Smart farming technologies in service of modernizing agriculture

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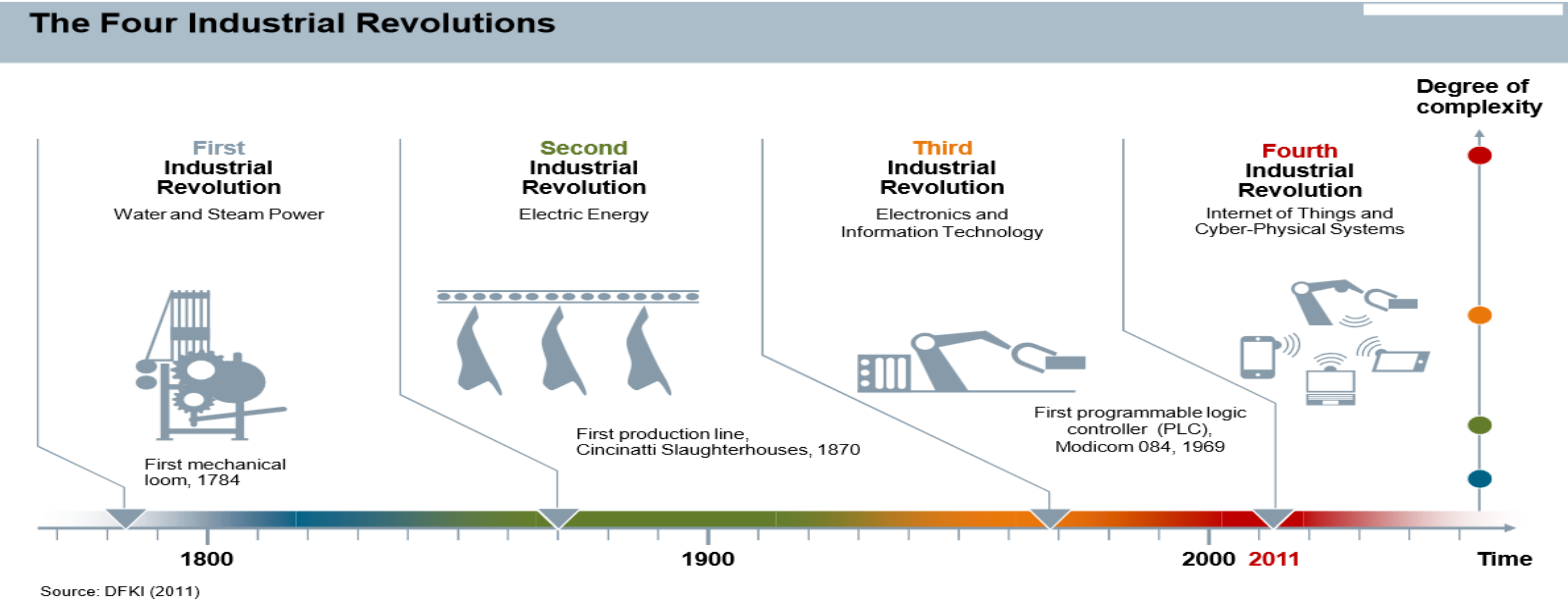
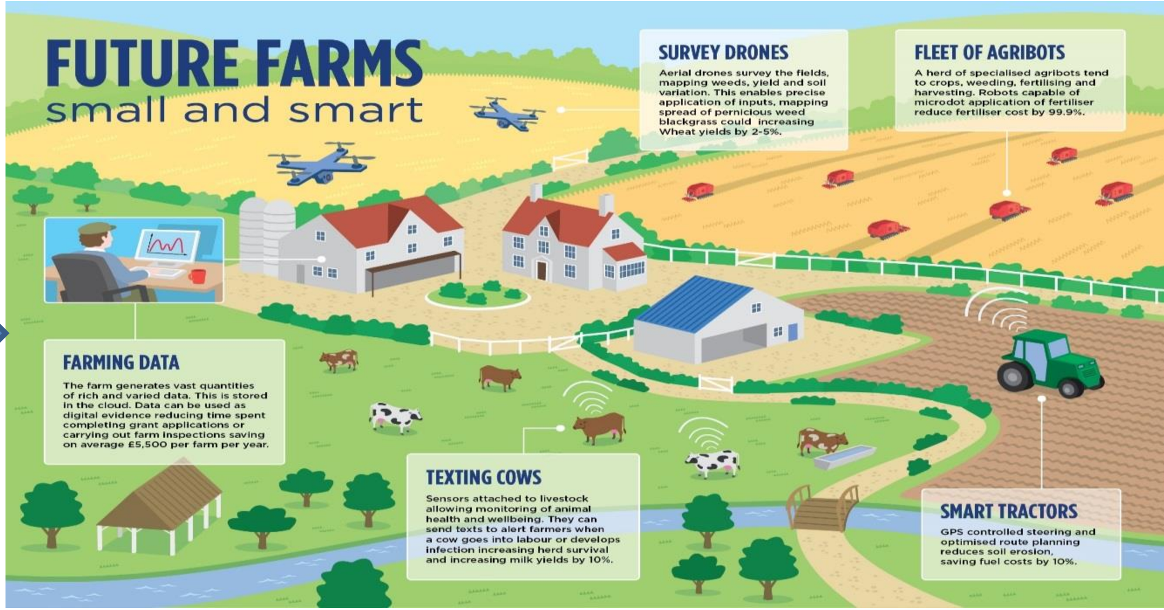
iBO Structure and Scientific Approach

4th Industrial Revolution



4th Industrial Revolution and Agriculture

AGRICULTURE 4.0



HOW:

Future agriculture will integrate all existing smart farming

...gies into an integrated syste...

... **making and actuating** wit...

intervention

... **platforms** equipped with

...crop, environmental, soil

...systems will be used to

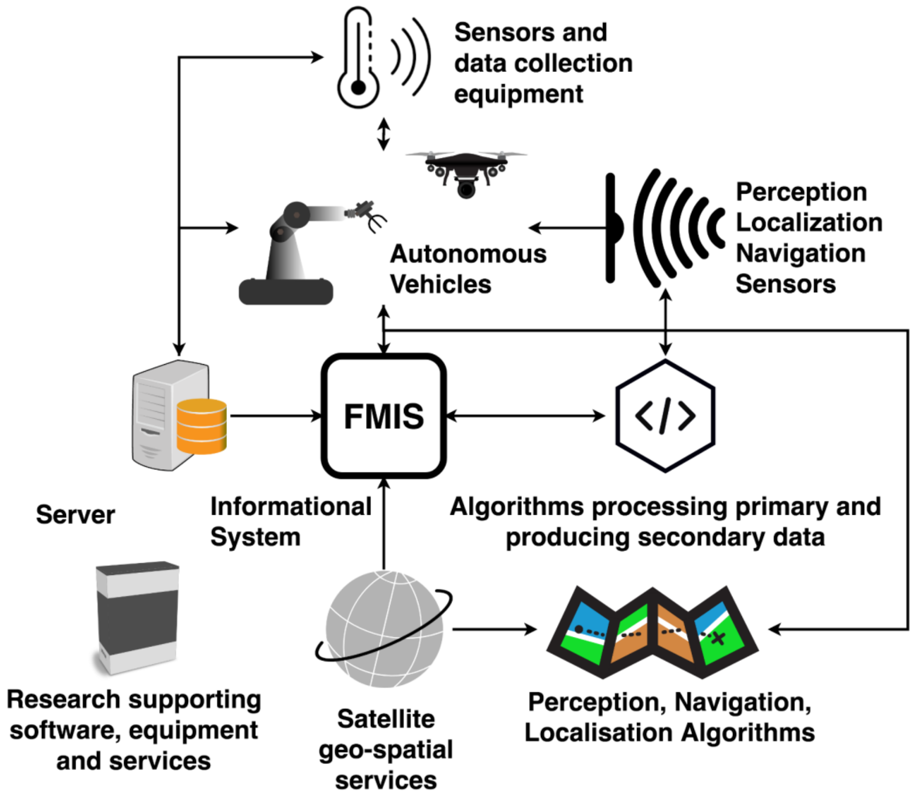
...al practices.

TARGET: novel integrated

system for producing agri...

(environmental and econo...

The Proposed Future Farming Concept



Co-creation of new technologies in agriculture

❑ Subject (what)

Analysis and refinement of technical, agronomic and physiological requirements as prerequisites for the effective development and implementation of the proposed system

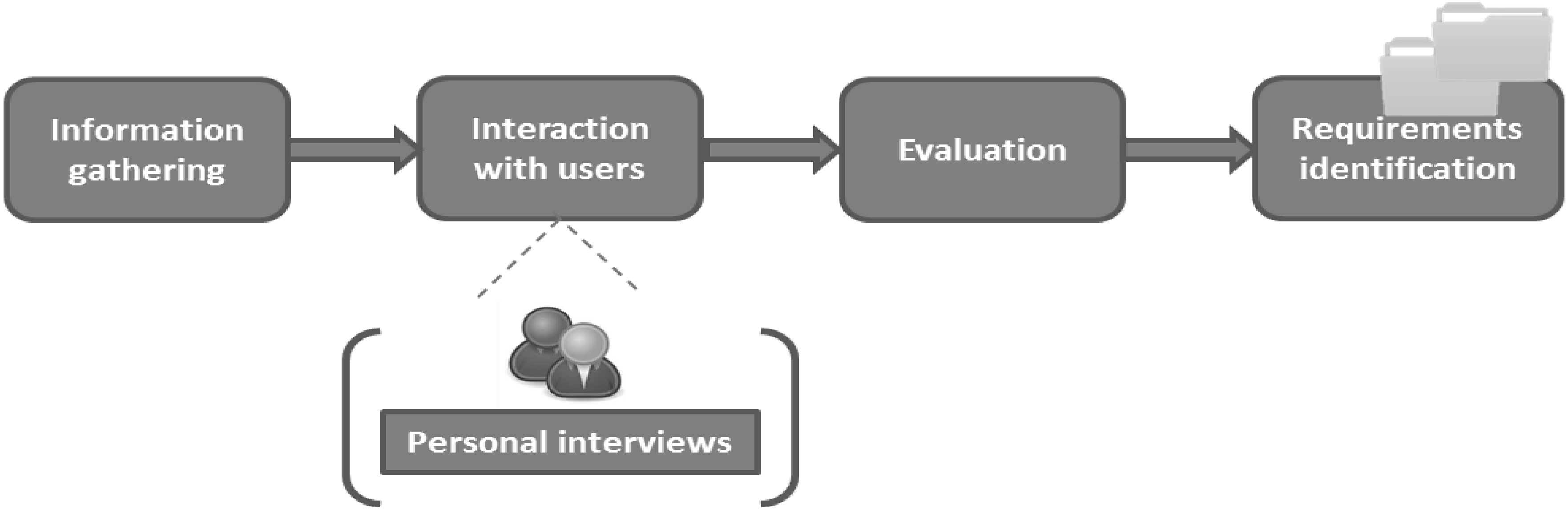
❑ Purpose (why)

- ✓ Creating a system built around the user.
- ✓ Development of applied research.

❑ Method (how)

- ✓ Set user requirements
- ✓ Definition of agronomic, physiological and technological requirements
- ✓ Key Performance Indicators (KPIs) of the system (economic-environmental)
- ✓ System architecture definition

Requirements Identification



End-user requirements (1)

Data collection and management

- Real-time parameters measurement
- Farm–field tracking
- Improved general knowledge of the production process
- Effective documentation system
- Detailed work time schedule
- Search engine (fast access to information)
- Data exchange interface

End-user requirements (2)

Predictive planning and optimization

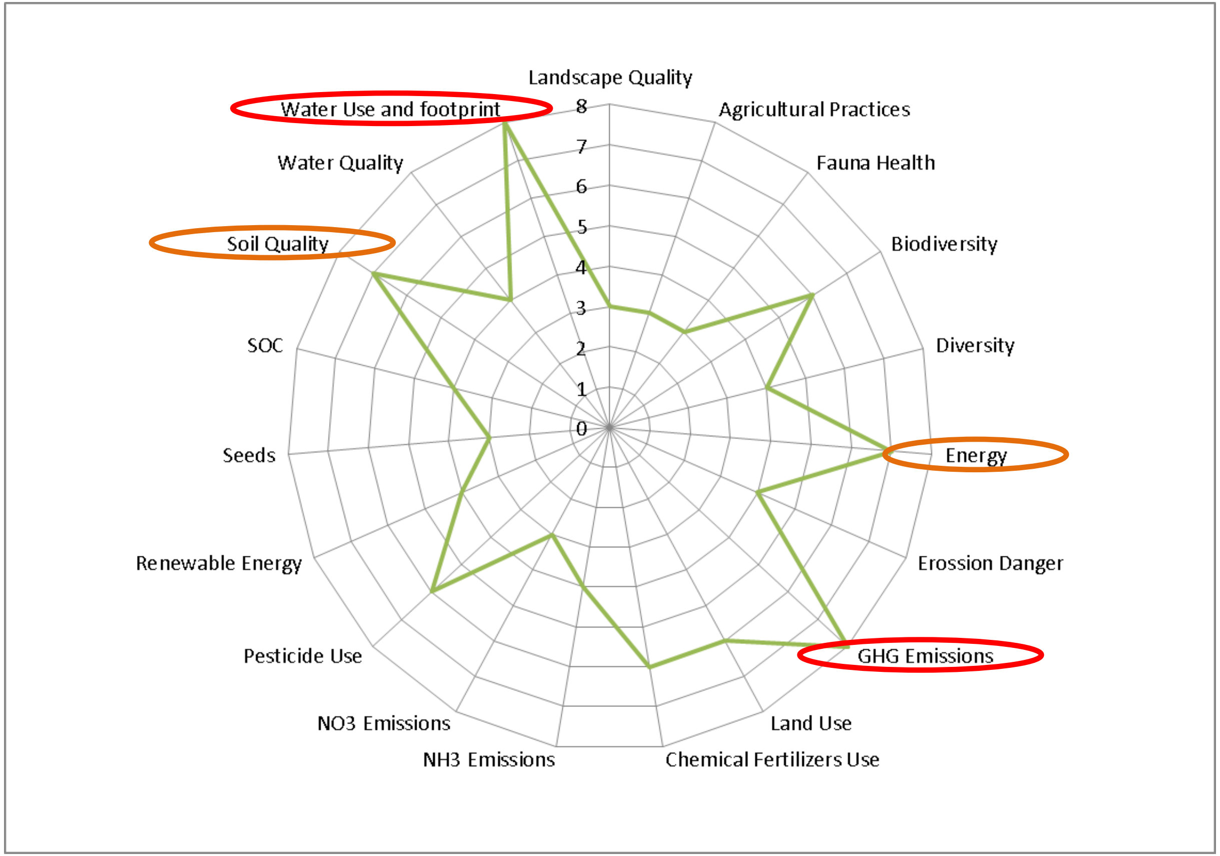
- Agricultural input minimization (fertilisers, pesticides, water, etc.)
- Series of agricultural practices management (time schedule)
- Environmental benefits (resources/input)
- Preventive system's components maintenance
- Benchmarking

End-user requirements (3)

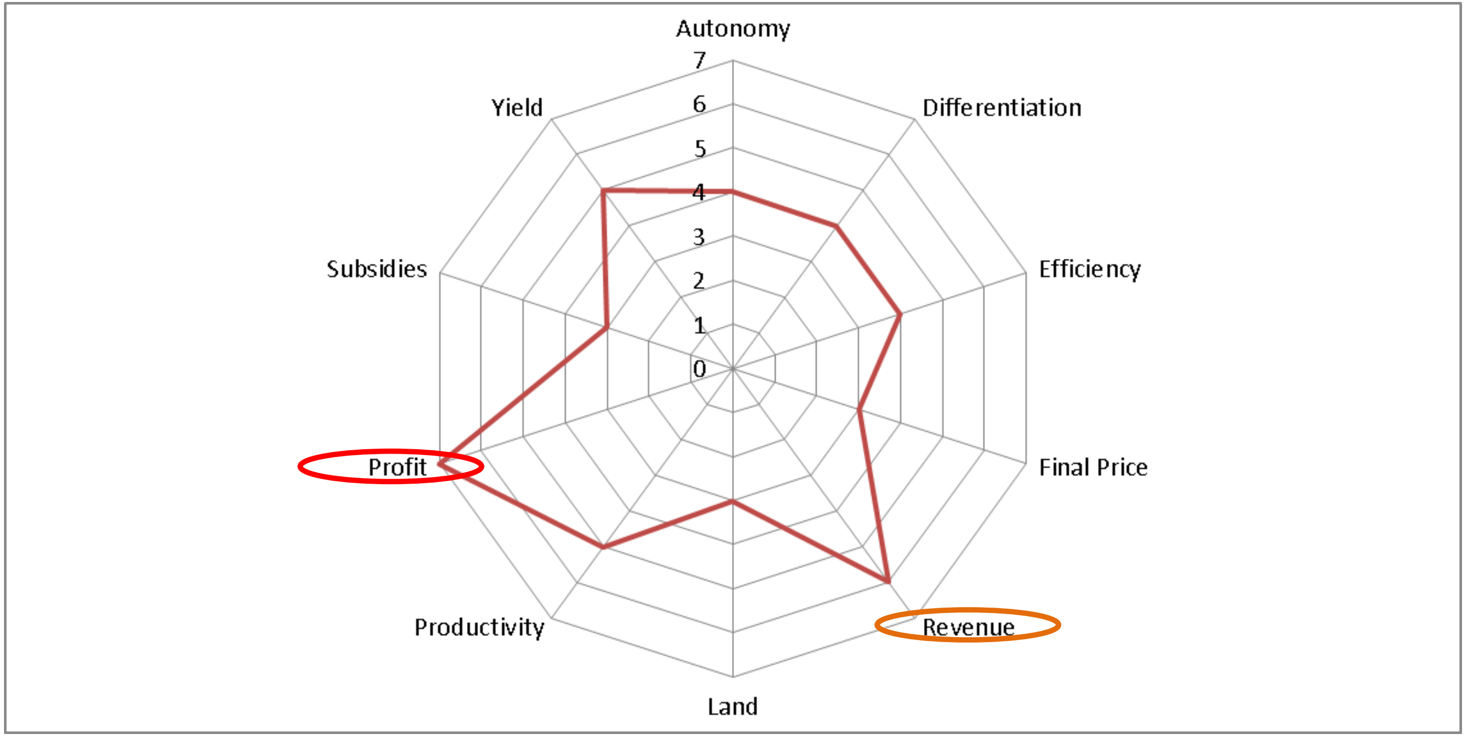
Software / Technological Infrastructure

- Dedicated **user-interface**
- Agricultural practices **planning agent**
- Weather conditions **monitoring**
- **Compatible formats** independent of existing company software solutions
- **Wireless** connection
- Sensor system for **continuous crop status** information
- **Communication** with internal/external databases

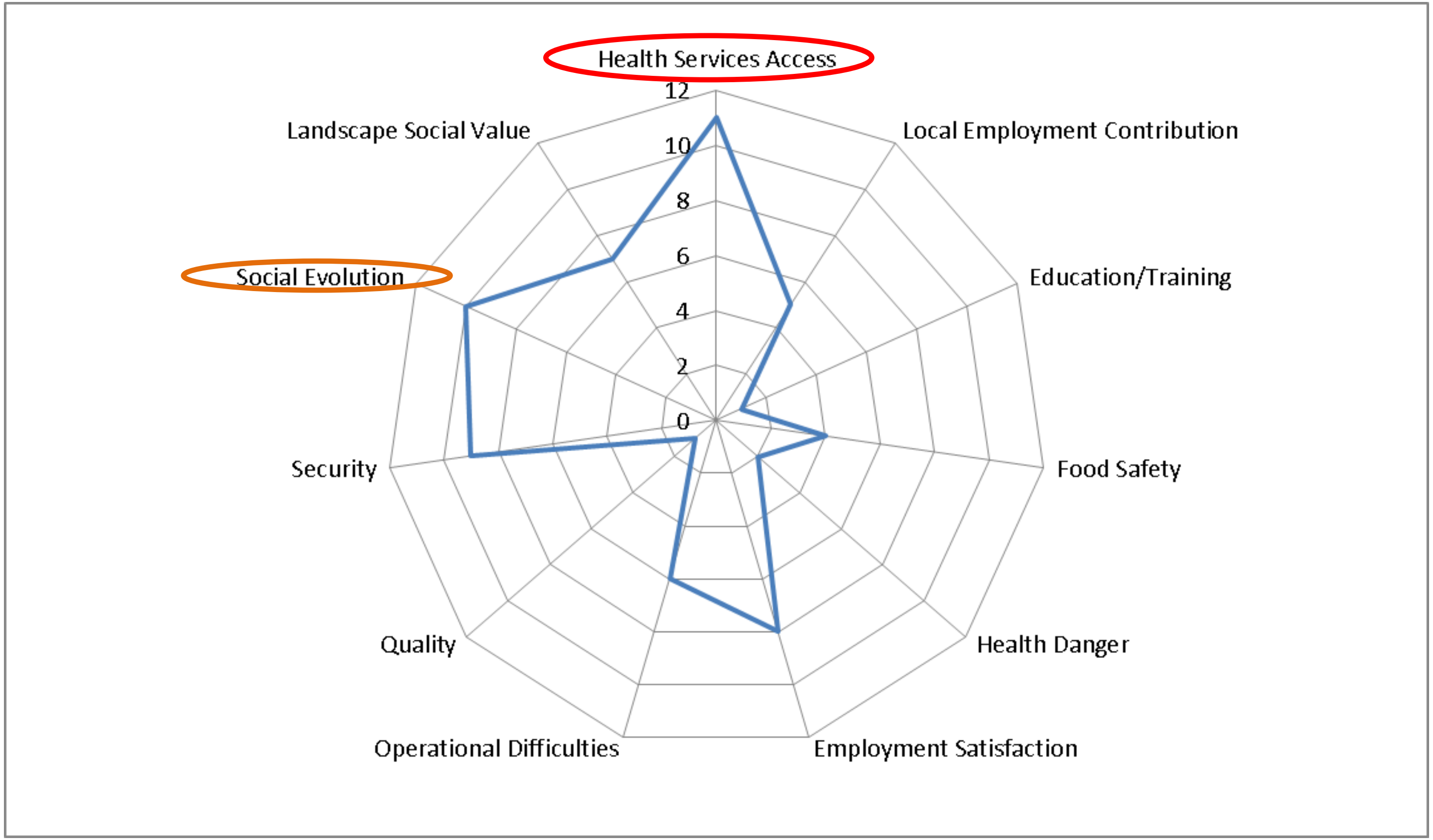
Frequency Analysis - Environmental Indicators



Frequency Analysis – Economic Indicators



Frequency Analysis – Social Indicators

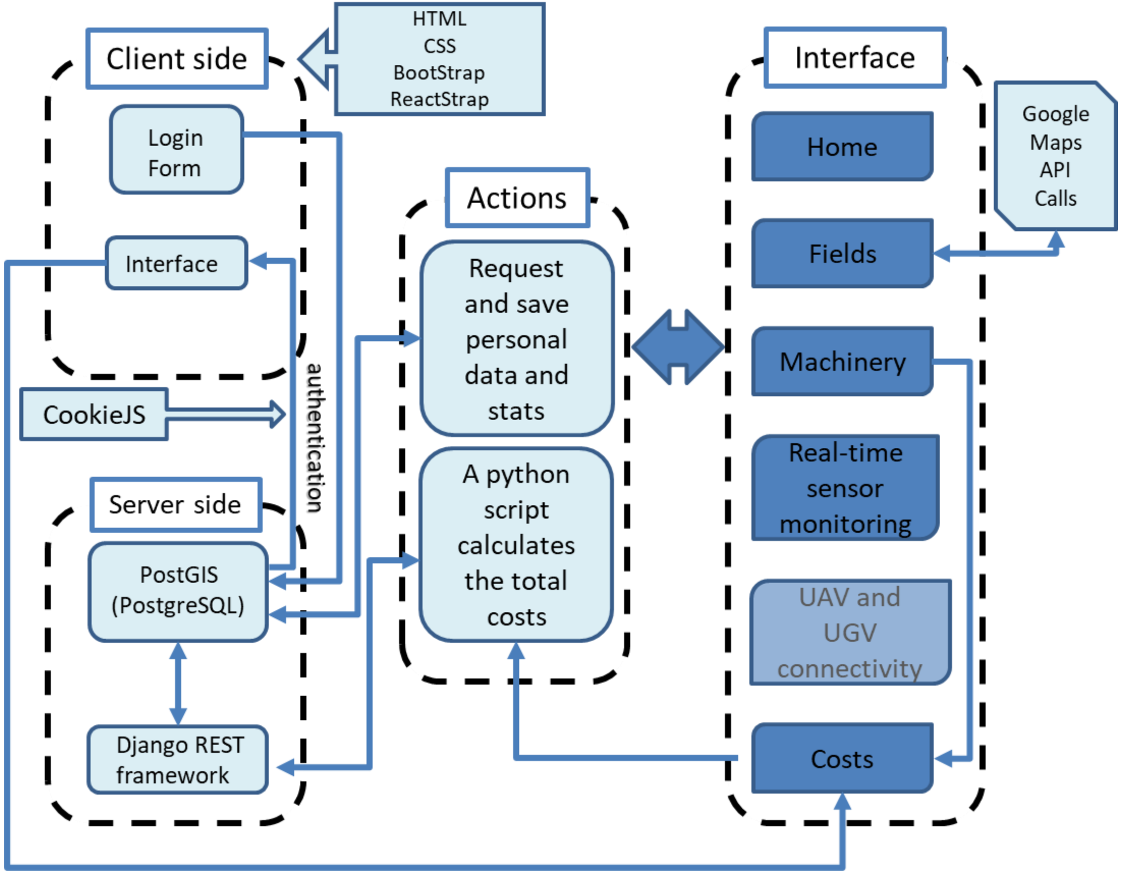


Specification of the integrated system

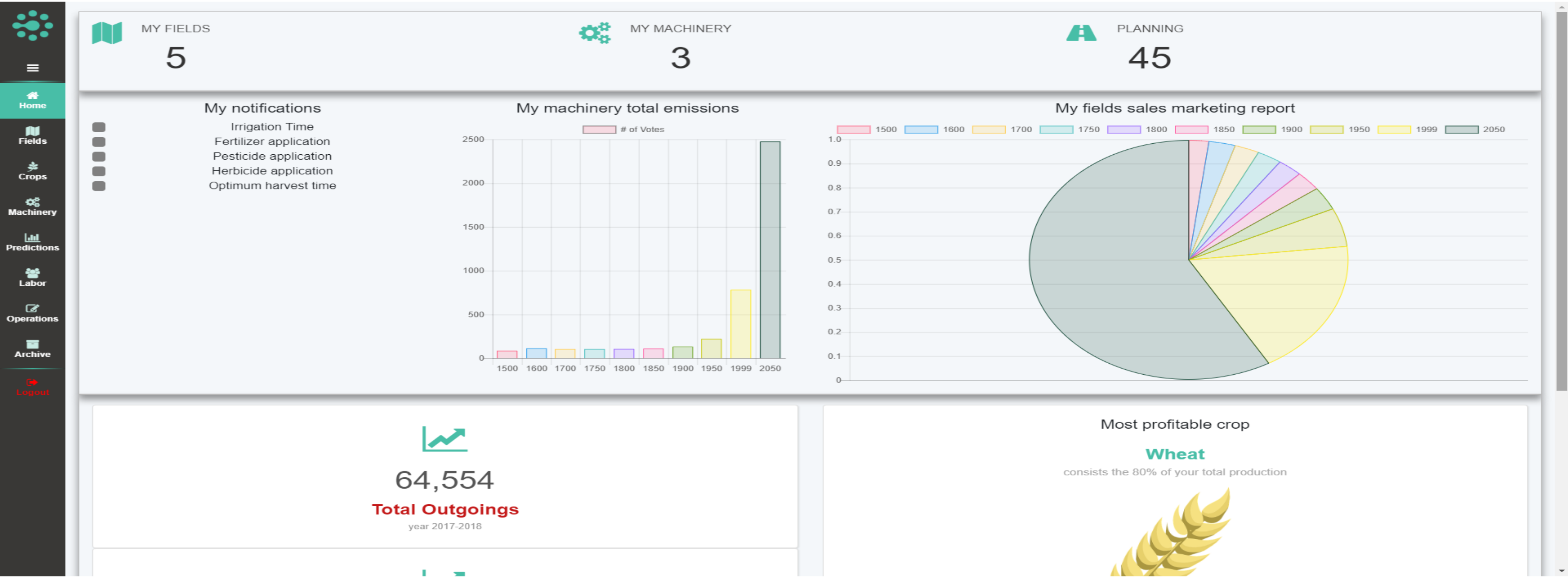
The smart farming integrated system is governed by the following principles:

- UAV utilization to **avoid time-consuming** terrestrial landscape mapping.
- Creation of information for **autonomous UGV navigation** in the field.
- Inform the user about the evolution of the processes in **real-time**.
- Identification of **dynamic obstacles.**
- Finding the **best route** in linear crops, orchards and greenhouses.
- **Interacting** with the **human factor** in the field.
- **Full feedback** between the system and the user.

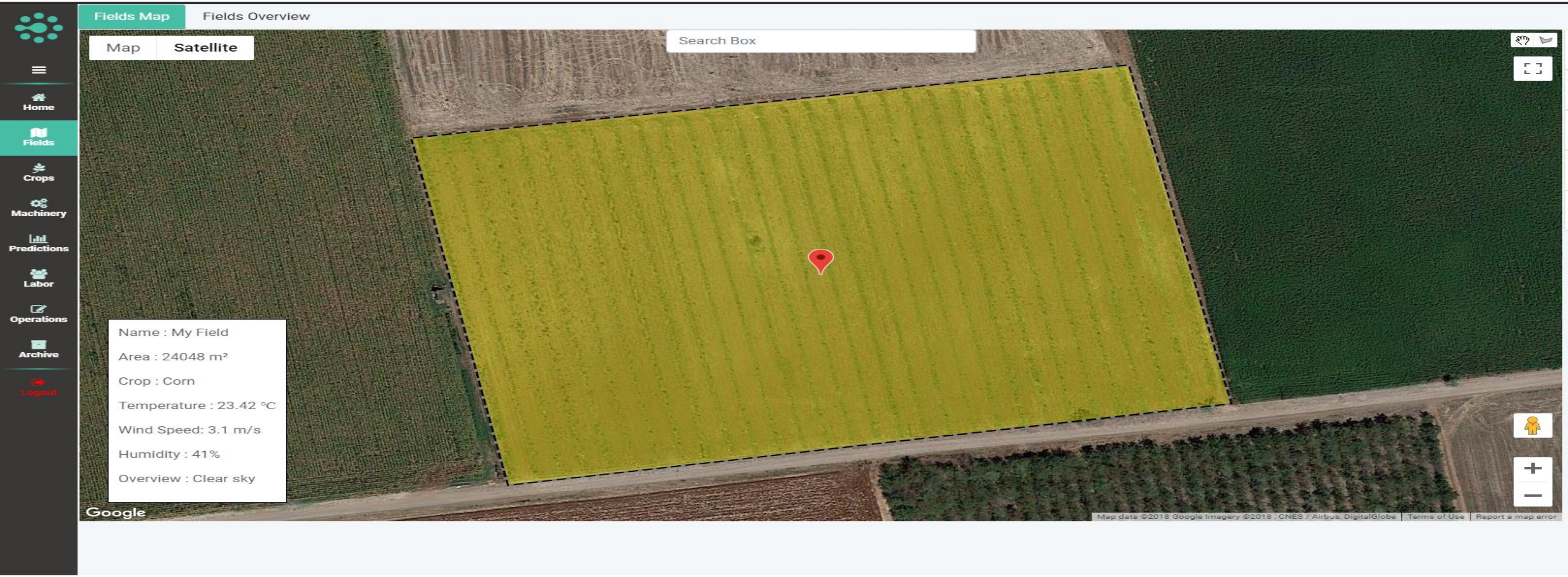
iBO Farm Management Information System Architecture



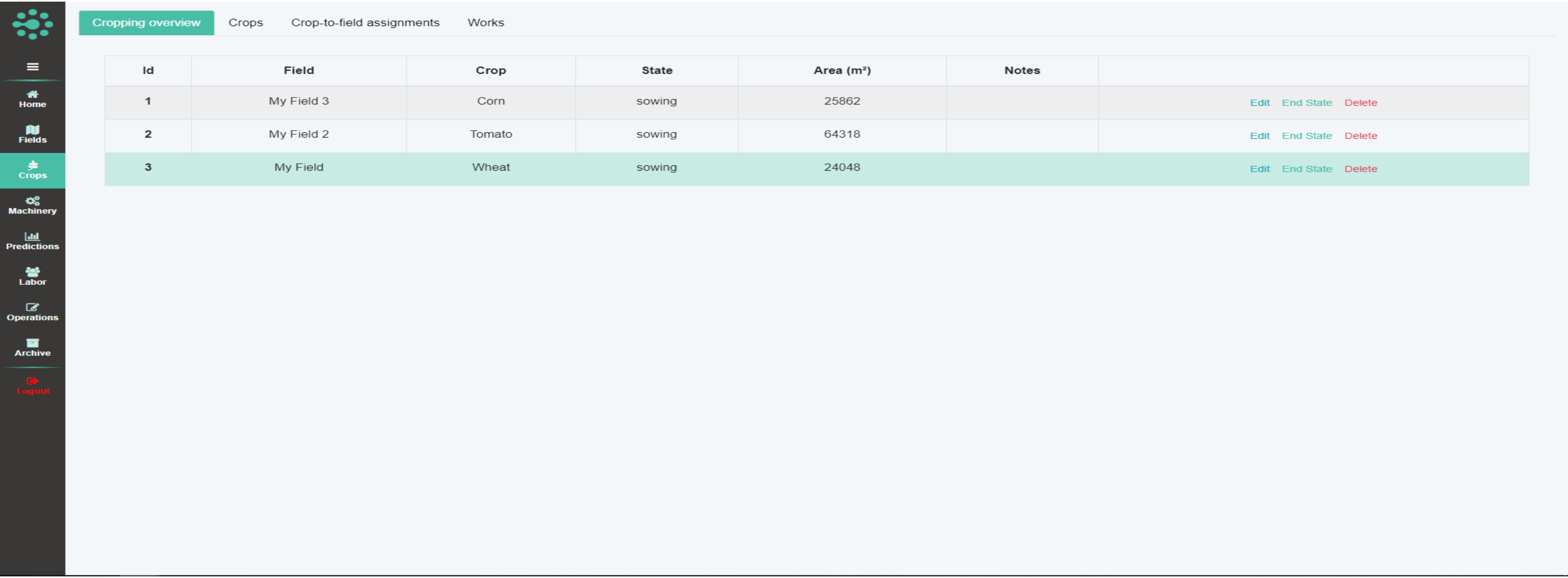
iBO Farm Management Information System | Success Story



iBO Farm Management Information System



iBO Farm Management Information System



Id	Field	Crop	State	Area (m²)	Notes	
1	My Field 3	Corn	sowing	25862		Edit End State Delete
2	My Field 2	Tomato	sowing	64318		Edit End State Delete
3	My Field	Wheat	sowing	24048		Edit End State Delete

iBO Farm Management Information System

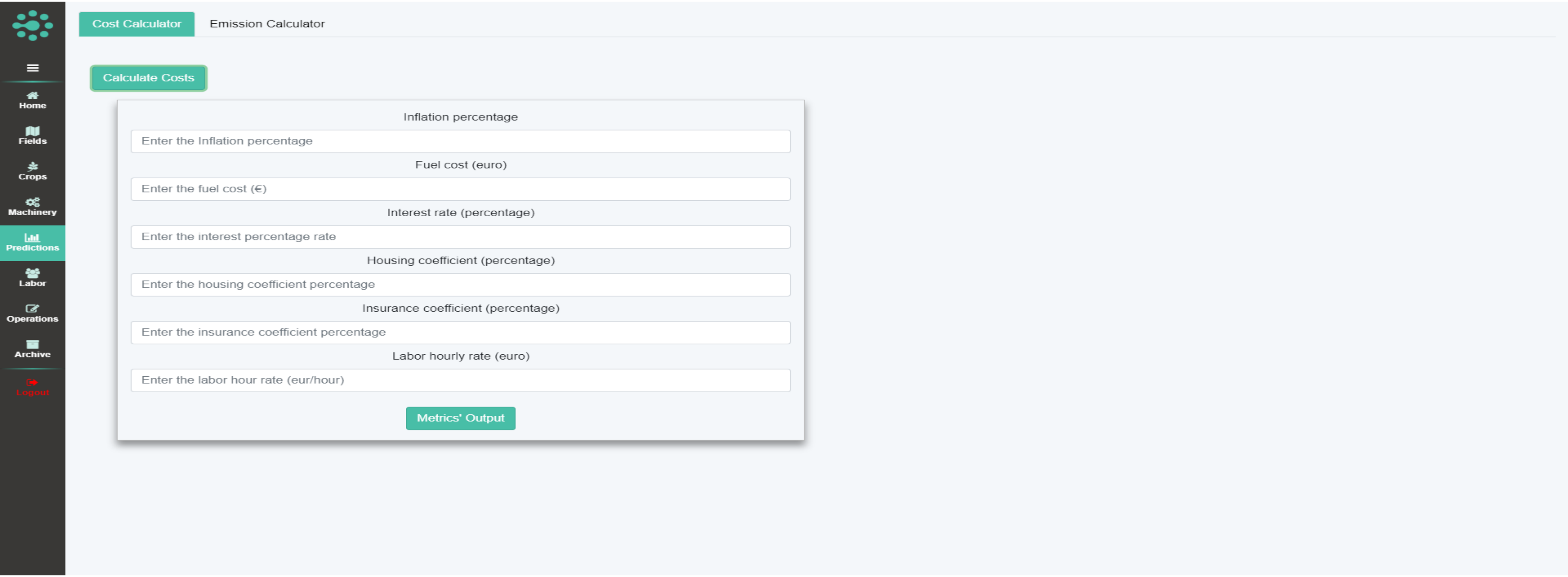
Home
Fields
Crops
Machinery
Predictions
Labor
Operations
Archive
Logout

Implements | Tractors | Self-propelled

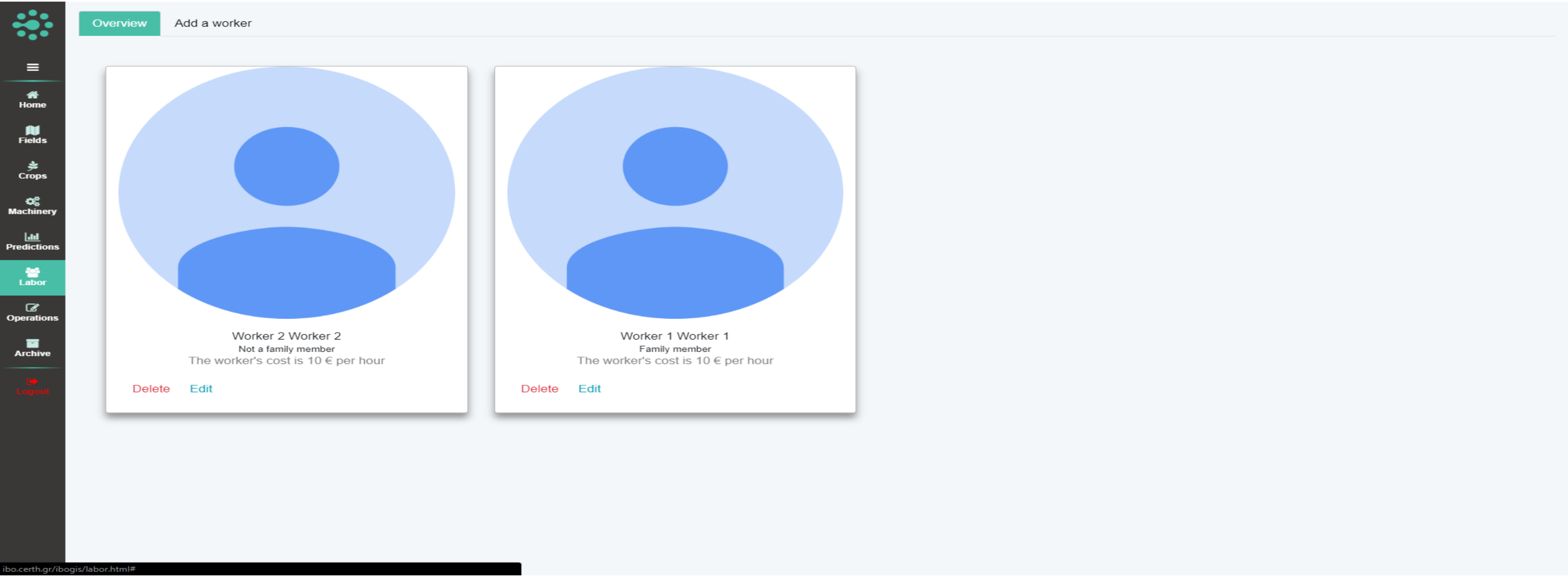
Add Implement

ID	Name	Annual Use (h/year)	Price (€)	Width (cm)	Type	SubType	Power Supply	Description	
1	Imp 4	12	133333	12	Imp 3	Rear-mounted		Imp 3	Edit Delete
2	Imp 3	150	150	50	Imp 3	test		Imp 3	Edit Delete
3	Imp 2	1230	120000	10	Imp 2	Test 4		Imp 2	Edit Delete
4	Imp 1	12	1000000	100	Imp 1	Front-mounted	Non-powered	Imp 1	Edit Delete

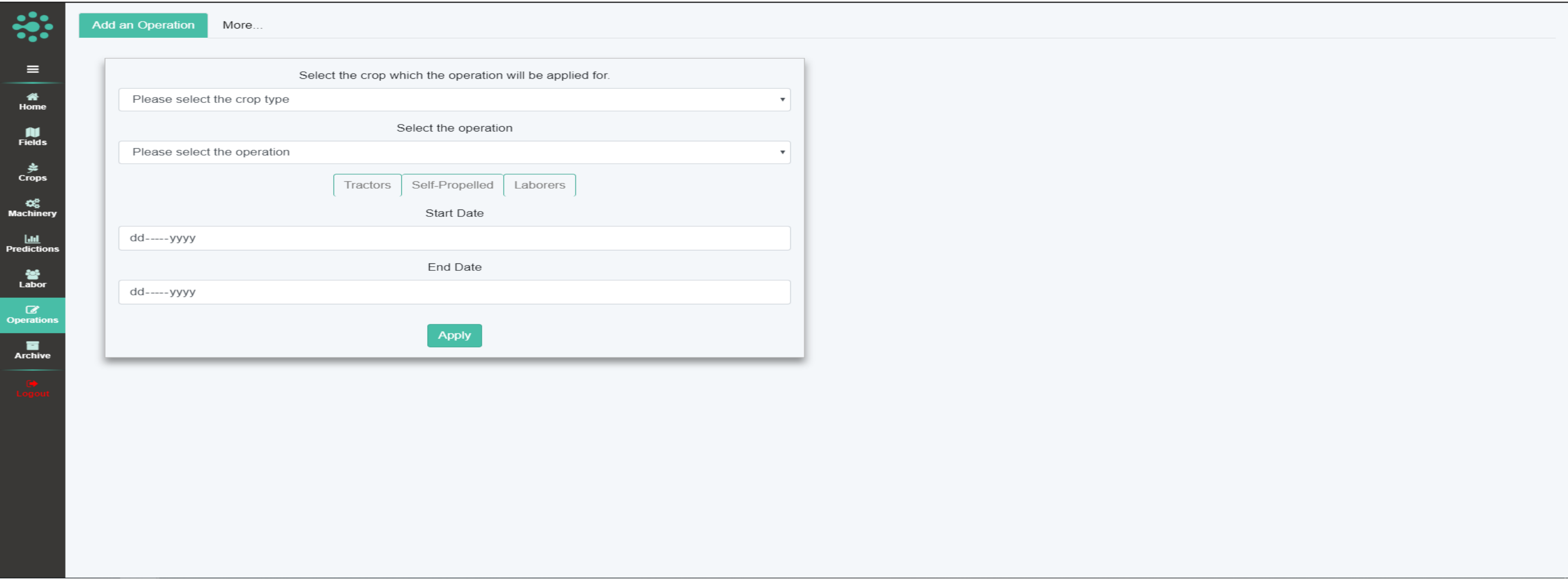
iBO Farm Management Information System



iBO Farm Management Information System



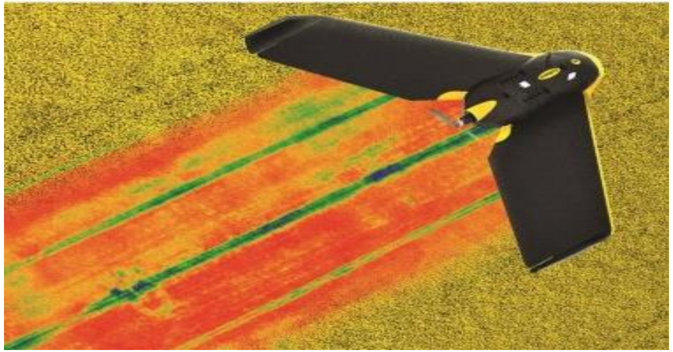
iBO Farm Management Information System




Fields Map
Fields Overview
Map
Satellite
Search Box
Home
Fields
Crops
Machinery
Predictions
Labor
Operations
Archive
Settings
Logout
Cosmos field
Field 4
My Field 3
My Field 2
My Field
Google

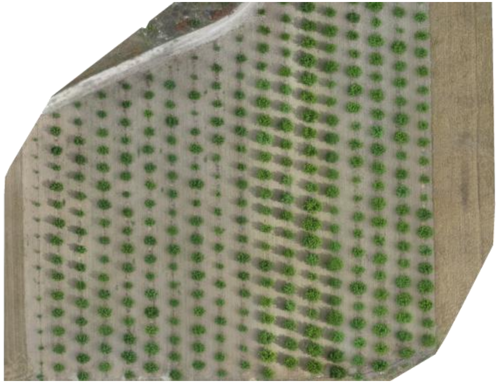
iBO/CERTH | Agri-Robotics Laboratory

- Field works robotic platform
- Production Parameter Monitoring robotic platform.
- Unmanned Aerial System (UAS)
- Fixed wing Unmanned Aerial Vehicle
- Unmanned Ground Velicles
- Collection of sensors for data collection (hyperspectral, multispectral, thermal, RTK, GPS, Lidar, etc.)
- Open-source Software Development for Unmanned vehicle mission planning.



Field Mapping using UAVs

- Cost Reduction
- Scouting of points of interest (obstacles, terrain type changes, etc.) to be used for the UGV path planning
- Management zones delineation using aerial NIR and RGB cameras for targeted input application



Tasks execution from UGVs

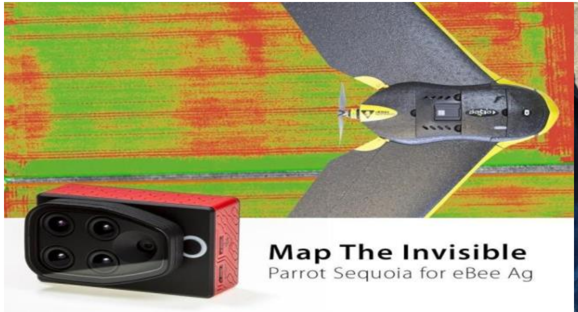
- Bilateral communication with the UAV in real-time
- Dynamic recognition of the neighboring environment
- Agricultural practices execution with high precision
  - ✓ Disease Detection
  - ✓ Targeted spraying
- Time consumption reduction

iBO UAV and UGV fleet

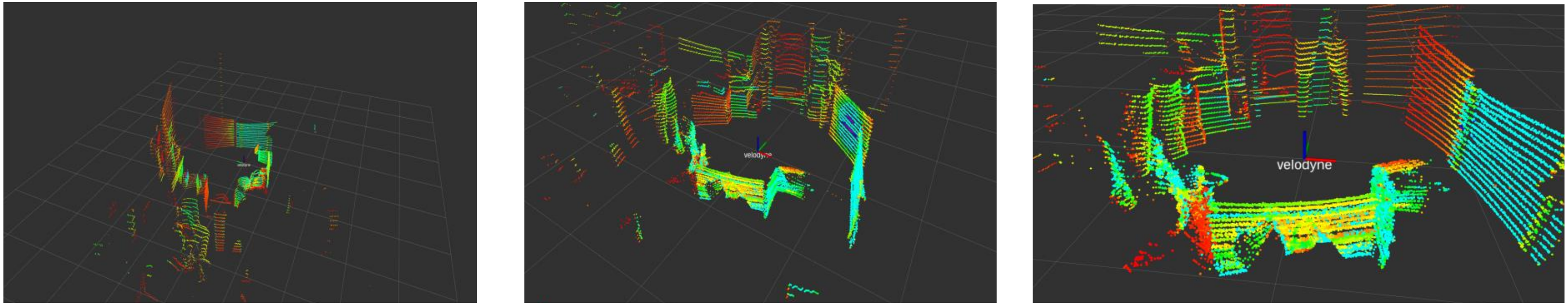
UGV: Husky, Clearpath Robotics and Thorvald, SAGA
UAV: DJI S1000 Spread Wings, DJI

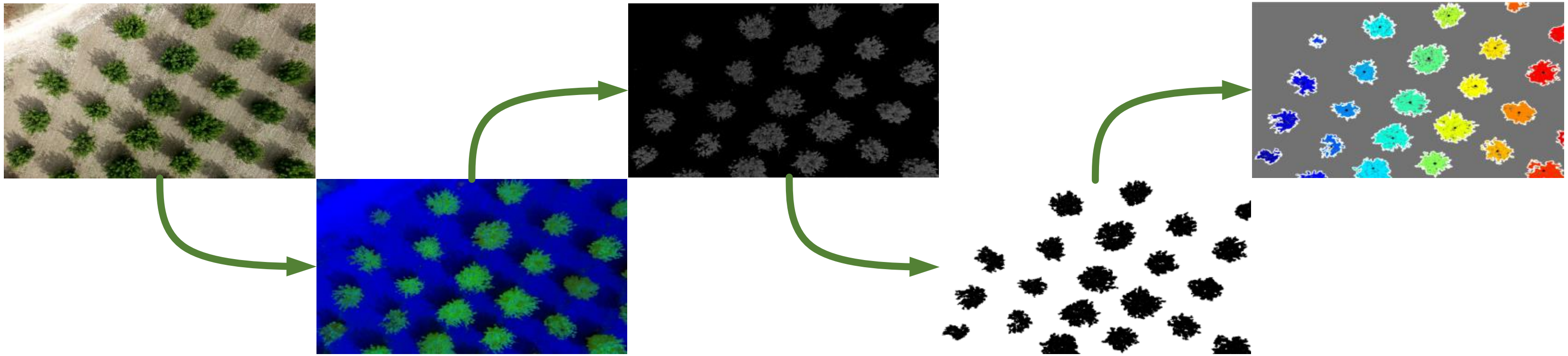
iBO UAV and other smart farming equipment

- Fixed-wing UAV eBee, SenseFly
- RTK-GNSS, Spectra
- Seqoia multispectral camera, Parrot
- Hyperspectral VNIR Camera FireflEYE 185, Cubert

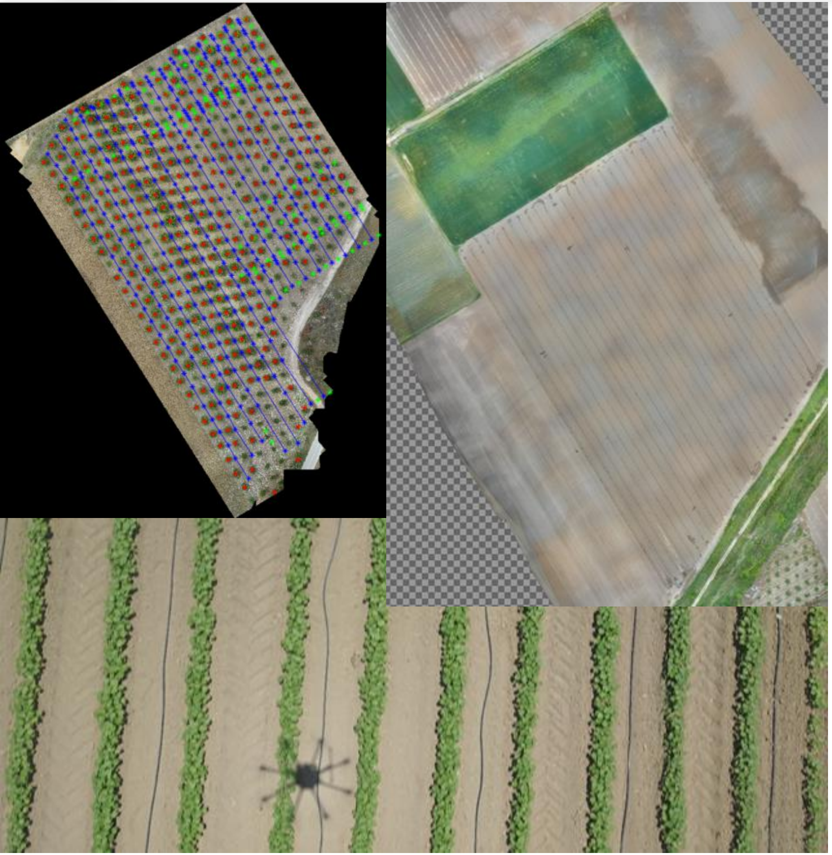


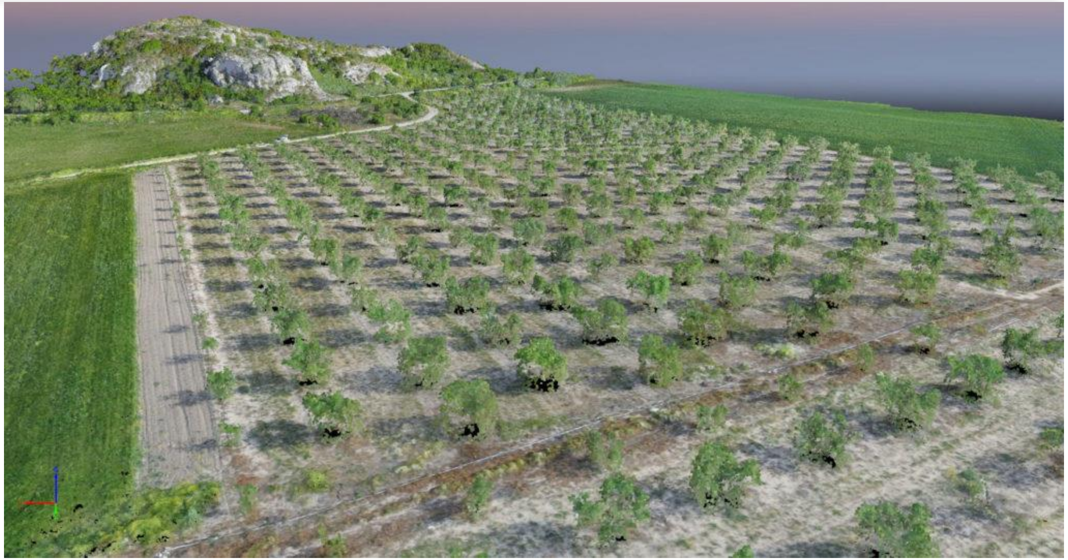
LiDAR environment recognition and image processing for tree identification

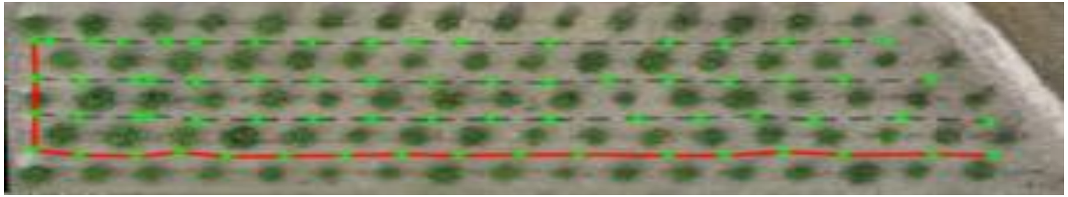




Creation of a cotton field mosaic and 3D orchard imaging.







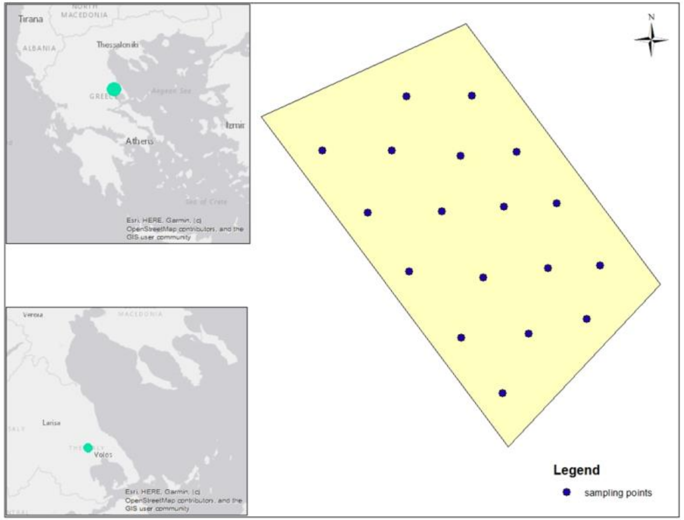
Real-time obstacles avoidance

Soil properties estimation using a UAV multispectral camera

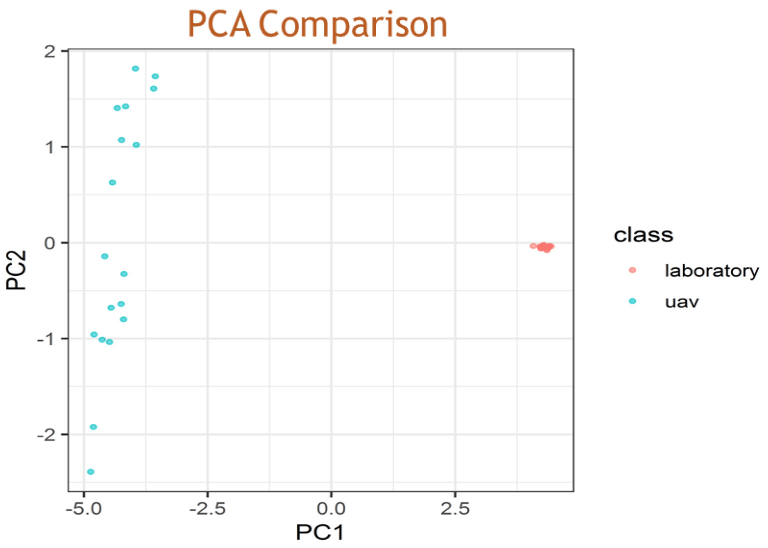
- Evaluate the capabilities of multispectral imagery predictive ability for SOM estimation acquired in bare soil conditions.
- A comparative analysis was performed with laboratory spectral measurements of 18 soil samples collected from the same field covering the complete VNIR-SWIR range (400-2500 nm).
- For model calibration, Support Vector Machine was performed, considering imagery data values and laboratory spectral signatures as input features, as well as a set of produced spectral indices.

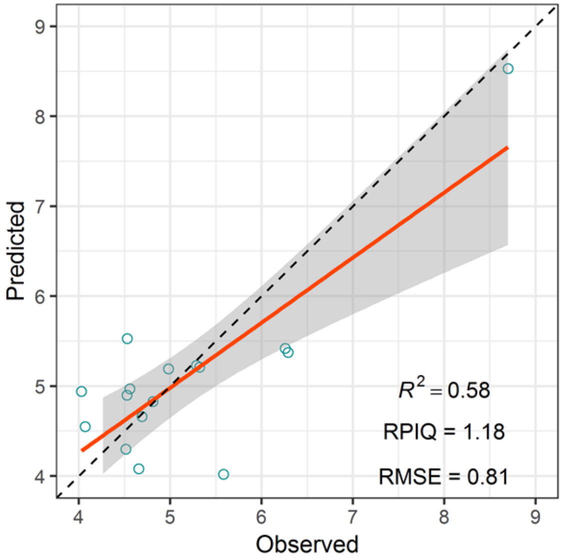
Materials and methods

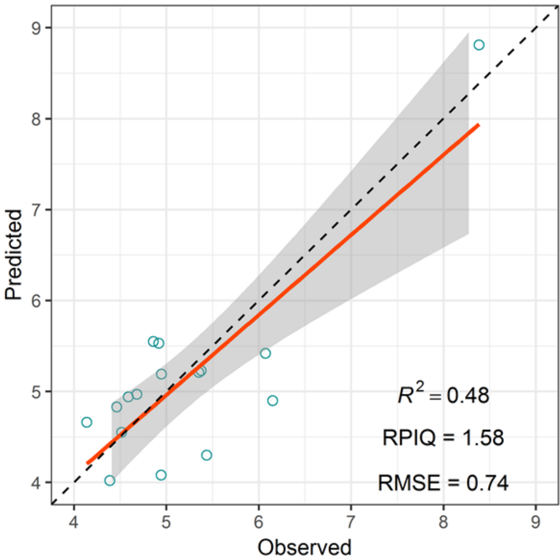
- The study area is a **0.6 ha** bare field in Rizomylos, Volos, Greece
- **18 topsoil** (0–30 cm) samples were collected
- **Parrot Sequoia+** camera for multi-spectral images. The camera detects 4 spectral bands with a sensitivity range between 400 and 810 nm. It was mounted in the **eBee UAV** platform. The flight altitude was **50m** and flight duration was 28 min.
- Laboratory spectral reflectance was calculated across the 350–2500 nm wavelength range using a **PSR + Spectral Evolution** in a dark box environment
- Model calibration by **Support Vector Machine** with radial basis kernel
- **Leave one out cross validation** (due to the low number of samples)
- **Inverse Distance Weighting** (for soil attribute mapping in order to generate spatially explicit indicators by point predictions)



Results

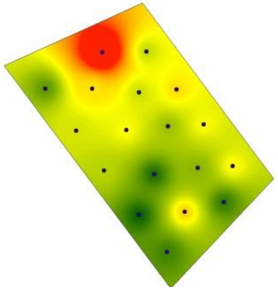


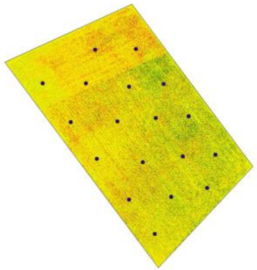




The differences between the laboratory spectroscopy and imaging data illustrate variations, due to:

- Atmospheric conditions
- Purity of pixels
- Instrumental noise
- Light conditions
- Soil roughness and moisture



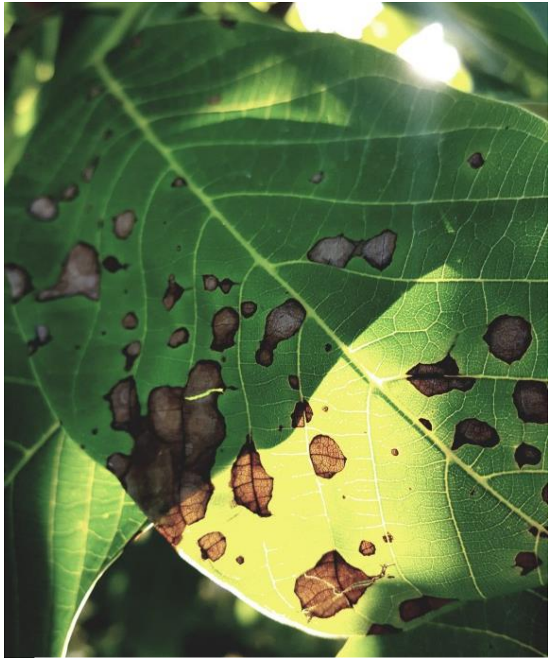


Conclusions

- Data acquisition is very important and its usefulness depends on both calibration and corrective tasks occurring in pre- and post-flight stages.
- Need for radiometric and geometric corrections and spectral calibration to preserve scientific rigor of acquired data
- Multispectral imaging lacks in spectral information compared to soil spectroscopy but can provide data with higher spatial resolution
- When using laboratory soil spectroscopy geo-statistical or interpolation techniques are required to infer continuous spatial information
- The lack of spatial variability may lead to low accuracy prediction models

Artificial Intelligence for Disease Detection

Fungal diseases such as **anthracnose**, can be catastrophic, can destructively damage the canopies of trees and can also spread easily to nearby trees.



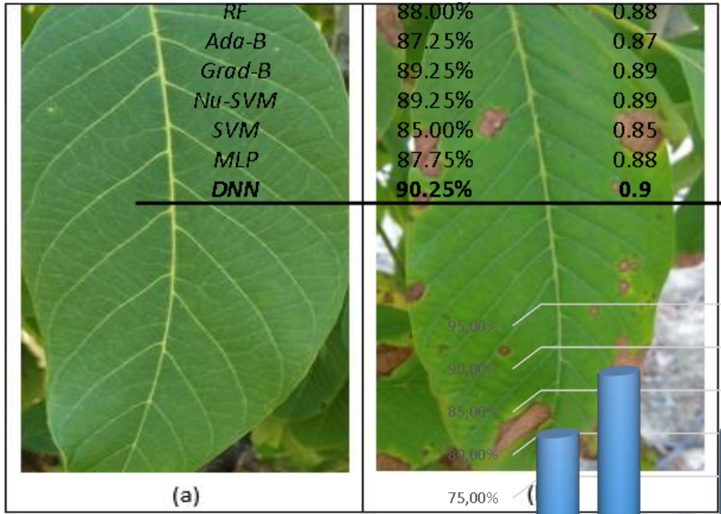
Copper spaying, adequate pruning and proper sanitation, renders the treatment of such diseases as easy, however, the main concern in such cases is the spreading prevention by early detection systems. This can be dealt with automated procedures offered in precision agriculture such as automatic image collection and real-time classification by smart systems.

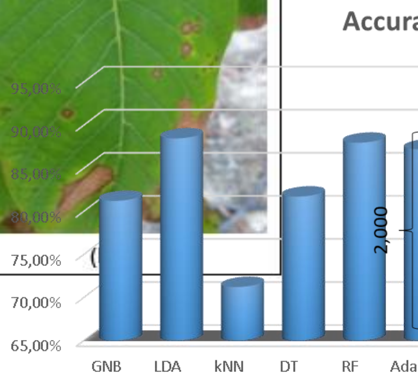
Machine Learning for anthracnose detection

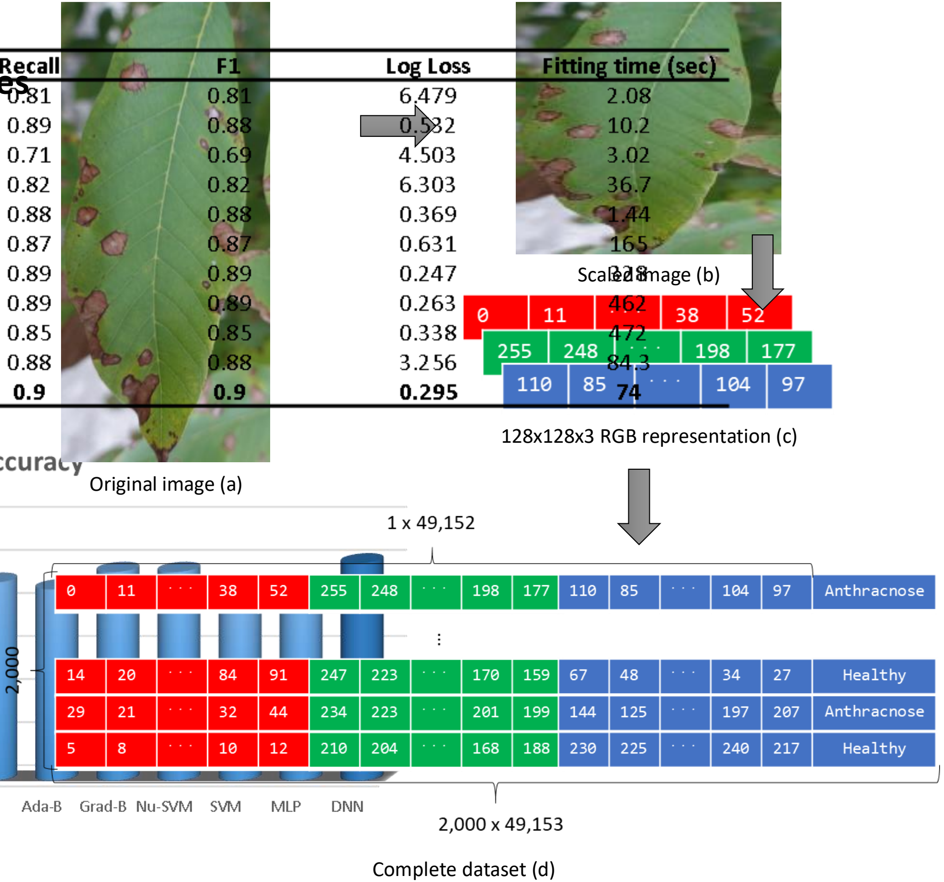
Machine learning algorithms comparison for image classification on anthracnose infected walnut tree canopies

Anagnostis et al. (under review)

Algorithms	Accuracy	Precision	Recall	F1	Log Loss	Fitting time (sec)
GNB	81.25%	0.81	0.81	0.81	6.479	2.08
LDA	88.50%	0.89	0.89	0.88	0.532	10.2
kNN	71.25%	0.8	0.71	0.69	4.503	3.02
DT	81.75%	0.82	0.82	0.82	6.303	36.7
RF	88.00%	0.88	0.88	0.88	0.369	1.44
Ada-B	87.25%	0.87	0.87	0.87	0.631	165
Grad-B	89.25%	0.89	0.89	0.89	0.247	328
Nu-SVM	89.25%	0.89	0.89	0.89	0.263	462
SVM	85.00%	0.85	0.85	0.85	0.338	472
MLP	87.75%	0.88	0.88	0.88	3.256	84.3
DNN	**90.25%**	**0.9**	**0.9**	**0.9**	**0.295**	**74**





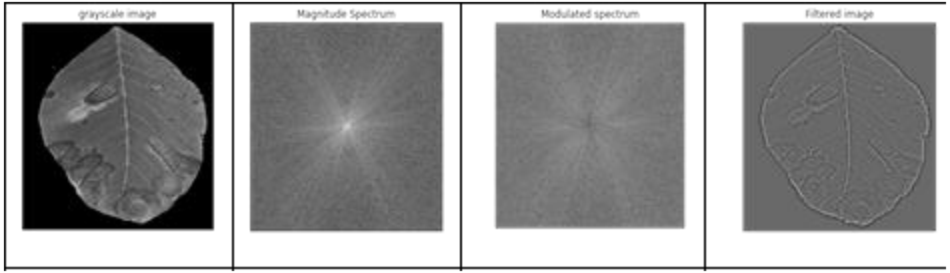


Convolutional Neural Networks

Background removal

Images of anthracnose-infected (with (a) and without (c) background) and healthy (with (b) and without (d) background) walnut leaves.

Feature extraction

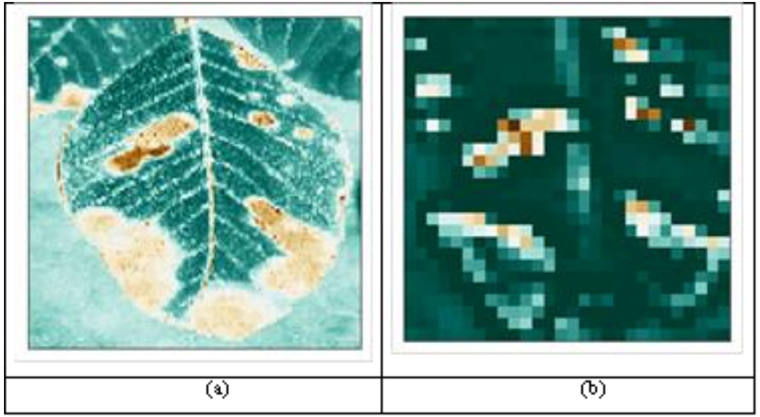


FFT steps where the original image (a) is analyzed into a magnitude spectrum (b), into a modulated spectrum (c) and finally into the feature-rich image (d).

Image classification on anthracnose infected walnut tree leaves with the use of Convolutional Neural Networks

Anagnostis et al. (to be submitted)

Convolutions activation maps

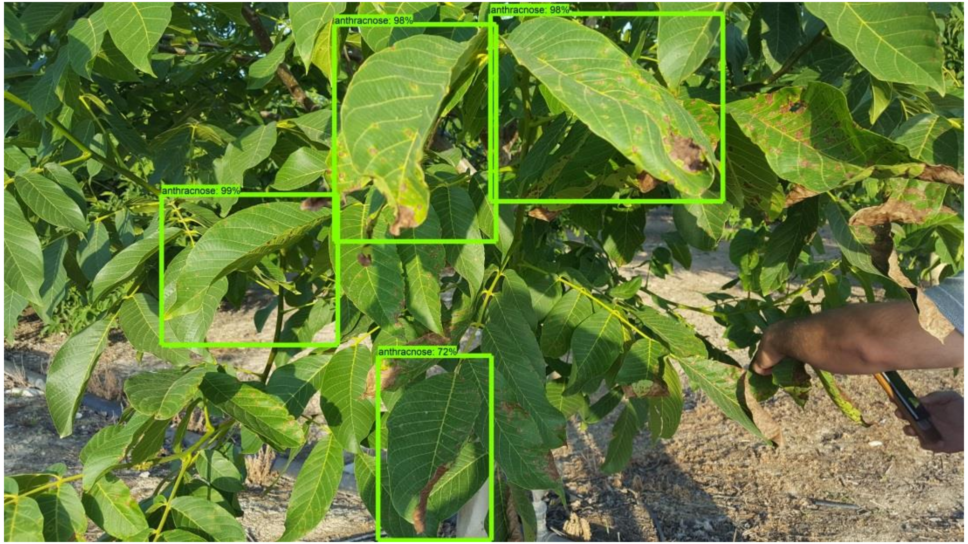


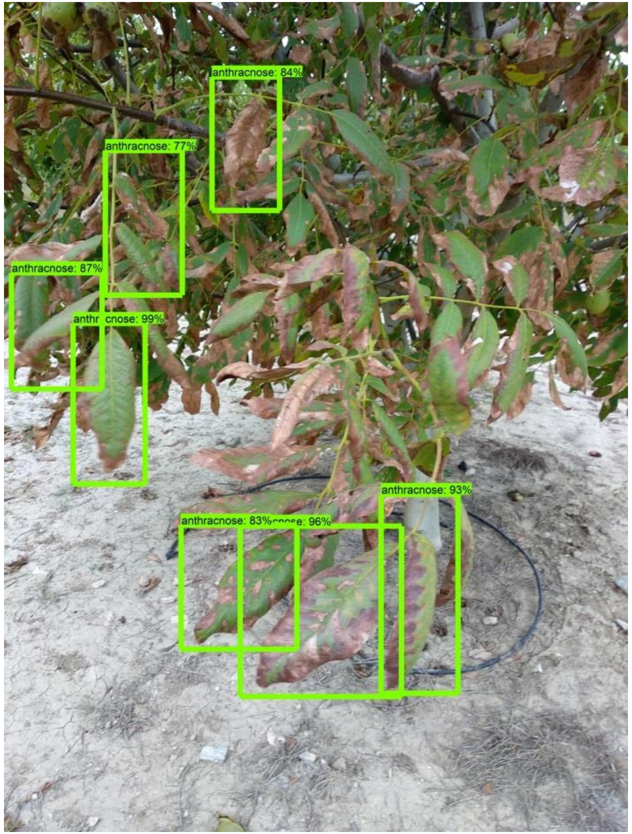
Classification accuracy results: > 99%

Object Detection

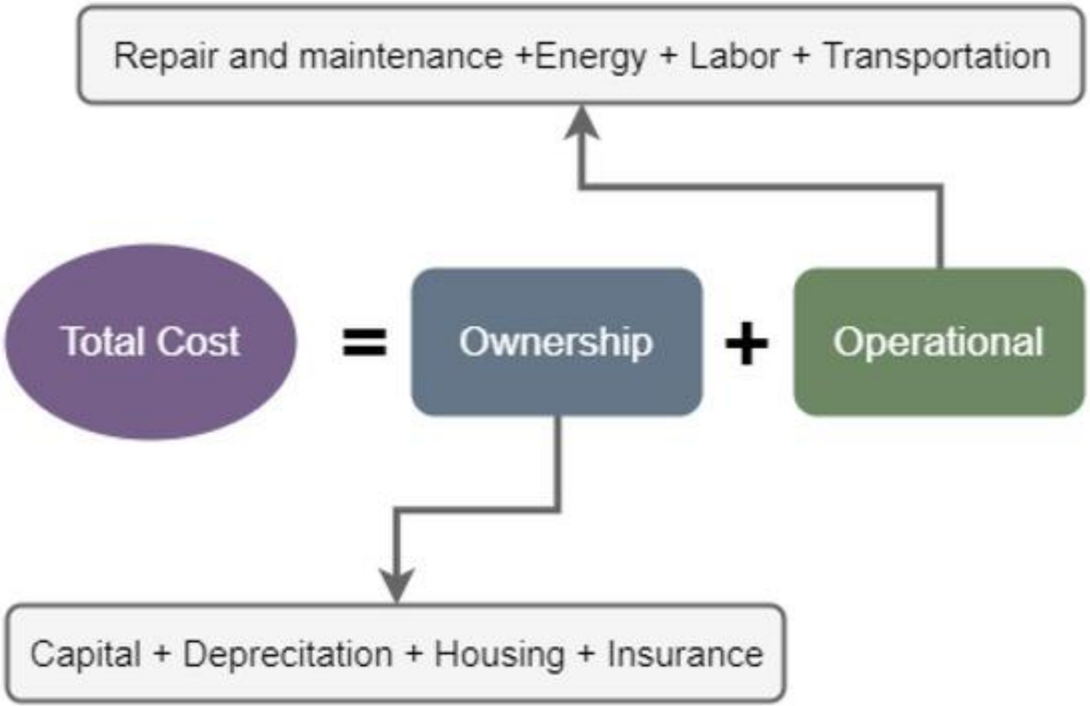
- *Sliding windows*
- *Single Shot Detector*
- *You Only Look Once*

(work in progress)

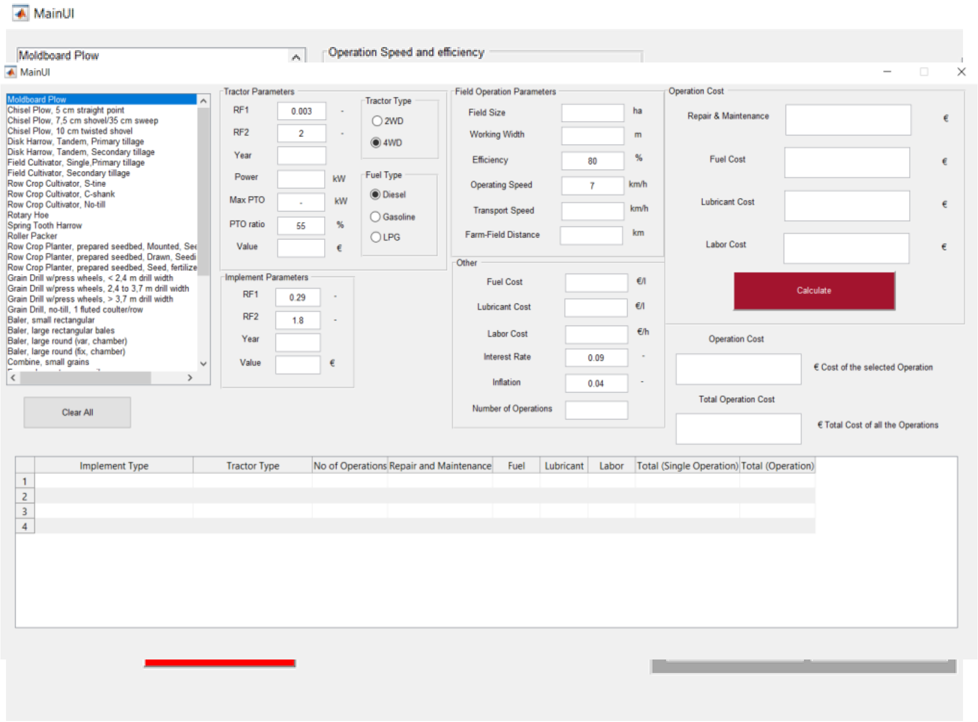




Machinery energy and cost calculator

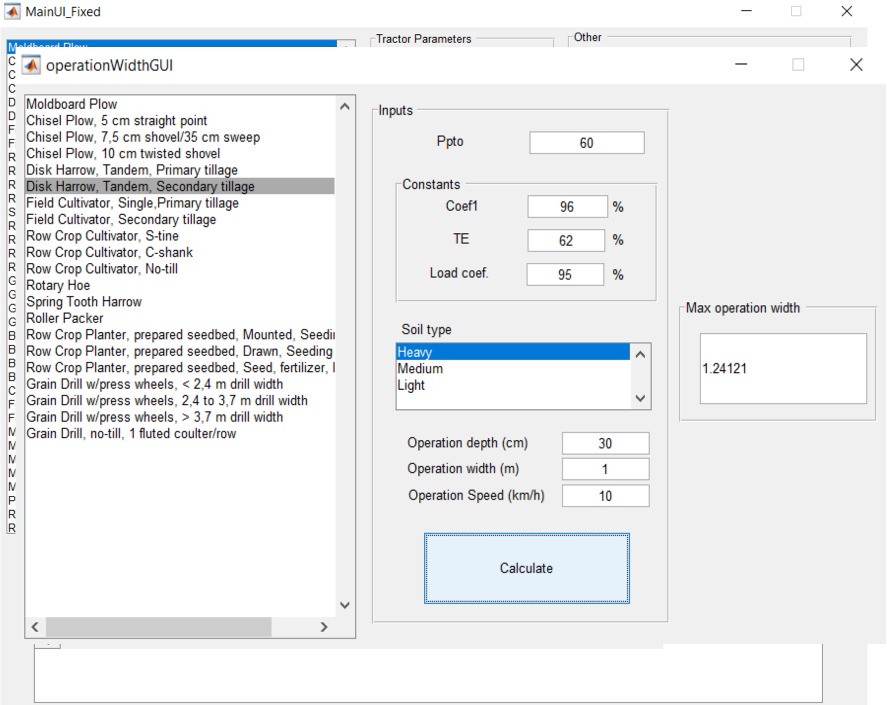


Machinery energy and cost calculator



Matlab user interface to calculate the required power to perform an agricultural practice

Matlab user interface for calculating variable work costs.

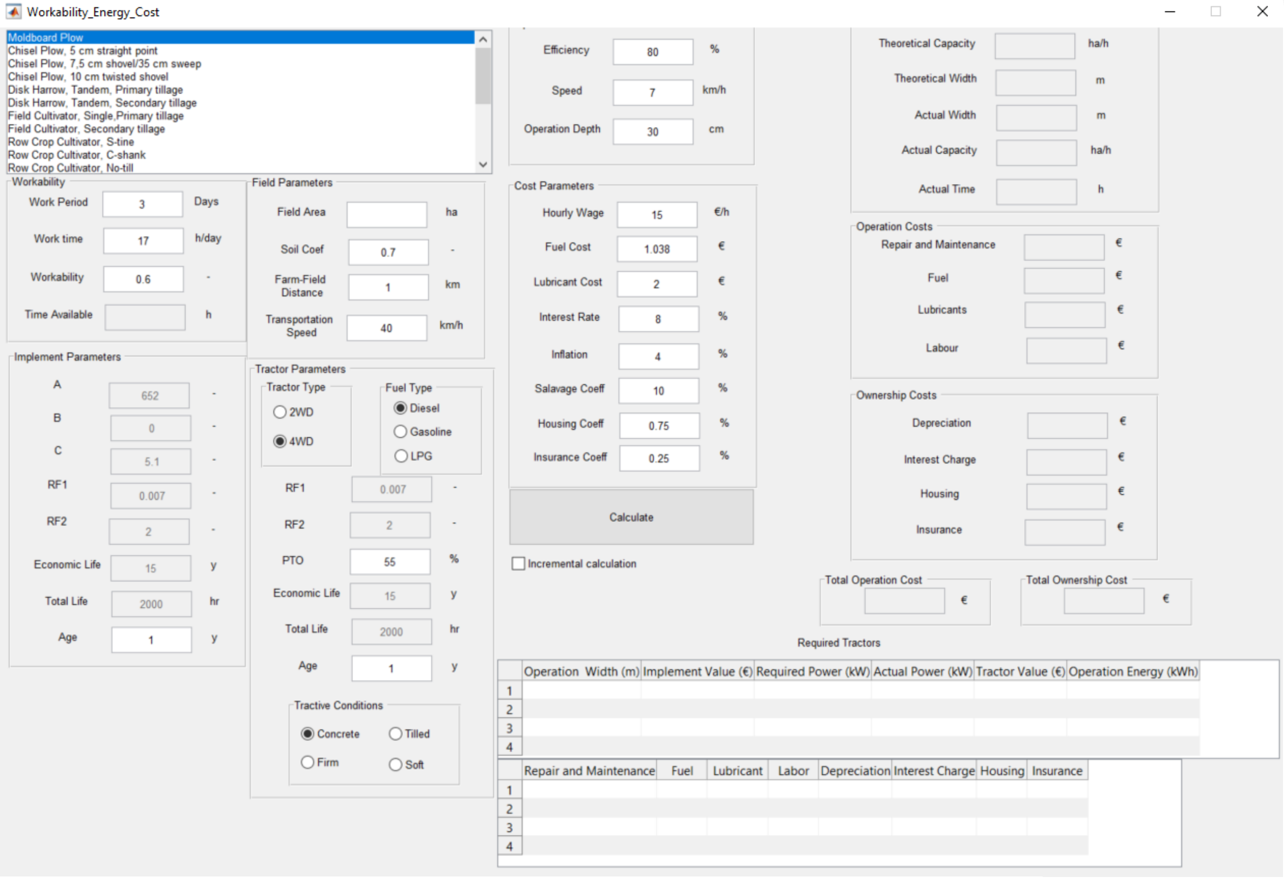


Matlab user interface for calculating fixed cost of equipment.

Matlab user interface for calculating the operating width required to perform an agricultural practice.

Agricultural Machinery Management

Matlab user interface for calculating the required number and size of machinery for agricultural practices execution with simultaneous cost calculation



Sustainability Analysis of UGVs replacing Tractors

❖ **Subject (what)**

Economic and Environmental Sustainability Assessment of proposed production systems.

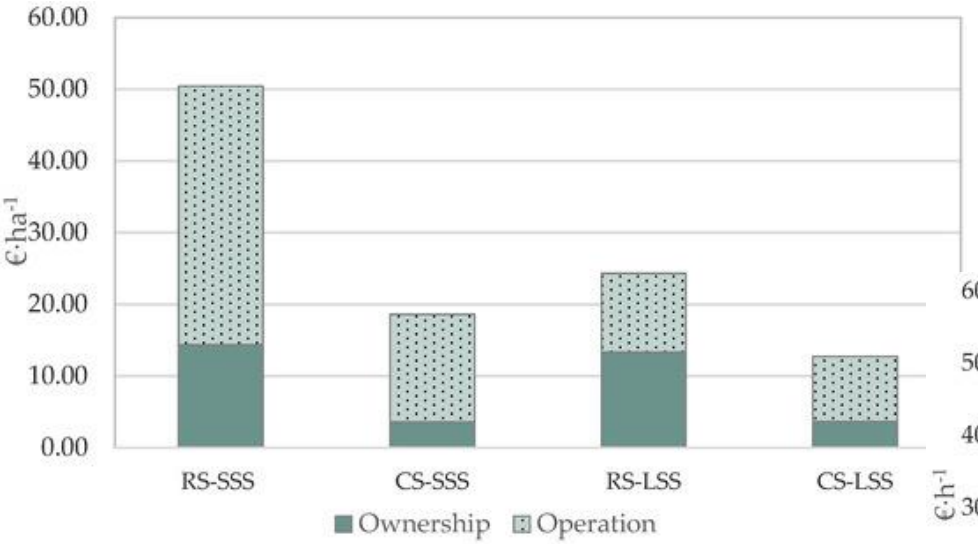
❖ **Purpose (why)**

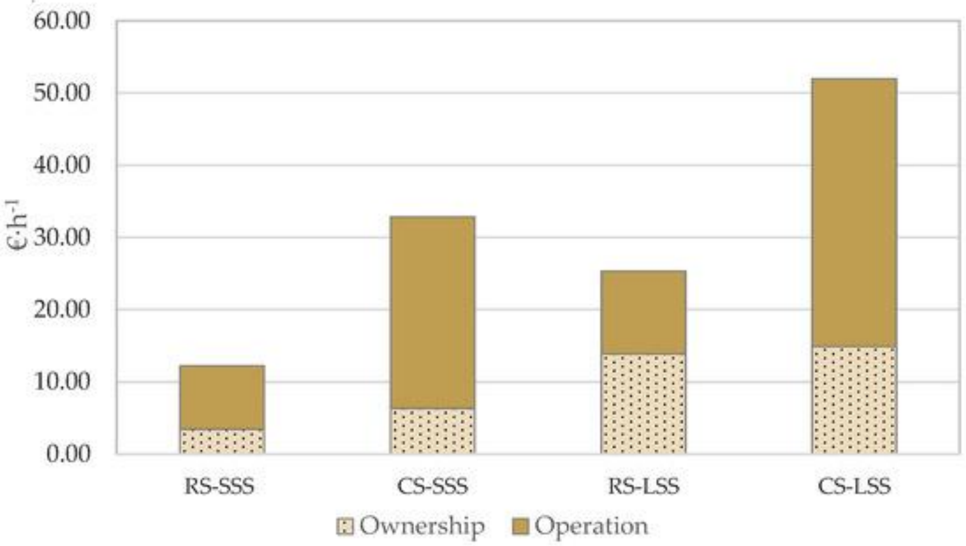
In order to support high-end technology adoption in agriculture, an assessment of the cost and benefits from robotic system application is required.

❖ **Methods (how)**

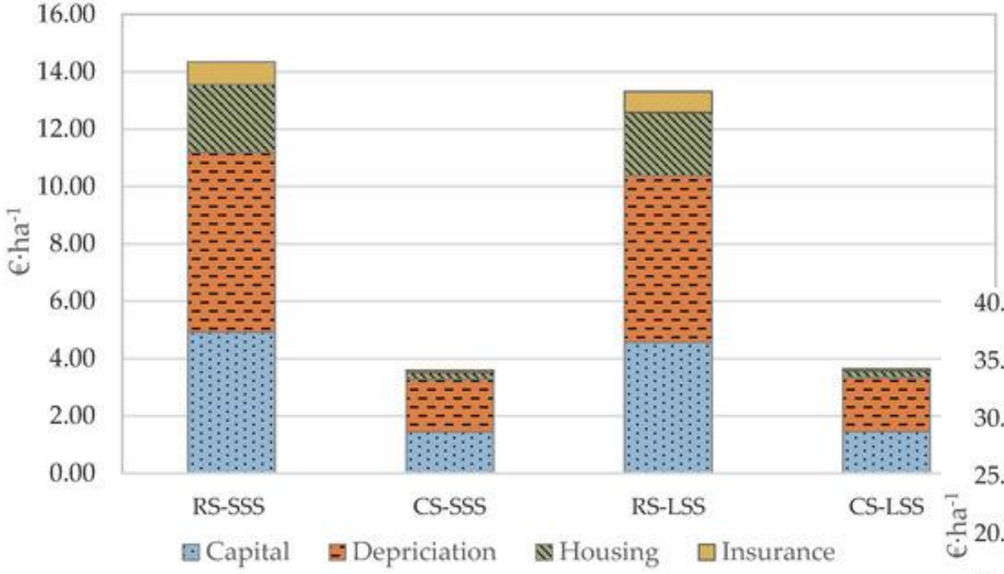
Robotic platforms are not followed with operational parameters specifications, as conventional agricultural machinery. Therefore, preliminary methodology on defining the cost of operation (light tillage) in arable farming was conducted and compared with existing technology. For environmental assessment, LCA is being used.

Sustainability Analysis of UGVs replacing Tractors

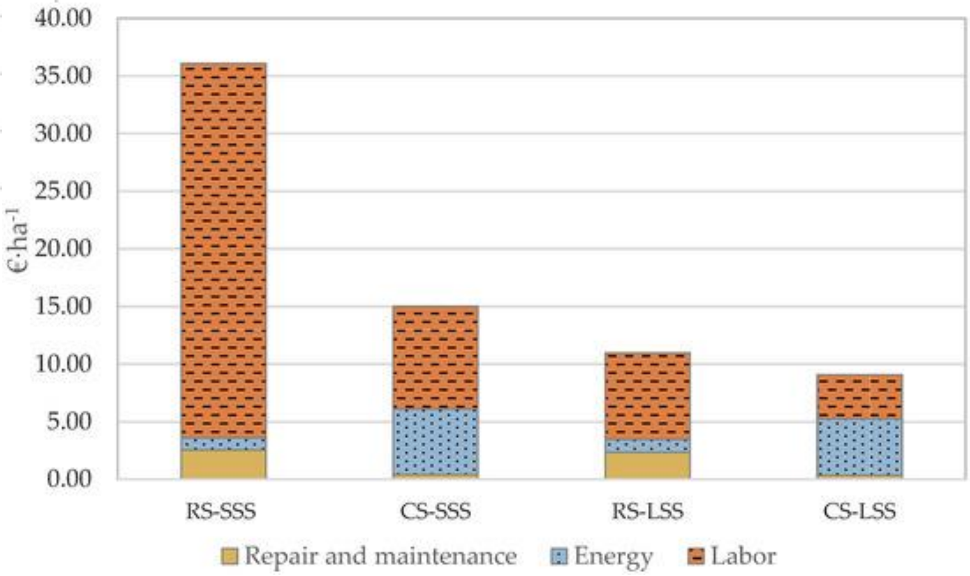


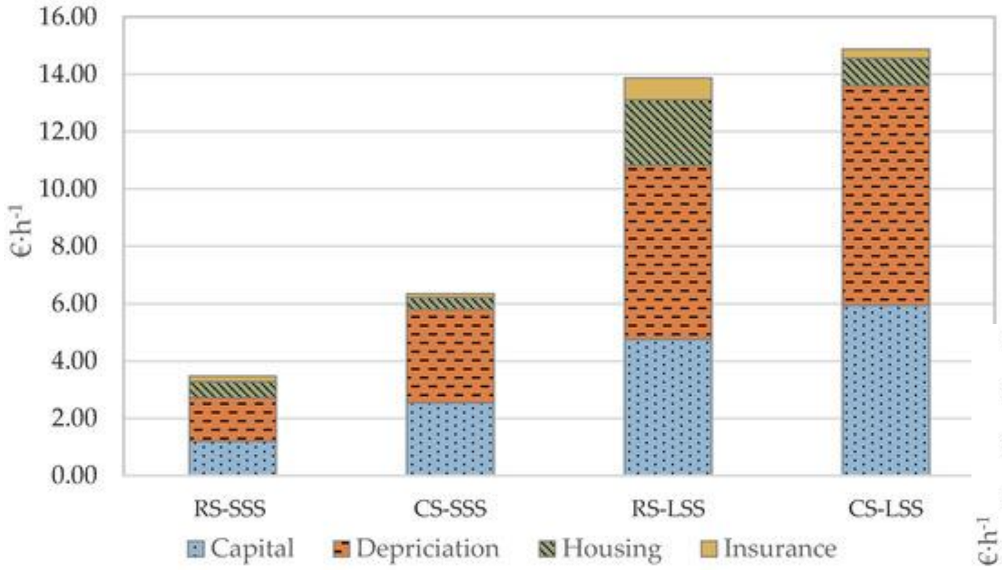


Sustainability Analysis of UGVs replacing Tractors

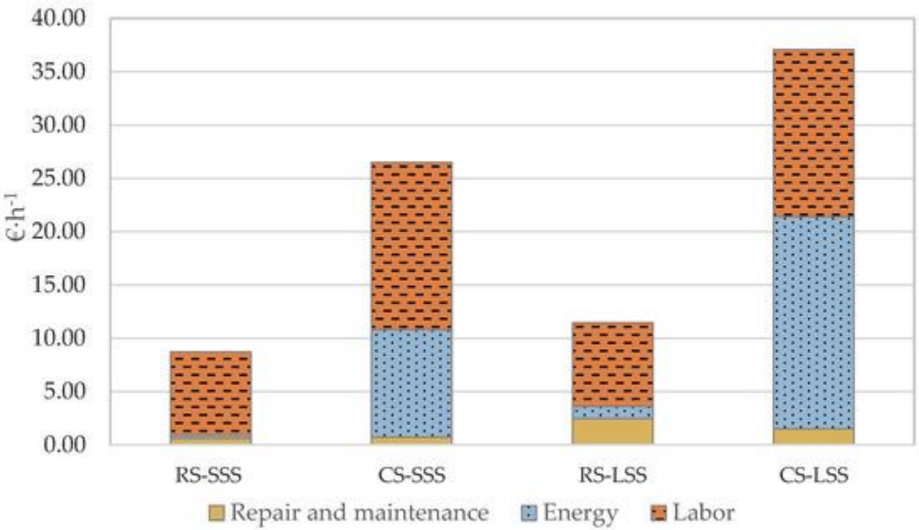


Ownership Cost per unit area

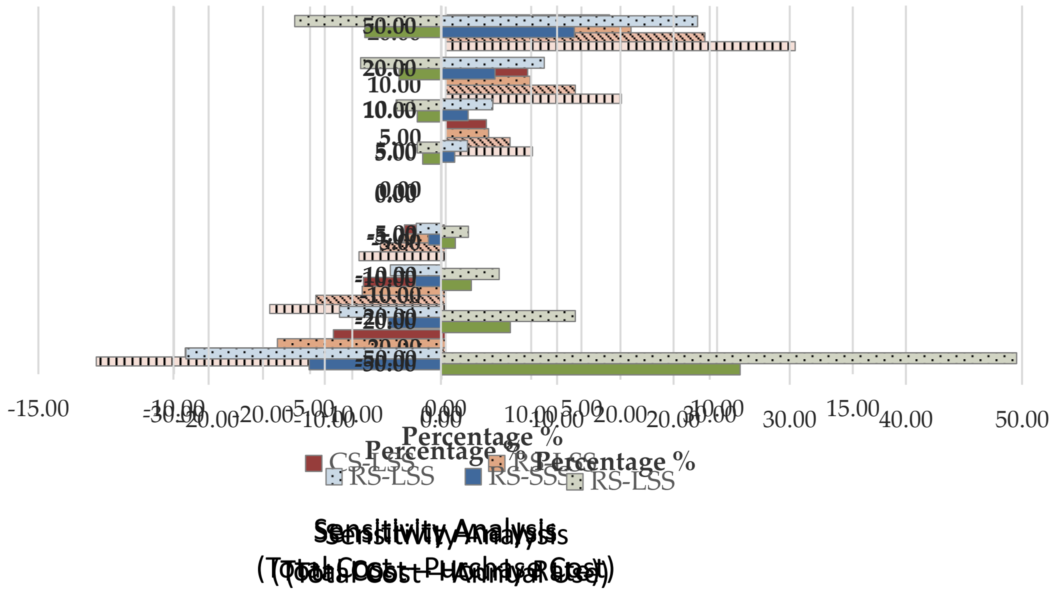




Ownership Cost per unit time

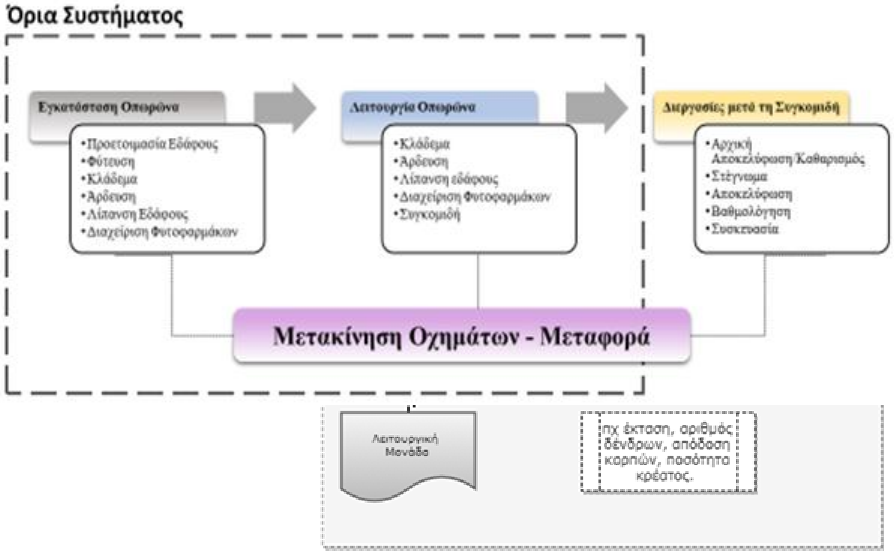


Main Results

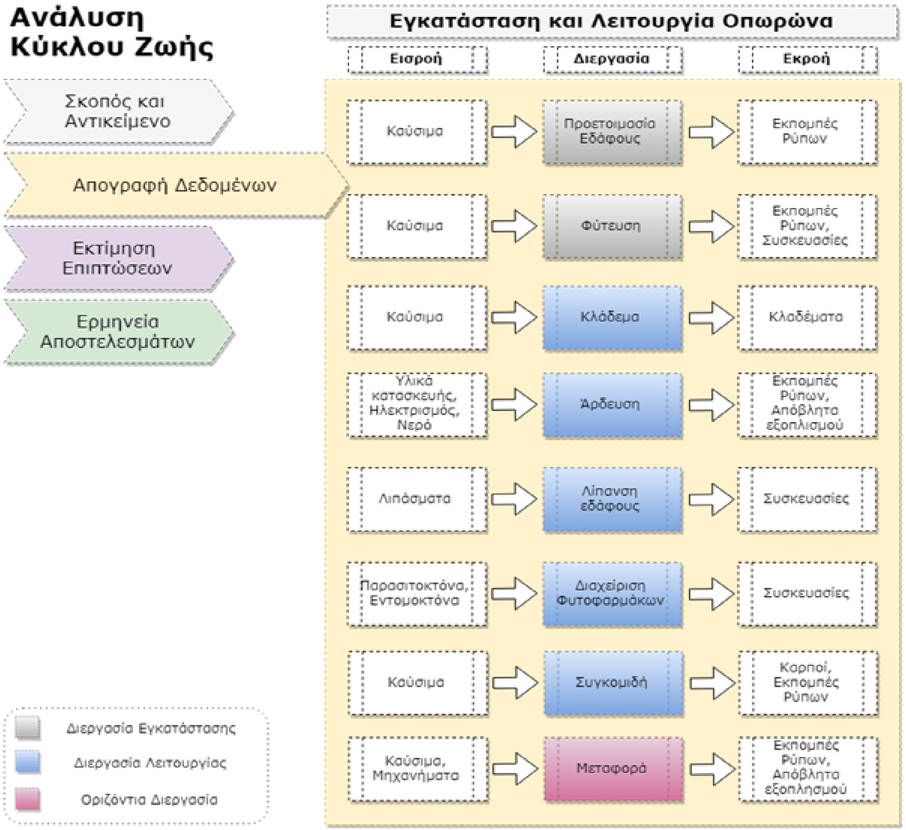


*RS: Robotic System; CS: Conventional System; SSS: Small Scale Scenario; LSS: Large Scale Scenario

LCA



Orchard Case Study
(Purpose and Subject)



LCA Stages

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OPTIMA

OPTIMA

Redefining Pest Management - a Holistic Approach

OPTimised Integrated Pest MAnagement

for precise detection and control of plant diseases in perennial crops and open-field vegetables

Current situation

OPTIMA

The present situation about crop protection

Few bio-PPP available

Poor sprayer adjustment

High number of treatments

High losses of PPP out of target

High cost

High environmental impact

OPTIMA field activities will be carried out in:

FRANCE
Crop: carrots in open field
Disease: Alternaria leaf blight
OPTIMA Partners:
IRSTEA, INVENIO, AGROCAMPUS

SPAIN
Crop: apple orchards
Disease: Apple scab
OPTIMA Partners: UPC

ITALY
Crop: vineyards
Disease: Grape downy mildew
OPTIMA Partners: UNITO, TERRE DA VINO

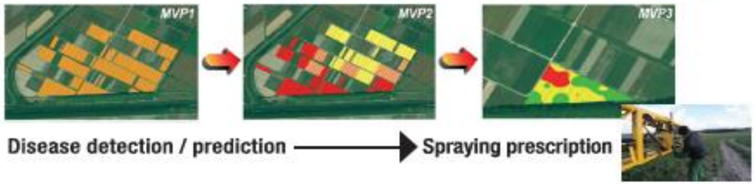
Objectives

To develop an environmentally friendly Integrated Pest Management (IPM) framework for orchards, vineyards and open-field vegetables through:

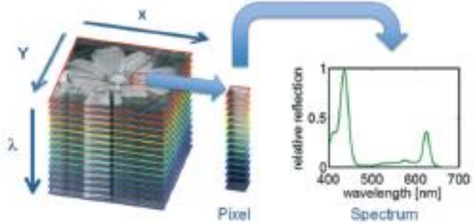
A. Combined use of bio-PPPs and synthetic PPPs

BIO PPPs + **Synthetic PPPs**

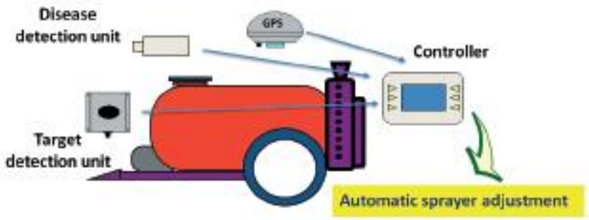
B. Decision Support System (DSS) for disease prediction and to address product choice, time of application and sprayer settings



C. Spectral disease detection systems



D. Precision spraying techniques



Actions

1 Optimise early disease detection method and disease prediction models

2 Screen and evaluate, first in lab then in field, biological and synthetic PPPs for maximal disease control

Carrot leaf blight   Vine downy mildew   Apple scab

3 Implement new precision spraying technologies on smart sprayer prototypes

Boom sprayer for carrots   Air assisted sprayer for vineyards   Air assisted sprayer for apple orchards

4 Create a DSS for supporting the operator in selecting appropriate time, PPP type and sprayer settings for each application

- Date of treatment
- Type of PPP
- Volume application rate (L/ha)
- Droplet size (fine, medium, coarse)
- Number of active nozzles
- Air flow rate
- Etc.

5 Evaluation of new IPM elements in the field

6 Assess health, environmental and socioeconomic impacts of the proposed IPM system

Expected results

OPTIMA

A Earlier detection and precise prediction of crop diseases in the field

B Improved IPM strategy to prevent and control crop diseases

C Optimised combination of biological and synthetic PPP to control crop diseases

D Adoption and spreading of smart technologies among farmers to optimise spray application

E Reduction of plant protection costs

F Reduction of environmental impact of PPP use

G Increase of agricultural products quality and minimisation of PPP residues

OPTIMA – Optimised Pest Integrated Management

OPTIMA

PREDICTION of plant disease outbreak

DETECTION of symptoms

SELECTION of a mix of bio and chemical PPPs

EMPLOYMENT of smart spraying solutions

ASSESSMENT of proposed IPM system

Pest Management as it ought to be...

@OptimalPM

@Optima_IPM

@optima_ipm

optima-ipm

http://optima-h2020.eu/

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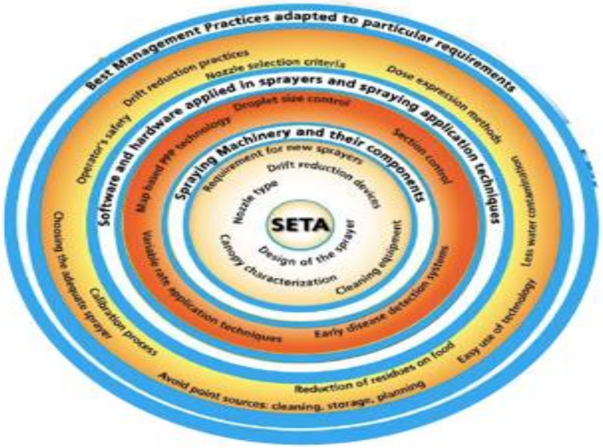
INNOSETA
INNOVATIVE SPRAYING EQUIPMENT TRAINING ADVISING

Accelerating INNOvative practices for Spray Equipment, Training and Advising in European agriculture through the mobilization of agricultural knowledge and innovation systems

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT NO.773864

SETA

Spraying, Equipment, Training and Advising (SETA) refers to the circle of tools that are required to cover the PPP use for crop protection including **Spraying Machinery and their components**, **electronic technologies** (software and hardware) applied in sprayers and s**pray application techniques** and **Best Management Practices** adapted to particular requirements.



Objectives

Objective 1. **Create an inventory** of directly applicable spraying equipment and technologies, training materials and advisory tools available from the large stock of research results and commercial applications.

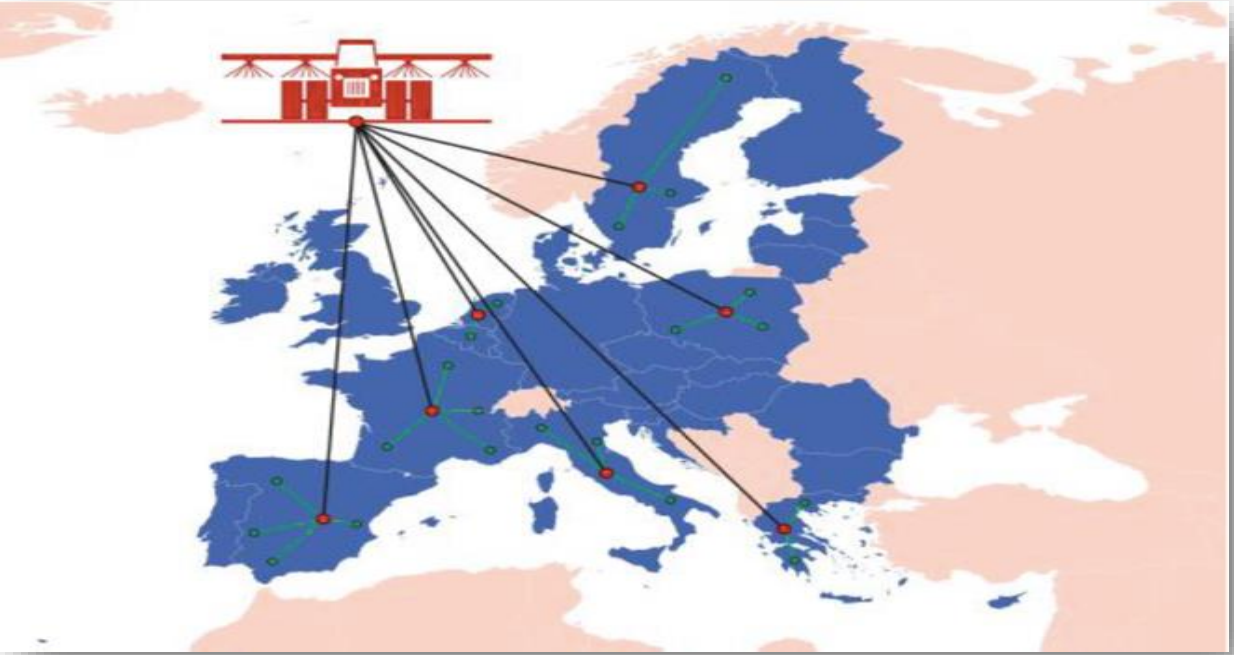
Objective 2. **Assess end-user needs and interests**, and identify factors influencing adoption taking into account regional specificities.

Objective 3. **Generate interactive multi-actor, innovation-based collaborations** among different stakeholders.

Objective 4. **Set up of an ICT tool** for the on-line assessment of the Spraying Equipment, Training and Advising and the crowdsourcing of grassroots-level ideas and needs.

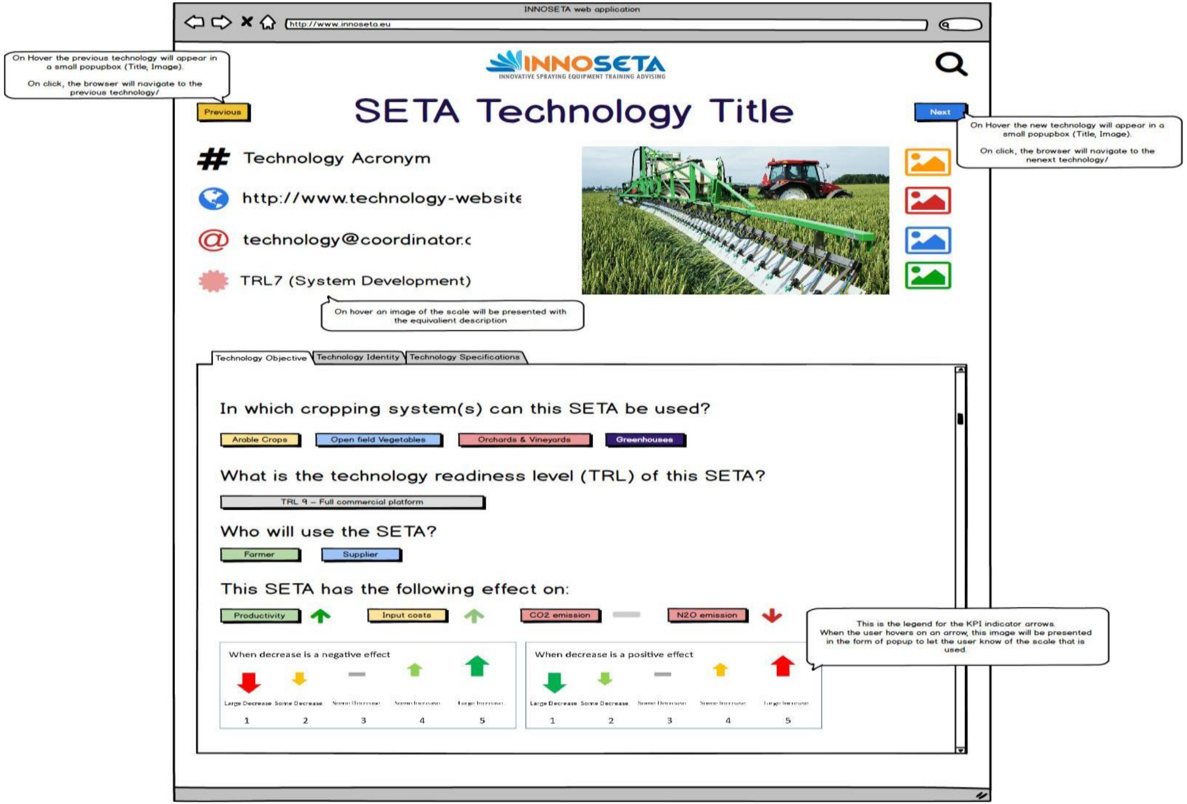
Objective 5. Liaise with EIP-AGRI and its structures

- 7 countries, 15 partners
- **Field crops, orchards, greenhouses**
- **Academia, Research, EU associations, farmer's associations, advisors**



Structure of platform

INNOSETA
INNOVATIVE SPRAYING EQUIPMENT TRAINING ADVISING



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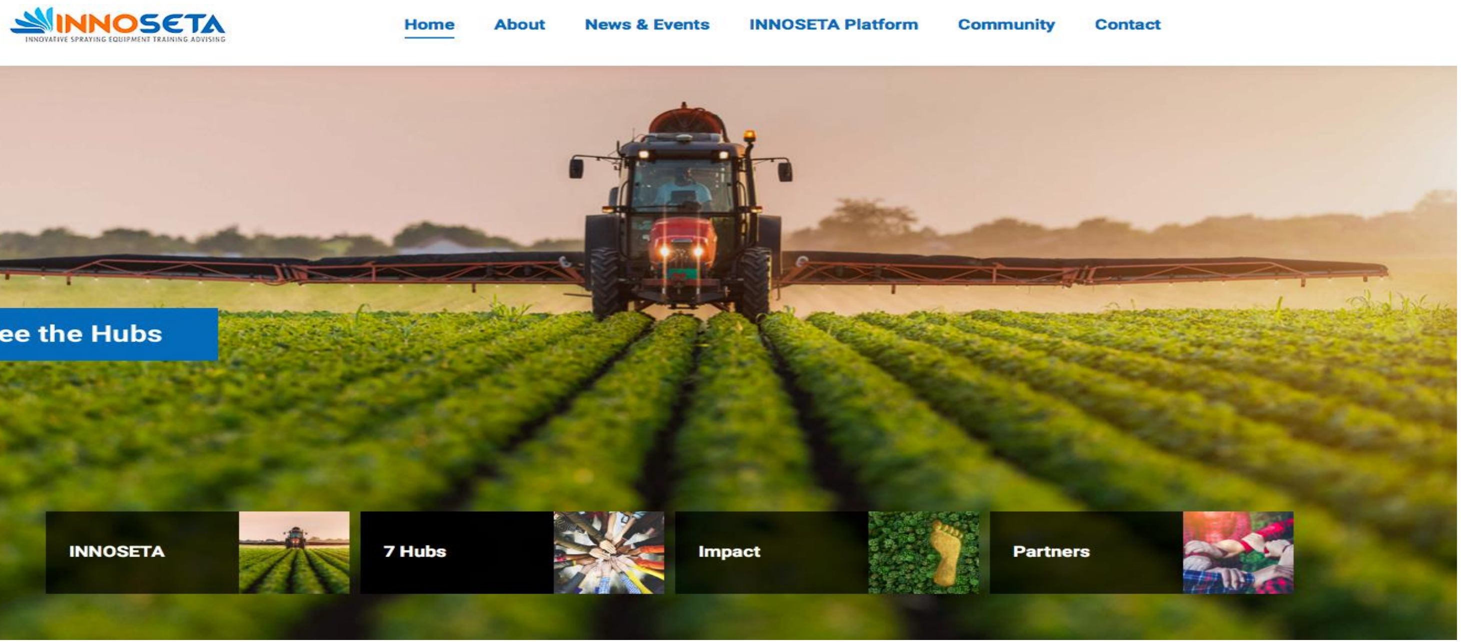

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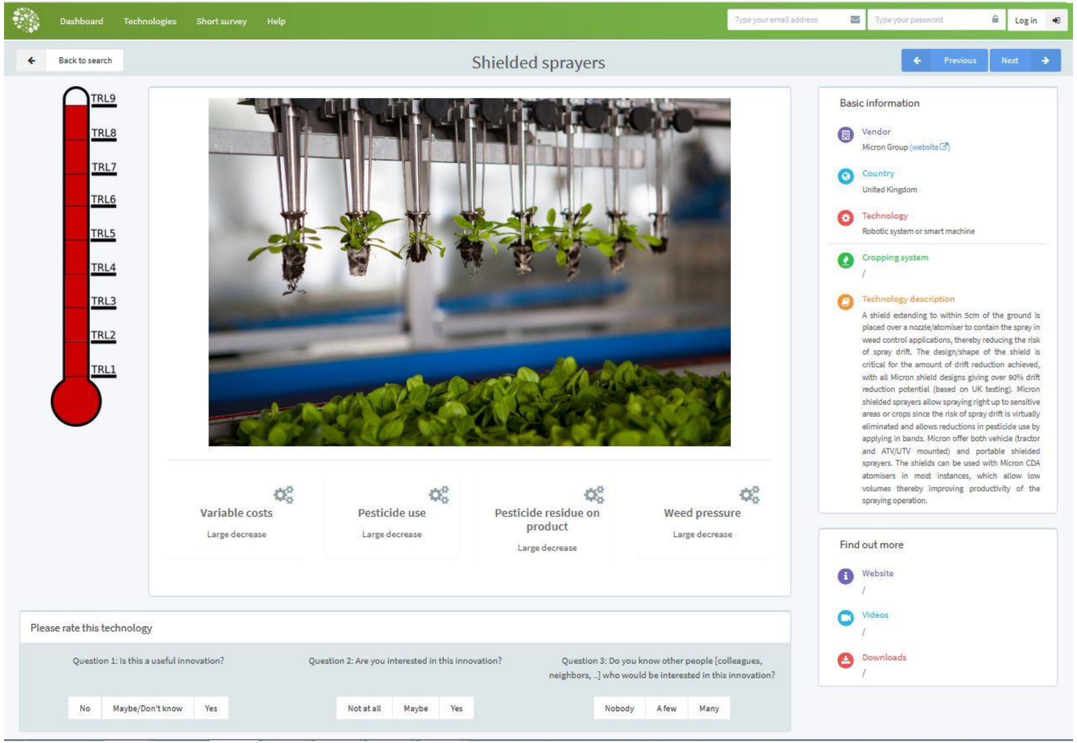
smartAKIS
Smart Farming Thematic Network



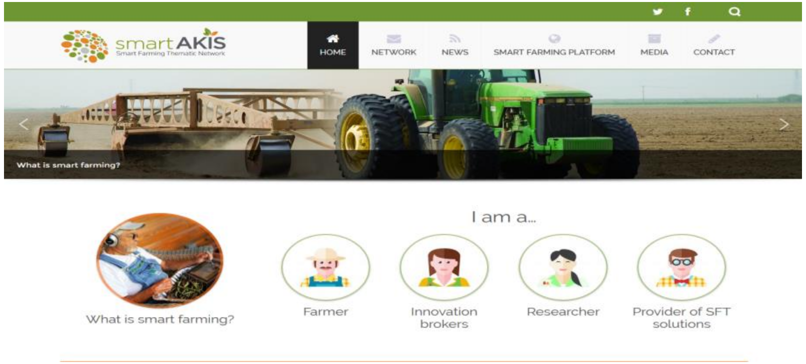
- 1094 SFTs have been included already in the Platform
- 172 entries are for commercial products (**FREE of charge promotion of SFTs**)

RESULTS IN FIGURES:

- **1100 Smart Farming solutions** showcased and assessed on Smart Farming Platform.
- **+ 50 Smart Farming solutions adopted** by farmers and practitioners.
- **>1000 stakeholders** engaged in 21 regional and 2 transnational Innovation Workshops through 7 Innovation Hubs.
- **35 collaborative innovation projects** on Smart Farming.
- **10 transnational collaborative innovation projects** on Smart Farming.
- **50 links** created with Operational Groups.
- **>700 users** of the Smart Farming Community Platform.

smart AKIS
Smart Farming Thematic Network

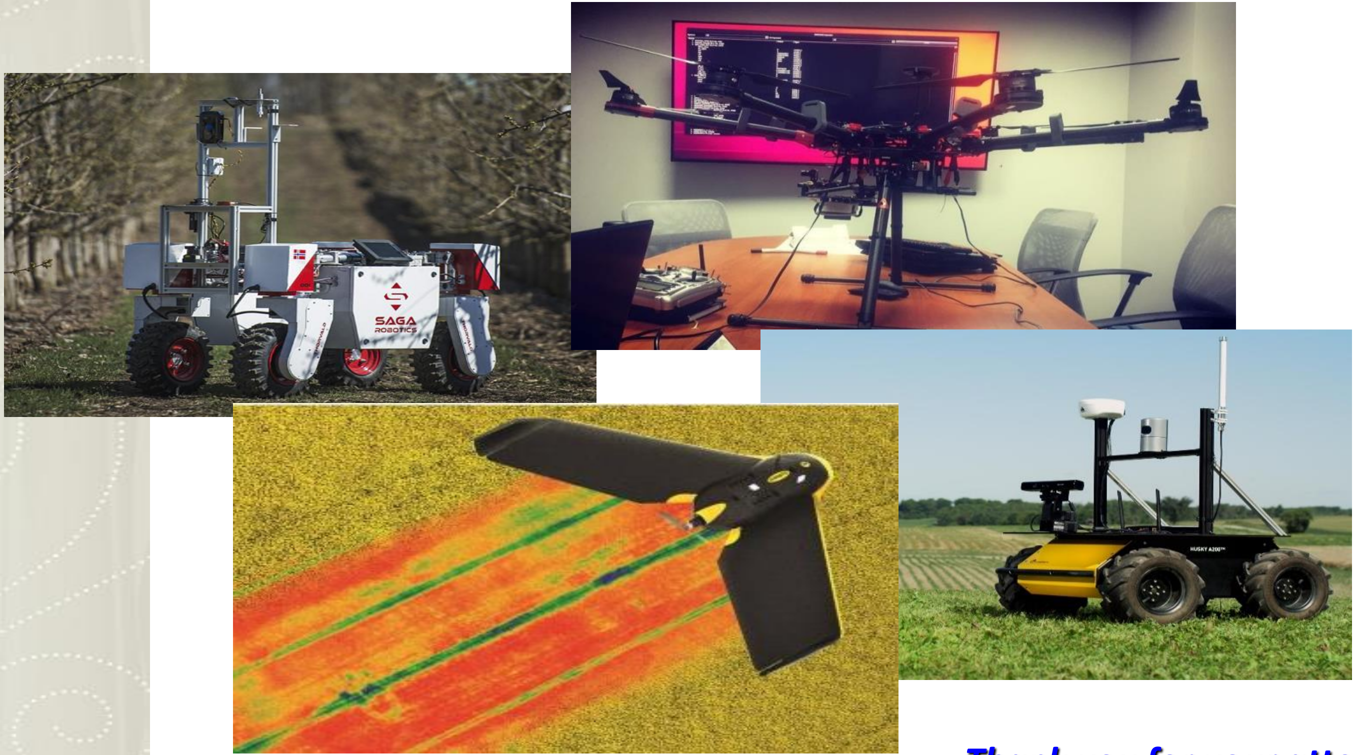
- WEBPORTAL: www.smart-akis.com
- FACEBOOK: @SmartFarmingNetwork
- TWITTER: @smart_akis



Conclusion – Knowledge society

- Knowledge Triangle => The 3 basic development strategy coefficients in the modern era are:

- Research creates knowledge
- New knowledge, on its behalf, is transferred through education and training to the society
- Human resources are obliged to be in a position to apply new technology and managerial methods and processes



Thank you for your attention!

For more details: a.balafoutis@certh.gr