Universidad Politécnica de Cartagena

MIEMBRO DE EUT+ EUROPEAN UNIVERSITY OF TECHNOLOGY

MINISTERIO DE CIENCIA E INNOVACIÓN

NextGenerationEU

Plan de Recuperación, Transformación y Resiliencia

AGENCIA ESTATAL DE INVESTIGACIÓN

smartDUMP

IoT for environmental monitoring

Air quality and Precission Agriulture

Índice

Part 1.

Internet of Things


IoT
Smart
WSN

Things

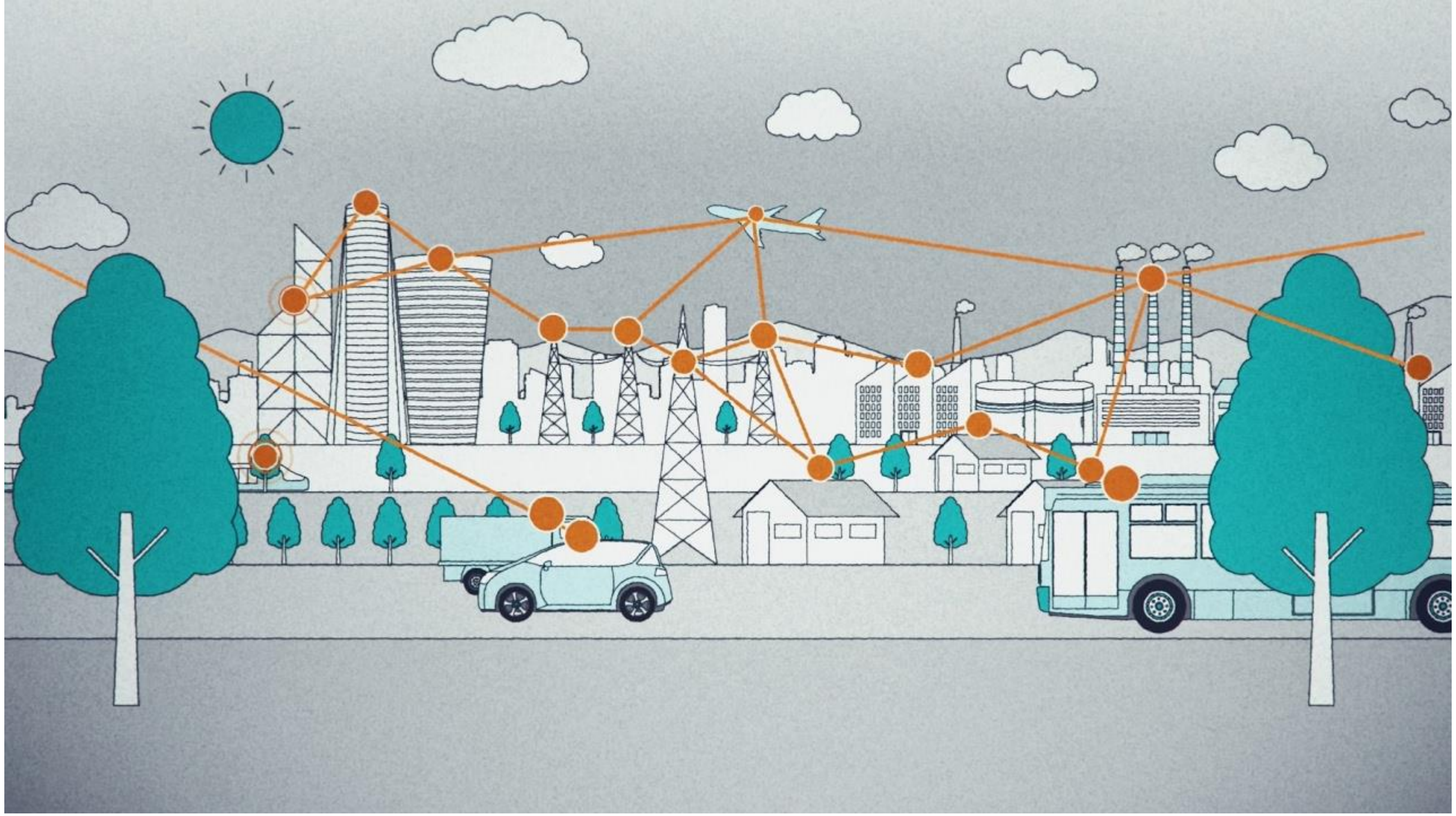
Example: Smart Watch 4G

- Conversation topic → Sensors data
- Data processing → Smart
- Ability to talk → Internet connection

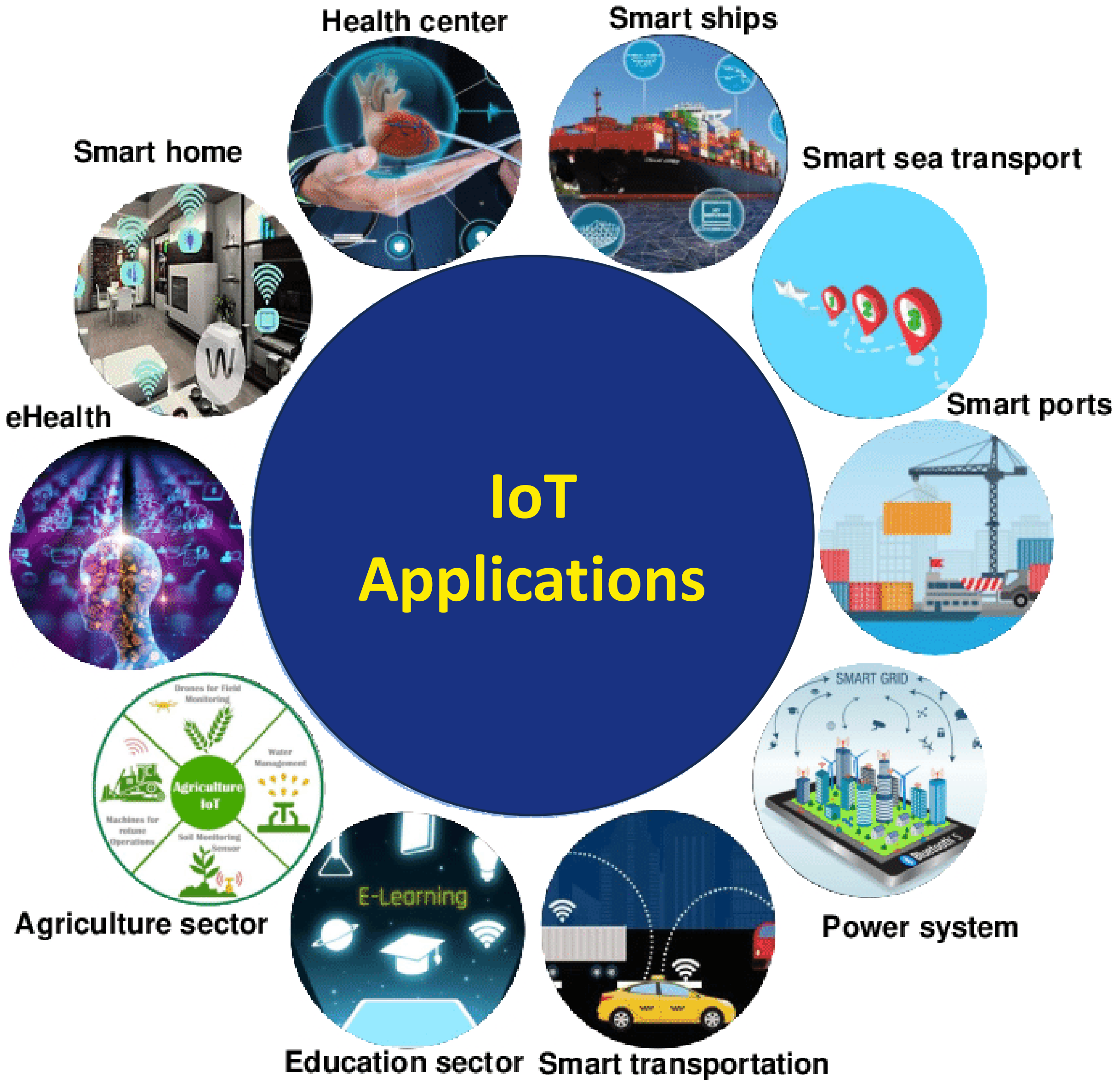
Sensors

- Temperature
- GPS
- Heart rate monitor
- Acelerometer
- Altimeter
- Gyroscope

Wireless Sensor Network



Where can I use IoT?



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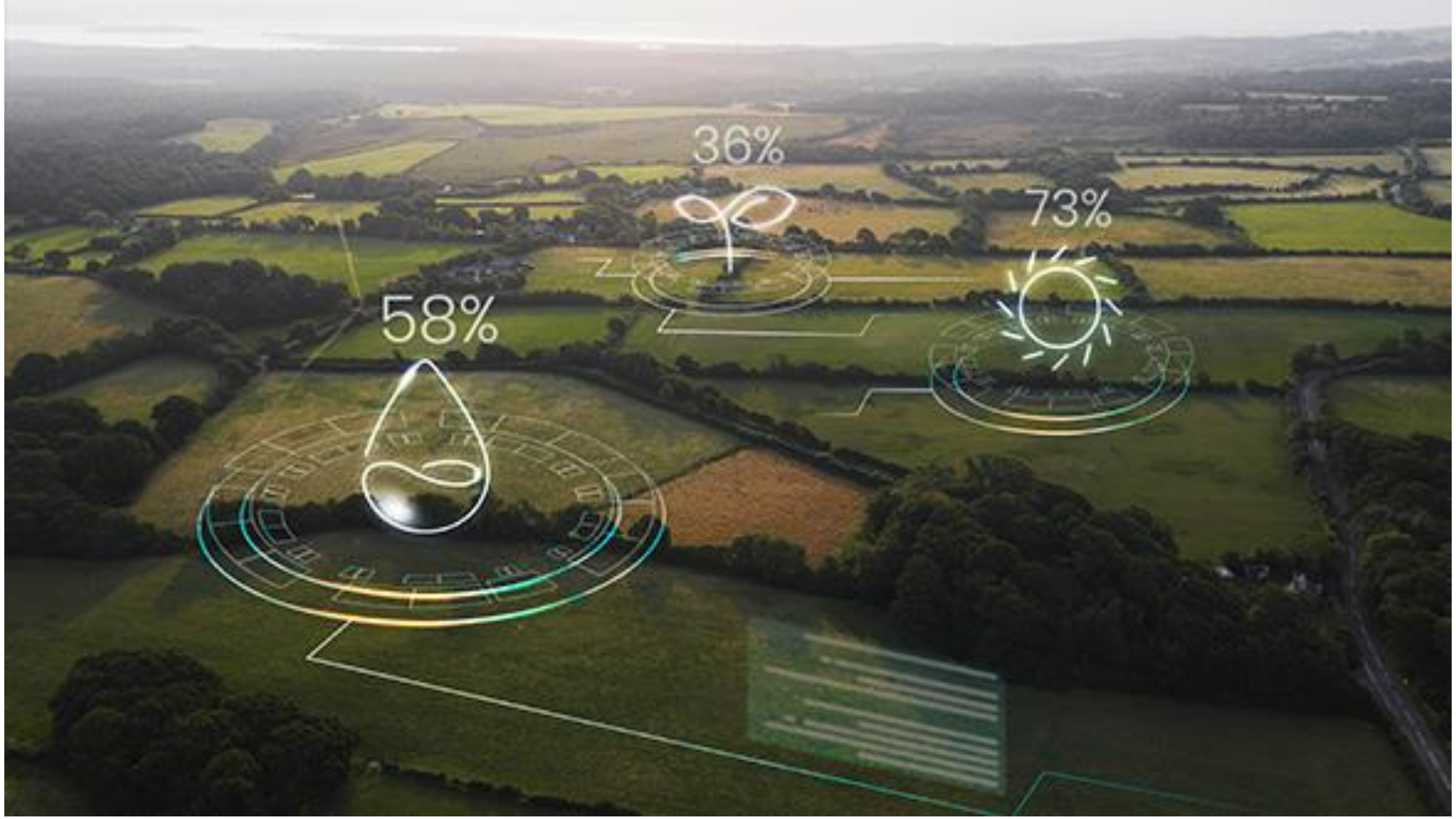
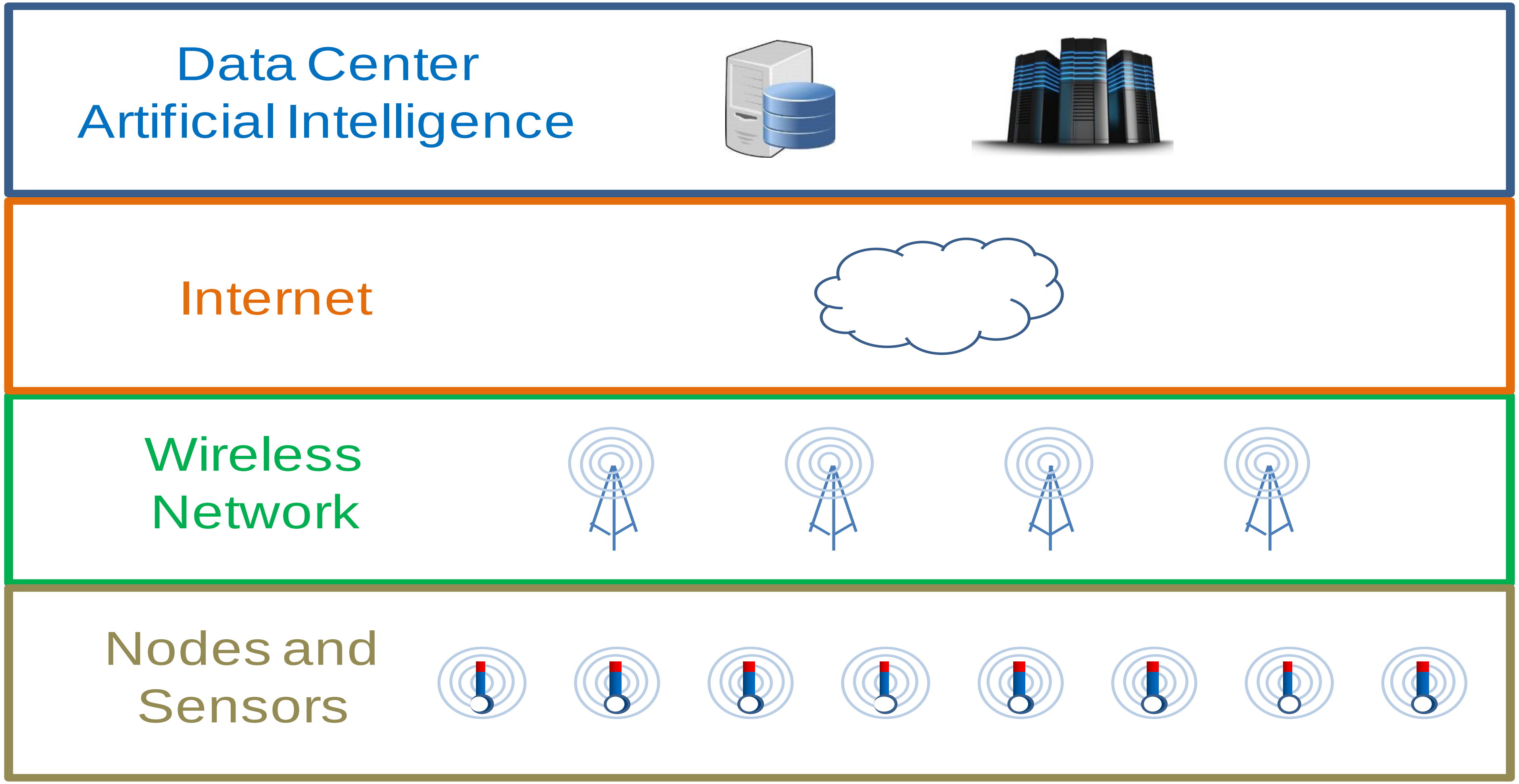
Environmental monitoring




Data Center
Artificial Intelligence
Internet
Wireless
Network
Nodes and
Sensors

Part 2.

Air Quality Monitoring

Why should we monitor Air Quality?

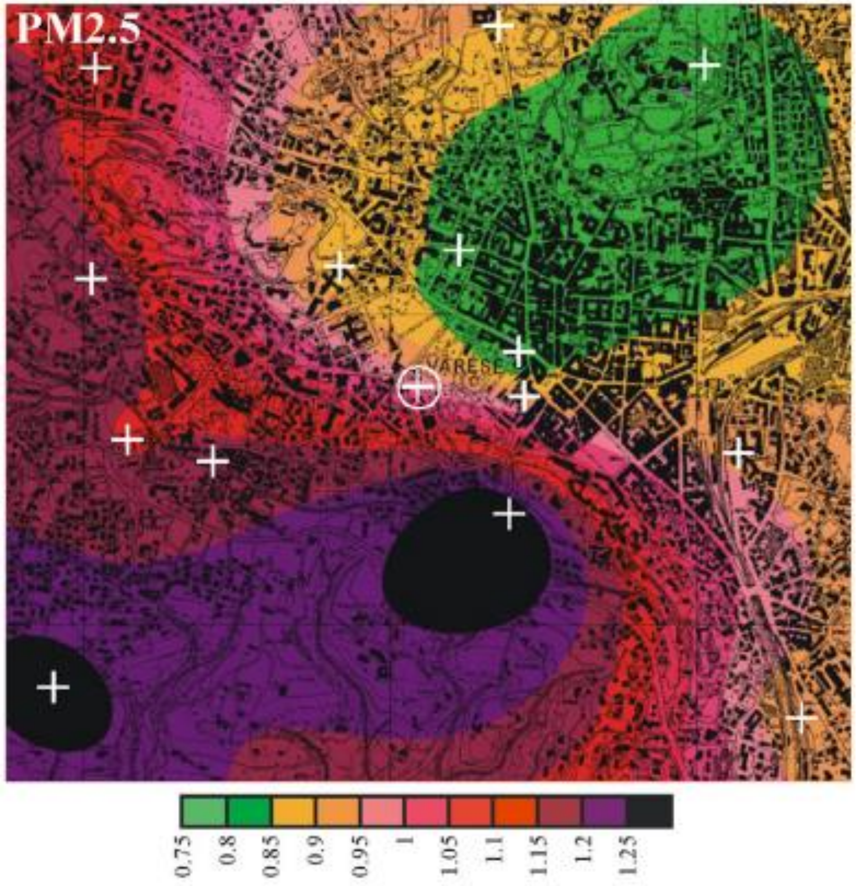
Pollution → **Health**

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0–50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51–100	Air quality is acceptable; however, for some pollutants ther may be a moderate health concern for a small number of people who are unusually sensitive to air pollution
Unhealthy for Sensitive Groups	101–150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151–200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201–300	Health alert: everyone may experience more serious health effects.
Hazardous	>300	Health warnings of emergency conditions. The entire population is more likely to be affected.

Suspended Particulate Matter

Particulate Matter	Cause
$PM_{1.0}$	Coal combustion, soil dust, vehicle exhaust.
$PM_{2.5}$	Emissions from combustion of gasoline, oil, diesel or Wood.
PM_{10}	Combustion and dust from construction sites, landfills, agriculture, wildfires, brush/waste burning, industrial sources, wind-blown dust or pollen.

Suspended Particulate Matter



Yatkin, S., Gerboles, M., Belis, C. A., Karagulian, F., Lagler, F., Barbiere, M., & Borowiak, A. (2020). Representativeness of an air quality monitoring station for PM2. 5 and source apportionment over a small urban domain. Atmospheric Pollution Research, 11(2), 225-233.

Gases

Gases	Cause	Effect
SO_2	Released from coal and oil combustion.	Can lead to respiratory diseases and even death.
NO_2	Produced by road traffic and other fossil fuel combustion processes.	It contributes to acid rain and can lead to pulmonary irritation.
CO	It is released from the combustion of wood, oil, charcoal, and natural gas.	It is linked to headaches, breathing difficulties, loss of consciousness and even death.
O_3	Originates from the chemical reaction between sunlight and the pollutant from vehicles and industries.	It can lead to breathing difficulties, respiratory infections, or premature death.

Air Pollution in Europe: Real-time Air Quality Index Visual Map

World | Asia | North America | South America | Africa | Australia | Middle East | India | China | Japan | South Korea | Thailand | Mexico | Poland

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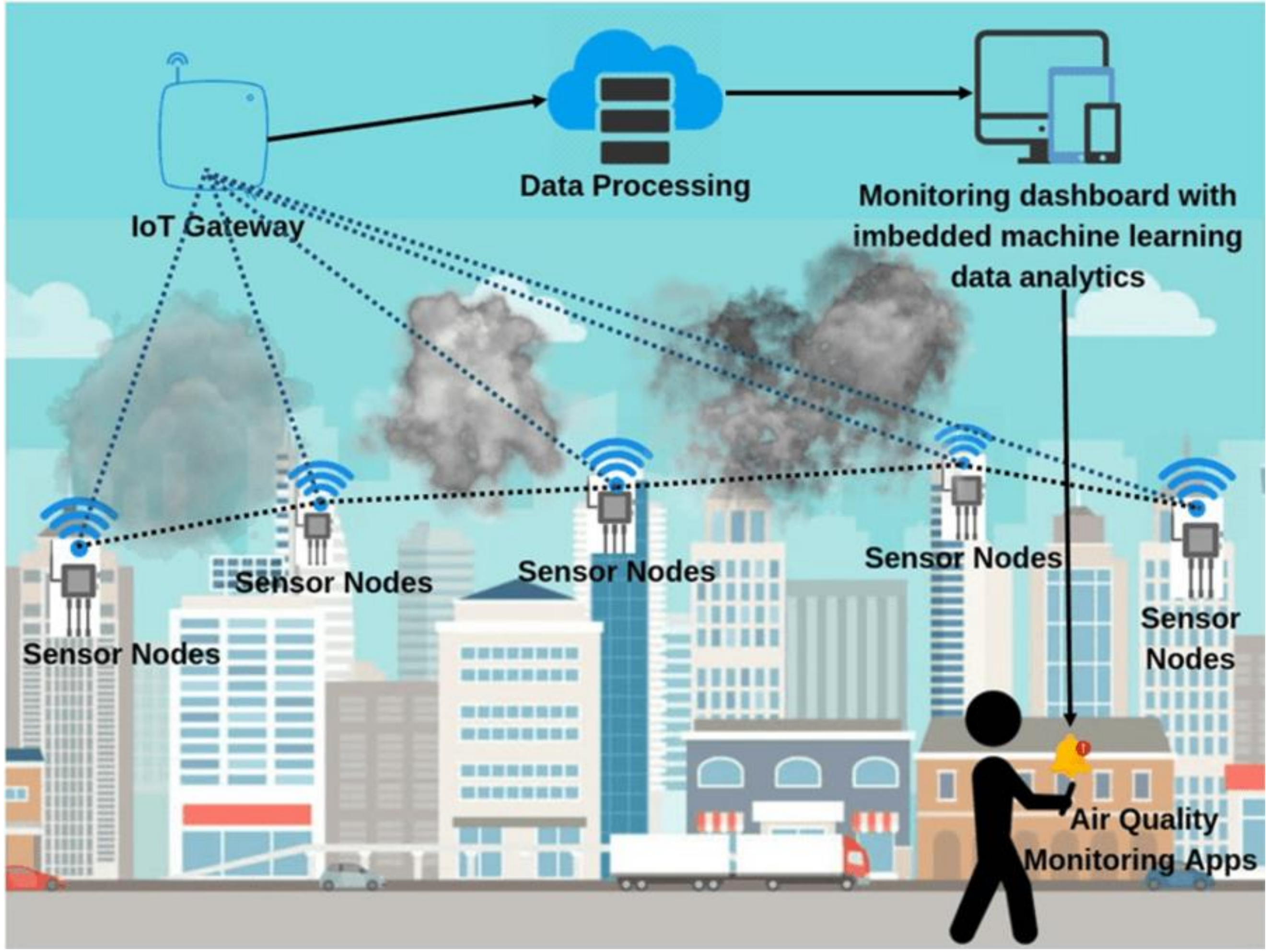
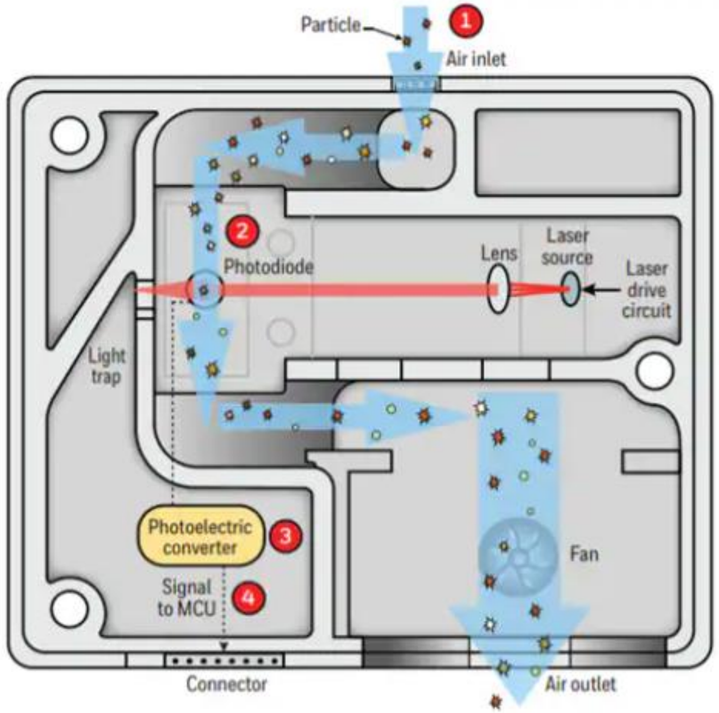
Architecture of an IoT Air Quality monitoring system



Sensors for particulate matter monitoring



1. Fan draws in air through inlet.
2. Air passes through the laser where the light reflected off the particles is captured by the photodiode.
3. The photodiode passes information to the photoelectric converter
   The photoelectric converter processes the signal from the particles into density.
4. Signal is transmitted to micro control unit where a proprietary algorithm processes the data and supplies outputs for the density of the particulate (μg/m³).

Honeywell

Model	Size (mm) (H × W × D)	Price (USD)	Detection range (μm)	Concentration range (μg/m³)	Declared Accuracy (μg/m³)	Sampling interval (s)	Particle count
Alphasense OPC-N2	60 × 64 × 75	443	0.38 to 17	0.01 to 1,500	Not known	1 to 10	Yes
Plantower PMS5003	38 × 21 × 50	28	0.3 to 10	0 to 500	±10	1	Yes
Plantower PMS7003	37 × 12 × 48	28	0.3 to 10	0 to 500	±10	1	Yes
Honeywell HPMA115S0	36 × 43 × 24	33	Not known	0 to 1,000	±15	<6	No

Bulot, F. M., Johnston, S. J., Basford, P. J., Easton, N. H., Apetroaie-Cristea, M., Foster, G. L., ... & Loxham, M. (2019). Long-term field comparison of multiple low-cost particulate matter sensors in an outdoor urban environment. *Scientific reports*, *9*(1), 7497.

Sensors for gas monitoring

- ✓ Range: 500 PPM
- ✓ Resolution: 0.1 PPM
- ✓ Power Consumption: 10 to 50 uW
- ✓ Response Time: < 30 seconds

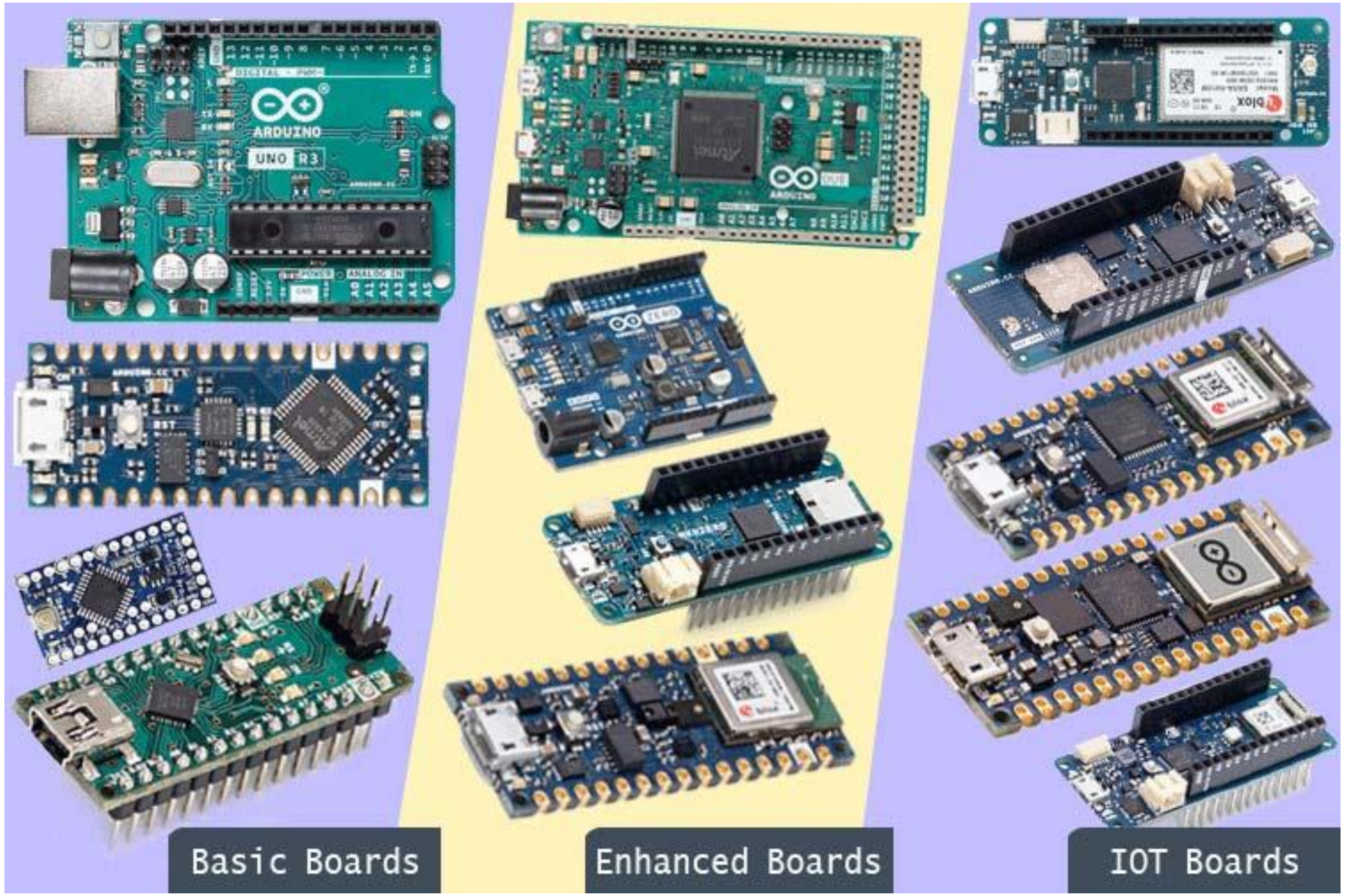
- ✓ Range: 50 PPM
- ✓ Resolution: 0.01 PPM
- ✓ Power Consumption: 10 to 50 uW
- ✓ Response Time: < 15 seconds

- ✓ Range: Upto 50 PPM
- ✓ Resolution: < 100 PPB
- ✓ Power Consumption: 10 to 50 uW
- ✓ Response Time: < 15 seconds

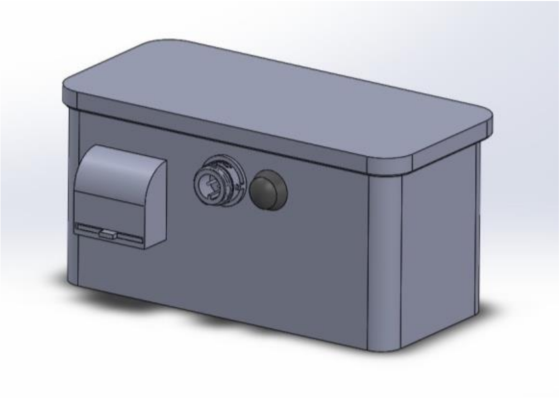
- ✓ Range: Upto 50 PPM
- ✓ Resolution: < 20 PPB
- ✓ Power Consumption: 10 to 50 uW
- ✓ Response Time: < 15 seconds

Prana Air

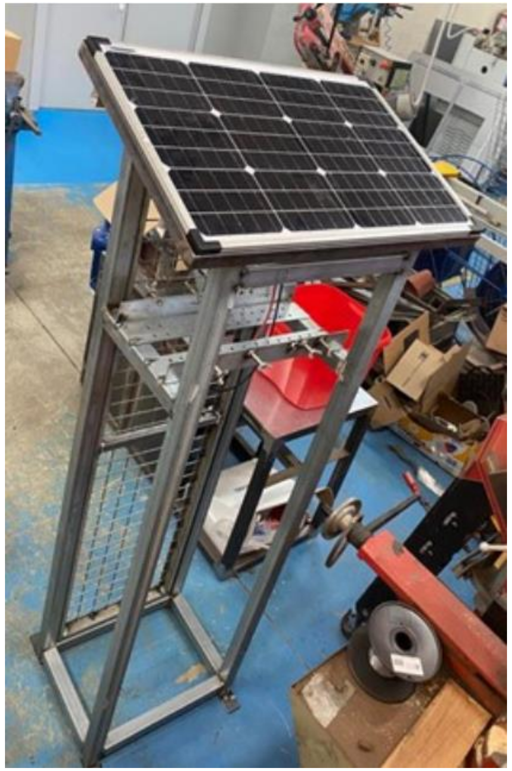
Development board



IoT Air monitoring devices



Power options

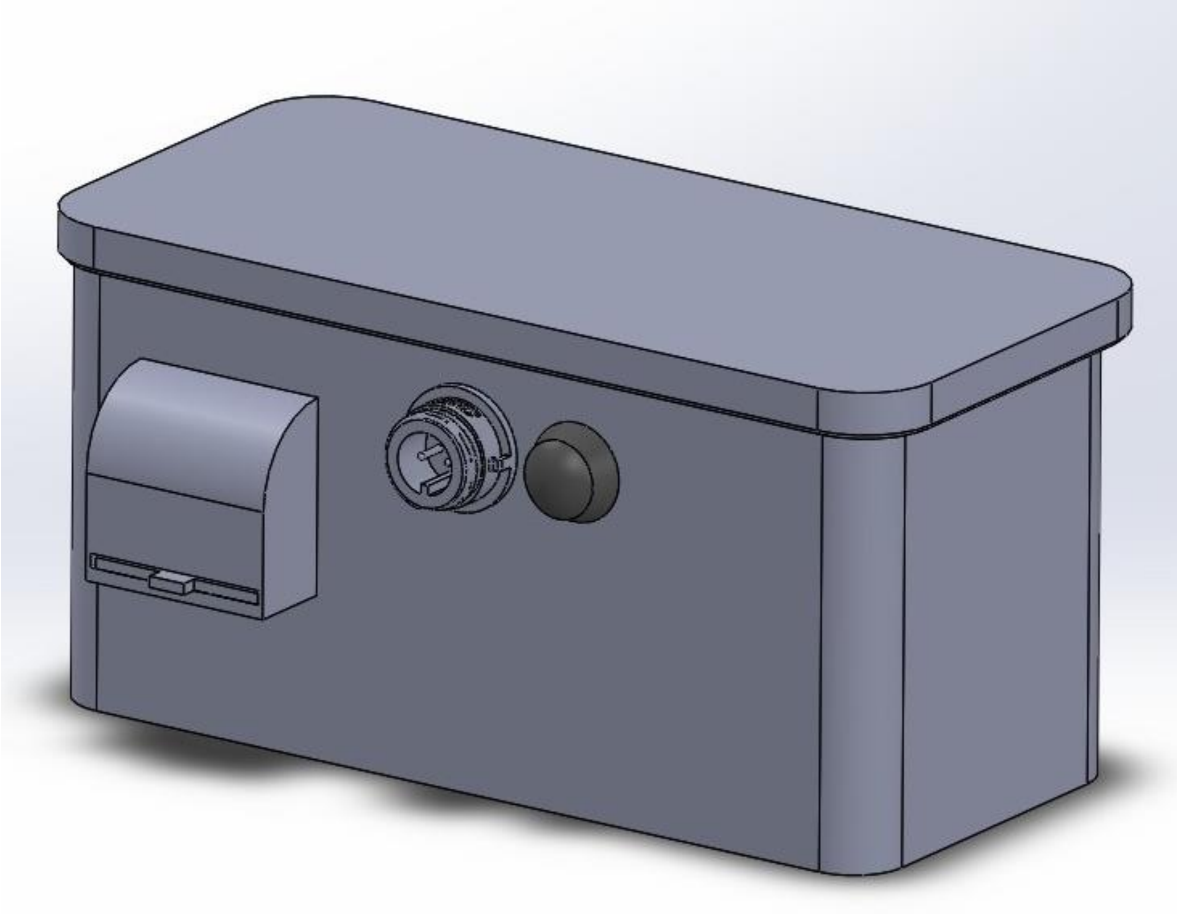


Solar Panel

Power Grid

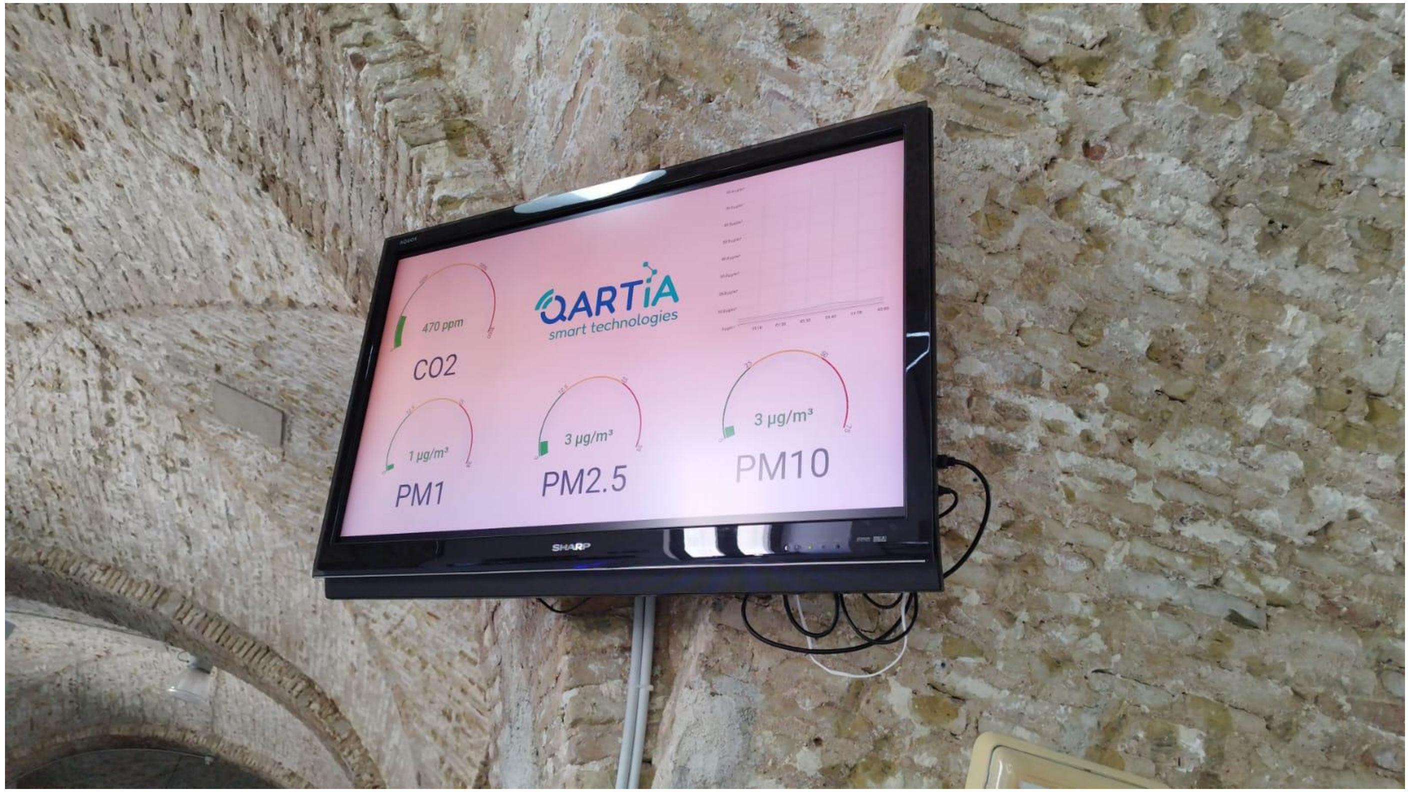
DIPASÓN – Particulate matter measurement (Outdoor)

- Measures particles with diameter from 0.35 to 40 microns
- Reports 3 configurable values (e.g. PM10, PM2.5, and PM1.0)
- Supports different connectivity tech. (WiFi, BLE, 4G, LoRa, Sigfox, …)
- Geolocalization.
- Real time monitoring.
- Preventive maintenance.
- Generation of contamination alerts.



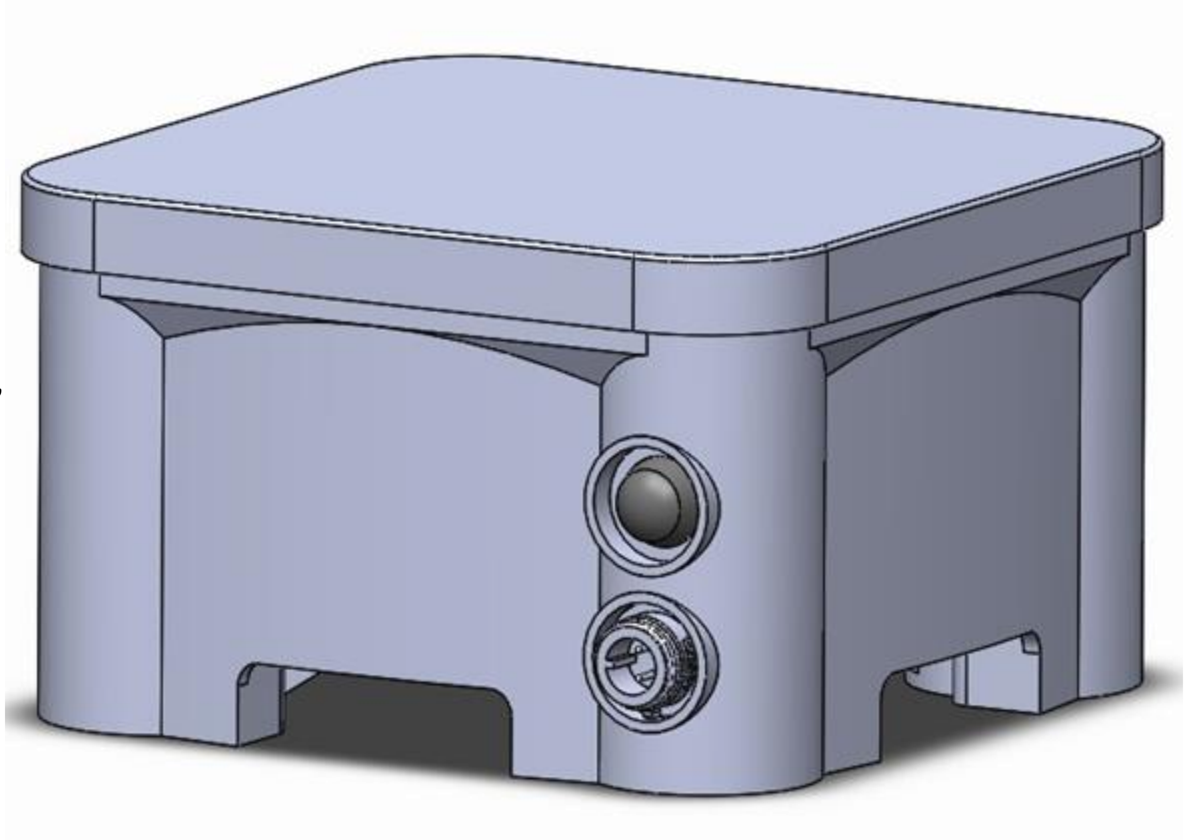
DIPASÓN – Particulate matter measurement (Indoor)

- Measures PM1, PM2.5, PM10, temperature, humidity, and CO_2
- Provides more accurate information than only CO_2 measurement
- Includes estimate of the number of people in the room



MEGAMIA – Contaminant gases measurement

- Measures contaminant gases criterion as defined by World Health Organization (WHO)
- Each device supports up to 4 different gases (according to customer requirements)
- Supports different connectivity tech. (WiFi, BLE, 4G, LoRa, Sigfox, …)
- Geolocalization
- Real time monitoring
- Preventive maintenance
- Generation of contamination alerts



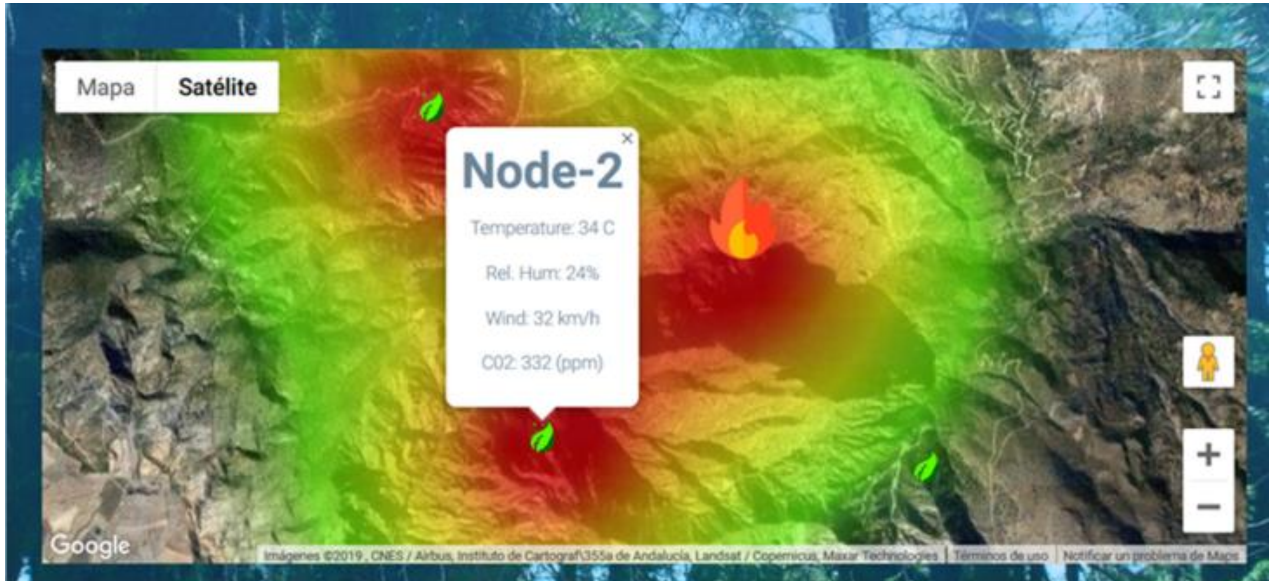
Use cases: Smart City (Cartagena city council)

- Quality of air
- Installed in street lamps
- Anti-vandal support casing
- More than one year in operation and under adverse weather conditions, without requiring maintenance yet

Use cases: Industry (Atlantic Copper)

- Very high concentrations of SO_2
- PM10
- Solution by ABB, high cost and ineffective

Use cases: Forest fire detection



MAP INFORMATION

The green leaf symbol indicates the level of C02 recorded by the sensors is lower than the value detected in a fire.

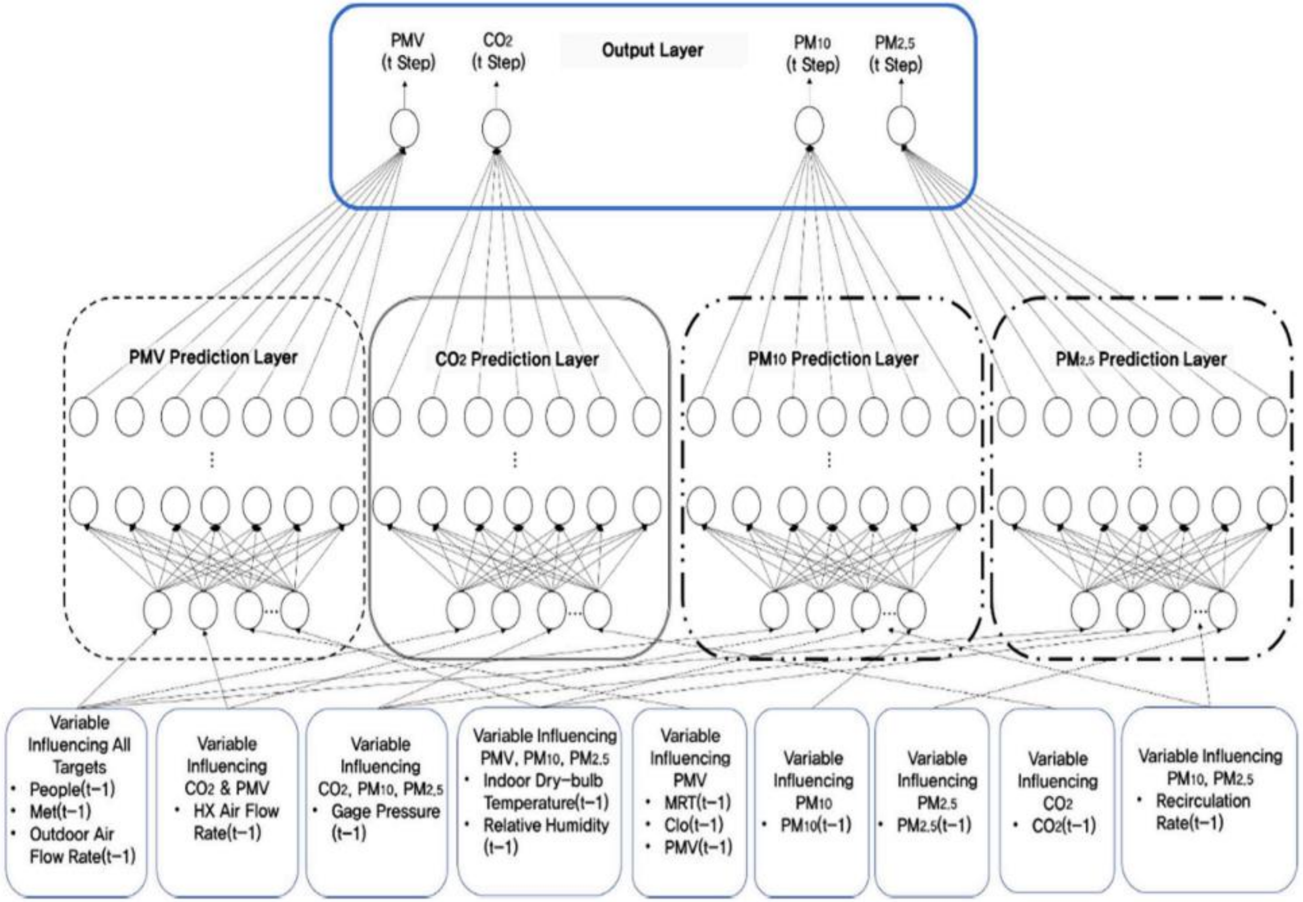
The flame symbol indicates that the level of C02 recorded by the sensors indicates the presence of a fire.

The heat zones on the map indicate that the risk values have been exceeded in that area, and therefore a fire may occur.

Get the sensor values by clicking on the markers.

Sendra, S., García, L., Lloret, J., Bosch, I., & Vega-Rodríguez, R. (2020). LoRaWAN network for fire monitoring in rural environments. *Electronics*, *9*(3), 531.

Future of Air Quality monitoring: Artificial Intelligence



Cho, J. H., & Moon, J. W. (2022). Integrated artificial neural network prediction model of indoor environmental quality in a school building. *Journal of Cleaner Production*, *344*, 131083.

Part 3.

IoT for Precision Agriculture

Why the technification of Agriculture is important?

Increase in population → More food needs

SOLUTION

The use of Precision Agriculture Solutions improves crop efficiency and reduces the use of resources such as water and fertilizers.

Challenges in Agricultural Environments

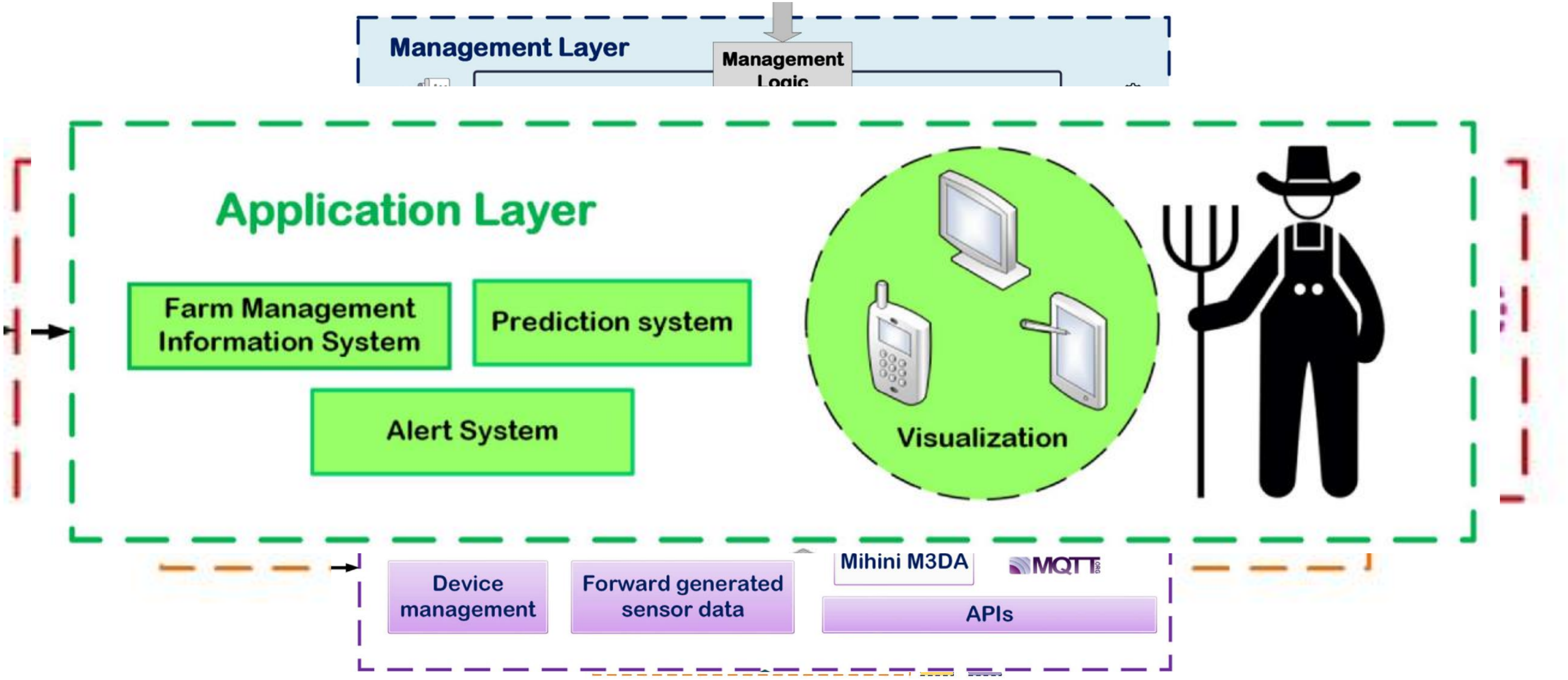
Communication difficulties

- Vegetation
- Farmer’s everyday activities
- Machinery
- Cost

Wireless technologies allow avoiding the posible damages and high cost of cabled communications.

The network design must consider the signal losses due to obstructions caused by vegetation.

Generic Architecture for Precision Agriculture IoT System

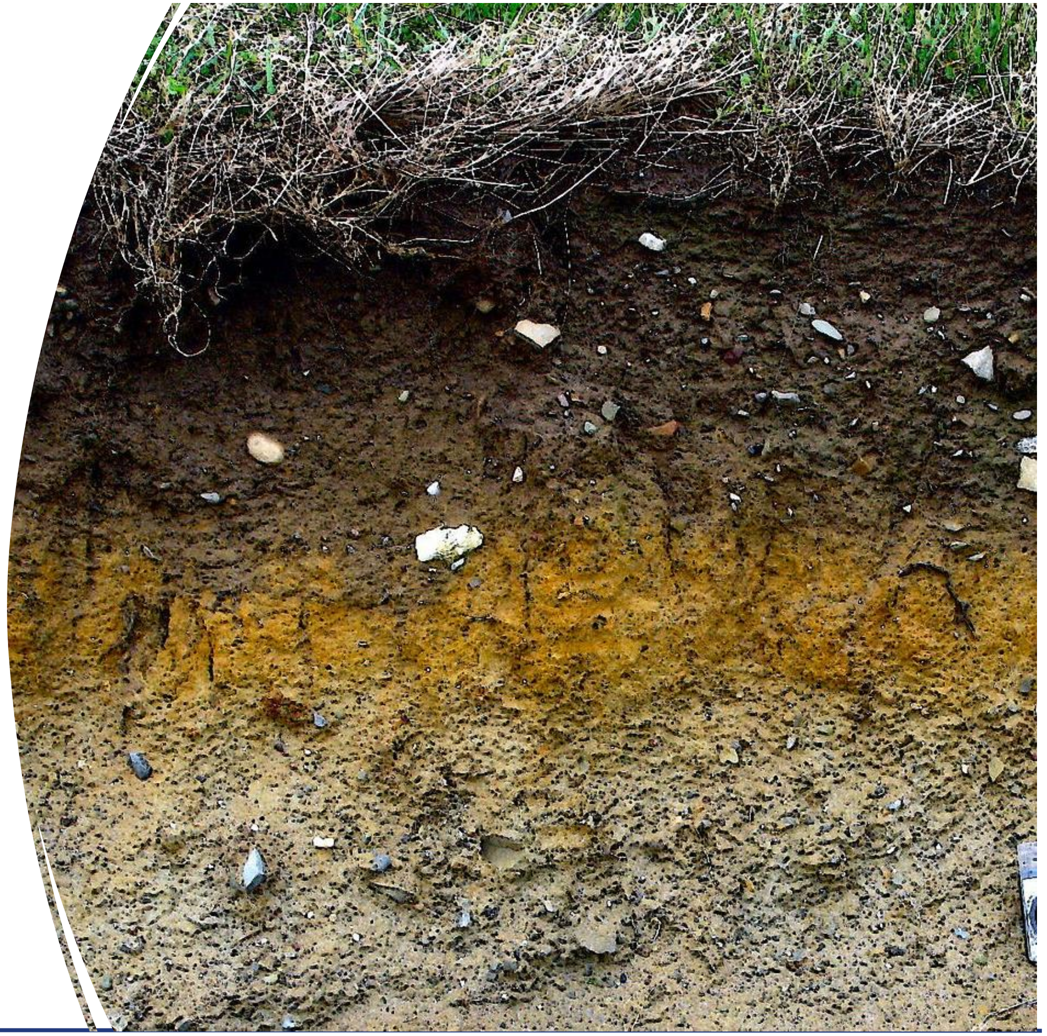


Triantafyllou, A., Sarigiannidis, P., & Bibi, S. (2019). Precision agriculture: A remote sensing monitoring system architecture. *Information*, *10*(11), 348.

What can we monitor in Agricultural Fields?

Soil

- Temperature
- Humidity
- Salinity
- Ph
- Nutrients



What can we monitor in Agricultural Fields?

Meteorology

- Temperature
- Relative humidity
- Rain
- Light / Radiation
- Wind

What can we monitor in Agricultural Fields?

Water

- Pollutants
- Ph
- Turbidity
- Salinity
- Water level

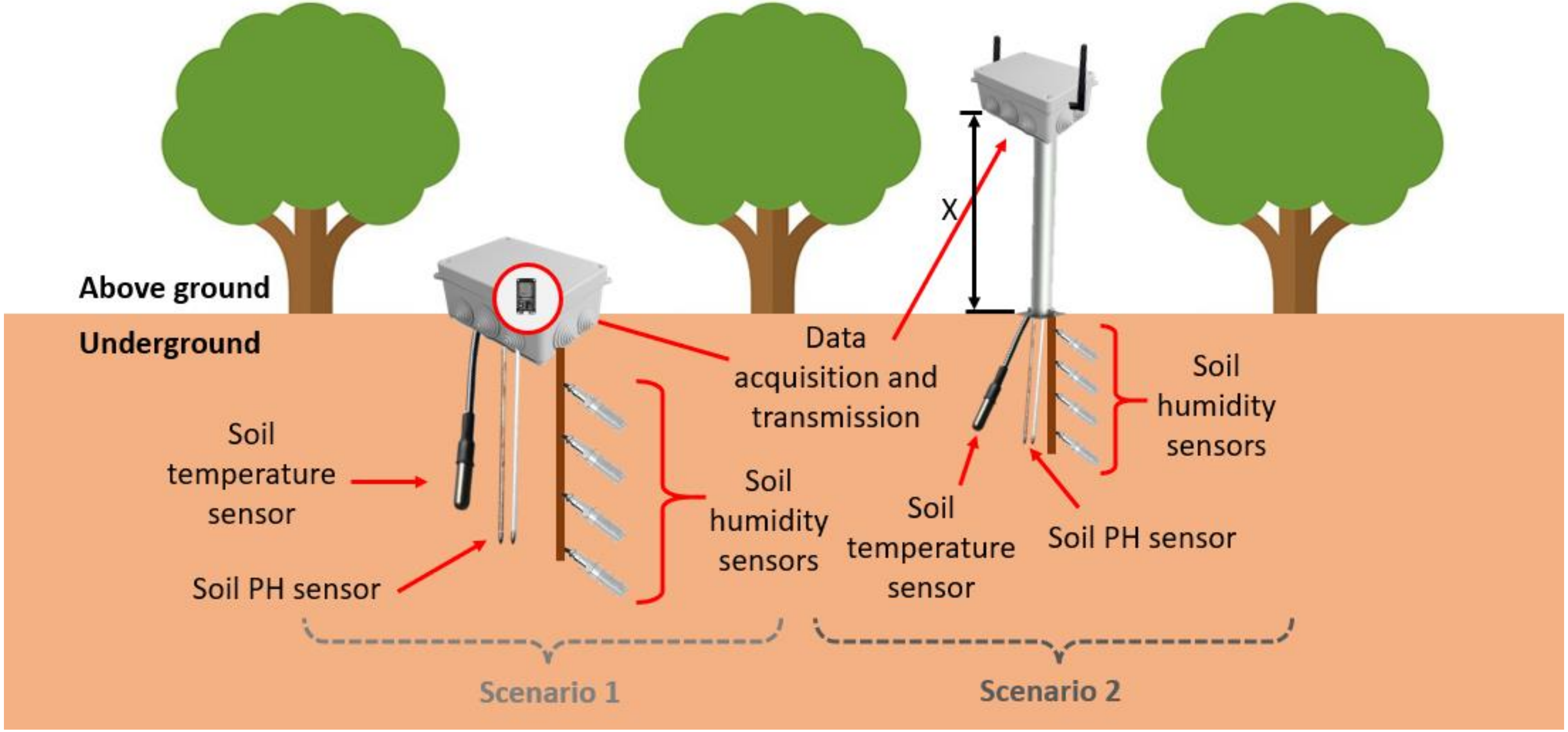
What can we monitor in Agricultural Fields?

Plants

- Pests
- Diseases
- Growth
- Production
- Caliber
- Weeds

How can I monitor Agricultural Fields?

Sensor devices: Soil



Sensor devices: Soil

Typical metrics

- Soil moisture
- Conductivity (Salinity)
- Soil Temperature

HydraProbe

Stevens Water Monitoring Systems

ECH2O EC-5

METER Group

GroPoint Profile

RioT Technology Corp.

Hydrascout

HSTi

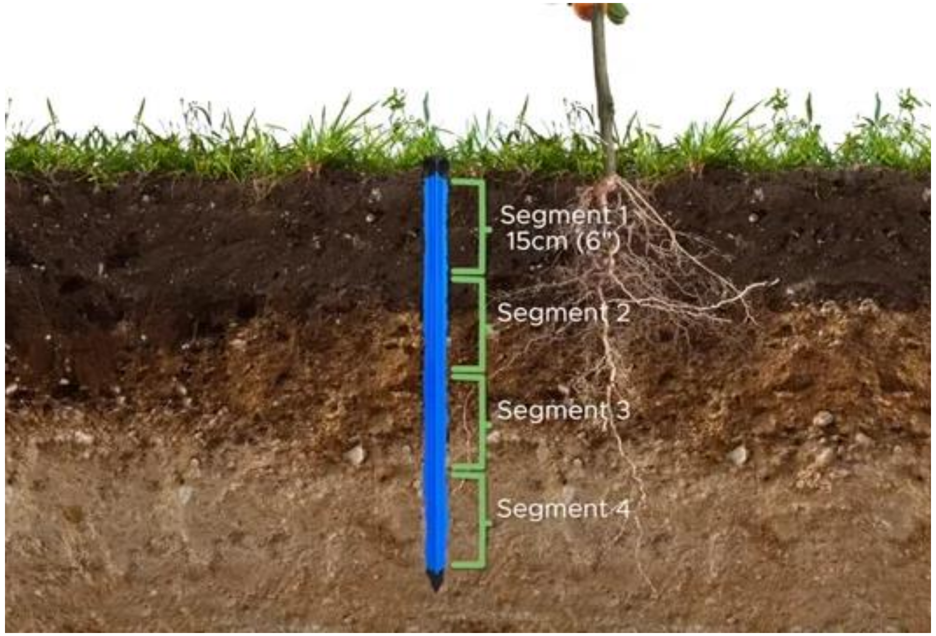
Single-point sensors

Profiling probes

Sensor devices: Soil

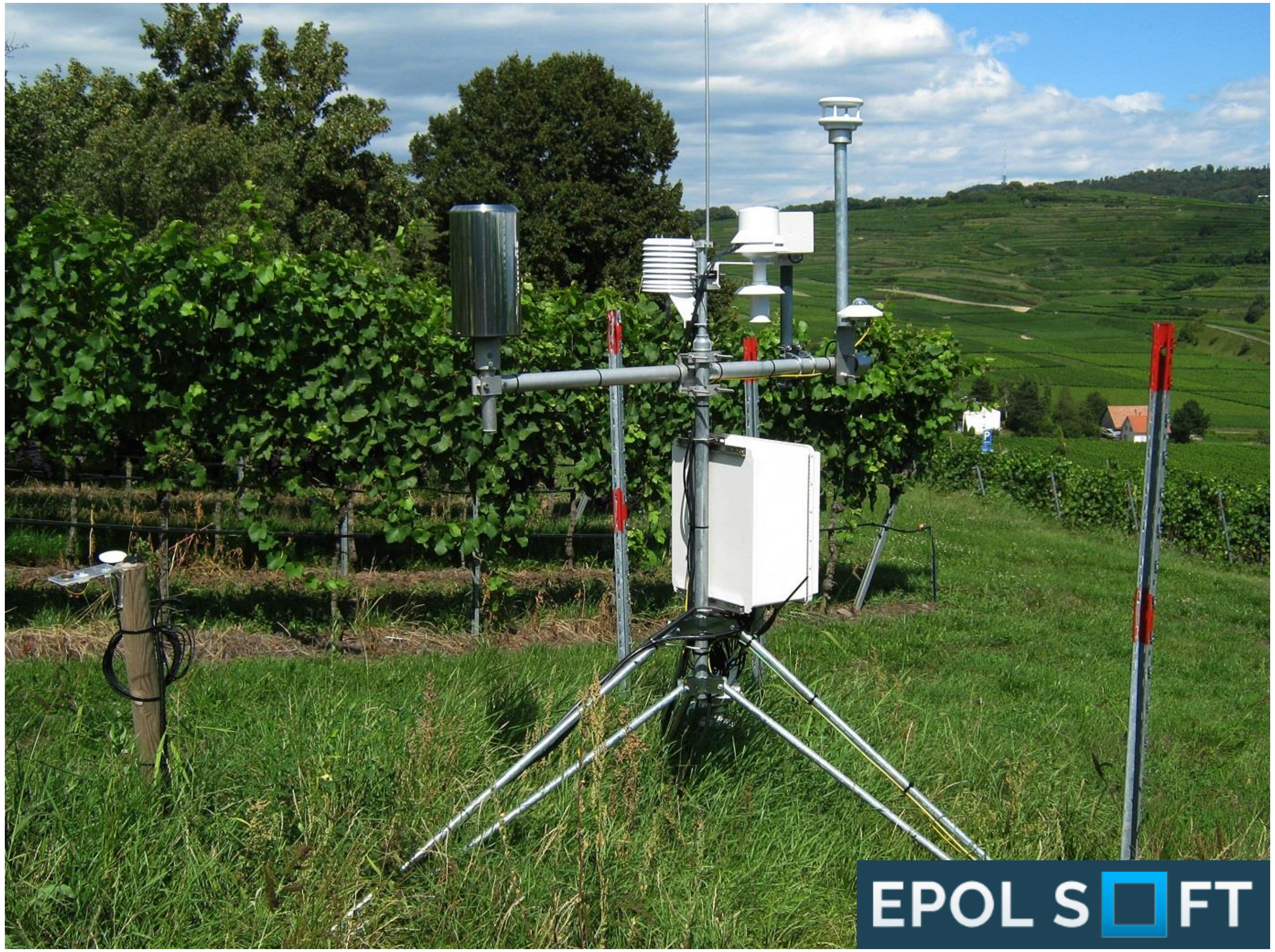
Installation

Single-point sensors



Profiling probes

Sensor devices: Meteorology



Sensor devices: Water

Anemometer

Pluviometer

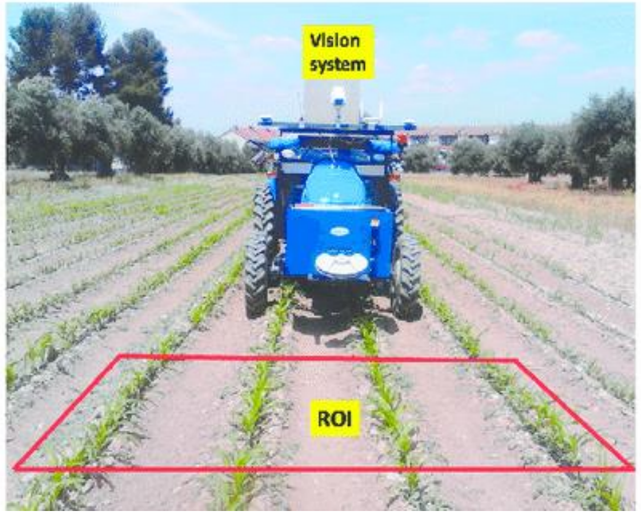
Temperature and
Relative Humidity

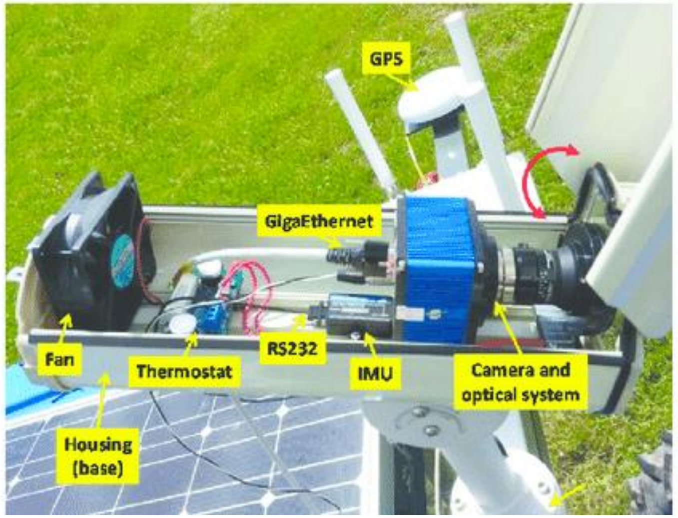
Pyranometer

Sensor devices: Plants

Computer Vision Cameras

Static





Mounted on vehicles

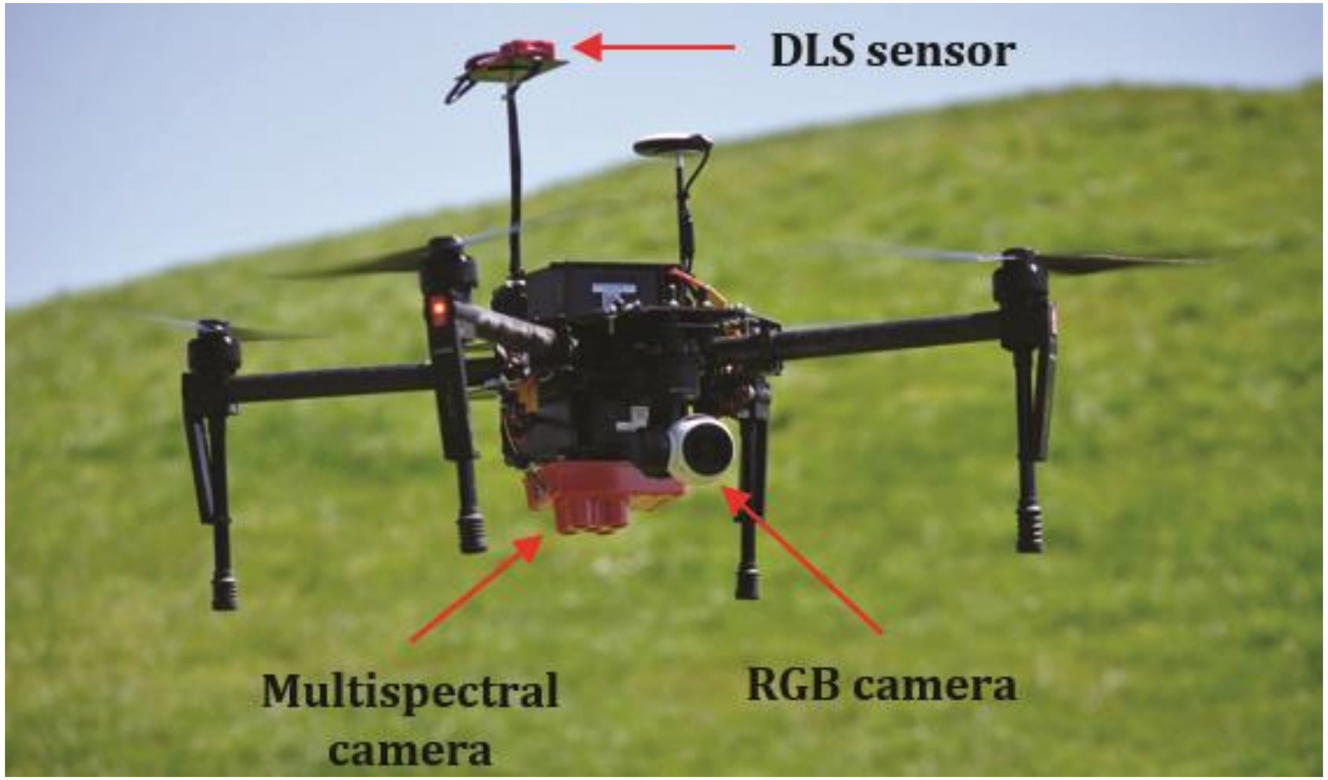
Pajares, G., García-Santillán, I., Campos, Y., Montalvo, M., Guerrero, J. M., Emmi, L., ... & Gonzalez-de-Santos, P. (2016). Machine-vision systems selection for agricultural vehicles: A guide. *Journal of Imaging*, *2*(4), 34.

Sensor devices: Plants

Wearable Plant Sensor

Plant disease and stress

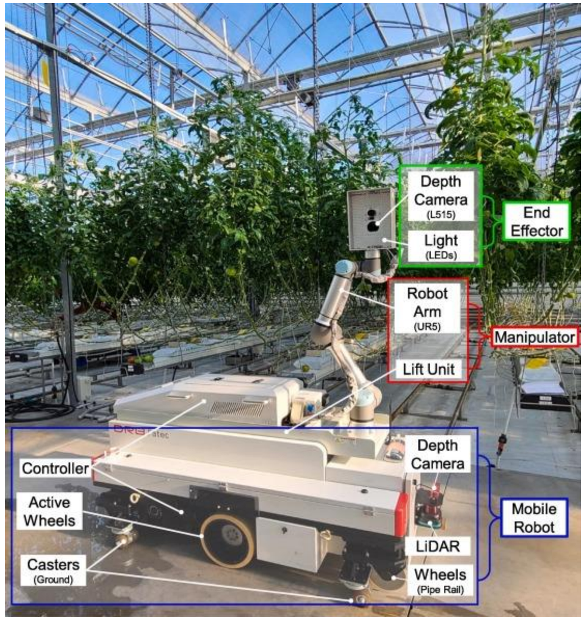
Machinery and vehicles equipped with sensors: Drones



Thompson, L. J., Shi, Y., & Ferguson, R. B. (2017). *Getting started with drones in agriculture*. University of Nebraska-Lincoln, Extension.

Machinery and vehicles equipped with sensors: Tractors

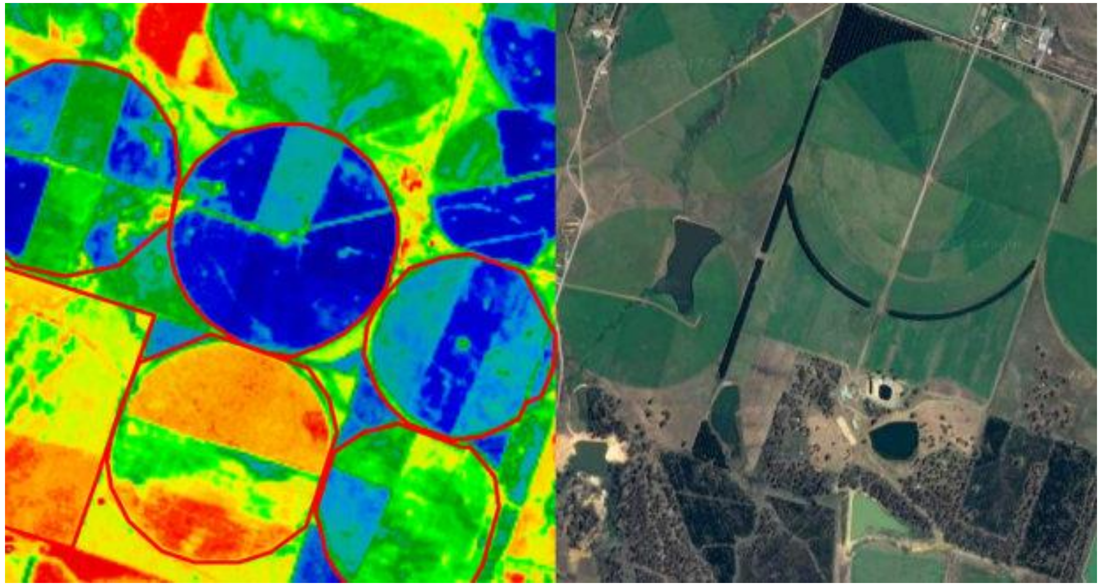
Machinery and vehicles equipped with sensors: Robots



Satellite imaging

Vegetation indexes

Normalized Difference Vegetation Index (NDVI)
Enhanced Vegetation Index (EVI)

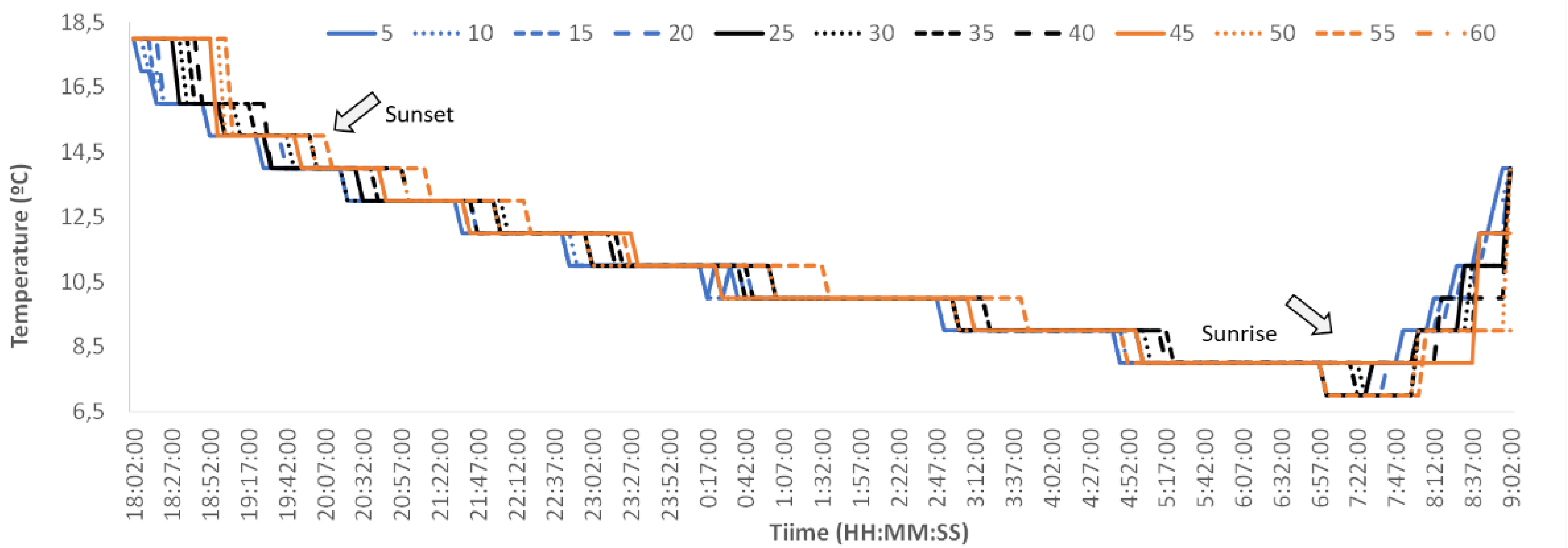


How are the sensor devices configured?

Aspects to consider

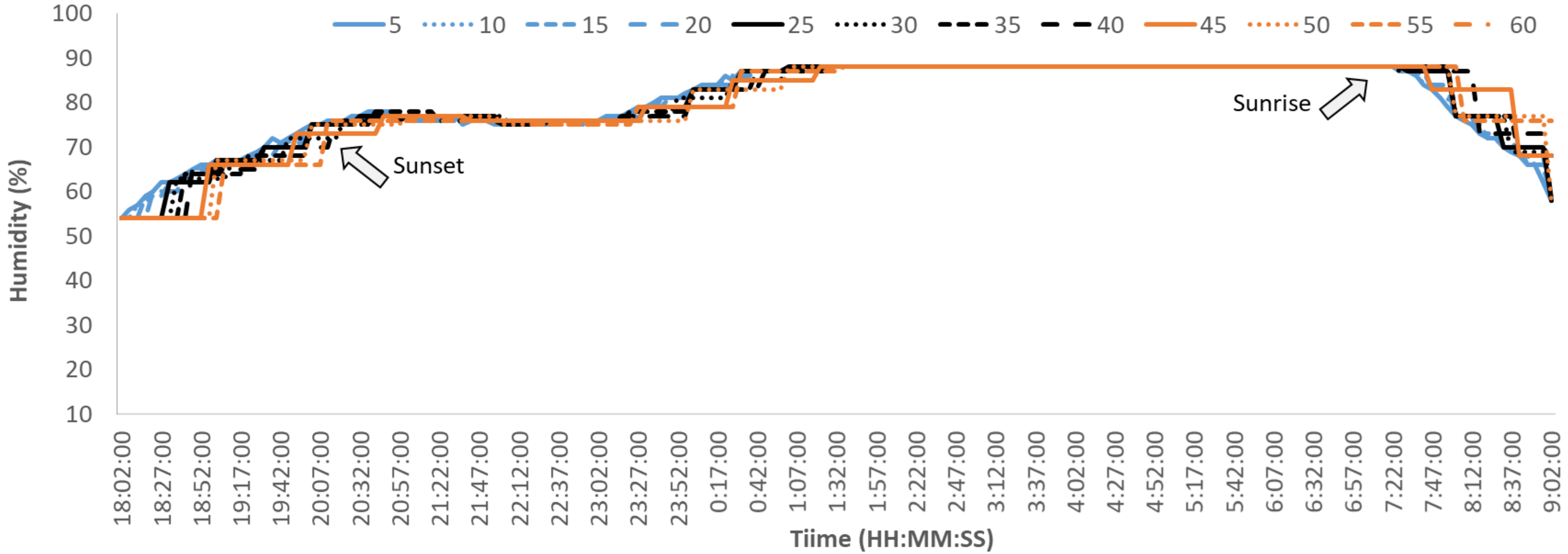
Data aquisition frequency

Aspects to consider: Data aquisition frequency



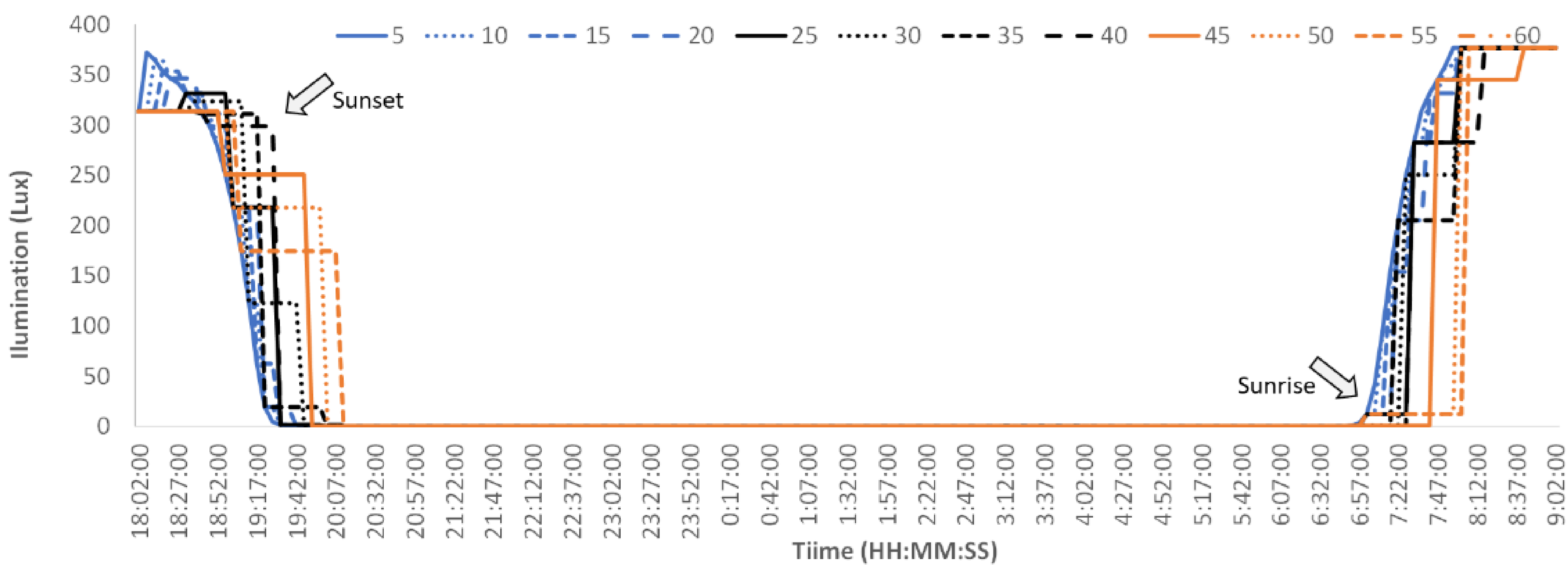
25 min

Aspects to consider: Data aquisition frequency



45 min

Aspects to consider: Data aquisition frequency

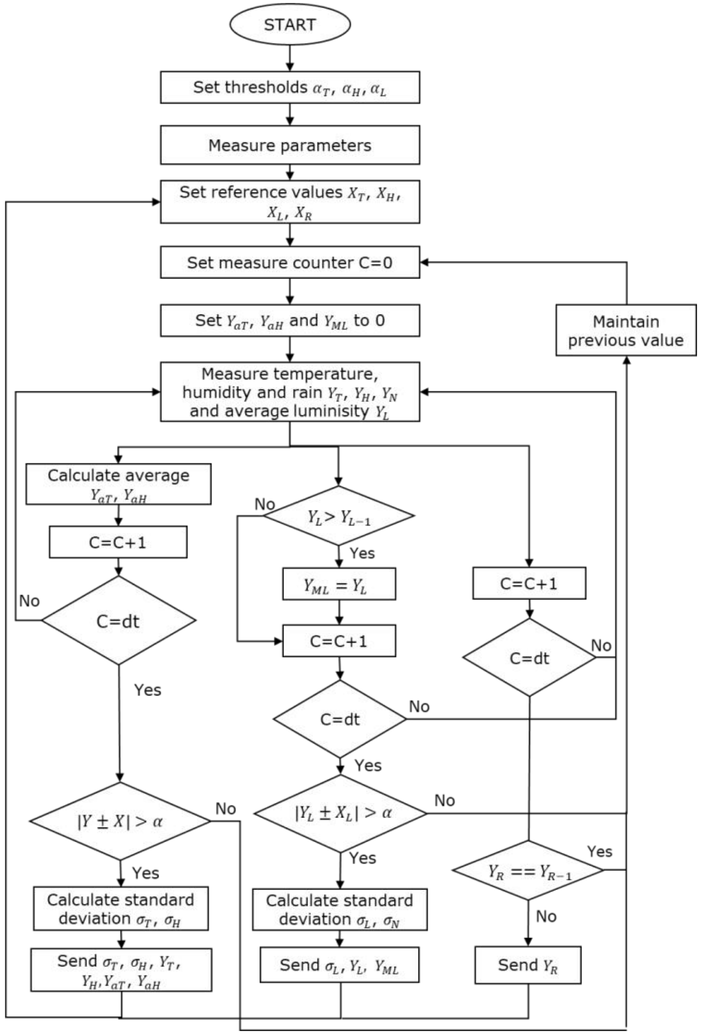


15 min

Aspects to consider

Data transmission frequency

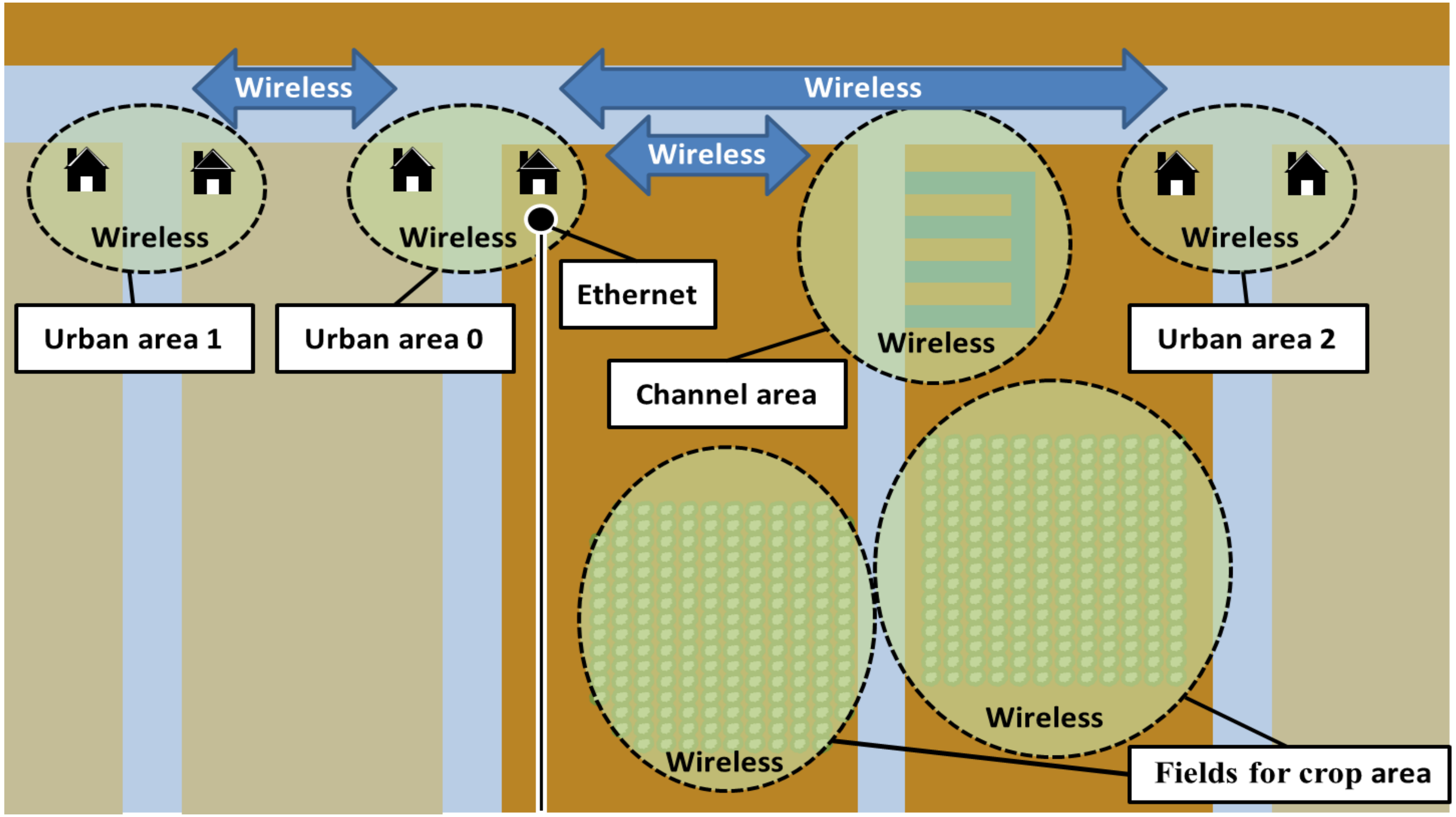
Aspects to consider: Data transmission frequency



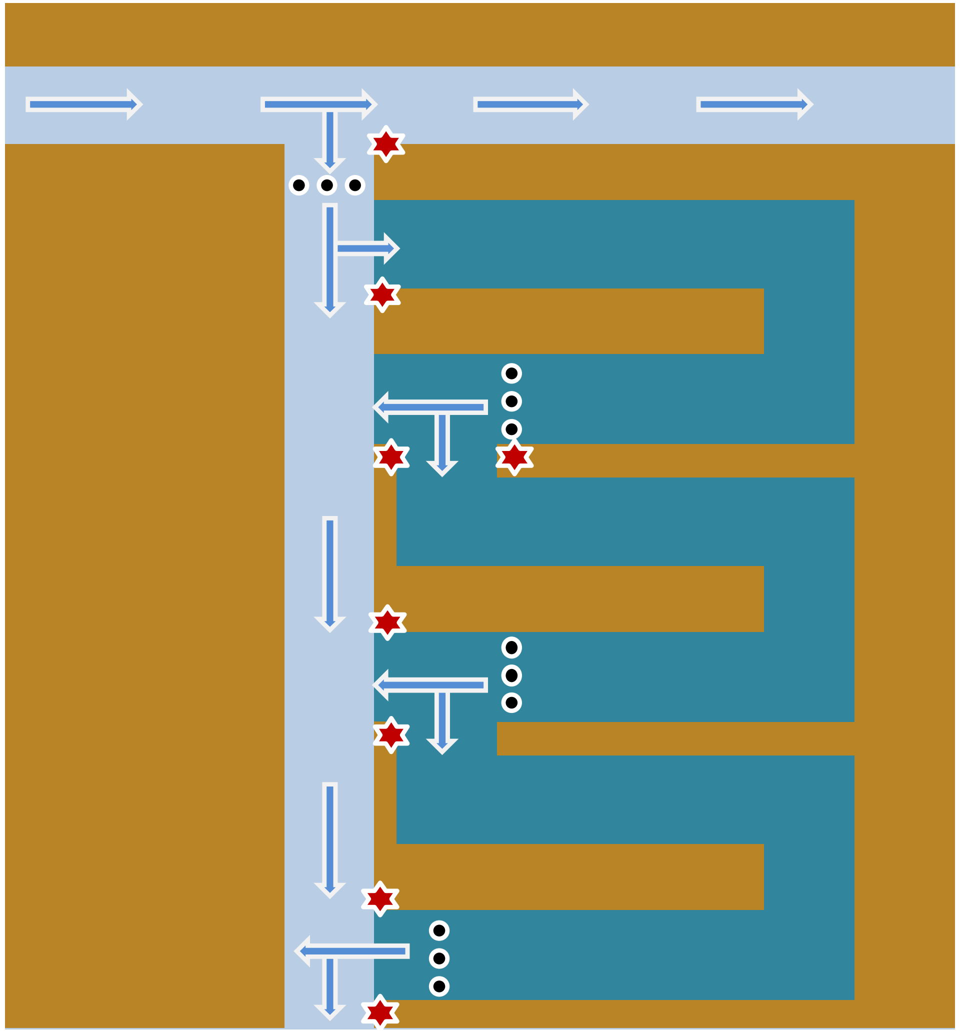
Aspects to consider

Deployment strategy

Aspects to consider: Deployment strategy



Aspects to consider: Deployment strategy



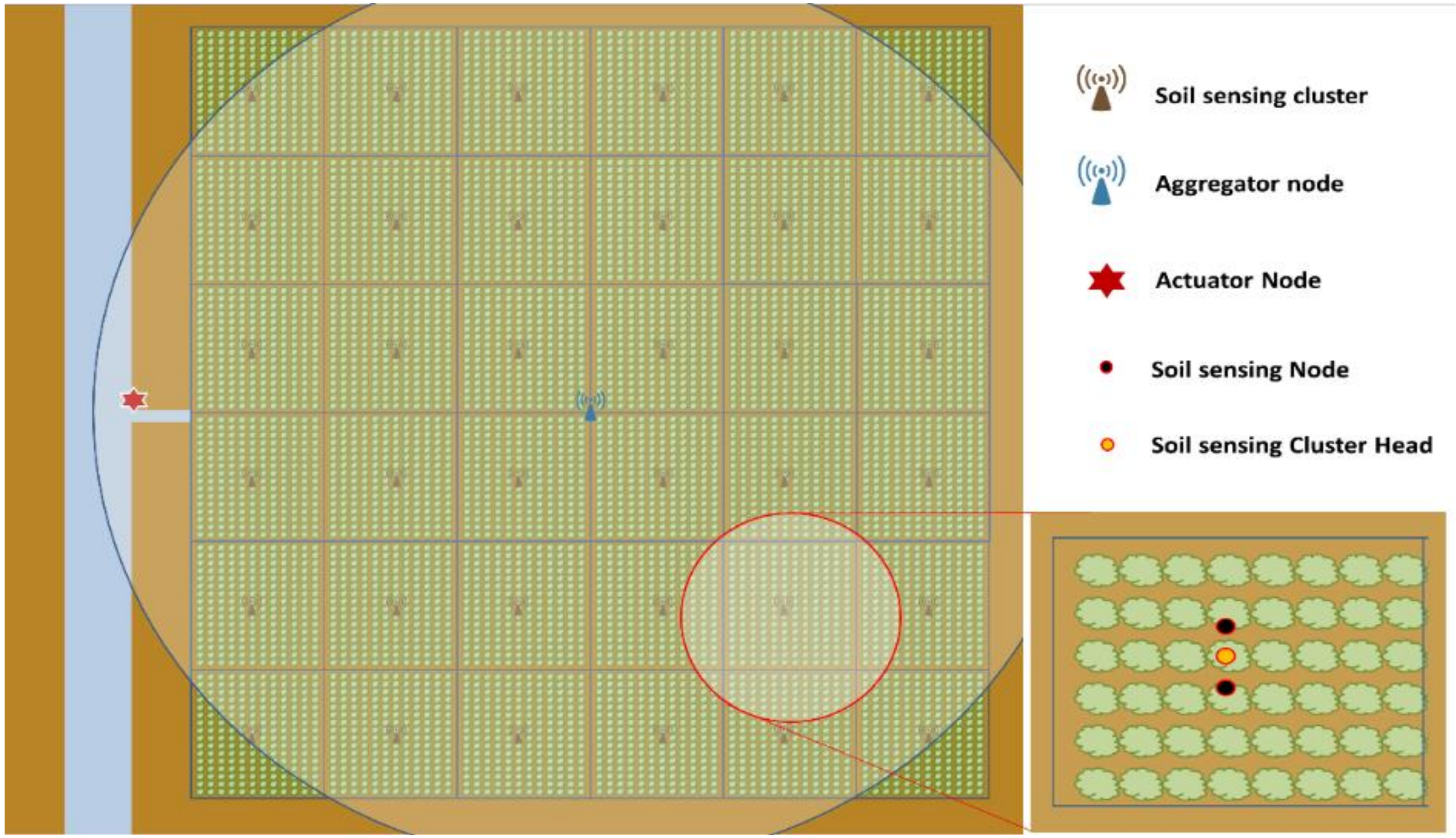
Water canal

Canal with bioabsortion materials

Node with sensors

Node with actuators

Aspects to consider: Deployment strategy



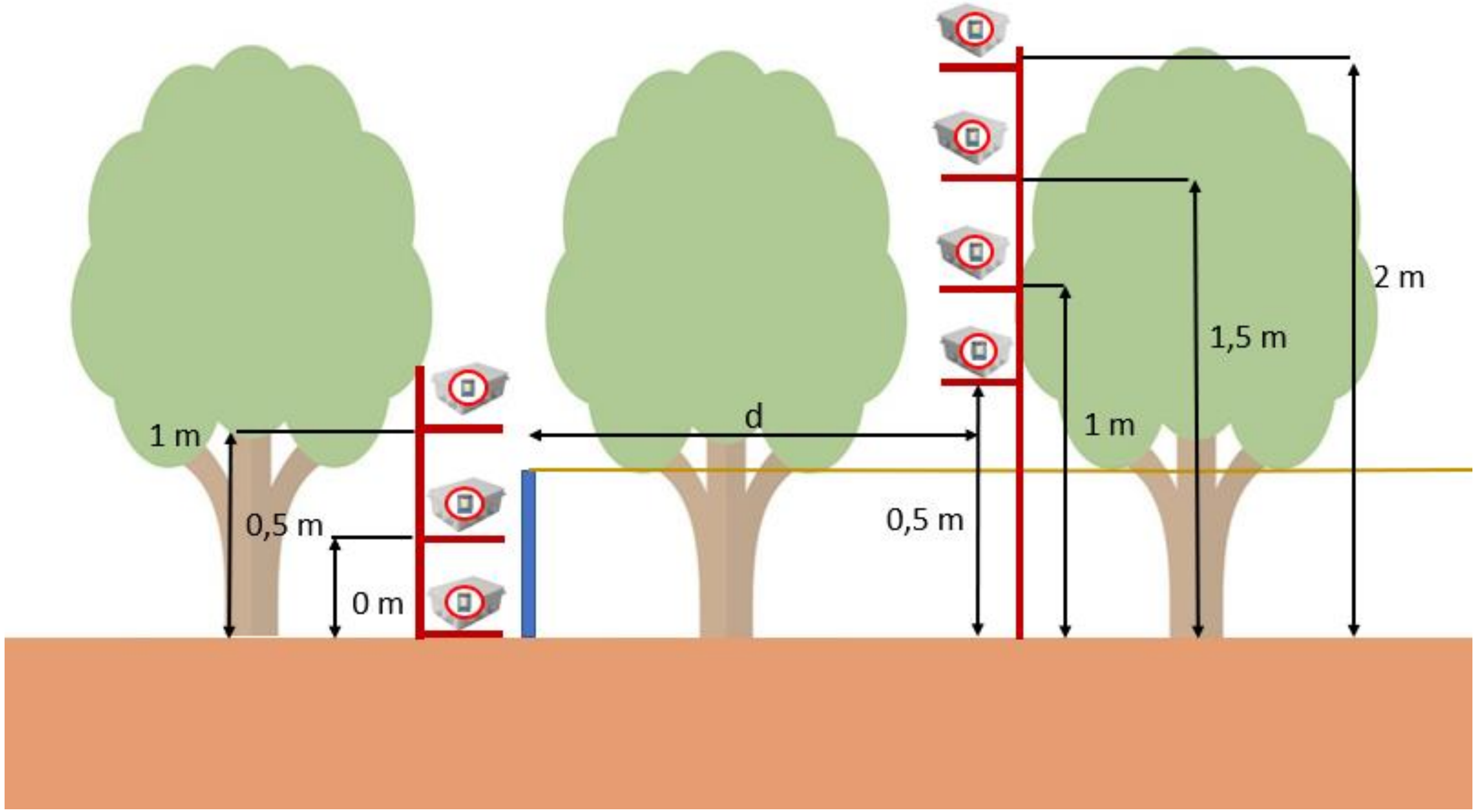
Aspects to consider: Deployment strategy

Vegetation height and density

a) b) c)

L. García et al., “Deployment Strategies of Soil Monitoring WSN for Precision Agriculture Irrigation Scheduling in Rural Areas,” Sensors, vol. 21, no. 5, p. 1693, Mar. 2021, doi: 10.3390/s21051693.

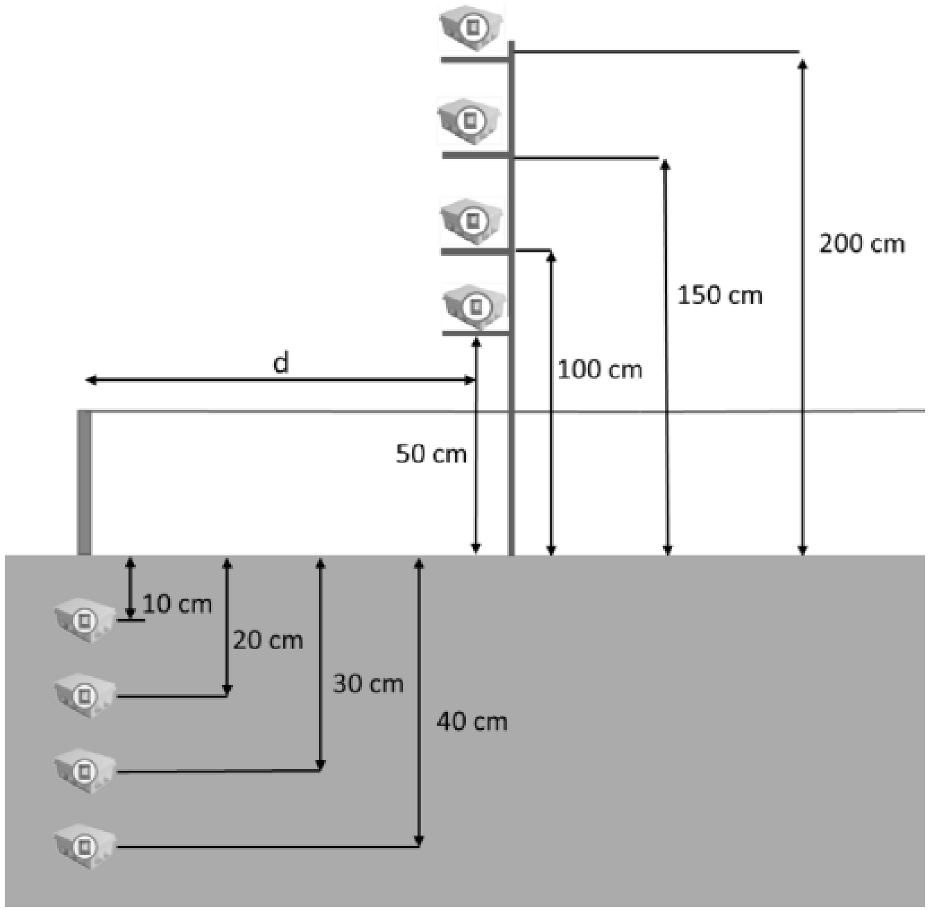
Aspects to consider: Deployment strategy



Lloret J, Sendra S, Garcia L, Jimenez JM. A Wireless Sensor Network Deployment for Soil Moisture Monitoring in Precision Agriculture. *Sensors*. 2021; 21(21):7243.
https://doi.org/10.3390/s21217243

Aspects to consider: Deployment strategy

Internet of Underground Things



Aspects to consider: Deployment strategy

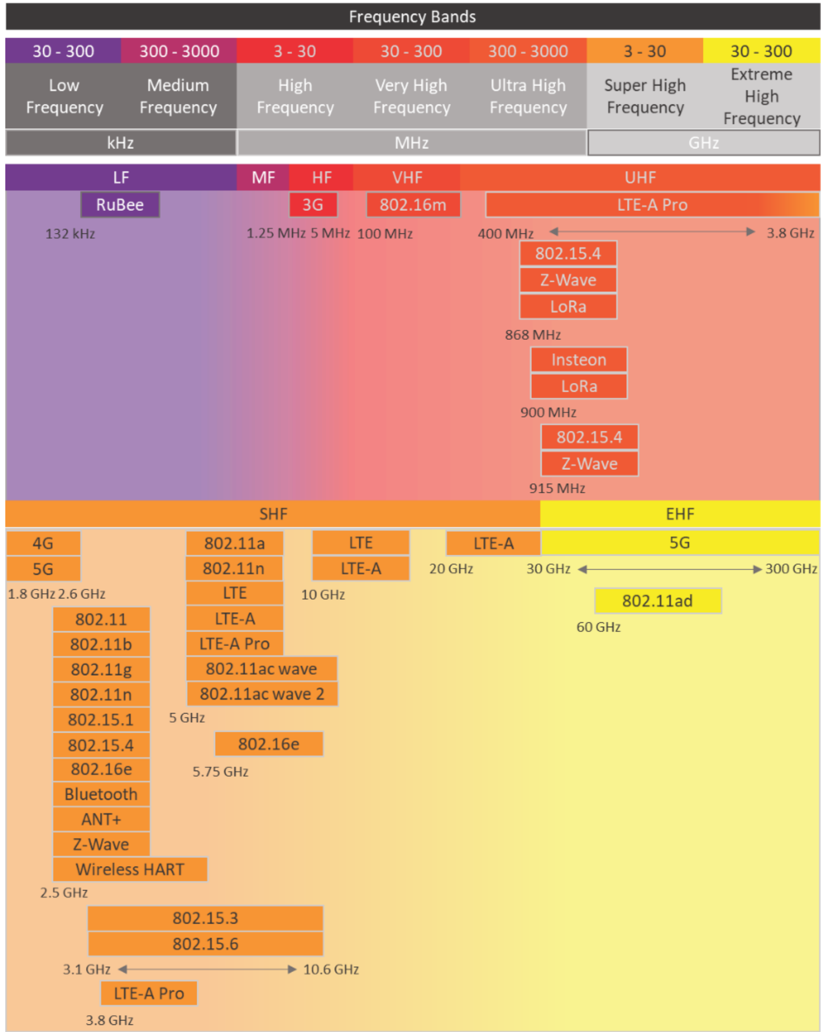
Drones or tractors as network gateways

a) b)

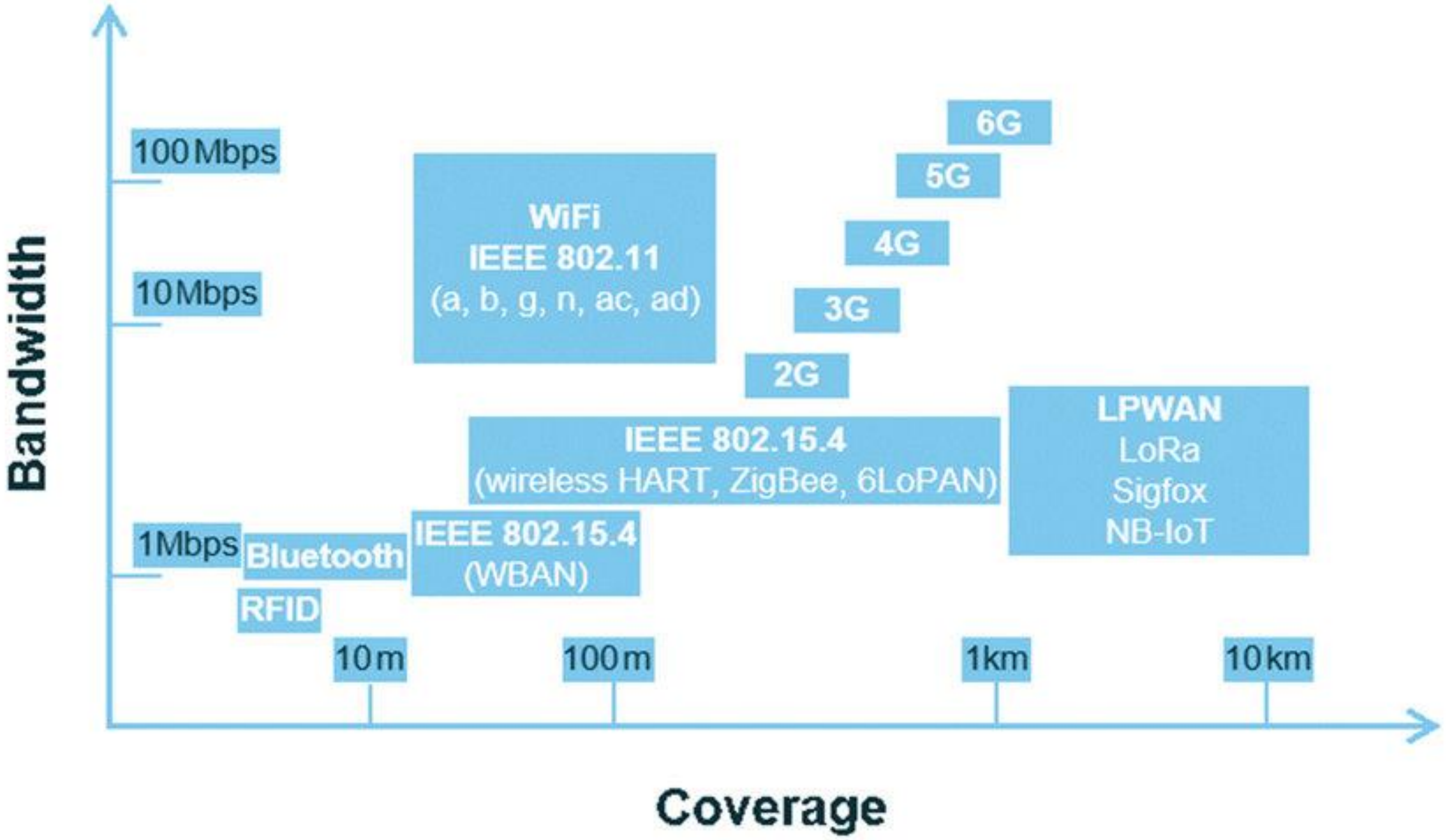
Aspects to consider

Communication technology selection

Aspects to consider: Communication technology selection



Aspects to consider: Communication technology selection



Beliatis, M. J., Jensen, K., Ellegaard, L., Aagaard, A., & Presser, M. (2021). Next generation industrial IoT digitalization for traceability in metal manufacturing industry: A case study of industry 4.0. *Electronics*, *10*(5), 628.

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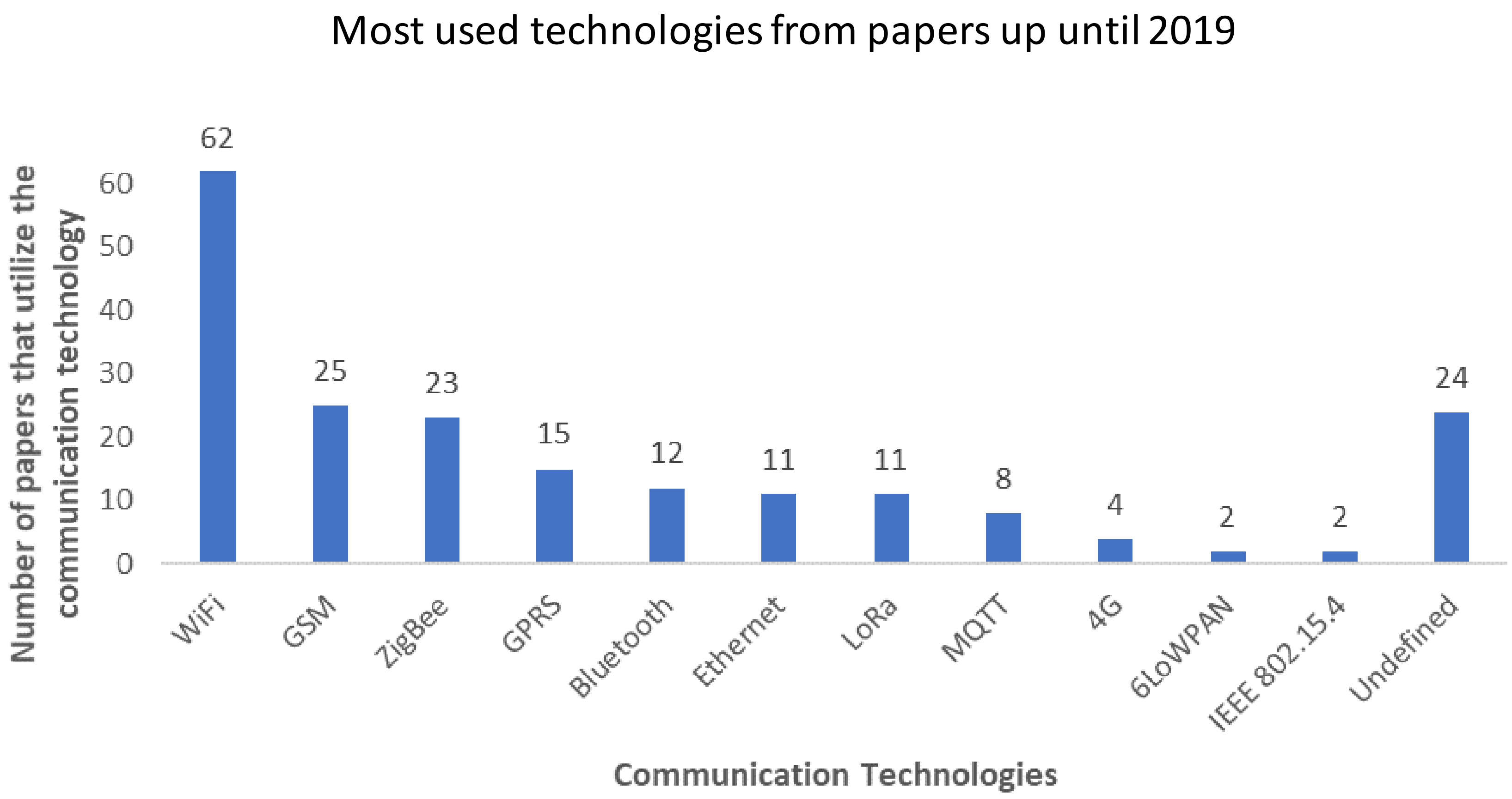
Aspects to consider: Communication technology selection



What can we do with the data?

Irrigation needs estimation

Necessary data to estimate irrigation needs according to the FAO

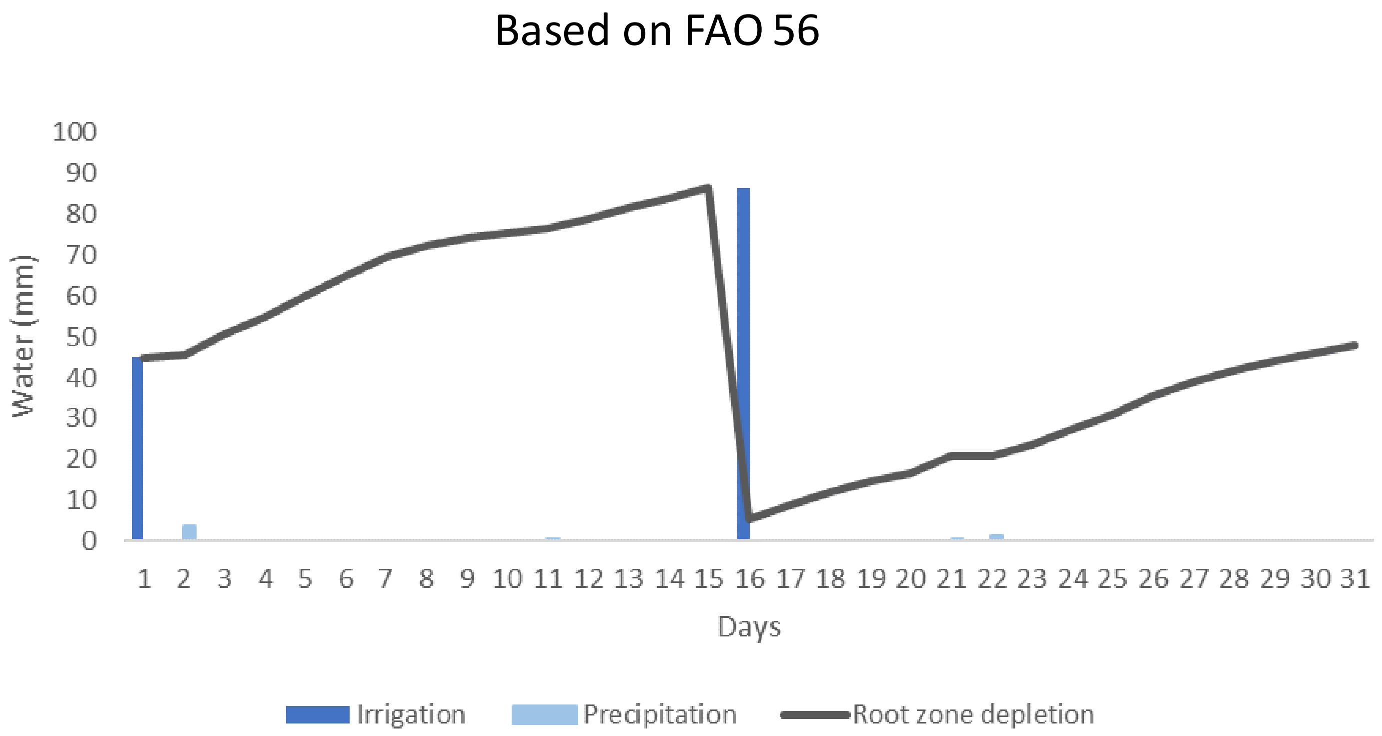
Fixed Variables	**Variables set by the User**
Elevation above sea level	Height of the tree
Date	Selection of soil type
Latitude	Time period for irrigation calculation
Height of wind speed measurement	Selection of Single Coefficient Approach or Dual Coefficient Approach for ETc calculation
Variables obtained from the monitored data	
Maximum air temperature of the day	Water salinity
Minimum air temperature of the day	Soil conductivity
Maximum relative humidity of the day	Soil humidity
Minimum relative humidity of the day	Soil temperature
Hours of sunlight of the day	Mean temperature of the actual month
Wind speed	Mean temperature of the previous month
Precipitation amount	Estimated mean temperature of the following month
Hour of the precipitation	

L. García et al., "Deployment Strategies of Soil Monitoring WSN for Precision Agriculture Irrigation Scheduling in Rural Areas," Sensors, vol. 21, no. 5, p. 1693, Mar. 2021, doi: 10.3390/s21051693.

Irrigation needs estimation

Algorithm 1. Irrigation algorithm

```
Variable initialization
User parameter initialization
ETo calculation
Determination of the Crop Stage
If Water stress then
   Calculate irrigation adjustment due to water stress
end if
If High salinity levels then
   Calculate irrigation adjustment due to salinity
end if
If Precipitation then
   Determine the precipitation amount
   Determine the hour of the precipitation
   Calculate irrigation adjustment due to precipitation
end if
Calculate ETc
Calculate Irrigation requirements of the crop
End.
```

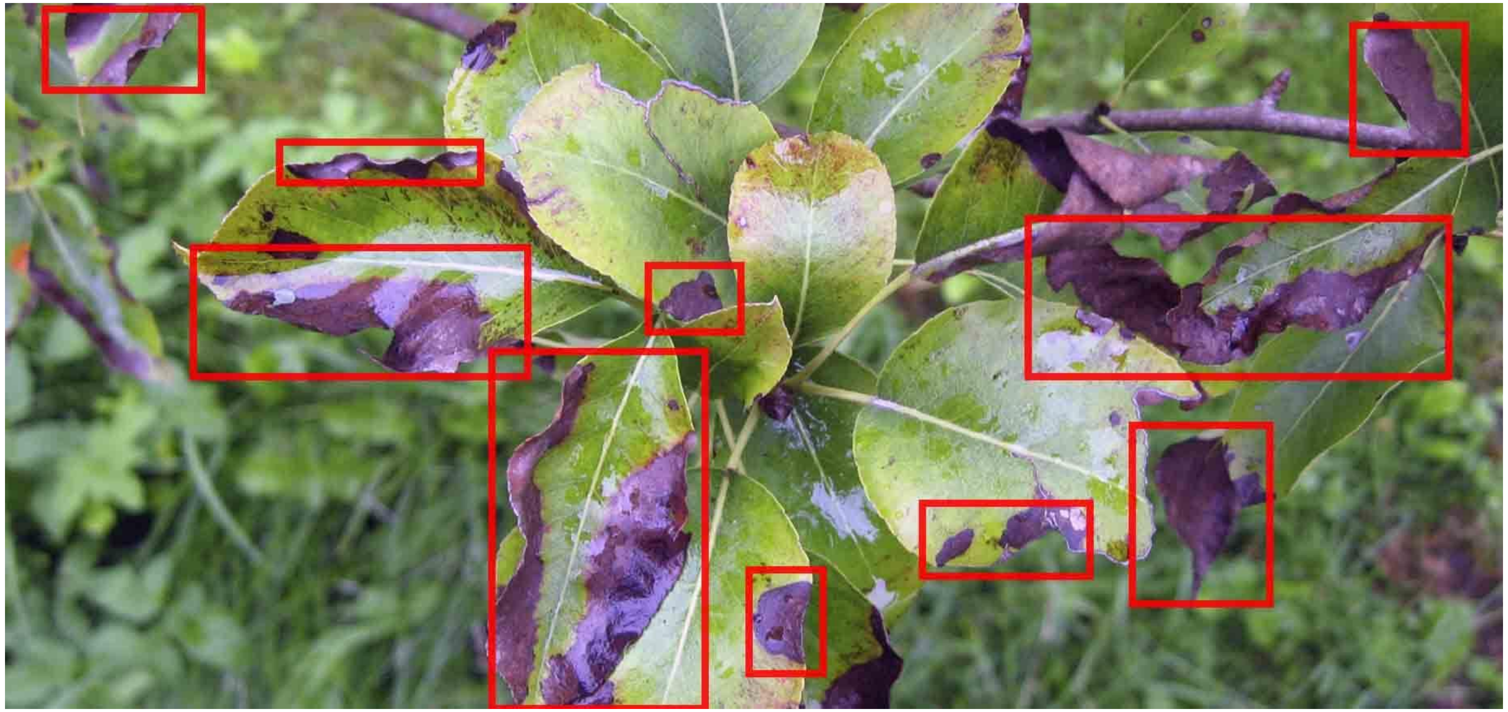


L. García et al., "Deployment Strategies of Soil Monitoring WSN for Precision Agriculture Irrigation Scheduling in Rural Areas," Sensors, vol. 21, no. 5, p. 1693, Mar. 2021, doi: 10.3390/s21051693.

Early detection of pests and plant diseases

Early detection of pests and plant diseases

Computer Vision



Disease Detection

Early detection of pests and plant diseases



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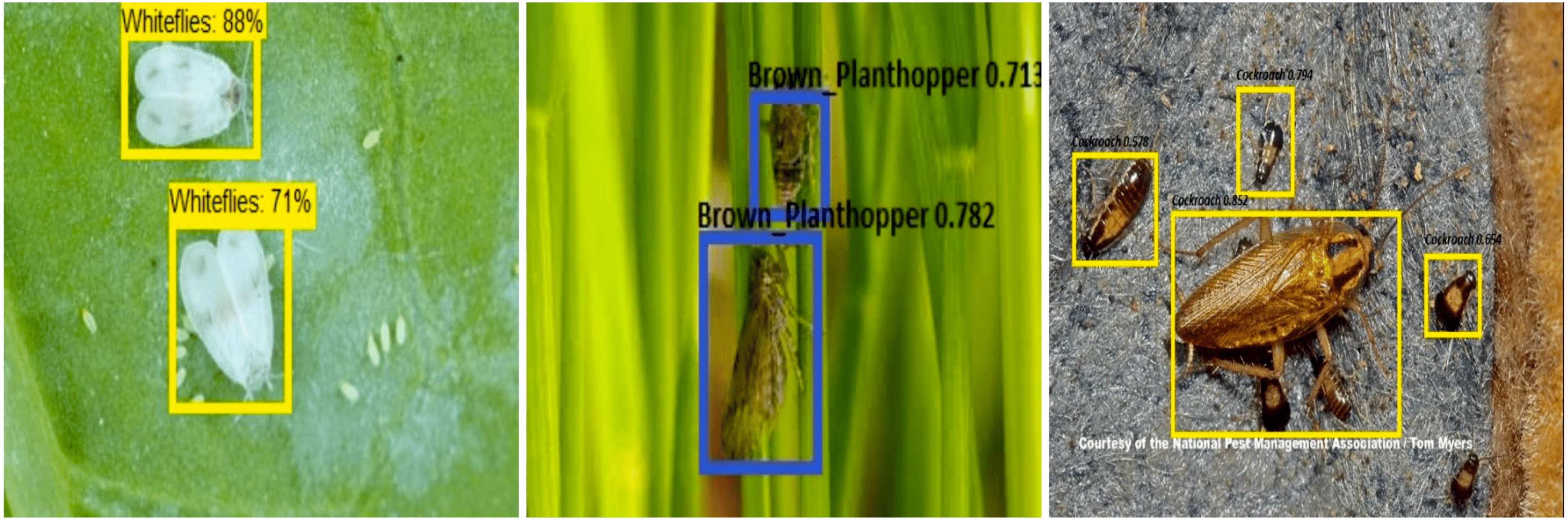
Early detection of pests and plant diseases



(**a**) White Flies (**b**) Brown Planthopper (**c**) Cockroach

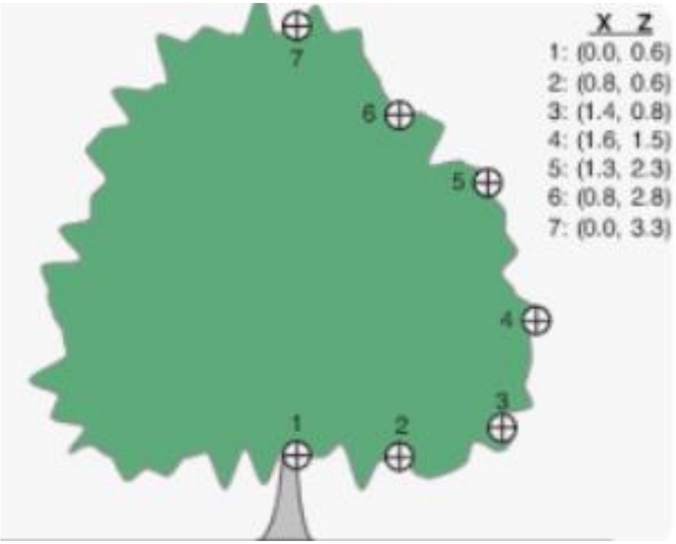
Ramalingam, B., Mohan, R. E., Pookkuttath, S., Gómez, B. F., Sairam Borusu, C. S. C., Wee Teng, T., & Tamilselvam, Y. K. (2020). Remote insects trap monitoring system using deep learning framework and IoT. *Sensors*, *20*(18), 5280.

Plant growth

Height

Stem width

Trunk width



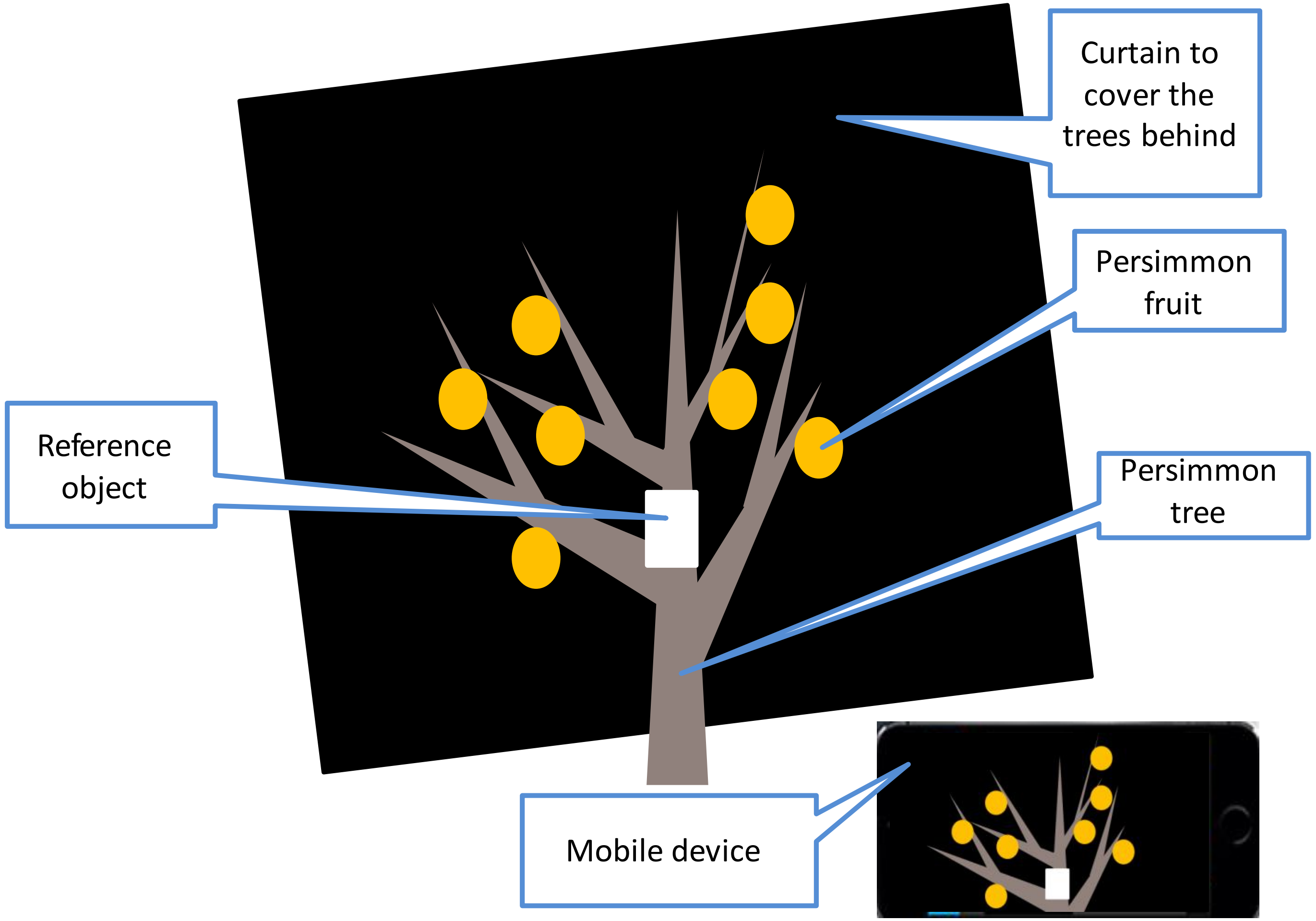
Foliage density/ Canopy volume

Plant growth

Computer Vision

Plant Growth

Crop production



GARCIA, Laura, et al. Quantifying the production of fruit-bearing trees using image processing techniques. En INNOV 2019, The Eighth International Conference on Communications, Computation, Networks and Technologies. ICNS, 2019. p. 14-19.

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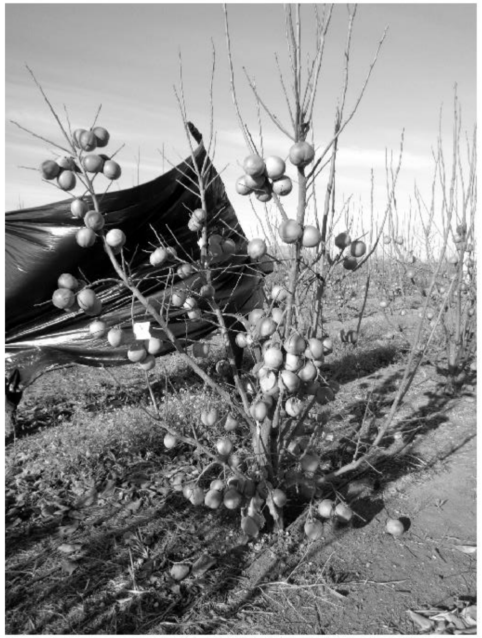
Crop production

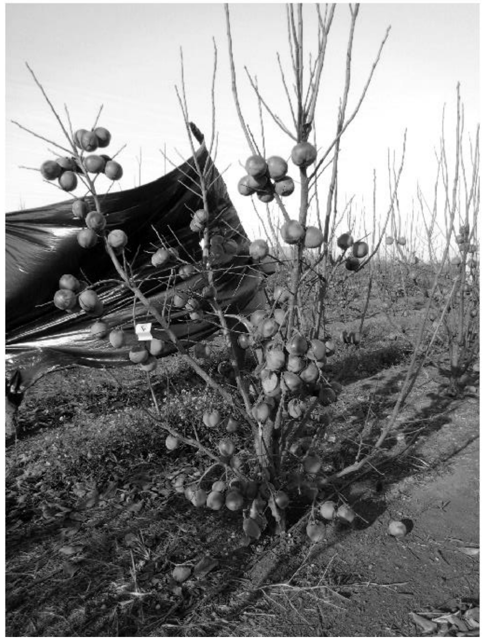
RGB composition

Red Band

Green Band

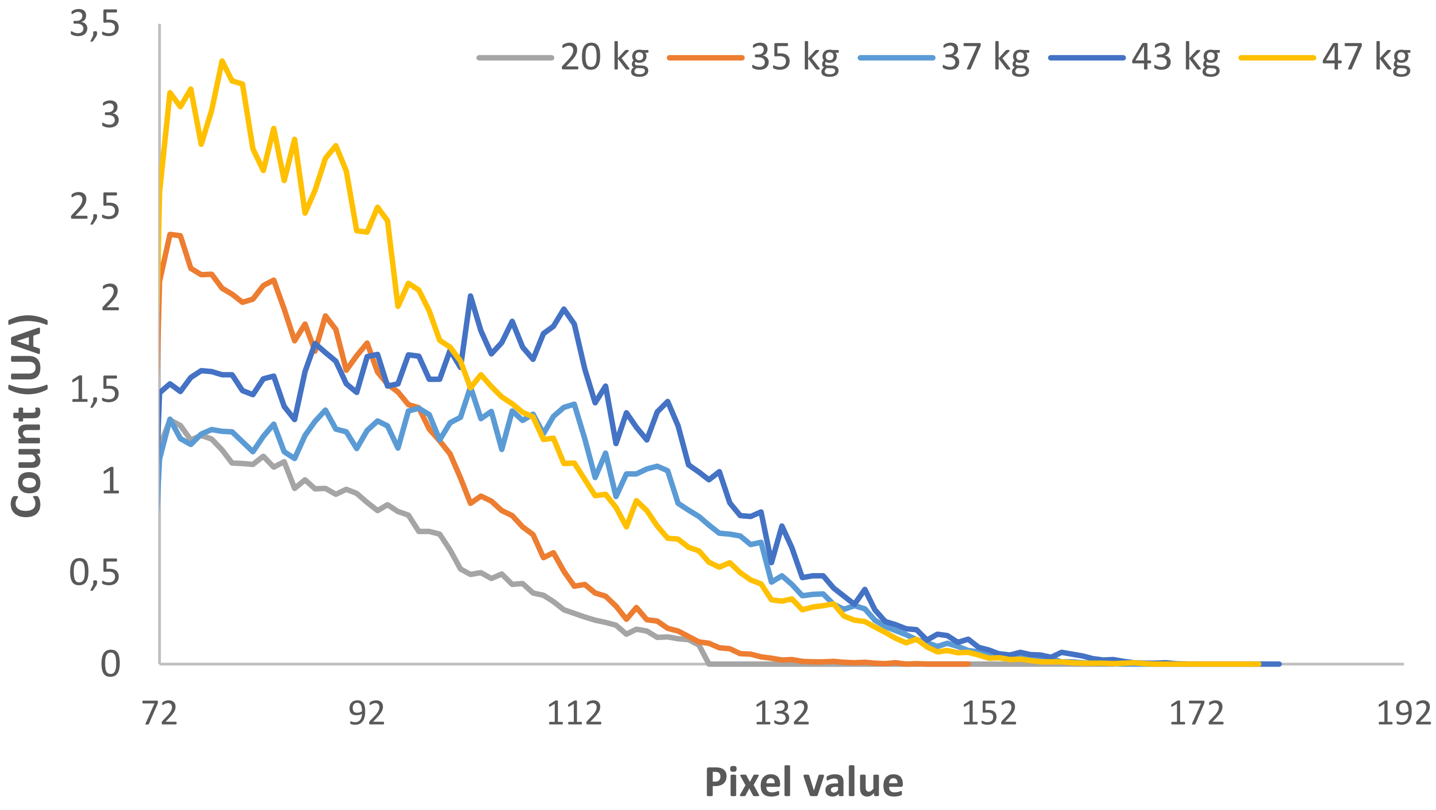


Blue Band



GARCIA, Laura, et al. Quantifying the production of fruit-bearing trees using image processing techniques. En INNOV 2019, The Eighth International Conference on Communications, Computation, Networks and Technologies. ICNS, 2019. p. 14-19.

Crop production



GARCIA, Laura, et al. Quantifying the production of fruit-bearing trees using image processing techniques. En INNOV 2019, The Eighth International Conference on Communications, Computation, Networks and Technologies. ICNS, 2019. p. 14-19.

Crop production

Computer Vision

- Ripeness Detection
- Fruit production
- Caliber

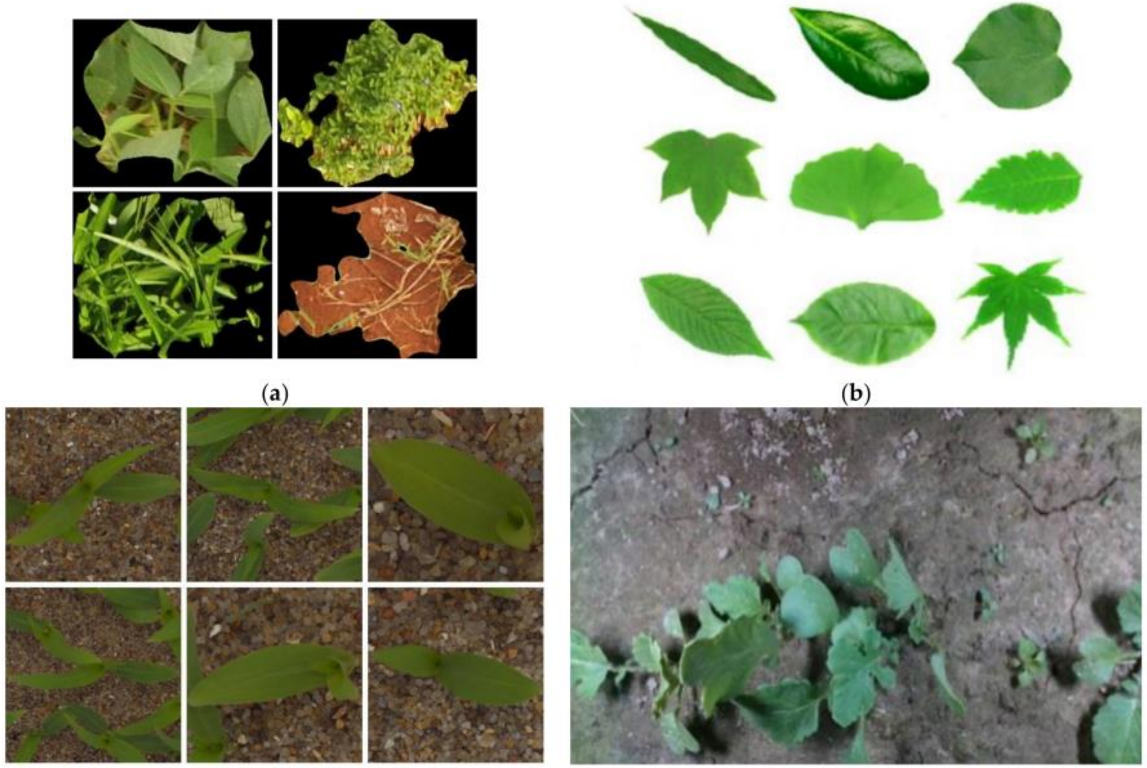
Produce caliber

Produce caliber

Computer Vision

Gongal, A., Karkee, M., & Amatya, S. (2018). Apple fruit size estimation using a 3D machine vision system. *Information Processing in Agriculture*, *5*(4), 498-503.

Weed detection



(a) (b) (c) (d)

Figure 1. Four typical plant datasets: (**a**) Grass-Broadleaf database [19], with images of soybean, broadleaf weed, grass, and soil; (**b**) Flavia dataset [28]; (**c**) plant seedlings dataset [20]; (**d**) food crops and weeds dataset [26].

WU, Zhangnan, et al. Review of weed detection methods based on computer vision. Sensors, 2021, vol. 21, no 11, p. 3647.

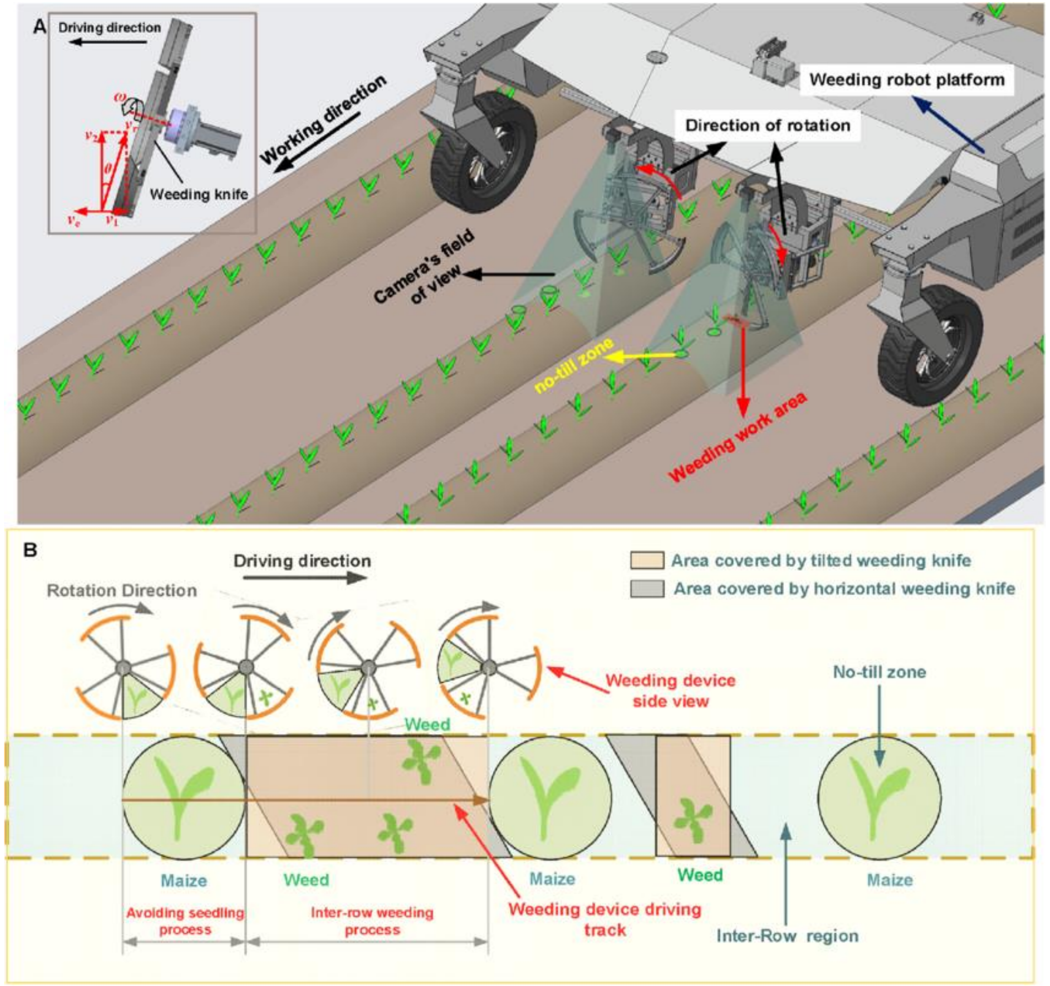
Weed detection

Computer Vision

Weed Detection

Tejeda, A. I., & Castro, R. C. (2019, February). Algorithm of weed detection in crops by computational vision. In *2019 International Conference on Electronics, Communications and Computers (CONIELECOMP)* (pp. 124-128). IEEE.

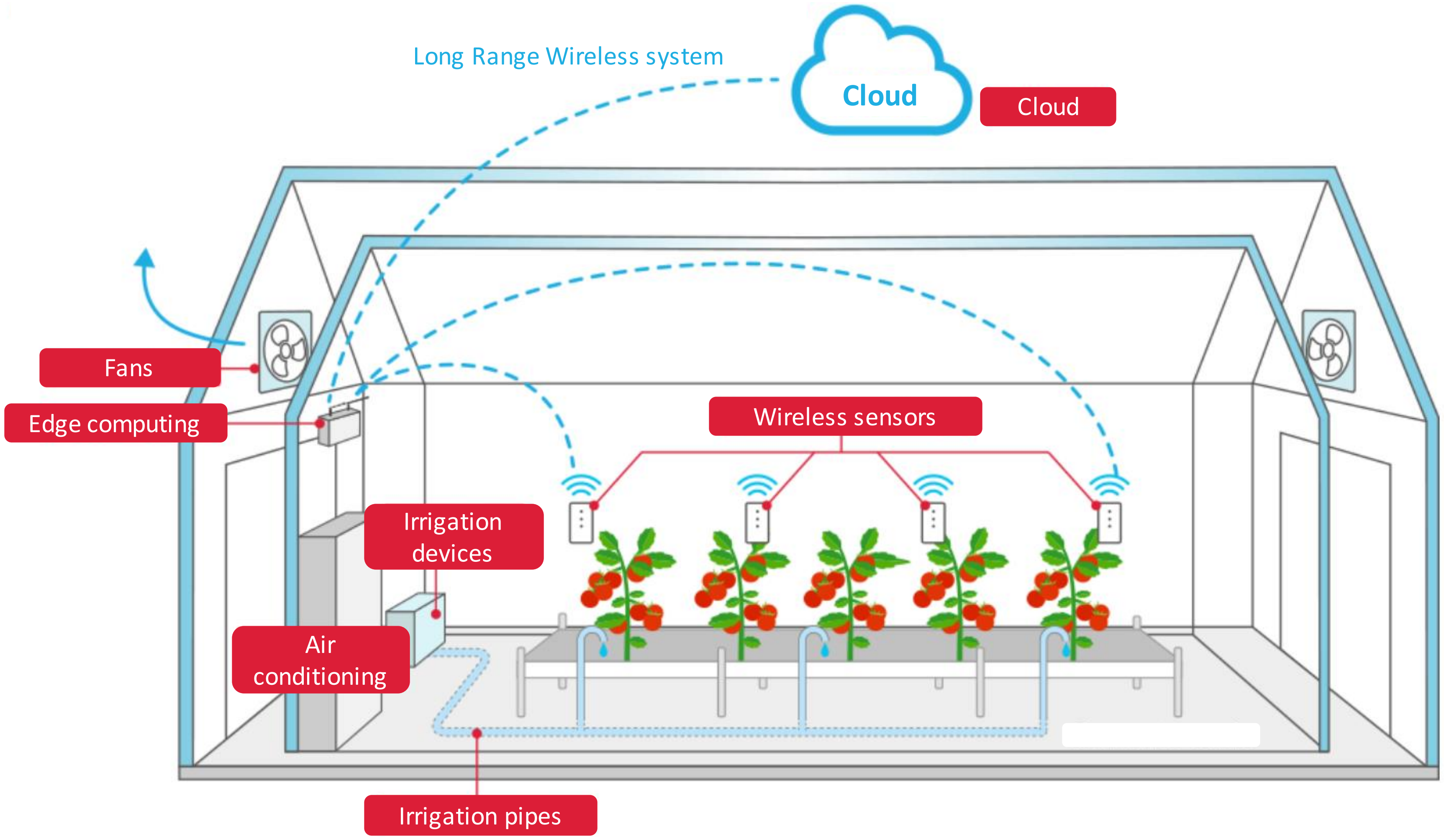
Weed detection



Quan, L., Jiang, W., Li, H., Li, H., Wang, Q., & Chen, L. (2022). Intelligent intra-row robotic weeding system combining deep learning technology with a targeted weeding mode. *Biosystems Engineering*, *216*, 13-31.

Not just monitoring but also controlling

Intelligent greenhouse



Automated irrigation systems

Irrigation actuator

Fertirrigation system

Drones and robots

Fumigation drone

Vineyard robot

Accessing data and controls

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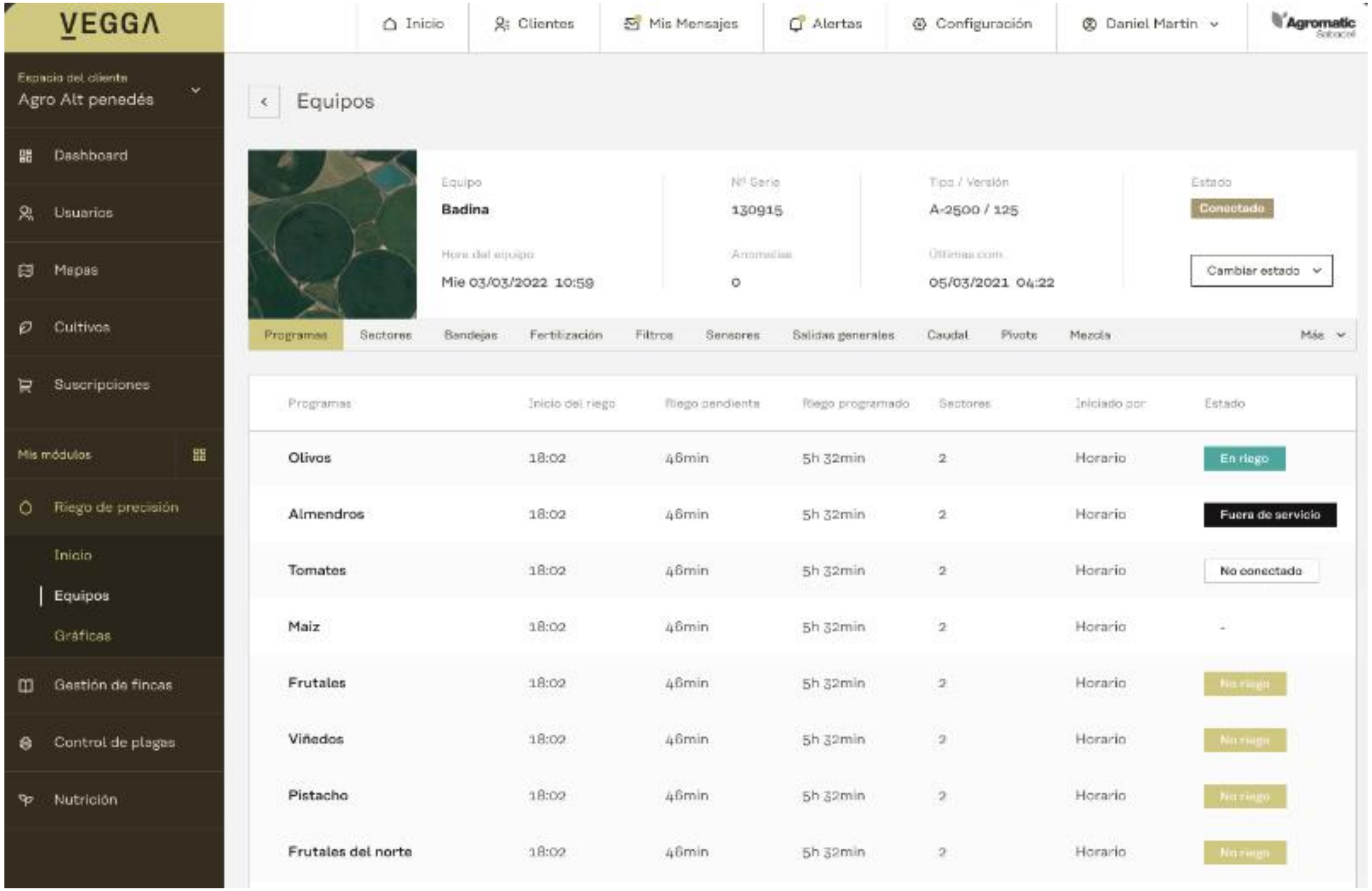
Accessing data and controls



In conclusion

More Tomorrow!