AST 426 :Internet of Things (IoT) in Agriculture

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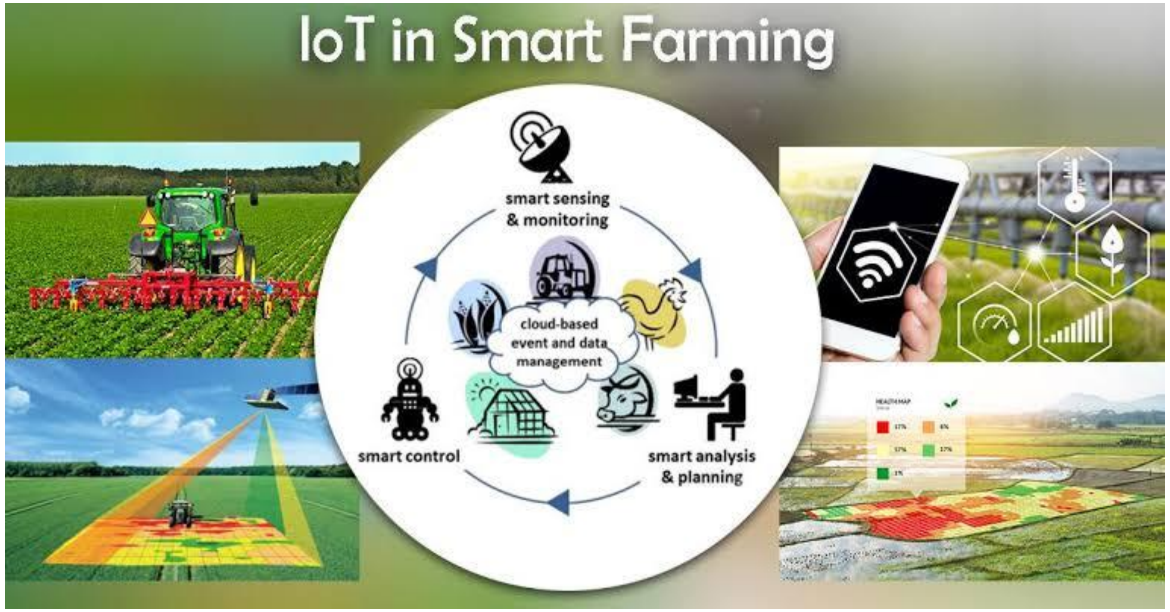
Introduction to IoT in Agriculture

What is IoT?

- Network of physical objects that **use sensors, software, and other technologies** to **connect and exchange data**
- IoT was Coined by **Kevin Ashton** (British technology pioneer who cofounded the Auto-ID Center at the Massachusetts Institute of Technology (MIT) in **1999**

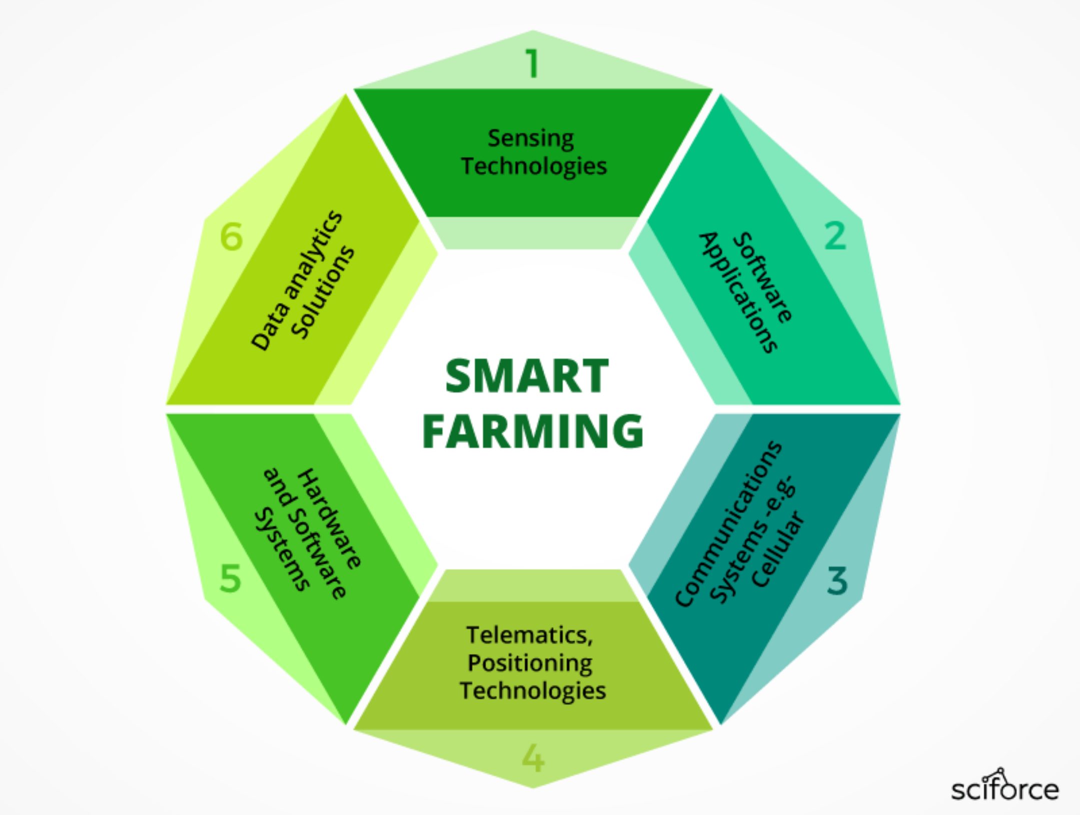


https://www.slideteam.net/blog/top-slides-on-iot-in-agriculture-free-ppt-pdf

https://agriculturalinformation4u.com/iot-smart-farmingadvantages-and-disadvantages-of-smart-farming/

IoT and Smart Farming

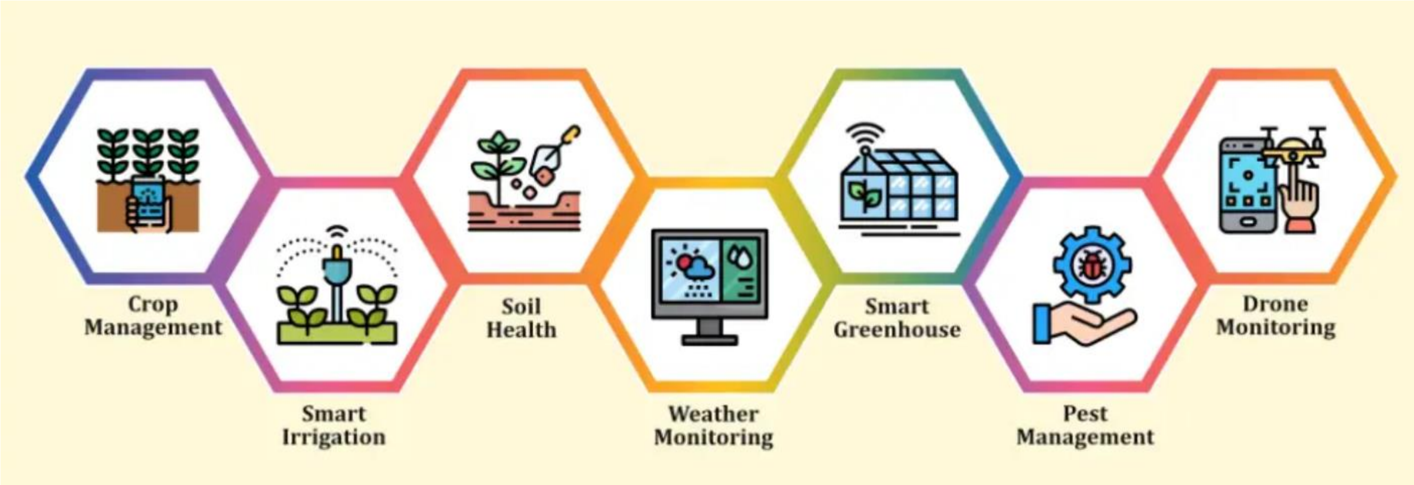
- **Automation** of farming processes
- **Real-time data collection** and **monitoring**
- By using IoT sensors to collect environmental and machine metrics, **farmers can make informed decisions**, and improve just about every aspect of their work – **from livestock to crop farming**
- IoT enables **Smart Farming** practices



https://www.iotforall.com/smart-farming-future-of-agriculture

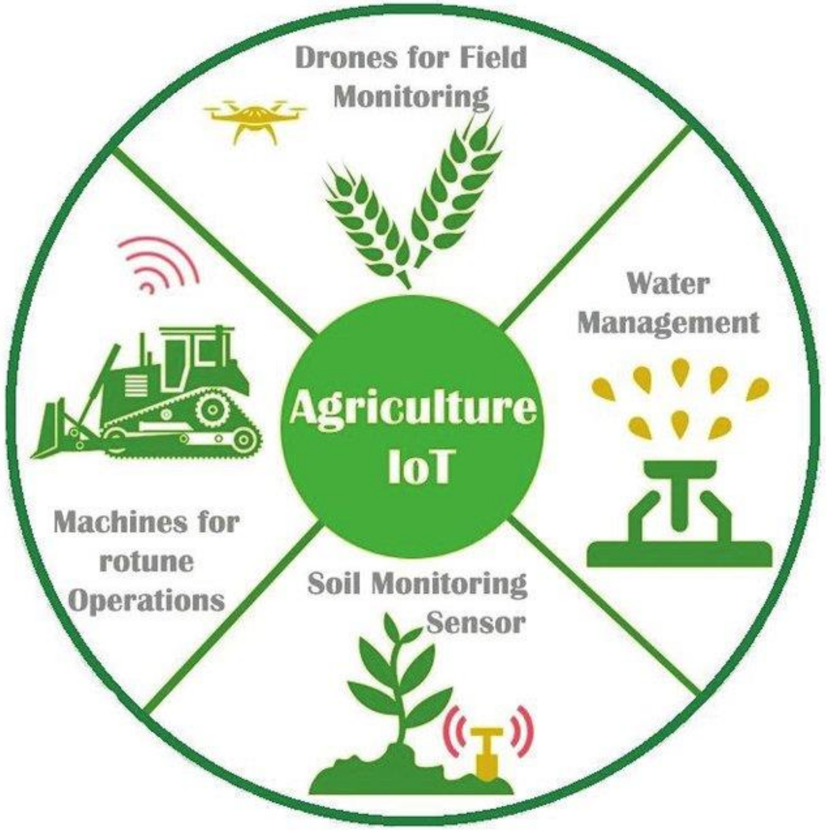
Importance of IoT in Precision Agriculture

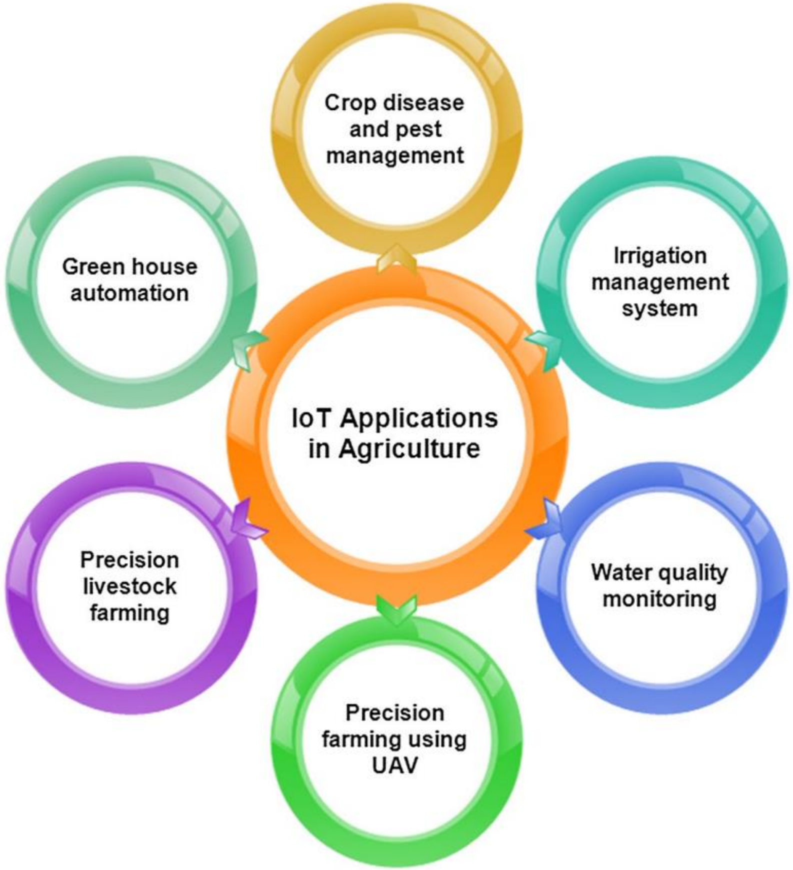
- IoT allows farmers to monitor equipment, soil conditions, and crop health in real-time, leading to reduced manual labor and better resource management
  - Automated tractors and harvesters reduce operational time and labor costs.
- **With IoT, farmers can make better, data-driven decisions** by analyzing real-time information from sensors and drones to optimize planting, watering, and harvesting schedules.
- **IoT helps in minimizing waste by enabling precision agriculture**, which optimizes the use of water, fertilizers, and pesticides, thereby reducing environmental impact.



https://psiborg.in/precision-farming-using-iot/

Importance of IoT in Precision Agriculture

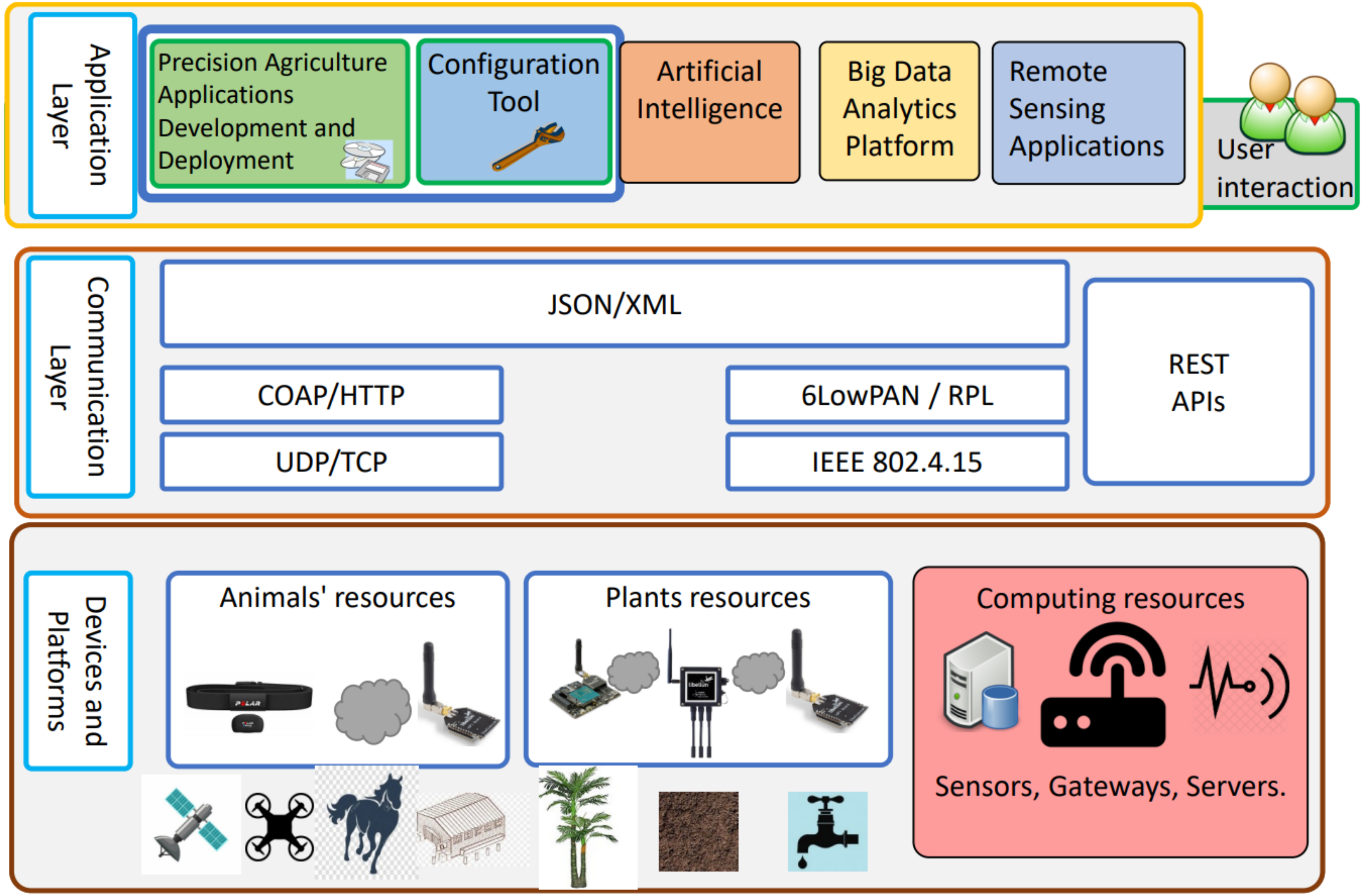




Futuristic IoT based Smart Precision Agriculture: Brief Analysis

Dahane, A., Benameur, R., & Kechar, B. (2022). An IoT low-cost smart farming for enhancing irrigation efficiency of smallholders farmers. Wireless Personal Communications, 127(4), 3173-3210.

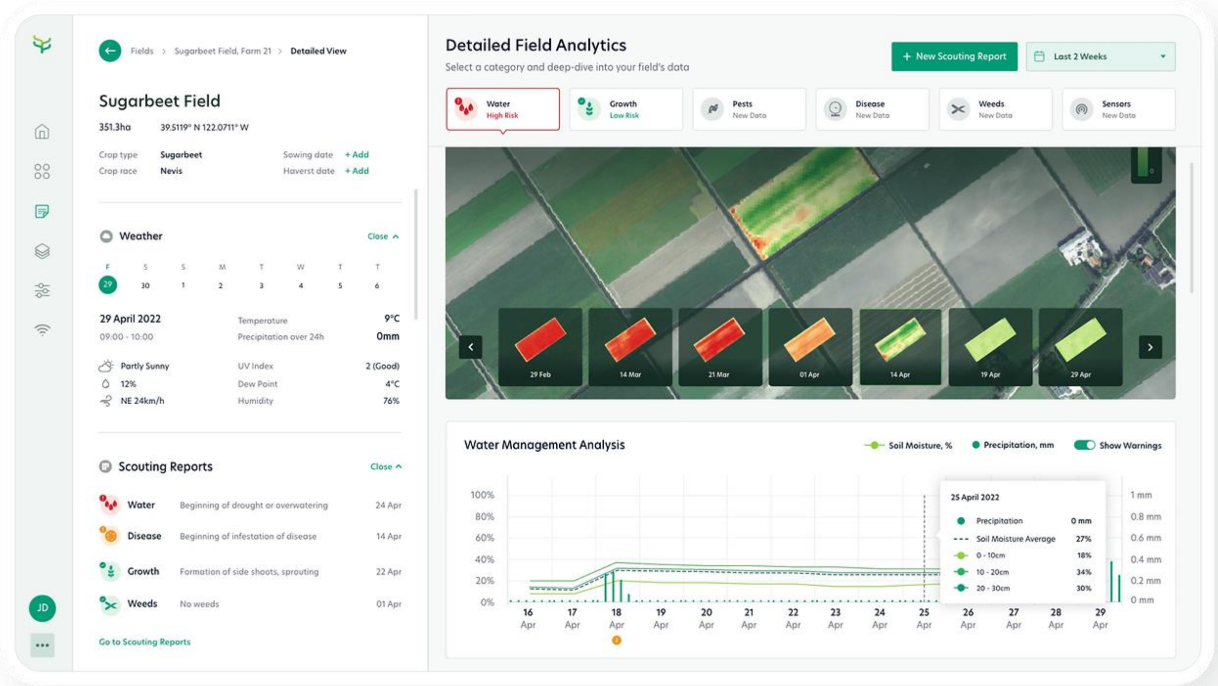
IoT System Architecture for Precision Agriculture



Atalla, S., Tarapiah, S., Gawanmeh, A., Daradkeh, M., Mukhtar, H., Himeur, Y., ... & Daadoo, M. (2023). IoTEnabled Precision Agriculture: Developing an Ecosystem for Optimized Crop Management. Information 2023, 14, 205.

Application Layer

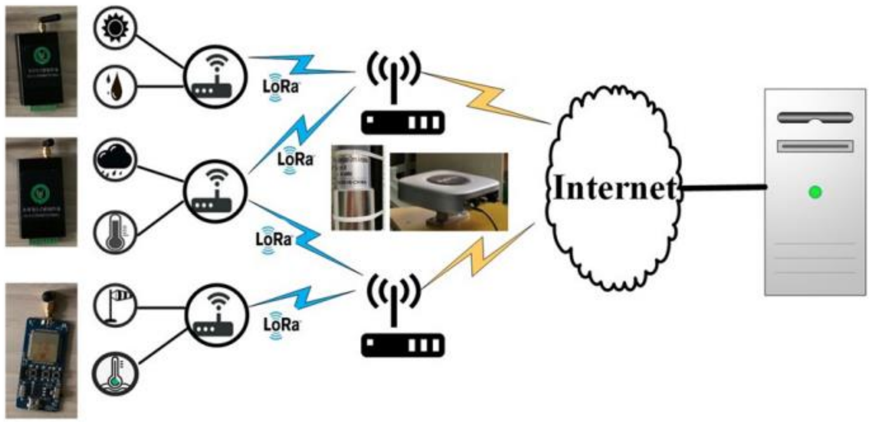
- The Application Layer is the topmost layer in an IoT system and interacts with the user through dashboards, mobile apps, or web-based systems.
- Provides farmers and agronomists with real-time data visualization through dashboards or mobile apps.
- Uses machine learning algorithms for analyzing data and making decisions (e.g., when to irrigate, fertilize, or monitor for pests).
- Integrates satellite and drone data to provide a comprehensive view of the field.
- Enables automated actions like activating irrigation pumps, adjusting temperature, or turning on lights in greenhouses



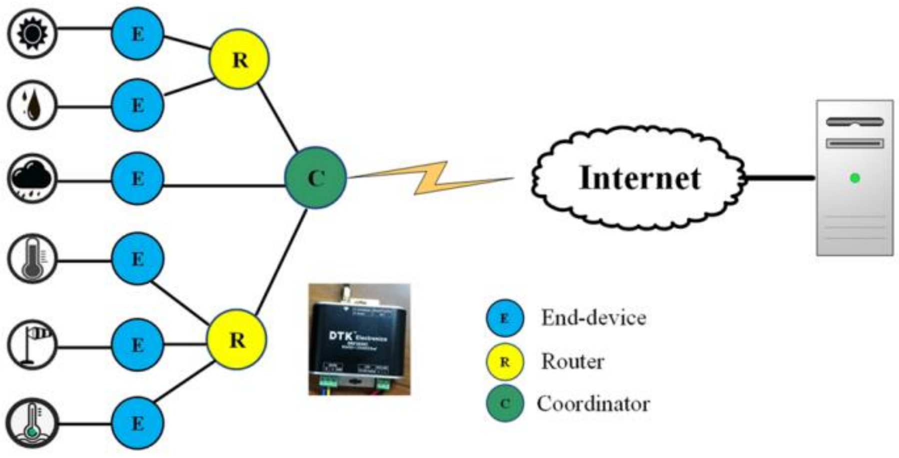
https://www.farm21.com/

Communication Layer

- Facilitates real-time communication between devices, sensors, and platforms.
- **6LoWPAN:** IPv6 over Low-Power Wireless Personal Area Networks for enabling efficient communication in IoT environments.
- **RPL (Routing Protocol for Low-Power and Lossy Networks):** Supports dynamic topologies and mobile nodes in agricultural fields.
- **COAP (Constrained Application Protocol):** Lightweight communication protocol ideal for IoT, designed for constrained networks with limited bandwidth and power.
- **IEEE 802.15.4:** Supports low-power communication, suitable for sensor networks in agriculture.
- **UDP/TCP:** Transport layer protocols used for reliable and unreliable data transmission.



LoRa WAN Example

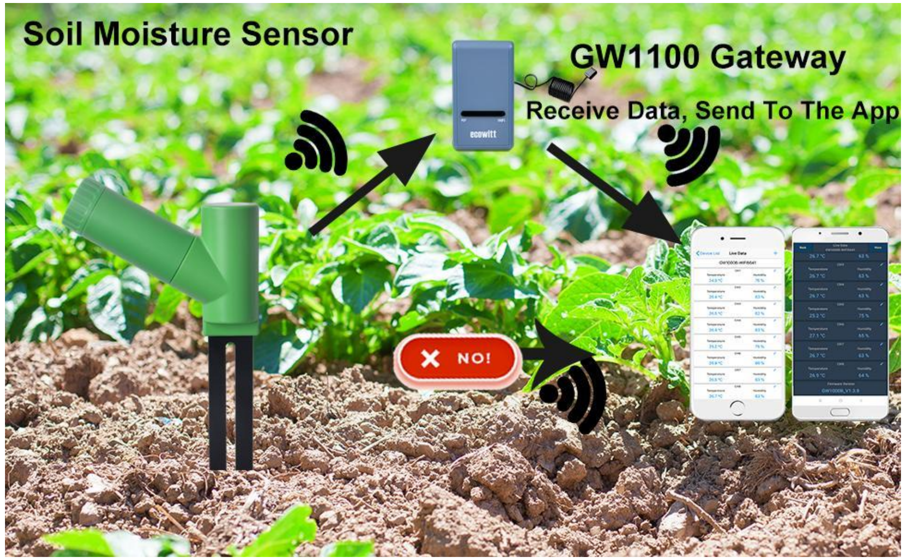


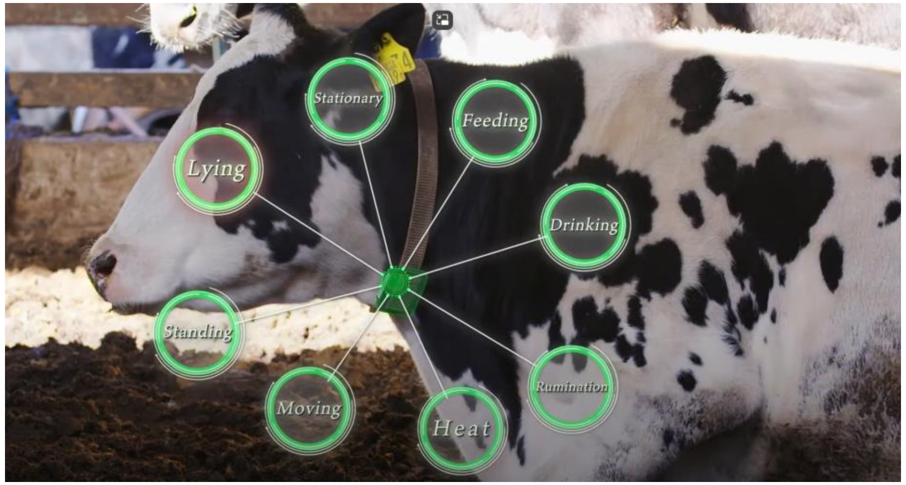
ZigBee Example

Feng, X., Yan, F., & Liu, X. (2019). Study of wireless communication technologies on Internet of Things for precision agriculture. Wireless Personal Communications, 108(3), 1785-1802.

Devices and Platform Layer

- Foundational layer that consists of hardware (sensors, gateways, servers) and platforms used to capture, transmit, and process agricultural data
- **Environmental Sensors:** Measure soil moisture, temperature, humidity, and crop growth. Example: soil moisture sensors for precise irrigation management.
- **Animal Sensors:** Monitors health metrics like heart rate, activity levels, and temperature for livestock.
- Gateways serve as intermediaries between sensors and cloud platforms, aggregating data and ensuring that different communication standards are supported.

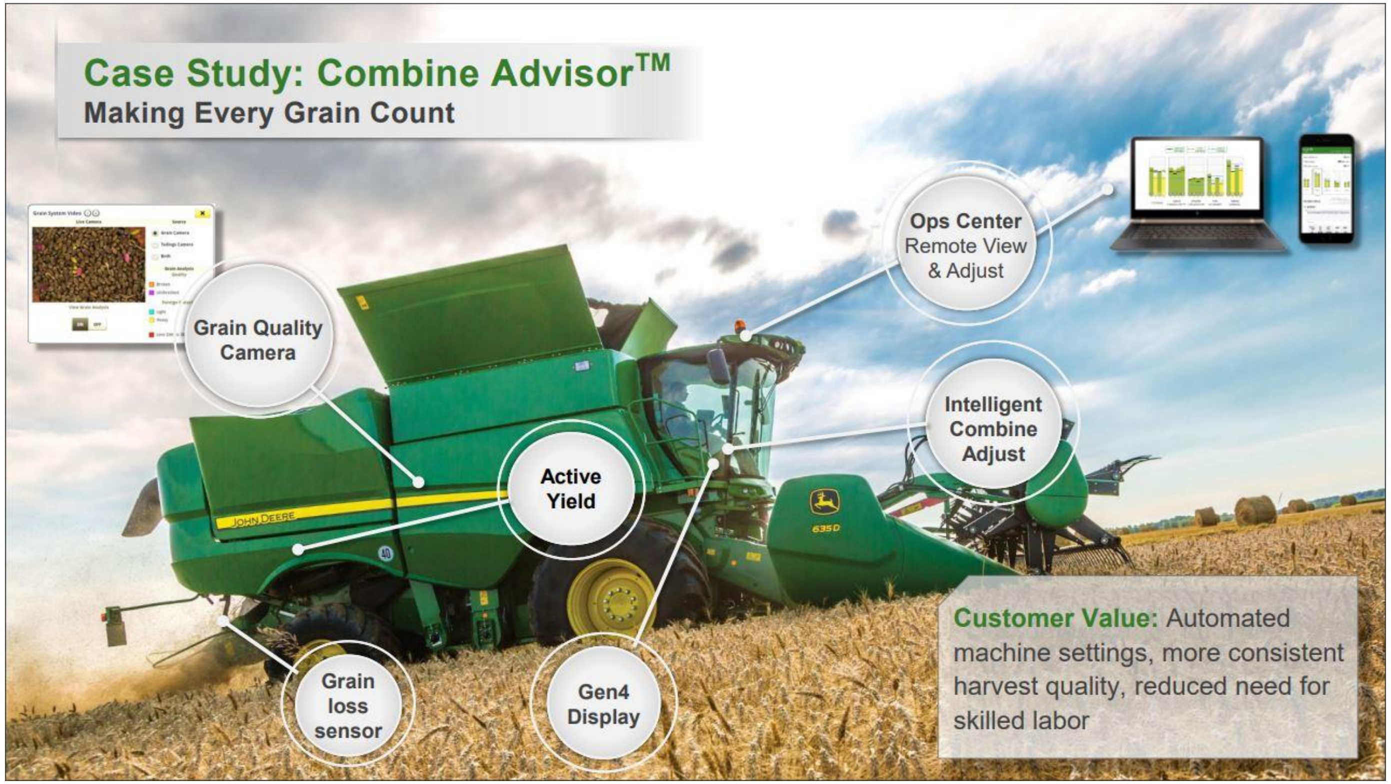




[IoT Analysis of cattle activity "U-motion(R)" -- Short version (youtube.com)]

Case Study: Combine Advisor

- John Deere, traditionally known as a farm equipment manufacturer, has evolved into a leader in precision agriculture through innovations in **IoT** and **data analytics**.
- By integrating sensors, data, and technology, John Deere helps farmers optimize operations, improve productivity, and maximize profitability.
- **Agronomic Data:** Information about crop management such as soil quality, moisture levels, seed placement, and nutrient levels.
- **Machine Operation Data:** Data from sensors on machines like fuel levels, engine RPM, machine hours, etc.



https://d3.harvard.edu/platform-digit/submission/farm-to-data-table-john-deere-and-data-in-precision-agriculture/

Case Study: Combine Advisor

- Data is collected from embedded sensors in both machinery and the field.
- **JDLink™ Connect** telematics uploads data to the cloud using cellular, Wi-Fi, or Bluetooth.
- **MyJohnDeere.com Portal**
    - Central platform where farmers access and manage data.
    - Operation Center App: Real-time monitoring of machine operations, analysis of performance, and collaboration with external partners (e.g., agronomists, input suppliers).
- Algorithms help determine optimal planting, irrigation, and fertilizer application based on data.

Quiz

1. **How do farmers access and manage their data collected from John Deere equipment?**

a) Through the MyJohnDeere.com portal
b) By manually downloading data from the tractor
c) Through a USB stick connected to the tractor
d) Using only mobile apps without any cloud platform

2. Which of the following technologies is used by John Deere to transmit data from the machines to the cloud?

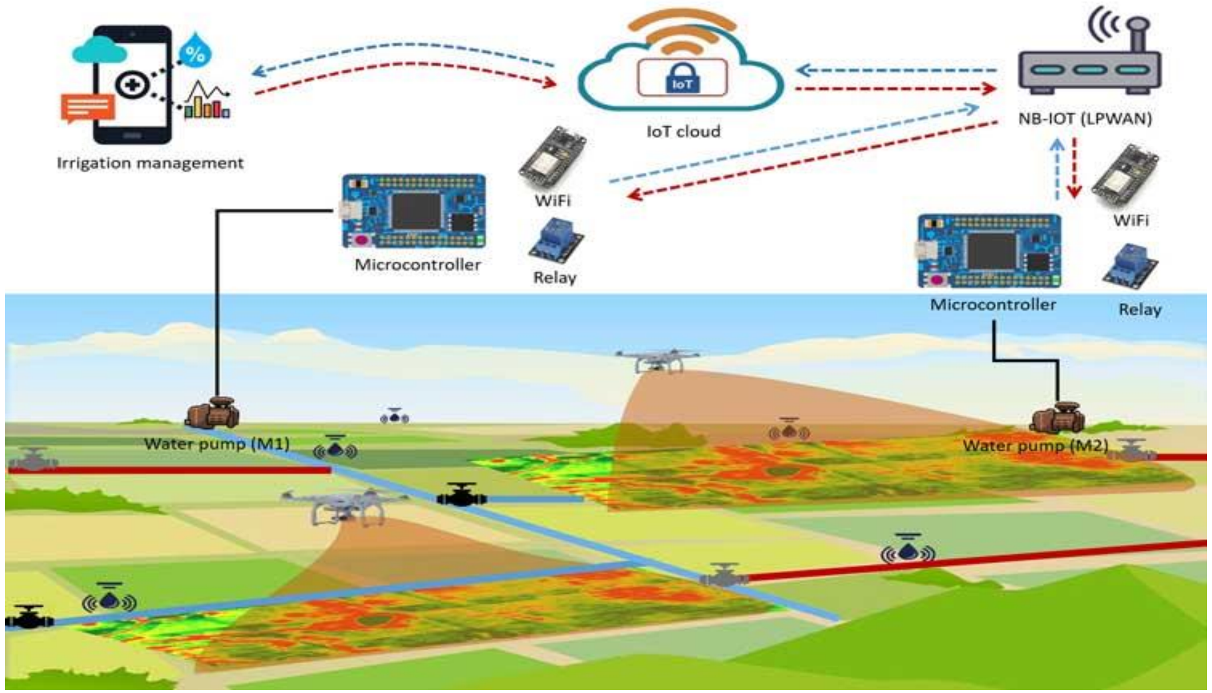
a) Satellite
b) JDLink™ Connect
c) Bluetooth only
d) Ethernet cables

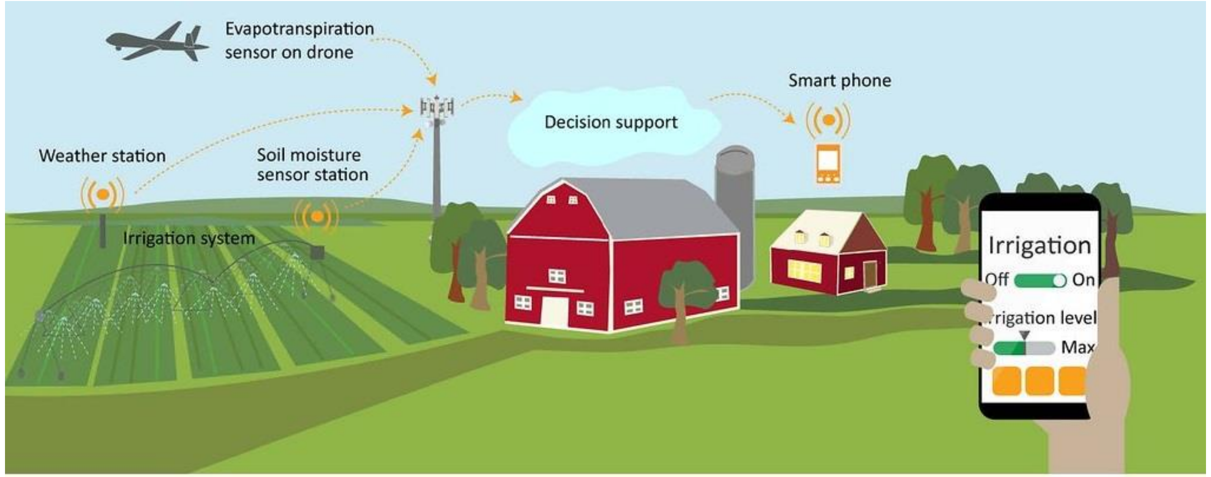
3. Which technology allows farmers to track the movement and health of livestock?

a) GIS
b) RFID tags and GPS collars
c) Drones
d) Tractors

IoT-Driven Smart Irrigation System

- **Smart irrigation** belongs to the precision agriculture farming management concept, whose goal is to increase field yield and reduce costs by using resources like water more sustainably and intelligently.
- Smart irrigation systems use **moisture, temperature, and other sensors** to collect **real-time data** about the **weather, the soil, and the irrigation system** directly on site.

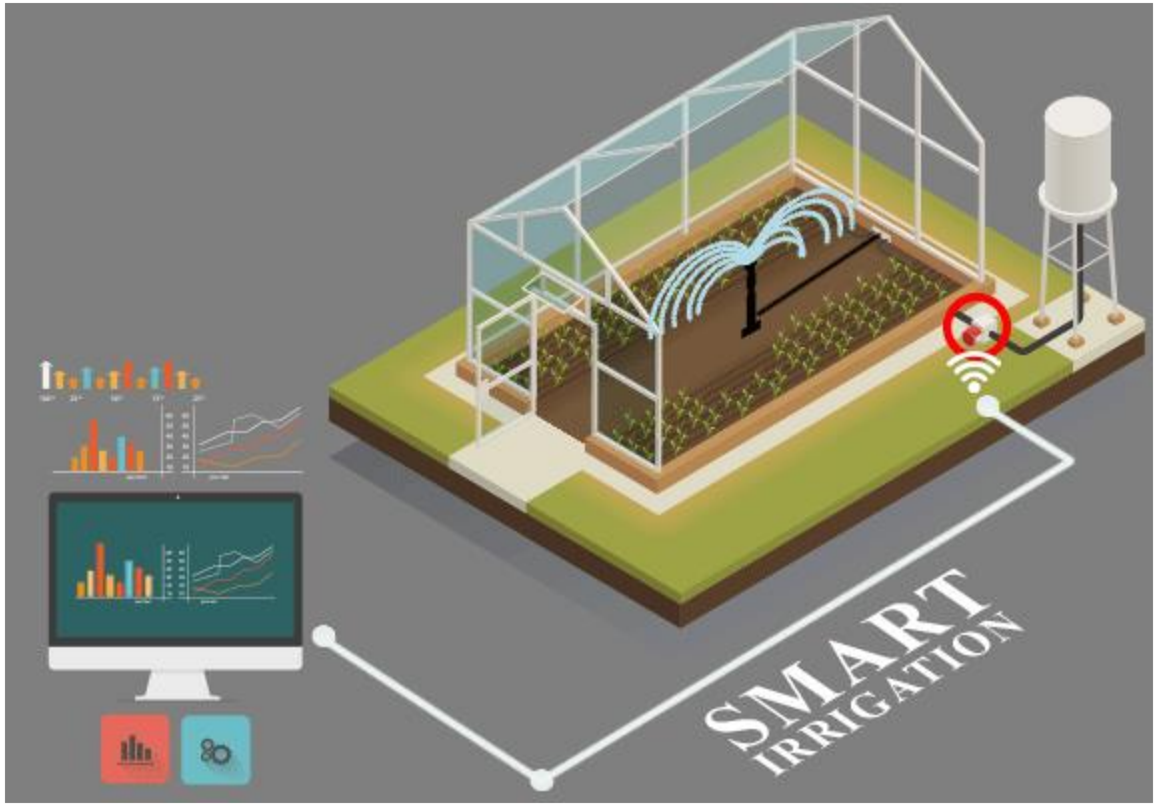


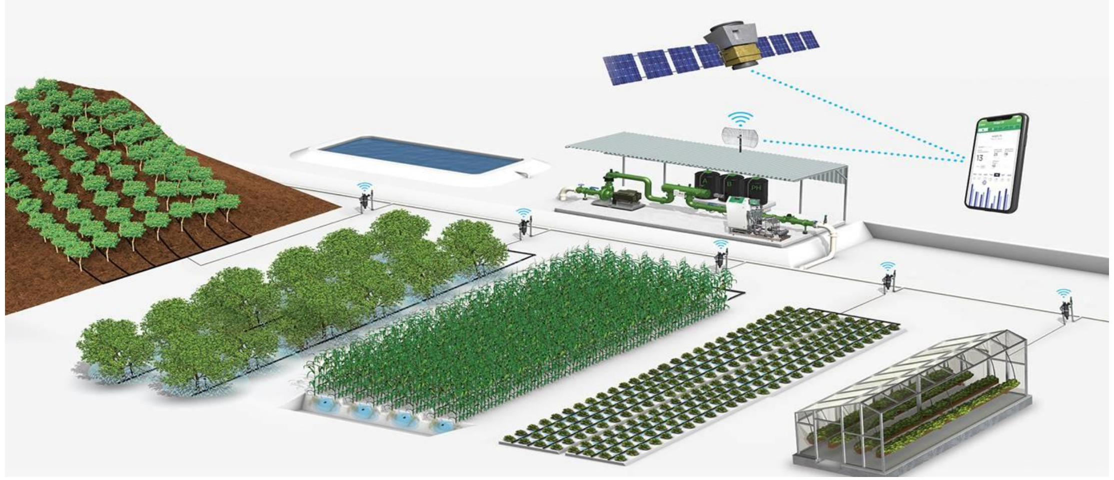


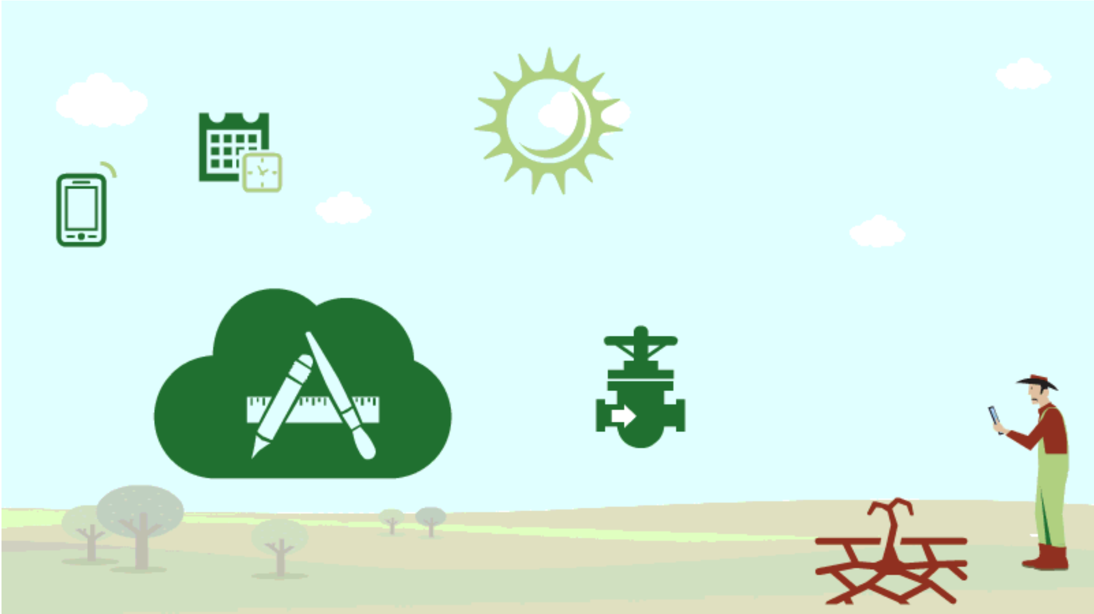
https://www.apo-tokyo.org/articles/deep-learning-and-iot-based-pump-systems-for-precision-irrigation/

https://www.skyfilabs.com/project-ideas/smart-irrigation-using-iot

IoT-Driven Smart Irrigation System

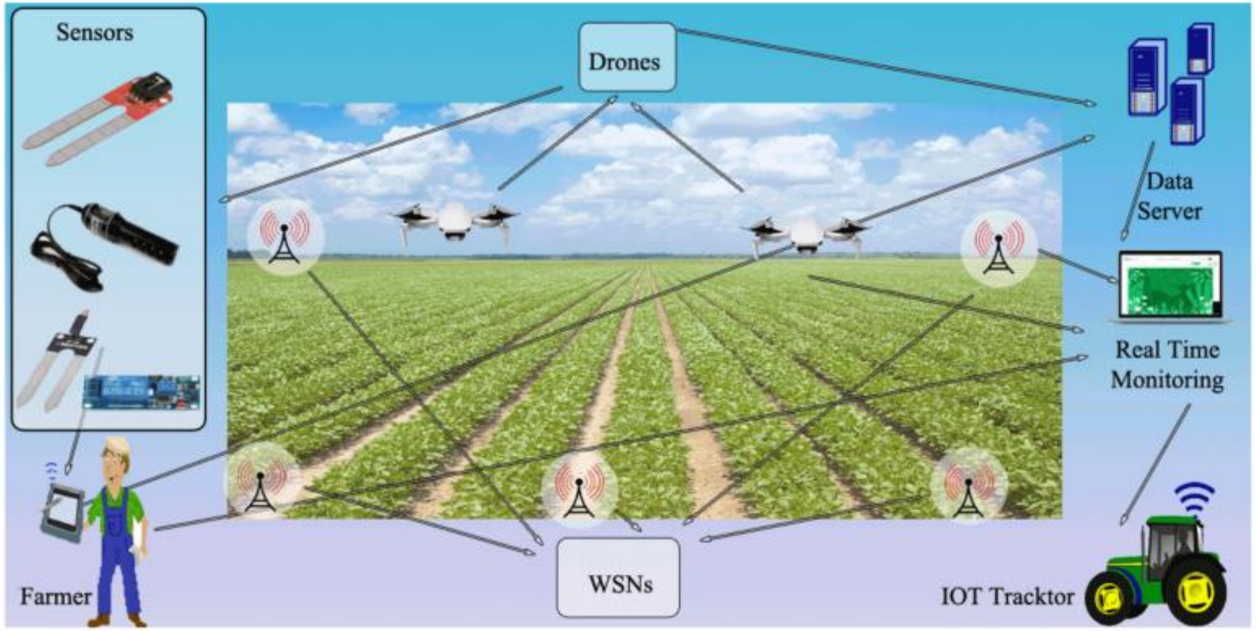






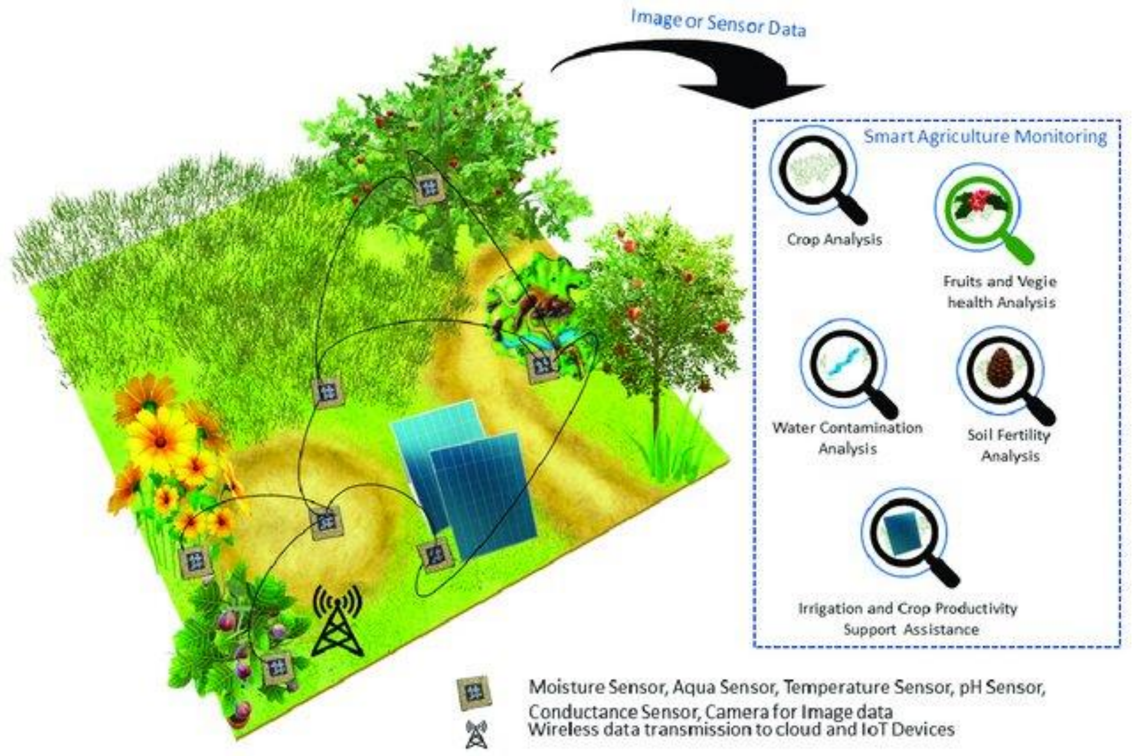
IoT-Driven Crop Monitoring

- IoT sensors placed around the **field or greenhouse** provide constant feedback on crop health indicators like **nutrient deficiency, water stress, or pest presence**.
- IoT systems integrated with **drones and satellite data** can help monitor large fields, **identify areas of the crop that need attention**, and **track plant growth over time**.
- By **combining sensor data with drone and satellite imagery**, **machine learning models** can **predict crop yields**, allowing farmers to **make more informed decisions** about **harvesting and resource allocation**.



Rehman, A., Saba, T., Kashif, M., Fati, S. M., Bahaj, S. A., & Chaudhry, H. (2022). A revisit of internet of things technologies for monitoring and control strategies in smart agriculture. Agronomy, 12(1), 127.

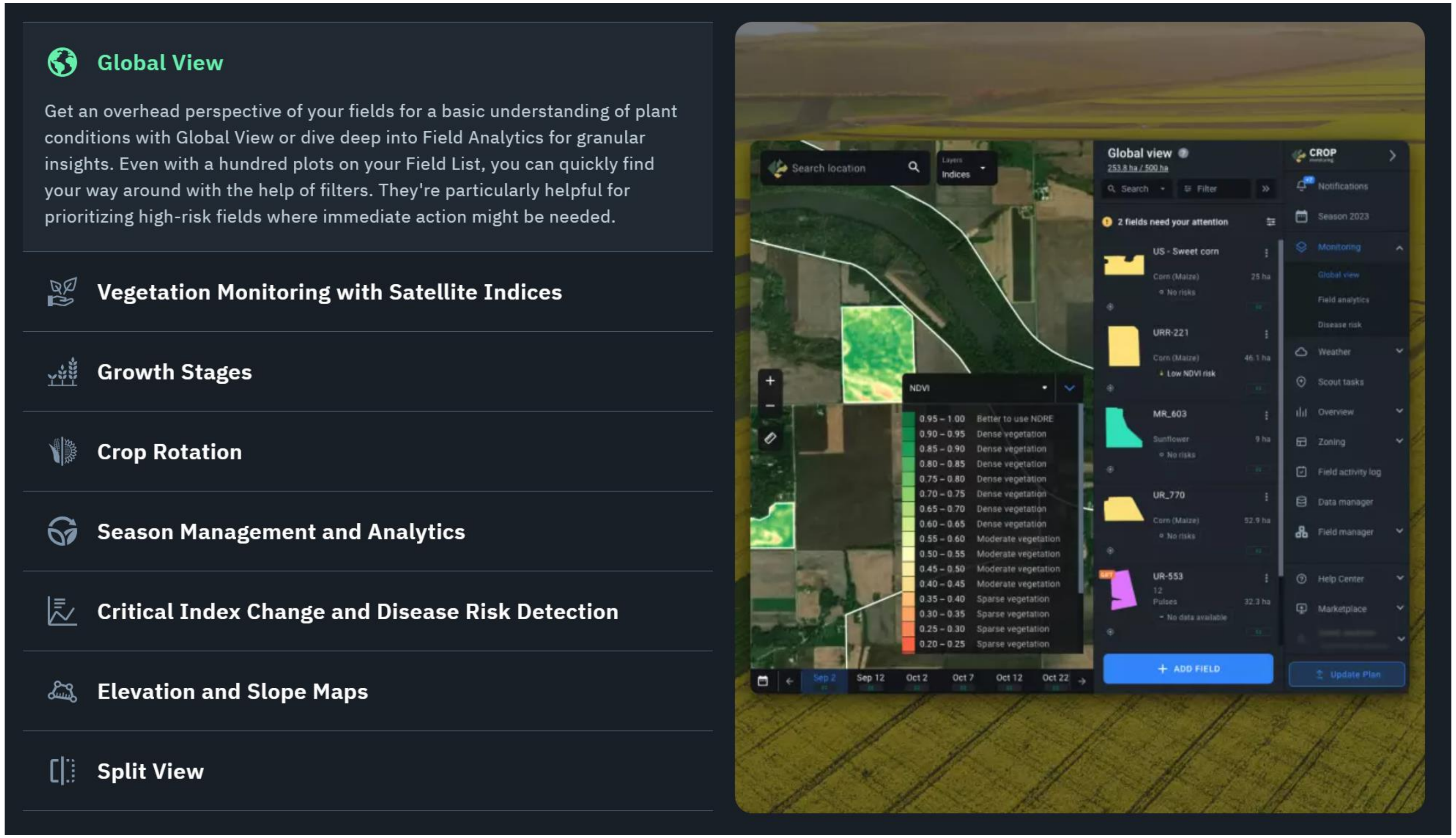
IoT-Driven Crop Monitoring



https://www.khetivyapar.com/en/smart-agriculture-devices-agricultural-drones-in-india-36

Ullo, S. L., & Sinha, G. R. (2020). Advances in smart environment monitoring systems using IoT and sensors. Sensors, 20(11), 3113.

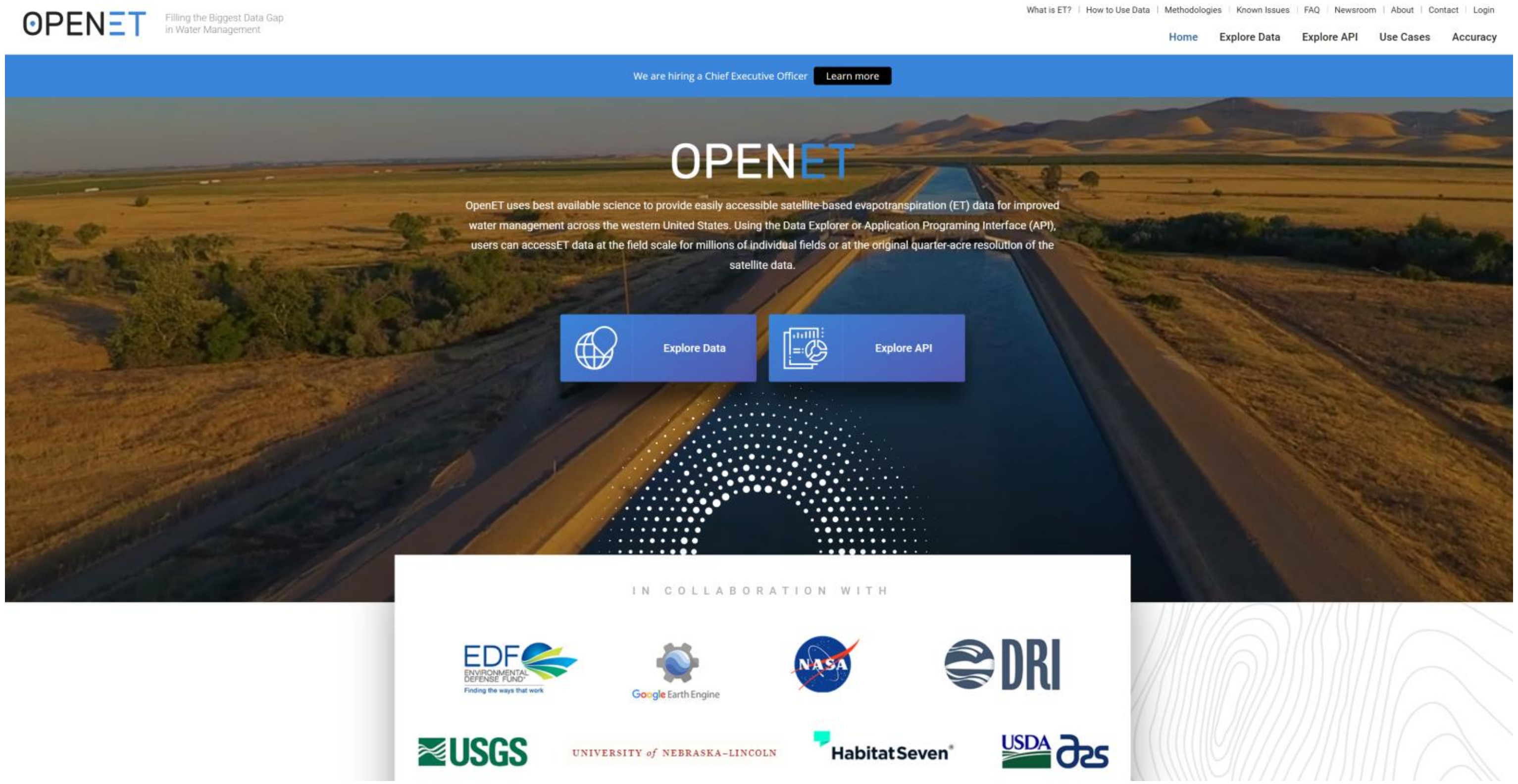
IoT-Driven Crop Monitoring



https://eos.com/products/crop-monitoring/key-functions/satellite-monitoring/

OpenET as an IoT Example

- OpenET is a cloud-based platform that uses satellite data and advanced models to estimate evapotranspiration (ET) at the field scale.
- Uses satellites (remote sensing) as IoT devices to collect data on land surface, water usage, and crop health.
- Provides real-time or near-real-time data on water consumption and crop conditions, making it accessible through web-based platforms for farmers and decision-makers.



Quiz

- **Can Google Earth Engine (GEE) be considered an example of IoT for crop monitoring?**

IoT for Automation in Farming

- **Tractors** and **robots equipped with IoT sensors** and **AI** can plant seeds, apply fertilizers, and harvest crops with little human intervention. Examples include John Deere's autonomous tractors and Naïo Technologies' weeding robots.
- IoT systems **monitor and control climate conditions** in **greenhouses**, adjusting temperature, humidity, and light levels to create ideal growing conditions.
- **IoT-enabled feeders** can **deliver food to livestock** based on pre-set schedules or when sensors detect animals need nourishment, improving feed efficiency.

IoT for Automation in Farming

Challenges and Solutions in IoT for Agriculture

- Many **rural areas lack reliable internet access**. **Solutions include using LPWAN** or **satellite networks** for connecting IoT devices over long distances.
- Protecting farm data from **cyberattacks** is crucial. **Encryption**, secure cloud services, and access control mechanisms are required to safeguard sensitive farm information.
- While IoT can improve efficiency, the **initial setup costs (sensors, communication devices, platforms) can be high**. However, advancements in technology are gradually reducing costs.
- **Ensuring that different IoT devices can communicate** and integrate with each other is a challenge. **Standardization of protocols** and software can help address this issue.

Next Lecture

- Robotics & Automation in Agriculture