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AGREENSMART

"Make agriculture sustainable through smart-farming"

BOOKLET OF SYLLABI PROPOSALS FOR THE CONSTRUCTION OF A FULL MASTER PROGRAM

August 2023

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This document could not be finalized without the contributions of all members of the consortium of 7 universities across Europe:

- Helsingin Yliopisto (Helsinki, Finland)
- Junia (Lille, France)
- Norges Miljø-og Biovitenskapelige Universitet (As, Norway)
- Perrotis College American Farm School (Thessaloniki, Greece)
- Sveriges Lantbruksuniversitet (Skara, Sweden)
- Université de Liège Gembloux Agro-Bio Tech (Gembloux, Belgium)
- Universidade de Tras-os-Montes e Alto Douro (Vila Real, Portugal)

We would like to thank all contributors from all those institutions.

This document has been also the fruit of all mobilities and exchanges between the students, the teachers and the socio-professional world (companies and industries) that interacted with AGREENSMART consortium from October 2020 to August 2023. The discussions, critics, questions and commentaries from all of those participants enriched our contributions to train the next generation of engineers, farmers, entrepreneurs, managers working in agriculture.

PLAN OF THE DOCUMENT

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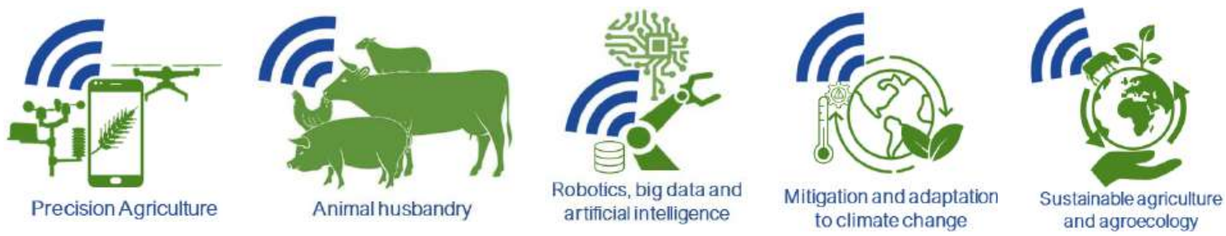
1. Introduction – context of AGreenSmart project

The AGreenSmart project had 2 main objectives:

(i) to develop a new curriculum treating current challenges of crop production and animal husbandry such as climate change, environment, landscape and biodiversity preservation,

(ii) and to train the next generation of farmers, technicians, entrepreneurs, researchers about the roles of technologies to improve the sustainability and the adaptability of agricultural practices to cope with above-mentioned challenges.

During the three (3) years of the project, a consortium of seven (7) universities (Helsingin Yliopisto – Finland, Junia Lille – France, Norges Miljø-og Biovitenskapelige Universitet – Norway, Sveriges Lantbruksuniversitet – Sweden, Perrotis College American Farm School – Greece, ULiège Gembloux Agro-Bio Tech – Belgium, Universidade de Tras-os-Montes e Alto Douro – Portugal) developed contents for three (3) cohorts of ninety-five (95) students in total related to the five (5) following topics:



Each year, the cursus was composed of three (3) activities giving in total 5 ECTS to the students:

- a preparatory project (25-hours) aiming at exploring the specific contexts of agricultural practices, use of technologies for crops and livestock farming and the impact of the use of those technologies on the sustainability of the farms using them within a case-study;
- an introductive e-learning (40-hours), hosted by the moodle platform of UTAD (http://ead.utad.pt/my/, requiring a specific access given by UTAD) aiming at giving refresher courses to all participants knowing that they are coming from different academic backgrounds;
- and an intensive program (70-hours) composed by courses, guided-works, visits, projects and group works covering the five (5) topics of AGreenSmart. It was hosted by 2 campuses (Helsinki-Finland in 2022 and Lille-France in 2023) and was done online in 2021.

2. The AGreenSmart deliverables

The project has four (4) main deliverables concluding intellectual outputs of the project's consortium:

- the first deliverable is related to the e-learning which contains introductive courses for each of the five (5) topics of the project. The plan of the e-learning is given in Table 1 and its access could be given by request (mail to: erasmusplus.agreensmart@junia.com);

- the second deliverable is related to the intensive program during which many contents and activities have been developed by the teachers of the consortium. The plan and the recordings of the activities done during the three (3) intensive programs are freely accessible on the website of the project (https://erasmusplus-agreensmart.eu/home/intensive-programs/);

- the third deliverable is a master level online course composed by the introductive part and with a deepening part which is also available on the moodle platform of UTAD. The access could be also given by request (mail to erasmusplus.agreensmart@junia.com). The plan of additional part (deepening courses) of that online course is given in Table 2, knowing that the introductive part is similar to the first deliverable (introductive e-learning);

- the fourth and final deliverable is the object of this booklet of syllabi which contains proposals of contents from the different stakeholders of the above-mentioned topics

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Table 1: Content of the introductive e-learning of AGreenSmart project

Chapters	Contributors	Plan of the contents
1. Mastering some tools for data analysis	- José Tadeu Marques Aranha (UTAD, Portugal) - José Martinho Lourenço (UTAD, Portugal) - Herinaina A. L. Andriamandroso (JUNIA, France)	1.1. Introduction to tools for data analysis in Smart-Farming 1.2. Introduction to R 1.2.1. The basics of R 1.2.2. Work with data in R 1.2.3. Visualize data in R 1.2.4. Write functions in R 1.3. Introduction to Octave 1.3.1. Where to get Octave 1.3.2. Vectors and matrices in Octave 1.3.3. M-files and plotting in Octave 1.3.4. Functions applied on vectors in Octave 1.4. Introduction to Matlab 1.4.1. Matlab: learn it online – what is Matlab Onramp? 1.4.2. Matlab Onramp tutorial for users 1.5. Introduction to QGIS 1.5.1. QGIS: starting a project 1.5.2. QGIS: deriving a project 1.5.3. QGIS: customizing a map 1.5.4. QGIS: finishing the project 1.5.5. To go further: QGIS full training manual
2. Precision Agriculture	- Johanna Wetterlind (SLU, Sweden) - Laura Alakukku (UHelsinki, Finland) - Athanasios Gertsis (Perrotis College, Greece) - Avraam Mavridis (Perrotis College, Greece) - Bo Stenberg (SLU, Sweden) - José Tadeu Marques Aranha (UTAD, Portugal) - José Martinho Lourenço (UTAD, Portugal)	2.1. Introduction: what is precision agriculture? 2.2. Introduction to soil sensors 2.3. Introduction to crop sensors 2.4. Introduction to weather stations 2.5. Introduction to Geographical Information Systems (GIS) 2.6. Introduction to Global Navigation Satellite Systems (GNSS) 2.6.1. Video transcription 2.6.2. To go further: introduction to GNSS (NovAtel E-book) 2.6.3. To go further: Introduction to GNSS On-demand webinars (NovAtel) 2.6.4. GNSS Quiz (optional) QUIZ – Precision agriculture

Chapters	Contributors	Plan of the contents
3. Animal husbandry	- Jérôme Bindelle (ULiège Gembloux Agro-Bio Tech, Belgium) - Katarina Arvidsson Segerkvist (SLU, Sweden) - Hélène Leruste (JUNIA, France) - Valérie Jacquerie (JUNIA, France) - Herinaina A. L. Andriamandroso (JUNIA, France)	3.1. Prerequisites 3.1.1. Some general vocabularies 3.1.2. Reminder on sexual development 3.1.3. Understand and evaluate the herd's reproductive performance 3.1.4. Some ruminants breeds 3.2. General introduction on animal husbandry 3.2.1. Roles of animals in human history and agriculture 3.2.2. Livestock production systems in Europe 3.2.3. Cycles, products, and reproduction in bovines 3.2.4. Dairy cow production 3.3. Ruminant nutrition 3.3.1. Ruminant digestive system 3.3.2. Digestion of carbohydrates and proteins 3.3.3. Quality of ruminant products 3.4. Introduction to animal welfare 3.4.1. Why do we talk about animal welfare. 3.4.2. Definitions of animal welfare 3.4.3. Measuring welfare 3.5. Grassland management 3.5.1. Planning a grazing operation 3.5.2. Grazing from the perspective of plants 3.5.3. Grazing from the perspective of animals QUIZ – Animal husbandry
4. Robotics, big data and artificial intelligence	- Lars Grimstad (NMBU, Norway) - Mikkel Einvik Stryker (NMBU, Norway) - Benoît Mercatoris (ULiège Gembloux Agro-Bio Tech, Belgium) - Hélène Soyeurt (ULiège Gembloux Agro-Bio Tech, Belgium) - Antti Lajunen (UHelsinki, Finland) - Szabolcs Galambosi (UHelsinki, Finland)	4.1. Introduction to automation 4.1.1. Automation in agriculture 4.1.2. Control strategy 4.2. What is robotics? 4.2.1. Agricultural robots: challenge and opportunities 4.2.2. How do robots perceive the world? 4.3. Introduction to big data and artificial intelligence

Chapters	Contributors	Plan of the contents
5. Adaptation and mitigation to climate change	- Benjamin Dumont (ULiège Gembloux Agro-Bio Tech, Belgium) - Gilles Colinet (ULiège Gembloux Agro-Bio Tech, Belgium) - João Carlos Andrade Dos Santos (UTAD, Portugal)	5.1. Introduction to climate change (including a mini-project) 5.2. Introduction to soil organic matter (SOM) and carbon (C) modelling 5.3. Introduction to crop modelling
6. Sustainable agriculture and agroecology	- Christos Vasilikiotis (Perrotis College, Greece) - Timo Sipiläinen (UHelsinki, Finland) - Hélène Desmyttère (JUNIA, France)	6.1. Sustainable agriculture and the 3 pillars 6.2. Agroecology 6.3. Ecological agricultural principles 6.4. Agroecological practices 6.5. Climate-smart agriculture QUIZ – sustainable agriculture and agroecology

Table 2: Deepening courses for the master level online course of AGreenSmart (to complete the courses, the introductive parts given in Table 1 should be added)

Chapters	Contributors	Deepening courses contents
2. Precision agriculture	- Johanna Wetterlind (SLU, Sweden) - Laura Alakukku (UHelsinki, Finland) - Athanasios Gertsis (Perrotis College, Greece) - Avraam Mavridis (Perrotis College, Greece) - Bo Stenberg (SLU, Sweden) - José Tadeu Marques Aranha (UTAD, Portugal) - José Martinho Lourenço (UTAD, Portugal)	2.8. Within field yield variation 2.9. Case-studies according to the elements: 2.9.1. Variable liming 2.9.2. Use of near-infrared spectroscopy for variable liming 2.8.3. Variable nitrogen fertilization 2.10. Case-studies from different countries 2.10.1. Why Precision Agriculture is important – Finnish examples 2.10.2. Precision Agriculture under Mediterranean conditions – Greek examples 2.10.3. Weather data for irrigation management - Greek examples 2.10.4. Case-study: GIS in vineyards management to control the grape moth 2.10.5. Case-study: Monitoring the expected alcohol degree in order to predict grapes 2.11. GIS and agroecology 2.11.1. GIS applications for agroecology 2.11.2. Case-study: example of GIS applications 2.11.3. Case-study: GIS in vineyards management to control the grape moth 2.11.4. Case-study: Monitoring the expected alcohol degree in order to predict grapes Harvest

Chapters	Contributors	Deepening courses contents
3. Animal husbandry	- Jérôme Bindelle (ULiège Gembloux Agro-Bio Tech, Belgium) - Katarina Arvidsson Segerkvist (SLU, Sweden) - Hélène Leruste (JUNIA, France) - Valérie Jacquerie (JUNIA, France) - Herinaina A. L. Andriamandroso (JUNIA, France)	3.6. Definition of Precision Livestock Farming 3.7. Precision Livestock farming tools used in practice and in research 3.7.1. Chewing activities 3.7.2. Feed intake 3.7.3. Heart rate 3.7.4. Body condition score 3.7.5. Bolus and rumen pH 3.7.6. Body temperature 3.7.7. CH4 measurement 3.7.8. Milk measurement 3.7.9. Accelerometer-based tool 3.7.10. Positioning-based tool 3.7.11. Other collar-based tool 3.7.12. Conclusion on tools used in PLF 3.8. Modelling grasslands 3.8.1. Introduction to the use of models for grassland modelling 3.8.2. Exercises with ModVege model (need of R software)
4. Big data, robotics and artificial intelligence	- Lars Grimstad (NMBU, Norway) - Mikkel Einvik Stryker (NMBU, Norway) - Benoît Mercatoris (ULiège Gembloux Agro-Bio Tech, Belgium) - Hélène Soyeurt (ULiège Gembloux Agro-Bio Tech, Belgium) - Antti Lajunen (UHelsinki, Finland) - Szabolcs Galambosi (UHelsinki, Finland)	4.4. Big data and artificial intelligence for milk production 4.4.1. Introduction to big data and AI 4.4.2. Case-study: detection of ketosis from milk samples (need of R software) a. data exploration b. data pre-processing c. use of artificial neural networks 4.5. Control theory for automated tools 4.5.1. The concept of control strategy 4.5.2. Feed forward control and feedback control 4.5.3. Focus on feedback control 4.5.4. Systems theory 4.5.5. Case-study: controller design 4.6. Robot navigation

Chapters	Contributors	Deepening courses contents
5. Mitigation and adaptation to climate change	- Benjamin Dumont (ULiège Gembloux Agro-Bio Tech, Belgium) - Gilles Colinet (ULiège Gembloux Agro-Bio Tech, Belgium) - João Carlos Andrade Dos Santos (UTAD, Portugal)	5.4. Climate change 5.4.1. Climate crisis, mitigation and adaptation to climate change 5.4.2. Climate-smart agriculture 5.4.3. Case-study: climate change impact assessment (need of QGIS, NASA Panoply and Climate Data Operators software) 5.5. Soil organic matter 5.5.1. Review of soil organic matter 5.5.2. The carbon stock issue 5.5.3. Soil carbon and priming effect 5.5.4. Soil carbon and agricultural practices 5.5.5. Case-study: the carbon modelling (need of R software) 5.6. Crop modelling and climate change 5.6.1. Context of soil and crop modelling 5.6.2. STICS model 5.6.3. MiniSTICS model 5.6.2. Exercises using STICS INRAe and Mini-STICS crop model 5.6.3. The mini-STICS: exercises about crop modelling and climate change (need of R software) Part 1: determination of the driest year Part 2: Impact of the stress on the crop growth Part 3: Impact of the soil change 5.6.4. Exercise: use of STICS crop model (2021)
6. Sustainable agriculture and agroecology	- Christos Vasilikiotis (Perrotis College, Greece) - Timo Sipiläinen (UHelsinki, Finland) - Hélène Desmyttère (JUNIA, France)	6.6. EU Green Deal and new common agricultural policies 6.7. Economics and sustainability 6.8. Exercises in SEGAE: a serious game platform for sustainability assessment

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3. The booklet of syllabi

Following the building of the contents and activities for AGreenSmart, the consortium admitted that 135 hours of workload in total would not be sufficient to train master level students about those five complementary topics. All teachers and experts of the consortium agreed to answer to the question: if we do have 2-years of completing Master program to cover all the 5 topics, which contents would you suggest?

The aim of this booklet of syllabi is to give a toolbox for academic people to prepare and build later a full Master program based on the proposals that will be given in this document and based on existing courses or similar courses that could be included to that new cursus.

The format of the complete 2 years would look live the figure 1. It includes 75 ECTS of courses, guided and practical works, projects activities and 45 ECTS of internships at the end of each level.

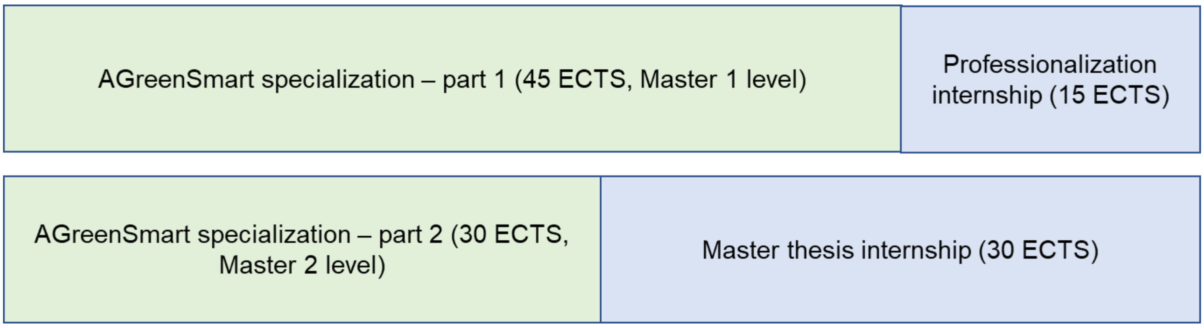
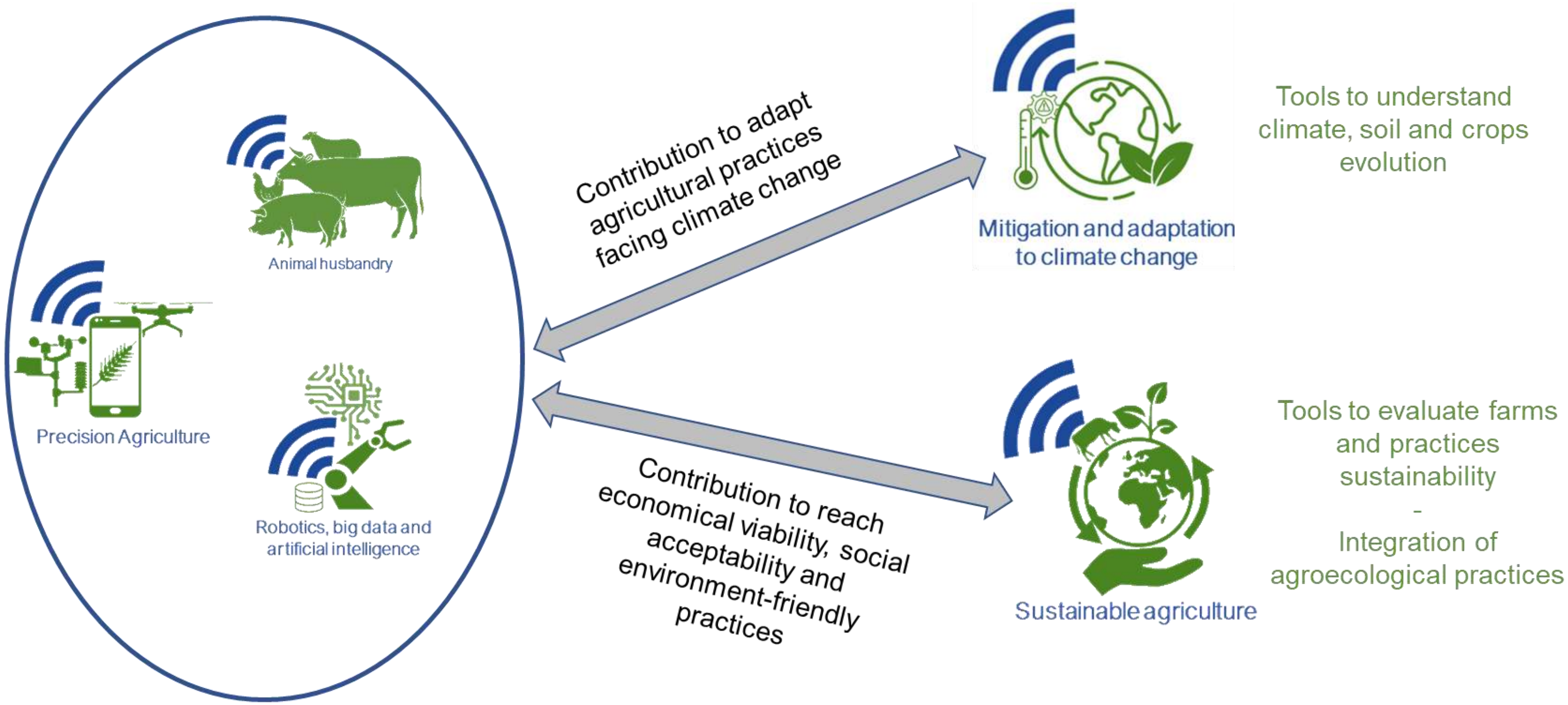


Figure 1: format of the 2-years Master AGreenSmart program proposal

The reflection was based on the complementarity between the five topics of AGreenSmart following the figure 2.

Then, each team of each topic gave proposals of courses to fill up the 75 ECTS of pedagogical contents as illustrated in figure 3. Those proposals are not fixed or immutable according to the objectives of the institution that would like to really build the Master program.



Understanding of agricultural practices
Overview of technologies for data acquisition and for decision support
Tools for data analysis

Figure 2: Thinking pattern used for the construction of the contents of a Master program covering the 5 topics of AGreenSmart

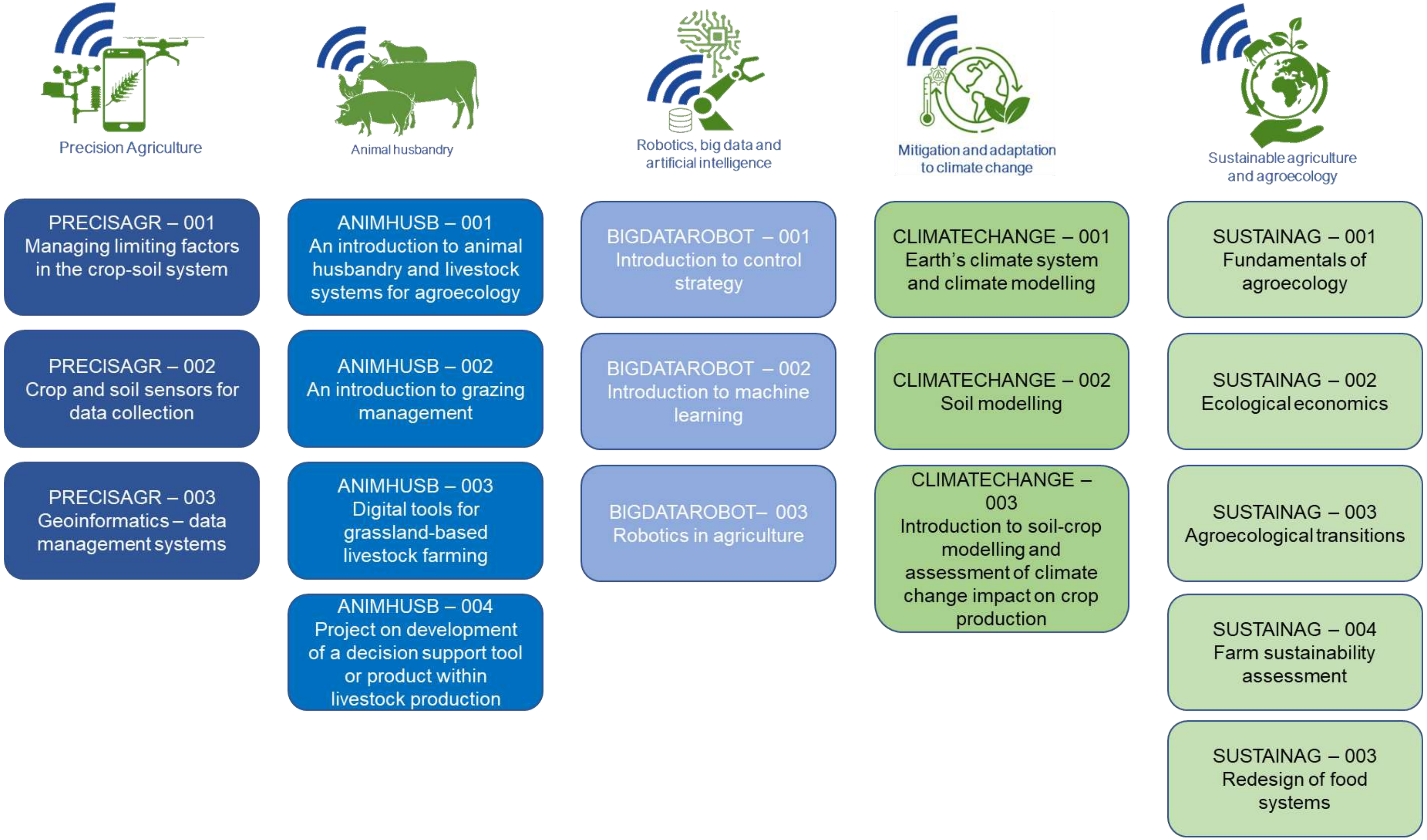


Figure 3: map of the syllabi proposals for the 5 topics of AGreenSmart: precision agriculture, animal husbandry, robotics/big data and artificial intelligence, mitigation and adaptation to climate change, sustainable agriculture and agroecology

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I. PRECISION AGRICULTURE

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PRECISAGR – 001: Managing limiting factors in the crop-soil system
Students level: Master 1 Language: English Keywords: Soil science; crop science; Crop management; Sustainability Ideal course period: N/A
ECTS: 6
Objectives: - To introduce students to the concept of precision agriculture and its driving forces - To identify factors that may limit production in the soil-crop systems - To discuss the influence of variability on resource use efficiency and sustainability - Discuss management strategies that consider limiting factors and their variability
Developed skills at the completion of the course: On completion of the course, students should: - be able to account for the concept of precision agriculture based on the official ISPA definition - have a good understanding of physical, chemical and biological factors in crop-soil systems that may limit production and what implications variability of these factors across cropping units might have on production, product quality, resource use efficiency, and sustainability. - be able to suggest management strategies for crop nutrition, crop protection, weed control and water supply that consider variability, limiting factors and available management opportunities in different climate regimes
Content of the course: 1. Introduction to precision agriculture including definition (Face-to-face 4h) 2. Main limiting factors in the soil-crop systems (Face-to face, 4h) 3. The concept and importance of variability (Face Face-to-face, 6h + guided works/calculation exercises in class 4h) a. Site given factors influencing (soil type/quality, topography, climate) b. Management related factors influencing (timing, crop sequence, manure in the crop sequense, soil management) c. How can variations within cropping units affect nutrient use efficiency, product quality, yields, losses including eutrophication and greenhouse gas emissions, pesticide requirements and water requirements, and what is the potential of adopting inputs to variations. 4. Management practices to increase resource use efficiency (IUE). This section will need to include some advanced crop management practice according to a-d below. (Face-to-face 10-12h + guide works on management plans 10-12h) a. Established fertilization strategies and how variable rate application can be implemented

b. Established pest and weed management strategies based on IPM and how site-specific considerations can be integrated c. Established water management strategies and opportunities for variable rate irrigation and soil management. d. Established tillage strategies and opportunities to spatially and temporally variable tillage 5. Study visits (visits 10-12h + practical works 10-12h) a. Field visit at experimental/demonstration farm b. Field visit at 1-2 regular farms with PA implemented c. Individual reports reflecting on the practical situation considering 1-4
<u>Examination format:</u> Quizzes for 1-4 and written reports on study visits (5c)
<u>Additional information:</u> Students should have a solid background in agronomy and soil and crop science.

PRECISAGR – 002: Crop and soil sensors for data collection

Students level: Master 1
Language: English
Keywords: Optical and radiometric sensors; Electrical and electromagnetic sensors; Mechanic sensors; Acoustic and pneumatic sensors; Electrochemical sensors; Reference analyses methods; Crop and soil sampling strategies; Digital decision support systems
Ideal course period: N/A

ECTS: 5

Objectives:

- To give an overview of principles behind different types of sensors
- To give an overview of data acquisition strategies
- To discuss factors influencing sensor measurements
- To practice mathematical transition of sensor output to crop and soil information - empirical multivariate modelling
- To have an introduction to multi sensor systems and decision support systems

Developed skills at the completion of the course:

On completion of the course, students will :

- be able to gather and assess data and provide services to the farming community,
- be able to select and use appropriate sensors to collect reliable data,
- be familiar with common types of multivariate calibration techniques, machine learning and AI (opportunities and limitations).
- be able to select and justify appropriate data sources and combinations of data and methods of analysis, taking into account the scale of application, data quality requirements, and cost and time requirements,
- be able to perform routine calibrations in standard software's, statistically evaluate and describe performance and reliability, and understand the importance of validation,
- be able to use and have an understanding of available DSS's and multi sensor systems to assess best practices and describe, at a general level, relevant legal aspects of data management, including the EU's General Data Protection Regulation (GDPR), as well as how to establish a data management plan.

Content of the course:

1. Introduction to sensor technologies (8h, Face-to-face)
   a. Overview of sensor and detector technologies
   b. Operating principles of proximal and remote platforms
   c. Continuous vs repeated measurement opportunities and limitations of use.

2. Setting up measurements systems (8h Face-to-face + 10-12h practical work + 4h guided works)
   a. Introduction to available data sources other than sensor data
   b. Introduction to different data acquisition strategies (random, stratified, etc; Vector vs. raster data)
   c. Use of support data for stratified sampling
   d. Practical sensor handling

e. Data management (collection, quality control, storage) f. Data base management g. planning a measurements system to estimate soil properties and crop development on a field during a growing season 3. Multivariate calibration, machine learning and artificial intelligence (8h Face-to-face + 10-12h practical work + 4h guided works) a. Introduction to multivariate calibration techniques b. Introduction to machine learning and AI in connection to data handling c. Robust calibration - Strategies for representative calibration and validation d. Solv a problem using multiple data sources e. Introduction to multi sensor systems and available decision support tools
<u>Examination format:</u> Quizzes and written reports from practical work

PRECISAGR – 003: Geoinformatics – data management systems

Students level: Master 1
Language: English
Keywords: GIS (Geographic Information Systems); Remote sensing; Proximal sensing; GNSS (Global Navigation Satellite System); geostatistics; Spatial modelling
Ideal course period: N/A

ECTS: 5

Objectives:

- To understand GIS and data management concepts
- To apply GIS tools to analyse soil and crop status and distribution
- To understand basic remote and proximal sensing concepts
- To apply proximal and remote sensing data to characterize crops and soil
- To understand the GNSS operating principles, error sources and positional accuracy
- To use GNSS to locate spatial crop data

Developed skills at the completion of the course:

On completion of the course, students will be able to:

- represent real world agriculture with GIS maps
- collect field data using GNSS systems
- use proximal data and remote sensing imagery to characterize crops and soils
- use GIS tools to model and analyse crops, design irrigation, crop protection and fertilization programs

Content of the course:

30 to 45 hours course
Face-to-face or e-learning course
Guide works and practical works

1. Geographical Information Systems (GIS)
    - 1.1. Data models: vector and raster
    - 1.2. Alfa numeric databases
    - 1.3. Spatial analysis: distance, neighbourhood, geostatistics, modelling
    - 1.4. Map algebra
    - 1.5. Cartography and Mapping
2. Remote sensing (RS)
    - 2.1. Basic principles
    - 2.2. RGB colour and false colour composition
    - 2.3. Vegetation indices calculation
    - 2.4. Image processing and unsupervised image classification: principal components analysis and cluster analysis
3. Global Navigation Satellite Systems (GNSS)
    - 3.1. Overview of GPS, GLONASS and EGNOS systems
    - 3.2. Error sources, precision and accuracy
        - 3.2.1. Wide area augmentation services
        - 3.2.2. Differential GNSS, RTK, PPK and post-processing corrections
4. GIS, RS, GNSS and other sources association in precision agriculture

Examination format:
Formal examination in classroom: students will have to create a GIS project integrating Remote Sensing and GNSS data. Characterize a farm and a crop, to create thematic maps and perform statistical analysis. Submit the GIS project and a report. Remote examination: the students must complete the same tasks as in formal examination and preset the project in an oral presentation (e.g. power point) in order to guarantee the authorship of the work and that they have real knowledge in the matter

II. ANIMAL HUSBANDRY

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LERUSTE Hélène (helene.leruste@junia.com)

ANDRIAMANDROSO Herinaina (herinaina.andriamandroso@junia.com)

ANIMHUSB – 001: An introduction to animal husbandry and livestock systems for agroecology
Students level: Master 1 Language: English Keywords: Livestock systems – Physiology – Production – Behaviour and welfare – Indicators of production Ideal course period: -
ECTS: 3
Objectives: - Acquire the specific vocabulary of animal production - Know how the main animal-based products are obtained (milk, meat, eggs) for different species (production cycle) - Know the physiology of reproduction and production - Know the importance of the main factors of production such as feeding strategy, comfort of housing and equipment - Know the indicators of the production in terms of quantity and quality and range of expected performance
Developed skills at the completion of the course: On completion of the course, students will be able to: - Describe and analyse the functioning and performance of specific livestock system in the european technical and geographic context - Describe some challenges of livestock productions in the European context
Content of the course: - Introduction to some of the main animal production in Europe (dairy cows, beef cows, dairy sheep and lamb meat, dairy goats, pigs, broilers, laying hens, rabbits) - self learning platform- 8h - Introduction to animal behaviour – Lecture – 3h - Introduction to livestock systems and tools to address agroecological approaches in livestock systems (based for example on the framework proposed Bonaudo et al 2014) – Farm visits – 12-16h - Introduction to animal welfare and welfare auditing tools - Lecture/practical + farm visit - 12h
Examination format: - Quizz on the online self-learning - Minutes of the farms visits

ANIMHUSB – 002: An introduction to grazing management
Students level: Master 1/Master 2 Language: English Keywords: Grazing lands – Physiology of forage plants – Herbivores – Pasture management – Diagnosis Ideal course period: April - May
ECTS: 3
Objectives: - To know the distribution and functions of grazing lands - To know the physiology of forage plants - To know how to plan a grazing operation - To be able to see the grazing from the plants and herbivores perspectives - To be able to monitor a pasture and to make a diagnosis on it
Developed skills at the completion of the course: On completion of the course, students will be able to: • understand the biotic and abiotic elements influencing the composition of forage plants, their growth, and their nutritive value; • Understand the underlying mechanisms of the interaction between herbivores and the grazed plants • understand how to use the tools required for pasture management in order to secure the long-term production potential of pasture and rangelands; • be able to identify the most important grasses and know their interests for herbivores; • master tools allowing to measure the quality of forage plants and grasslands, measure the production potential and determine their carrying capacity with insights to the use of IT into grasslands agriculture.
Content of the course: Alternance of face-to-face course, practical exercises and field trips. A. Face-to-face courses are divided in six key chapters (3h of teaching each): 1. Distribution and functions of grazing lands a. Definition of key concept (grazing, grazing management, pastureland, rangelands, grazing lands, forage) b. Distribution of rangelands in the world and factors influencing this distribution c. Overview of key natural pasturelands (prairies, cold steppes, tundra, shrublands, woodlands, savannas, hot steppes) d. Role of grazing lands for Mankind and ecosystem services provision e. Energy flows in grassland ecosystems and management levers to influence the efficiency of energy transfer 2. Physiology of forage plants a. Why focus on poaceae? b. Morphology c. Growth stages d. Photosynthesis e. Tolerance to heat, drought and waterlogging f. Winter hardiness 3. Planning a grazing operation a. The 3 levels in space and time to organize and plan the management of grazing lands

   b. Inventory of grazing resources (including the forage system)
   c. Function of the pastures
   d. The management of grazing
4. Grazing from the perspective of the plants
   a. The prey-predator relationship
   b. Strategies to cope with the threat of defoliation
   c. Mechanisms of grazing resistance
      i. avoidance
      ii. tolerance
   d. Management levers to optimize grazing based on plant centered concepts
      i. Stocking rate
      ii. Grazing duration, interval, intensity in rotational stocking
5. Grazing from the perspective of the herbivores
   a. Multiple scales of the grazing process
   b. Key elements in the mechanics of grazing
   c. Relationship between sward structure and bites
6. Pasture diagnostics and monitoring (in the field showing the use of the different tools)
   a. Diagnostics and the role of vegetation composition
   b. Methods to assess the botanical composition
   c. Monitoring methods
      i. Biomass
      ii. Height
      iii. Fields methods, reference methods, estimate, remote sensing
      iv. Monitoring the animals

B. Practical exercises support the face-to-face teaching and allow students to deepen their knowledge and connect the different chapters together :

1. Planning a grazing operation => calculation of a feed budget of a model farm (based on an excel sheet as practical tool)
2. Physiology of forage plants + grazing from the perspective of the plants => Monitoring forage growth (based on grass plots that are weekly cut by the students at different sward height)
3. Grazing from the perspective of the herbivores => observation of grazing cows or ewes (on pasture with contrasting attributes (e.g. sward height) student count the key features of the grazing behavior (feeding stations, grass-severing bites, steps) and compare them)
4. Pasture diagnostics and monitoring => diagnose a pasture by general observation, identifying key species, drawing conclusions and management recommendations for farmers (similar to pasture management consultant, use of an excel sheet for data analysis).

- C. Half-a-day field visit to a forage extensionist or forage variety testing center, etc.

Examination format:

Individual reports on the four practical exercises and discussion on a personal mind map of grazing management built using the the theory an exercise.

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ANIMHUSB – 003: Digital tools for grassland-based livestock farming
Students level: Master 1/Master 2 Language: English Keywords: grassland modelling, machine learning, wearable sensors, spatialization Ideal course period: -
ECTS: 3
Objectives: To learn how to provide useful information for the management of livestock using grassland-based systems as case-study: - grassland vegetation models - information extracted from wearable sensors
Developed skills at the completion of the course: Upon completion of the course, students will be able to: - understand how discrete dynamic mechanistic vegetation models work - analyze technological innovation for their relevancy in the framework of improving the sustainability of animal husbandry - use the statistical software R for the mathematical modelling of grasslands dynamics and sensor data processing - analyze large data sets coming from wearable sensors
Content of the course: Chapter 1: introduction to grasslands modelling (face-to-face lecture - 3h): - general reminders on dynamic mechanistic modelling; - similarities and differences between crop and grasslands models - types of grasslands models (which and how processes are simulated: phenology, photosynthesis, stomata, carbon allocation, N uptake, etc.) - presentation of the structure and the equations of a dynamic mechanistic grassland model (e.g. ModVege; Jouven et al., 2006) used in the course Chapter 2: applied grassland modelling exercises (guided works – 6h): - based on the R code of a dynamic mechanistic grassland model (e.g. ModVege; Jouven et al., 2006), explore the structure of the model by adding variables, editing equations, etc.; - perform a sensitivity analysis on key parameters; - use a user-friendly model interface (e.g. R-Shiny) to explore *in silico* the impact of key management practices (grazing calendar, mowing, botanical composition, etc.) on the dynamics of grassland growth across a 20-year climate series Chapter 3: spatialization of vegetation models (face-to-face lecture - 3h): - reasons to spatialize models or not (weather, soil, vegetation, animals?); - definition of heterogeneity and relationship with the grazing process; - metrics of heterogeneity and ways to measure it (field methods vs. remote sensing); - methods to spatialize models (scale? Implicit vs. Explicit spatialization? Elementary geometric shapes? etc.) - examples of spatialized models Chapter 4: applied spatialization of model exercises (guided works – 3h): - adapt the R code of the model used in Chapter 2 to spatialize the model - extract useful state variables to initialize a spatialize model from RPAS remotely sensed data (vegetation maps based on spectral data and surface-from-motion algorithms)

Chapter 5: presentation of automated measurement on animals (face-to-face lecture – 3h):

- key elements to measure (location, activity, intake, temperature, reproduction events, production, gait, etc.) and reference methods
- types of sensors (physical) and signals
- illustration of research and commercial solutions to automatically extract information related to animal health, reproduction, growth, activity, etc.

Chapter 6: extracting information from wearable sensors (guided works – 9h):

- Use an actual dataset from IMU and GPS data coming from wearable sensors worn by grazing herbivores (experimental data)
- Describe the data treatment pipeline to convert from raw sensor data to activity of animals
- Cleaning and synchronising raw sensor data with observation data
- Explore the dataset by extracting signals related to specific unitary behaviours (e.g. grazing vs. rumination) and plot the different raw signals in time and frequency domains
- Train predefined ML algorithms to predict grazing, rumination and other unitary behaviours based on IMU data
- Use the GPS data to extract spatialized information on the exploration of the pasture by herbivores during the grazing process
-

Examination format:

-Exercise with R scripts related to the content of the course

ANIMHUSB – 004: Project on development of a decision support tool or product within livestock production
Students level: Master 1 semester 2 or Master 2 semester 1 Language: English Keywords: Decision support tool – livestock – Development Ideal course period: N/A
ECTS: 6
Objectives: - To understand how decision tools in animal production work - To design a new decision tool within animal production
Developed skills at the completion of the course: On completion of the course, students will be able to: - analyse the demand of a sponsor/client - propose a solution/tool to this demand - manage a project (project schedule, anticipation of risks, evaluation of the resources and constraints, distribution of tasks) - develop relationships and communication (within the group, with the sponsor and tutor)
Content of the course: - 10 days of group work spread over the semester - Before the beginning of the project, the teachers will have prepared a list of requests of partner companies and/or farmers who agreed to participate to the course as “clients” for the groups of student. - Work phases, based on the topic selected from the provided list: literature analysis / benchmark of existing solutions, writing a technical specification agreement, development of a tool/solution, test of the solution on a data sample and/or on a farm
Examination format: - Technical report presenting the solution and the methodology to get it - Oral presentation of the solution
Additional information: The sponsor can be a private company, technical institute, research center. The project can be integrated in a broader research or R&D project

III. ROBOTICS, BIG DATA AND ARTIFICIAL INTELLIGENCE

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BIGDATAROBOT – 001: Introduction to control strategy
Students level: Master 2 Language: English Keywords: control theory, systems dynamics, feedback systems Ideal course period: fall
ECTS: 4
Objectives: - To acquire the specific vocabulary of the control in autonomous systems. - To understand the concept of feedback and feed-forward control strategies. - To understand the basics of systems theory. - To establish the functional scheme of the dynamic behavior of a system. - To analyze the dynamic specifications of a feedback control. - To model the feedback control of an autonomous navigation system.
Developed skills at the completion of the course: After the course, the student will be able to describe the dynamic behavior of a feedback control, assess its specifications and develop models to design basic control of a path tracking system. The student will be also able to communicate with engineers and technicians in the field of automation.
Content of the course: The course is composed of 3 parts: • Part 1: Systems theory • Part 2: Control theory and feedback specification • Part 3: Case study: design of a controller for path tracking Each part includes: • one face-to-face session (2h) developing the theoretical concepts. • one practical session (3h) applying in practice the exposed theoret-ical concepts using exercises supervised by computer. • one homework (3h) based on the modeling of a more complex case. Consequently, the course is composed of 6h of face-to-face, 9h of practi-cal session and 9h of homework.

Examination format:
- Implementation of a project related to navigation modeling.
- Oral examination:
    o answering questions related to the theory.
    o discussing the outputs of the project.

BIGDATAROBOT – 002: Introduction to machine learning
Students level: Master 1 Language: English Keywords: data mining, machine learning Ideal course period: fall semester
ECTS: 4
Objectives: - To acquire the specific vocabulary of machine learning - To understand the concept of linear and penalized regression - To understand the concept of neural network - To propose an architecture of multi-layer perceptron following the specificities of the data structure - To conduct an exploratory data analysis - To write the most appropriate results obtained after performing a machine learning
Developed skills at the completion of the course: After the course, the student will be able to conduct a complete exploratory data analysis from the data cleaning to the practical implementation and develop penalized regressions and multi-layer perceptron. The student will be also able to communicate the obtained results to stakeholders.
Content of the course: The course is composed of 2 parts: • Part 1: Linear, Ridge and Lasso regression • Part 2: Neural network Each part includes: • one face-to-face session (2h) developping the theoritical concepts • one e-learning session (3h) applying in practice the exposed theo-retical concepts using exercises supervised by computer. • one homework (3h) based on the resolution of a full data analysis dedicated to the exposed theoretical concepts. Consequently, the course is composed of 4h of face-to-face, 6h of e-learning session and 6h of homework.

Examination format:
- Resolution of a complete data analysis and redaction of a report containing the most appropriate results and reflections
- Oral exam:
    o answering 3 questions related to the theory
    o discussing the outputs of the resolved exercise

BIGDATAROBOT – 003: Robots in agriculture
Students level: Master 1 Language: English Keywords: robotics, agricultural machines Ideal course period: N/A
ECTS: 4
Objectives: - To acquire the specific vocabulary of robotics - To understand how differences between factories and farm environments affect requirements to robotic solutions - To be familiar with the state-of-the art in agricultural robotics - To know the most common sensors used by robots in agriculture - To understand how we can use sensor fusion to improve the robots state estimates - To understand common robot navigation strategies
Developed skills at the completion of the course: On completion of the course, students will be able to: - Describe how robots use sensors and logic to perform tasks on a farm - Describe some challenges of agricultural robotics - Describe state-of-the-art technology within agricultural robotics
Content of the course: - Lectures (11.5h): o Introduction to agricultural robotics and challenges of deploying robots on farms at a commercial scale o Introduction to common sensors used in robotics o Introduction to state estimation and sensor fusion o Introduction to robot navigation o Introduction to robot manipulation and manipulation tasks in agriculture - Practical exercises with robotic systems (6.0h) - Online quizzes - Computer exercises and written exercises - Field visit to see robot demonstrations - Group project on developing a robot concept dedicated to a precise agricultural practice
Examination format: - Quiz on the online self-learning - Project presentation

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IV. MITIGATION AND ADAPTATION TO CLIMATE CHANGE

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CLIMATECHANGE – 001: Earth's climate system and climate modelling

Students level: Master 1
Language: English
Keywords: Atmospheric Sciences, Climate Impact Science, Climate modelling, Climate projections
Ideal course period: N/A

ECTS: 5

Objectives:
Acquisition of knowledge on the Earth's climate system, its components, interactions and scales. Understanding climate change and its driving mechanisms. Basics on climate modelling and climate change projections. Tools for treatment and analysis of climate data

Developed skills at the completion of the course:
On completion of the course, students will be able to understand climate change and its potential impacts on agrarian systems. Students will be also capable of analyzing complex climate datasets, using different tools, either for temporal or spatial analysis, including GIS.

Content of the course:

1. The Earth's Climate System (4 hours), hybrid (face-to-face & remote) lecturing with short illustrative practical works
2. Climate change fundamentals (4 hours), hybrid lecturing with short illustrative practical works
3. Climate modelling and projections (4 hours), hybrid lecturing with short illustrative practical works
4. Climate impact assessment (4 hours), hybrid lecturing with short illustrative practical works
5. Methodologies for climate data analysis (8 hours), group intensive computational practical work
6. Presentation of group projects and discussion (4 hours)

Examination format:

- 1 Test in Moodle (50% of the final score)
- 1 Group project written report (30% of the final score)
- 1 Discussion of the group project (20% of the final score)

CLIMATECHANGE – 002: Soil carbon modelling
Students level: Master 1 Language: English Keywords: Modelling, organic carbon, dynamics, soils Ideal course period: N/A
ECTS: 5
Objectives: Acquisition of knowledge on importance of soil organic matter (SOM) in soil functions and ecosystemic services, and on modelling of SOM evolution according to agricultural practices. Understanding the processes behind various soil C models from very simple to more complex. Learning how to perform the analysis of data and how to make links with other parts of WP : climate change scenarios and crop modelling
Developed skills at the completion of the course: On completion of the course, students will be able to understand how organic matter evolves in soils under the influence of climatic and anthropic factors and how SOM interacts with other soil constituents to drive soil quality. Students will be able to use modelling as tools to assess the impact of agricultural practices on the fate of soil organic status and to build decision-support tools.
Content of the course: 1. What is soil organic matter? What is soil Carbon ? Why do they matter ? (4 hours - Lecture and reference literature) 2. Basics of soil data analysis: effect of agricultural practices on Soil C (3h – Descriptive manual to manipulate tools of data analysis –quality control, outlier identification, correlation analysis, multivariate statistics) 3. First step with soil C model : package “soilr” in R (4 hours – Descriptive manual, step-by-step guide to understand and manipulate the one-pool, two-pools and RothC models and corrected proof of exercices) 4. Assessing impact of climate changes and agrciultural practices on space and long-term evolution of SOM pools (4 hours – step-by-step guide to build a framework for Soil C sequestration maps)
Examination format: 1 Theoretical test in Moodle (30% of the final score) 2 Different practical exercises to be completed (70% of the final score)
Additional information State-of-the-art bibliography will be provided, along with supporting notes (manual, presentation) for individual study. Step-by-step guides (manual and presentations) are also provided. R free package will be used to for soil C modelling.

CLIMATECHANGE – 003: Introduction to soil-crop modelling and assessment of climate change impact on crop production
Students level: Master 1/Master 2 Language: English Keywords: soil-crop modelling, climate change Ideal course period: N/A
ECTS: 5
Objectives: Acquisition of knowledge on soil-crop system modelling, its components and functioning. Understanding how to run a simple crop model (web interface) and a complex crop model (through a computer user interface). Learning how to implement climate change scenario in a crop model and how to perform the analysis of the multiple climate change scenarios. Learning tools for treatment and analysis of crop model outputs.
Developed skills at the completion of the course: On completion of the course, students will be able to understand the way soil-crop model function. Students will be also capable of analyzing the impact of climate change projections on crop production, through their main outputs (phenological development, biomass, yield elaboration, etc.).
Content of the course: 1. What is crop modelling: global overview ? (2 hours - Lecture and reference literature) 2. First step with a crop model: mini-STICS (4 hours – Descriptive manual, step-by-step guide to manipulate the simple model and corrected proof of exercises) 3. Familiarization and manipulation of a complex crop model: STICS (4 hours – Descriptive manual and step-by-step guide to manipulate the complex model) 4. Assessing climate change impact on crop production (4 hours – Step-by-step guide to implement multi-simulation and analyze model outputs)
Examination format: 1 Theoretical test in Moodle (30% of the final score) 5 Different practical exercises to be completed (70% of the final score)
Additional information State-of-the-art bibliography will be provided, along with supporting notes (manual, presentation) for individual study. Step-by-step guides (manual and presentations) are also provided. Free software (Mini-STICS, STICS, R) will be used to run crop model and conduct the analysis.

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V. SUSTAINABLE AGRICULTURE AND AGROECOLOGY

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The following courses syllabi proposals could be completed by existing courses in the contributing institutions:

- Sustainability in agriculture (Master in Sustainable agriculture and management, Perrotis College, Greece)
- Ecological economics (Master in food Economy and Consumption, Helsingin Yliopisto, Finland)
- Ecological crop protection (Master in Sustainable agriculture and management/ Ecologically based pest and disease management, Perrotis College – Greece | Master in Agricultural Sciences, Helsingin Yliopisto – Finland | Master in Agriculture / Biocontrol, Junia ISA Lille – France)
- Regenerative agriculture or Carbon farming (Master in Sustainable agriculture and management / Agroecological design and integrated farming systems, Perrotis College, Greece)
- Farm sustainability assessment (Master in Agriculture / DA Sustainable agriculture and smart-farming, Junia ISA Lille – France)
- Redesigning food systems (Master in Forest science, Helsingin Yliopisto – Finland)

SUSTAINAG – 001: Fundamentals of agroecology
Students level: Master 1 Language: English Keywords: soil-crop modelling, climate change Ideal course period: Fall semester
ECTS: 5
Objectives: - Mastering Agroecology and its concepts - Understanding concepts related to social, environmental and agronomic sciences - Discovering a few agroecological practices in theory and it the field
Developed skills at the completion of the course: On completion of the course, students will be able to: - Define what agroecology is as a science, social movement, and practice - Understand the environmental and agronomic challenges of agroecosystem management
Content of the course: 1. History of Agroecology (reading, 3 hours) 2. Agroecology as a science: ecology of agroecosystems and ecosystems services (face-to-face lecture, 6 hours) 3. Agroecology as a social movement (face-to-face lecture, 6 hours) 4. Agroecology as a practice: a. Agroforestry (face-to-face lecture and visit, 9 hours) b. Integrated crop-livestock systems (readings and visit, 9 hours) c. Intercropping (face-to-face lecture and visit, 9 hours) 5. Opening agroecological transition (face-to-face lecture and visit, 3 hours)
Examination format: Written individual examination

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SUSTAINAG – 002: Ecological economics
Students level: Master 1/Master 2 Language: English Keywords: economics, ecology Ideal course period: Fall semester
ECTS: 5
Objectives: During the course students will become familiar with the principles and key concepts of ecological economics (EE). They will learn how to apply these concepts and frameworks in the context of the food sector. In more practical terms the students will acquire knowledge about governance frameworks and measures used for instance by companies, regulators and other societal actors.
Developed skills at the completion of the course: The students will be encouraged to adopt a critical predisposition towards concepts, measures and statistics discussed during the course. The students will also acquire problem solving and group working skills to address complex socio-economic challenges related to the food system.
Content of the course: 1. Transdisciplinarity of ecological economics 2. Tools and methods of EE applicable to economic, social, and environmental problem solving 3. Theories and comparison of ecological and neoclassical economics 4. EE analysis of sustainable scale, circular economy, distribution of justice, animal welfare and rights in the food system 5. Group exercise (EE application), peer review, seminar presentations
Examination format: Learning diary and a group exercise, which is evaluated by student peer review method, as well as by the teacher.

SUSTAINAG – 003: Agroecological transition – case studies
Students level: Master 1 Language: English Keywords: agroecology – case-studies Ideal course period: Spring semester
ECTS: 5
Objectives: - Dismantling the main obstacles and motivations/incentives to agroecological transition - Designing feasible agroecological transition pathways with and for farmers
Developed skills at the completion of the course: On completion of the course, students will be able to: - Support farmers in agroecological transition by adapting the pathway to the specific context of the farmer
Content of the course: 1. Introduction to agroecological transition (face-to-face lecture, 3 hours) 2. Success stories: studying transition testimonies (readings and visit, 9 hours) 3. Main barriers to transition (technical, economic, social...) (face-to-face lecture and readings, 6 hours) 4. The importance of the collective: group of farmers (visits, 3 hours) Group work on supporting farm's transition: real case-studies • Meeting with farmers • Current situation analysis • Co-design of desirable future • Scenario establishment • Feasibility study • Design of the transition pathway
Examination format: Report and oral presentation of the designed agroecological transition pathways (feasibility and acceptance)

SUSTAINAG – 004: Farm sustainability assessment
Students level: Master 2 Language: English Keywords: sustainability, farms, advising Ideal course period: Fall semester
ECTS: 5
Objectives: - Understanding the complexity of farm sustainability assessment - Putting students in the shoes of an agricultural advisor by conducting a sustainability assessment for a farmer
Developed skills at the completion of the course: On completion of the course, students will be able to: - Use existing farm sustainability assessment tools and built their own; - Conduct a farm sustainability assessment; - Advise farmers on feasible improvement levers to enhance farm sustainability.
Content of the course: 1. Basics of sustainability assessment (face-to-face lecture, 6 hours) 2. Discovery of different farm sustainability assessment tools (face-to-face, guided works and serious games, 9 hours) 3. Construction of an evaluation tool according to the objectives and constraints identified (practical work, 9 hours) 4. Real farms case-studies (visits, survey, 3 hours) 5. Farm sustainability assessment (practical work, 12 hours) 6. Advising farms (practical work, 12 hours)
Examination format: Report (for farmers) and oral presentation of the farms assessment and advice for sustainability improvement

SUSTAINAG – 005: Redesign of Food Systems
Students level: Master 1/Master 2 Language: English Keywords: food systems, transition Ideal course period: Fall semester
ECTS: 5
Objectives: The course will address how behaviors of consumers/citizens, farmers and other stakeholders are related to large-scale sustainability transformations, as well as barriers and drivers to behavioral change. The course will focus on the conceptual models and empirical tools to explain and facilitate behavioral change, such as such as policy instruments, nudging, information provision, and marketing. The course will especially focus on theories and methods used in social and environmental psychology but will also discuss their relation to behavioral economics and sociology.
Developed skills at the completion of the course: In this course, students will learn to apply different conceptual models to the context of sustainability transformations. The students will also learn to compare how behavioral change is examined from other disciplinary perspectives, such as behavioral economics, policy sciences, and sociology. Students will learn to identify different behavioral change tools, identify and apply a relevant tool to change the target behavior. By the end of the course, the students will be able to design a behavioral change project, choose a relevant conceptual model and behavioral change tools, and anticipate the results.
Content of the course: 1. Introduction to large scale sustainability transformation 2. Barriers and drivers of behavioral change 3. Theories for supporting sustainability transformation of food systems 4. Co-design workshops: groupwork, seminars with peer review
Examination format: Participation in lectures, written behavioral change project plan and final exam