AI applications in agriculture

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Agriculture
Benefits of agriculture

- **Food** being produced in **appreciable abundance**
- Farming creates **opportunities to lift people out of poverty** in developing nations
- Over 60 percent of the world’s working poor works in agriculture

- **Farming creates more jobs:**
  - farmers, farm equipment makers, food processing plants, transportation, infrastructure and manufacturing

- Agriculture – a **scientific area**
- Farmers more **educated**
- Agriculture - **modernized**
Threats

- Human population approaches 10 billion people by 2050
- Modern agriculture’s huge reliance upon a few crops
- Climate change
- Huge environmental and health pressure (biodiversity loss, water pollution, pesticides, ...)

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Modernization of agriculture

- Transforming agriculture from traditional labour-based to technology-based agriculture

- New technologies (precision farming, drones, robots) for
  - combatting disease and pests
  - monitoring nutrient levels
  - monitor soil and growing conditions
  - ...

- Huge amounts of structured or unstructured data produced daily!
Challenges

- Data
- Threats
- SDGs

AI in agriculture
Challenges

AI in agriculture
AI in agriculture

- Most popular applications of AI in agriculture fall into three major categories:
  - **Agricultural robots** – autonomous robots to handle essential agricultural tasks at a higher volume and faster pace than human laborers
  - **Crop and soil monitoring** – computer vision and deep learning algorithms to process data captured from drones and/or software-based technology to monitor crop and soil health
  - **Predictive analytics** – machine learning models developed to track and predict various variables/aspects in agriculture
AI applications in agriculture at JSI

- More than 15 years of work in this area
- Different areas of agriculture:
  - Co-existence of GM and conventional crops
  - Water pollution with plant protection products
  - Biological pest control
  - Soil preservation and assessment of soil functions
  - Tomato resilience and resource use efficiency
  - Sustainability of legume agri-food chains
  - Integrated pest management
Co-existence of GM and conventional crops

- Analysis of results of **large-scale** and **individual-based** simulation models
  - Crops: oilseed rape and maize
  - Simulation models: GENESYS, MAPOD, IBM-OSR

- Problem:
  - **Co-existence** issue
  - Influence on **natural habitats**
  - Consequences on **human health**
  - 0.9% of GM material in conventional harvest

- Machine learning analysis:
  - Relational decision trees
  - Equation discovery
  - Process-based modelling
Water pollution with plant-protection products

Crop production without environment pollution
Water pollution with plant-protection products

Crop production without environment pollution

PESTICIDES APPLICATION
Water pollution with plant-protection products

Crop production without environment pollution

Directives
- European water framework directive
- Directive on the sustainable use of plant protection products

Application instructions of pesticide producers

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Monitoring of water quality
INDICATES WATER POLLUTION

PESTICIDES APPLICATION

Check the level of pollution risk for a certain crop management plan
Water pollution with plant-protection products

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PESTICIDES APPLICATION

Check the level of pollution risk for a certain crop management plan

Apply crop management plan
No risk
Water pollution with plant-protection products

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Application instructions of pesticide producers

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INDICATES WATER POLLUTION

PESTICIDES APPLICATION

Check the level of pollution risk for a certain crop management plan

Apply crop management plan
- No risk
- Risk

Change crop management plan
Water pollution with plant-protection products
Water pollution with plant-protection products
Water pollution with plant-protection products
Water pollution with plant-protection products
Water pollution with plant-protection products
Water pollution with plant-protection products

Management plan

Risk assessment

No risk
Risk

Risk management

Apply management plan

Mitigation options

Active substance
Application time
Dosage
Soil management

What-if

List of mitigation measures

Data

Water pathway

Flow/drainage period

Soil

Crop

Application time

Dosage

Active substance

Evaluation

EVADIFF
Biological pest control

- **Understanding and management of biodiversity** of agricultural ecosystems (natural enemies of pests)

- **Reduce pressure of agriculture** on the environment
  - Smaller amounts of plant protection products used
  - Enhanced biological pest control

- Research goals:
  - **Effects of** agricultural management, cropping systems, landscape and climate on natural enemies populations (abundance and diversity)
  - **Effect of** natural enemies on pests (aphids, slugs) populations
  - Case study: Boigneville, Erceville, Maise, Picardie (France)
  - Natural enemies: syrphids, carabids
Biological pest control

The potential of Syrphids and Carabids for biological pest control

Syrphidae (hoverflies) and Carabidae

Modelling the size and structure of populations of syrphid and carabid species
Biological pest control

- Huge amount of **preprocessing** to harmonize datasets → very **complex dataset**
  - **Taxonomic, meteorological** and **landscape** data
  - **Diversity indexes** calculated
  - **Functional categories** defined
Biological pest control

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AI APPLICATIONS IN AGRICULTURE

15
Assessment of soil functions

- **5 soil functions**
- **Goal:** development of the Soil Navigator DSS that operates on field level
- Provides advices on the management of soils that optimizes the 5 soil functions

- Water regulation & purification
- Carbon sequestration
- Biodiversity
- Nutrient cycling
- Primary production
Assessment of soil functions

Assessing the performance of the five soil functions

- specific management practices
- environmental/climatic conditions
- soil characteristics

Choosing appropriate management practices that will improve the performance of the soil functions under:

- climatic conditions
- soil characteristics
- management options
Assessment of soil functions

PRIMARY PRODUCTIVITY

The capacity of a soil to produce plant biomass for food, feed, fibre and fuel within natural or managed ecosystems.

WATER REGULATION and PURIFICATION

Capacity of a soil to receive, store and conduct water, prevent droughts, flooding, erosion and chemical compounds.

CLIMATE REGULATION and CARBON SEQUESTRATION

Carbon sequestration is the capacity of a soil to store carbon in a stable form. Climate Regulation is the capability of soils to store carbon dioxide, methane and nitrous oxide.

HABITAT FOR BIODIVERSITY

The multitude of soil organisms and processes, interacting ecosystems, providing society with a rich biodiversity and contributing to a habitat for aboveground organisms.

NUTRIENT CYCLING

The capacity of a soil to receive nutrients in the form of by-products, and to provide nutrients from internal reservoirs or to support the acquisition of nutrients from air or water, and to effectively carry over these nutrients into harvested crops.
Assessment of soil functions

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Verification
### Average weights

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Verification → Sensitivity analysis → Calibration

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Verification → Sensitivity analysis → Calibration → Validation
SOIL NAVIGATOR

Open access: www.soilnavigator.eu

A Decision Support System for assessing and optimizing soil functions

The Soil Navigator decision support system (DSS) was developed in the Horizon 2020 project LANDMARK. It assesses the initial capacities of five soil functions within a field including primary productivity, nutrient cycling, water purification and regulation, carbon sequestration and climate regulation, as well as biodiversity and habitat provision. In addition, this evidence-based DSS offers targeted solutions and management recommendations to improve the supply of several soil functions simultaneously and assisting farmers and farm advisors to make the right decisions for long-term sustainability.
GRAPHICAL USER INTERFACE - DATA ENTRY

INPUT DATA

Soil physical properties

- Soil type: Organic
- Soil texture: Clay
- Clay content: Select
- Soil erosion/shearing: Yes
- Thickness of organic layer: 0-10 cm
- Potential rooting depth: 0-50 cm
- Groundwater table depth: 0.4-1.0 m
- Soil organic carbon: <1 %

Unless otherwise specified, all input values are for the specific field and soil measurements are in the 0 to 25 cm soil layer.
ASSESSMENT AND SUGGESTIONS FOR IMPROVEMENT OF THE SOIL FUNCTIONS

INITIALLY ASSESSED AND DESIRED CAPACITY OF SOIL FUNCTIONS

Primary productivity  Water purification and regulation  Biodiversity and habitat provision  Nutrient cycling  Climate regulation

Assessment of functional indicators

Primary productivity  Water purification and regulation  Biodiversity and habitat provision  Nutrient cycling  Climate regulation

Capacity of soil functions

Primary productivity

Initial  Flexibility

Initial  Flexibility

Initial  Flexibility

Initial  Flexibility

Initial  Flexibility

Initial  Flexibility

EVALUATION REPORT ON OPTIMIZED CAPACITIES OF SOIL FUNCTIONS

Initial, desired, and achieved capacities

Primary productivity  Water purification and regulation  Biodiversity and habitat provision  Nutrient cycling  Climate regulation

Management recommendation

NITROGEN FERTILIZATION (MINERAL)

Expand significant change processes by keeping use of the following nitrogen sources:

Increase mineral N fertilization in compliance with national fertilizer regulations.

Increase nitrogen balance in fertilization in compliance with national fertilizer regulations to meet crop demand. Increase lime production and reseeder carbon in this soil.

Requirement for compliance with national and in compliance with GAC and CMT

AI APPLICATIONS IN AGRICULTURE

22
Sustainability of legume agri-food chains

- Identify “transition paths” to increase sustainable legume cultivation and consumption across Europe
- Include the entire value chain of legume feed and food
- Develop a decision support tool for primary producers, agronomists, processors, associated businesses and decision makers
  - Help determine a range of options for successful transitions
  - Take into account the three different aspects of sustainability and their intersections
Sustainability of legume agri-food chains
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An integrated decision support system for assessment of the sustainability of legume systems

Tier 1: Links of Agri-food chain

Tier 2: Agri-food chain
Tomato resilience and resource use efficiency

The overall goal of TOMRES is to enhance resilience to combined water and nutrient stress in tomato and to maximize water and nutrient use efficiency by designing and testing in the field novel combinations of genotypes and management practices reducing the environmental impact of agricultural activities.

Goals:
- To investigate the factors that influence the water, nitrogen and phosphorus use efficiency under experimental conditions using machine learning.
- To assess open-field and glasshouse tomato production from socio-economic, environmental and RUE perspective using qualitative decision modelling.
Conclusions

- Agriculture is becoming **digital**
- **AI in agriculture** is already a **reality**
- More efficient and **sustainable agriculture**
  - Environmental benefits

- Some **disadvantages**:
  - Modernization/digitalization of agriculture is **expensive**
  - **Decrease in employment** and workforce in the agricultural sector