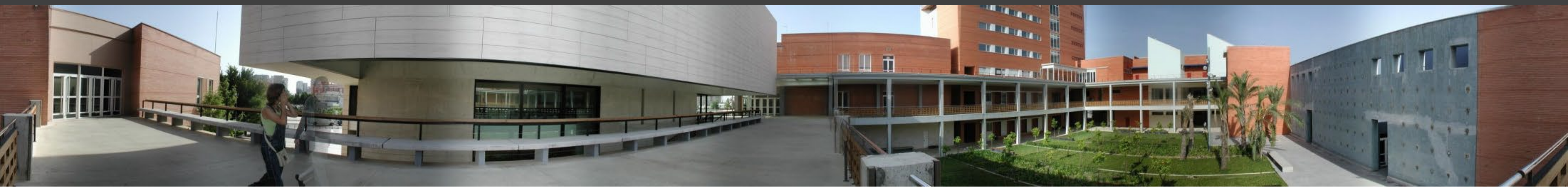

Needs and Challenges for the Modernization and Technification of a More Sustainable Agriculture

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IARIA

TechWorld 2024 & DigitalSustainability 2024

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Valencia, Spain

Outline

1. Introduction

What is Agriculture?

- Agriculture is one of the oldest and most fundamental human activities, which has allowed the development of civilizations throughout history.

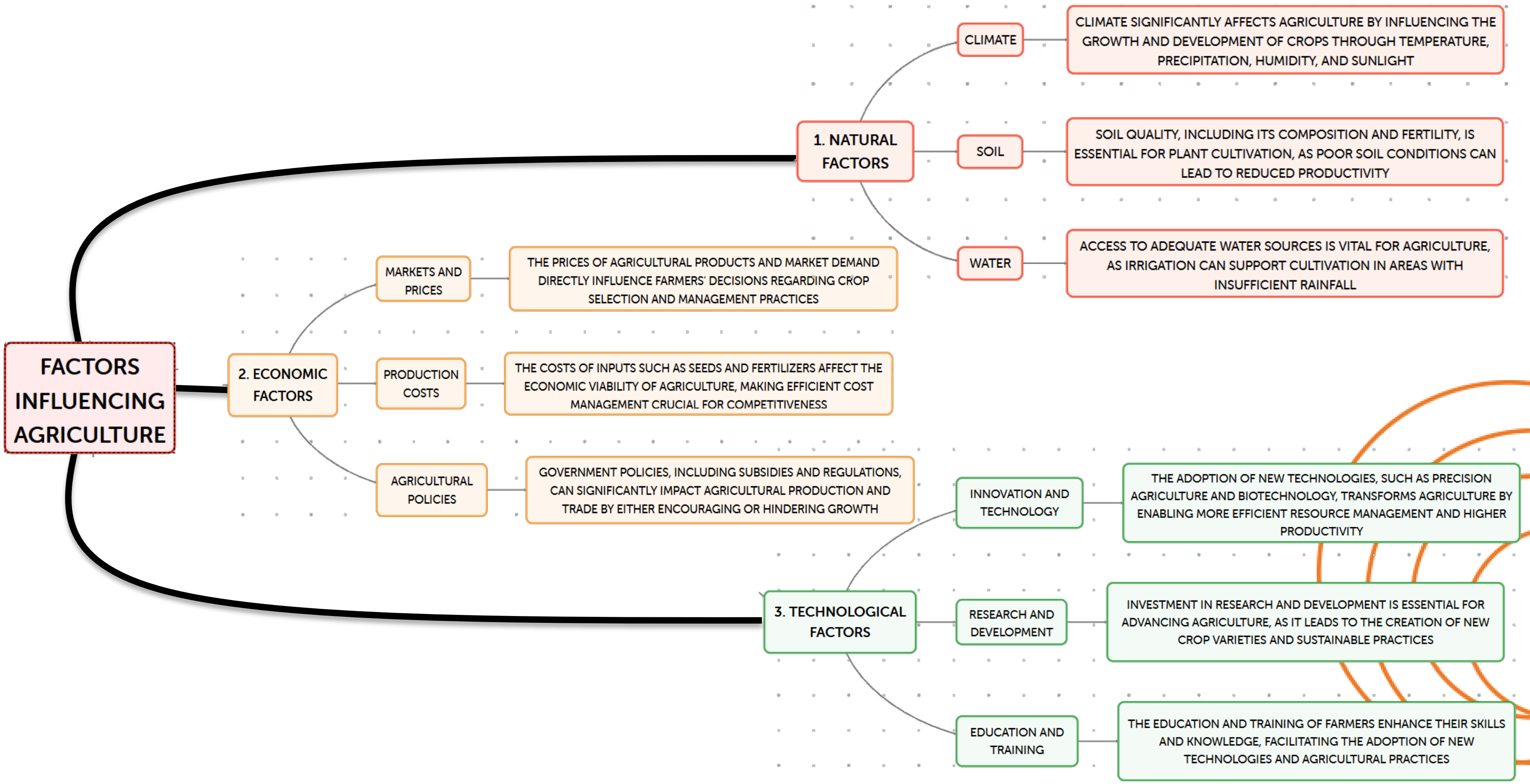
- Set of techniques and knowledge dedicated to cultivate the land and raise animals for the production of food, fibers, medicines, and other products necessary to sustain and improve human life.

- It includes crop production and livestock farming but also forestry, horticulture, and aquaculture.

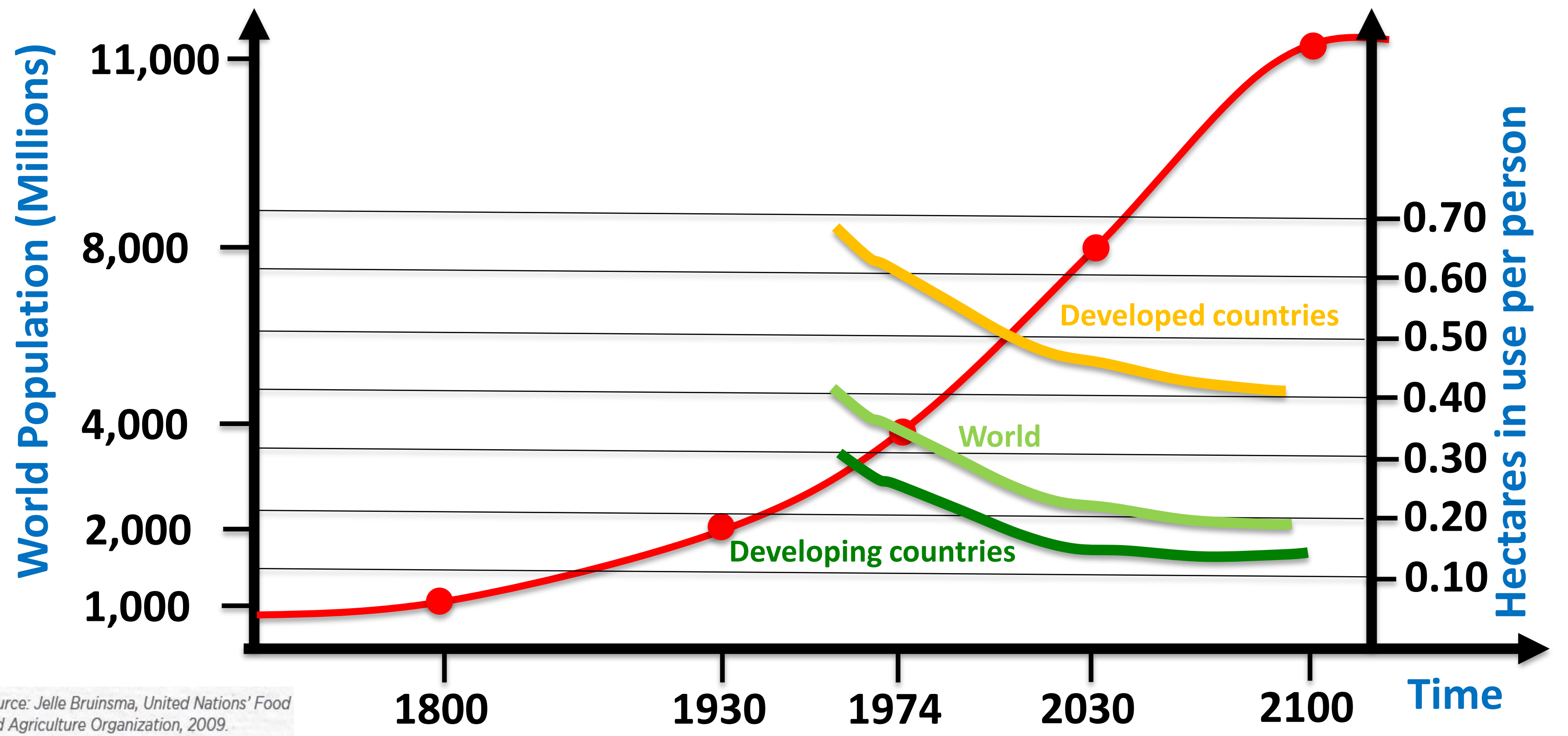
What is Agriculture?

- Agriculture has evolved significantly.
- Today, agriculture is a global industry that employs millions of people and is essential to the world economy.
- The modernization and technification of agriculture, known as Agriculture 4.0, is revolutionizing the sector through the use of advanced technologies such as drones, sensors, robotics, artificial intelligence, and blockchain.
- Important improvement is efficiency, reducing costs, and minimizing environmental impact, enabling more sustainable and profitable production.

Factors Influencing Agriculture



Population in the world vs. arable lands



Source: Jelle Bruinsma, United Nations' Food and Agriculture Organization, 2009.

Technological and Environmental Needs

1. **Efficient Water Management:**
   1. Efficient irrigation systems (drip, smart scheduling).
   2. Rainwater harvesting and storage.
2. **Soil Conservation:**
   1. Conservation agriculture (no-till, cover crops).
   2. Crop rotation.
3. **Use of Advanced Technologies:**
   1. Drones and sensors for real-time monitoring.
   2. Internet of Things (IoT) for device interconnection.
4. **Reduction of Agrochemical Use:**
   1. Biofertilizers and beneficial microorganisms.
   2. Biological control methods.
5. **Renewable Energy:**
   1. Incorporation of solar and wind energy.

Economic and Social Needs

1. **Education and Training:**
   1. Continuous training programs for farmers.
   2. Strengthening agricultural extension services.
2. **Policies and Government Support:**
   1. Subsidies and incentives for sustainable practices.
   2. Environmental regulations.
3. **Diversification and Resilience:**
   1. Agroforestry for diversification and resilience.
   2. Regenerative agriculture.
4. **Access to Markets and Finance:**
   1. Microfinance and credit for small farmers.
   2. Promotion of sustainable supply chains.
5. **Research and Development:**
   1. Agricultural innovation and development of new crop varieties.
   2. Dissemination of sustainable agricultural practices.

2. Evolution of Agriculture over the years

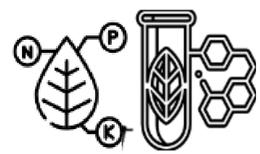
Digitalization of agriculture

Agriculture 1.0

- Intensive in hand work
- Low productivity

Agriculture 2.0

- Green Revolution
- Genetic enhancement
- Use of fertilizers and pesticides
- Agricultural machinery

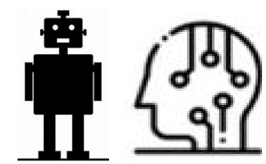


Agriculture 3.0

- Precision Agriculture
- Global positioning systems
- Biotechnology
- Softwarization of agriculture

Agriculture 4.0

- Cloud computing
- Sensors' Networks
- Drones
- Satelite Images
- Big Data
- Mobile Applications



Agriculture 5.0

- Artificial Intelligence
- Robotics
- synthetic biology
- 3D and 4D impressions
- Vertical Farming

Before 1950 — 1950 — 1990 — 2015 — Today

3. Agriculture 4.0

Agriculture 4.0

- The term Agriculture 4.0 refers to 4th Industrial Revolution.
- It upgrades traditional production methods and world agriculture strategies to an optimized value chain using a range of emerging technologies that enhance disruptive solutions at all stages of the agricultural production chain.

Importance of Agriculture 4.0

- Agriculture 4.0 is a crucial model in the development of the primary sector.
  - It allows for greater control over production costs: at all stages of cultivation, from planting to harvesting. Reducing expenses is the best way to enhance land productivity.
  - It facilitates planning: the data obtained and analyzed allow for scheduling each stage and are very useful in decision-making.
  - It reduces waste generation: especially water waste. Let's not forget that Spain is going through a severe drought period that is seriously affecting agriculture. This set of techniques can optimize water use and also prevent or detect the early appearance of diseases and pests.
  - It improves traceability: Agriculture 4.0 also allows for controlling all stages of the production and supply chain to ensure the highest possible quality.

Key Technologies in Agriculture 4.0

- Some technologies are essential to collect, manage, and interpret crop data,.
    - **Drones:** Drones are small unmanned aerial vehicles whose function in Agriculture 4.0 is to supervise and monitor crops in real-time. They are equipped with cameras that transmit live to a player. They can even map the terrain.
    - **Sensors:** Sensors are designed to detect and measure certain parameters, such as soil moisture levels or the presence of a specific nutrient. This information is sent to a computer program that makes the appropriate decisions at each moment.
    - **Robotics:** This includes autonomous tractors, which do not need an operator to guide them. They can handle harvesting, seed distribution, or weed removal, among many other tasks.

Connectivity and Communication

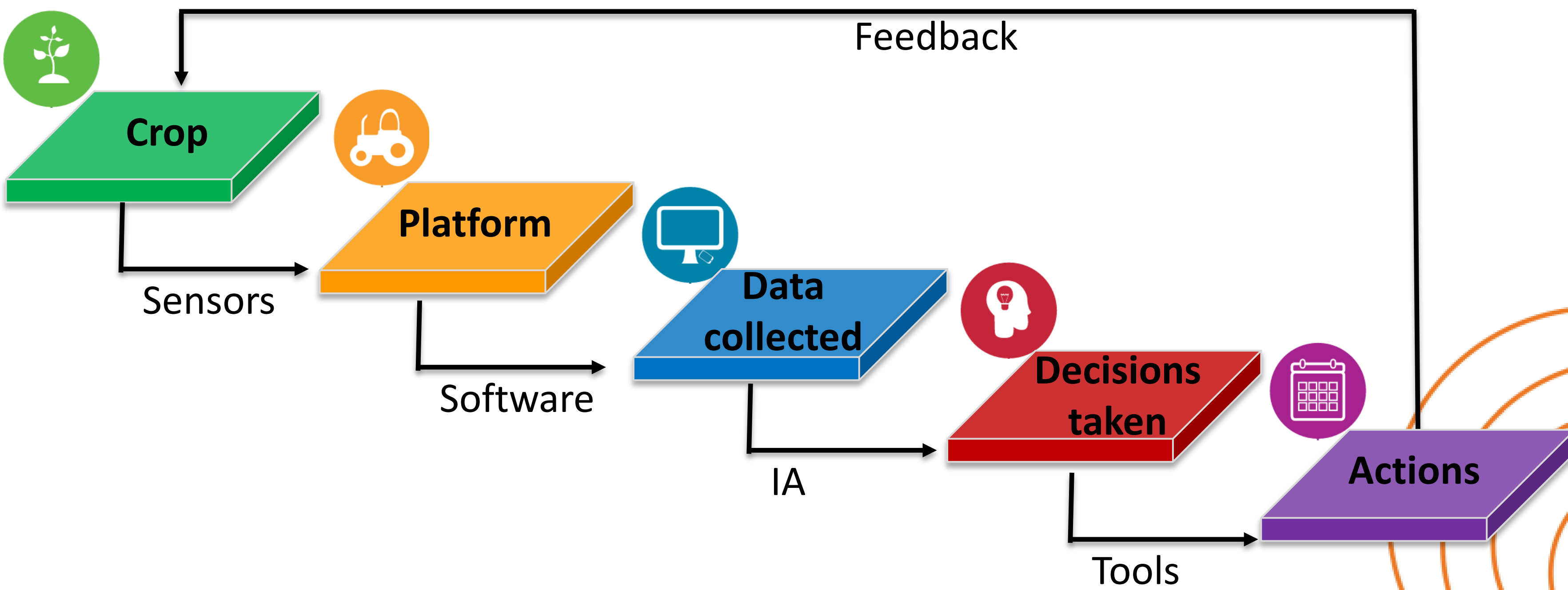
- **Internet of Things (IoT):** The aforementioned devices can remain permanently connected to the Internet and communicate with each other to exchange information. This creates a harmonized environment where all devices work together towards the same goal, which is to increase crop profitability.
- **5G Connectivity:** 5G offers high-quality internet connections at high speeds with imperceptible latency periods. This makes it possible to collect, transfer, and analyze data in real-time, resulting in more effective, safe, and profitable agricultural activities.
- **The Cloud:** This technology allows data to be stored on external and remote servers that can be accessed at any time as long as there is an Internet connection. It also facilitates collaborative work among farmers who are in very distant locations.

Artificial Intelligence and Security

- **Machine Learning:** Machine learning, which could be literally translated as 'machine learning,' but whose definition is more accurately 'automatic learning,' is a subfield of computer science and artificial intelligence. It is a technology that allows computer programs and machines to learn certain aspects.

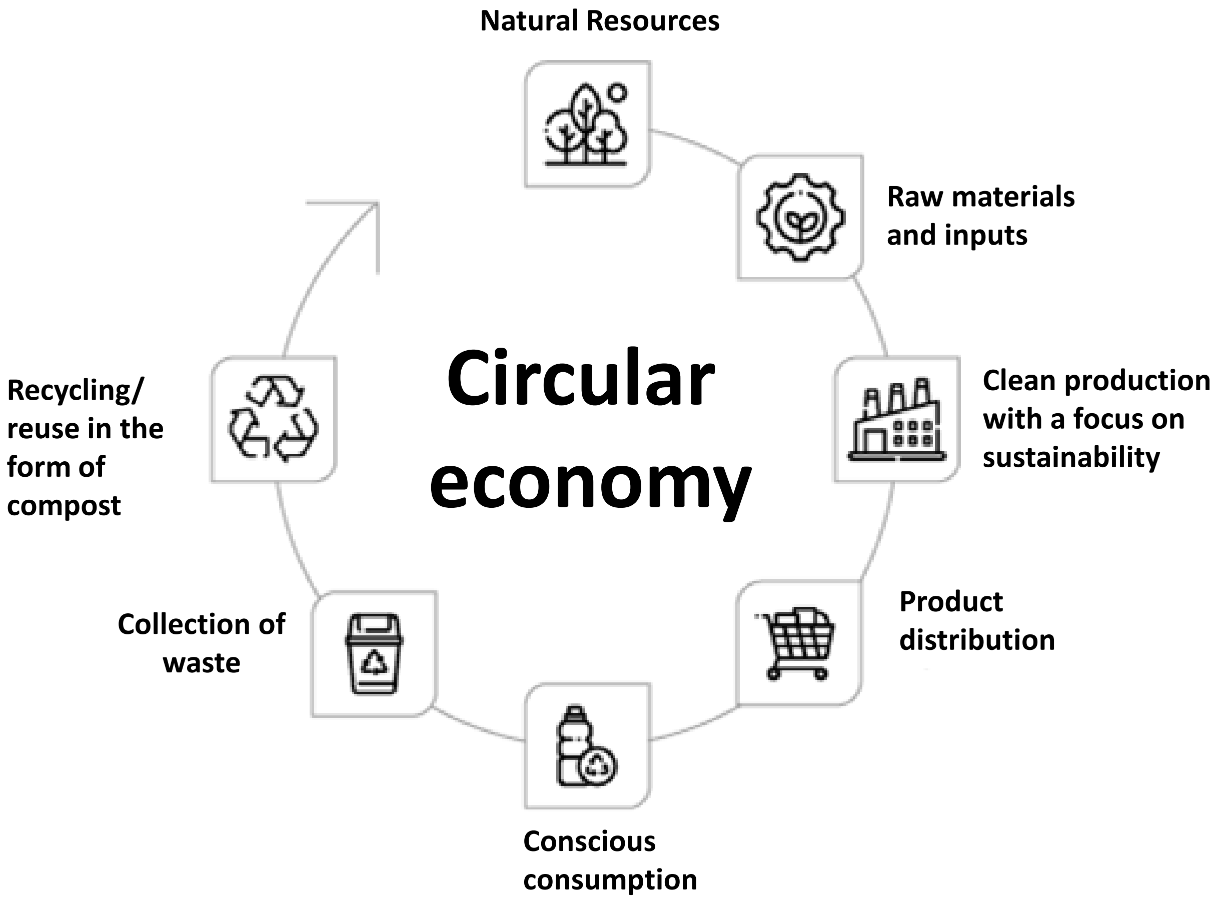
- **Blockchain:** Blockchain is a technology that became popular thanks to the cryptocurrency sector. However, it is also very useful in Agriculture 4.0, especially for safeguarding the integrity and confidentiality of collected data. The reason? It guarantees the anonymity of actions and is practically impenetrable to hackers.

How to mix all these concepts?

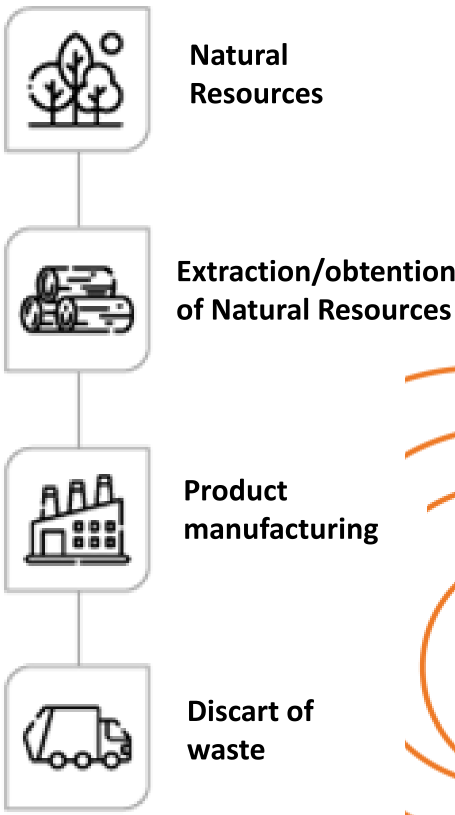


Management cycle based on the information for modern agriculture

What about the economic model for enhancing the sustainability?



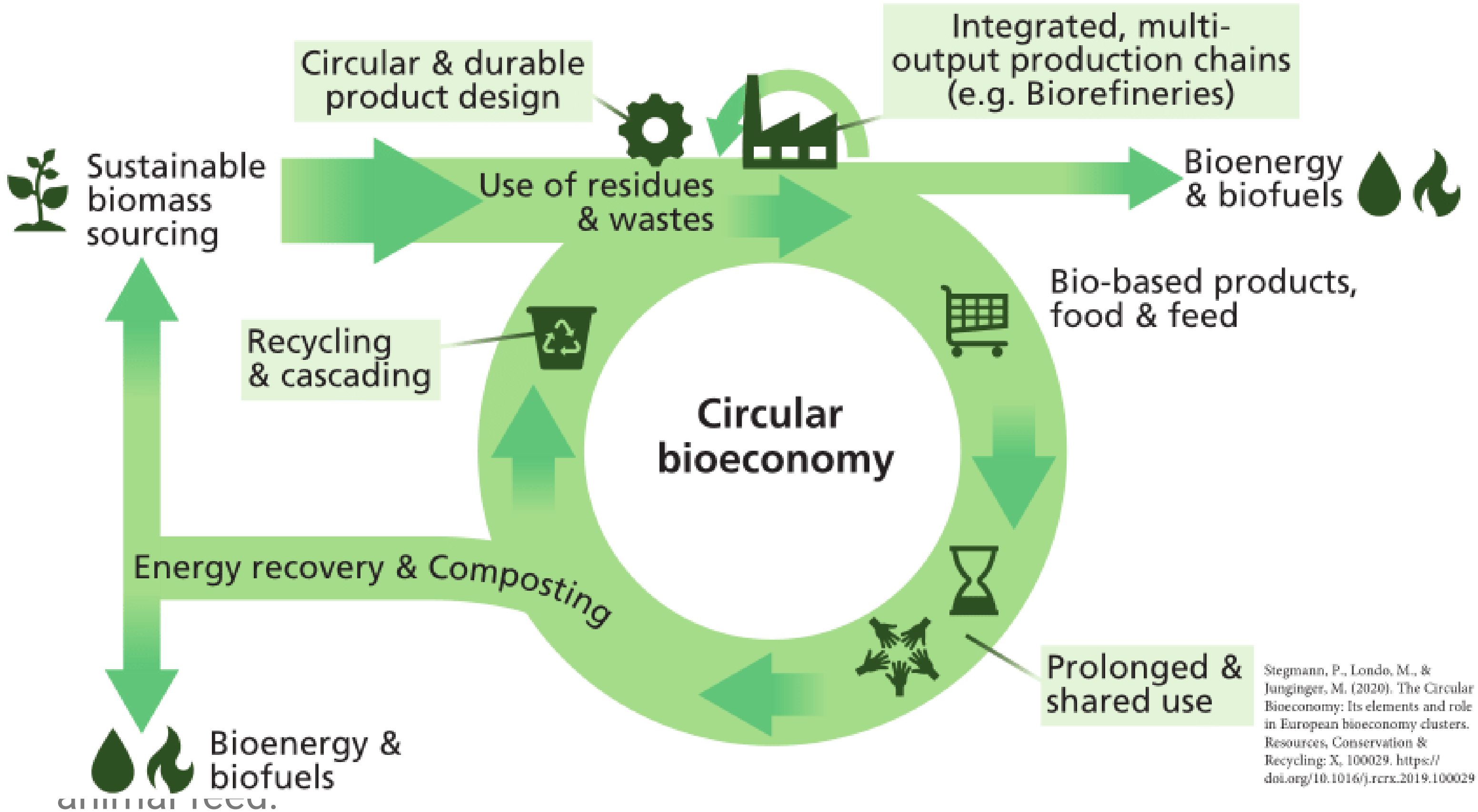
Linear economy



What is circular agriculture?

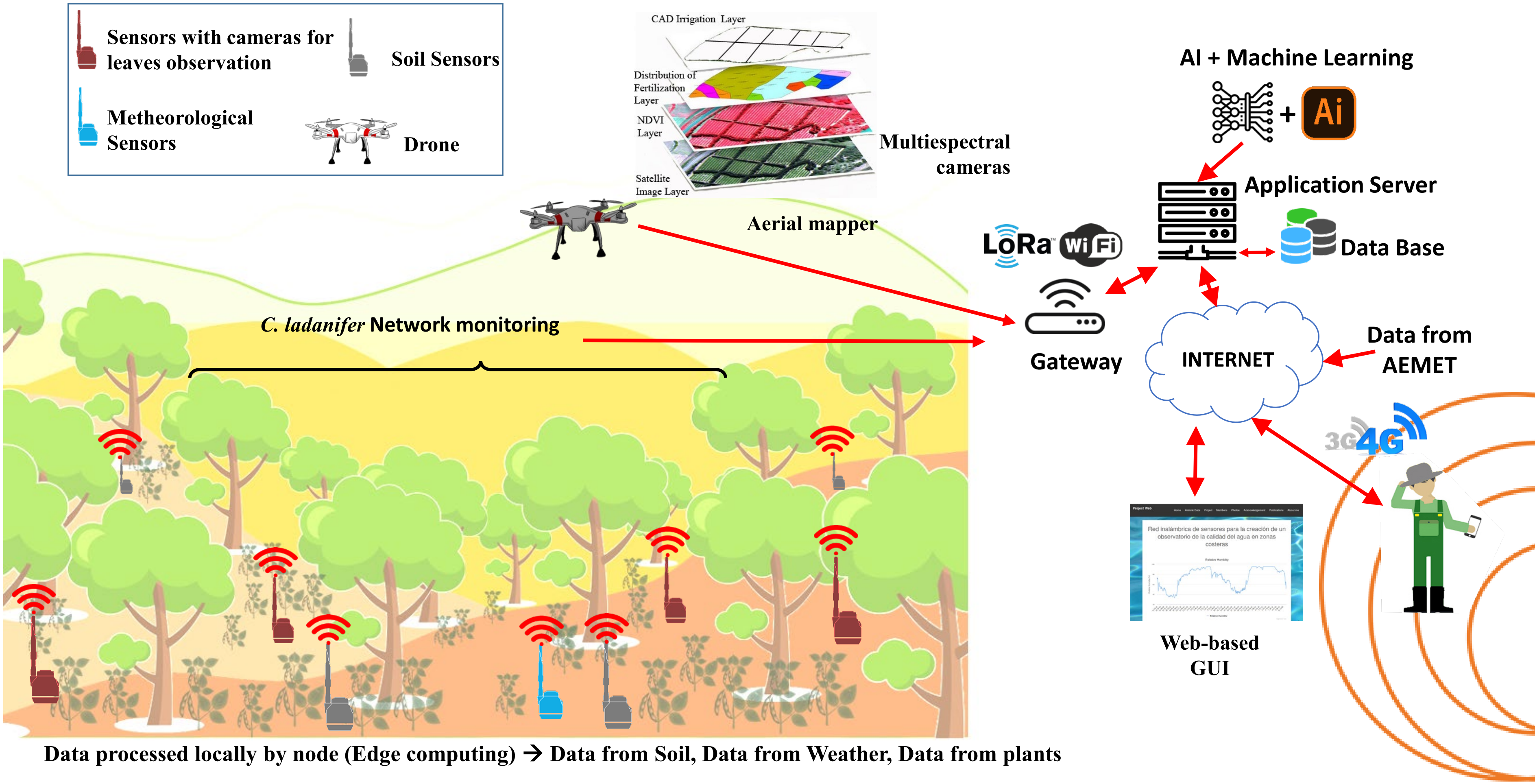
- It is a way of generating cultivation taking into account:
- Cultivated varieties.
- Control of the waste that is generated.
- The optimization of water and energy.
- Plan agri-food services.
- Respect for the environment.
- Save resources.
- Maximize product quality.
- The key to circular agriculture is related to the 3Rs (**reduce, recycle, reuse**).
- We must **reduce** expenses, losses, waste and natural resources such as water and energy.
- We must **recycle** the waste and the seeds obtained from the fruits.
- **Reuse** the land by exchanging crops and residues, turning them into compost or animal feed.

Resource-efficiency, Optimizing value of biomass over time, Sustainability



Stegmann, P., Londo, M., & Junginger, M. (2020). The Circular Bioeconomy: Its elements and role in European bioeconomy clusters. Resources, Conservation & Recycling: X, 100029. https://doi.org/10.1016/j.rcrx.2019.100029

4. Real Developements for Agriculture 4.0



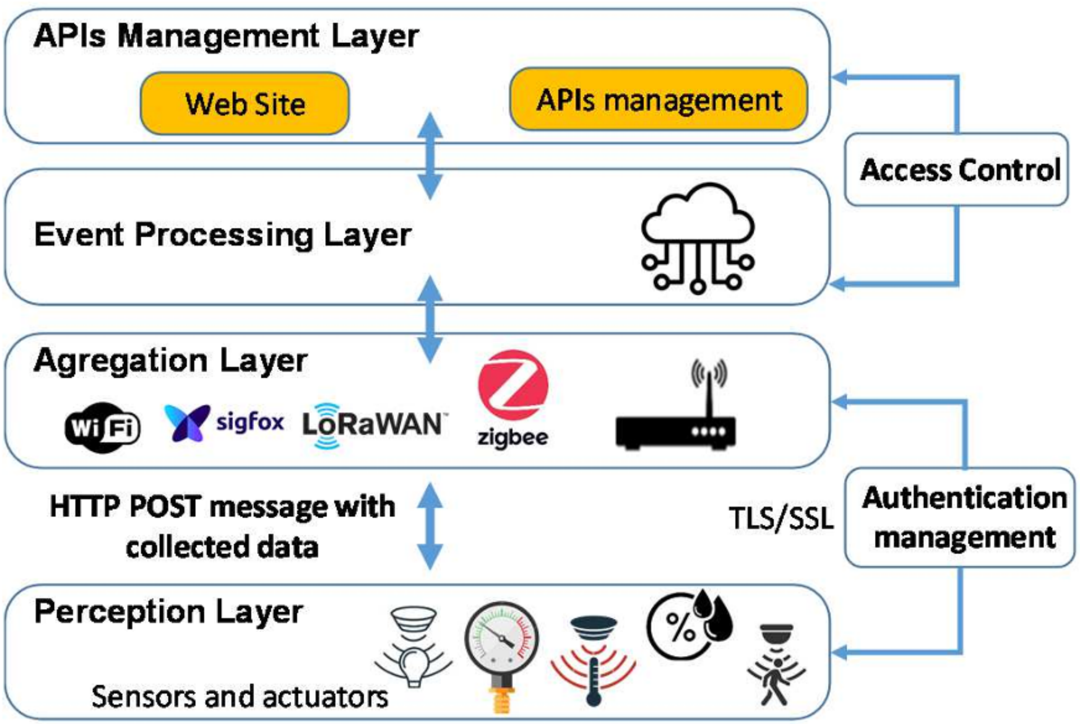
Data processed locally by node (Edge computing) → Data from Soil, Data from Weather, Data from plants

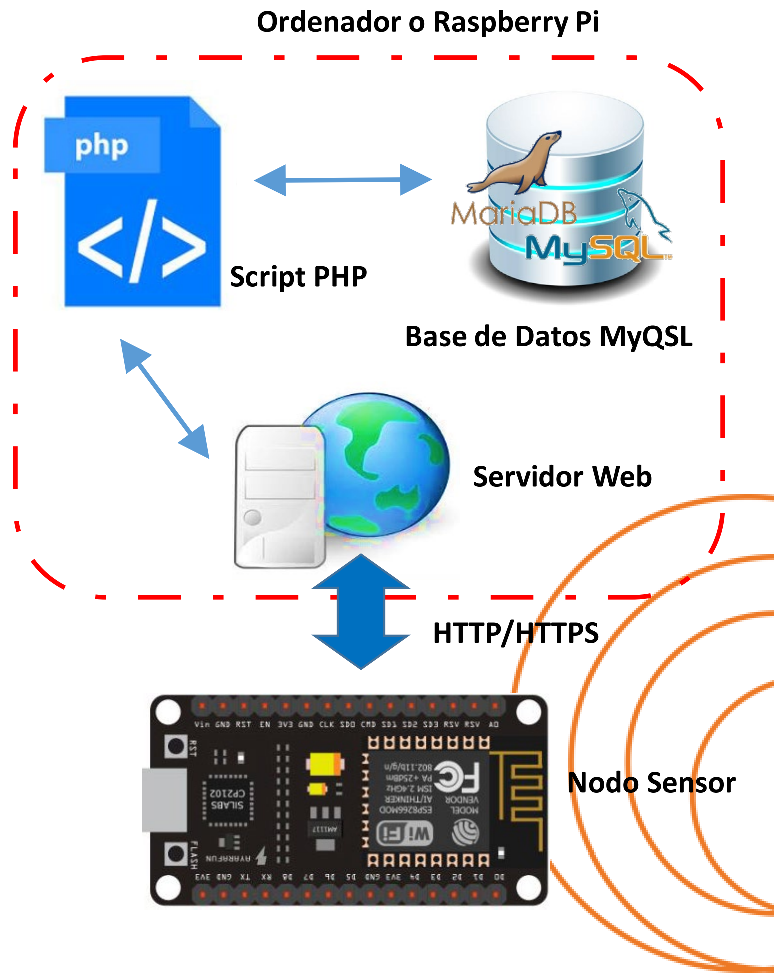
Management and storage of collected data

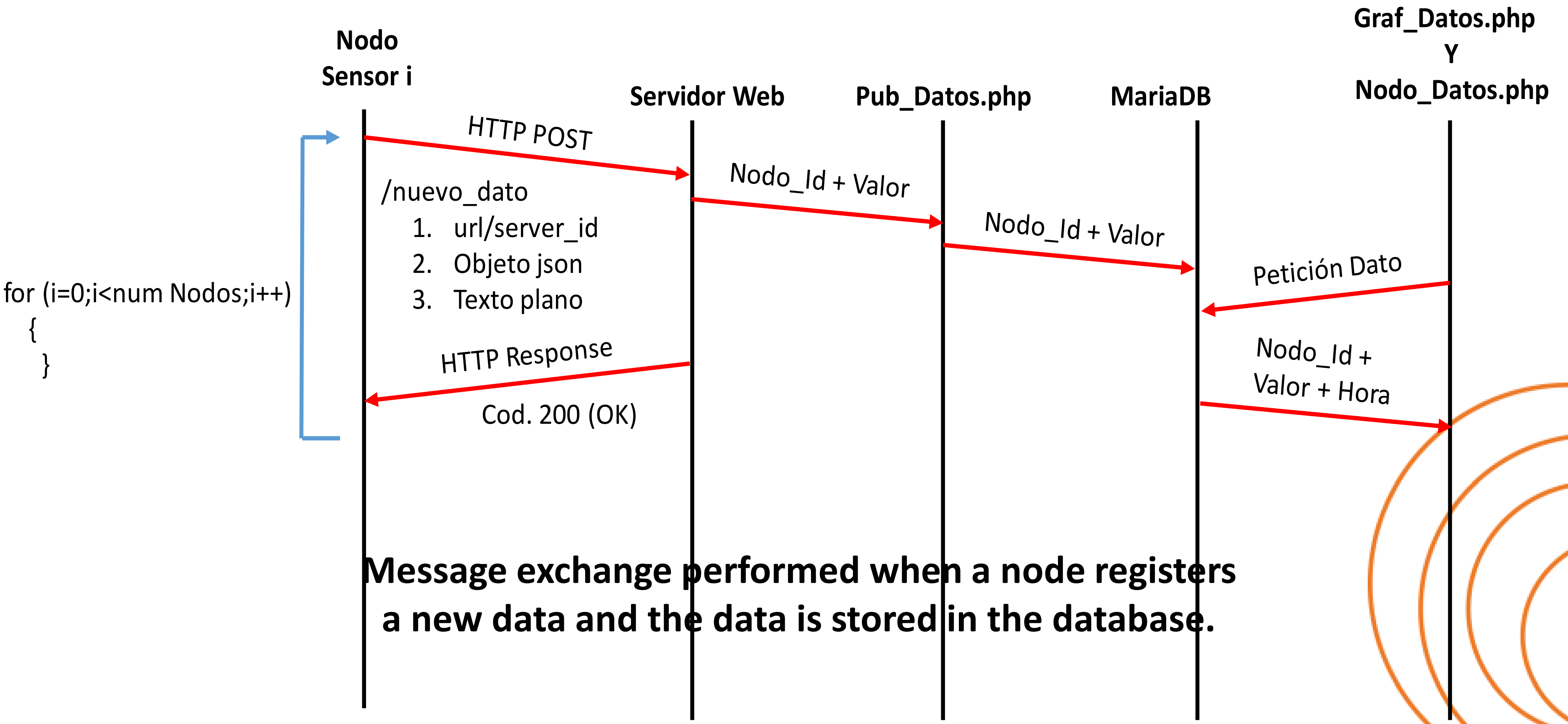
Miguel Zaragoza-Esquerdo, Alberto Ivars-Palomares, Sandra Sendra, Jaime Lloret, Diseño de una Plataforma para el Almacenamiento y Gestión de los datos en Redes IoT, XVI Jornadas de Ingeniería Telemática (*JITEL 2023*), 8-10 Noviembre 2023, Barcelona, España

A. Ivars-Palomares, M. Zaragoza-Esquerdo, S. Sendra and J. Lloret, "Design of a Platform for Data Storage and Data Management in IoT Networks," 2023 10th International Conference on Wireless Networks and Mobile Communications (WINCOM), Istanbul, Turkiye, 2023, pp. 1-6, doi: 10.1109/WINCOM59760.2023.10322905.

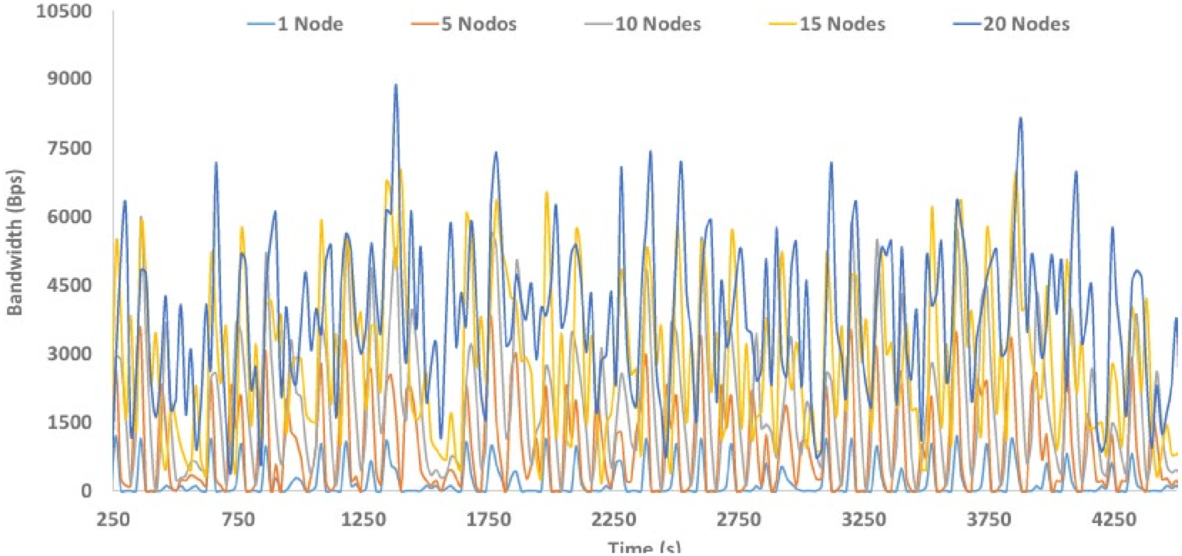
Network architecture for an IoT system





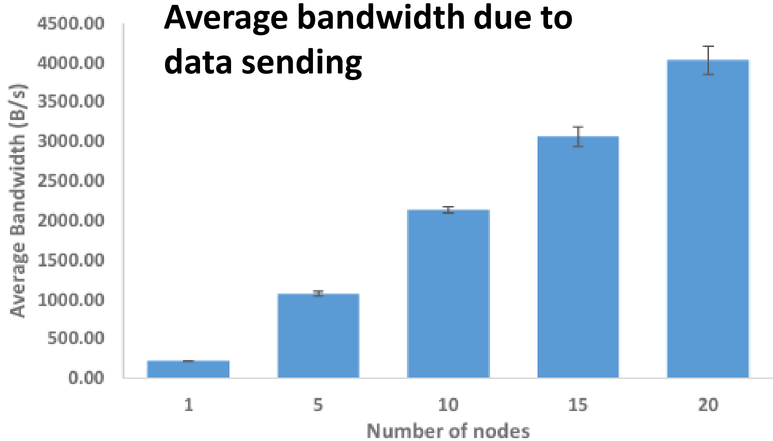


Message exchange performed when a node registers a new data and the data is stored in the database.

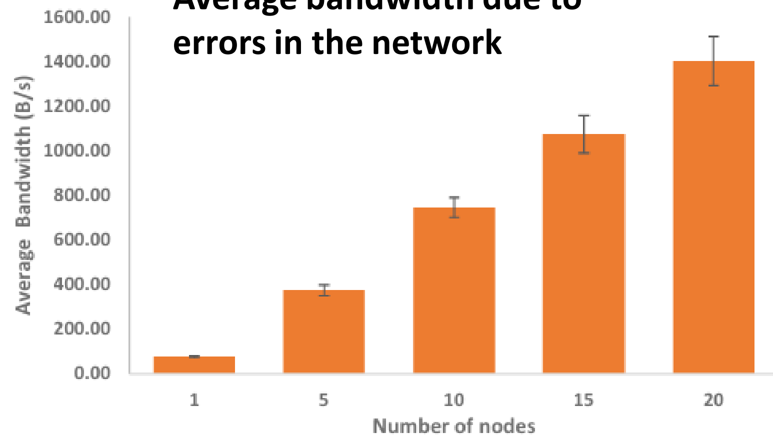


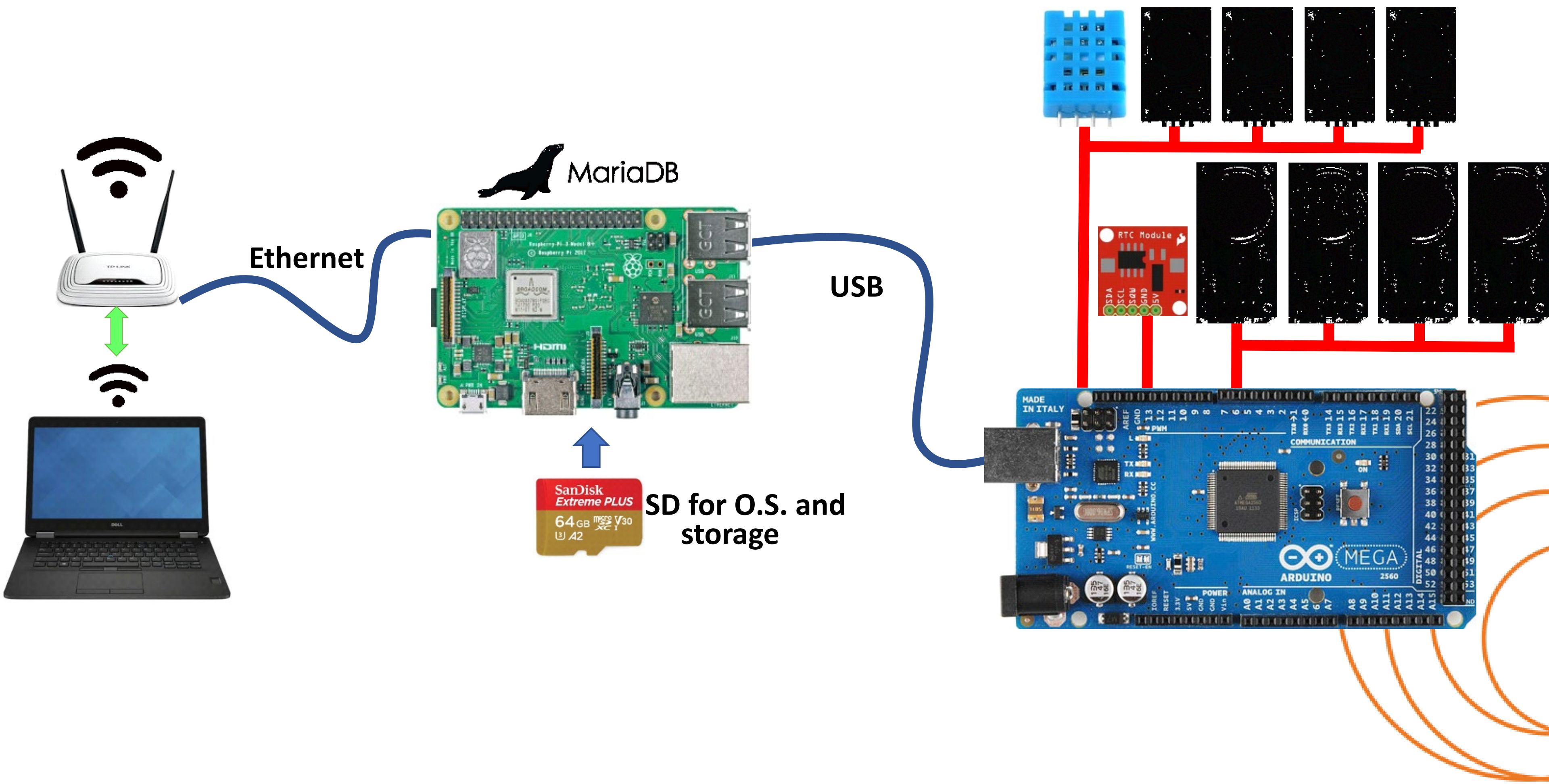
Bandwidth due to the sending of data from sensor nodes

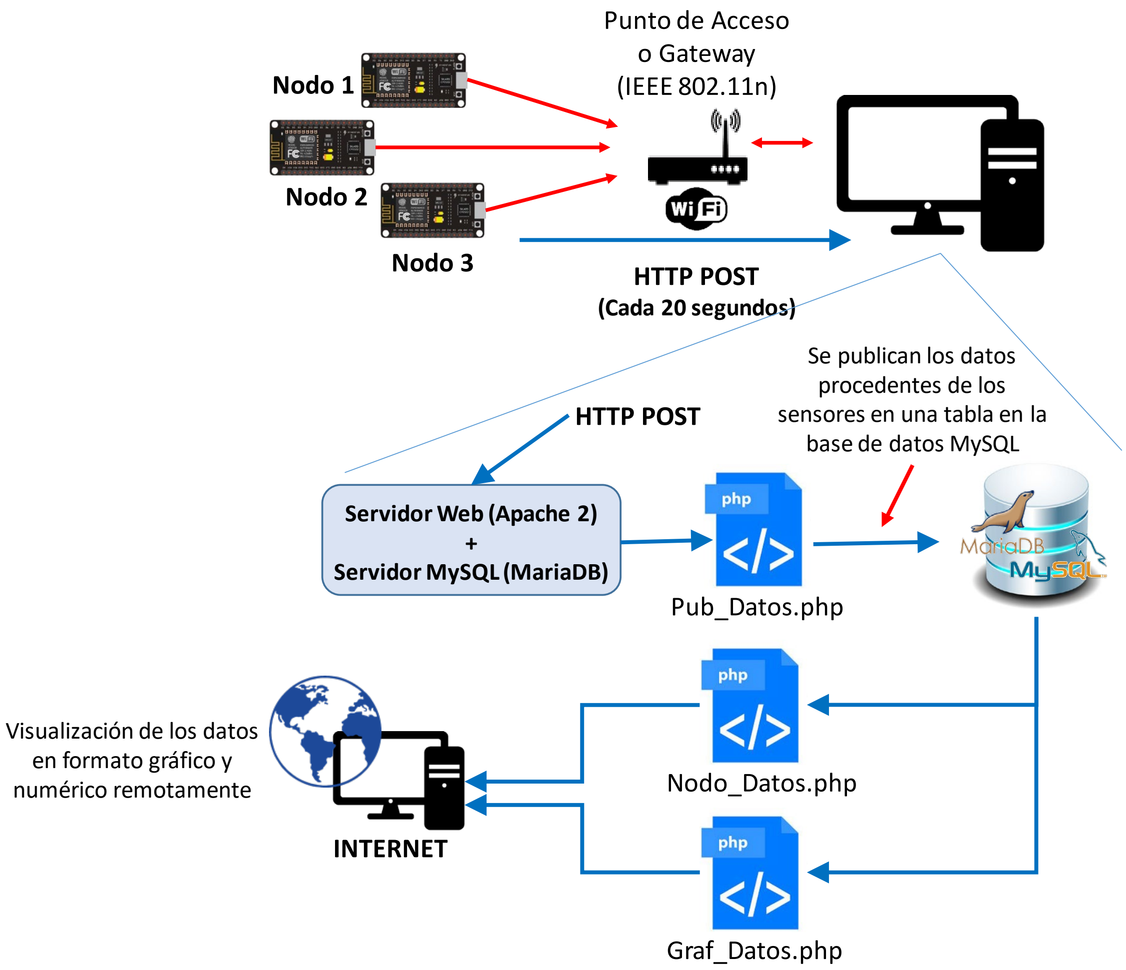
Average bandwidth due to data sending



Average bandwidth due to errors in the network




MariaDB
Ethernet
USB
SD for O.S. and storage
RTC Module


Punto de Acceso
o Gateway
(IEEE 802.11n)
Nodo 1
Nodo 2
Nodo 3
HTTP POST
(Cada 20 segundos)
Se publican los datos procedentes de los sensores en una tabla en la base de datos MySQL
HTTP POST
Servidor Web (Apache 2)
+
Servidor MySQL (MariaDB)
Pub_Datos.php
MariaDB
MySQL
Visualización de los datos en formato gráfico y numérico remotamente
INTERNET
Nodo_Datos.php
Graf_Datos.php

Punto de Acceso
o Gateway

Multiparametric sensor

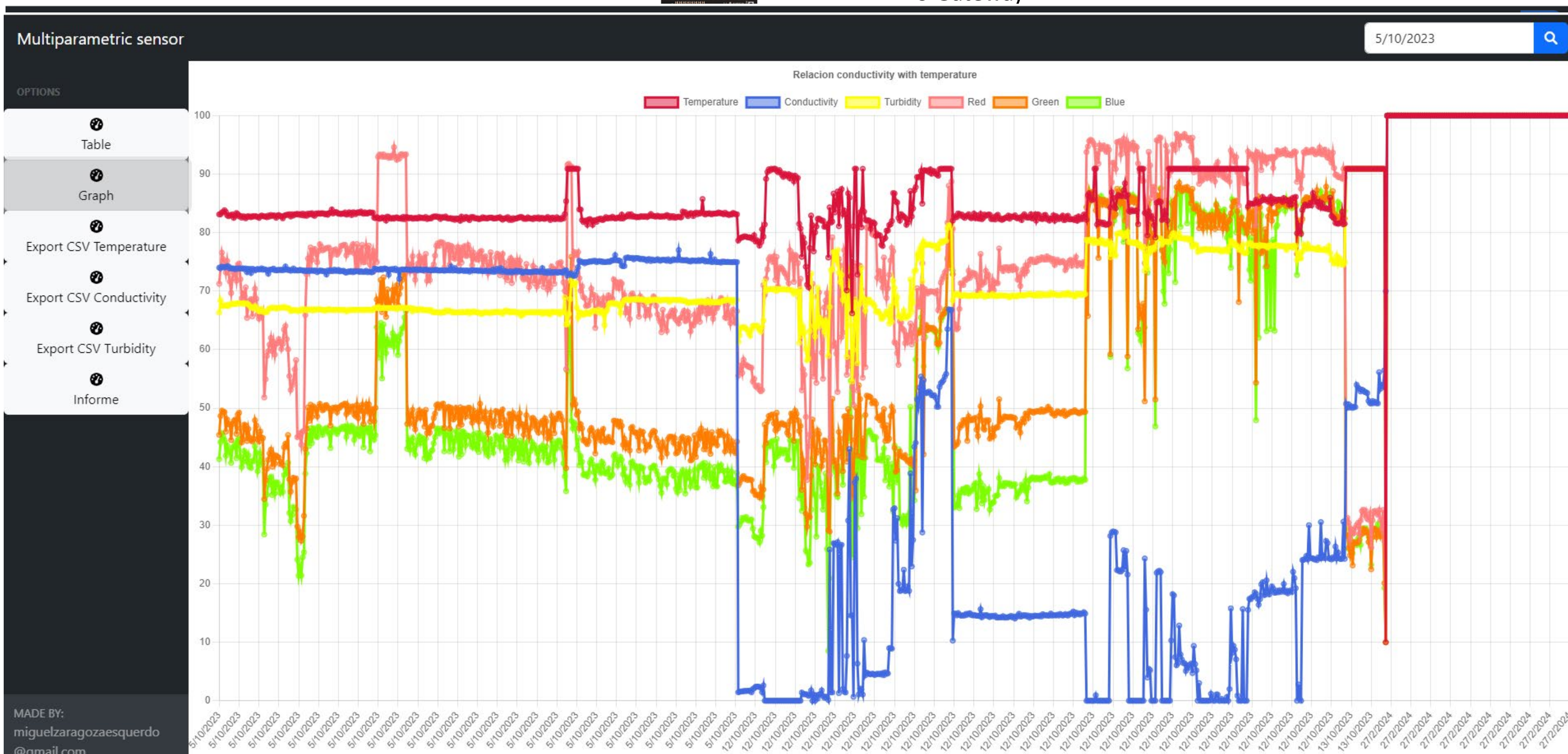
5/10/2023

OPTIONS
- Table
- Graph
- Export CSV Temperature
- Export CSV Conductivity
- Export CSV Turbidity
- Informe

#	Date	Time	Temperature	Conductivity	Turbidity	Red	Green	Blue
2444	5/10/2023	13:17:48	83.12	74.01	66.33	71.26	45.44	41.29
2445	5/10/2023	13:17:55	83.14	73.9	68.44	73.99	48.66	44.2
2446	5/10/2023	13:18:2	83.47	74.19	67.53	76.58	49.59	45.69
2447	5/10/2023	13:18:9	83.49	74.13	67.44	75.48	49.37	45.13
2448	5/10/2023	13:18:16	83.83	74.04	67.53	74.97	49.33	44.56
2449	5/10/2023	13:18:24	83.52	74.15	67.6	73.21	45.98	41.87
2450	5/10/2023	13:18:31	82.96	74.24	67.53	75.16	48.06	43.65
2451	5/10/2023	13:18:38	82.81	74.24	67.44	73.16	47.24	42.56
2452	5/10/2023	13:18:45	83.01	73.9	67.73	71.62	47.26	42.74
2453	5/10/2023	13:18:52	82.92	73.88	67.78	69.67	44.56	40.65
2454	5/10/2023	13:18:59	83.12	73.9	67.84	72.19	47.29	43.27
2455	5/10/2023	13:19:7	82.52	73.86	67.84	73.04	47.84	43.4
2456	5/10/2023	13:19:14	82.87	73.75	67.78	73.19	48.06	43.91
2457	5/10/2023	13:19:21	83.34	73.88	67.91	71.77	45.6	41.45
2458	5/10/2023	13:19:28	83.16	73.86	67.91	74.51	48.91	44.56
2459	5/10/2023	13:19:35	82.78	73.88	67.91	74.73	49.22	44.78
2460	5/10/2023	13:19:42	82.87	73.88	67.91	72.04	46.53	41.71
2461	5/10/2023	13:19:50	82.56	73.88	67.91	68.77	44.16	39.94
2462	5/10/2023	13:19:57	82.76	73.9	67.91	69.65	44.69	40.85
2463	5/10/2023	13:20:4	82.76	73.75	67.84	69.08	47.2	42.69

Graf_Datos.php

Punto de Acceso
o Gateway



Graf_Datos.php

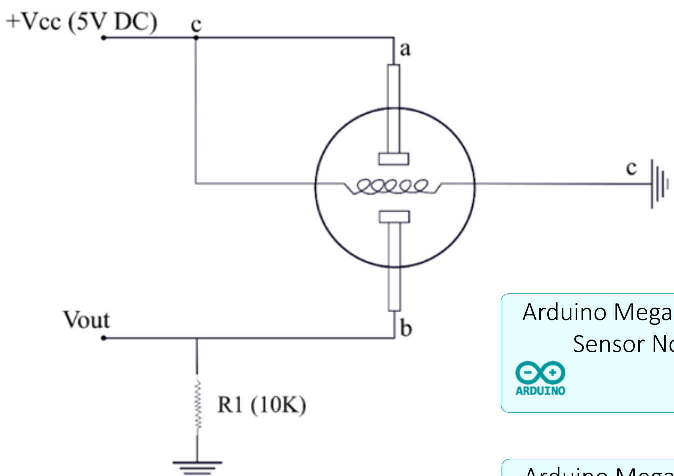
Web integration:

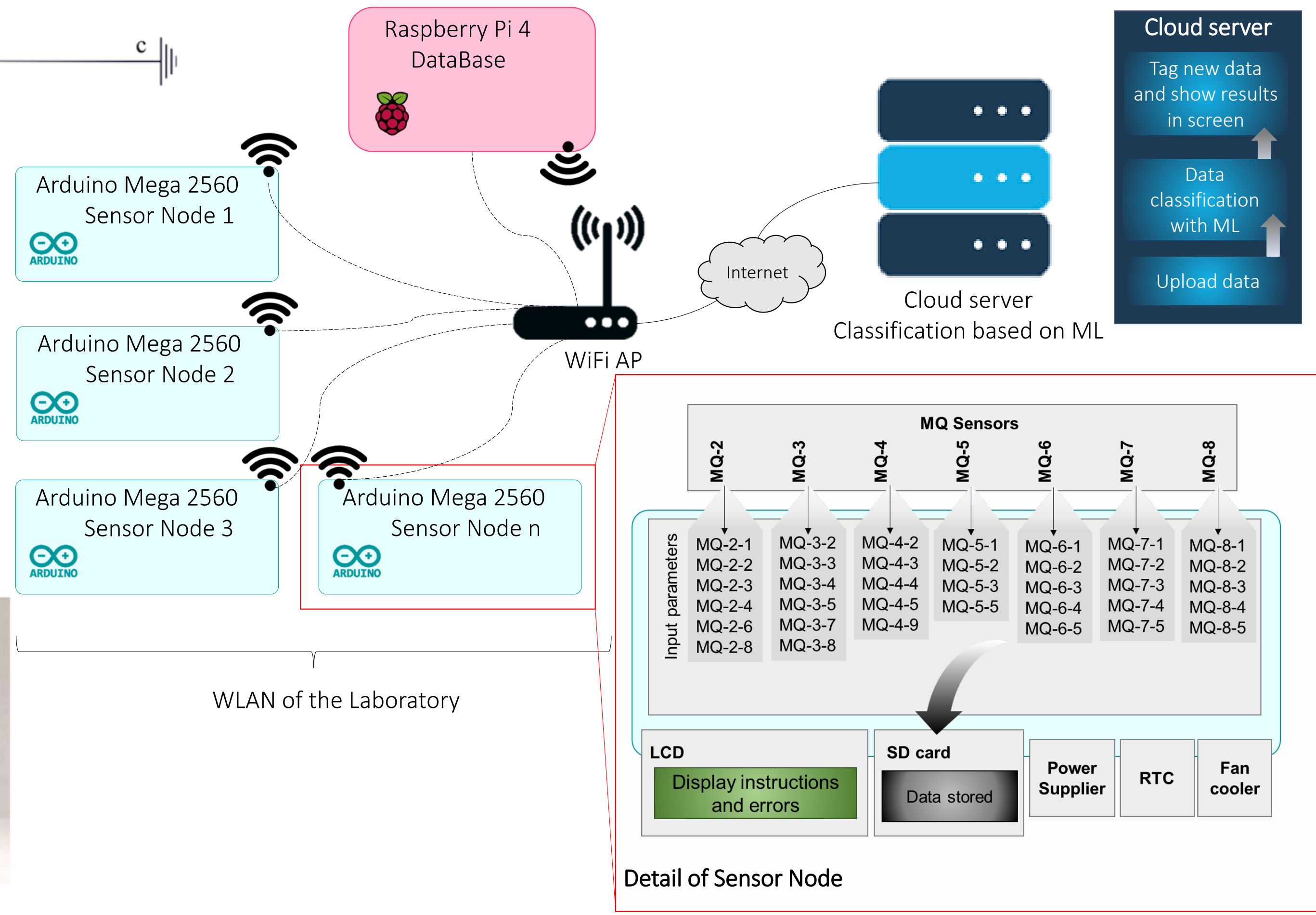
http://jlloret.webs.upv.es/meteorologia/

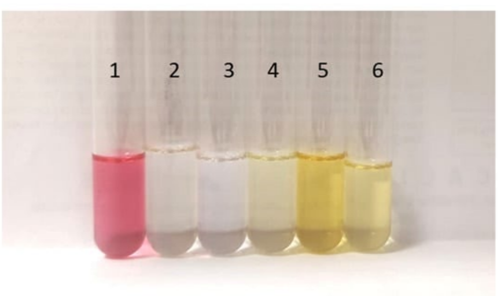
Fingerprinting of vapors generated by essential oils

Viciano-Tudela, S.; Parra, L.; Navarro-Garcia, P.; Sendra, S.; Lloret, J. Proposal of a New System for Essential Oil Classification Based on Low-Cost Gas Sensor and Machine Learning Techniques. Sensors 2023, 23, 5812. https://doi.org/10.3390/s23135812

Francisco Javier Diaz Blasco, Sandra Viciano-Tudela, Lorena Parra, Ali Ahmad, Veronika Chaloupková, Raquel Bados, Luis Saul Esteban Pascual, Irene Mediavilla, Sandra Sendra, Jaime Lloret, Employment of MQ gas sensors for the classification of Cistus ladanifer essential oils, Microchemical Journal, 2024, Vol. 206, pp. 111585.


+Vcc (5V DC)
c
a
c
Vout
b
R1 (10K)

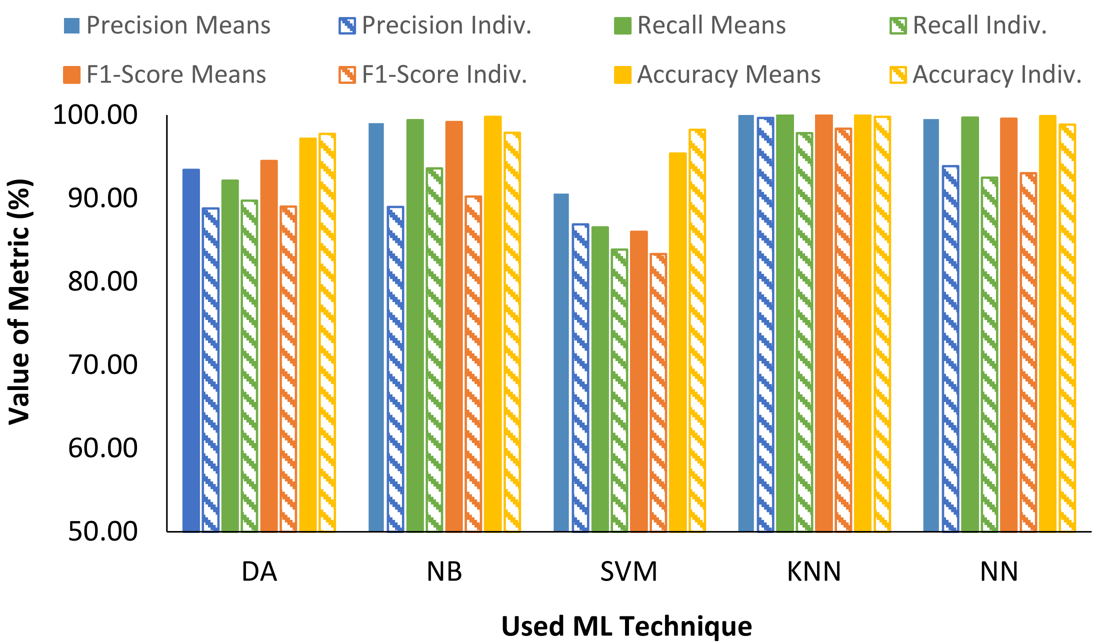

Raspberry Pi 4
DataBase
Cloud server
Tag new data and show results in screen
Data classification with ML
Upload data
Cloud server
Classification based on ML
Internet
WiFi AP
Arduino Mega 2560
Sensor Node 1
ARDUINO
Arduino Mega 2560
Sensor Node 2
ARDUINO
Arduino Mega 2560
Sensor Node 3
ARDUINO
Arduino Mega 2560
Sensor Node n
ARDUINO
WLAN of the Laboratory
MQ Sensors
MQ-2
MQ-3
MQ-4
MQ-5
MQ-6
MQ-7
MQ-8
Input parameters
MQ-2-1 MQ-2-2 MQ-2-3 MQ-2-4 MQ-2-6 MQ-2-8
MQ-3-2 MQ-3-3 MQ-3-4 MQ-3-5 MQ-3-7 MQ-3-8
MQ-4-2 MQ-4-3 MQ-4-4 MQ-4-5 MQ-4-9
MQ-5-1 MQ-5-2 MQ-5-3 MQ-5-5
MQ-6-1 MQ-6-2 MQ-6-3 MQ-6-4 MQ-6-5
MQ-7-1 MQ-7-2 MQ-7-3 MQ-7-4 MQ-7-5
MQ-8-1 MQ-8-2 MQ-8-3 MQ-8-4 MQ-8-5
LCD
Display instructions and errors
SD card
Data stored
Power Supplier
RTC
Fan cooler
Detail of Sensor Node


1
2
3
4
5
6

Sensorç	Sensitive to
MQ135[26]	Air Quality (CO, CO_2, Ammonia, Benzene, Alcohol, smoke)
MQ-131 [27]	Ozone
MQ136 [28]	Hydrogen Sulphide gas
MQ-137 [29]	Ammonia, NH_3, Ethanol, CO
MQ-138 [30]	Benzene, Toluene, Alcohol, Acetone, Propane, Formaldehyde gas, Hydrogen
MQ214 [31]	Methane, Natural gas
MQ2 [32]	Methane, Butane, LPG, smoke
MQ3 [33]	Alcohol, Ethanol, smoke
MQ4 [34]	Methane, CNG Gas
MQ5 [35]	Natural gas, LPG
MQ6 [36]	LPG, butane gas
MQ7 [37]	Carbon Monoxide
MQ8 [38]	Hydrogen Gas
MQ-9 [39]	Carbon Monoxide, LPG, CH_4

Source	Acronym	Nº of Individual Measurements
Cistus ladanifer	Cla	1813
Pinus pinaster	Pp	1213
Cistus ladanifer + Pinus pinaster	CP	1241
Melaleuca alternifolia	Ma	410
Citrus limonum	Cli	2062
Red fruits	Rf	375

ML Technique	Precision	Recall	F1-Score	Accuracy
DA	0.91	0.91	0.82	0.97
NB	0.94	0.97	0.95	0.99
SVM	0.89	0.85	0.85	0.97
KNN	1.00	0.99	0.99	1.00
NN	0.97	0.96	0.96	0.99



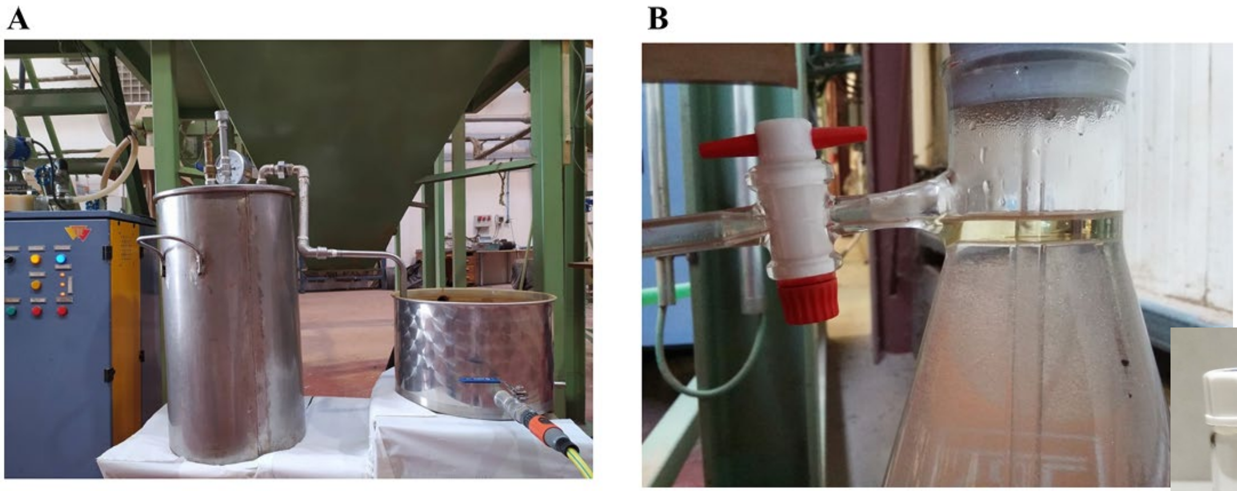


Fig. 1. Pilot plant for EO extraction. A) Steam distillation pilot plant B) EO and hydrolate detail.

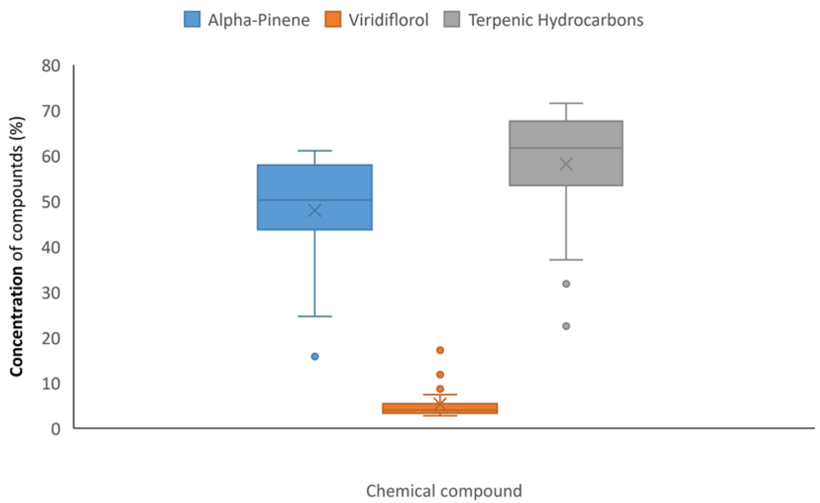
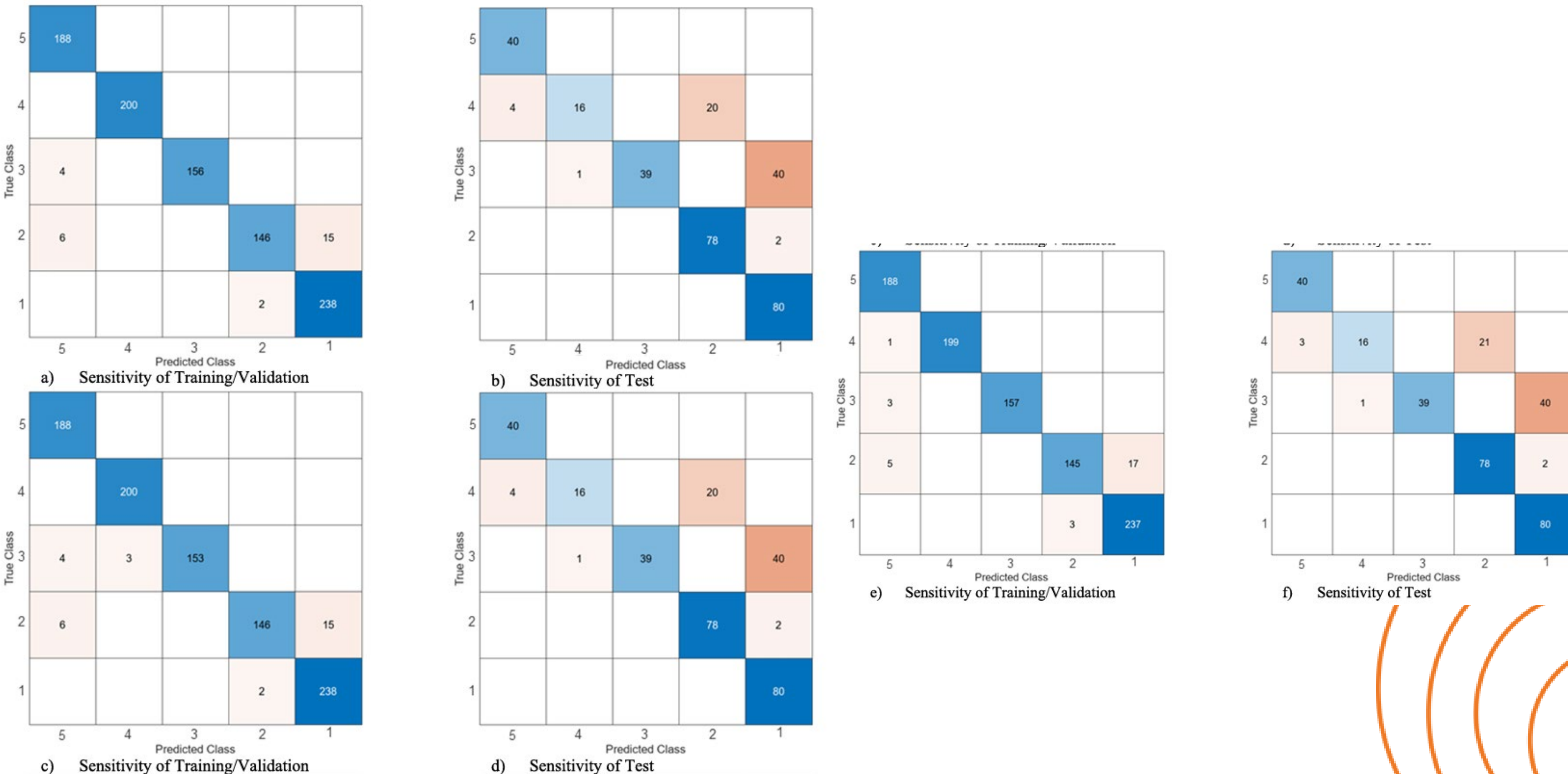


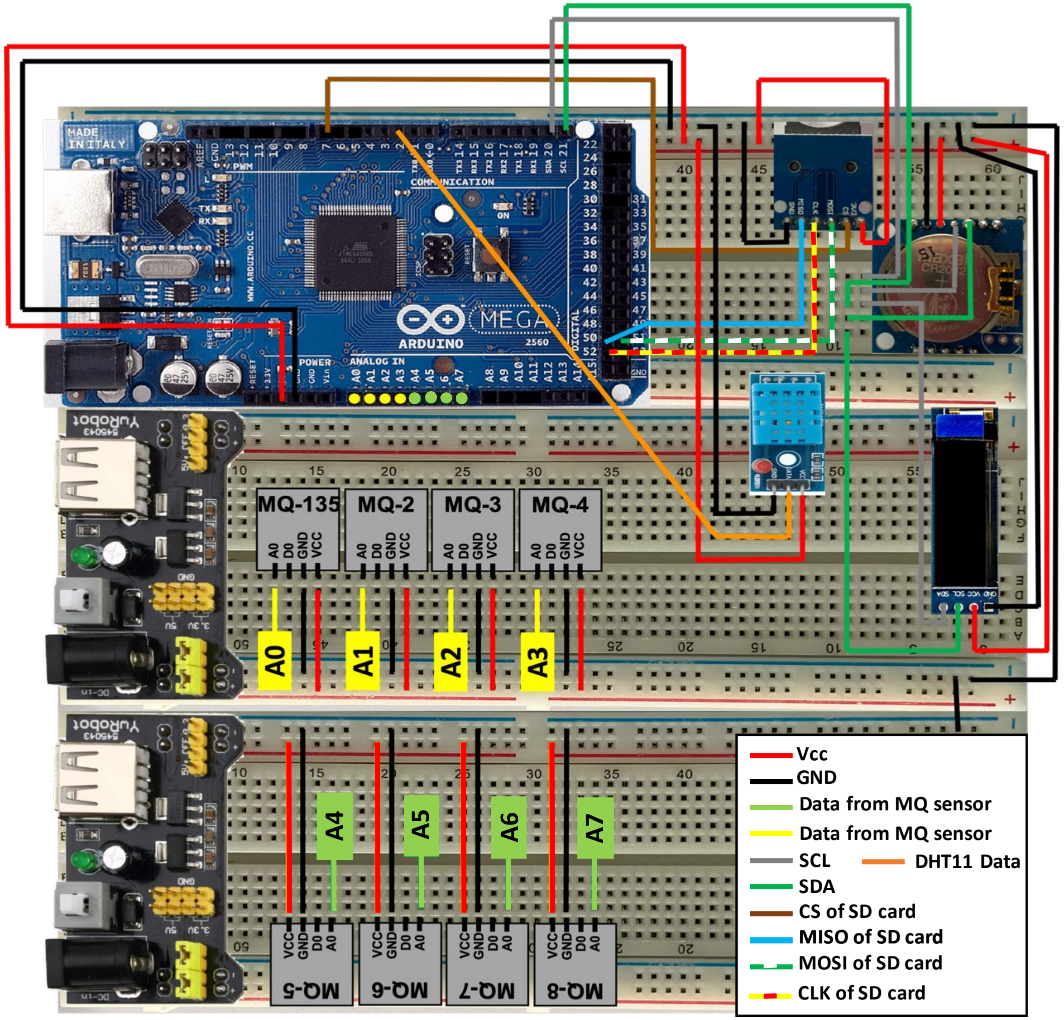
Fig. 3. Maximum and minimum concentration ranges for the studied organic compounds in *Cistus ladanifer* EOs.



Confusion matrix for different models in both training/validation and test with Medium Gaussian SVM model. a) training/validation for 11 features, b) test for 11 features, c) training/validation for 12 features, d) test for 12 features, e) raining/validation for 13 features, f) test for 13 features.

Detection of essential oils adulteration of Cistus Ladanifer

Viciano-Tudela, S.; Sendra, S.; Parra, L.; Jimenez, J.M.; Lloret, J. Proposal of a Gas Sensor-Based Device for Detecting Adulteration in Essential Oil of Cistus ladanifer. Sustainability 2023, 15, 3357. https://doi.org/10.3390/su15043357


MQ-135
MQ-2
MQ-3
MQ-4
MQ-5
MQ-6
MQ-7
MQ-8
A0
A1
A2
A3
A4
A5
A6
A7
ARDUINO MEGA 2560
Vcc
GND
Data from MQ sensor
Data from MQ sensor
SCL
DHT11 Data
SDA
CS of SD card
MISO of SD card
MOSI of SD card
CLK of SD card

-1.0 | 1.0

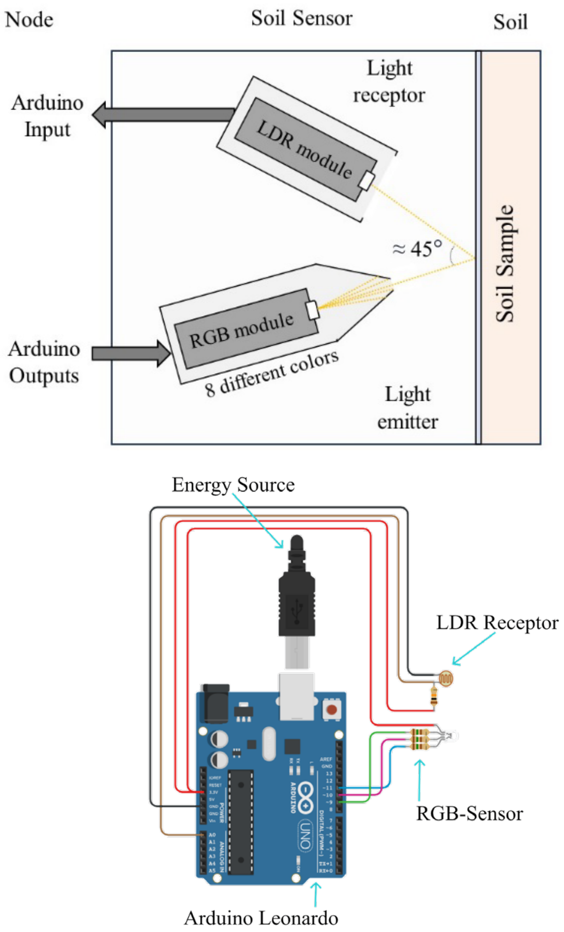
	Sample	MQ2-1	MQ2-2	MQ2-3	MQ2-4	MQ2-6	MQ3-2	MQ3-3	MQ3-8	MQ4-2	MQ4-3	MQ4-4	MQ4-5	MQ4-9	MQ5-1	MQ5-2	MQ5-3	MQ5-4	MQ5-5	MQ6-1	MQ6-2	MQ6-3	MQ6-4	MQ6-5	MQ7-1	MQ7-2	MQ7-3	MQ7-4	MQ7-5	MQ8-1	MQ8-2	MQ8-3	MQ8-4	MQ8-5
Sample		X	-0.47	-0.40	-0.43	-0.48	0.42	0.45	X	-0.32	-0.53	-0.57	-0.36	-0.55	-0.85	-0.47	-0.83	-0.84	-0.87	0.64	0.68	X	0.51	0.67	0.40	X	0.40	X	X	-0.42	-0.50	-0.44	-0.47	-0.47
MQ2-1	X		0.33	0.34	0.34	0.33	-0.38	-0.36	X	X	X	X	X	X	0.42	0.33	0.42	0.42	0.42	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MQ2-2	-0.47	0.33		0.99	1.00	1.00	X	X	X	X	X	X	X	X	0.67	1.00	0.69	0.68	0.64	-0.57	-0.62	X	-0.46	-0.61	-0.31	-0.34	-0.31	-0.29	X	0.65	0.78	0.88	0.72	0.87
MQ2-3	-0.40	0.34	0.99		1.00	0.99	X	X	X	X	X	X	X	X	0.60	0.99	0.62	0.61	0.57	-0.51	-0.56	X	-0.41	-0.55	X	-0.29	X	X	X	0.59	0.74	0.87	0.67	0.85
MQ2-4	-0.43	0.34	1.00	1.00		1.00	X	X	X	X	X	X	X	X	0.64	1.00	0.66	0.64	0.60	-0.54	-0.59	X	-0.44	-0.58	-0.27	-0.32	-0.28	-0.27	X	0.62	0.76	0.88	0.69	0.87
MQ2-6	-0.48	0.33	1.00	0.99	1.00		X	X	X	X	X	X	X	X	0.68	1.00	0.70	0.69	0.64	-0.57	-0.63	X	-0.47	-0.62	-0.31	-0.34	-0.32	-0.29	X	0.65	0.79	0.88	0.72	0.87
MQ3-2	0.42	-0.38	X	X	X	X		0.99	X	X	X	X	0.37	X	-0.43	X	-0.39	-0.41	-0.46	X	X	X	X	X	-0.45	-0.71	-0.45	-0.75	X	0.49	0.33	X	0.41	X
MQ3-3	0.45	-0.36	X	X	X	X	0.99		X	X	X	X	0.36	X	-0.45	X	-0.41	-0.44	-0.49	X	X	X	X	X	-0.43	-0.70	-0.43	-0.74	X	0.46	0.30	X	0.38	X
MQ3-8	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-0.28	X	-0.28	X	X	X	X	X	X	X
MQ4-2	-0.32	X	X	X	X	X	X	X	X		0.63	0.71	0.87	0.80	X	X	X	X	X	X	X	X	X	X	-0.30	X	-0.30	X	X	X	X	X	X	X
MQ4-3	-0.53	X	X	X	X	X	X	X	X	0.63		0.98	0.75	0.91	0.31	X	0.32	0.32	0.32	-0.28	-0.29	X	X	-0.29	-0.37	-0.27	-0.37	X	X	X	X	X	X	X
MQ4-4	-0.57	X	X	X	X	X	X	X	X	0.71	0.98		0.84	0.97	0.30	X	0.30	0.31	0.32	-0.30	-0.30	X	-0.28	-0.30	-0.42	-0.31	-0.42	X	X	0.29	X	X	X	X
MQ4-5	-0.36	X	X	X	X	X	0.37	0.36	X	0.87	0.75	0.84		0.94	X	X	X	X	X	X	X	X	X	X	-0.47	-0.43	-0.47	-0.38	X	0.33	X	X	0.28	X
MQ4-9	-0.55	X	X	X	X	X	X	X	X	0.80	0.91	0.97	0.94		X	X	X	X	X	X	X	X	X	X	-0.46	-0.38	-0.46	-0.32	X	0.33	X	X	0.29	X
MQ5-1	-0.85	0.42	0.67	0.60	0.64	0.68	-0.43	-0.45	X	X	0.31	0.30	X	X		0.67	1.00	1.00	1.00	-0.76	-0.80	-0.42	-0.63	-0.79	-0.29	X	-0.29	X	X	0.49	0.61	0.60	0.56	0.63
MQ5-2	-0.47	0.33	1.00	0.99	1.00	1.00	X	X	X	X	X	X	X	X	0.67		0.69	0.68	0.64	-0.57	-0.62	X	-0.46	-0.61	-0.31	-0.34	-0.31	-0.29	X	0.65	0.78	0.88	0.72	0.87
MQ5-3	-0.83	0.42	0.69	0.62	0.66	0.70	-0.39	-0.41	X	X	0.32	0.30	X	X	1.00	0.69		1.00	0.99	-0.76	-0.80	-0.42	-0.63	-0.79	-0.29	X	-0.30	X	X	0.51	0.63	0.61	0.58	0.64
MQ5-4	-0.84	0.42	0.68	0.61	0.64	0.69	-0.41	-0.44	X	X	0.32	0.31	X	X	1.00	0.68	1.00		0.99	-0.76	-0.80	-0.42	-0.63	-0.79	-0.29	X	-0.29	X	X	0.50	0.62	0.61	0.57	0.63
MQ5-5	-0.87	0.42	0.64	0.57	0.60	0.64	-0.46	-0.49	X	X	0.32	0.32	X	X	1.00	0.64	0.99	0.99		-0.76	-0.79	-0.41	-0.62	-0.78	-0.29	X	-0.29	X	X	0.46	0.58	0.57	0.53	0.60
MQ6-1	0.64	X	-0.57	-0.51	-0.54	-0.57	X	X	X	X	-0.28	-0.30	X	X	-0.76	-0.57	-0.76	-0.76	-0.76		0.99	0.85	0.96	1.00	0.65	0.57	0.65	0.52	X	-0.73	-0.76	-0.63	-0.76	-0.68
MQ6-2	0.68	X	-0.62	-0.56	-0.59	-0.63	X	X	X	X	-0.29	-0.30	X	X	-0.80	-0.62	-0.80	-0.80	-0.79	0.99		0.79	0.94	1.00	0.65	0.56	0.65	0.50	X	-0.75	-0.80	-0.67	-0.78	-0.72
MQ6-3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-0.42	X	-0.42	-0.42	-0.41	0.85	0.79		0.89	0.80	0.51	0.53	0.52	0.57	0.30	-0.52	-0.49	-0.34	-0.51	-0.39
MQ6-4	0.51	X	-0.46	-0.41	-0.44	-0.47	X	X	X	X	X	-0.28	X	X	-0.63	-0.46	-0.63	-0.63	-0.62	0.96	0.94	0.89		0.94	0.67	0.61	0.67	0.58	X	-0.72	-0.71	-0.54	-0.72	-0.59
MQ6-5	0.67	X	-0.61	-0.55	-0.58	-0.62	X	X	X	X	-0.29	-0.30	X	X	-0.79	-0.61	-0.79	-0.79	-0.78	1.00	1.00	0.80	0.94		0.65	0.57	0.66	0.51	X	-0.75	-0.79	-0.66	-0.78	-0.71
MQ7-1	0.40	X	-0.31	X	-0.27	-0.31	-0.45	-0.43	-0.28	-0.30	-0.37	-0.42	-0.47	-0.46	-0.29	-0.31	-0.29	-0.29	-0.29	0.65	0.65	0.51	0.67	0.65		0.89	1.00	0.80	X	-0.85	-0.75	-0.44	-0.81	-0.52
MQ7-2	X	X	-0.34	-0.29	-0.32	-0.34	-0.71	-0.70	X	X	-0.27	-0.31	-0.43	-0.38	X	-0.34	X	X	X	0.57	0.56	0.53	0.61	0.57	0.89		0.90	0.97	X	-0.90	-0.77	-0.47	-0.84	-0.54
MQ7-3	0.40	X	-0.31	X	-0.28	-0.32	-0.45	-0.43	-0.28	-0.30	-0.37	-0.42	-0.47	-0.46	-0.29	-0.31	-0.30	-0.29	-0.29	0.65	0.65	0.52	0.67	0.66	1.00	0.90		0.81	X	-0.86	-0.75	-0.44	-0.81	-0.53
MQ7-4	X	X	-0.29	X	-0.27	-0.29	-0.75	-0.74	X	X	X	X	-0.38	-0.32	X	-0.29	X	X	X	0.52	0.50	0.57	0.58	0.51	0.80	0.97	0.81		X	-0.83	-0.70	-0.41	-0.77	-0.48
MQ7-5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.30	X	X	X	X	X	X		X	X	X	X	X
MQ8-1	-0.42	X	0.65	0.59	0.62	0.65	0.49	0.46	X	X	X	0.29	0.33	0.33	0.49	0.65	0.51	0.50	0.46	-0.73	-0.75	-0.52	-0.72	-0.75	-0.85	-0.90	-0.86	-0.83	X		0.97	0.76	0.99	0.82
MQ8-2	-0.50	X	0.78	0.74	0.76	0.79	0.33	0.30	X	X	X	X	X	X	0.61	0.78	0.63	0.62	0.58	-0.76	-0.80	-0.49	-0.71	-0.79	-0.75	-0.77	-0.75	-0.70	X	0.97		0.89	0.99	0.94
MQ8-3	-0.44	X	0.88	0.87	0.88	0.88	X	X	X	X	X	X	X	X	0.60	0.88	0.61	0.61	0.57	-0.63	-0.67	-0.34	-0.54	-0.66	-0.44	-0.47	-0.44	-0.41	X	0.76	0.89		0.83	0.99
MQ8-4	-0.47	X	0.72	0.67	0.69	0.72	0.41	0.38	X	X	X	X	0.28	0.29	0.56	0.72	0.58	0.57	0.53	-0.76	-0.78	-0.51	-0.72	-0.78	-0.81	-0.84	-0.81	-0.77	X	0.99	0.99	0.83		0.88
MQ8-5	-0.47	X	0.87	0.85	0.87	0.87	X	X	X	X	X	X	X	X	0.63	0.87	0.64	0.63	0.60	-0.68	-0.72	-0.39	-0.59	-0.71	-0.52	-0.54	-0.53	-0.48	X	0.82	0.94	0.99	0.88	

First Digit of the Sample ID	Description
1	Essential oil of Cistus ladanifer
2	Adulterated essential oil of Cistus ladanifer
3	Essential oil of Pinus pinaster
4	Empty chamber after Cistus ladanifer measurement
5	Empty chamber after Pinus pinaster measurement

Current Sample	Assigned Sample				
	1	2	3	4	5
1	100%	0%	0%	0%	0%
2	0%	100%	0%	0%	0%
3	0%	0%	100%	0%	0%
4	0%	0%	0%	100%	0%
5	0%	0%	0%	0%	100%

Detection of soil composition

Diaz, F.J.; Ahmad, A.; Parra, L.; Sendra, S.; Lloret, J. Low-Cost Optical Sensors for Soil Composition Monitoring. Sensors 2024, 24, 1140. https://doi.org/10.3390/s24041140



A

Salt		Predicted			
		0	0.83	1.667	5
Real	0	100	0	0	0
	0.83	0	66.67	33.33	0
	1.667	0	0	100	0
	5	0	0	0	100

B

Salt		Predicted			
		0	0.83	1.667	5
Real	0	100	0	0	0
	0.83	0	100	0	0
	1.667	0	0	100	0
	5	0	0	0	100

C

Sand		Predicted				
		0	25	50	75	100
Real	0	100	0	0	0	0
	25	66.67	33.33	0	0	0
	50	0	0	100	0	0
	75	0	0	33.33	66.67	0
	100	0	0	0	0	100

D

Sand		Predicted				
		0	25	50	75	100
Real	0	100	0	0	0	0
	25	0	100	0	0	0
	50	0	0	100	0	0
	75	0	0	0	100	0
	100	0	0	0	0	100

E

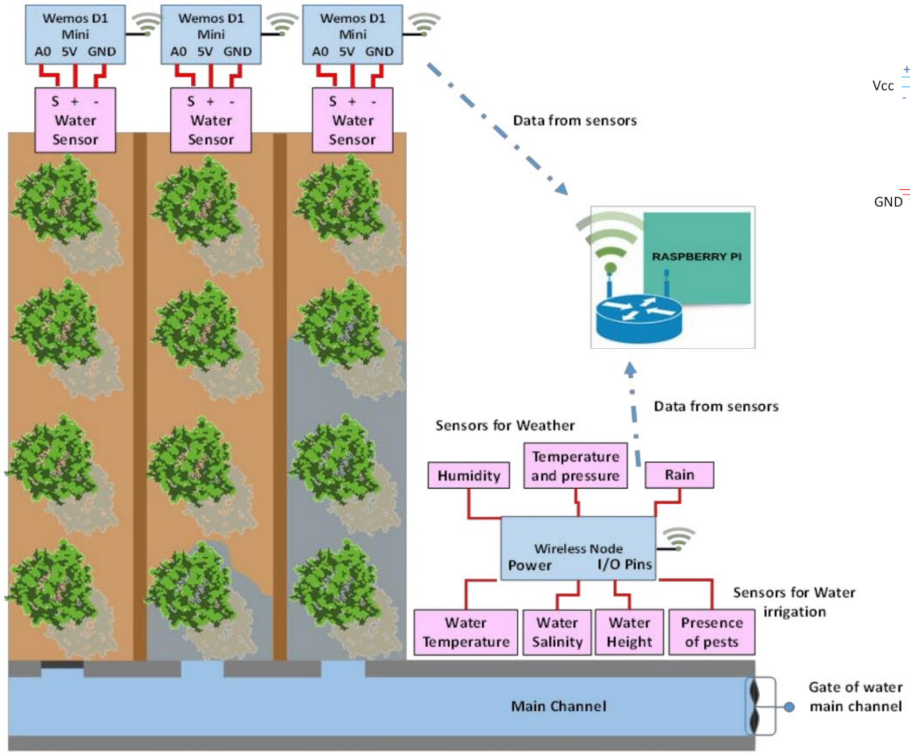
Nitro phosphate		Predicted			
		0	0.833	1.667	5
Real	0	100	0	0	0
	0.833	0	66.67	0	33.33
	1.667	0	0	100	0
	5	0	33.33	0	66.67

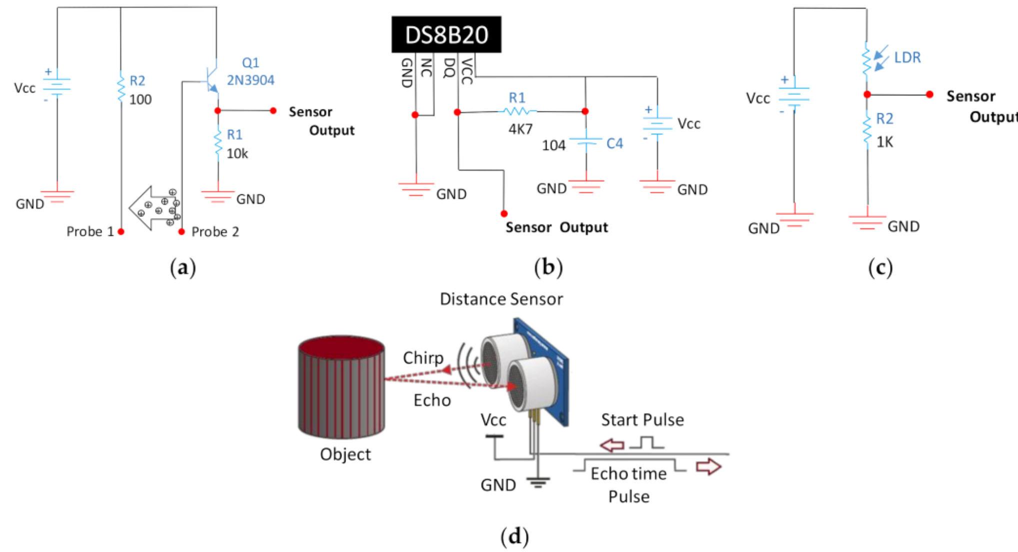
F

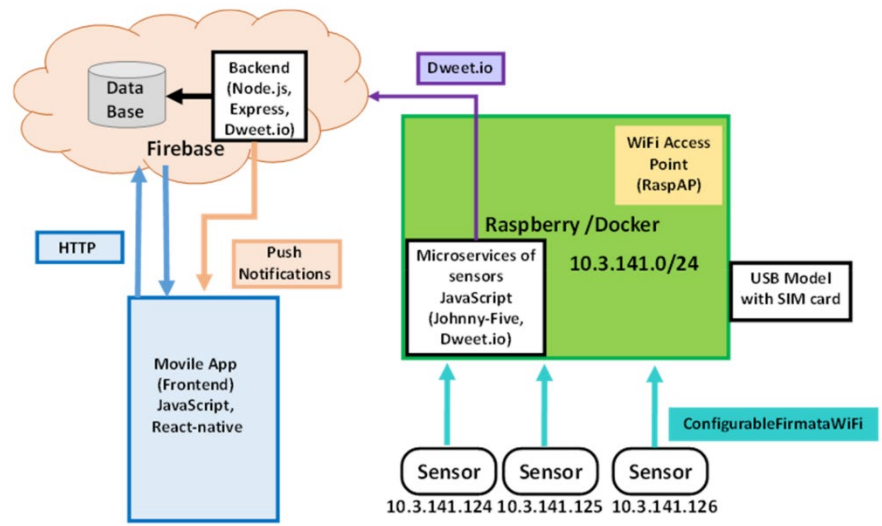
Nitro phosphate		Predicted			
		0	0.833	1.667	5
Real	0	100	0	0	0
	0.833	0	100	0	0
	1.667	0	0	100	0
	5	0	0	0	100

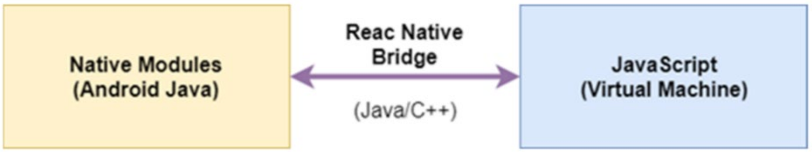
System for controlling irrigation processes

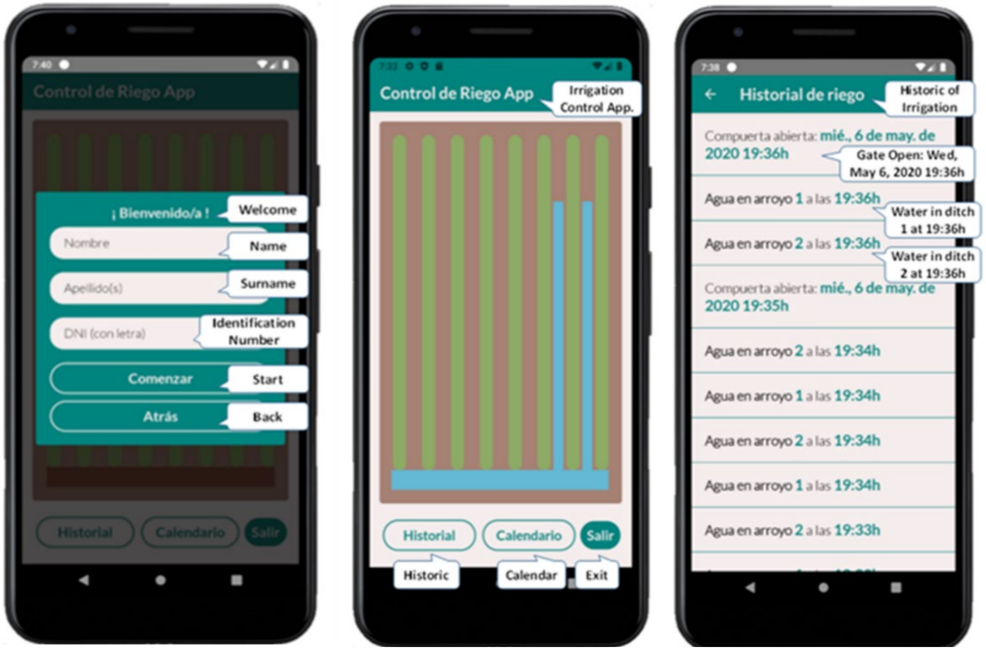
Lloret, J.; Sendra, S.; García-Fernández, J.; García, L.; Jimenez, J.M. A WiFi-Based Sensor Network for Flood Irrigation Control in Agriculture. *Electronics* **2021**, *10*, 2454. https://doi.org/10.3390/electronics10202454

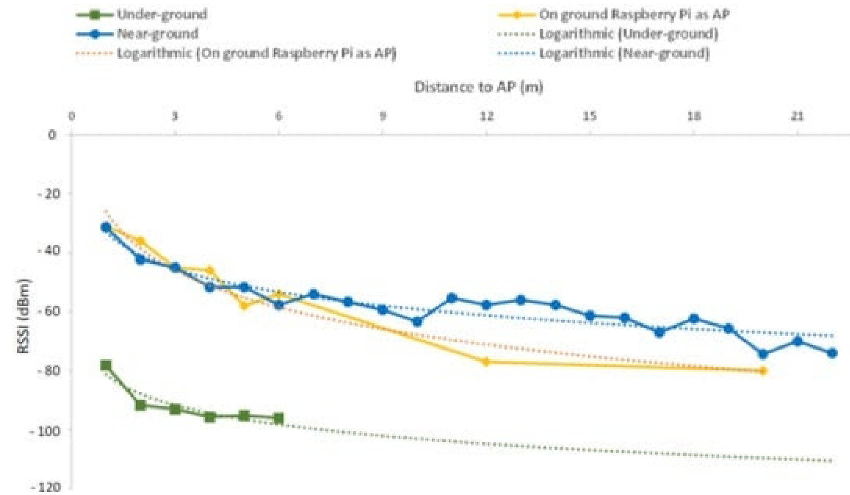

Wemos D1 Mini
A0 5V GND
S + -
Water Sensor
Data from sensors
RASPBERRY PI
Data from sensors
Sensors for Weather
Humidity
Temperature and pressure
Rain
Wireless Node
Power
I/O Pins
Sensors for Water irrigation
Water Temperature
Water Salinity
Water Height
Presence of pests
Main Channel
Gate of water main channel

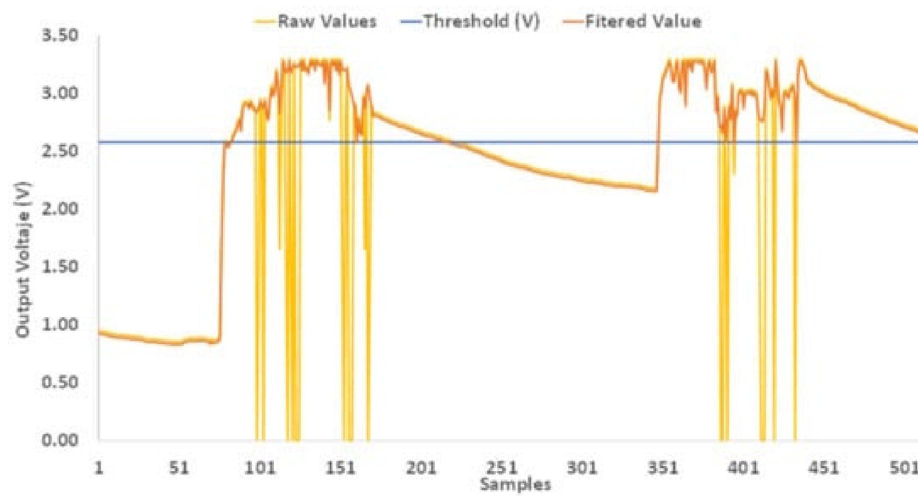

Vcc
R2
100
Q1
2N3904
Sensor Output
R1
10k
GND
GND
Probe 1
Probe 2
(a)
DS8B20
GND NC DQ VCC
R1
4K7
104
C4
Vcc
GND
GND
GND
Sensor Output
(b)
Vcc
LDR
Sensor Output
R2
1K
GND
GND
(c)
Distance Sensor
Chirp
Echo
Object
Vcc
Start Pulse
GND
Echo time Pulse
(d)

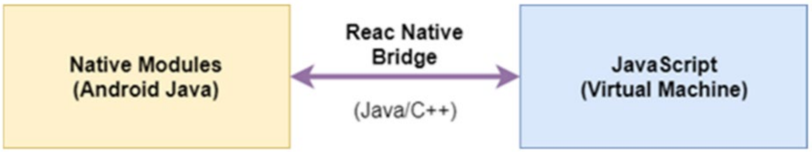

Data Base
Backend (Node.js, Express, Dweet.io)
Firebase
Dweet.io
WiFi Access Point (RaspAP)
Raspberry /Docker
10.3.141.0/24
Microservices of sensors JavaScript (Johnny-Five, Dweet.io)
USB Model with SIM card
HTTP
Push Notifications
Movile App (Frontend) JavaScript, React-native
ConfigurableFirmataWiFi
Sensor
Sensor
Sensor
10.3.141.124
10.3.141.125
10.3.141.126

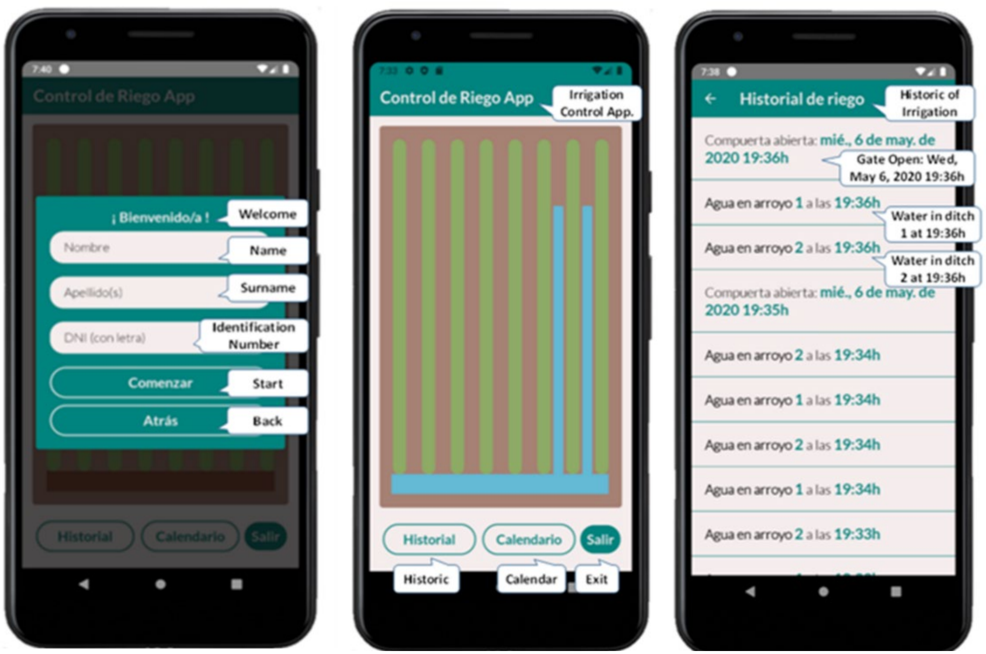

Native Modules
(Android Java)
Reac Native
Bridge
(Java/C++)
JavaScript
(Virtual Machine)

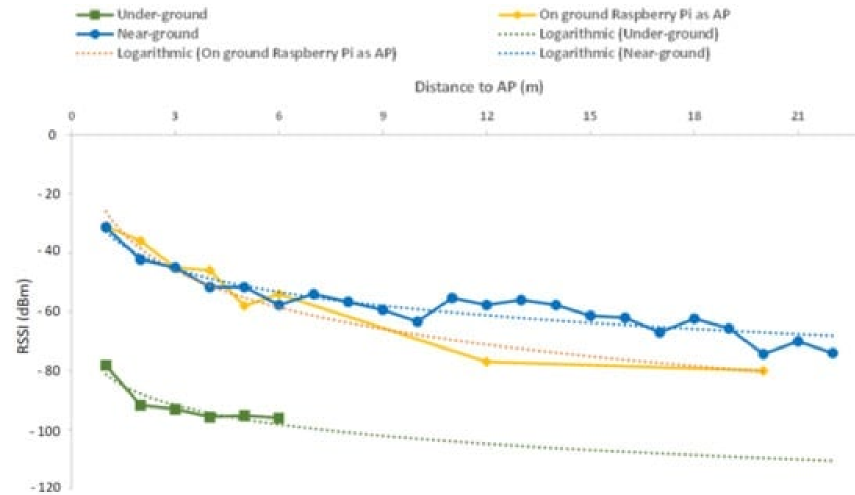

Control de Riego App
¡ Bienvenido/a !
Welcome
Nombre
Name
Apellido(s)
Surname
DNI (con letra)
Identification Number
Comenzar
Start
Atrás
Back
Historial
Calendario
Salir
Control de Riego App
Irrigation Control App.
Historial
Calendario
Salir
Historic
Calendar
Exit
Historial de riego
Historic of Irrigation
Compuerta abierta: mié., 6 de may. de 2020 19:36h
Gate Open: Wed, May 6, 2020 19:36h
Agua en arroyo 1 a las 19:36h
Water in ditch 1 at 19:36h
Agua en arroyo 2 a las 19:36h
Water in ditch 2 at 19:36h
Compuerta abierta: mié., 6 de may. de 2020 19:35h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:33h

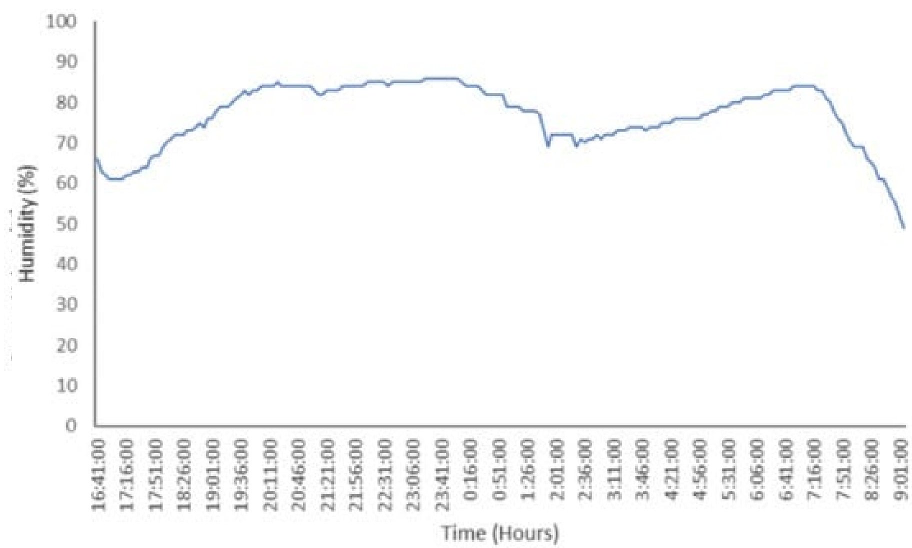

Under-ground
Near-ground
Logarithmic (On ground Raspberry Pi as AP)
On ground Raspberry Pi as AP
Logarithmic (Under-ground)
Logarithmic (Near-ground)
Distance to AP (m)
0
3
6
9
12
15
18
21
RSSI (dBm)
0
-20
-40
-60
-80
-100
-120

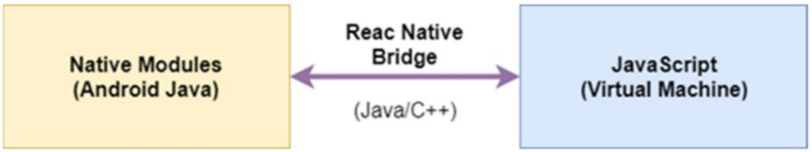

Raw Values
Threshold (V)
Fitered Value
Output Voltaje (V)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1
51
101
151
201
251
301
351
401
451
501
Samples

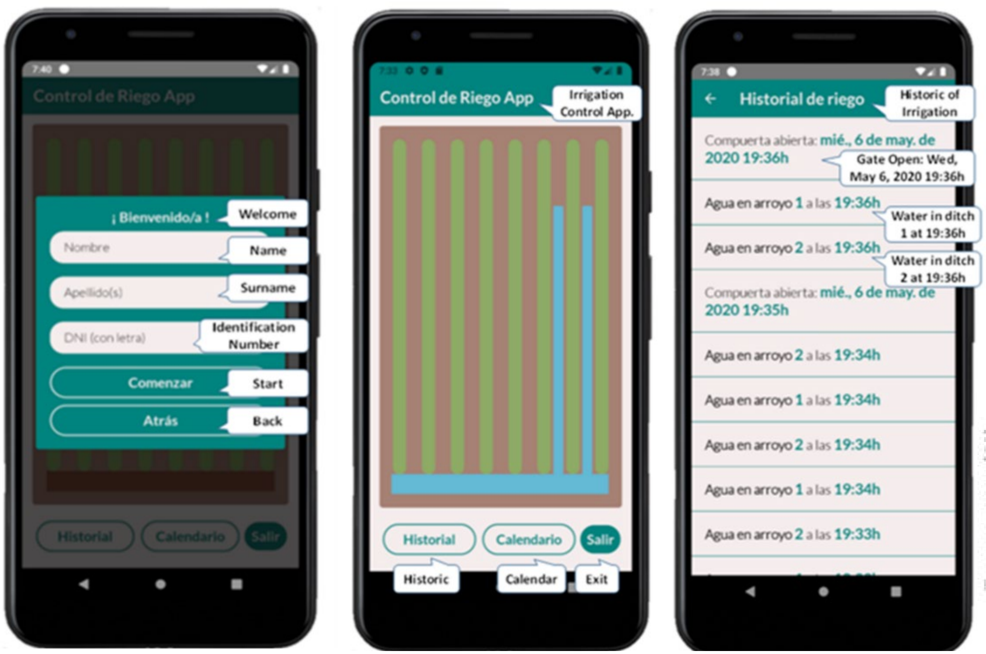

Native Modules (Android Java)
Reac Native Bridge
(Java/C++)
JavaScript (Virtual Machine)

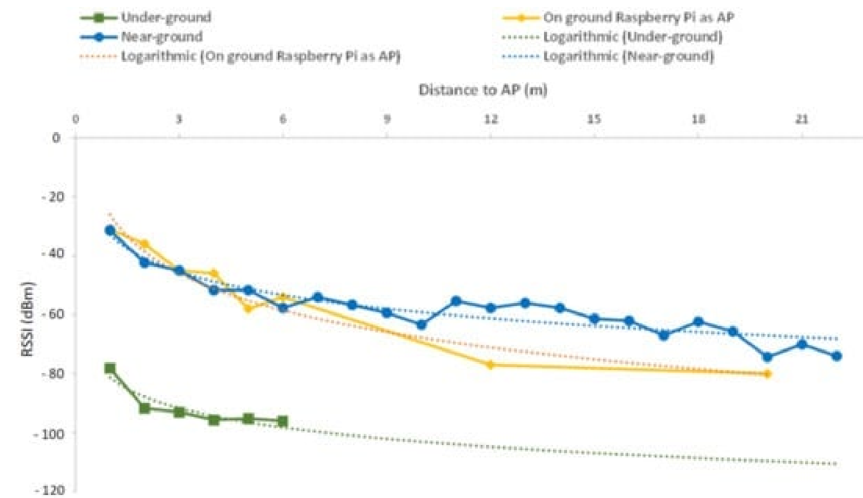

Control de Riego App
¡ Bienvenido/a !
Welcome
Nombre
Name
Apellido(s)
Surname
DNI (con letra)
Identification Number
Comenzar
Start
Atrás
Back
Historial
Calendario
Salir
Control de Riego App
Irrigation Control App.
Historial
Calendario
Salir
Historic
Calendar
Exit
Historial de riego
Historic of Irrigation
Compuerta abierta: mié., 6 de may. de 2020 19:36h
Gate Open: Wed, May 6, 2020 19:36h
Agua en arroyo 1 a las 19:36h
Water in ditch 1 at 19:36h
Agua en arroyo 2 a las 19:36h
Water in ditch 2 at 19:36h
Compuerta abierta: mié., 6 de may. de 2020 19:35h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:33h

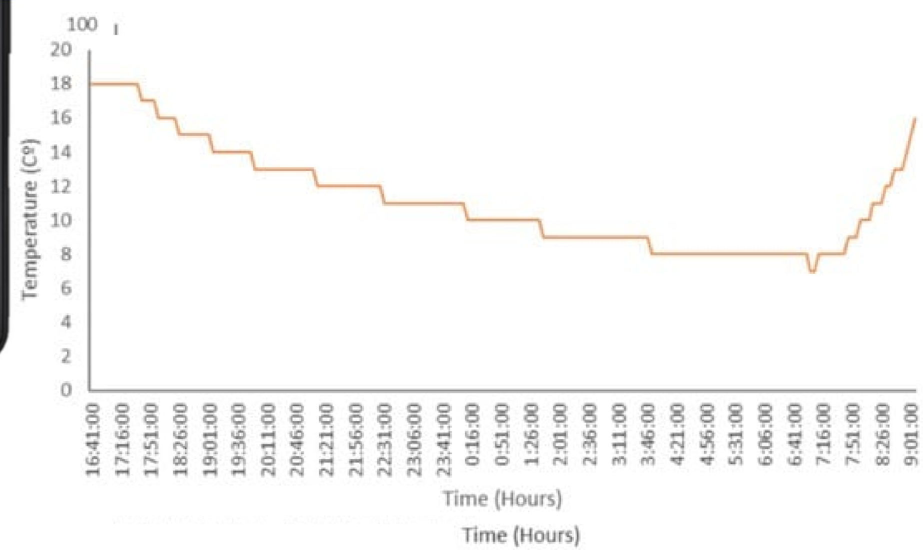

Under-ground
Near-ground
Logarithmic (On ground Raspberry Pi as AP)
On ground Raspberry Pi as AP
Logarithmic (Under-ground)
Logarithmic (Near-ground)
Distance to AP (m)
0
3
6
9
12
15
18
21
RSSI (dBm)
0
-20
-40
-60
-80
-100
-120


Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
16:41:00
17:16:00
17:51:00
18:26:00
19:01:00
19:36:00
20:11:00
20:46:00
21:21:00
21:56:00
22:31:00
23:06:00
23:41:00
0:16:00
0:51:00
1:26:00
2:01:00
2:36:00
3:11:00
3:46:00
4:21:00
4:56:00
5:31:00
6:06:00
6:41:00
7:16:00
7:51:00
8:26:00
9:01:00
Time (Hours)


Native Modules (Android Java)
Reac Native Bridge
(Java/C++)
JavaScript (Virtual Machine)

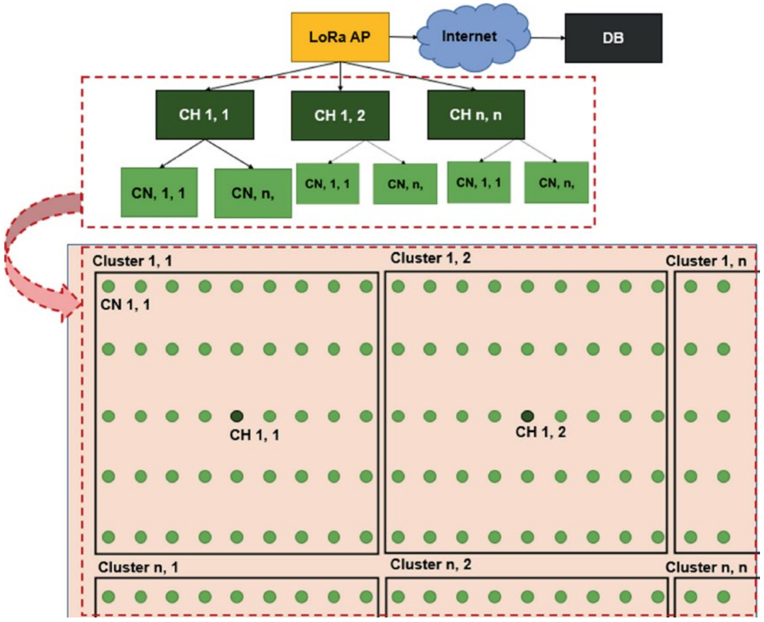

Control de Riego App
¡ Bienvenido/a !
Welcome
Nombre
Name
Apellido(s)
Surname
DNI (con letra)
Identification Number
Comenzar
Start
Atrás
Back
Historial
Calendario
Salir
Control de Riego App
Irrigation Control App.
Historial
Calendario
Salir
Historic
Calendar
Exit
Historial de riego
Historic of Irrigation
Compuerta abierta: mié., 6 de may. de 2020 19:36h
Gate Open: Wed, May 6, 2020 19:36h
Agua en arroyo 1 a las 19:36h
Water in ditch 1 at 19:36h
Agua en arroyo 2 a las 19:36h
Water in ditch 2 at 19:36h
Compuerta abierta: mié., 6 de may. de 2020 19:35h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:34h
Agua en arroyo 1 a las 19:34h
Agua en arroyo 2 a las 19:33h

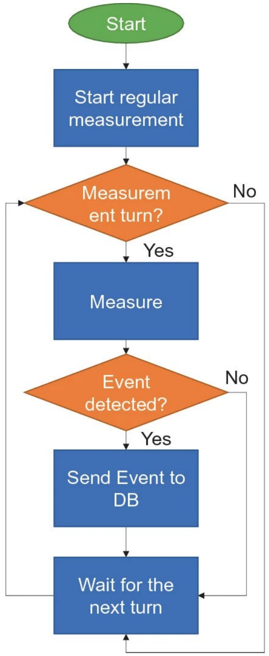

Under-ground
Near-ground
Logarithmic (On ground Raspberry Pi as AP)
On ground Raspberry Pi as AP
Logarithmic (Under-ground)
Logarithmic (Near-ground)
Distance to AP (m)
0
3
6
9
12
15
18
21
RSSI (dBm)
0
-20
-40
-60
-80
-100
-120

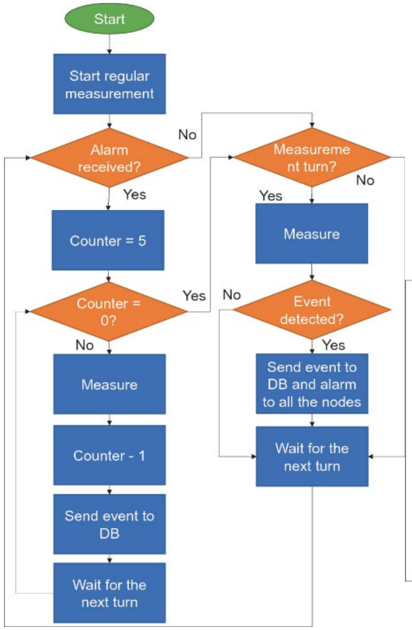

100
20
18
16
14
12
10
8
6
4
2
0
Temperature (Cº)
16:41:00
17:16:00
17:51:00
18:26:00
19:01:00
19:36:00
20:11:00
20:46:00
21:21:00
21:56:00
22:31:00
23:06:00
23:41:00
0:16:00
0:51:00
1:26:00
2:01:00
2:36:00
3:11:00
3:46:00
4:21:00
4:56:00
5:31:00
6:06:00
6:41:00
7:16:00
7:51:00
8:26:00
9:01:00
Time (Hours)
Time (Hours)

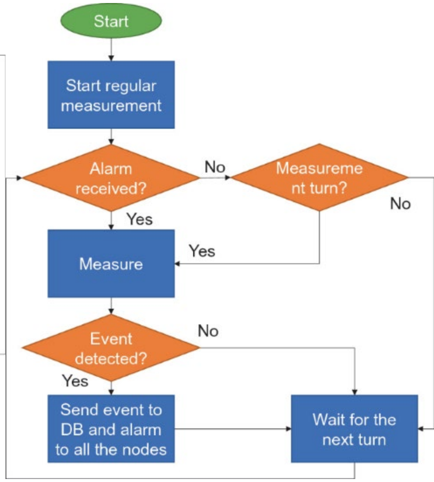
Improvements in the network deployments

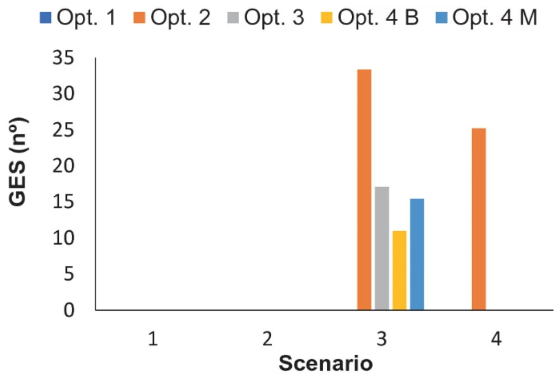
Viciano-Tudela, S., Navarro-Garcia, P., Parra, L., Sendra, S., Lloret, J. (2023). Proposal and Evaluation of Collaborative Event-Triggered Algorithms in Ultra-Dense Wireless Sensor Network. In: Luo, Y. (eds) Cooperative Design, Visualization, and Engineering. CDVE 2023. Lecture Notes in Computer Science, vol 14166. Springer, Cham. https://doi.org/10.1007/978-3-031-43815-8_1

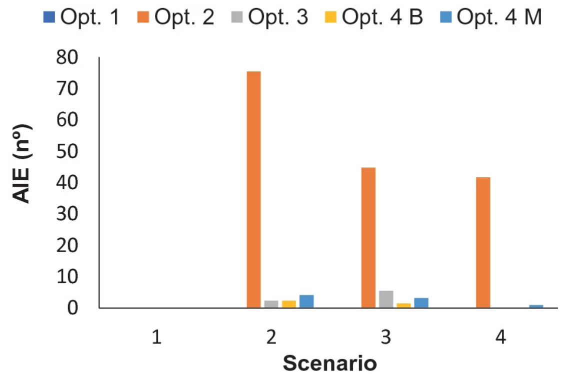

LoRa AP
Internet
DB
CH 1, 1
CH 1, 2
CH n, n
CN, 1, 1
CN, n,
CN, 1, 1
CN, n,
CN, 1, 1
CN, n,
Cluster 1, 1
Cluster 1, 2
Cluster 1, n
CN 1, 1
CH 1, 1
CH 1, 2
Cluster n, 1
Cluster n, 2
Cluster n, n

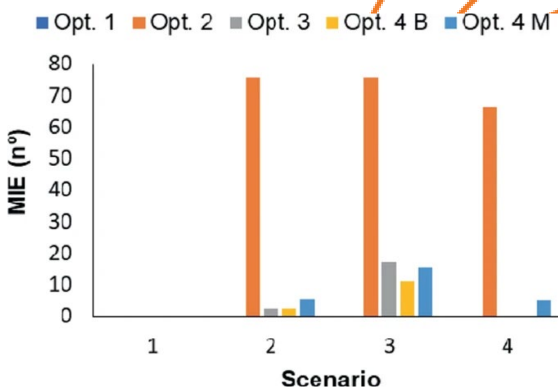

Start
Start regular measurement
Measurement turn?
No
Yes
Measure
Event detected?
No
Yes
Send Event to DB
Wait for the next turn


Start
Start regular measurement
Alarm received?
No
Yes
Counter = 5
Counter = 0?
Yes
No
Measure
Counter - 1
Send event to DB
Wait for the next turn
Measurement turn?
No
Yes
Measure
Event detected?
No
Yes
Send event to DB and alarm to all the nodes
Wait for the next turn


Start
Start regular measurement
Alarm received?
No
Yes
Measurement turn?
No
Yes
Measure
Event detected?
No
Yes
Send event to DB and alarm to all the nodes
Wait for the next turn


Opt. 1
Opt. 2
Opt. 3
Opt. 4 B
Opt. 4 M
GES (nº)
35
30
25
20
15
10
5
0
1
2
3
4
Scenario

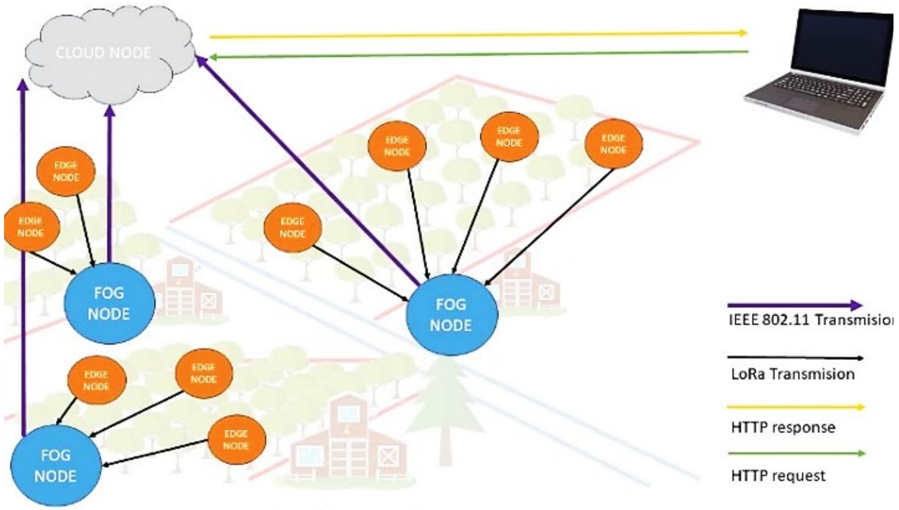

Opt. 1
Opt. 2
Opt. 3
Opt. 4 B
Opt. 4 M
AIE (nº)
80
70
60
50
40
30
20
10
0
1
2
3
4
Scenario

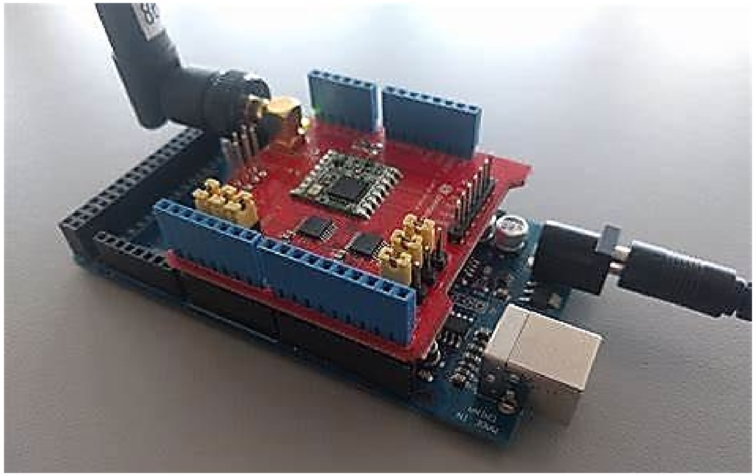

Opt. 1
Opt. 2
Opt. 3
Opt. 4 B
Opt. 4 M
MIE (nº)
80
70
60
50
40
30
20
10
0
1
2
3
4
Scenario

Use of AI for determining the optimal momento of harvest

Diaz Blasco F.J., Viciano-Tudela S., Parra L., Ahmad A., Chaloupková V., Bados R., Esteban Pascual L. S., Mediavilla I., Sendra S., Lloret J., Employment of MQ gas sensors for the classification of Cistus ladanifer essential oils, Microchemical Journal, 2024, Vol. 206, pp.111585. https://doi.org/10.1016/j.microc.2024.111585.

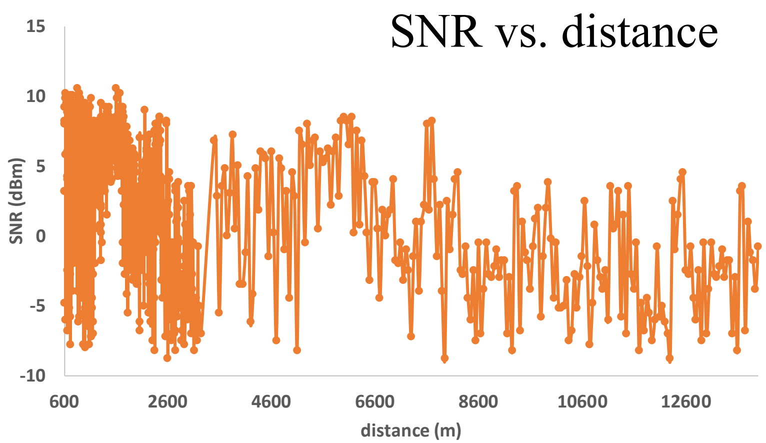
Ahmad A., Diaz-Blasco F.J., Zaragoza-Esquerdo M., Sendra S., Parra L., Viciano-Tudela S., Lloret J., Chaloupková V., Bados R., Esteban Pascual L. S., Mediavilla I., LoRaWAN-based Network for Harvest Time Estimation in *Cistus Ladanifer*, The 11th International Conference on Internet of Things: Systems, Management and Security (IOTSMS 2024). Malmö, Sweden. September 2-5, 2024

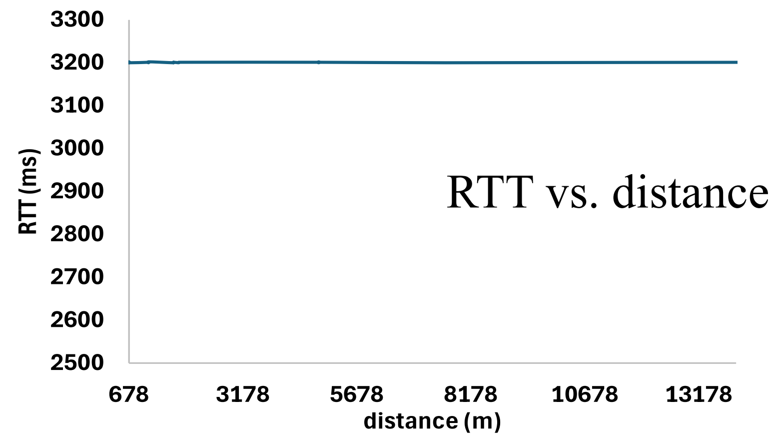


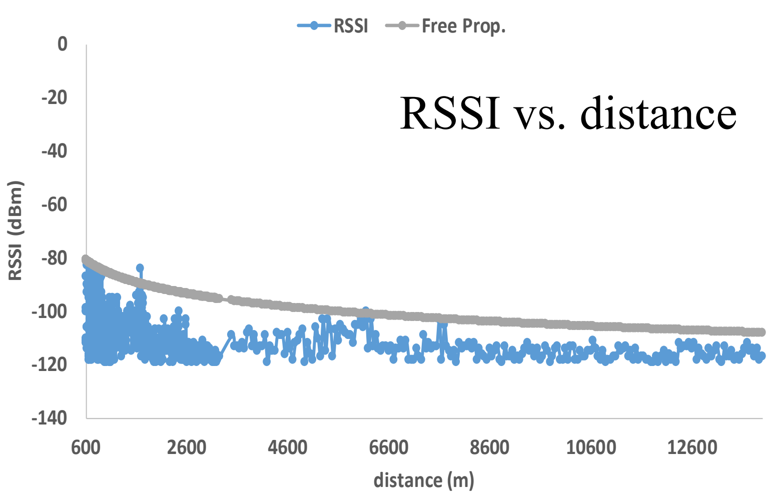


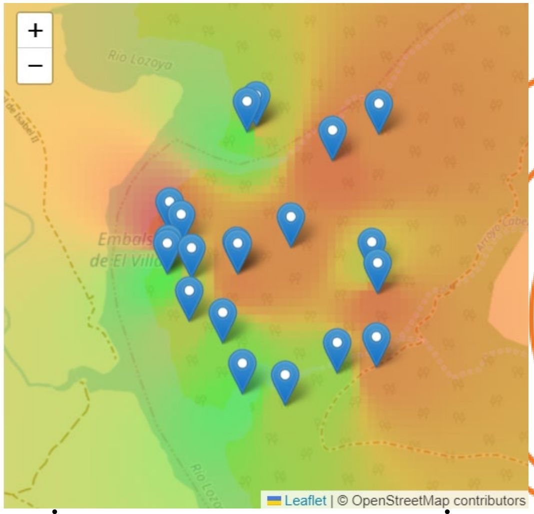
ID	Model Type	Accuracy % (Test)	Prediction Speed (obs/sec)	Selected Features
1	Naive Bayes	62.5	8077.46	13/38
2	Naive Bayes	62.5	9400.81	12/38
3	Naive Bayes	62.5	8918.45	11/38
4	Naive Bayes	61.875	1555.54	10/38
5	Ensemble	61.875	1418.03	11/38
6	Ensemble	61.5625	1414.19	13/38
7	Ensemble	61.25	1681.46	12/38
8	Ensemble	60.9375	1622.84	14/38
9	Discriminant	60.9375	30513.23	10/38
10	Ensemble	60.9375	1486.86	10/38

Data transmission over LPWAN -- LoRaWAN









Alpha-pinene gas concentration map

Image processing for determining the leaves status

Sandra Sendra, Alberto Ivars-Palomares, Miguel Zaragoza-Esquerdo, Jaime Lloret, Edge-based IoT Image Processing System for Detecting Changes in Leaves, Global (IEEE) Congress on Emerging Technologies (GCET-2024), Gran Canaria, Spain. December 9-11, 2024

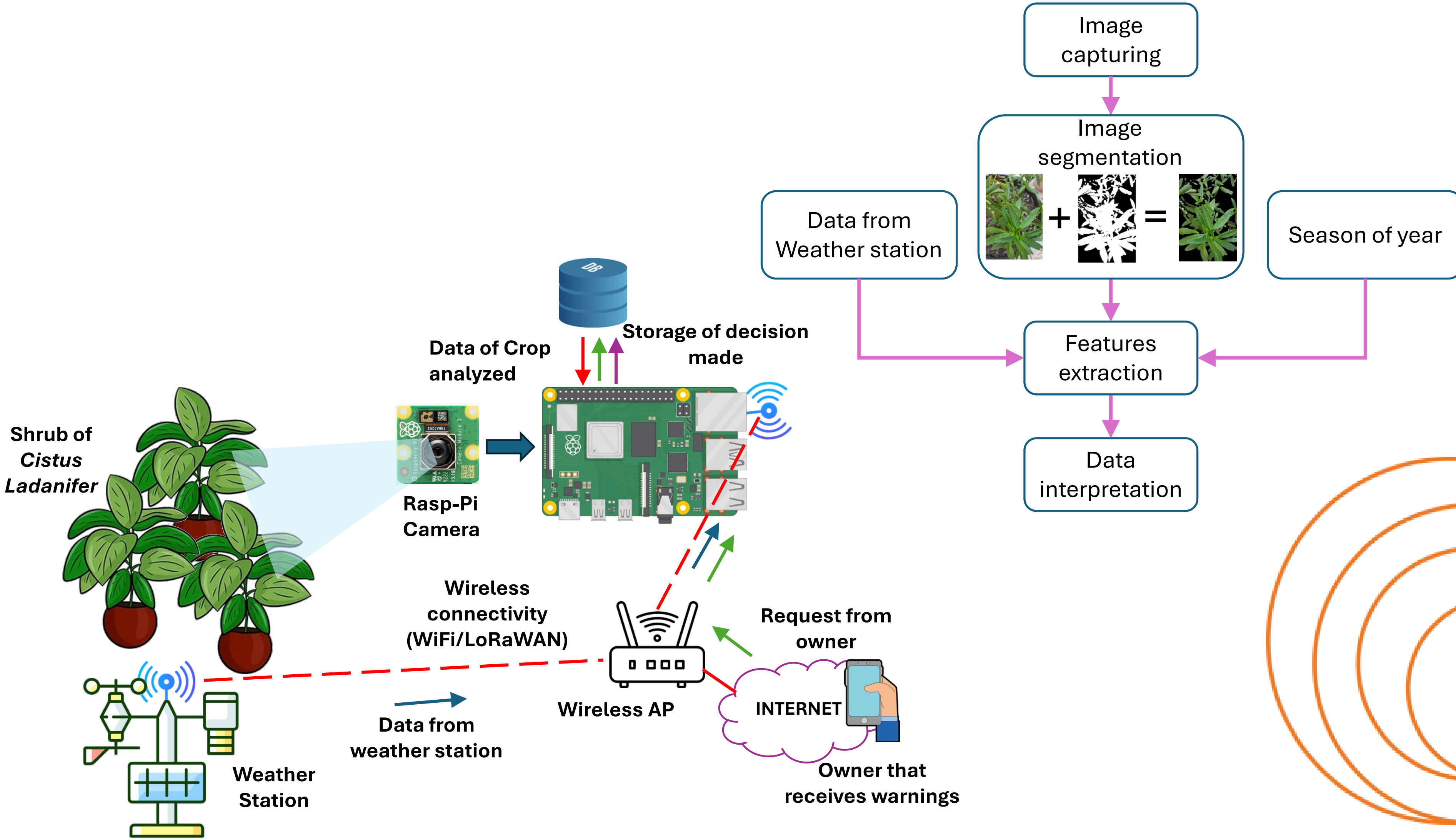


Image capturing
Image segmentation
+
=
Data from Weather station
Season of year
Features extraction
Data interpretation
Storage of decision made
Data of Crop analyzed
Shrub of *Cistus Ladanifer*
Rasp-Pi Camera
Wireless connectivity (WiFi/LoRaWAN)
Request from owner
Wireless AP
INTERNET
Data from weather station
Weather Station
Owner that receives warnings

Last tests with images

Average brightness: 51.38

Average brightness: 64.38

Average brightness: 33.35

Average brightness: 30.07

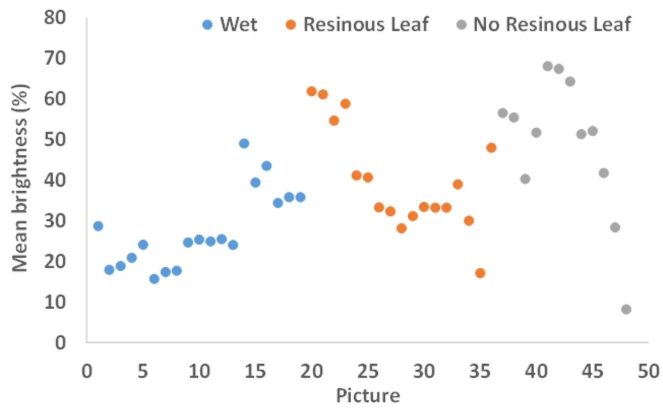


Fig. 4. Mean value of brightness of each picture.

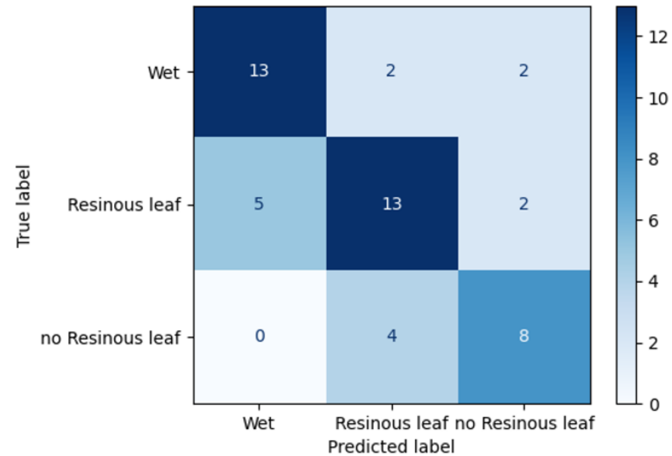


Fig. 5. Confusion matrix when only pictures are considered

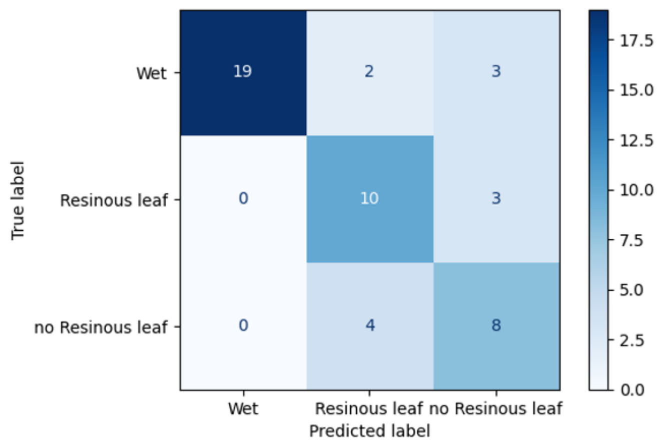


Fig. 6. Confusion matrix when pictures and weather station values are considered

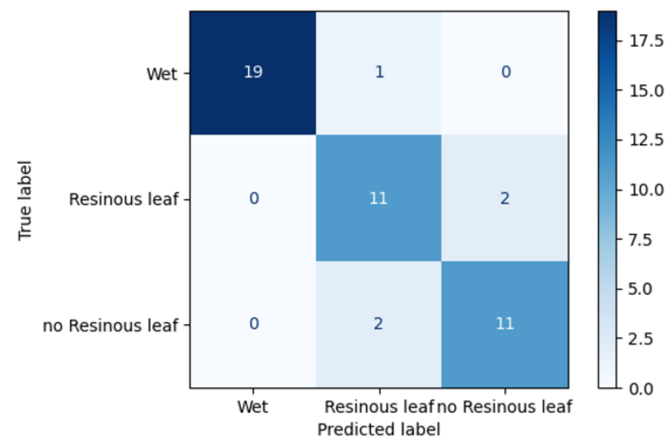
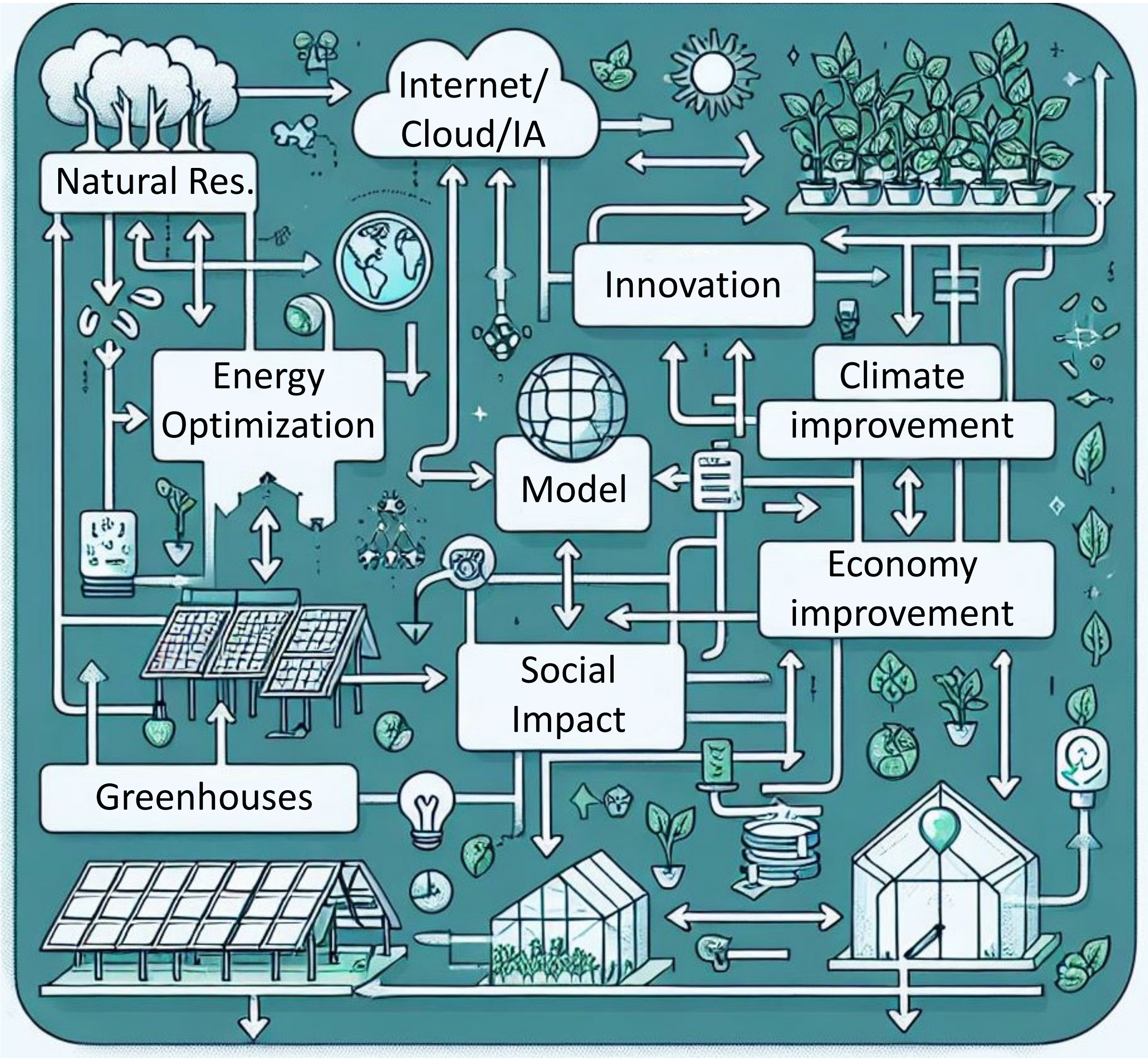


Fig. 7. Confusion matrix when pictures, weather station values and season of year are considered

5. Conclusion


Internet/
Cloud/IA
Natural Res.
Innovation
Energy
Optimization
Climate
improvement
Model
Economy
improvement
Social
Impact
Greenhouses

Strategies to Achieve Circular Agriculture

- **The foundation of circular agriculture** lies in making it sustainable and ecological. Consumers increasingly seek quality, while farmers aim to optimize production by increasing yield and reducing costs. The key is to create a closed-loop system encompassing all phases of production and services, conserving water and energy, protecting the environment, and meeting consumer needs. Additionally, converting waste into resources is essential.

Sustainable Development: From the outset of the plantation, farmers should implement strategies to:

- **Reduce product losses**.
- Ensure production is feasible, equitable, and both economically and socially sustainable.
- **Respect the environment**.
- Minimize expenses.

Promote Renewable Resources: Utilize the resources that nature provides:

- **Maximize solar energy usage**: Install solar panels to control humidity and temperature sensors.
- **Use water responsibly**: Optimize irrigation methods to suit each crop and encourage the use of rainwater.
- **Manage organic waste**: Recycle branches and weeds to naturally regenerate the land.
- **Create natural fertilizers**: Use compost and animal manure.
- **Promote electric vehicles** whenever possible.

Control climate change

A crucial aspect of circular farming is minimizing the impact on climate change:

- Reduce or recycle natural waste, which is abundant in intensive plantations, such as pruning branches, leaves, and unusable fruits, by turning them into natural fertilizers.
- Recycle plastics used in greenhouses and intensive plantations for covering furrows.
- Avoid salinity by controlling the accumulation of salts through controlled irrigation.
- Regenerate the soil atmosphere with tillage.
- Restore degraded or eroded soils.
- Rotate crops seasonally to prevent soil erosion.
- Use covers to prevent evaporation, which can be natural from the farm itself or plastic.
- It is essential to avoid pesticides.

All these practices are encompassed within a circular economy that affects all sectors and helps foster sustainability.

Acknowledgement

RED HETEROGENEA INTELIGENTE DE SENSORES INALAMBRICOS PARA MONITORIZAR Y ESTIMAR EL CONTENIDO DE RESINA DE CISTUS LADANIFER

(PID2020-114467RR-C33)

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
AGENCIA ESTATAL DE INVESTIGACIÓN

EDGE COMPUTING INTELIGENTE EN REDES INALAMBRICAS HETEROGENEAS DE SENSORES PARA LA AGRICULTURA DE PRECISION Y LA DISEMINACION DE LA AGRICULTURA DIGITAL (SOLUCION)

(TED2021-131040B-C31)

GOBIERNO DE ESPAÑA
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Sandra Sendra (sansenco@upv.es)