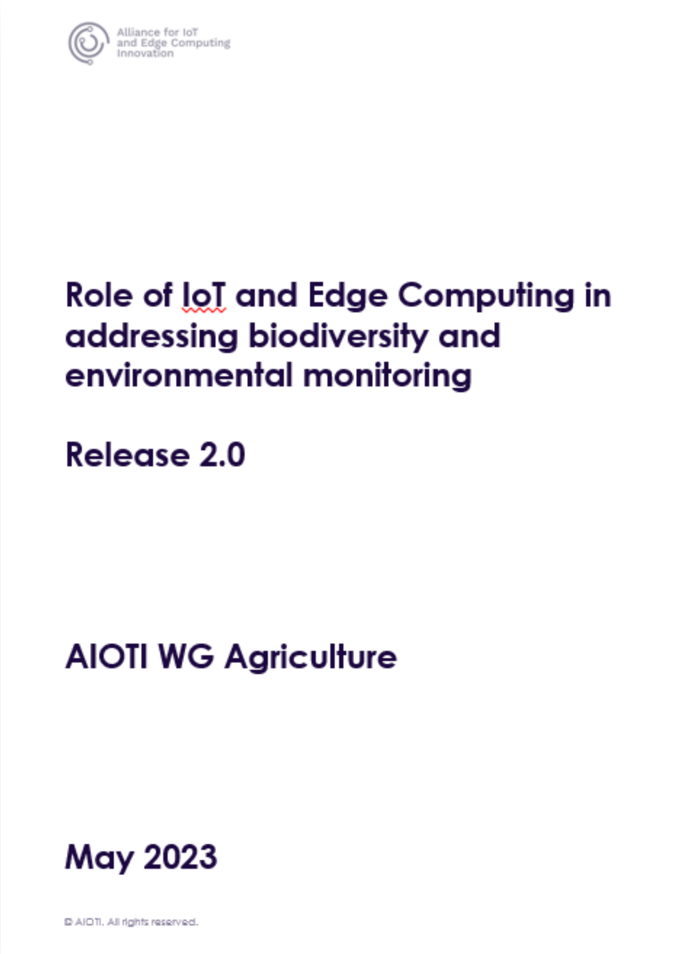
Published document


Alliance for IoT and Edge Computing Innovation

Role of IoT and Edge Computing in addressing biodiversity and environmental monitoring

Release 2.0

AIOTI WG Agriculture

May 2023

https://aioti.eu/wp-content/uploads/2022/12/AIOTI-Role-of-IoT-in-addressing-biodiversity-and-environmental-monitoring-Final.pdf

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Introduction – policy context

1. Legally protect at least 30% of the EU's land area and 30% of the EU's sea area
2. Strictly protect at least a third of the EU's protected areas
3. Effectively manage all protected areas, including proper monitoring measures
4. Reverse the decline in pollinators
5. Reduce the use of chemical pesticides by 50%
6. Bring at least 10% of the agricultural area under high-diversity landscape features
7. At least 25% of the agricultural land is under organic farming, and significantly increase the uptake of agro-ecological practices.
8. Reduce the use of fertilisers by at least 20% and reduce the losses of nutrients from fertilisers' use by 50%
9. Eliminate the use of chemical pesticides in sensitive areas such as EU urban green areas

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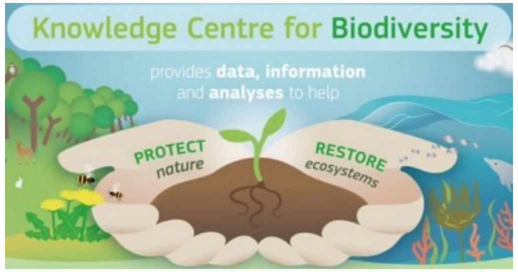
Landscape of initiatives

Strategic EU initiatives

biodiversa+
European Biodiversity Partnership



DOPA

EU and national projects

EU BON

PLANES COMPLEMENTARIOS
Biodiversidad

EUROPABON
Europa Biodiversity Observation Network: integrating data streams to support policy

BIODT
biodiversitydigitaltwin

ARISE

Standardisation initiatives

Essential Biodiversity Variables (**EVBs**) and
Essential Ecosystem Services Variables (**EESVs**)

ISO
TECHNICAL COMMITTEES
ISO/TC 331
Biodiversity

Summary

Focus of environment and agriculture policies on **preservation of landscapes and biodiversity**

Need for **measurement and monitoring capabilities** that are scalable, reliable and practical.

Biodiversity measures the **number, variety, and variability** of living organisms (animal and plant species, fungi, micro-organisms).

Challenges, gaps, real examples…

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Gaps and recommendations

1. Elaborate lists of requirements for the monitoring of biodiversity (**what and why should be measured**) which bridges the gap between the needs of the biodiversity community and capabilities of the technology developers.

2. Elaborate a **mapping between biodiversity features and physical variables/parameters** to be measured, with a special focus on understanding indirect monitoring techniques.

3. Analyse rigorously the **business case for biodiversity monitoring** in order to facilitate the feasibility analysis of different monitoring approaches.

4. Connect the biodiversity monitoring initiatives and projects with the EU Green Deal and Agriculture data spaces, taking into account from the beginning the **data standardisation** aspects.

5. Identify **synergies with the new CAP** where biodiversity monitoring can form an integral part of the technologies under development to facilitate environmental monitoring and linked policy impact assessment.

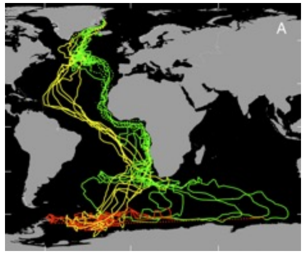
Presentation of the use cases

Christopher Brewster (TNO)
Marcin Plociennik (PSNC)
Alan O'Riordan (Tyndall)

Technological Advances in Biodiversity Monitoring

- New technologies have changed human species ability to monitor other species:
  - E.g. battery technology + GPS + cellular networks = **wildlife telemetry**
  - Made famous tracking birds such as the Arctic Tern - Related technologies now widely used to track cattle in some farms.
- BUT tracking =/= biodiversity monitoring
- There is a whole variety of methods and tools that can directly or indirectly help with biodiversity monitoring

https://milsar.com/examples/examples.html



https://www.pnas.org/doi/full/10.1073/pnas.0909493107

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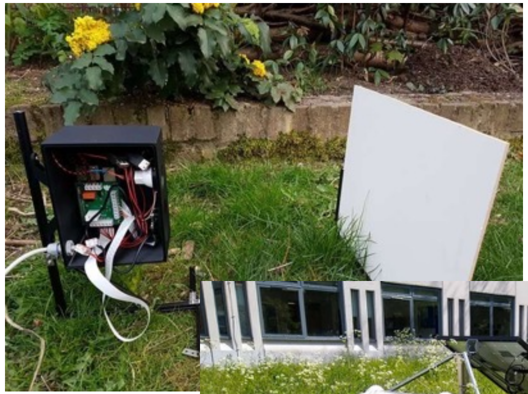
In-situ monitoring

- Camera traps for insects
  - In combination with automated insect identification
  - Various projects in Netherlands leading on this e.g. ARISE project
  - Partly made possible by large imaging data sets from crowd sourcing.
- Acoustic monitoring (e.g.) for birds, and other noisy wildlife.
  - This depends on species having different sounds and can only capture specific life stages
- Radar monitoring (e.g.) for birds and bats
  - Continuous scanning of the heavens together with identification



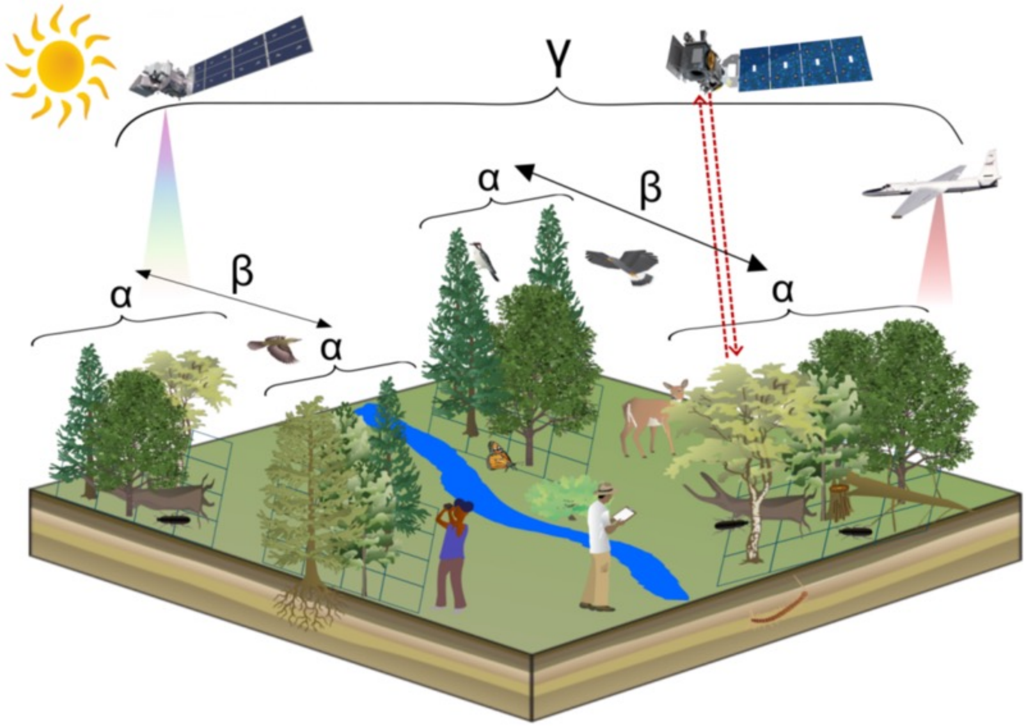
https://www.ceh.ac.uk/ukceh-ami-trap-automated-monitoring-insects

https://phys.org/news/2019-05-automatic-insect-identification-grasp-biodiversity.html

https://swiss-birdradar.com

Remote sensing and Earth Observation

- Using satellites, airplanes and drones
  - Using multi-spectral and lidar scanning for landscape changes
  - Can monitor large scale changes over longer periods of time.
  - Typical example is monitoring of rainforest destruction in tropical regions.
  - i.e. health of vegetation indirectly reflects health of biodiversity
- Growing use for more specific species monitoring



https://www.mdpi.com/2072-4292/14/21/5363

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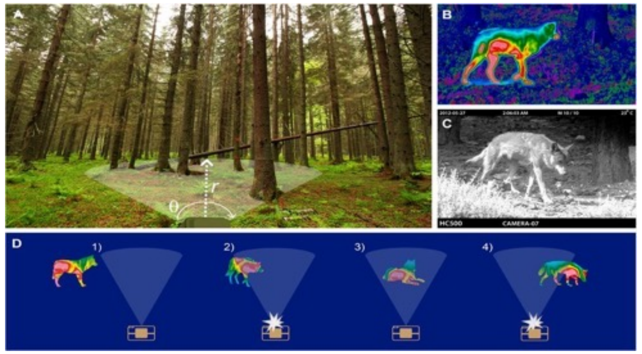
Cameras and multispectral imaging

- Camera traps mentioned above – they are static (as opposed to traditional human transects)
- Challenge is collecting images to train image recognition algorithms
- Great dependence on citizen science (esp. in Europe) for creating large datasets.
- Ever greater use of multi/hyperspectral imaging in combination with species distribution models.



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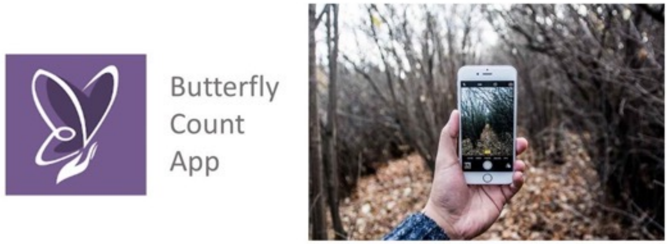
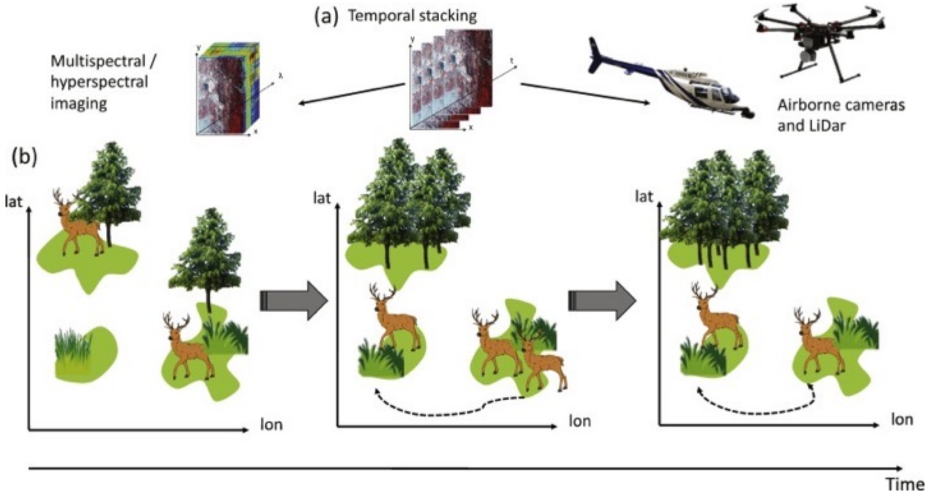


https://butterfly-monitoring.net/hr/ebms-app



https://www.sciencedirect.com/science/article/pii/S0034425719306467

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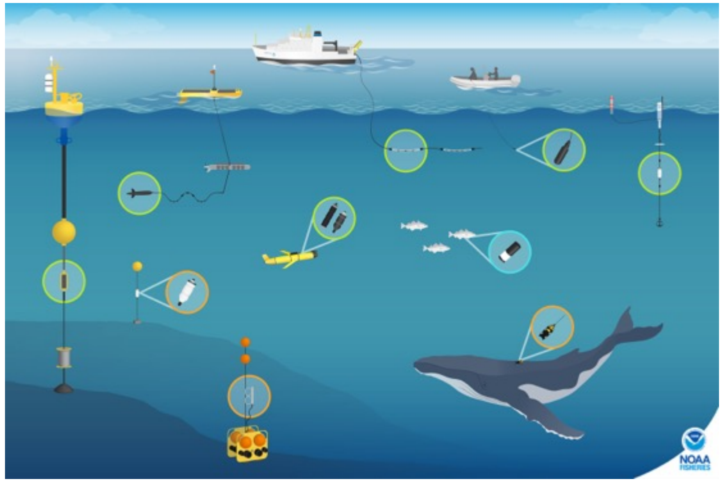
Audio sensors and acoustic monitoring

- Extensive use is made of audio sensors/acoustic recoding.
  - "Passive acoustic monitoring"
  - Birds, bats, aquatic species (whales etc.), wolves, elephants, frogs and some insects
- New uses of acoustic monitoring include early warnings, epidemiological research for zoonotic diseases, and even soil health
- Major challenge is interpretation of complex soundscapes with multiple species present

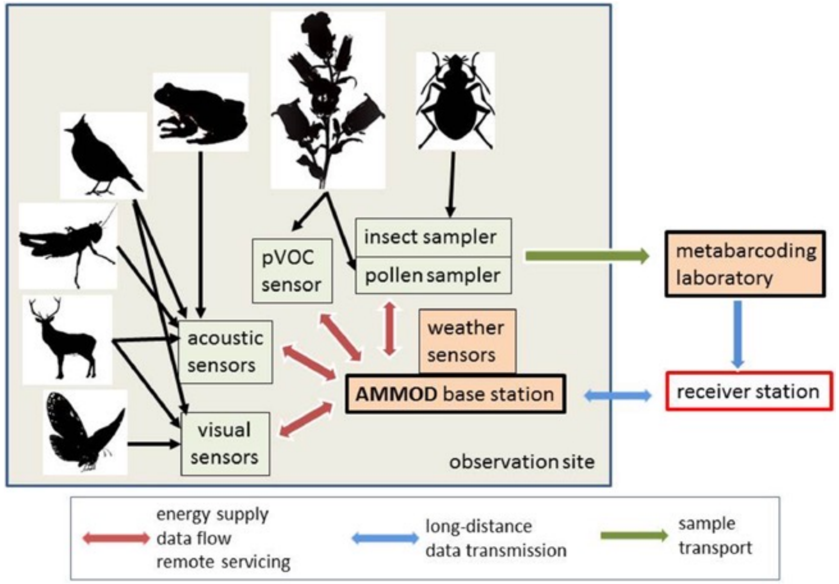
https://bou.org.uk/blog-metcalf-pass-acou-monitoring/



https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/passive-acoustic-research-atlantic-ocean

Integration of Technologies

- Recent research gives examples of “multi-sensors” or integration of multiple different sensors measuring different parameters.
  - cf. AMMOD project in DE, Arise project in NL
- General move towards integration of multiple data sources - Potentially very fruitful avenue
- Opportunity for the development of continuous monitoring – significant for agriculture/biodiversity interaction



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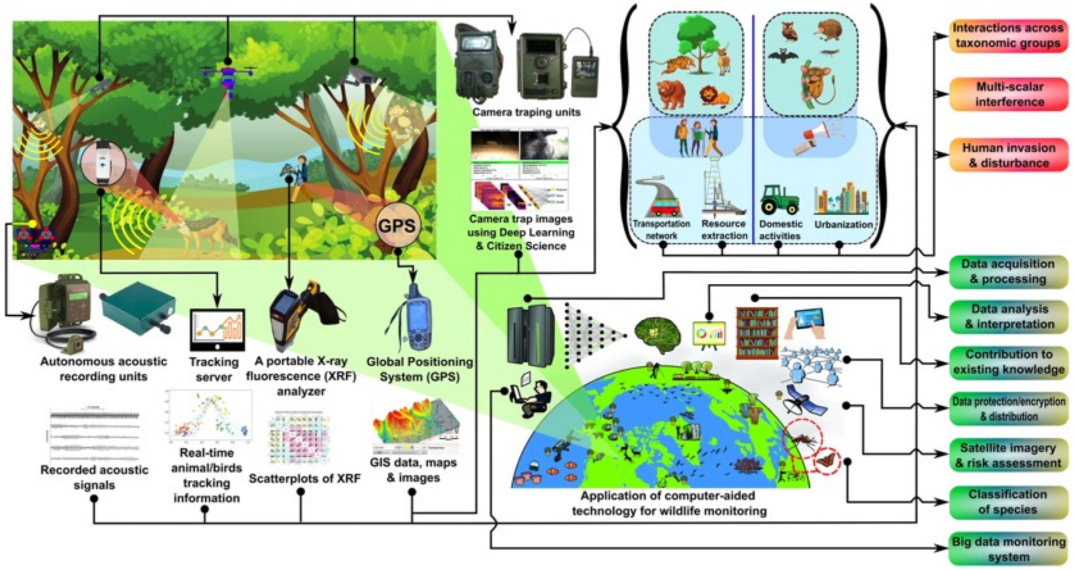

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What is missing? The Digital Twin conundrum

- Some issues with "technical" monitoring of biodiversity:
  - Funding tends to run out and technology is (initially) expensive
  - Technology measurements are not (necessarily) comparable or commensurable with past data
  - Lack of validation of data i.e. is species recognition accurate?
  - Technologies are good at "extreme scale" of biodiversity monitoring i.e. tracking an individual animal or coarse grained regional assessments - more work needs to be done to enable species diversity monitoring.
  - Need for **complementarity** with human observation – for continuity of data, for adoption, acceptance, and validity.
- BUT, BUT … we want (?) a **digital twin** for regional biodiversity (cf. BioDT project)
  - Most current data is "snapshot" data even if over long time scales
  - Digital Twin assumption is continuous, large-scale data feeds
  - CAP monitoring of ecological impact of agriculture has similar needs
  - Currently we are far from consistent, coordinated, standardized pan-European monitoring of biodiversity
  - **Great collaboration/communication between biodiversity community and IoT has many possibilities**

Use case: Pollination monitoring and optimisation

- Bees are one of the most economically valuable pollinators of crop monocultures worldwide
- Some fruit, seed and nut crops decrease by more than **90%** without these pollinators
- Recent studies indicate that pollination world-wide is declining:
  - EU countries losing up to one-third of their colonies each winter
  - US exceeds 30% colonies lost each winter, and in winter 2015/16 lost 44% of colonies
- Many reasons for decline:
  - diseases
  - exposure to chemicals
  - losses in plant diversity
  - adverse climatic conditions
  - deterioration of bees' natural (natural or human factors)
- Bees are critically important for the environment and economy
  - It is estimated* that pollinators contribute at least 22 billion € each year to the European agriculture
  - EU is 2nd world producer (250 kilotons) of honey (after China) and biggest importer
  - 17,000,000 beehives, 600,000 beekeepers in Europe

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IoT apiary protection and monitoring system

- ControlBee is an IoT apiary protection and monitoring system
- Created as an anti-theft and bees wellbeing tool, expanding with new functionalities
- Covers colony of hives
- Provides mobile application to beekeepers, allowing real time data tracking and notifications

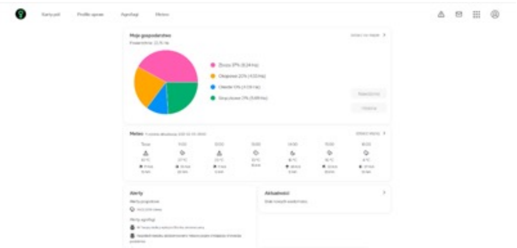
ControlBee
Twój bezpieczny ul

Devices and hardware

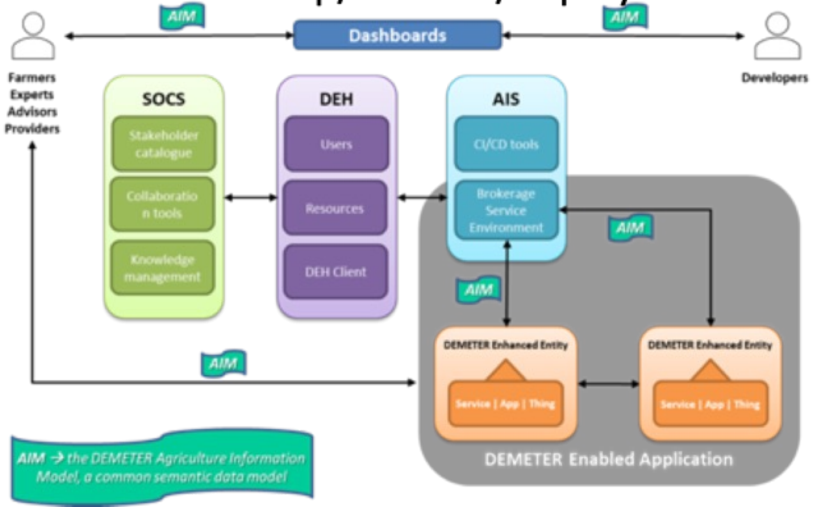
- Temperature, humidity and acoustic sensors
- Theft alert
- Knock-over alert
- Colony development – comparison with other colonies
- Queen mating and status

Digital platforms as enablers for new services

- Internet Platform for Consulting and Decision Support in Integrated Plant Protection coordinated by WODR
- The primary outcome is to rationalize the use of pesticides in agriculture
- Platform will provide four e-services for polish farmers, agriculture advisors and administration units:
  - Virtual Farm
  - Tracing the origin of agricultural products and plant protection products used
  - Risk reporting
  - Sharing of meteorological data



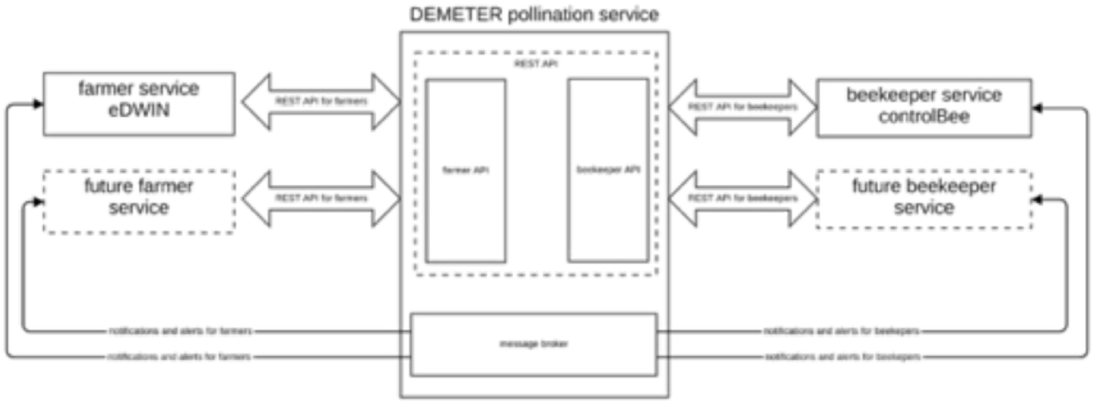
- Stakeholders Open Collaboration Space (SOCS)
  - multi-actor approach
  - resolves farmer needs
- DEMETER Enabler Hub (DEH)
  - information about different elements of DEMETER ecosystem
- Agriculture Interoperability Space (AIS)
  - full set of interoperability mechanisms
  - devolp/validate/deploy solutions



Work carried out under the H2020 DEMETER project (Grant Agreement No 857202) that is funded by the European Commission under H2020-EU.2.1.1. eDWIN is a Polish national project under patronage of Polish Ministry of Science in the Digital Poland initiative.

Pollination Optimisation Service

- Opens new venues for applications
  - new domain for ControlBee
    - information about fields where beehives are deployed
    - tracking of plant protection products poisonous for bees
  - new functionality in eDWIN's Virtual Farm
    - invite beekeepers to improve yield by utilising pollination
    - comply with rules and regulations regarding usage of plant protection products
- How to achieve it?
  - DEMETER enablers!



- Calculating pollination needs for field
  - size and shape of field
  - type of crop
  - region
- Communication between farmers and beekeepers
  - farmer creates invites specifyng pollination needs
  - beekeepers browse and accepts invites
  - specify apiaries deployment timeline
  - send alerts between systems in case of pest threat and pesticides usage

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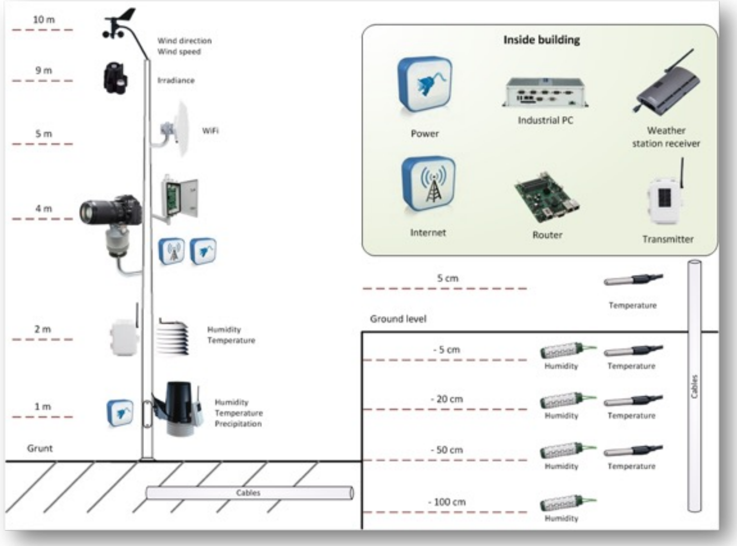
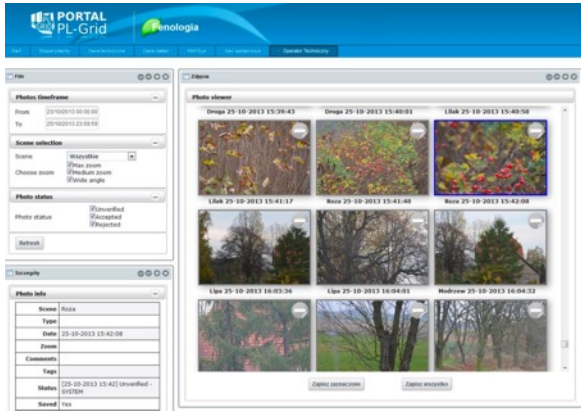
Use case: phenological observation

- Phenological observation is a record a crop or plant describing the development stage.
- As an example, plant flowering is a seasonal ecological function considered as a phenological stage.
- It is a good indicator of the impact of climate change over natural systems and shifts in phenological stages have been detected in different taxonomical groups worldwide.
- Information regarding phenology are very useful data for planning, timely execution of preventive and protective agricultural activities on specific stages of crop development.





Use case: phenological observation

PSNC is involved since 2011 automated fitophenological observations pipeline which archives continuous time-lapse pictures of plant species identified at the deployment site in Wielkopolska National Park

Infrastructure in Poland:
- Build or integrated over 550 agrometeo stations
- 20 phenological observations stations

AI4EOSC project is training the AI models for the selected diseases recognition in the wheat and sugar beets, where phenological observation cameras are one of the sources.

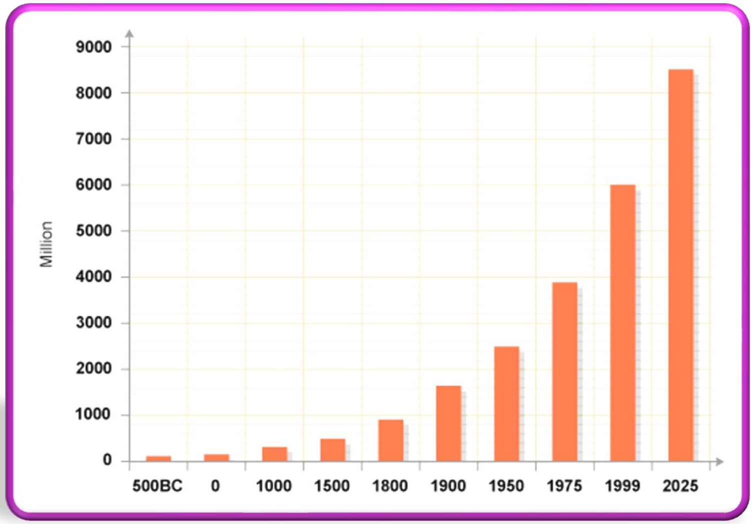
The work presented in the use case is based on work carried out under eDWIN, that is a Polish national project under patronage of Polish Ministry of Science in the Digital Poland initiative and was supported under grant from the European Regional Development Fund and under the Horizon Europe AI4EOSC project
(Grant Agreement No 101058593) that is funded by the European Commission in the call of HORIZON-INFRA-2021-EOSC-01

Sensors for Sustainable AgriFood & the Environment

Dr. Alan O'Riordan
Senior Research Fellow
PI, VistaMilk SFI Centre

Why AgriFoods? Societal Impact

Motivation: Food Production +70% by 2050



SUSTAINABLE DEVELOPMENT GOALS

The Nitrates Directive

Water Framework Directive

The way towards healthy waters

Climate Change

Competition for land

Loss of Biodiversity

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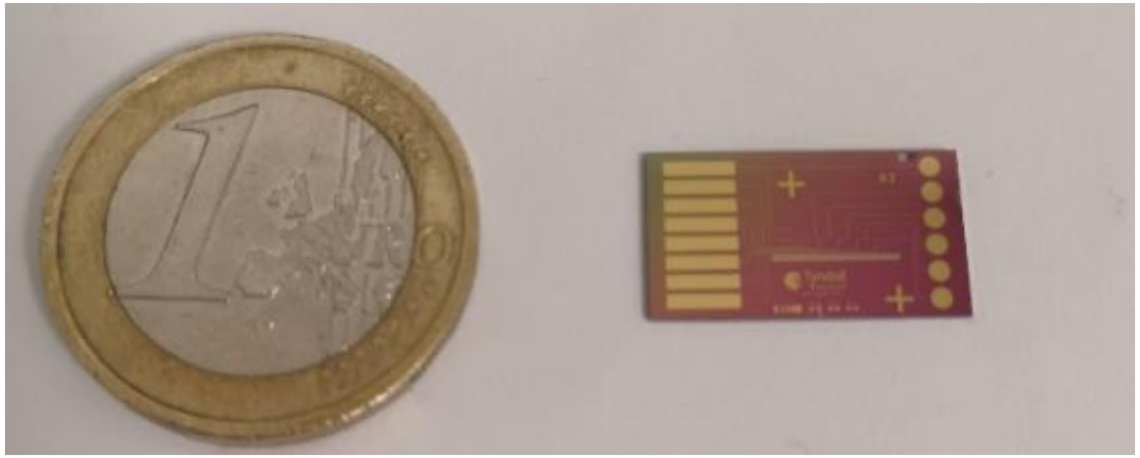
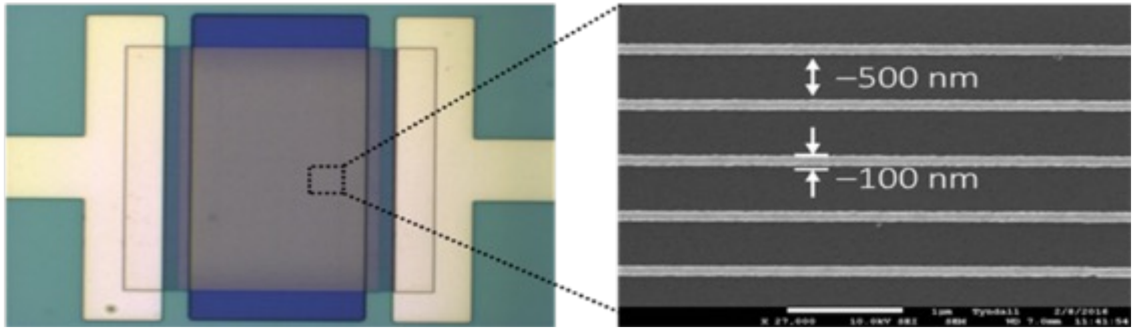
Electrochemical Nanosensor - Advantages



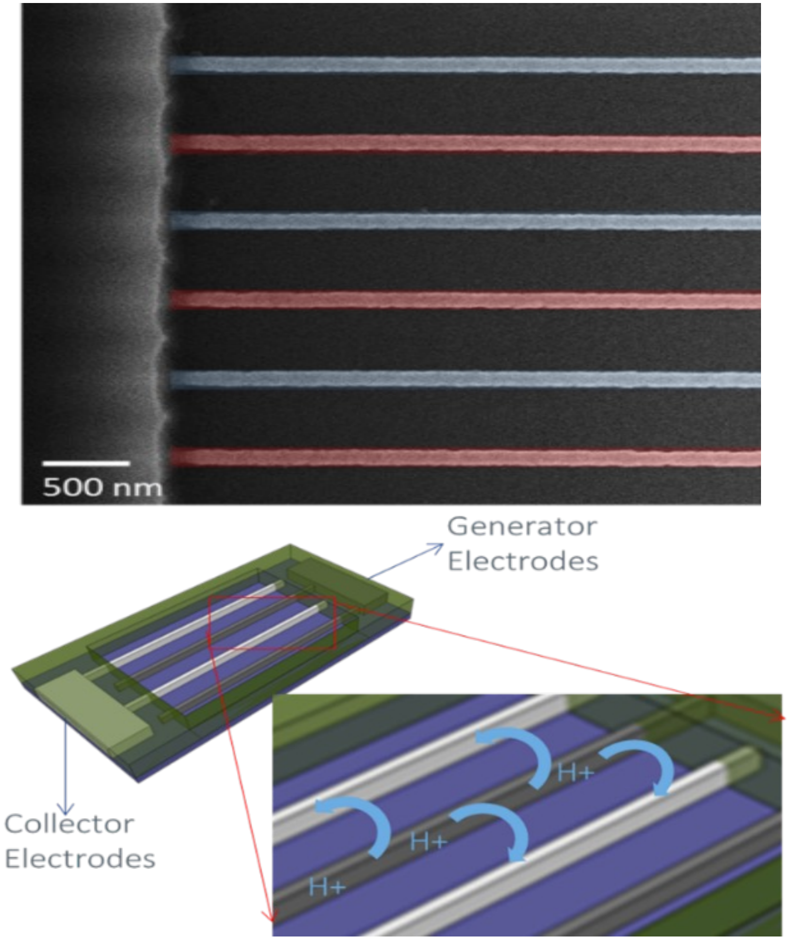


- ✓ On a similar size scale to analyte molecules of interest
- ✓ Demonstrate enhanced sensitivity arising from enhanced analyte mass transport
- ✓ Significantly reduced signal noise (background noise)
- ✓ Can be fabricated at high density (nm separation)
- ✓ Multiplexed detection
- ✓ Enable direct electrical signal readout
- ✓ Very low analyte concentrations
- ✓ Rapid Sensing

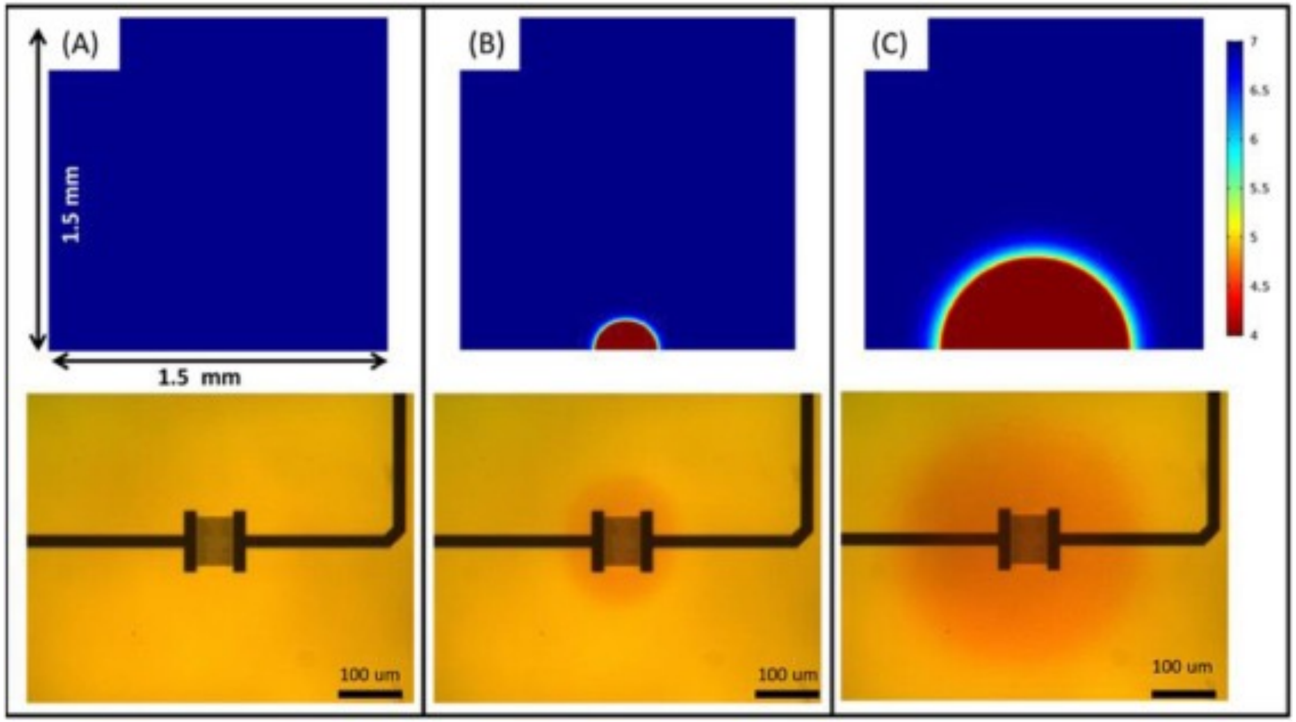
Key Challenges

- Reference electrode drift
- Specificity requires modification
- Need to add chemical reagents

Nanoelectrodes – No reagent addition



Simulation of proton diffusion of protons from protonator electrode:
t=0 s t= 1s t=10 s



Visualisation of pH change using crystal violet pH indicator dye.

Oxidation: $2\ H_2O(l) \rightarrow O_2\ (g) + 4\ H^+(aq) + 4e^-$

Reduction: $2\ H^+(aq) + 2e^- \rightarrow H_2\ (g)$

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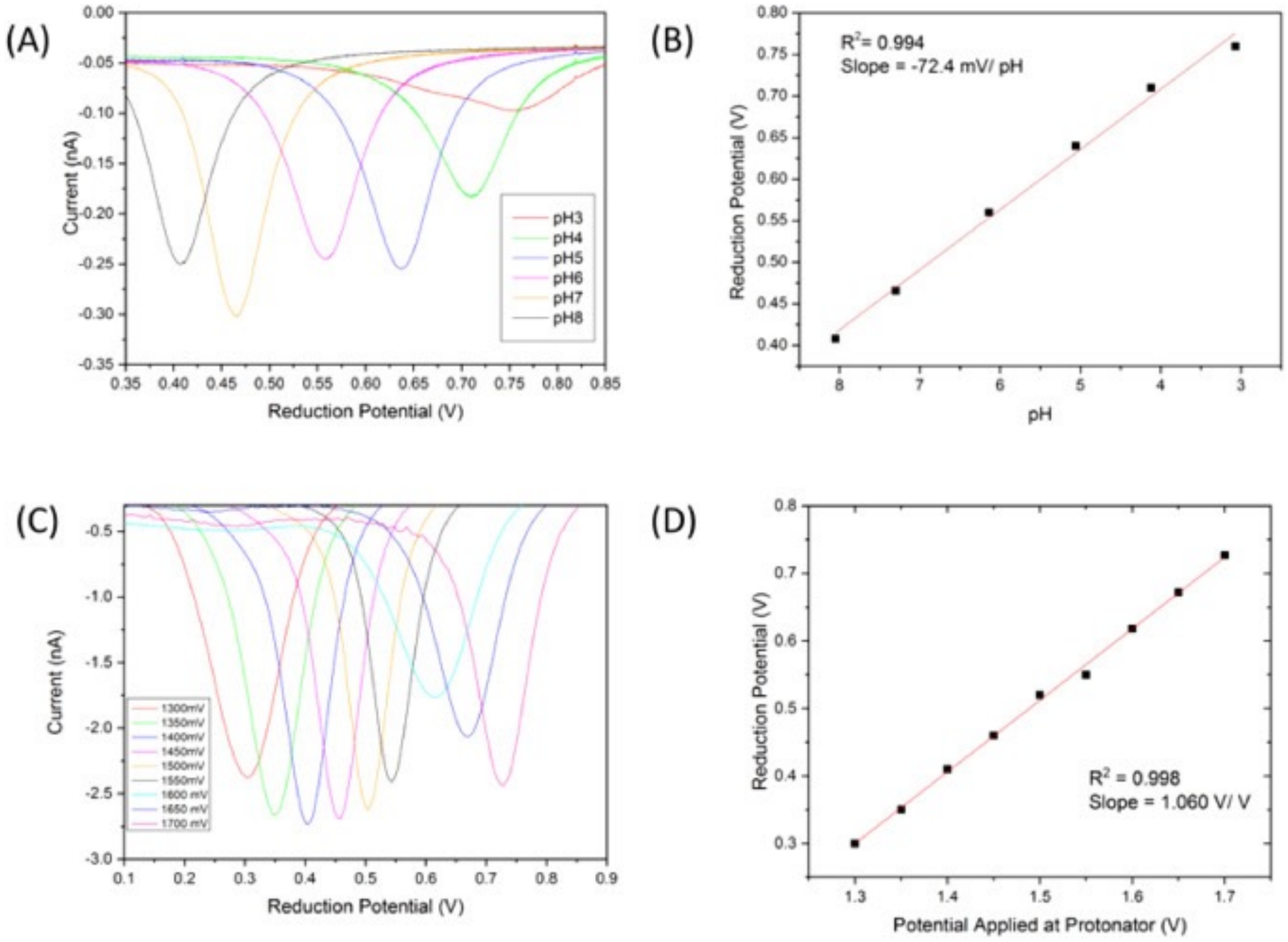
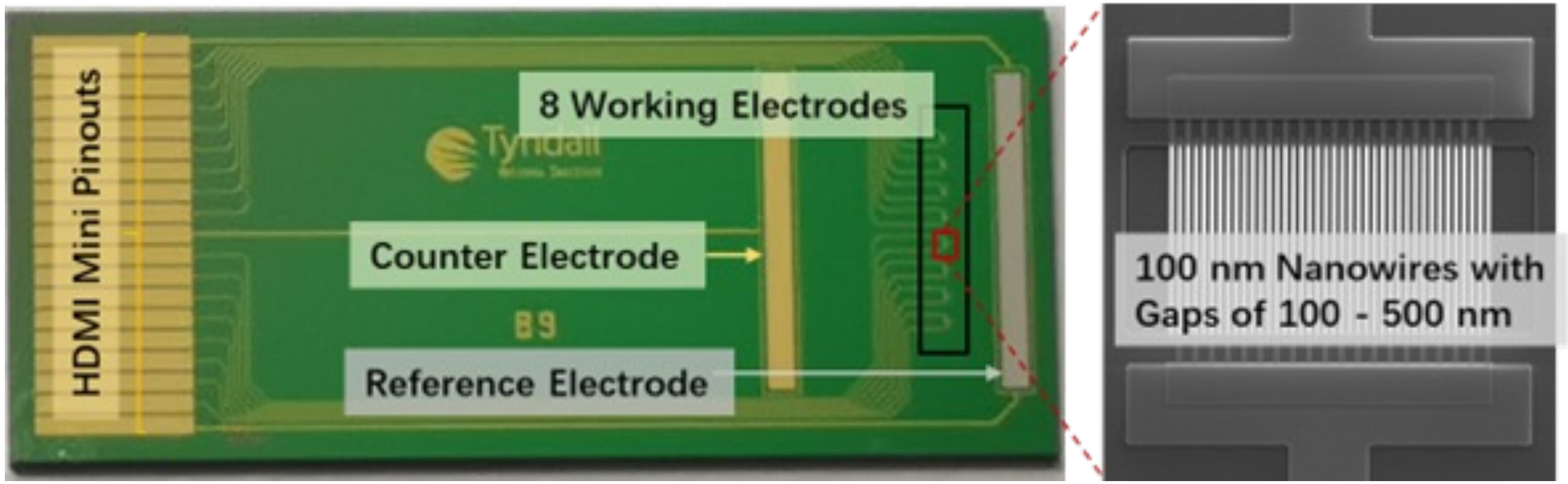
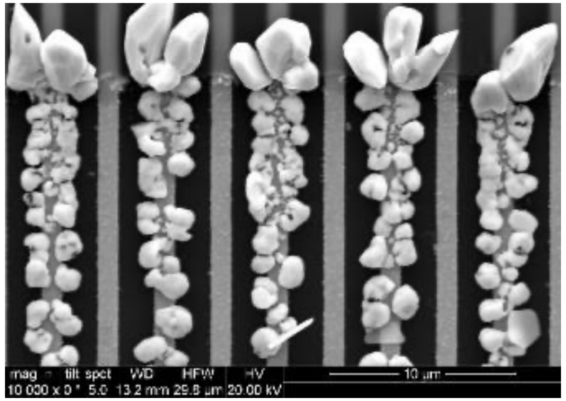
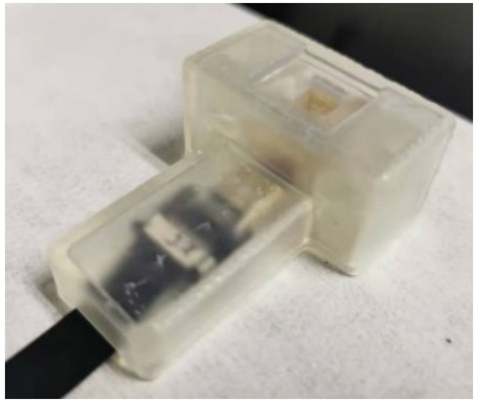
Electrochemical In-situ pH control

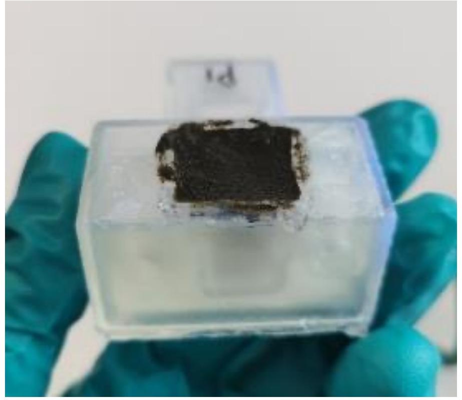


Nitrate detection: Materials Development (Selectivity)

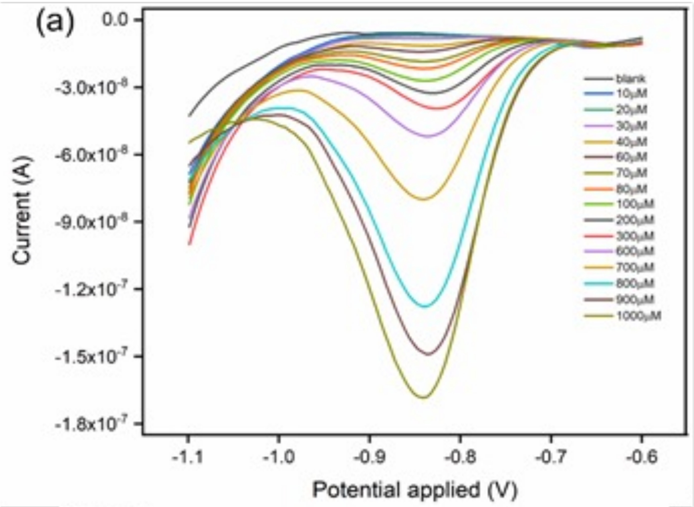


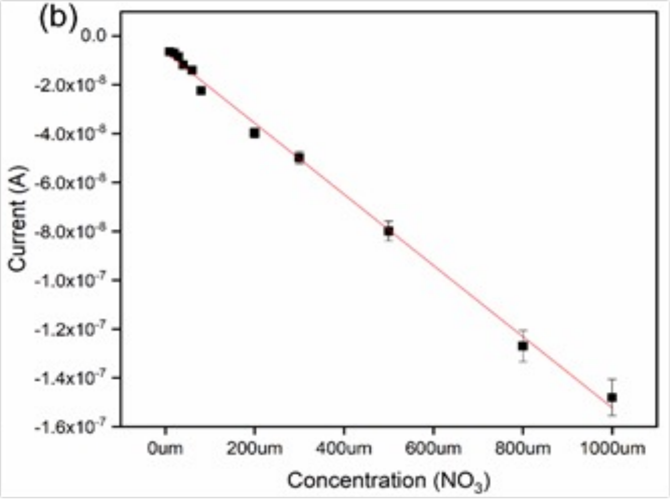


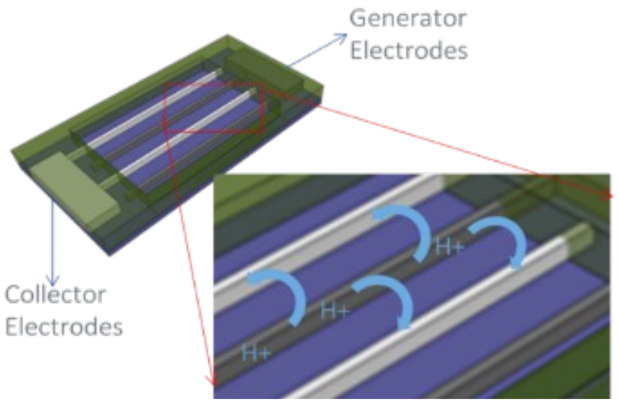


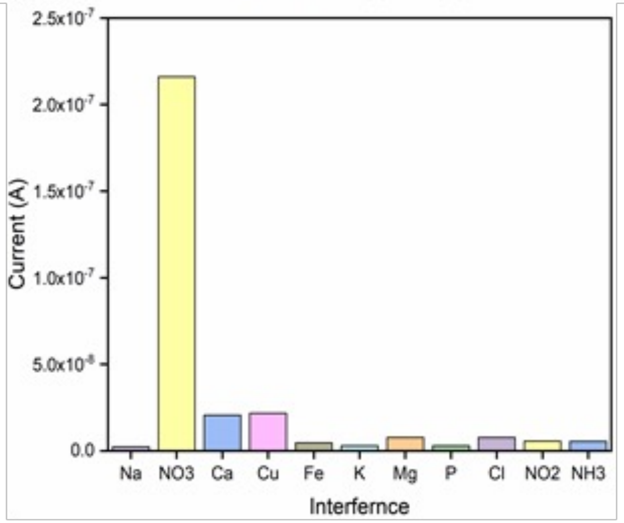


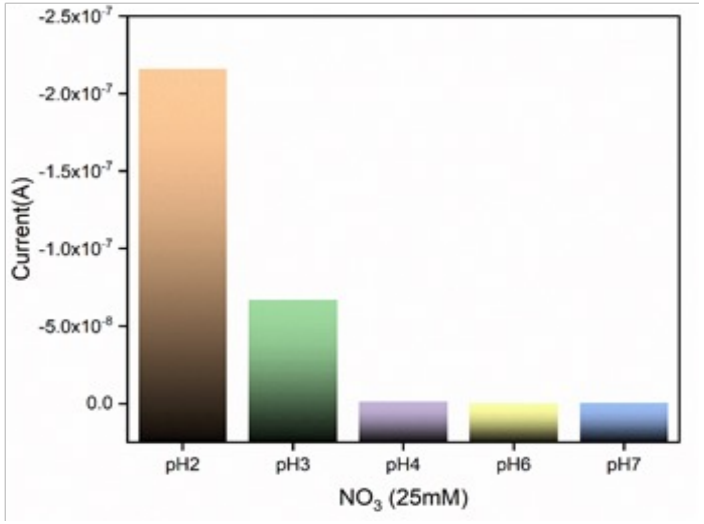
Nitrate: Real-Time, On-Farm

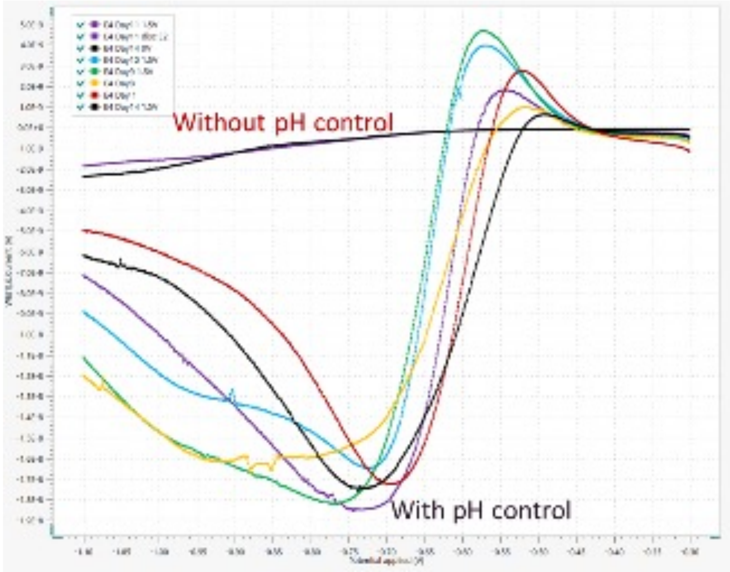






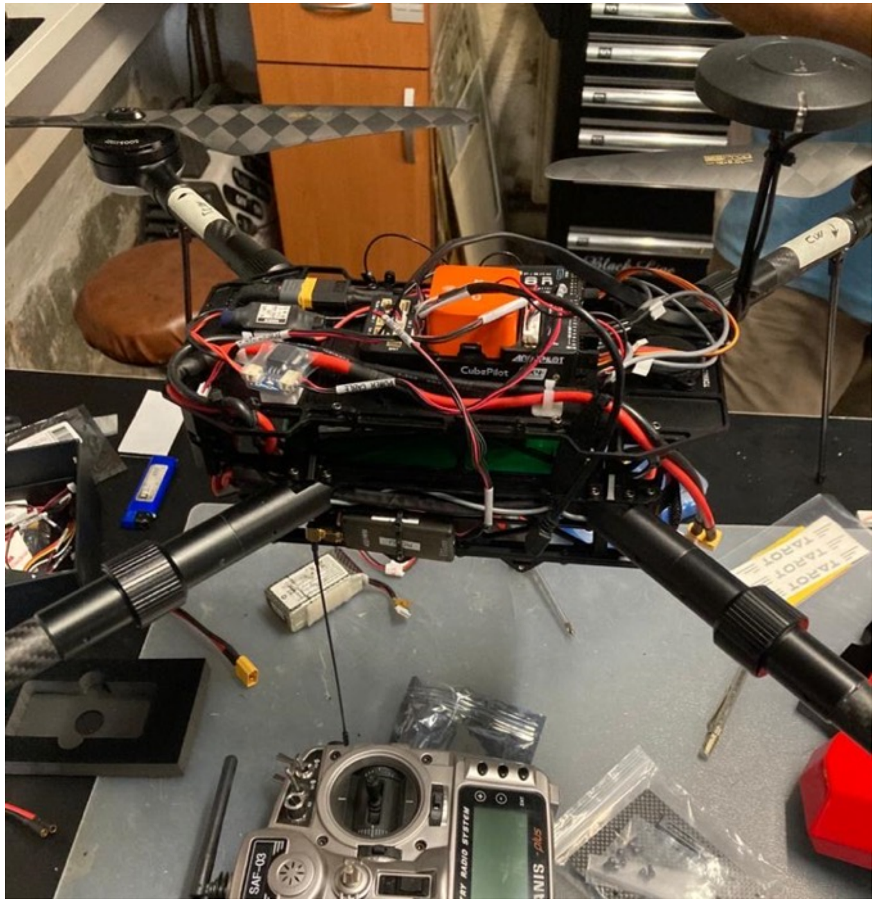






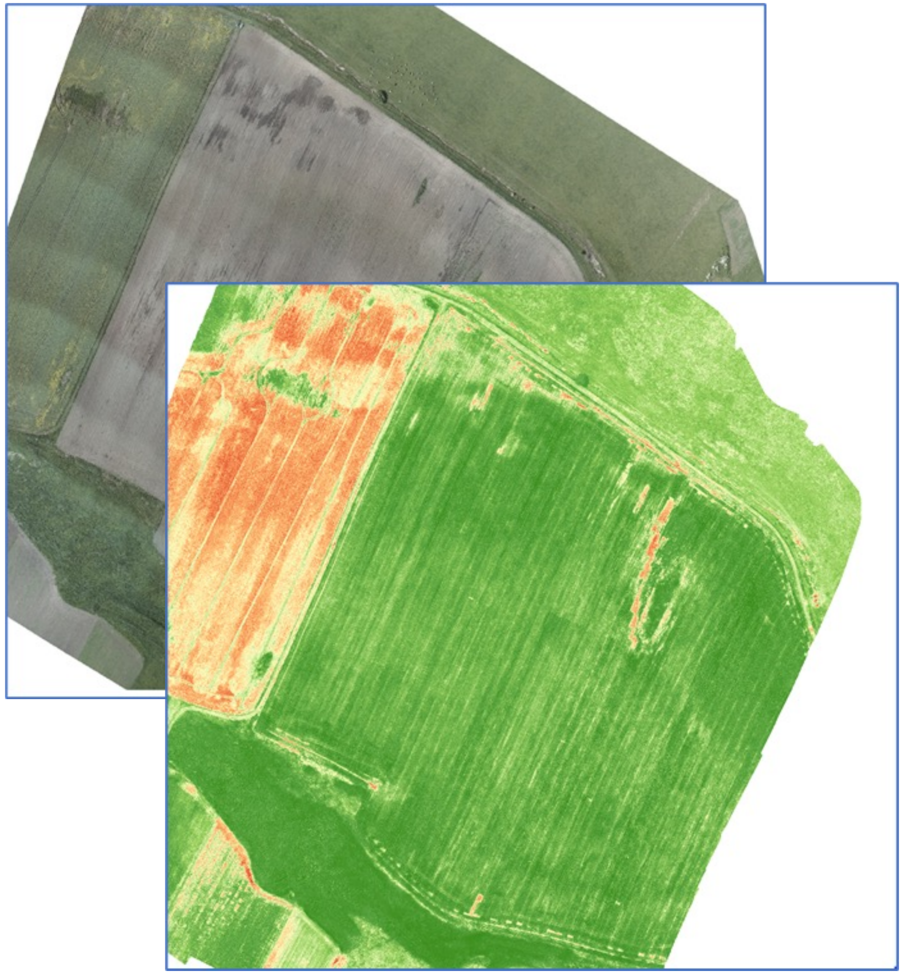
Local pH control

Preparation of field deployment



- **Gather historical map data**
- Validate flight infrastructure by :
    - Performing flight tests with custom made quadcopter
    - Integrate several cameras (ortho-photo, thermal and spectral – Micasense RedEdge MX) for best results

Preparation of field deployment



- **Validate collection and post process spectral data by:**

  - Using different flight scenarios
  - Output data collected in a single format using software such as Pix4D and OpenDroneMap
  - Post process spectral image (Tiff format) using QGis software for generating various spectral index maps (ENDVI, LAI, NDRE, NDVI)
  - Compare output with SANTINEL satellite gather data

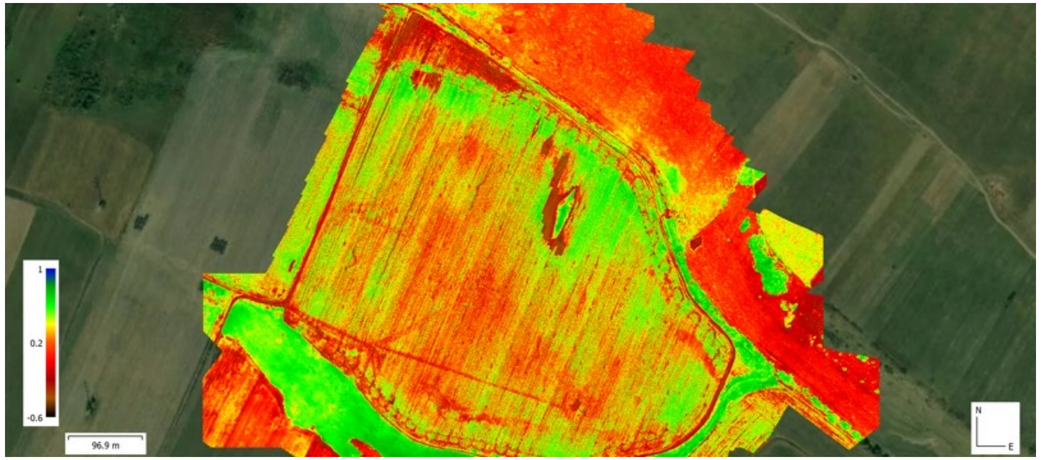
Sensor data validation and interpretation

Validation infrastructure setup

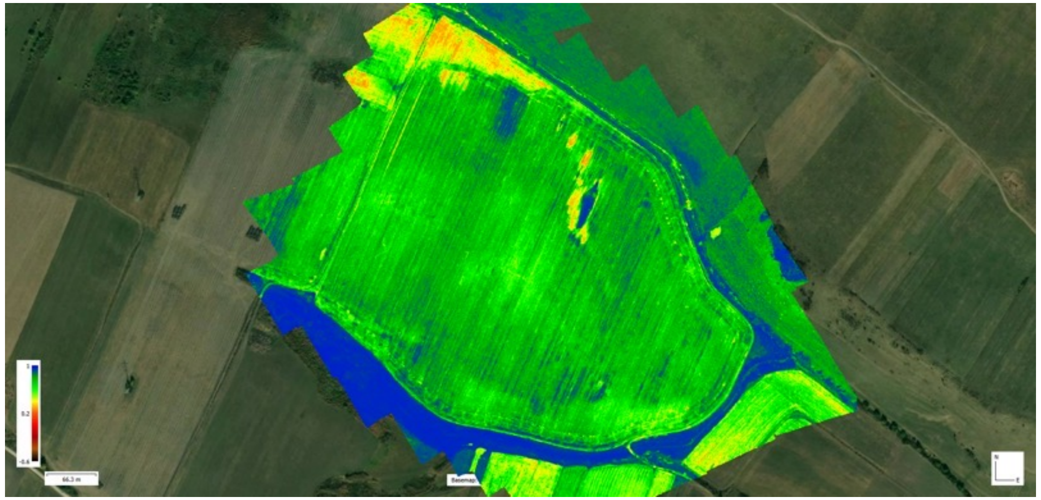
- Continues spectral data collection from both satellite sources and drone mounted RedEdge Mx spectral camera

Data	Activitate/Fenofaza	Flight altitude (m)	Amount of data collected (GB)	Post-processing Tool
01-May	spectral imagery and ortho	50	14.30	DroneMap, Pix4D, Agisoft
15-May	spectral imagery and ortho	75	18.20	DroneMap, Pix4D, Agisoft
19-May	spectral imagery and ortho	50	26.90	Pix4D, Agisoft
09-Jun	spectral imagery and ortho	100	8.40	Agisoft, QGIS
16-Jun	ortho	100	2.82	Agisoft, QGIS
18-Jun	spectral imagery and ortho	100	11.10	Agisoft, QGIS
23-Jun	spectral imagery and ortho	100	10.50	Agisoft, QGIS
29-Jun	spectral imagery and ortho	100	10.00	Agisoft, QGIS
15-Jul	spectral imagery and ortho	100	11.60	Agisoft, QGIS
28-Jul	spectral imagery and ortho	100	7.70	Agisoft, QGIS
02-Aug	spectral imagery and ortho	100	8.06	Agisoft, QGIS
05-Aug	spectral imagery and ortho	100	15.60	Agisoft, QGIS
13-Aug	spectral imagery and ortho	100	8.56	Agisoft, QGIS
21-Aug	spectral imagery and ortho	100	8.18	Agisoft, QGIS
31-Aug	spectral imagery and ortho	100	8.30	Agisoft, QGIS
01-Oct	spectral imagery and ortho	100	8.06	Agisoft, QGIS
24-Oct	spectral imagery and ortho	100	8.23	Agisoft, QGIS

Table 1: Spectral imagery collection history

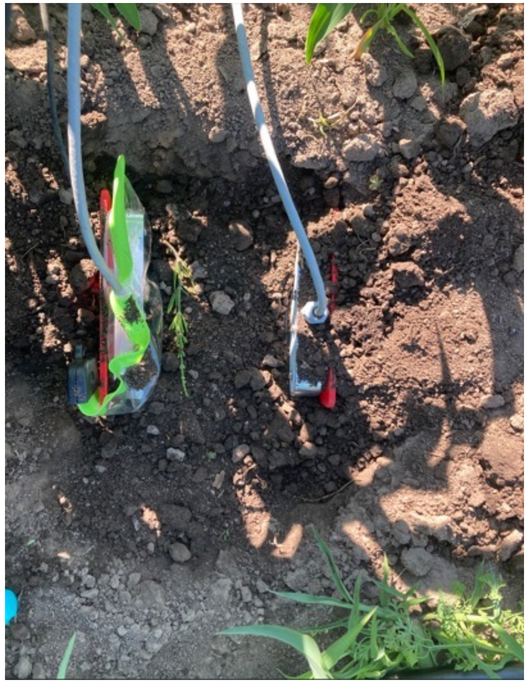


ENDVI spectral output 19.05.2022



NDVI spectral output 21.06.2022

Sensor in field installation and maintenance



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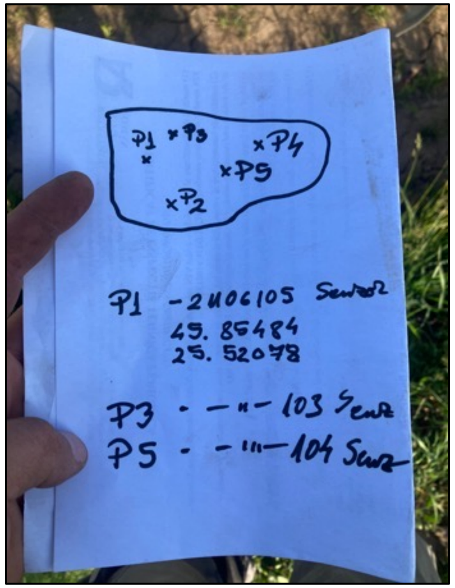
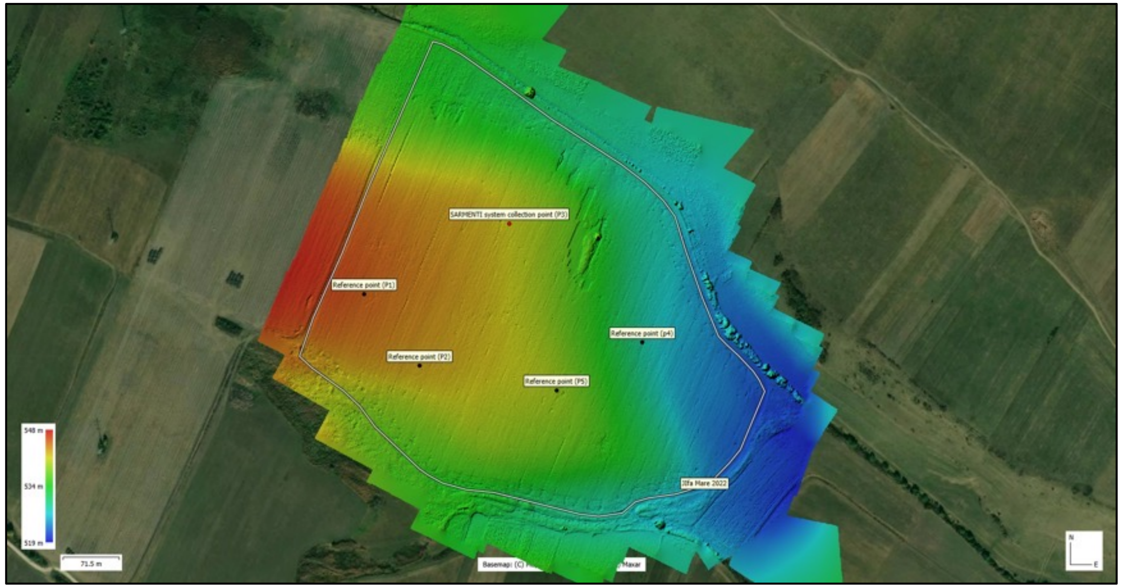
Reference soil sample collection

Aprox. every 10 days during crop life cycle, soil sample collection was performed from 5 different points of the field and classic lab analysis were performed

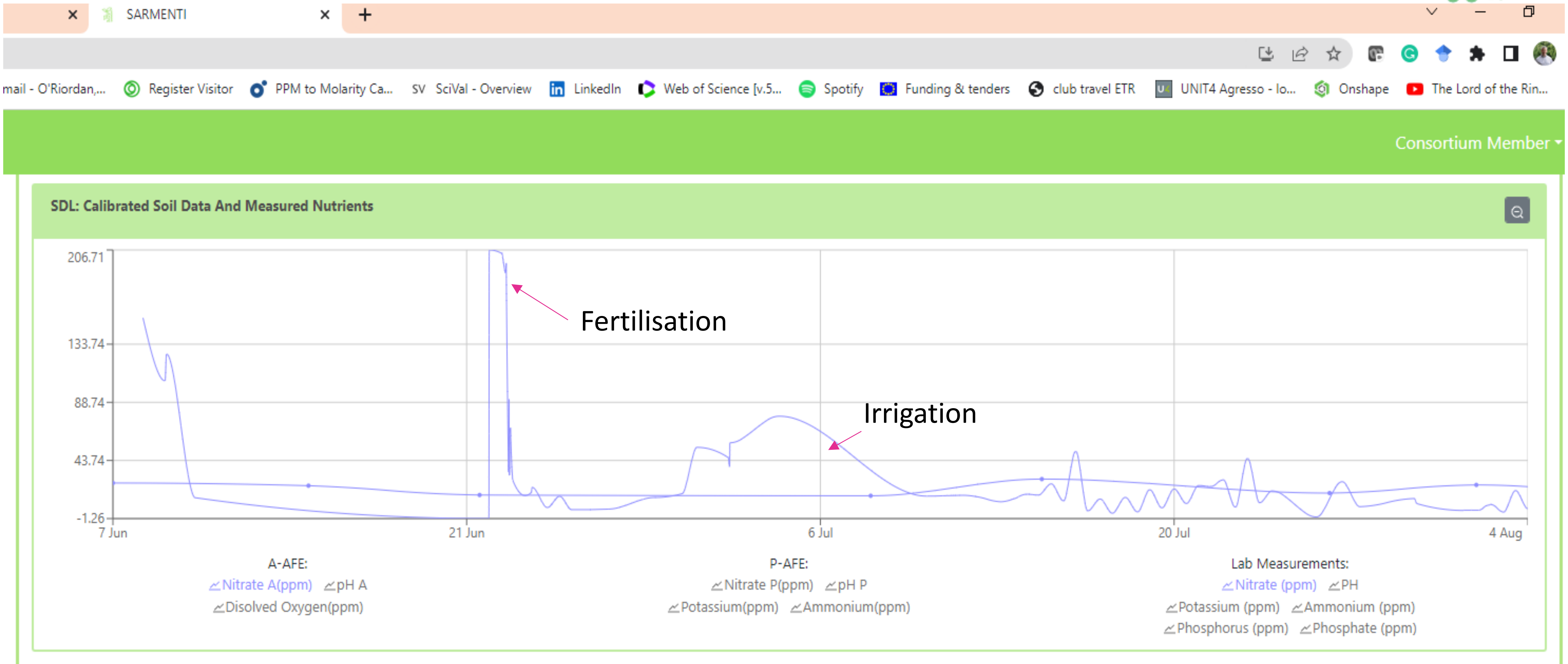
- Results were inserted into Sarmenti Webpage, together with corn life cycle stages





In field reference points distribution

Back end server

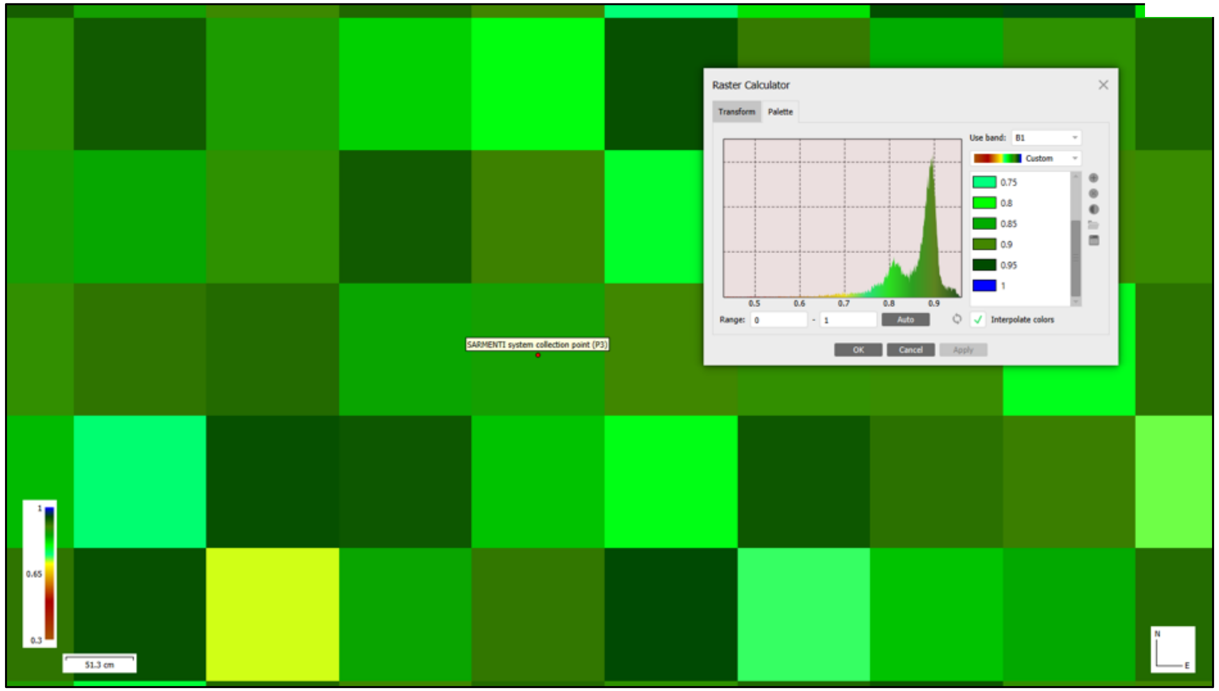


Sensor Fusion

Validation infrastructure setup

- In vegetation fertilization decision based on nitrogen sensor readings and soil samples collection with urea prill on 22.06.2022, using variable spread rate

NDVI index map (1sqm/pixel resolution) (21.06.2022)



Detail of NDVI index value (0.887), corresponding to location where SARMENTI system was installed, collected on 21.06.2022 with Micasense RedEdge Mx spectral camera

Sensor informed fertilisation strategy

Operationalize of Vicon RO-M Geospread 2008 fertilization machine GPS driven (20.05.2022), for applying in season granulate fertilizers such as urea with variable spread rate.

Urea spreading in-season with John Deere 6800 tractor and Vicon Geospread RO-M fertilizer machine driven and controlled with Trimble CFX GPS system

Achievements

Sarmenti system and its web application:

- All data produced by the Sarmenti project
- Can support the farmer with data presentation and decision making
- Allows viewing real-time evolution of field conditions
- Enables farmers to correlate weather events with nutrients evolution and plant response

From Spiro point of view:

- Agronomical practice is improved by using Sarmenti built tools
- Economical efficiency has improved (500 kg of less urea over 21 Ha)
- Environmental hazards (Nitrate losses) are reduced

System was functional up until 23rd of January 2023 (6+ months), including a few very harsh winter days ☺

Questions from the Audience

Moderated by:
Luis Perez-Freire, AIOTI WG Agriculture Chair (Gradiant)

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Wrap up and end of the Workshop

Luis Perez-Freire, AIOTI WG Agriculture Chair (Gradiant)

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Thank you for listening

Any questions?

You can find us at @AIOTI_EU or email sg@aioti.eu

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