smart skills
smart sustainable agriculture

Course 3: Mechatronics in Agriculture

M1: Fundamentals of Renewable Energy in Agriculture

Co-funded by the European Union

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contents

In this module, Learners will understand the role of mechatronics in agriculture, recognising how robotics and automation improve efficiency and sustainability. They will identify key agricultural robots, system components, and the benefits of automation.
The module will help learners adopt a forward-thinking mindset for sustainable farming while also considering the ethical and social aspects of automation

01 Basics of Mechatronics in Agriculture

02 Key Mechatronic Systems

03 Components of Mechatronic Systems

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01

BASICS OF MECHATRONICS IN AGRICULTURE

What is Mechatronics?

Mechatronics is an **interdisciplinary field** that combines **mechanical engineering, electronics, computer science, and automation** to develop **intelligent, automated systems**. These systems enhance **efficiency, precision, and productivity** across industries, including agriculture.

In agriculture, mechatronics integrates **robotic machinery, sensors, control systems, and artificial intelligence** to optimise farming operations. Unlike traditional mechanical farming tools, mechatronic systems **respond to real-time data** and can **automate complex tasks** such as planting, irrigation, pest control, and harvesting.

What is Mechatronics?

Key **technologies in agricultural mechatronics** include:

- **Embedded sensors** that monitor soil conditions, crop health, and environmental factors.
- **Automated machinery** such as self-driving tractors and robotic harvesters.
- **Artificial Intelligence (AI) and IoT** that process data for smart decision-making.
- **Precision control systems** that optimize resource use, reducing waste and environmental impact.

By integrating **intelligent control** with mechanical operations, mechatronics **minimizes human effort**, increases **accuracy**, and **boosts productivity** while ensuring **sustainable farming practices.**

Why is Mechatronics Important in Agriculture?

Mechatronics is reshaping modern agriculture, making farming more efficient, precise, and sustainable.

By **integrating automation, AI, and robotics**, farmers can:

- increase yields,
- reduce environmental impact,
- tackle labour shortages,

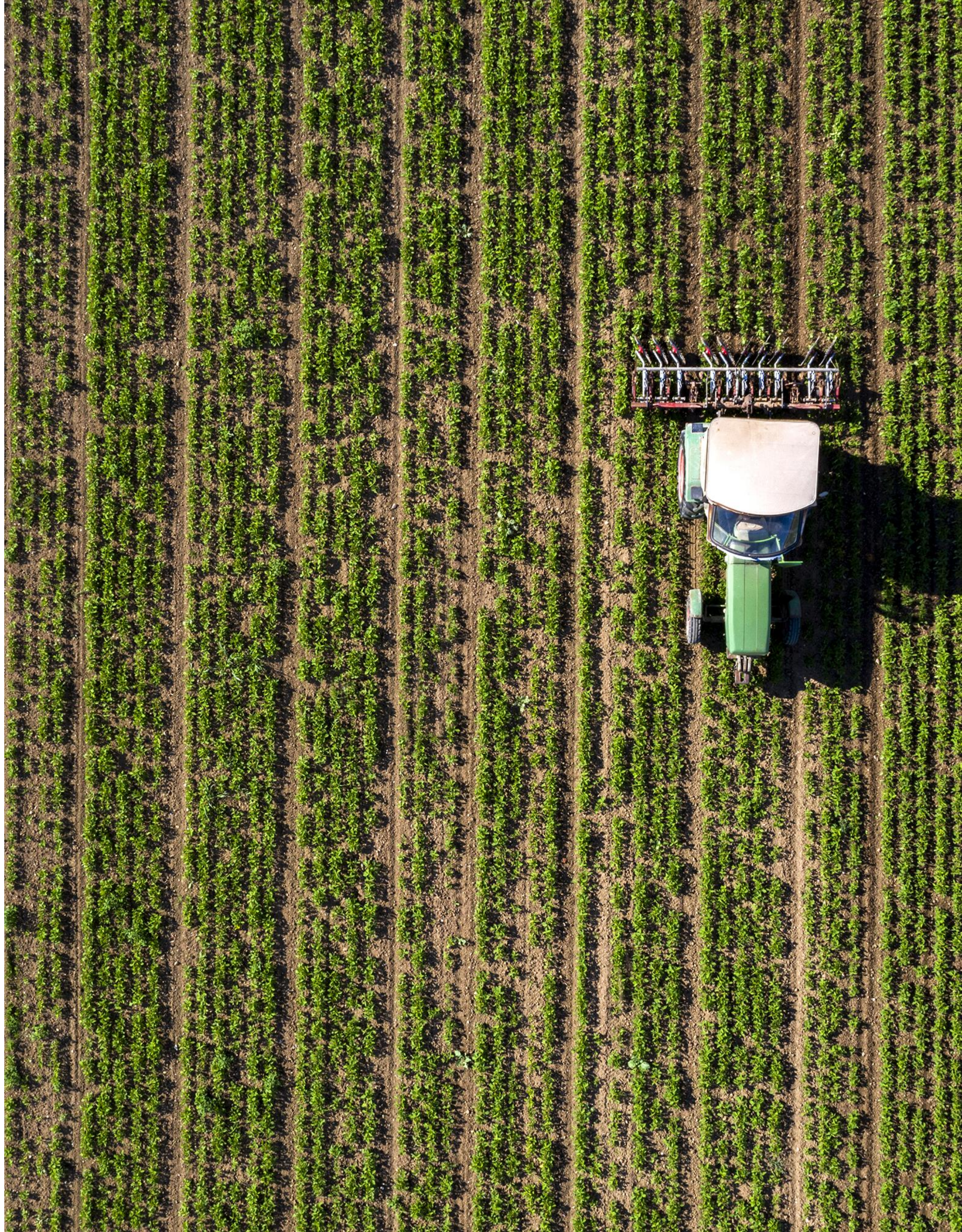
ensuring the long-term viability of food production in a rapidly changing world.

The Future of Agriculture

The main reasons why mechatronics is essential for modern agriculture:

Increases Efficiency: Mechatronic systems automate labour-intensive processes, reducing the need for manual intervention and significantly improving productivity. Autonomous tractors, robotic harvesters, and automated irrigation systems can operate 24/7, increasing field coverage and output.

GPS-guided machinery ensures that tasks such as ploughing, seeding, and spraying are performed with minimal errors and time waste.



The Future of Agriculture

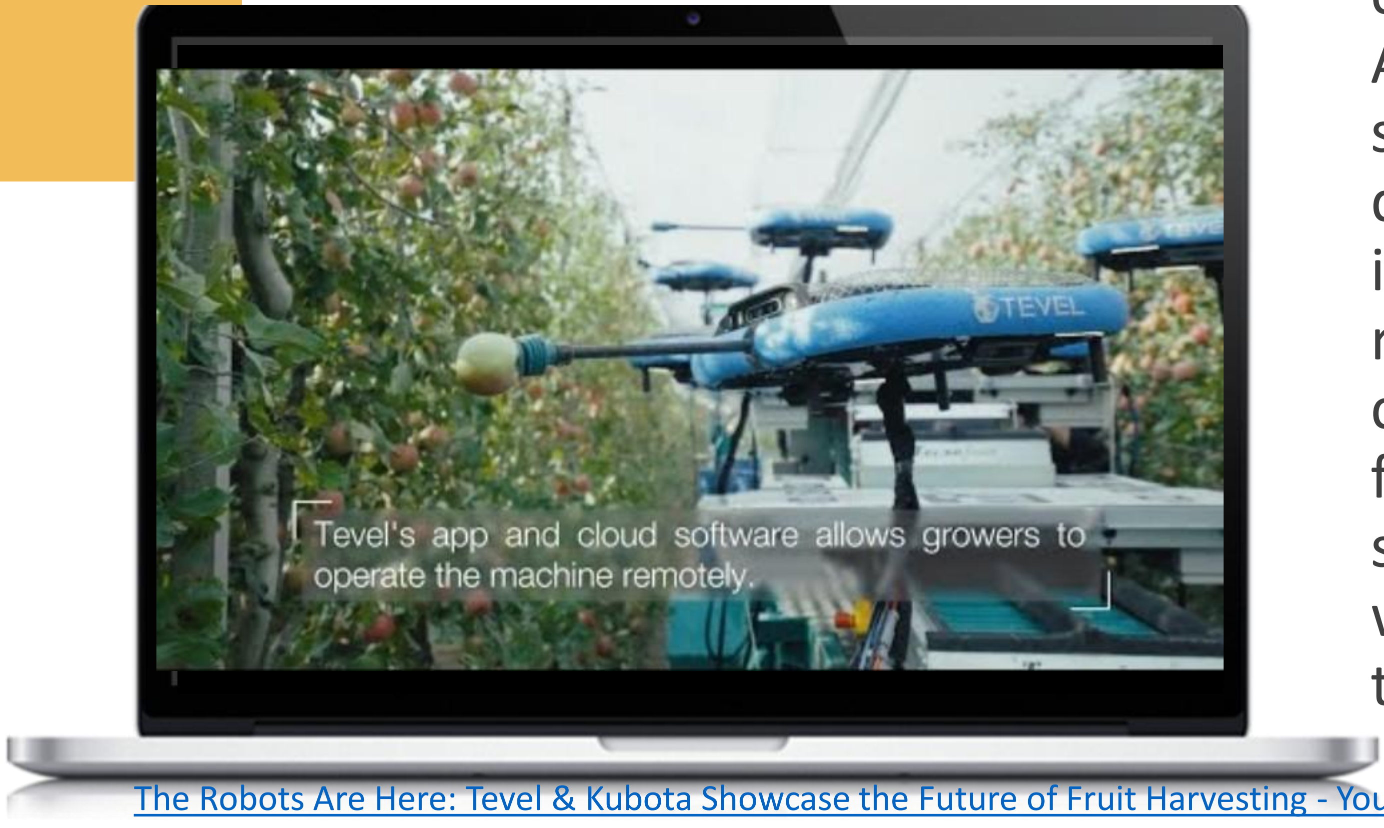
Enhances Precision: Modern agriculture relies on precision farming, where sensors, AI, and automated machinery ensure accurate planting, irrigation, fertilization, and pest control. By collecting and processing real-time data, mechatronic systems apply inputs (water, fertilizers, pesticides) exactly where needed, **reducing waste and improving yield** (e.g. Variable Rate Technology (VRT) in smart sprayers applies fertilisers or pesticides only to affected areas based on real-time crop health data, preventing overuse and environmental harm).

.

The Future of Agriculture

Improves Sustainability: Smart farming technologies powered by mechatronics help farmers use resources more efficiently, **reducing water consumption, chemical application, and fuel usage.** Automated irrigation systems measure soil moisture levels and adjust water distribution accordingly, preventing over-irrigation and conserving water. Similarly, robotic weeders reduce reliance on chemical herbicides, promoting eco-friendly farming (e.g. Drip irrigation systems with automated controls reduce water wastage by up to 50% compared to traditional methods).

The Future of Agriculture



[The Robots Are Here: Tevel & Kubota Showcase the Future of Fruit Harvesting - YouTube]

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02

KEY MECHATRONIC SYSTEMS IN AGRICULTURE

Key Mechatronic Systems in Agriculture

Mechatronic systems in agriculture integrate robotics, sensors, automation, and artificial intelligence to enhance efficiency, precision, and sustainability. Below are the most impactful technologies transforming modern farming:

- **Autonomous Tractors & Harvesters**
- **Drones & UAVs (Unmanned Aerial Vehicles)**

Autonomous Tractors & Harvesters

What They Do: Perform field operations such as ploughing, planting, and harvesting with minimal human intervention, using GPS, AI, and sensor technology.

How They Work:

- GPS-guided tractors use satellite navigation to follow predefined routes with centimeter-level accuracy, reducing fuel consumption and soil compaction.
- AI-powered harvesters detect crop ripeness, automatically adjust cutting height, and separate grains from chaff in real-time.
- Remote monitoring systems allow farmers to oversee field operations from mobile apps, reducing manual supervision.

Autonomous Tractors & Harvesters

John Deere 5ML Autonomous Diesel Orchard Tractor Revealed at CES 2025 - YouTube

Example: John Deere's Autonomous Tractor uses LiDAR sensors and AI to navigate fields without a driver, improving efficiency and reducing costs.

Benefits: Increased productivity, reduced labor dependency, precise fuel and input usage, and optimised field coverage.

Click on the Video to see an example

Drones & UAVs (Unmanned Aerial Vehicles)

What They Do: Monitor crop health, detect pests and diseases, apply fertilisers, and collect real-time data to support precision farming

How They Work:

- Multispectral and thermal imaging cameras on drones scan fields to identify plant stress, water deficiency, and nutrient needs.
- AI-powered analytics process images to generate maps for variable-rate fertilisation and targeted pesticide application.
- Spraying drones distribute liquid fertilisers and pesticides precisely where needed, reducing chemical runoff.

Drones & UAVs (Unmanned Aerial Vehicles)

DJI Agras MG-1 ALL NEW! Agriculture Spraying Drone! - YouTube

Example: DJI Agras MG-1 drone autonomously sprays crops 40 times faster than manual spraying, ensuring even coverage and reducing water usage.

Click on the Video to see an example

03

COMPONENTS OF MECHATRONIC SYSTEMS

Components of Mechatronics Systems

Mechatronic systems in agriculture rely on **seamless integration of hardware and software components** to ensure **automation, precision, and real-time decision-making**. The key components include:

- **Sensors**
- **Actuators**
- **Microcontrollers**
- **AI**

Each plays a crucial role in optimising farm operations.

Sensors: Measuring and Monitoring Agricultural Conditions

Sensors are the eyes and ears of mechatronic systems, continuously collecting real-time data on environmental and crop conditions. They provide the **necessary input for automated decisions**, helping optimise farming processes with minimal human intervention.

Types of Sensors Used in Agriculture:

- **Soil Moisture Sensors** – Measure water levels in the soil to optimise irrigation.
- **Temperature & Humidity Sensors** – Monitor climate conditions for greenhouse and open-field crops.
- **Nutrient & pH Sensors** – Analyse soil fertility and recommend precise fertiliser application.
- **Optical & Multispectral Sensors** – Assess plant health by detecting stress, pest infestations, and chlorophyll levels.
- **LiDAR & Proximity Sensors** – Used in autonomous tractors and drones for obstacle detection and navigation.

Actuators: Enabling Movement and Control

Actuators **convert electrical signals into physical movement**, allowing robots & machinery to perform tasks such as **spraying, seeding, harvesting, and irrigation control**.

Types of Actuators in Agricultural Mechatronics:

- **Hydraulic Actuators** – Used in **autonomous tractors and robotic arms** for high-power applications.
- **Pneumatic Actuators** – Operate **lightweight robotic mechanisms**, such as fruit-picking robots.
- **Electric Motors & Servo Motors** – Provide **precise movement control** in robotic weeders and sprayers.
- **Solenoid Valves** – Automate water flow in **precision irrigation systems**.

Example: In **robotic weeders**, actuators control mechanical arms that **pinpoint and remove weeds without herbicides**, reducing chemical dependency.

Microcontrollers & AI: Data Processing and Automation

Microcontrollers and AI-powered processors **analyse sensor data, make real-time decisions, and control actuators** to optimise farming operations **without human input**.

Key Technologies:

- **Microcontrollers (Arduino, Raspberry Pi, PIC)** – Handle **real-time automation** in small-scale mechatronic systems.
- **Edge AI Processors** – Allow farm robots to **process data on-site**, reducing reliance on cloud computing.
- **Machine Learning Algorithms** – Enable **precision agriculture** by detecting crop diseases and predicting yield.
- **IoT Connectivity** – Links farm equipment to the **cloud** for remote monitoring and predictive analytics.

Example: In **autonomous tractors**, microcontrollers process GPS data and adjust steering, speed, and tool deployment **based on AI-driven algorithms**, optimizing fuel efficiency and field coverage.

"The future of agriculture lies in automation and precision. By integrating mechatronics, we can farm smarter, not harder."

Dr. Simon Blackmore,
Precision Agriculture Pioneer

04

LET'S PRACTICE

Learner Exercise:

Practical Activity: *"Explore Mechatronics in Action"*

- Research and identify one real-world mechatronic system used in agriculture (e.g., an autonomous tractor, robotic weeder, or smart irrigation system).
- **Task:** Create a summary (100-150 words) explaining how the system works, its benefits, and its impact on farming efficiency.
- **Optional:** If possible, find a video demonstration of the system and share key takeaways.

Group Exercise:

Discussion Prompt:

How do you see mechatronics **shaping the future of farming** in your region? What **challenges** do you think farmers might face when adopting these technologies?

Purpose: This engages learners, encourages critical thinking, and allows them to connect theory with real-world applications.

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