“Artificial Vision and IoT for Automation of Remote Reading for Limnimeters in Hydraulic Weirs”

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Universidad de las Fuerzas Armadas ESPE

2022

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6th Computational Methods in Systems and Software 2022

"Artificial Vision and IoT for Automation of Remote Reading for Limnimeters in Hydraulic Weirs"

October 2022

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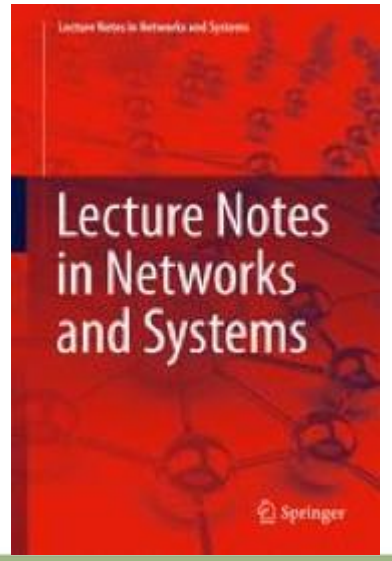
100 años

CONGOPE
Consorcio de Gobiernos Autónomos Provinciales del Ecuador

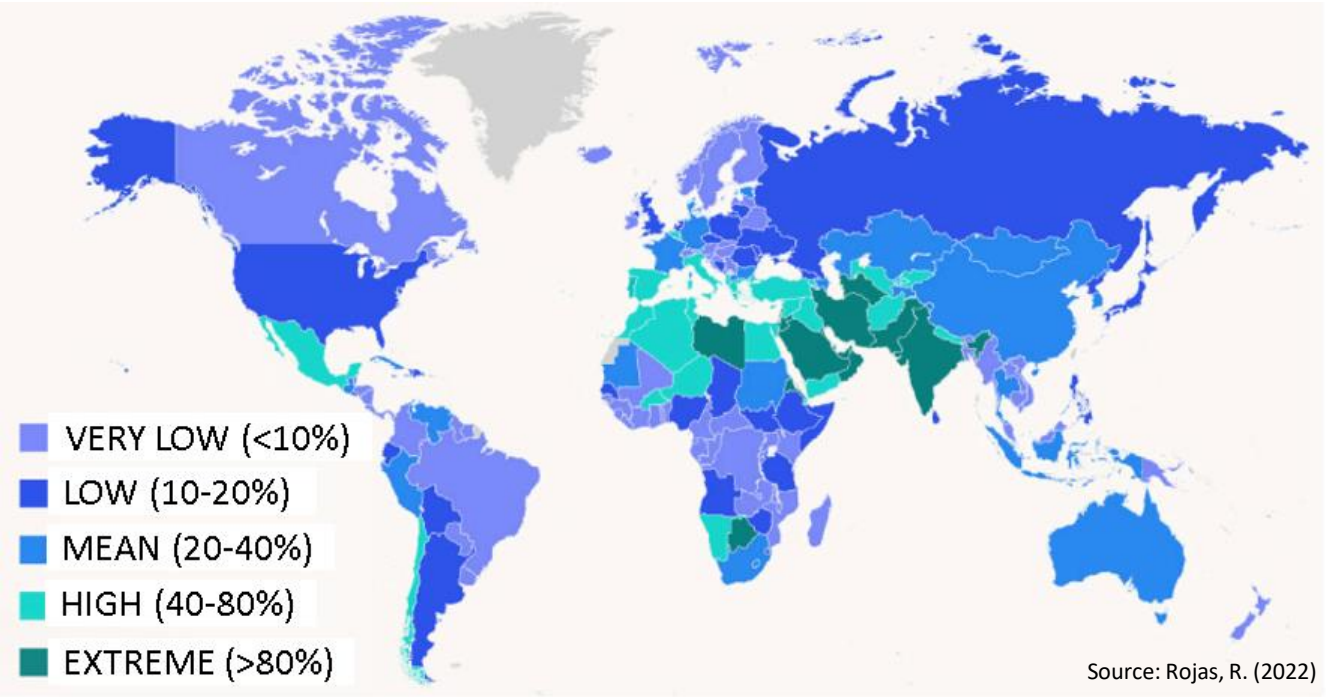


Springer

Faculty of Electrical Engineering

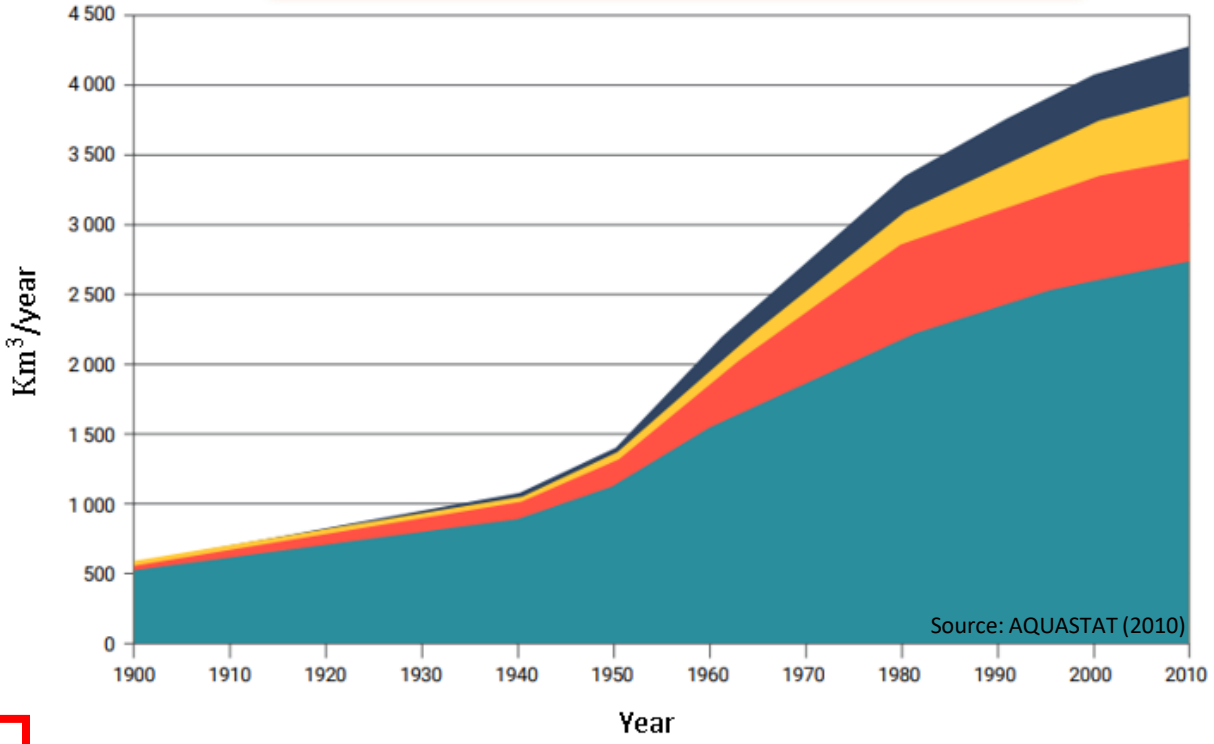
PROBLEM: Water Availability

Level of vulnerability to water stress in the world



Source: Rojas, R. (2022)

World Water Extractions, 1900-2010



unesco

OCDE

International Institute for Applied Systems Analysis

2030 Water Resources Group

"The world could face a 40% global water deficit by 2030"

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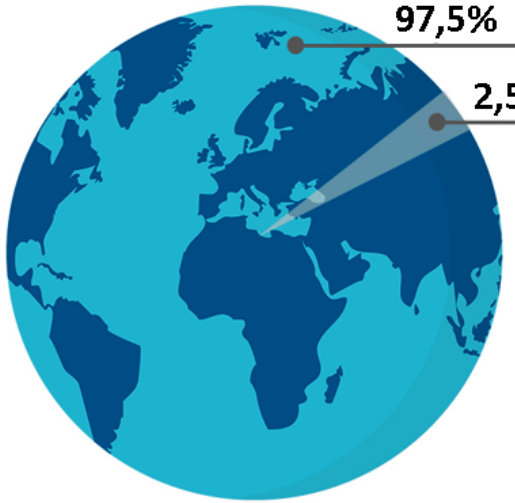
Water Distribution

Seas and oceans are only 0.023% of the total mass of the planet



97,5% SALTED WATER

2,5% SWEET WATER

69,7% GLACIERS

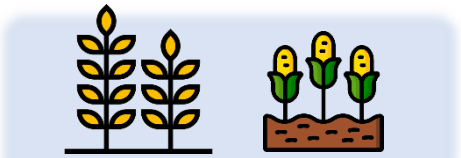
30% AQUIFERS

0,3% RIVERS AND STREAMS

Only 0.007% of the water is available for human consumption

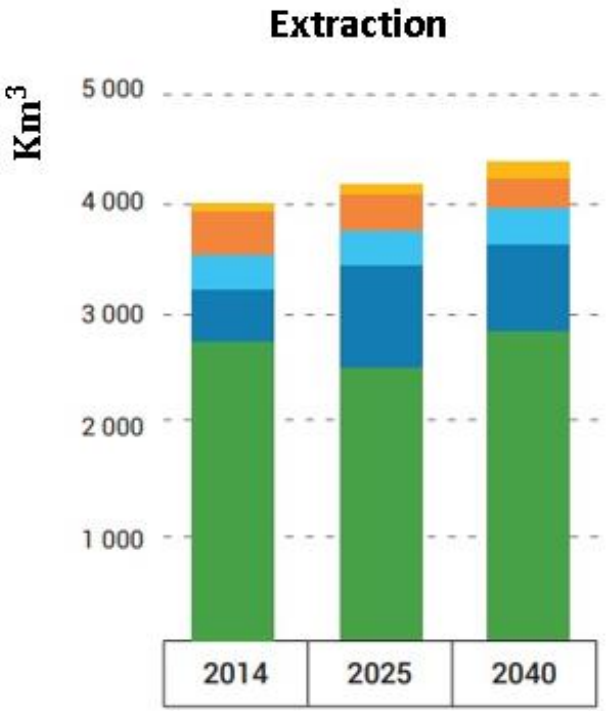
Source: FAO!ONU

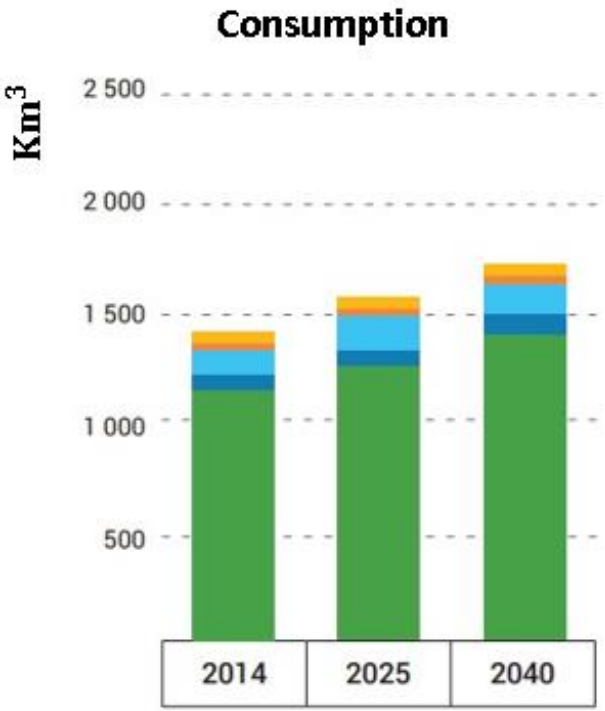
69%



19%

12%





"Water abstractions for irrigation are the leading cause of groundwater depletion around the world"

- Primary energy production
- Power generation
- Industry
- Municipality
- Agriculture

Source: ONU (2018)

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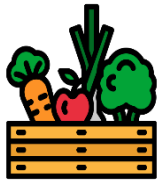
PROBLEM: Food Insecurity

60% - 2050

93 countries

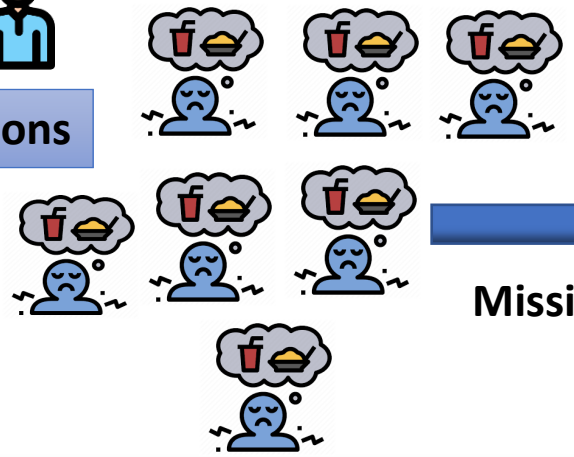


50%

"FAO recognizes that the amount of water withdrawn for agriculture can only be increased by 10%"

Source: FAO (2018)

800 Millions



Missing

- Availability
- Stability
- Supply

Food Insecurity

- Health degradation
- Increased risk of birth defects birth defects
- Acute malnutrition
- High mortality

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FAO's Sustainable Development Goals - 2030

En septiembre de 2015, 193 Estados Miembros de las Naciones Unidas aprobaron los 17 ODS, incluyendo el

HAMBRE CERO PARA 2030

EN EL AÑO 2030 SE PREVÉ QUE LA POBLACIÓN MUNDIAL AUMENTE HASTA ALCANZAR LOS

8 300 millones

LA DEMANDA DE ALIMENTOS CRECERÁ

Aumentar la inversión en agricultura. Crear infraestructuras de mercado y mejorar los bienes públicos para ayudar a incrementar la productividad y los ingresos rurales.

ODS 1 2 9 10

Gestionar de modo sostenible los bosques, océanos, agua, tierras y suelo, y promover un enfoque ecosistémico para obtener un mayor rendimiento agrícola con menos insumos.

ODS 2 6 13 14 15

EL AUMENTO DE LA DEMANDA DE ALIMENTOS

ESTÁ INTENSIFICANDO LA COMPETENCIA POR LOS RECURSOS NATURALES

HOY EN DÍA

MÁS DE 820 MILLONES DE PERSONAS PASAN HAMBRE

Establecer sistemas de protección social, tales como alimentación escolar y transferencias de efectivo. Sin alimentos, los seres humanos no pueden aprender ni llevar una vida sana y productiva.

ODS 1 2 3 4 8 10

Promover políticas de nutrición, incluida la educación sobre la alimentación, y pasar a enfoques del consumo y la producción que promuevan beneficios para la salud a largo plazo.

ODS 2 3

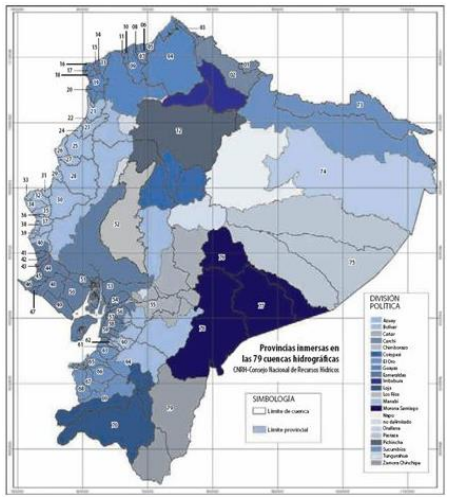
Source: http://www.fao.org/sustainable-development-goals/es/

PRINCIPIOS PARA LA INVERSIÓN RESPONSABLE EN LA AGRICULTURA Y LOS SISTEMAS ALIMENTARIOS

"FAO points out that, by 2030, developing countries will only be able to increase production by 33%, using only 12% more water, but with new and more efficient irrigation technologies that mean less waste and optimization of the resource"

Hydrographic Division of Ecuador

31 Hydrographic Systems



79 Hydrographic Basins

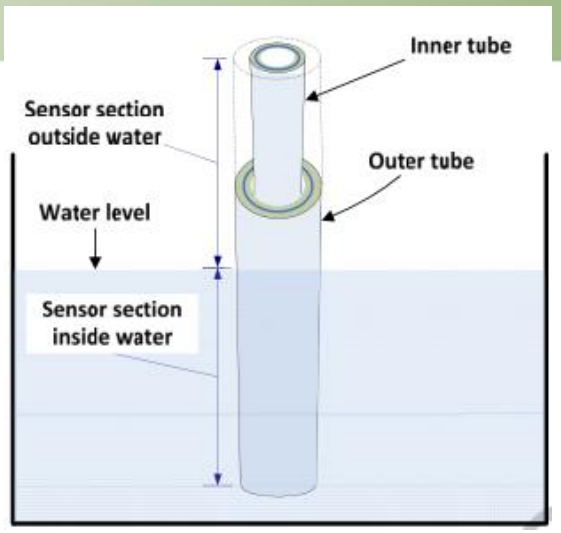
Gauging Stations

Hydraulic Weirs

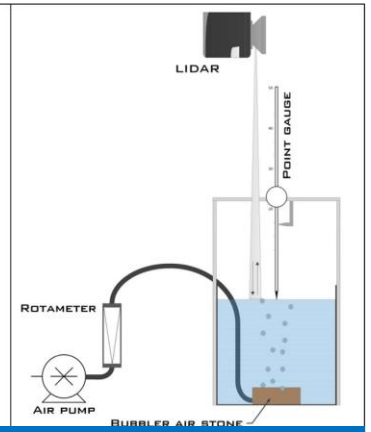
80%

Limnimeter

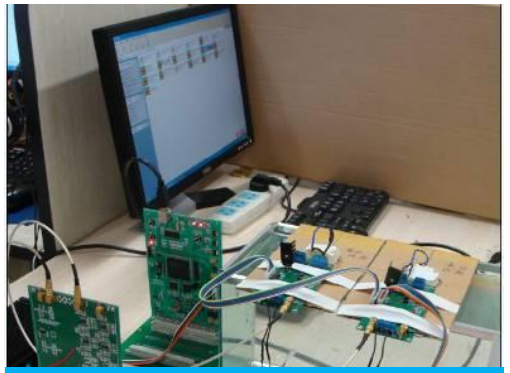
Flotation System



Capacitive System

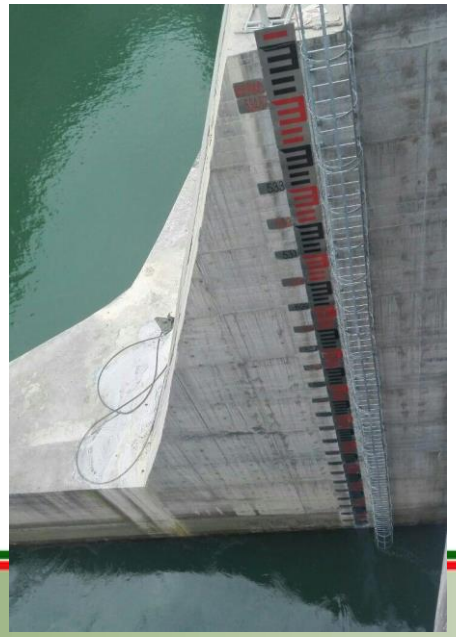


Laser Scanning

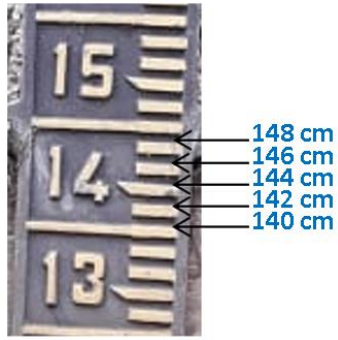


Electromagnetic Technique

Use of Limnimeters



Level Measurement



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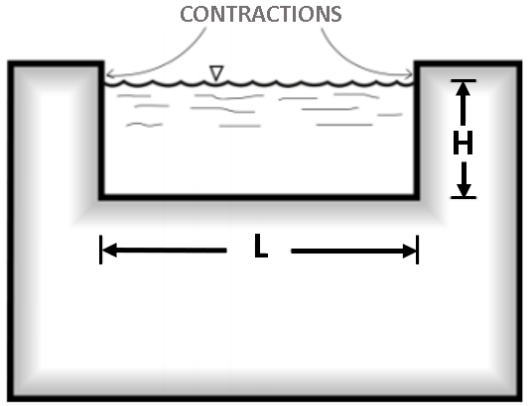
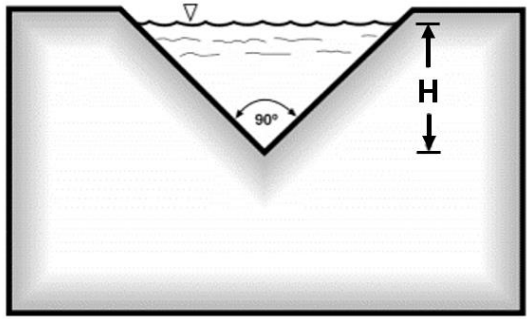
Weir and Orifice Methods

Rectangular weir with two contractions



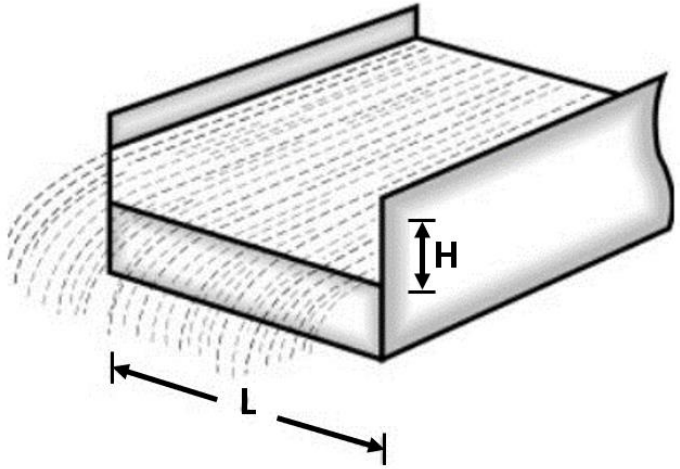
$$Q = 1.84\,(L - 0.2H) \times H^{3/2}$$

Triangular weir



$$Q = 1.4 \times H^{5/2}$$

Rectangular weir without contractions



$$Q = 1.84\,L \times H^{3/2}$$

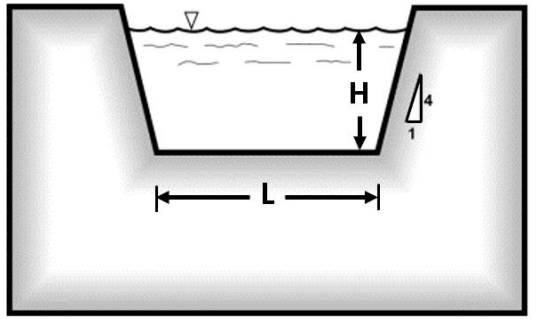
Q = Flow rate (m^3 / s)

L = Crest length (m)

H = Weir load (m)

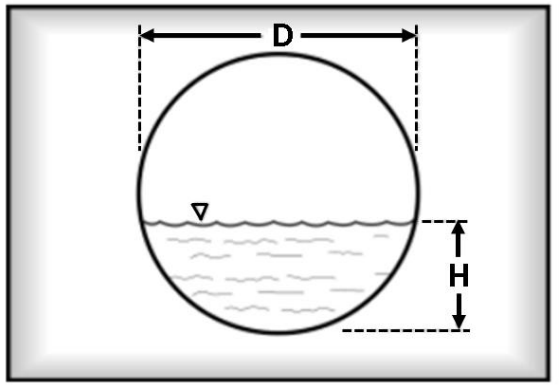
D = Diameter of circle (m)

Trapezoidal weir



$$Q = 1.859 \times L \times H^{3/2}$$

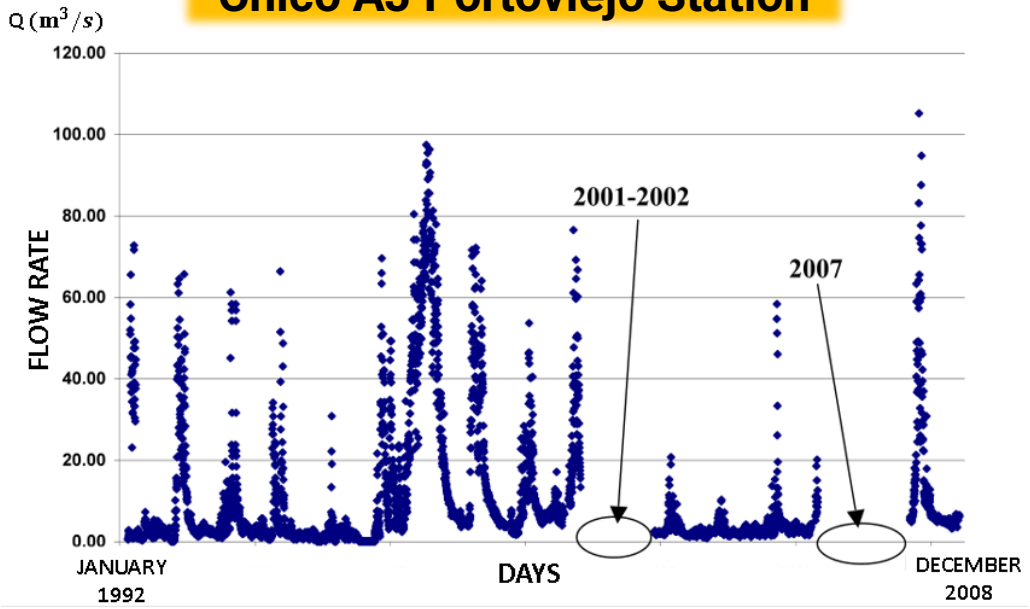
Circular weir



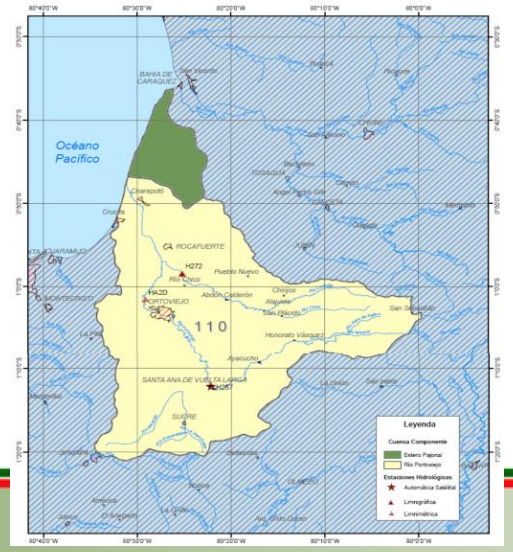
$$Q = 1.518 \times D^{0.693} \times H^{1.807}$$

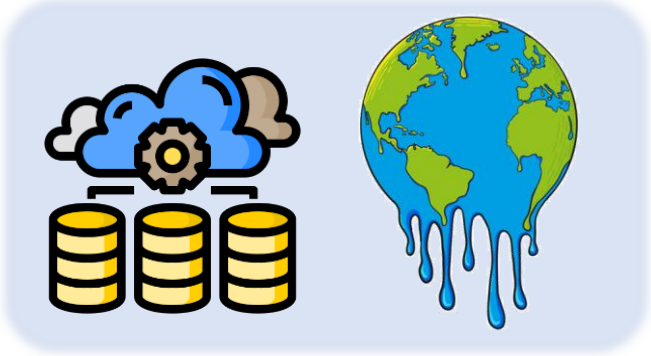
Availability of Hydrometric Data

Chico AJ Portoviejo Station

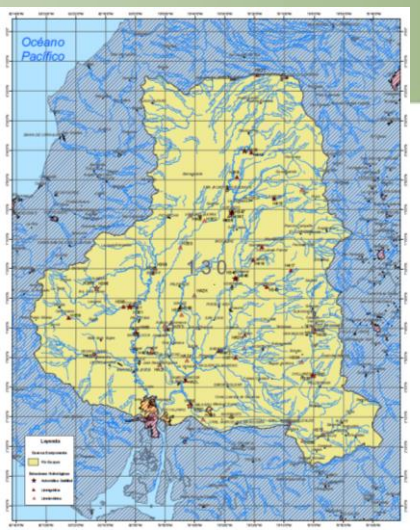


Source: Muñoz, Á.G., Macías, S., García, M.B. (2014)

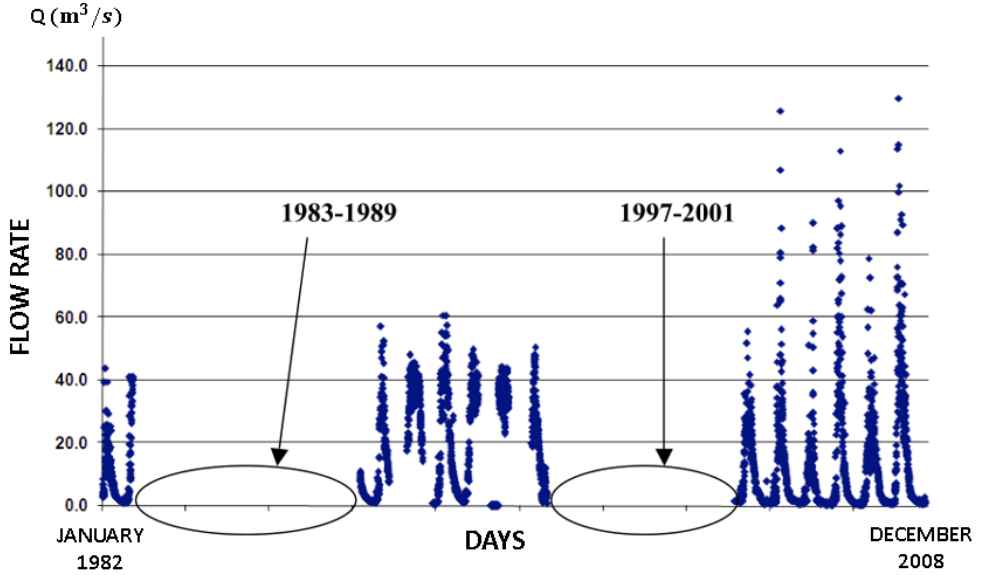




INAMHI



Embarcadero EN H.CLEM (Pot-Sta. Rosa) Station



Source: Muñoz, Á.G., Macías, S., García, M.B. (2014)

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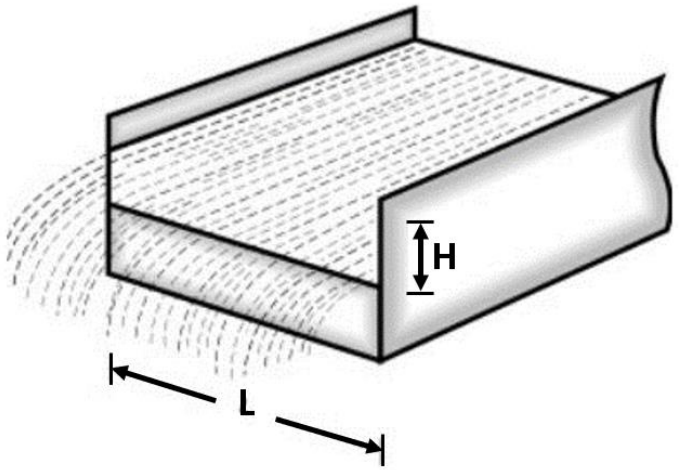
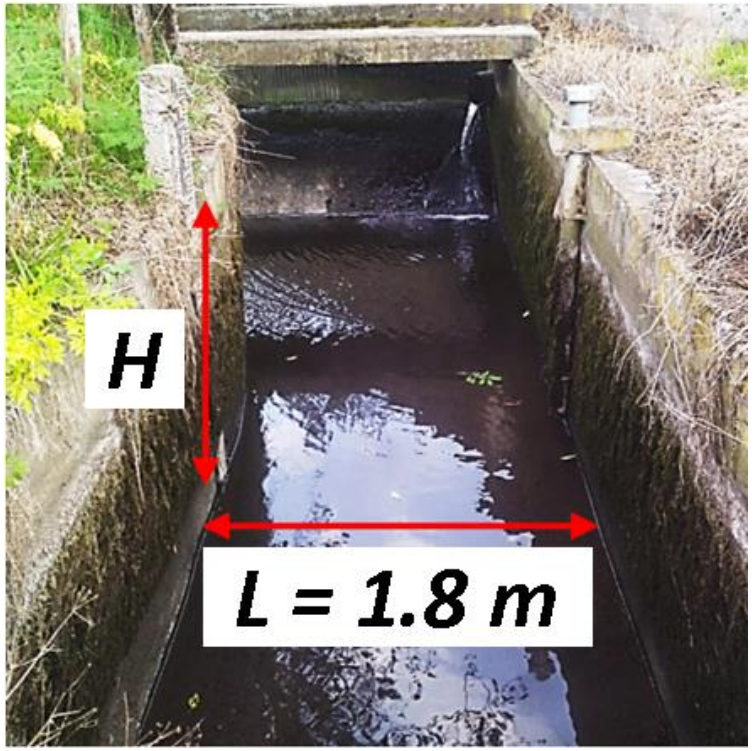
Experimental Weir

Rectangular weir without contractions



$$Q = 1.84\, L \times H^{3/2}$$

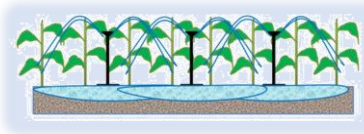


Limnimeter

Honorable Gobierno Provincial de Tungurahua

Pachanlica River Basin

Irrigation



Domestic use

474 (l/s)- 2035

89.141 Residents

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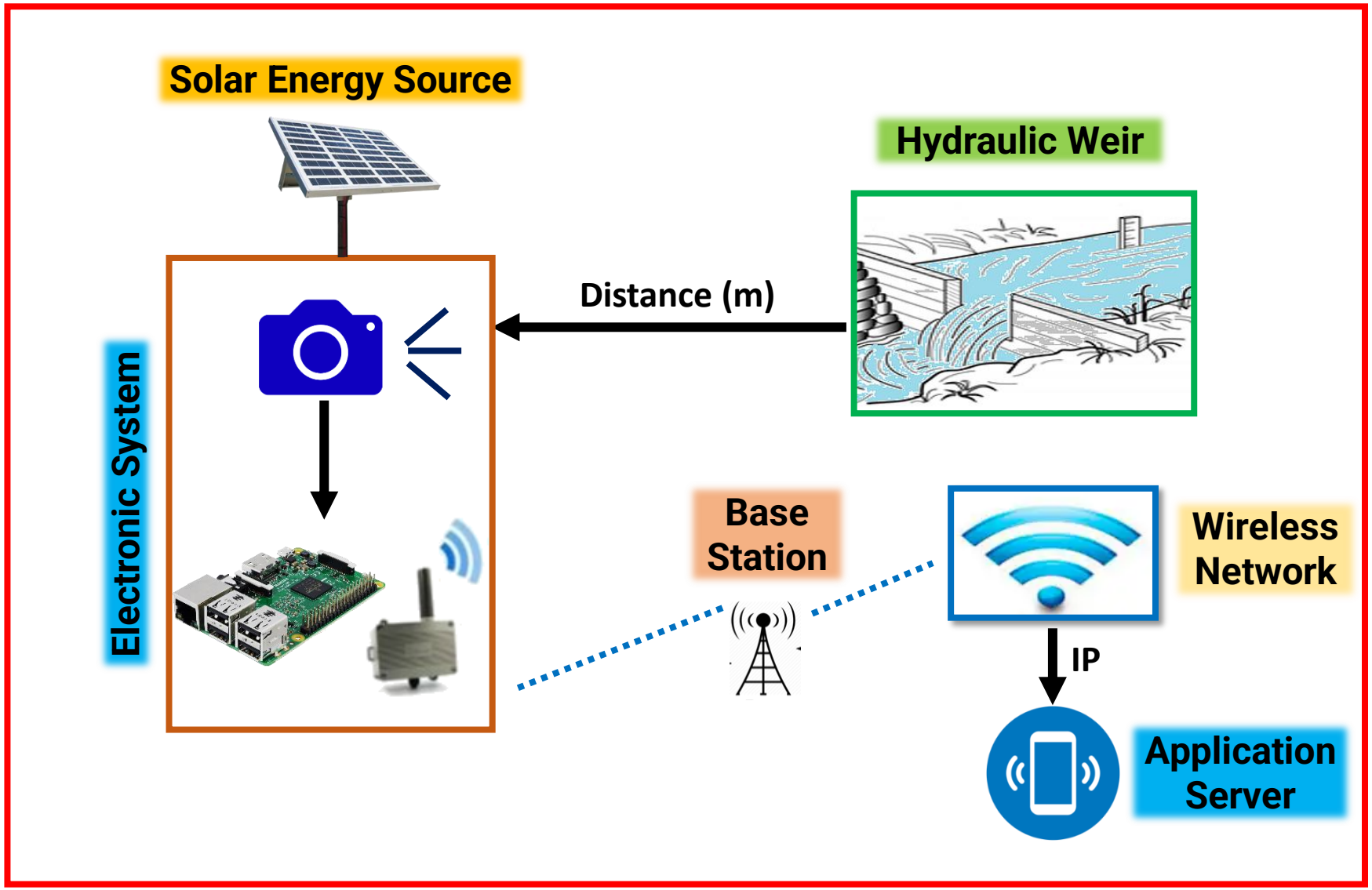
Proposed



Photovoltaic System

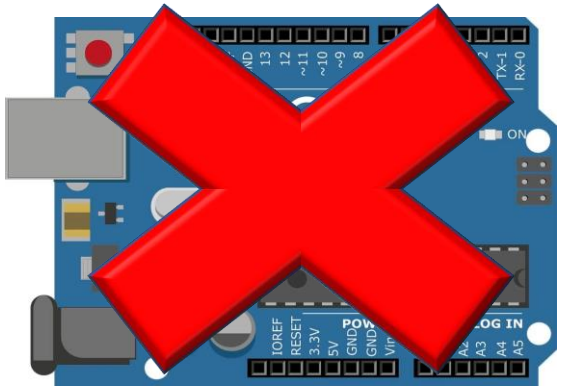
- Solution Architecture
- Microcomputer
- Devices with Wireless Communication
- IoT platform

Microcomputer

Raspberry PI 3B+

- CPU + GPU: Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit 1.4GHz
- RAM: 1GB LPDDR2 SDRAM
- Wi-Fi + Bluetooth: 2.4GHz y 5GHz IEEE 802.11.b/g/n/ac, Bluetooth
- 4.2, BLE
- Ethernet: Gigabit Ethernet about USB 2.0 (300 Mbps)
- 4 ports USB 2.0

Arduino



Camera

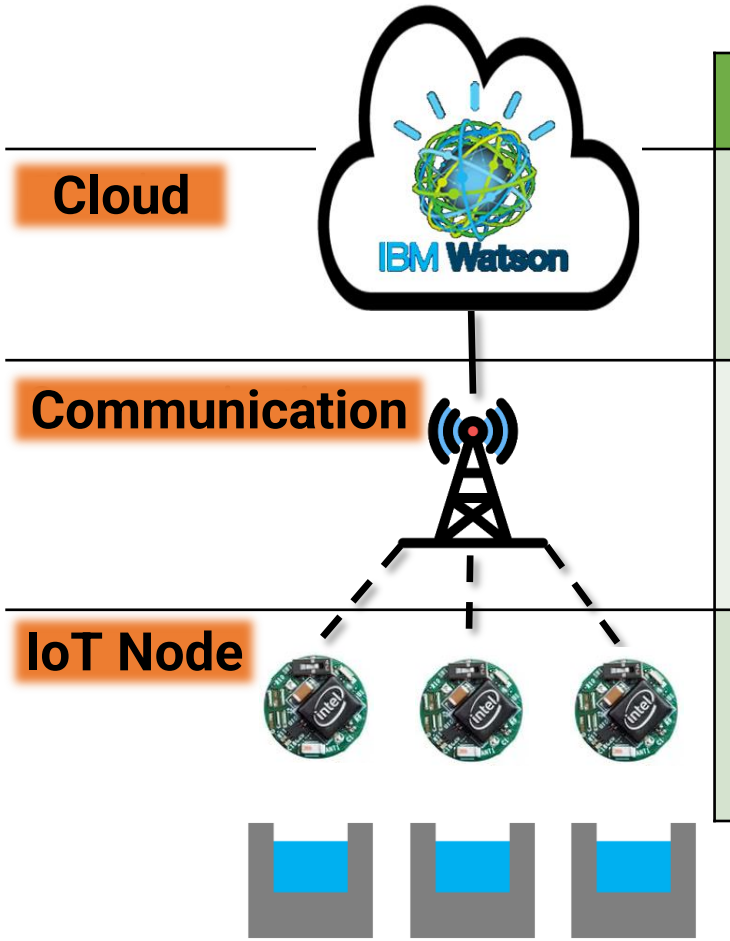
USB

IP

Raspberry Pi3 5mp

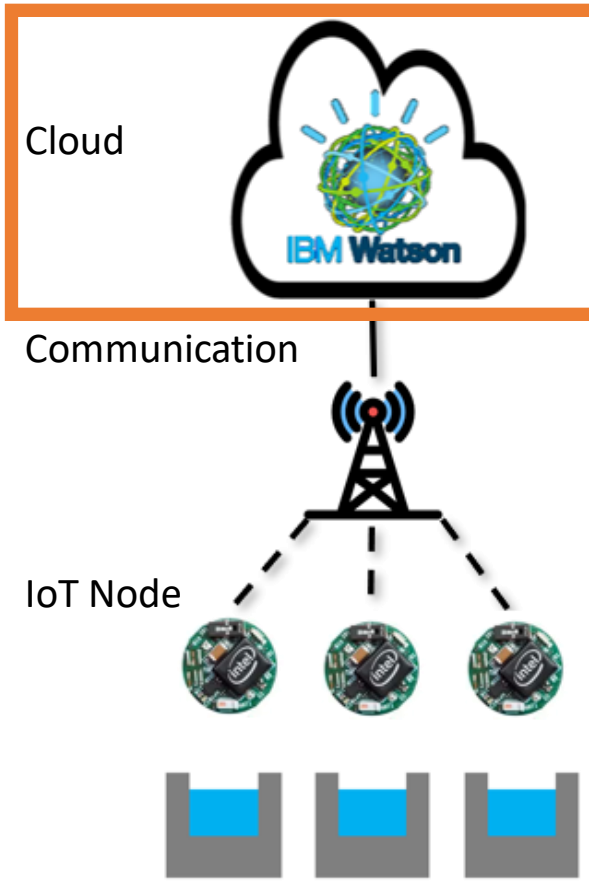
- 5 MP 1080P
- Resolution: 2592 x 1944 pixels
- 1080P 30 fps 720P 60 fps 640x480 90 fps
- Automatic switching between day and night mode

IOT Solution Architecture



Functions	
Visualization	Data Analytics
Connectivity	
Sensing	Action / Decision

IOT Solution Architecture



	Challenges	
Cloud	Interoperability	Scalability
Communication	Coverage	Scalability
IoT Node	Autonomy, interoperability, security, complexity	Scalability

Different options:

IoT Cloud

Visualization and analysis of data from Internet of Things solutions.

Aspects to take into account:

- ✓ Scalability (1 -100 -1.000- 1.000.000 nodes)
- ✓ Availability
- ✓ Security
- ✓ Ease of programming
- ✓ Interoperability
- ✓ Cost

Big Data

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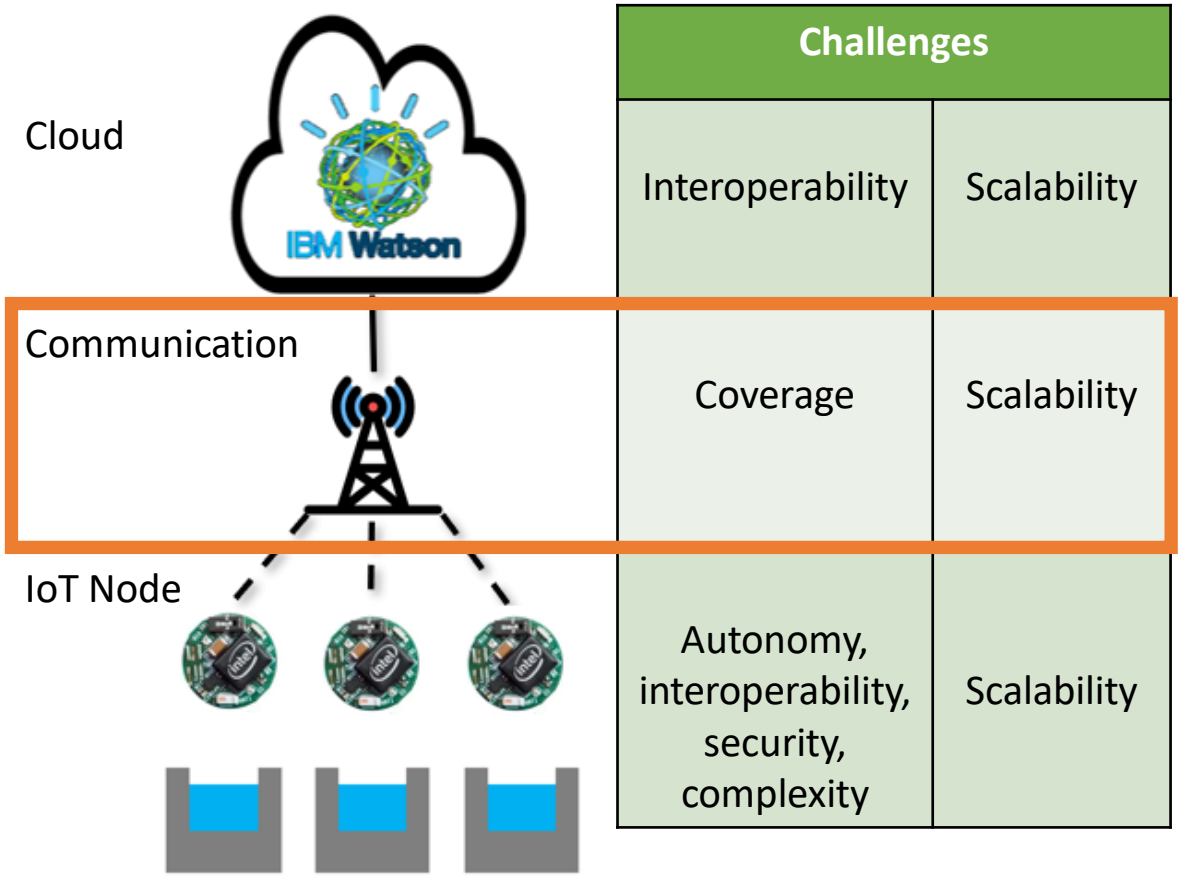
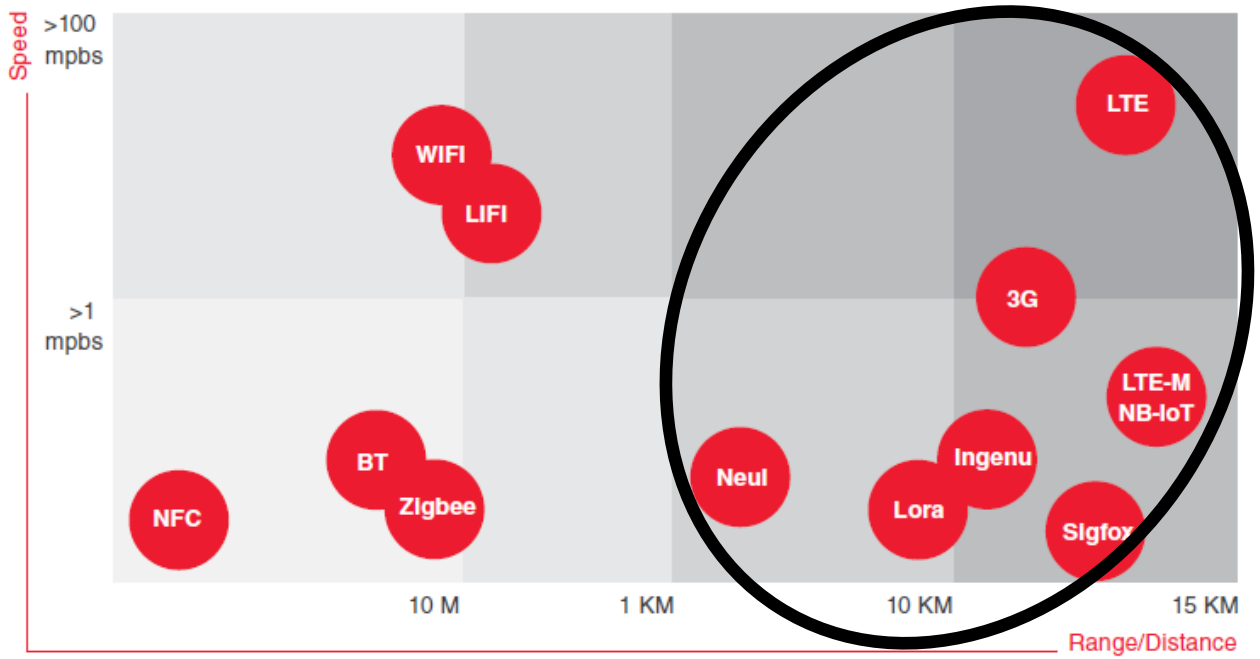
IOT Solution Architecture



Challenges	
Interoperability	Scalability
Coverage	Scalability
Autonomy, interoperability, security, complexity	Scalability

Communication for IoT

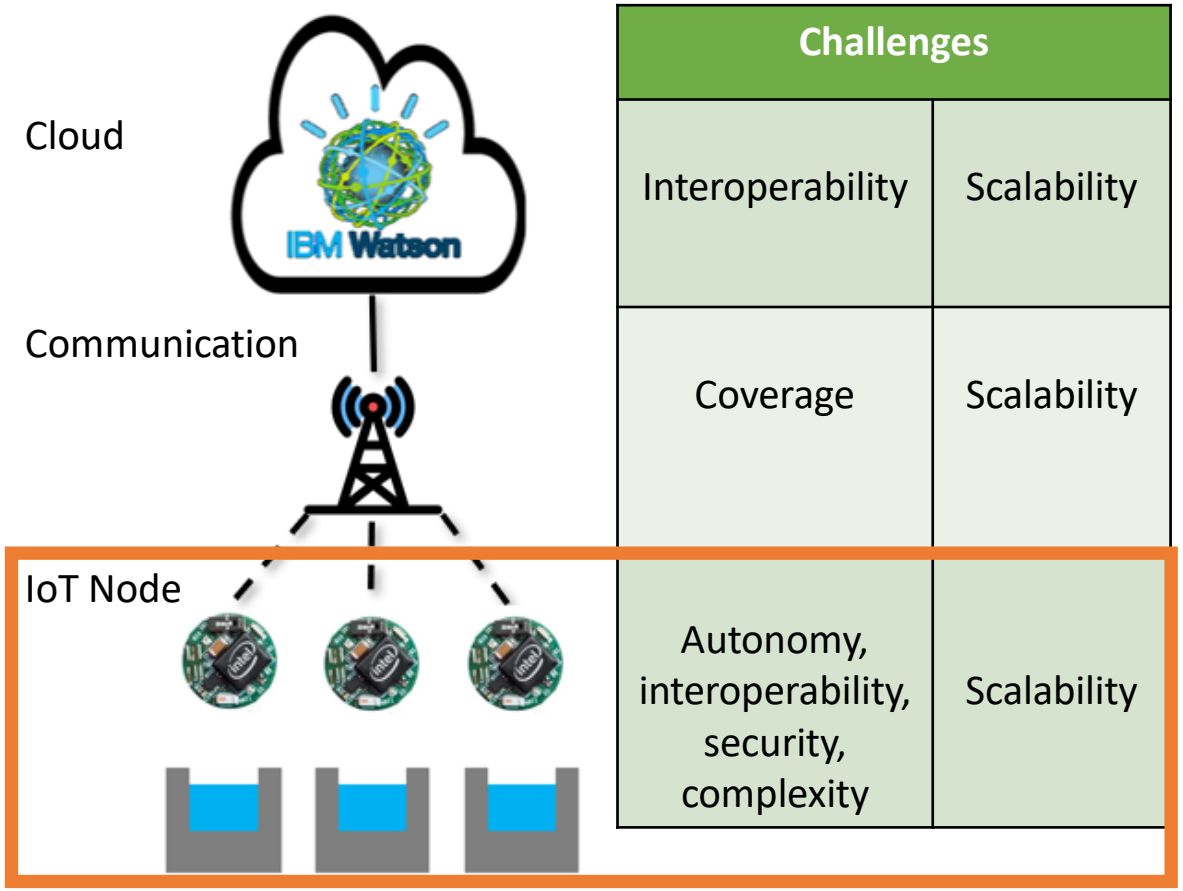


Aspects to take into account:

- ✓ Service coverage (urban vs. rural area).
- ✓ Number and size of messages required.
- ✓ Availability.
- ✓ Radio spectrum availability.
- ✓ Cost.

Source: Frost & Sullivan. (2019)

IOT Solution Architecture



Challenges	
Interoperability	Scalability
Coverage	Scalability
Autonomy, interoperability, security, complexity	Scalability

IoT Node

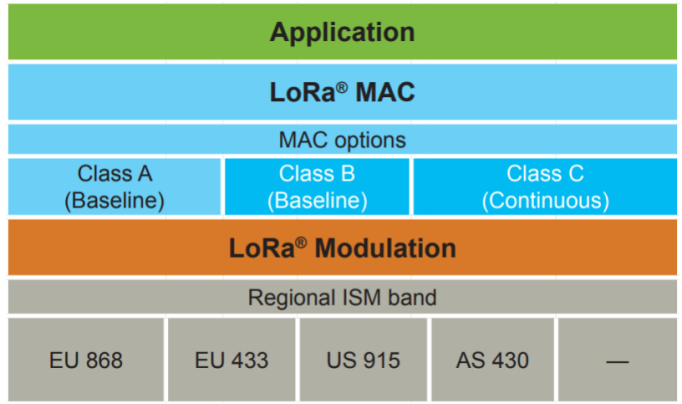
The electronic device for monitoring the variables of interest

Aspects to take into account:

- ✓ Energy autonomy: batteries, solar panels.
- ✓ Sensors: physical principle, ranges, accuracy, calibration, certification, sensor communication protocols.
- ✓ Communication technology, antennas.
- ✓ Robust firmware design
- ✓ Remote update.
- ✓ Node status monitoring.
- ✓ Physical support structure (station).
- ✓ Installation.
- ✓ Logical and physical security.
- ✓ Manufacturing options.
- ✓ Cost.

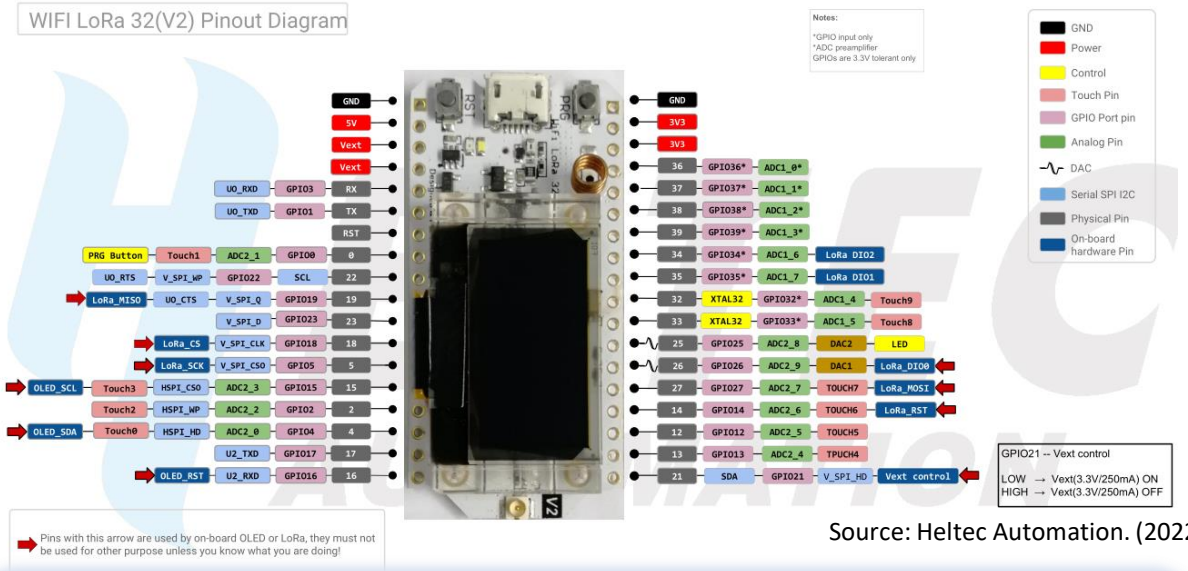
Devices with LoRa Communication

LoRa	
Scope	2-5km (city) 15km (rural)
Frequency band	433/868/915MHz ISM
Data sending rate	300 bps a 50kbps
Data reception rate	300 bps a 50kbps
Standard	LoRaWAN



Source: Lora Alliance. (2015)

Heltec WiFi LoRa 32 (V2)



Source: Heltec Automation. (2022)

- Microprocessor: ESP32 (dual-core 32-bit MCU + ULP core), with LoRa node chip SX1276/SX1278.
- Onboard 0.96-inch 128*64 dot matrix OLED display.
- Integrated CP2102 USB to serial port chip.
- ESP32 + LoRaWAN protocol Arduino® library.
- Support the Arduino development environment.
- Sleep current ≤800uA.

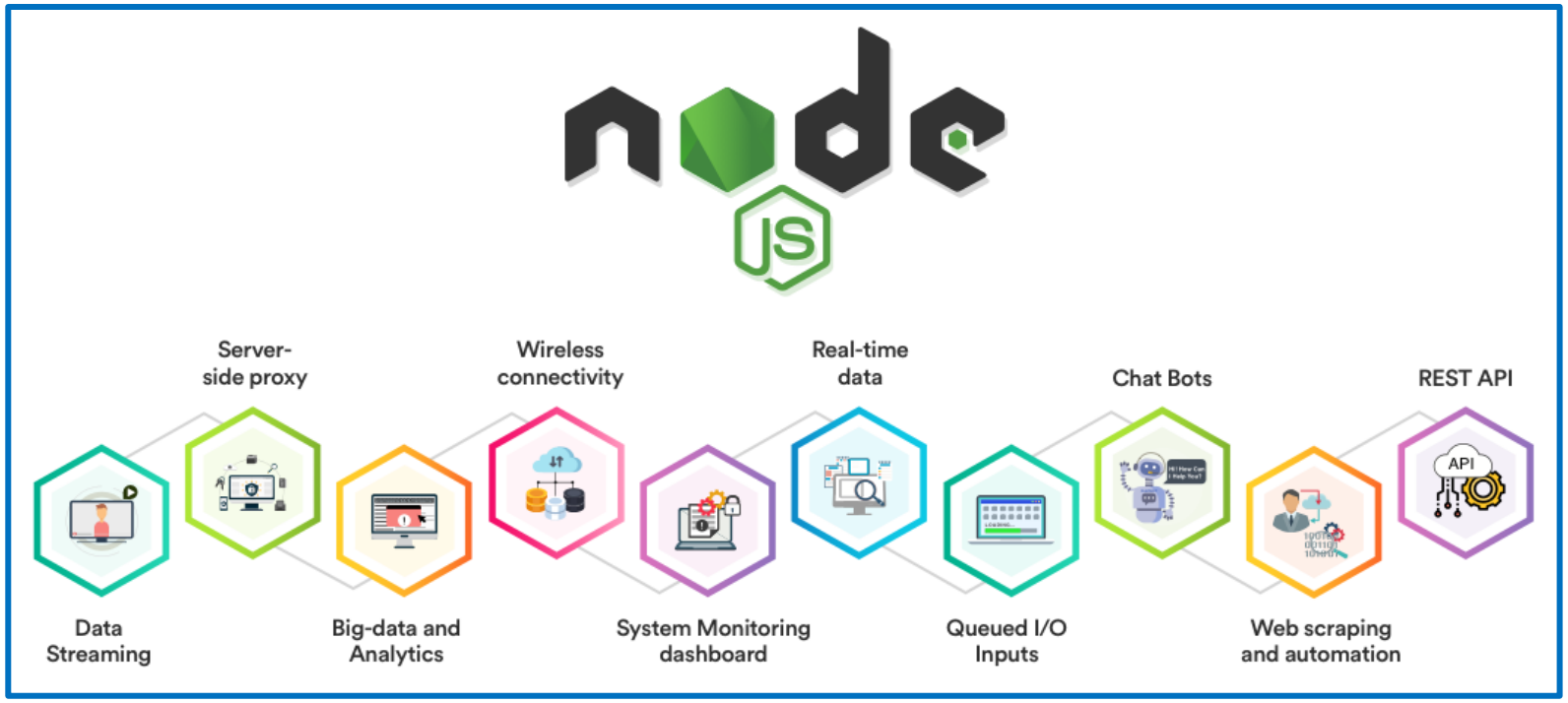
IoT Platform

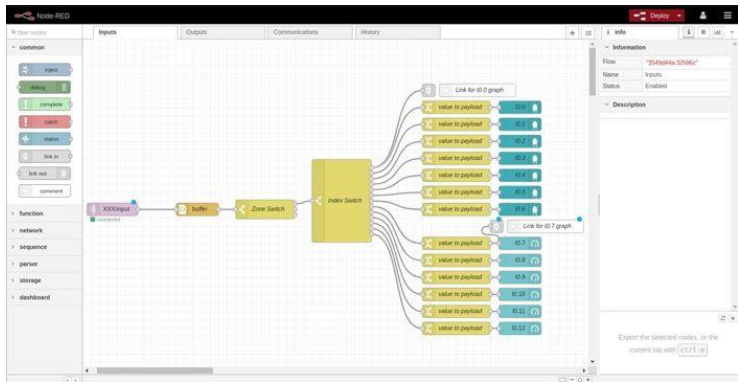
Node-RED

Node-RED

IBM

JavaScript





Sources: Node-RED: OpenJS Foundation. https://nodered.org
Node.js Foundation: https://nodejs.org/en/

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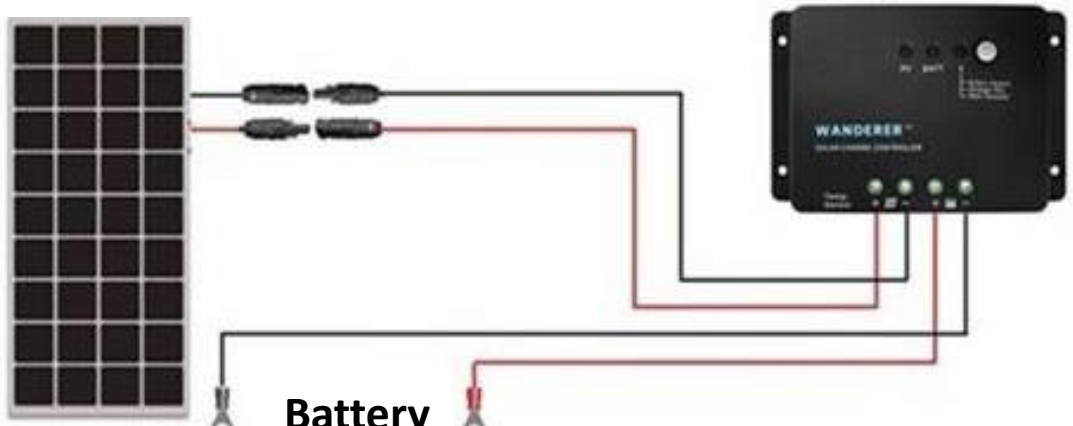
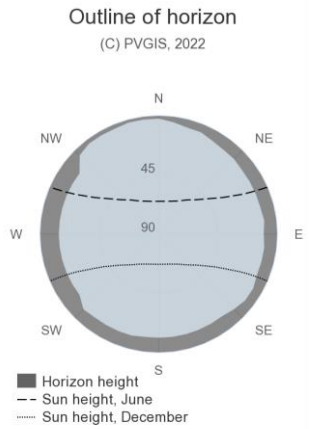
Photovoltaic System

Comisión Europea

Solar Panel

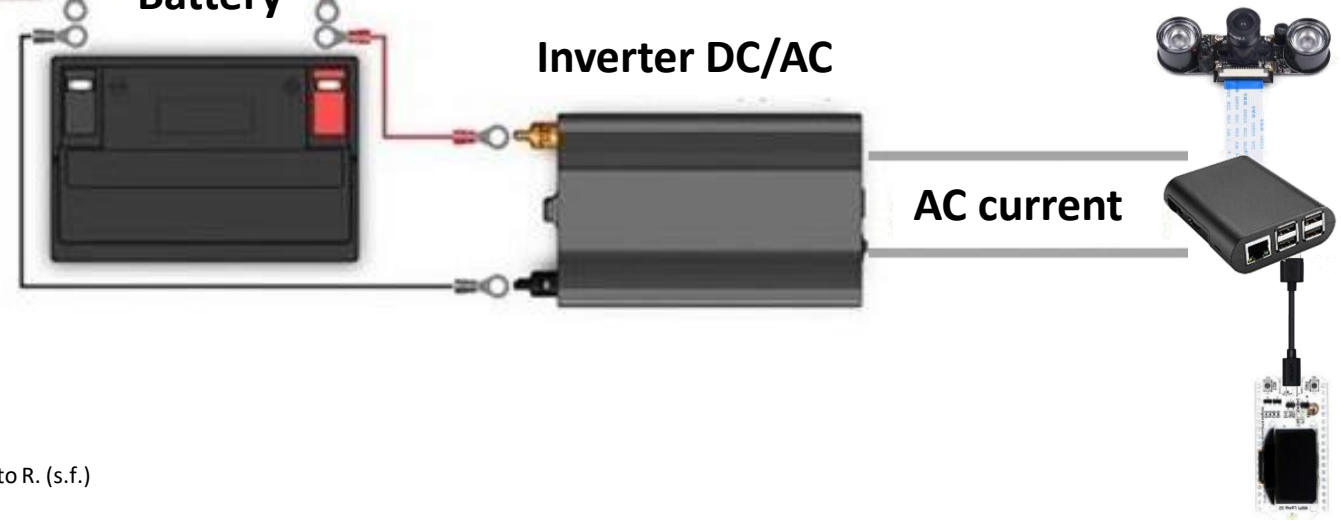
Regulator





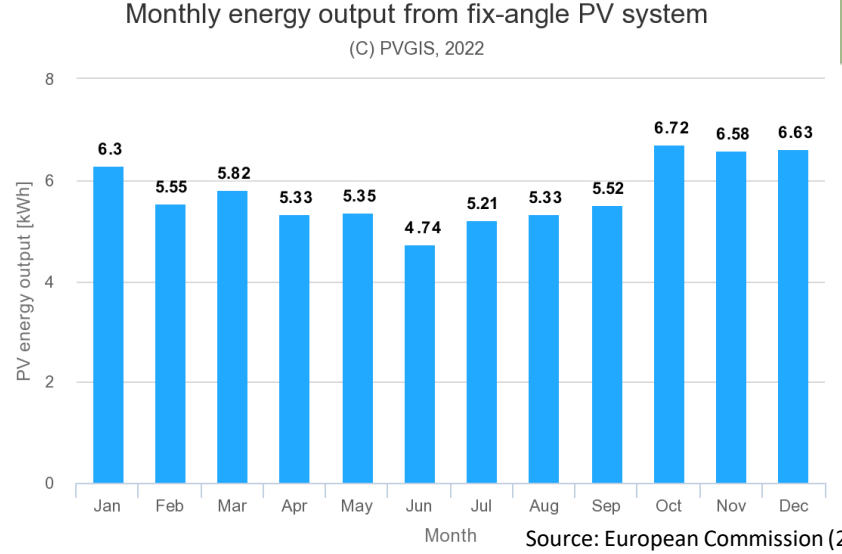
Battery

Inverter DC/AC

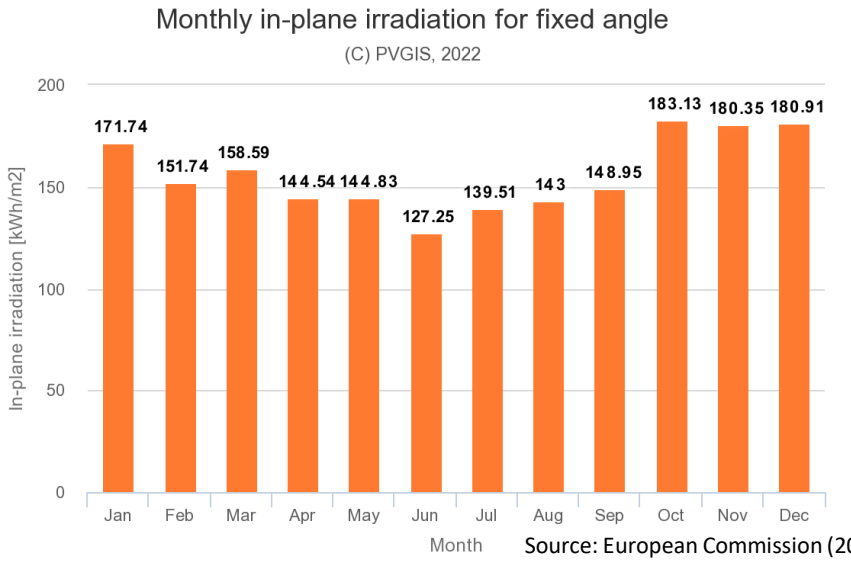


AC current

Source: Ernesto R. (s.f.)



Source: European Commission (2022)



Source: European Commission (2022)

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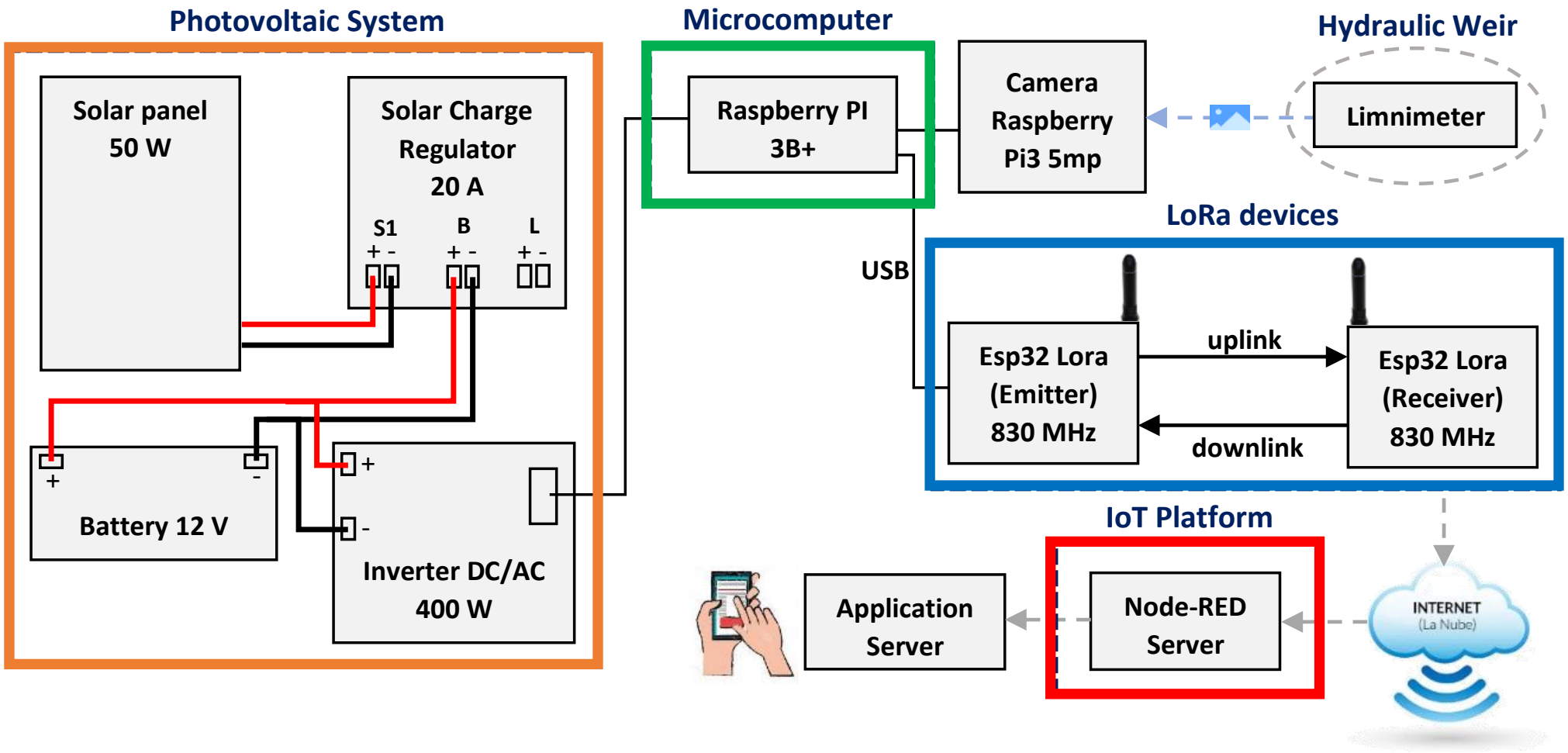
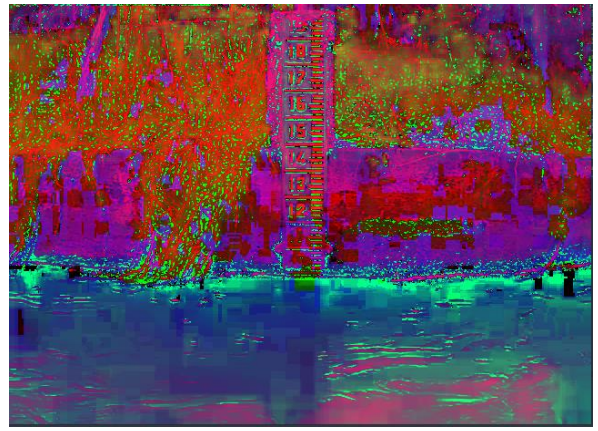
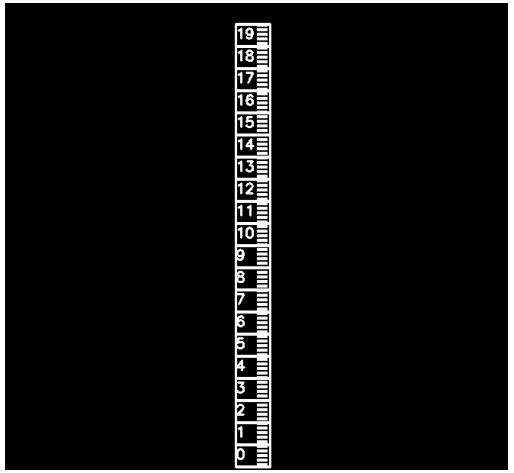
Schematic Design of the System for the Automation of Remote Reading of Limnimeters in Hydraulic Weirs



Video Image Digitization

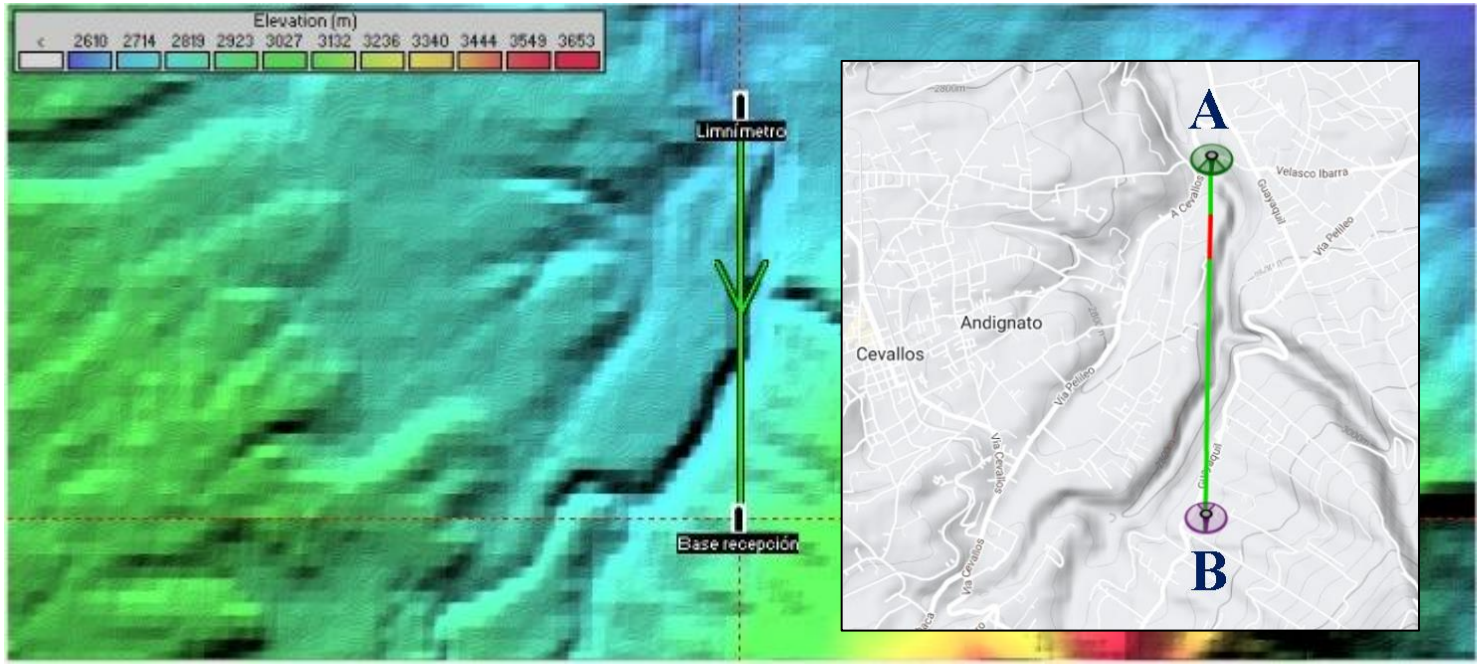


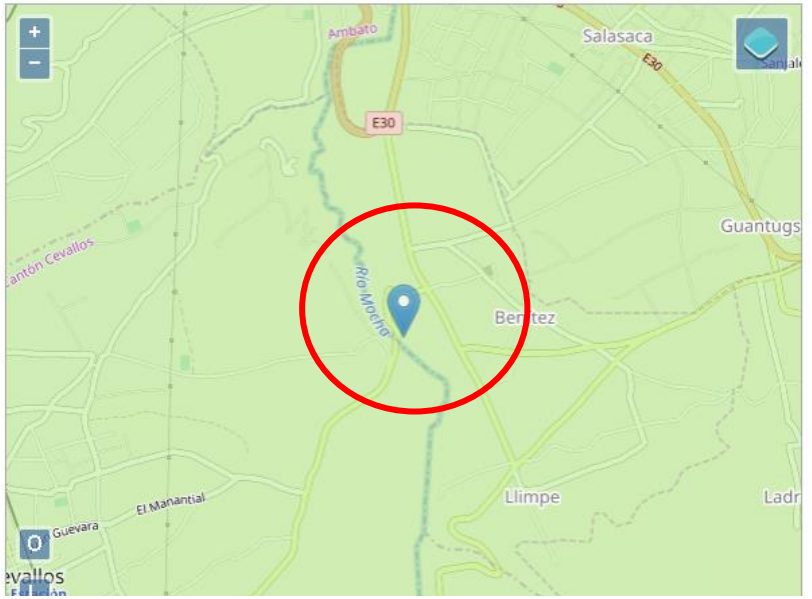
Digital ruler

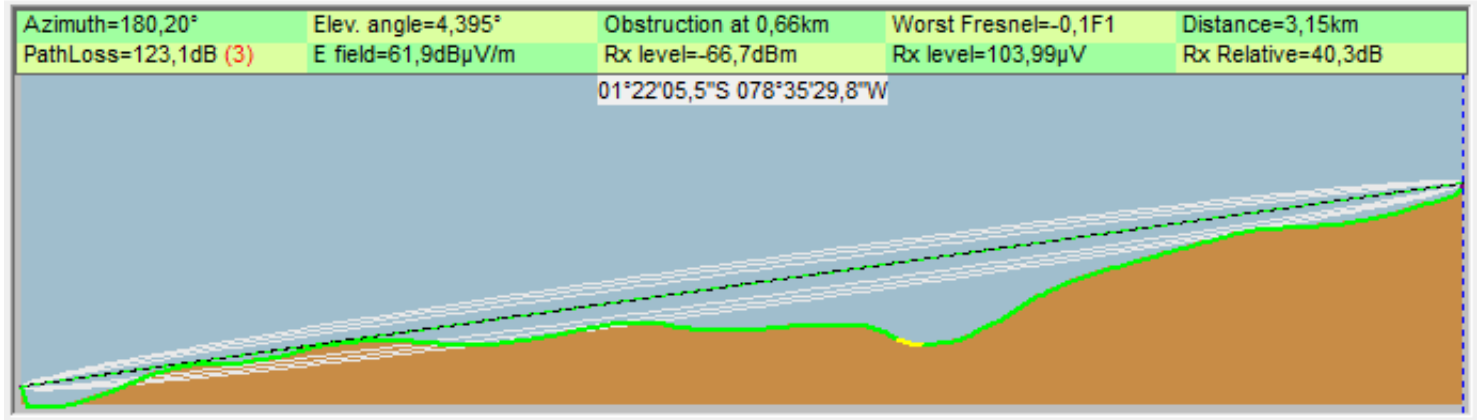


Source: Otsu, N. (1979)

Radio Link Study







Source: https://www.ve2dbe.com/rmonlineinfospa.html

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RADIOMOBILE

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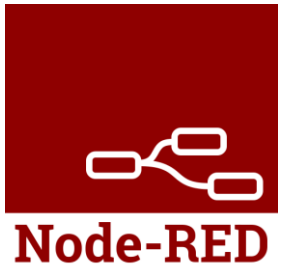
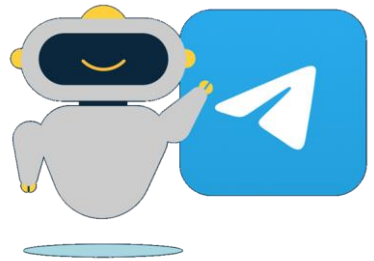
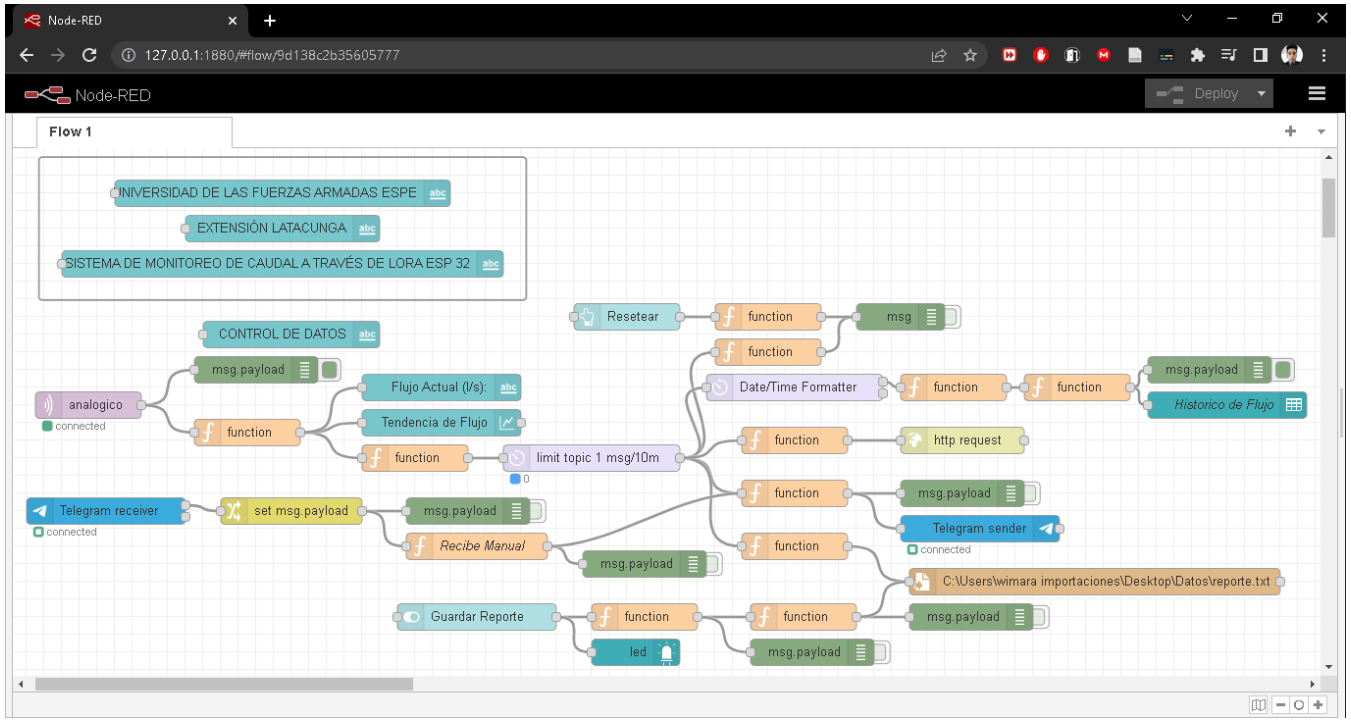
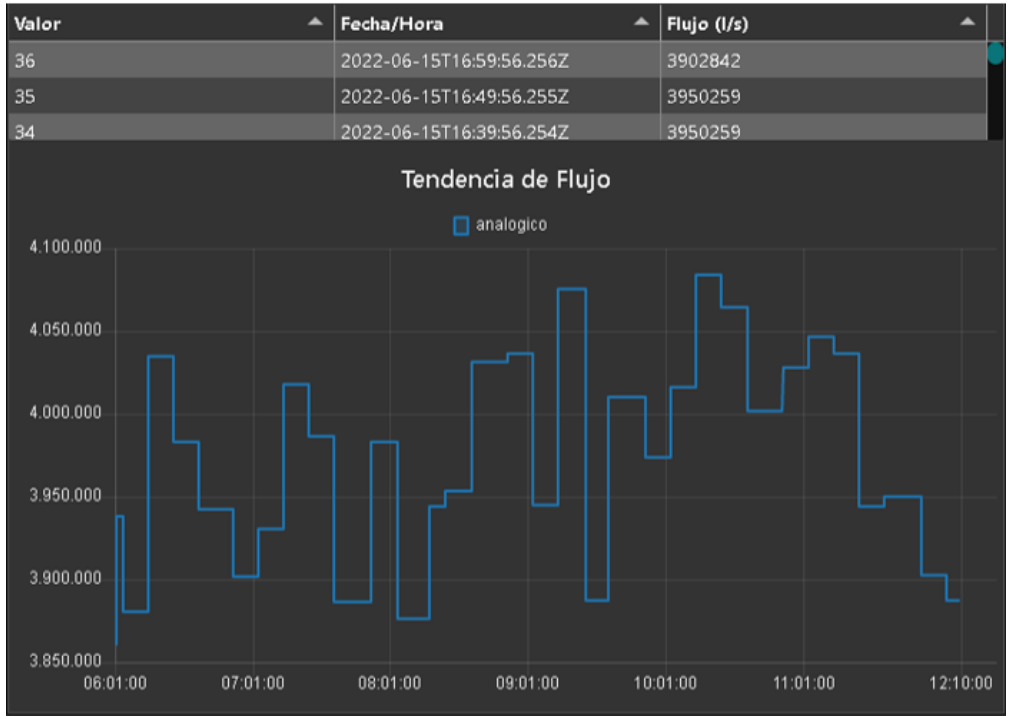
IoT Platform



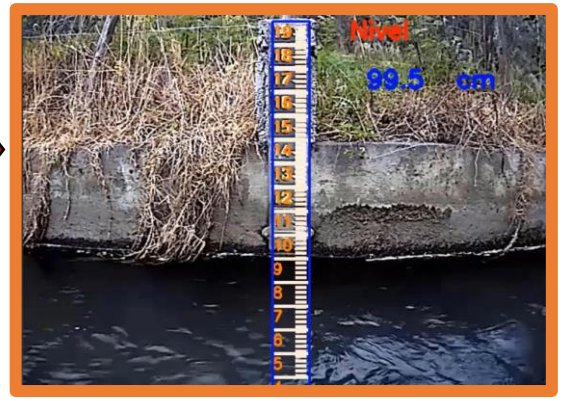


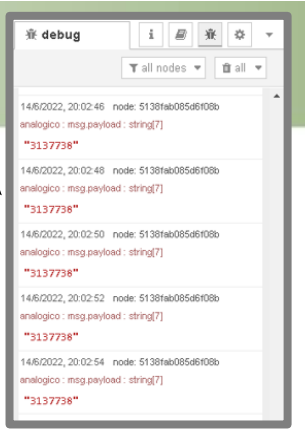


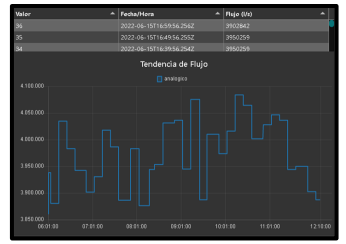


Sources: https://nodejs.org/es/
Eclipse Mosquitto: https://mosquitto.org/
Watson Visual Recognition (IBM Watson): https://www.ibm.com/watson/services/visual-recognition/

Monitoring

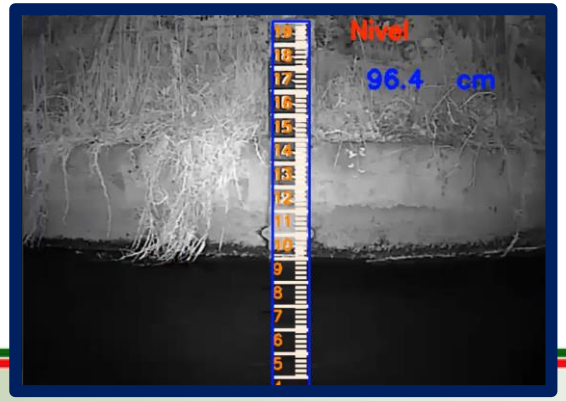


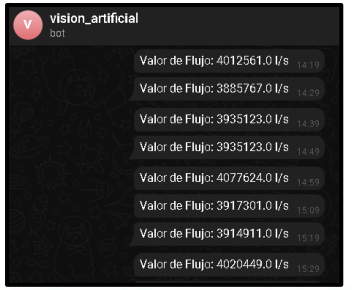




Level (cm)

Flow Rate (l/s)





Telegram

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Benefits

Greater impact than that produced by the individual use of a wireless sensor network in a single weir.

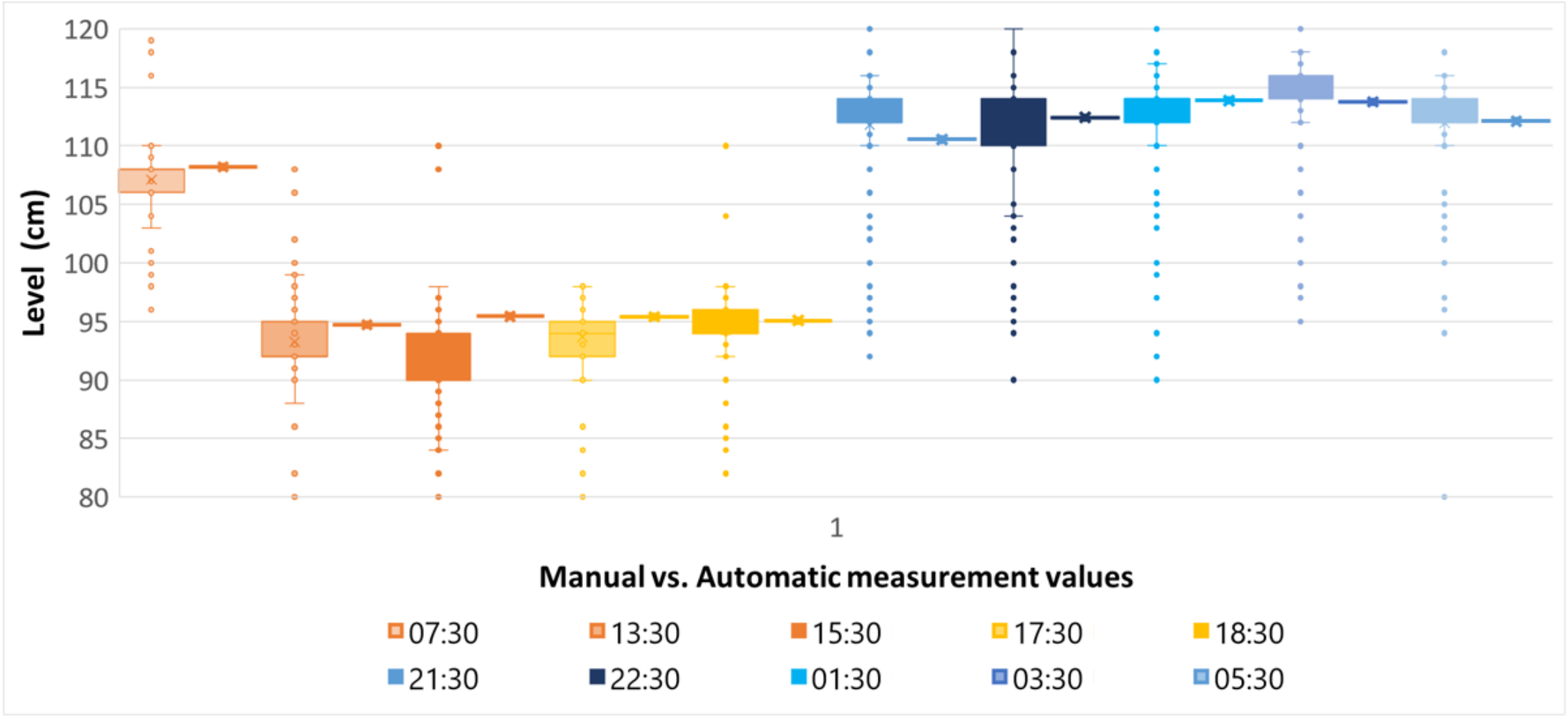
Improved production and quality.

Optimal resource management.

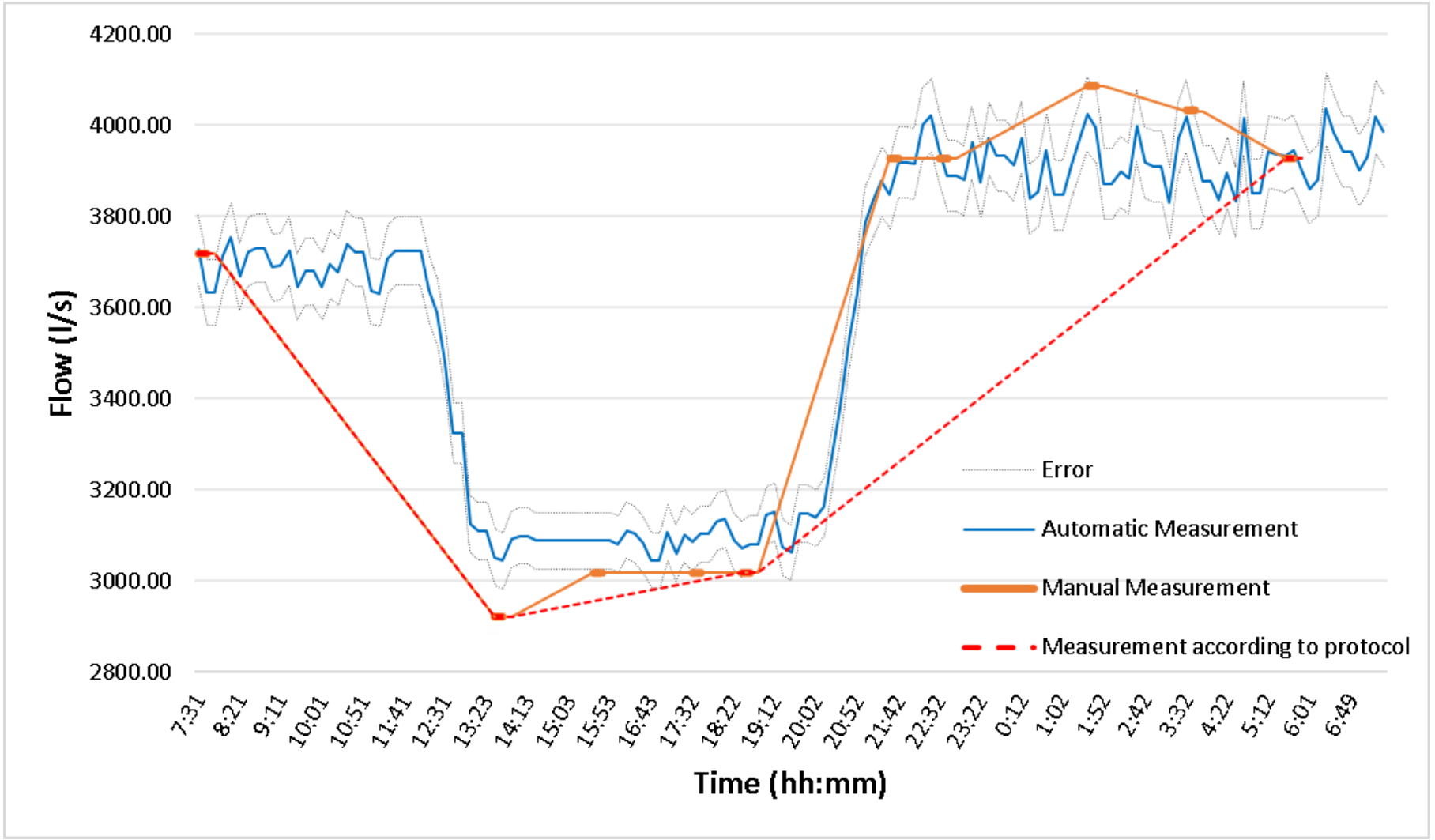
Technological inclusion of small farmers.

Implementation of an appropriate action plan based on the actual needs of hydraulic weirs.

Results


120
115
110
105
100
95
90
85
80
Level (cm)
1
Manual vs. Automatic measurement values
07:30
13:30
15:30
17:30
18:30
21:30
22:30
01:30
03:30
05:30

Results


4200.00
4000.00
3800.00
3600.00
3400.00
3200.00
3000.00
2800.00
Flow (l/s)
7:31
8:21
9:11
10:01
10:51
11:41
12:31
13:23
14:13
15:03
15:53
16:43
17:32
18:22
19:12
20:02
20:52
21:42
22:32
23:22
0:12
1:02
1:52
2:42
3:32
4:22
5:12
6:01
6:49
Time (hh:mm)
Error
Automatic Measurement
Manual Measurement
Measurement according to protocol

Conclusions

- The accumulated error of the measurement with the designed instrument is ± 1.1080%, its standard deviation is 0.6497 cm and its sensitivity is ± 0.1 cm.

- The automation of remote reading of limnimeters in hydraulic weirs through artificial vision and IoT, allows a constant monitoring of the water resource and there is no loss of data at any time.

- The implemented electronic system allows to obtain as a result the effective flow rate of the hydraulic weir in l/s without the need to visualize directly the linear scale of the limnimeter.

- LoRaWAN technology represents a practical alternative for implementing the IoT concept, as it is a very wide area network with low power consumption.

“Artificial Vision and IoT for Automation of Remote Reading for Limnimeters in Hydraulic Weirs”

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Alex Chiliquinga

Tutor: Ing. David Rivas PhD.

Co-Tutor: Ing. Víctor Bautista Mg.

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2022