Ref. Ares(2022)1364737 - 23/02/2022

D4.1 Publication of the summer school programme

[VERSION 0.5]

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Date: 26/10/2021

This project has received funding from the *European Union's Horizon 2020 coordination and support Action program* under grant agreement No 952051

Document Information

Grant Agreement #	952051
Project Title	Stepping up and bringing out the scientific excellence and innovation capacity in soil research of the University of Lisbon
Project Acronym	SOILdarity
Project Duration	36 months (1st September 2020 – 31st August 2023)
Work Package	WP4
Deliverable number	D4.1
Lead organization	UGENT
Due date	31/11/2021
Actual submission date	

Document Revision History

Date	Beneficiary	Author	Version (Notes)
28/06/2021	UGENT	Lalit M. Kandpal	V0.1
09/09/2021	UGENT	Abdul M. Mouazen	V0.1 checked
03/10/2021	UGENT	Lalit M. Kandpal	V0.2
05/10/2021	UGENT	Abdul M. Mouazen	V0.2 checked
06/10/2021	UGENT	Lalit M. Kandpal	V0.3
26/10/2021	UGENT	Abdul M. Mouazen	V0.4 corrected following comments by Cristina Cruz
22/02/2022	UGENT	Abdul M. Mouazen	V0.5 Correction following the recommended correction by the reviewer on 15th M meeting.

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Executive Summary

This document is an integral part of the activities described in the Description of Action (DoA) of the project SOILdarity, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952051. It provides a description of the programme of a summer school on management and optimization of farming input resources and adoption of precision agriculture solutions. This will provide the necessary knowledge and tools to increase key performance indicators and research outputs of FC.ID and CIÊNCIAS in the related topics.
The summer school program will focus on theoretical session on precision agriculture and field demonstration on different sensing, modelling and control technologies. The training module will take place in February - April 2022 for 5 days.

The document provides a detailed description of the D4.1 - Summer school on precision agriculture course, which is consider as an integrated part of WP4. In the following sections, the programme will be described, covering different aspects such as the training objectives, their location, activities to carry out, and target audience.

1. Deliverable 4.1

1.1. Aim

Deliverable 4.1 is part of WP4. The objective of WP4 is to develop an informal learning structure to strengthen and consolidate the competences which have been already acquired and provide the attendees with new research insights. This approach aims at stimulating new educational and learning methods in an informal setting. This experience has proved its value in many previous projects or initiatives in which consortium partners were coordinators or participants. The aim of D4.1 is to organise and deliver the programme of a summer school course on management and optimization of farming input resources and adoption of precision agriculture solutions.

1.2. Consortiums' roles and responsibilities

SOILdarity consortium FC.ID, CIÊNCIAS & MIGAL will coordinate with UGENT during the training program and EUKNOW will support locally, to manage the programs' implementation (identification of students available for trainings, selection of participants, venue organization).

1.3. Target Participants

About 15 attendees from FC.ID or CIÊNCIAS will take part in the activities, notably Early Stage Researchers (ESRs) and M.Sc. graduate students who have an adequate background and knowledge of the topics addressed by this deliverable. These crosscutting initiatives could also be made open to other stakeholders such as government entities, industry, public authorities, other educational institutions, professionals etc. The participants will improve their theoretical and practical knowledge in the field of precision agriculture, specifically in soil quality measurements using advance proximal soil and crop sensing, remote sensing and geostatistical modelling.

1.4. Expected Outcome of D4.1

It is expected that participants will:

- Understand the basic concepts of precision agriculture, different sensing, modelling and control technologies.
- Understand the basics of proximal soil and crop sensing methods used in precision agriculture
- Understand remote sensing assets e.g., Unmanned Aerial Vehicles (UAV), airborne, satellite and their application in crop monitoring.
- Some insight into geostatistical modelling tools including mapping.
- Learn about agricultural machinery with variable rate technologies used for site specific fertilization, fungicide, herbicide, seeding, weeding, etc.
- Learn about environmental, socio-economic benefits of precision agriculture.
- Learn about the combination between agroecology and precision agriculture, its strengths and weakness
- Share what they learned in the training modules and practice their research skills with their peers.

2. Detail plan for D4.1

2.1. Course structure

D4.1 plan is composed of two parts:

- Theoretical lectures on precision agriculture.

- Field demonstration on sensing, modelling and control technologies.

2.2. Location, Delivery date & Duration

According to the DoA, the summer school should be held in Lisbon, Portugal in April-May/2022, designed for 5 days.

2.3. Training mode

Schedule via Zoom meetings (Just in case the limitations related to the spread of the COVID-19 should continue) or on-site course (in case the limitations related to COVID-19 have eased to allow physical travelling).

2.4. Supporting material

The creation of specific supporting materials also corresponds to an important part of the preparation process. These materials will be essential to create, discuss or communicate new ideas. Supporting materials include digital tools such as PowerPoint presentation, videos, web-based tools, etc.

2.5. Experts for Theoretical & Practical sessions

Prof. Abdul M. Mouazen, (M), is a full professor in precision soil and crop management and a group leader of Precision SCoRing Group in Ghent University. He holds a PhD degree in numerical modelling of soil-tillage tools interaction and has a background in the application of engineering principles to soil and water management with specific application in soil dynamics, tillage, traction, compaction, mechanical weeding, soil remediation and management. He teaches in topics related to proximal soil sensing for precision agricultural applications at UGent. This includes two courses, namely, Precision Agriculture and Environmental Soil Sensing. He is a member of Global Proximal Soil Sensing Committee, since established. He has implemented Vis-NIR and MIR spectroscopy for analysis of soil, manure, honey, milk, cheese, mandarin, and other food and environmental materials. His experience in vis-NIR spectroscopy and chemometric tools enabled him to develop one of three internationally patented on-line measurement systems of soil properties (Mouazen, 2006). He has coordinated two major European projects (FarmingTruth funded by Euoropean Space Agency & FarmFUSE, funded by EU-FP7 under IRA-NET, ICT-AGRI), and has been a partner in several other national and international projects. He is also the scientific coordinator of H2020 SIEUSOIL project (2019-2022). He also coordinating wo new ERA-NET research projects on topics related to D2.2: 1) ADDFerti - A Data-Driven Platform for Site-Specific Fertigation (funded by the ICT-AGRI-FOOD), and 2) POSHMyCo - Potential of selective harvest based on mycotoxins content assessment in cereal crops (funded by the ICT-AGRI-FOOD). Prof. Abdul is an Associate Editor of Soil & Tillage Research, Soil Research, Biosystems Engineering, Remote sensing and Soil Systems, and has some 190 indexed contributions in Web of Science (h index = 41). Abdul has supervised several postgraduate students working on vis-NIR and MIR spectroscopy applications, with majority working on sensing and control for precision agriculture applications.

Prof. Iggy Litaor, (M), received his PhD in geochemistry from the University of Colorado in 1986. He has been involved in research of soil, water and snow dynamics in the alpine zone of Colorado Front Range since 1981 to present as part of the CULTER program. Between 1990 and 1996, he studied the fate and transport of radionuclides (Pu, Am & U) around a nuclear facility and their potential influence on residential areas around the site. Since 1996, Prof. Litaor is conducting research on the hydro-geochemistry of P in wetlands and in altered wetland soils. The studies encompass the assessment of the mineralogy, sorption-desorption mechanisms, fate and transport in highly fractured peat environs, impact of various land use and land use change on P transport to waterways. More recently Prof Litaor developed a new design of aerated cells/constructed wetlands to treat organic-rich wastewaters such as winery, dairy and olive mills wastewaters. Most recently, his research deals with optimal soil sampling using Pareto optimization approach. His current research projects are: (1) testing the feasibility of P capture, recycling and utilization for sustainable agriculture and a clean environment using Al/Organic Composite water treatment residuals (Al/O-WTR) and Fe-desalinization treatment residue (Fe/O-DTR). (2) Exploring the possibility of co-addition of compost and zeolites for improvement of soil quality and fertility by increasing K availability. (3) Exploring the possibility of co-addition of compost and zeolites for improvement of soil quality in agro- forested setting. (4) Development of integrated solution systems for precision irrigation and fertilizer management.

Prof. Dimitrious Moshou, (M), Prof. Dimitrios Moshou is Head of the Agricultural Engineering Laboratory of AUTH (from December 2011) and Head of the Department of Hydraulics, Soil science and Agricultural engineering. Since November 2018, he is a Full Professor at the Department of Hydraulics, Soil Science and Agricultural Engineering, Aristotle University of Thessaloniki. Between 2008 and 2013, he has been an Assistant Professor at the same Department and Associate Professor between 2014 and 2018. From 2000 to 2008, he was a Senior Researcher and Research Manager at the Department of Biosystems (Research Division MeBioS-MEchatronics, BIOstatistics and Sensors), Katholieke Universiteit Leuven. From 1996 to 1999, he was a Research Engineer at the Department of Biosystems, Katholieke Universiteit Leuven. He received the M.Sc. (5-year Diploma) in Electrical Engineering in 1990 from Demokrition University of Thrace, Greece, the M.Sc. degree in Control and Information Technology in 1994 from University of Manchester, Institute of Science and Technology, UK and the Ph.D. degree in Electrical Engineering in 2005 from Katholieke Universiteit Leuven, Belgium.

Dr. Yafit Cohen, (F), Yafit Cohen is a senior research scientist at the Institute of Agricultural Engineering at ARO. Israel. She possesses a B.A. and Ph.D. in geography from Bar-Ilan University, with specialization in Geographical Information Systems and Remote Sensing. She served as a post-doctoral fellow at the Technion, Haifa during 2002 and specialized in remote sensing for land-use recognition and mapping. Since 2003 she is a research scientist in the Institute of Agricultural Engineering at ARO. She is an adjunct faculty at the Faculty of Agriculture, Hebrew University, and teaches GIS for the last 8 years. During the past 10 years, she served as a member of a number of scientific committees and reviewer of several international peer reviewed journals. She has published more than 40 papers in international peer-reviewed journals, more than 80 papers in other journals and conference proceedings, has served as a guest editor of a special issue of the journal of Biosystems Engineering, and serves today as a member of the editorial board of the Remote Sensing journal.

Prof. Annamaria Castrignanó, (M), Annamaria Castrignanó is a research director at the Council for Agricultural Research and Economics in Bari (Italy). She has been actively involved in the discipline of pedometrics and digital soil mapping for many years. Her knowledge and expertise in geostatistics and statistics has been exemplified in several oral presentations in International conferences and peer-refereed journal articles. She has published more than 250 papers. She has been the scientific leader of national and international projects aimed at the application of precision farming to the cultivation of durum wheat and tomato in Southern Italy and at the use of proximal and remote sensing technologies in agriculture. She has been giving several basic and advanced courses on geostatistics to national and international PhD students and researchers in Italy and abroad. She is currently involved in the implementation of multivariate geostatistical techniques of data fusion with proximal and remote sensors.

Prof. Ludwig Lauwers (°1957) graduated as agricultural engineer (Ghent University, 1980) and obtained master degrees in spatial planning (Ghent University, 1988) and in operational research (Free University of Brussels, 1991). He obtained his PhD in applied biological sciences, agricultural economics (Ghent University, 1994) with a dissertation on the manure problem and structural change in the Flemish pig sector. Currently, he is scientific director at the Social Sciences Unit of the Flanders Research Institute for Agricultural, Fisheries and Food, ILVO, (http://www.ilvo.vlaanderen.be/) and part-time professor farm management at the Department of Agricultural Economics of Ghent University. His fields of expertise are farm management, sustainable agricultural systems and integrated ecologicenvironmental assessment. His main publications are in the field of environmentally adjusted efficiency measurements, sustainable development processes and operational farm planning tools. As a scientific director, he is, and has been, involved in various national and international multi- and interdisciplinary research projects. He successfully led 12 PhD researchers. Both at ILVO and Ghent University, he is involved in precision agriculture research. At ILVO, research mainly concerns precision livestock farming, in particular on the role of PLF on animal health. One of his papers deals with the information value of PLF. He also participates to the ILVO Living Lab on Precision Agriculture. At Gent University, he contributes with an invited lecture to the specialist course on precision agriculture. The lecture discusses production economics and psycho-sociological features as drivers for the adoption of precision agriculture at farm level.

Dr. Lalit M. Kandpal, (M), is a Postdoc Researcher in Precision SCoRing Group in Ghent University. Lalit Mohan Kandpal received his B.S. degree in Radiology from Government Medical College Haldwani, India in 2010. His MS-PhD from Chungnam National University Daejeon, South Korea in 2017. He was working as a Postdoc and Research Professor at the Chungnam National University from 2017 to 2019 where he developed his skills in spectroscopy/imaging and chemometric modelling for quality analysis of agro-food and pharmaceutical products. His field of interest include advance sensing technologies and their applications, data mining, data processing and project management.

2.5. Theoretical lectures on precision agriculture

The different parts of this course are presented by topic-specific specialists. One or more experts from UGENT, MIGAL, and invited lecturers (e.g., Prof. Moshou, Dr. Cohen, and Prof. Castrignanó**)** will deliver each course lecture. The plan of the training program is shown in Figure 1.

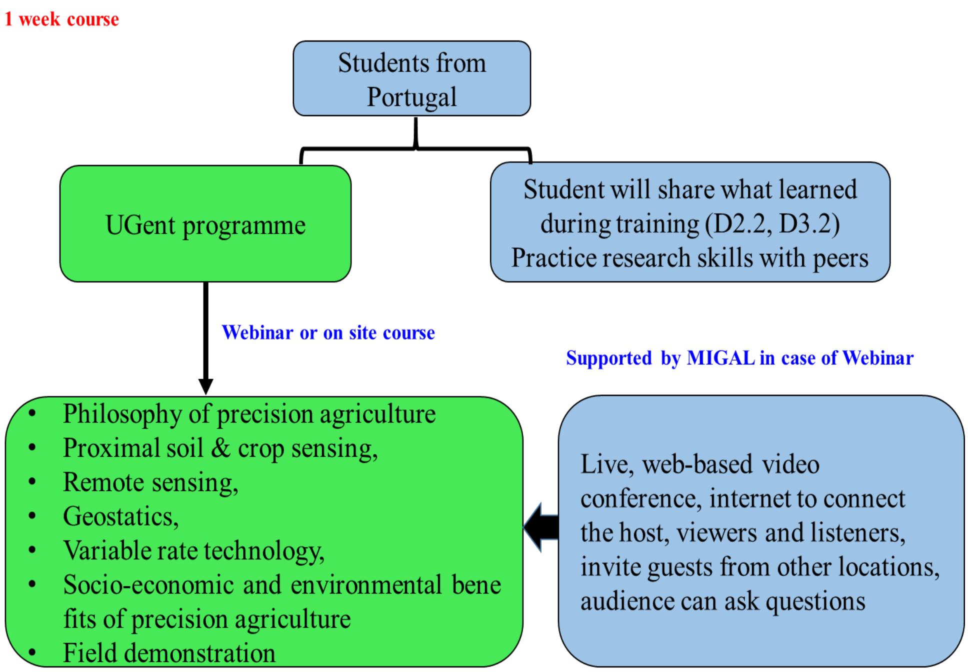


Figure 1: Planning of the summer school on precision agriculture

- **Lecture on philosophy of precision agriculture (by Prof Abdul M. Mouazen).** Precision agriculture aims at managing spatial and temporal variabilities (at field/subfield level) by applying the right farm input (fertilizers, water for irrigation, pesticides, seeds) in right amount, right place and the right time, using the right technologies and practices (Figure 2). The scale of management of variability is down to within field of 5 m by 5 m or even less. The final target of precision agriculture is successful management of within field variability to maximise yield at reduced input cost, and reduced environmental impacts and waste. The final farm output is increased profit and farming production efficiency, whereas a reduced risk for pollution can be achieved by applying less agrochemicals into the environment (e.g., into soil, water and air). The implementation of precision agriculture requires the combination of several technologies into an integrated agricultural management system. These technologies often include global positioning systems, geographical information systems, remote sensing of crop, proximal soil and crop sensing, yield monitoring, geostatistical modelling and mapping, decision support tool (PA software), and variable rate technologies. Apart from the introduction lecture on the philosophy of precision agriculture, the other theoretical lectures that will be discussed under the summer school on precision agriculture are explained below:

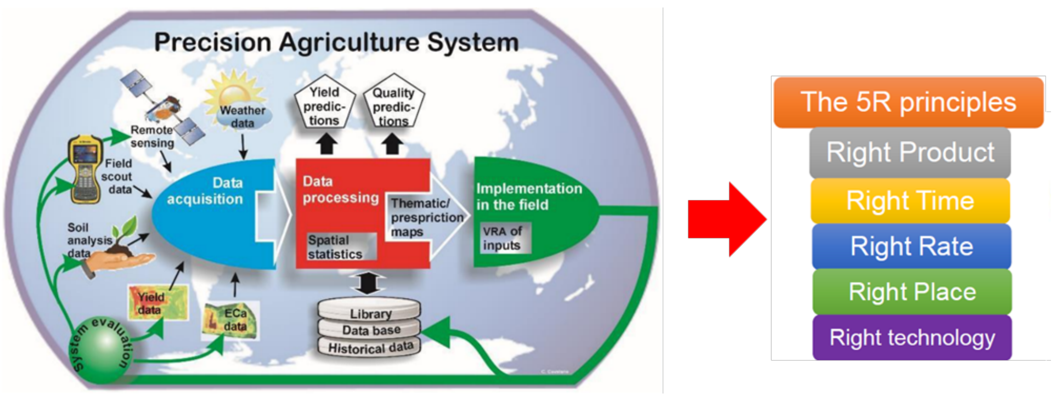


Figure 2: A Precision agriculture system

- **Lectures on Proximal soil sensing (by Prof Abdul M. Mouazen & Prof. Iggy Litaor).** This lecture will be divided into two lectures, with one focuses on geophysical methods (by Prof. Iggy Litaor) and the other one on geochemical methods (by Prof Abdul M. Mouazen).

  Proximal soil sensing refers to the use of field-based sensors to obtain signals from the soil when the sensor's detector is in contact with or close to soil (2-3 m away). The sensors provide information on physical measures that can be related to the soil and its properties. This proximal soil sensing lecture will focus on below topics:

  - **Categorization of proximal soil sensors:** Proximal soil sensors are described by how they measure and operate, the source of their energy and the inference used in the measurement of the target soil property. Figure 3 summarizes the possibilities.

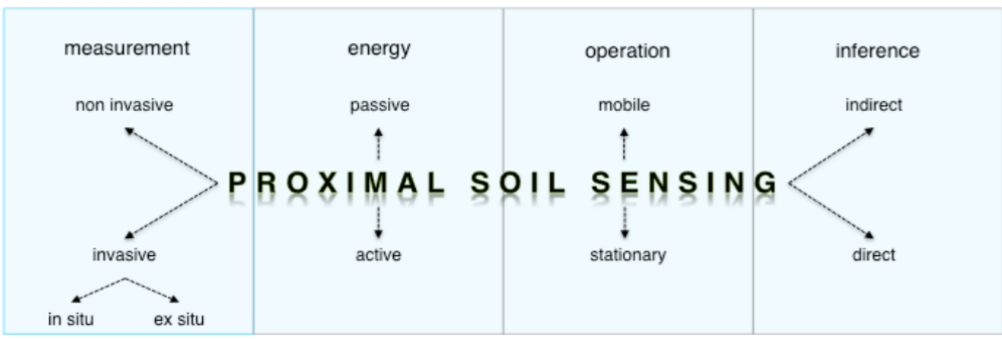


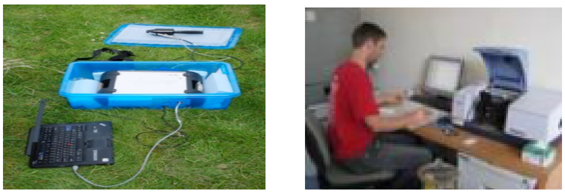
Figure 3: Characterization of Proximal soil sensors (Viscarra Rossel, 2011)

  - **Invasive vs non-invasive sensing techniques:** A proximal soil sensor is said to be invasive if during measurement there is sensor-to-soil contact, otherwise it is non-invasive (Figure 4).

(A) (B)

Figure 4: Proximal soil sensing. (A) Invasive sensing (the sensor is contained within the soil volume being measured), (B) Non-invasive sensing (the sensor is outside the volume of soil)

- **In situ and ex situ techniques:** If measurements are invasive then the sensors may be further described as in situ if the measurements of soil occur in the field in natural position (natural volume of soil) or ex situ if the soil is removed from its natural position e.g. to the lab, which might be associated with sample treatment (drying, sieving, etc.) (Figure 5).



(A) (B)

Figure 5: Proximal soil sensing. (A) In situ technique, (B) Ex situ technique

- **Mobile vs stationary techniques:** Proximal soil sensors may be described as being mobile, in which the sensing system is capable of readily moving and measuring across the soil space or they may be stationary, whereby measurements are made in a fixed position during data collection (Figure 6).

(A) (B)

Figure 6: (A) Mobile technique, (B) Stationary technique

- **Active vs passive techniques:** A proximal soil sensor that produces its own energy from an artificial source for its measurements is said to be active. It is passive if it uses naturally occurring radiation from the sun or earth (Figure 7).

(A) (B)

Figure 7: (A) Passive technique, (B) Active technique

- **Proximal soil sensing methods:** These techniques include optical [visible and near infrared (vis-NIR), x-ray fluorescence (XRF) and mid infrared (MIR) spectroscopy], geophysical (e.g., conductivity, resistivity, and permittivity), electrochemical, passive radiometric gamma ray, strength-draught soil sensors, and multi-sensor & data fusion approach. For more details on the lectures please refer to D2.2 - specialized training program on the use of sensor-based technology, biofertilisers & precision agriculture techniques.

► **Lecture on proximal crop sensing (by Prof Abdul M. Mouazen)**

Like the proximal soil sensing, the crop sensing to the use of field-based sensors to obtain signals from the crop when the sensor's detector is in contact with or close to soil (2-3 m away). The following sensor technologies will be discussed in this lecture.

- Contact sensors (mechanical sensors): These works based on direct contact with the crop canopy, that create deviation of mechanical pendulum from original position.
- Non-contact sensors: These measure reflection by the crop of some sort of radiation (ultrasonic, laser, light). These will also discuss optical sensors, e.g., RGB, multispectral, hyperspectral and thermal cameras (Figure 8).

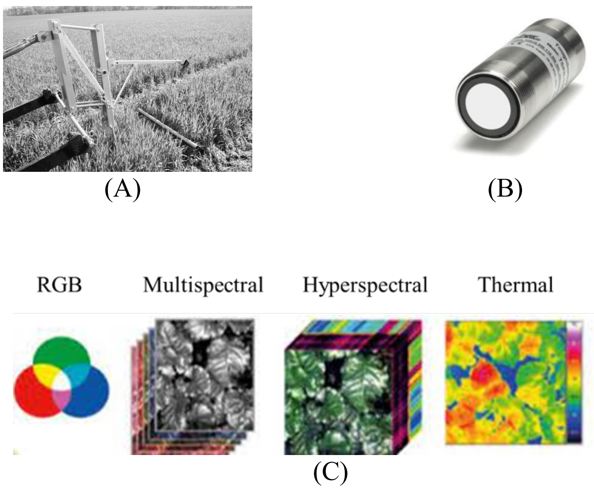


Figure 8: (A) Mechanical (pendulum meter), (B) Ultrasonic sensor, (C) Optical sensors

► **Lecture on remote sensing (by Dr. Yafit Cohen).** Remote sensing is the art, science and technology of obtaining reliable information from non-contact imaging and other sensor system about the earth and its environment, and other physical objects and process through recording, measuring, analyzing and representation. The outline of the lecture is given below:

- **Basics of Remote sensing:** Remote sensing using electromagnetic spectrum to image the land, ocean and atmosphere. Different objects reflect or emit different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both material and the incident energy (angle of incidence, intensity and wavelength). Detection and discrimination of objects or surface features is done through the uniqueness of the reflected or emitted electromagnetic radiation from the object. A device to detect this reflected or emitted electromagnetic radiation from an object is called a "sensor" (e.g., camera and scanners). A vehicle is used to carry the sensor is called a "platform" [e.g., Unmanned Aerial Vehicles (UAV), aircrafts and satellites]. In this lecture we will discuss main stages involved in remote sensing and some application examples (Figure 9).

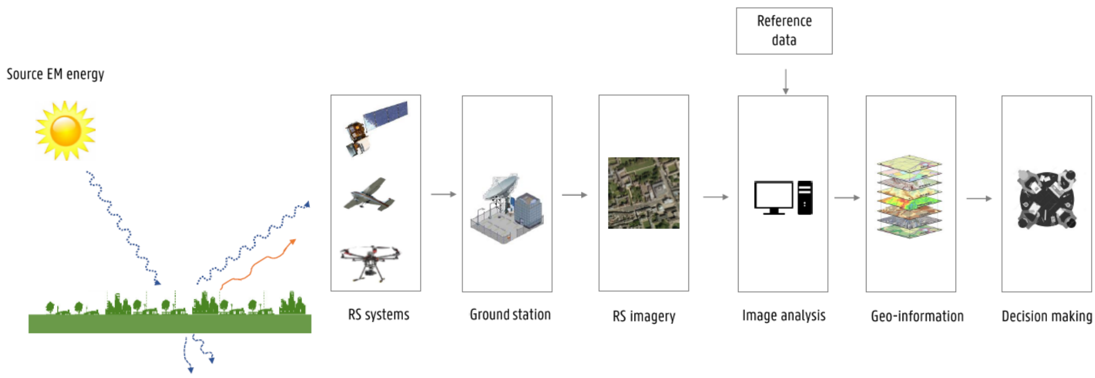
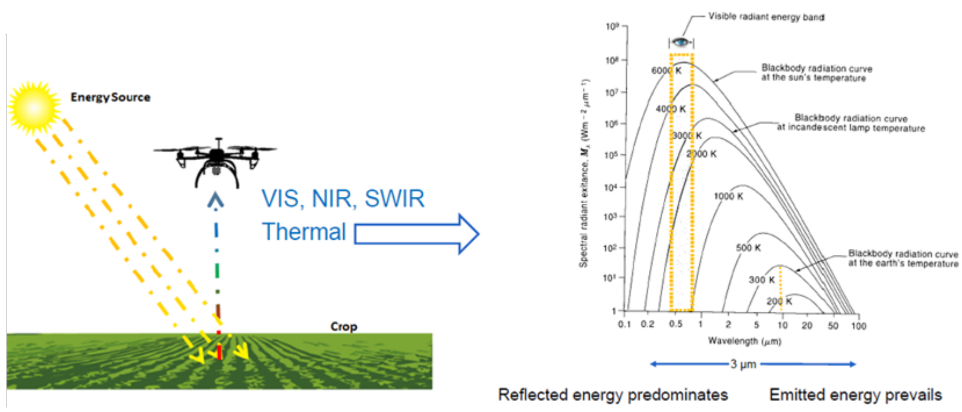
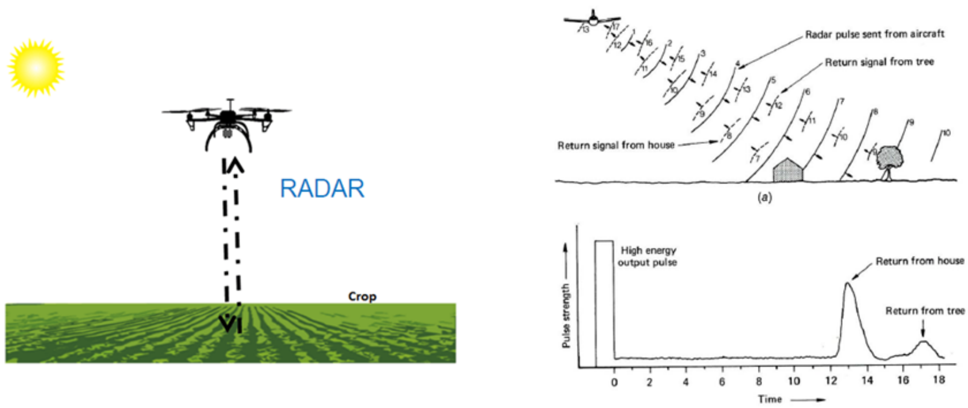


Figure 9: Elements of a remote sensing (RS) system

- **Modes of Remote sensing:** Depending on the source of electromagnetic energy, remote sensing can be classified as passive and active remote sensing (Figure 10). In case of passive remote sensing, source of energy is naturally available such as sun. Most of the remote sensing work is in passive mode [e.g., Vis, NIR, short wavelength infrared (SWIR) and Thermal sensing]. In case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform. Most of the Radar and Lidar sensing is done through active mode.



(A)



(B)

Figure 10: Modes used in remote sensing. (A) Passive sensing, (B) Active sensing (www.senteksystems.com)

- **Remote sensing images:** Remote sensing is one of the first disciplines based on analyzing and using digital images, for which many image-processing techniques were developed under remote sensing projects. Today, digital images are everywhere and remote sensing accounts for only a tiny fraction of their uses. This topic will discuss the fundament characteristics of remote sensing images that include spectral resolution and spatial resolution (Figure 11).

(A) (B)

Figure 11: Remote sensing images. (A) Spectral resolution, (B) Spatial resolution

- **Types of Remote sensing platforms in agriculture:** Remote sensing platforms can be classified as aerial remote sensing and space borne remote sensing (Figure 12). From each of these platforms, remote sensing can be done either in passive or active mode. The aerial remote sensing can be divided into drone and airplane, whereas the space borne remote sensing included satellite-based assets.

Figure 12: Example of Remote sensing platform used in agriculture

- **Vegetation indices (VIs) in remote sensing:** VIs obtained from remote sensing-based canopies are quite simple and effective algorithms for quantitative and qualitative evaluation of vegetation cover, vigor, and growth dynamics, among other applications (Table 1). These indices have been widely implemented with remote sensing applications using different airborne and satellite platforms with recent advances using UAV.

Table 1: Some recently used vegetation indices for remote sensing (Sishodia, 2020)

Index	Definition/Equation	Applications (References)
Normalized difference vegetation index (NDVI)	$\frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}}$	Biomass [144]; breeding, phenotyping [145]; yield [146]; disease [108]; n-management [147]; soil moisture [148]; water stress [149]
Green NDVI (GNDVI)	$\frac{R_{NIR} - R_{green}}{R_{NIR} + R_{green}}$	Water stress [150]; yield [151]; biomass [28,152,153]; disease [154]
Normalized difference red edge (NDRE)	$\frac{R_{NIR} - R_{red\ edge}}{R_{NIR} + R_{red\ edge}}$	Crop yield and biomass [155]; N-management [147]; disease [154,156]
Red edge normalized difference vegetation index (RENDVI)	$\frac{R_{NIR} - R_{red\ edge}}{R_{NIR} + R_{red\ edge}}$	Yield [100,111]; irrigation management [99]; N-status/application [140]; disease [156]
Soil adjusted vegetation index (SAVI)	$\frac{(R_{NIR} - R_{red})(1 + L)}{R_{NIR} + R_{red} + L}$ L - soil conditioning index	Yield [79]; biomass [28,153]; disease [157]; N-concentration and uptake [142]; water stress [158]
Modified soil adjusted vegetation index (MSAVI)	$\frac{2R_{NIR} + 1 - \sqrt{(2R_{NIR} + 1)^2 - 8(R_{NIR} - R_{red})}}{2}$	Biomass [153]; crop yield [159]; N-uptake [142]; chlorophyll content [112,160]
Renormalized difference vegetation index (RDVI)	$\frac{R_{NIR} - R_{red}}{\sqrt{R_{NIR} + R_{red}}}$	Crop yield [159]; N-uptake [142]; soil moisture [148]; biomass [28]
Wide dynamic range vegetation index (WDRVI)	$\frac{\alpha R_{NIR} - R_{red}}{\alpha R_{NIR} + R_{red}}$	N-Application, yield [161]; crop growth (LAI) [162]; disease [113]

- **Application of remote sensing for crop monitoring:** The lecture with discuss several applications including weed detection, assessing nutrient levels, drought stress detection, crop water stress index, pathogen detection, bacterial infraction detection, fungal infection detection, yield prediction, etc.

- **Advantages/disadvantages of remote sensing:** Remote sensing provides data of large areas, particularly for very remote and inaccessible region, in a rapid and cost-effective data collection manner. The interpretation of imagery requires a certain skill level, as data from multiple sensors may create confusion, and that distortions may occur in an image due to relative motion of sensor and source.

- **Lecture on Multi-sensor data-fusion (By Prof. Dimitrious Moshou).** Data fusion as data mining techniques combine elements of raw or predicted data from multiple sensors (e.g., NIR, MIR, HSI, XRF) to extract the greatest amount of information possible about the sensed environment, which is greater than the sum of its contributing parts. Data refers to the actual spectral measurement taken by the sensors and fusion is the process of combining the spectral data in such a way that the results provide more information than the sum of the individual parts. Moreover, one sensor can hardly measure all factors (e.g., soil related yield potential factors) alone, which calls a need for multi-sensor data fusion approach. A schematic picture of multi-sensor data approach is given in Figure 13. The lecture will focus on:

- Multi-sensor data fusion: Theoretical background and types of multi-sensor data fusion techniques (e.g., fusion after prediction, fusion before prediction, etc.).
- Introductory to machine learning and chemometrics techniques applicable for data fusion modelling.
- Case studies based on multi-sensor data fusion. Case studies on specific fungicide application; site specific potato seeding; selective harvest, site specific manure application and site-specific N, P and K fertilization will be presented.
- Practical session of implementation of data fusion techniques. Students will apply different multi-sensor data fusion techniques during the practical sessions in Part 2 of D4.1.

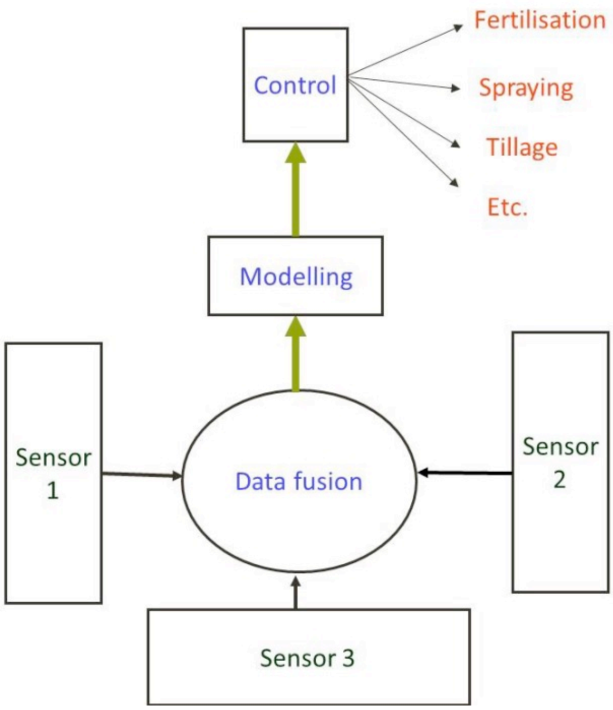


Figure 13. Multi-sensor data fusion in precision agriculture.

► **Lecture on Geostatistics (by Prof. Annamaria Castrignanò).** This course aims to provide a solid background in standard and more advance geostatistical methods, such that they can apply these in their own research. This lecture will include the following topics:

- **Geostatistical theory:** Geostatistics is concerned with the analysis and modelling of spatial variability. It also addresses how quantified spatial variability can be used in optimal spatial interpolation and spatial stochastic simulation.

- **Spatial interpolation methods:** This lecture will discuss about spatial interpolation methods such as Trans surface analysis, Inverse Distance Weighting (IDW) and Kriging. Kriging is the most commonly used geostatistical approach for spatial interpolation. Different methods of kriging will be discussed in this lecture.

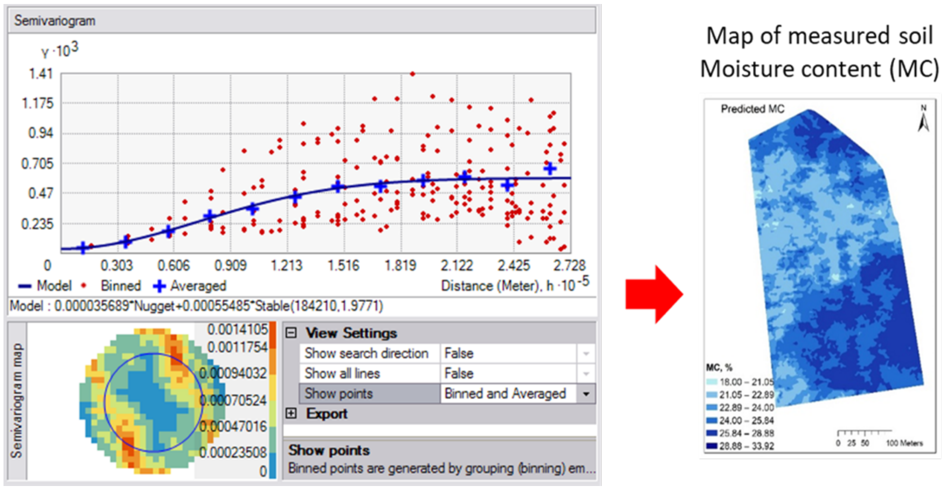


Figure 14: On-line soil moisture content (MC) map developed after semivariogram analysis using ArcMap Geostatistical software

- **Semi-variogram analyses:** Kriging techniques rely on a spatial model between observations (defined by a variogram) to predict attribute values at unsampled locations. One of the specificities of kriging methods is that they do not only consider the distance between observations but they also intend to capture the spatial structure in the data by comparing observations separated by specific spatial distances two at a time. The objective is to understand the relationships between observations separated by different lag distances. All this knowledge is accounted for in the variogram. Kriging methods then derive spatial weights for the observations based on this variogram. It must be noted that kriging techniques will preserve the values of the initial samples in the interpolated map (Figure 14).

- **Clustering and management zone delineation (MZD):** MZD has become an integral part and pillar for the implementation of Precision Agriculture solutions, by dividing the field into zones having similar characteristics according to soil attributes, topography attributes and crop growth and yield. The lecture will demonstrate K-mean clustering approach (Figure 15) and other kinds of approaches such as Fuzzy C-mean for MZD in precision agriculture.

  K-mean algorithm: The k-means algorithm is standard, simplest, unsupervised, and hard clustering algorithm. It is most useful when one wants to form small number of clusters from a large number of given samples. It requires variables that are continuous with no outliers. It chooses a pre-specified number of clusters centers (k) to minimize the within-class sum of squares from those centers. The main idea is to classify k centers, one for each cluster. The best way to place centers is to keep them far away from each other (as much as possible). To do that, in the subsequent step each point belonging to a given data set is taken and is correlated to the nearest center. When all the data points are associated with some or the other centers, the first step is completed and an early grouping is done. At this point it is needed to repeat the step for k new centroids as barycentre of the clusters resulting from the previous step. After these k new centroids, a new association has to be formed between the dataset points (same points) and the nearest new center. For the same a looping structure will be created. In the results of the looping it may be noticeable that the k centers remain the same after some iteration (Galambosova, 2014). Finally, the algorithm aims at minimizing an objective function. The objective function is given as:

$$J(V) = \sum_{i=1}^{c}\sum_{j=1}^{c_i}(\|x_i - v_j\|)^2$$

  where,

$\|x_i - v_i\|$ is the Euclidian distance between x_i and v_j; c_i is the number of data points in i^{th} cluster; c is the number of clusters.

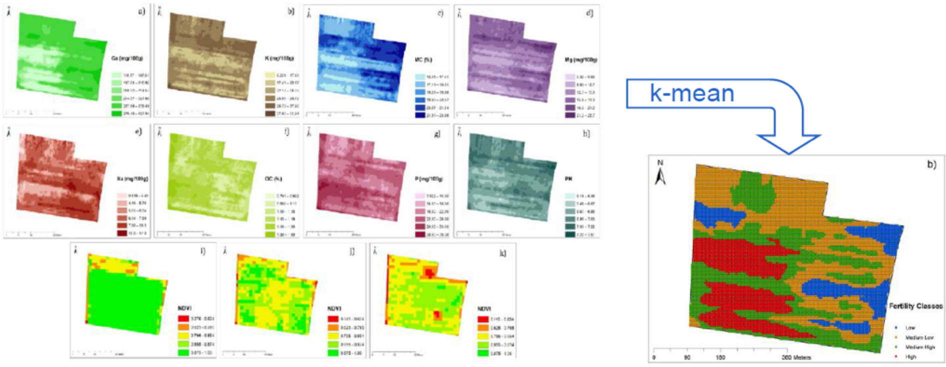


Figure 15: Example of K-means clustering and delineation of MZD for Ca, K, MC, Mg, Na, OC, P and pH.

- **Lecture on variable rate technologies (by Prof Abdul M. Mouazen).** This lecture will focus on variable rate technology (VRT) is the context of precision agriculture that automates the application of farm inputs such as fertilizers, pesticides, manure and seeds according to the crop needs. The lecture will focus on below topics:
    - Variable rate technologies to implement farm resources site specifically. These include machinery for manure application, fertilization, seeding, irrigation, and pesticide application (Figure 16).
    - Potential of socio-economic and environmental benefits precision application of farm input resources. To support the lecture aim, previous and current examples of site-specific applications of farm input resources will be presented.
    - Auto-steering, controlled traffic farming and robotics

Figure 16: Application of variable rate technology in agriculture

- **Lecture on Socio-economic and environmental benefits of precision agriculture (by Ludwig Lauwers).** Misuse of fertilizers and pesticides and lack of awareness of the field parameters can decrease productivity and endanger the environmental balance. PA is about managing variations in the field precisely to grow more food using less input. All aspects of the environment; soil, weather, water varies from place to place. All these factors decide crop growth and agriculture success. Farmers have always been aware of this, but they lacked the tools to measure, map and manage these variations precisely. Thus, PA can make a difference to agricultural production facing the challenge of a growing population and can help farmers to achieve (Figure 17). The topic will discuss key socio-economic and environmental benefits of precision agriculture. The overall objective is to pictures factors to create a successful business model for PA on farms. Will be the production-economic underpinnings, psycho-social factors of adoption and possibilities for co-creating the future developments. The lecture will be structured around three blocks:

1. Features of a good business: how to make business from PA (Canvas Model, Verdienwijzer of ILVO, …)
2. What PA claims (enumerate and position on the Canvas). Under this block the following items are few to mention among others:

    - Yield benefit through increased efficiency.
    - Fertilizer reduction by more precise placement.
    - Pesticide reduction by more accurate application
    - Fuel savings due to less overlap and better monitoring
    - Water saving through more accurate sensing of needs

3. Why these claims do not (yet) drives for PA adoption in practice? From a pessimistic to an optimistic view. This follows the four major steps that will be discussed in the lecture:
    - economic postulates,
    - psycho-social attributes,
    - evidence for added value, and
    - need for co-creative future development.

Figure 17: Benefits of Using Precision Agriculture (source: agrivi.com)

We also intend to discuss the strengths and weaknesses of combining agroecology with precision agriculture, including the barriers for adoption by farmers and potential solutions to overcome these barriers. The main scientific barriers are thought to be the need to generate trustful and correct data on key soil and crop response parameters, and recommendations for variable rate applications. The technological and social barriers concern complexity and high cost of the technology, data sharing, and compatibility of the solution. For the stakeholder (e.g., farmers) other social and economic barriers slow down the adoption of new technologies. These barriers include 1) lack of data proving the economic benefits under different farming conditions and systems for different crops, 2) Social aspect associated with farmers behavior e.g., being reluctant to change, 3) Lack of coordinated demonstration and training programs, 4) Financial risks associated with lack of data of business models and return on investment specially for small- and medium-size farmers.

Potential solutions are:

- Long-term cost-benefit analyses to prove profitability (>5 years research projects).
- Long-term demonstration projects towards benefits/profitability of PA technologies.
- Develop PA technologies that are simple to use, and affordable.
- Hunting for ‘sensing’ technologies in other domains (physics, engineering, chemistry etc) to ensure correct data.
- Science-based technologies to avoid false data collection and recommendations.
- Simplify complexity and enhance automation of existing PA technologies.
- New decision support tools that match requirements of new technologies.
- Continuous training programmes on the use of PA technologies.
- Support service providers-based businesses – *per ha per year charging rate*.
- Long-term studies on environmental & societal benefits of PA.
- Specific subsidies for farmers to invest in PA technologies (e.g., CAP Pilar II).
- Coordinated research actions among EU members.

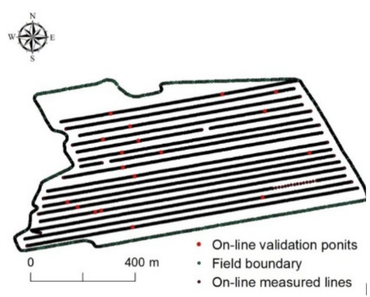
2.6. Field demonstration & practical sessions (Part 2)

The theoretical lectures are also supported by field demonstrations of different sensing, modelling and control technologies.

- **Field demonstrations and practical sessions on sensing techniques.** After theoretical lectures, UGENT team will present a demo about laboratory-based & field-based sensing platforms (shown in Figure 18 and Figure 19). The laboratory-based sensing will be in the form of pre-recorded video. From the video, participants/students will able to understand the actual components of the multi-sensor platform, soil-scanning technique with sensors, spectra collection and data analysis.

Figure 18: UGENT multi-sensor. (a) visible and near infrared (vis-NIR), (b) vis-NIR, (c) mid infrared (MIR), (d) hyperspectral camera, (e) x-ray fluorescence (XRF), and (f) Gamma ray

However, the form of the field-based multi-sensor platform (Figure 17) will be done in reality, by transporting the UGent platform to Lisbon. There the idea is not only a demonstration of the system working in the field, but also to actually scan 2-3 fields and collect soil samples for laboratory analysis. The data output will be used for the following practical session on soil mapping. This output will also feed into D2.3, under which the attendees are trained on how to write a scientific paper.



(A) (B)

Figure 19: UGENT online soil sensing platform (Mouazen, 2006), based on visible and near infrared (vis-NIR) spectroscopy (A). On-line measurement and Measured transects and position of sampling points (B)

- **Demonstration and practical session of spectra pre-processing and modelling technologies.** This lecture will discuss about concept of multivariate statistics used for the analysis of collected data with proximal soil sensors. The focus will be on on-line collected vis-NIR spectral data of soils (the online system is explained in D2.2). The practical session will cover a range of spectra pre-processing and modelling methods such as machine learning techniques and chemometrics (Figure 18). The lectures will focus on both linear and non-linear modelling techniques such as; multiple linear regression (MLR), principle component regression (PCR), partial least square (PLS), linear and non-linear support vector machine (SVM), artificial neural network (ANN), convolutional neural networks (CNN) etc. The entire lecture will follow a series of steps to complete spectral modelling and prediction, as shown in Figure 20.

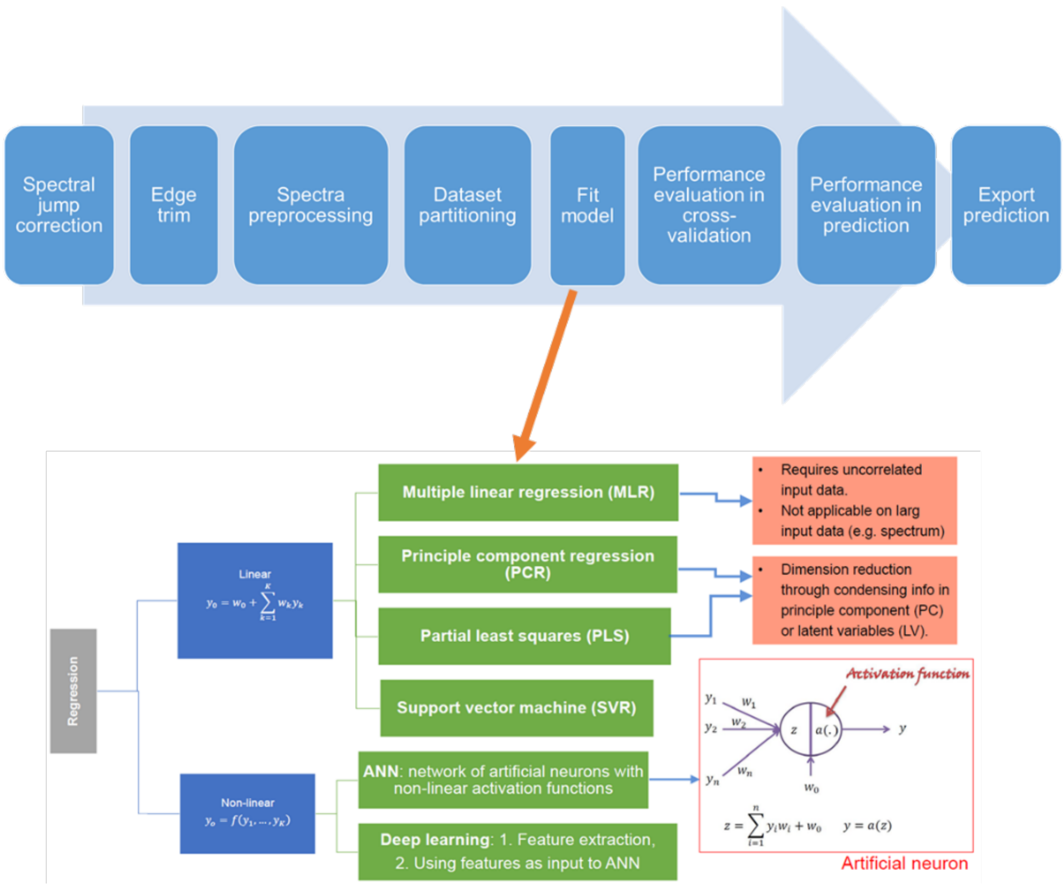


Figure 20: Spectral processing and multivariate calibration techniques used for prediction of several soil properties.

- **Demonstration and practical session on mapping.** The practical session will use the predicted values of soil properties [resulted from the online collected soil spectra to produce high resolution soil maps in ArcGIS software (version 10.0)]. The students will learn the basic steps required for soil mapping in ArcGIS software, and they will apply these steps to generate their own soil maps. The practical part will recall the required knowledge about geospatial features creations, coordinate systems both in geographic and projection scale, spatial interpolation both in deterministic and geostatistical interpolation techniques. Inevitable step of building variogram model for the case of geostatistical interpolation method will also be covered followed by ordinary kriging using the geostatistical analyst toolbox in ArcGIS. Lecture will be ended with exporting soil maps with the desired format after legend generation. The entire process of practical session on mapping is given in Figure 21.

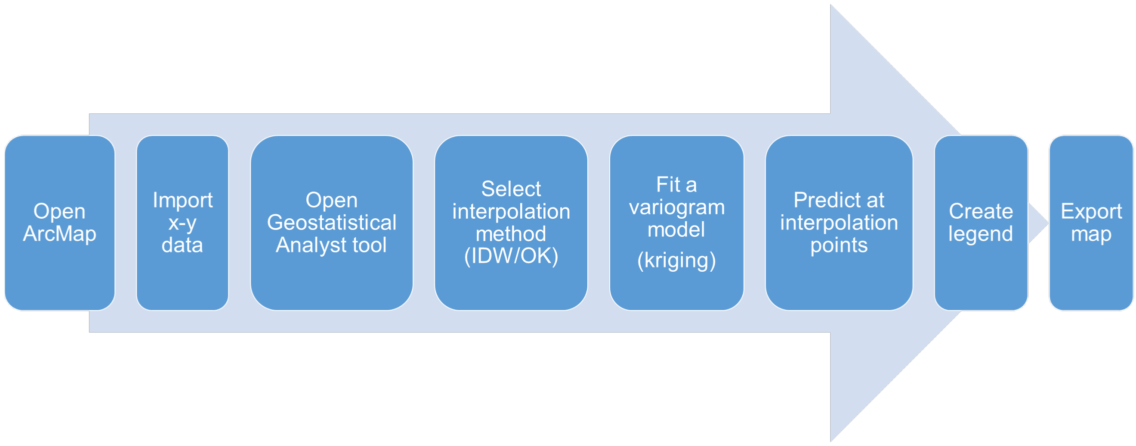


Figure 21. Steps of soil mapping using ArcGIS after online predicted high-resolution soil data.

3. Calendar and Schedule

Table 2: Schedule of summer school programme

Year: 2022; **Location:** Portugal**, Date/Time: April-May**				
Schedule	**Activity**	**Speaker**	**Course description**	**Consortiums role**
Day 1 (5 hr)	Lecture on Proximal sensing	Prof. Mouzazen & Prof. Litaor	**Lecture topics** • Philosophy of precision agriculture • Proximal soil sensing • Proximal crop sensing	UGENT coordinate & MIGAL

Day 1 (3 hr)	Lecture on remote sensing	Dr. Cohen	**Lecture topics** • Basics of Remote sensing • Passive and Active remote sensing • Remote sensing platforms in agriculture	UGENT coordinate
Day 2 (3 hr)	Lecture on multisensor data-fusion	Prof. Moshou	**Lecture topics** • Theoretical background and types of multi-sensor data fusion techniques. The lecture will also include chemometrics and machine learning tools. • Case study on the use of multi-sensor data fusion in precision agriculture.	UGENT coordinate
Day 2 (3 hr)	Lecture on Geostatistics	Prof. Castrignanò	**Lectures topics** • Geostatistical theory • Kriging & Variogram modelling • Clustering and management zone delineation: K-means clustering	UGENT coordinate
Day 2 (1.5 h)	Lecture on variable rate technologies	Prof. Mouazen	• Variable rate machinery (tillage, seeding, fertilization, and spraying of pesticides)	UGENT coordinate
Day 4 (7.5 hr.)	Lecture & workshop on socio-economic & environmental benefits of precision agriculture	Prof. Lauwers & Prof. Mouazen	**Lectures** • Features of a good PA business model • What PA claims (enumerate and position on the Canvas) • Why these claims do not (yet) drives for PA adoption in practice? **Workshop** • Actor gaming • Delphi methods • Priority setting with limited budget • Strengths and weaknesses of combining agroecology with PA • Barriers and solutions to enhance adoption	UGENT coordinate

Day 5 (7.5 hr.)	Field demonstration & practical sessions	Dr. Munnaf	**Field demonstration & practical sessions** • Sensing technologies • Control technologies	UGENT coordinate
Day 5 (7.5 hr.)	Practical sessions	Dr. Munnaf	**Practical sessions** • Demonstration of spectra processing, data fusion and modelling technologies • Demonstration and practical session on mapping	UGENT coordinate

4. References

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