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Original Article

Design of an Autonomous System Applying IoT for the Correct Monitoring of the Municipal Nursery of the District of Mi Perú – Callao

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Abstract *- The contamination of the biodiversity that exists in the Peruvian territory has caused the authorities and the Ministry of the Environment to promote the implementation of various nurseries in the municipalities and regions, among others, whose objective is to produce various species of plants to meet the demands of reforestation programs due to global warming that the planet welcomes. That is why the Municipality of the commune of Mi Perú, located in the Callao region, committed itself in recent years to implement a nursery, in which it has generated more than 100 species of plants, where it was observed that the process could be optimized of insemination and production, using a system that provides a more efficient and practical follow-up. That is why, faced with this problem, the design of an autonomous system applying IoT using renewable energies for the correct nursery inspection is proposed. It is intended to use the ESP32 platform and environmental sensors, such as temperature (DHT11), humidity of the soil (FC-28), hydrogen energy (Ph4502C) and ultraviolet radiation (ML8511), in which they will work with actuators that will simulate ventilation and automatic irrigation pumping. Finally, the system is intended to serve as an economic and universal instrument to monitor the various biodiversity according to the requirement or case studies. In addition, IoT technology will facilitate more autonomous control through the GRAFANA virtual platform that is used to monitor in real-time and store in the Influx DB database.*

Keywords *- Nurseries, Biodiversity, Sensors, IoT, ESP32, Database.*

1. Introduction

The nursery is a set of facilities whose main purpose is the production of plants. It plays a very important role in society since its productions, in many cases, are used to apply them in places that have lost green areas for various reasons, such as deforestation and warming, among other actions generated by humans. Likewise, it is also used for the production of vegetables since one of the limiting factors is the climate, in which the use of a greenhouse is very lethal to monitor and produce these plant species [1].

Currently, Spain is the second country in the world with the largest area of greenhouses, with an average of 69,000 Ha, which represents 0.14% of the total arable land. The fact of monitoring in order to control various environmental magnitudes allows favouring the development of plants outside their usual cultivation period, as well as cultivating certain products in places where they would not survive due to the climatic conditions of the place. That is why it is common to see that technology is used to cultivate vegetables in that country [2, 3].

On the other hand, in Argentina, it is estimated that there are around 7,000 hectares of nurseries in the country, of which 80% are used for horticulture, 11% for floriculture, and the rest are dedicated to nurseries and aromatic plants, among other crops. Currently, the application of technology in nurseries is very insufficient since there is little information regarding the influence of the most common type of structures in relation to internal environmental factors [4, 5].

Likewise, in Peru, it was indicated that in recent years between 2001 and 2020, 2,636,585 ha have been lost, with the departments of Loreto, San Martín, Ucayali, Junín, Madre de Dios and Amazonas concentrating more than 77 % of forest loss last year [6]. That is why, after the Red the Trees Foundation was created in 2015, they promoted the planting and reforestation campaign, in which they contributed to the development and improvements of various municipal nurseries in the country, such as the garden nursery with 30,000m2, Kantu, Miraflores, gardens, among others. Some of these nurseries are based in the 3 regions of the country, with the purpose of including and improving forestry, which is essential to contribute to sustainable development.

On the other hand, although it is true that the Tree Network Foundation program contributes to the development of nurseries in Peru, not all of them are considered for a certain program, as is the case of the municipal nursery Mi Perú - Callao, which is an enclosure that houses various species of plants that contribute to the afforestation of parks and gardens in their locality, which in recent times have been working using traditional methodology, which is expected to be modernized in the short term to optimize the fertilization process and plantation production together with other nurseries near the town, to promote not only the afforestation of local gardens but also contribute to the care of Ventanilla wetlands that have been degraded by global warming and various human actions [7].

One of the main problems observed in the study area is that the traditional methodology used in the Mi Perú municipal nursery generates disadvantages compared to a technical nursery. For example, in certain seasons, the demand for plant production with the traditional method of seeds would have to be used, and its cultivation process is more extensive, while a technical one uses the cloning method, which, together with the applied technology, supplies the market demand according to the needs of the client or locality.

That is why, seeing this problem, the objective of this work is to reinforce the control of the green nursery of the district of Mi Perú through an autonomous system using renewable energies and the use IoT technology, with economic resources that are easy to install, for the correct surveillance of the study area, which seeks to increase and recover the green areas that have been lost in the urban areas of the town.

The automatic monitoring system will work through renewable energy using photovoltaic panels; the ESP32 platform and environmental sensors will be used in the control stage. DHT 11, ML8511, FC-38, PH 5202C that will monitor temperature, relative humidity, ultraviolet radiation, soil moisture and hydrogen energy, which are essential for the correct monitoring of the plants, together with the automatic irrigation and ventilation system will generate correct control when monitoring through IoT technology, that can be monitored by smartphone, computer or tablet that has internet.

The IoT platform will work in GRAFANA together with the Influx DB database, which will serve to store the weekly and monthly monitoring of the study area. It should be noted that the platform will have a user registry, which can only be accessed by authorized personnel, entering through an identification and password to inspect remotely.

The present work is structured in the following way: in section 2, the review of the literature will be explained; in section 3, the methodology, in which the design of the system and the operation of the devices are shown; in section 4, the Results and discussion. Finally, in section 5, the conclusions and recommendations of the research work will be shown.

2. Literature Review

Today, there are various technological systems in nurseries and greenhouses that are used to monitor the magnitudes of the various plant species. However, they do not count as an alternative to using a system deployment model that monitors automatically through an IoT platform that uses inexpensive, easy-to-install electronic devices. That is why various research papers related to the proposed topic will be reviewed in this section. considerably

The research work [10, 11] indicates that, in Colombia, the interest in nutritional quality has increased; however, factors such as the time for the cultivation of the plants and the adequate space inside the houses prevent them from carrying out their own cultivation. That is why the author proposes a greenhouse prototype for the cultivation of edible plants, vegetables and fruits in environments located within an enclosure in a controlled and automated way. The system that he proposes is made up of the main components of the Arduino platform, which he will monitor through DHT11, LDR and SKU (SEN0114) sensors, which will read the magnitudes of temperature, air humidity, lighting and soil humidity.

Likewise, for the irrigation system, a PF-228 water pump is used that has a level control through the ULN 2803 integrated circuit. After the description of the devices, the author proceeded to carry out the various tests, obtaining the following results. To obtain the respective measurements, he delimited a 0.4 m2 land area where he placed a hose with diffusion points so that the water could come out and irrigate the soil for each use test of 500 ml of water. Additionally, in the monitoring of the sensors, it was concluded that it was necessary to use fans to generate air recirculation to avoid suffocation of the plant.

On the other hand, in the article [8, 9], the author indicates that, in India, more than 60% of the population depends on agriculture for their food, and today, it is urgent to increase crop productivity with efficient and effective water use. Therefore, the author proposes an intelligent automatic irrigation system for agriculture and greenhouses in India. The system that he applies is GSM.

In addition, an Arduino platform, soil humidity, temperature, PH and turbidity sensors will be displayed on a mobile device. Likewise, it uses renewable energy generators such as solar and wind panels. In which he concludes that this system will be very useful for the operator since he will be able to control the already-named devices at any distance, thanks to the GSM application.

In the same way, it happens in the article [10, 11], where the author presents an automatic irrigation system using IoT based on environmental sensors, which can be used moderately in monitoring mint or any type of plant. This system comprises the Arduino Uno platform, sensors for temperature, soil humidity and water flow, and a relay module and a water pump. On the other hand, after its implementation, they proceeded to carry out the tests and monitoring through the Arduino IDE serial terminal to visualize the values detected by the sensors, which indicates that the temperature did not reach the threshold of 30°C despite the fact that the soil humidity exceeded the interval of 360.

Also, regarding the pump test, it turned on automatically, reaching 144L/hour in 5 seconds, always when the soil humidity exceeded >360. Therefore, the car indicates that the system works efficiently; however, it is recommended that it could be improved by using more prominent IoT platforms, as well as using wireless technology such as WIFI or Bluetooth.

On the other hand, in article [12], the author indicates that today, overpopulation has caused agricultural land to be affected, causing a reduction in crop production in India. In addition, farmers also have to bear huge financial losses due to incorrect weather predictions. That is why the author proposes a dynamic model for greenhouses using the Arduino platform, soil humidity sensor (FC-28) and temperature (LM35), which will have a solar panel as a power source, water pump and fans.

In the respective tests, he used the serial terminal of the ARDUINO IDE software to display the monitored parameters of the system, in which he checked the operation of the fan when the temperature threshold level reached < 42°C; it remained off and when exceeded that value it operated correctly. They also checked the humidity sensor, in which, if the humidity were low, the water pump would turn on for 5s, and if the level was medium, it would turn on for 3s. Finally, the water pump would not turn on when the humidity level was high.

Additionally, in the work [13], it is commented that the majority of nurseries located in Ecuador do not have an automatic control system based on daily variables with respect to the type of land, where environmental magnitudes play a very important role. That is why the author proposes an automatic control system applying IoT to monitor various magnitudes, such as temperature, soil humidity and turbidity, with the objective of facilitating the administration control of variables to have better-distributed irrigation and improve the quality of the plants.

The system is made up of the Arduino platform and the ESP8266 Wi-Fi module, which uses a 0.5 Hp water pump, DHT11, FC-28 sensors and a turbidity sensor. The system was evaluated by means of 4 types of plants, such as palm trees, croto, cypress and fern. The results they obtained were an average of 15 ° C, a level of 6 pH and a humidity of 60%. It should be noted that all the data was collected by a smartphone for 24 hours, being effective in its operation, as demonstrated in its results.

In summary, it was seen that the authors have contributed to developing several prototypes related to the monitoring of nurseries and greenhouses according to the need or requirement of the study area.

However, I believe that this nursery monitoring initiative could be enhanced by using renewable energy and emerging technologies such as IoT, which has greatly increased the development of environments and platforms that support more extensive and comprehensive study or monitoring. That is why this article proposes an autonomous design applying IoT for easy installation and monitoring through a wireless device such as a tablet or smartphone, in which, as a study area, it seeks to technify the green nursery of the district of Mi. Peru is located in the province of Callao, Peru.

3. Methodology

In this section, the various steps for developing the design of the autonomous system applying IoT for monitoring the municipal nursery were developed.

3.1. Study Area

The nursery shown in Fig.1 has more than 5,000 species of plants, such as ornamentals and vegetables. It is located on Av. Puno, sector M, in the constitutional province of Callao, in the district of Mi Perú, has 60,000 inhabitants distributed in 44 human settlements.

3.2. General System Diagram and Component Description

In this section, each part of the segmentation of the autonomous design is developed by applying IoT to the green nursery.

Fig. 1 Municipal nursery of the district of Mi Peru - Callao

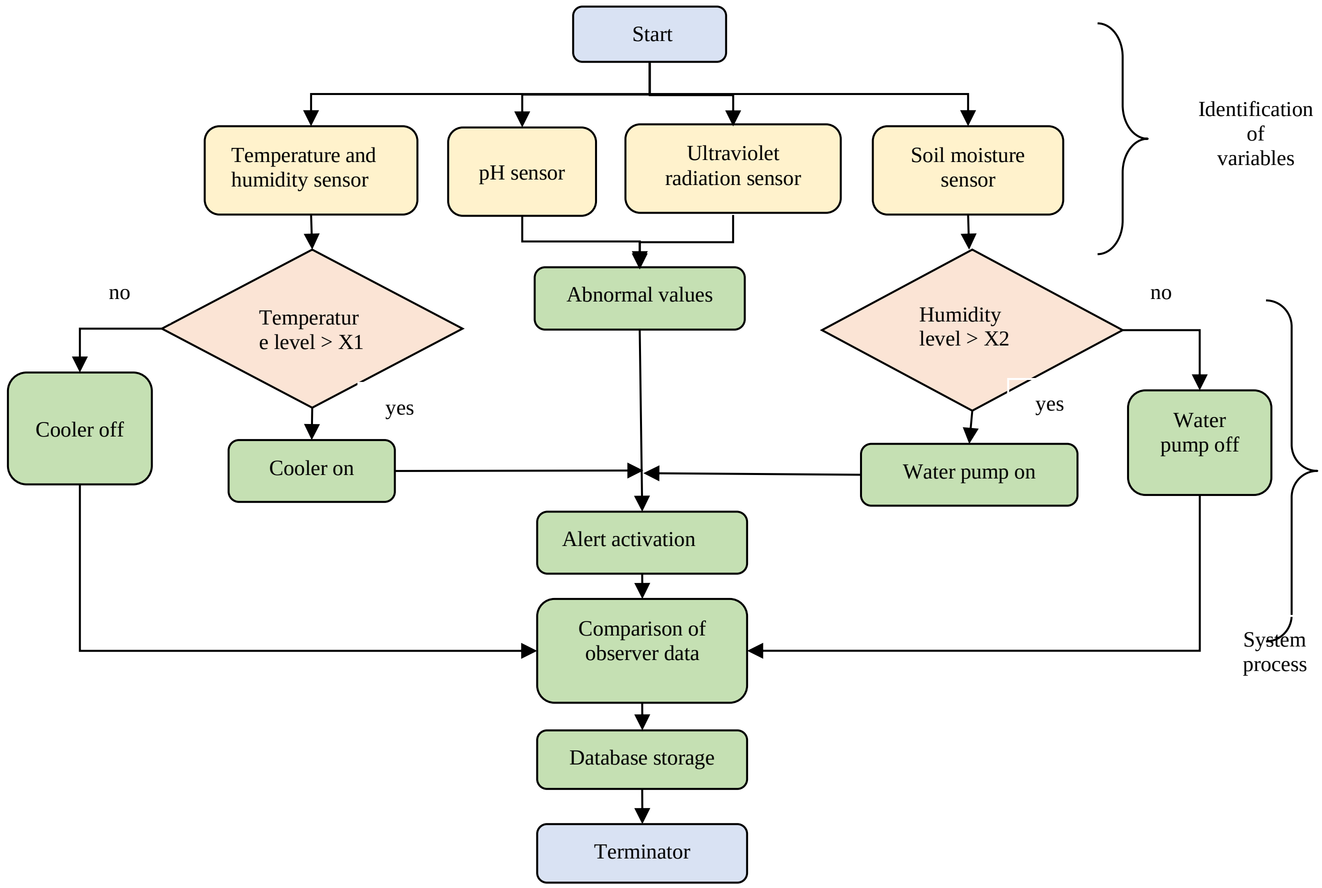

Fig. 2 Flow diagram of the autonomous system applying IoT for the detection of environmental parameters of the municipal nursery

Figure 2 shows the main operation of the system, in which the declaration and leveling of variables are established as the first point, which is determined by 4 environmental sensors. On the other hand, the second point indicates the process of the system that was determined by 2 conditions to automate the monitoring with respect to the level of temperature and humidity of the soil, where 2 variables are indicated as X1 and X2 that represent values of N that will be programmed, according to the plant species to be monitored in the municipal nursery. It should be noted that the temperature and humidity of the soil will determine the automatic irrigation system and the ventilation system. On the other hand, the 4 sensors that will detect the environmental magnitudes of the study area will be processed by a microcontroller that will send the sensor reports to the database, which will then be displayed on the IoT platform that will serve to compare the different values environmental established in the system. Next, identifying variables and the system process are detailed in greater depth.

3.2.1. Identification of Variables

This section shows the technical data of the electronic devices selected for the municipal green nursery's autonomous monitoring system, including the DHT 11, ML 8511, FC 38 and PH 5202C sensors.

Temperature Sensor

The DHT 11 digital sensor is widely applied today due to its easy adaptation to platforms and microcontrollers such as Arduino ESP 32, among others, being used for temperature and humidity detection. This type of sensor is internally composed of a thermistor and a capacitive sensor responsible for detecting the 2 physical variables already mentioned [14]. Next, Table 1 shows the technical characteristics that must be considered before its implementation.

Table 1. Characteristic of the temperature sensor DHT 11

Model	**DHT 11**
Power supply	3.3 -6 VDC
Operating range (humidity)	20 - 90 % RH +/- 4%
Operating range (temperature)	0 - 50ºC +/- 2ºC
Voltage output	digital
Resolution	Humidity (1%RH) temperature (0.1ºC)

Ultraviolet Radiation Sensor

The UV sensor is a device that converts a signal based on the amount of ultraviolet light it detects in the environment. It is applied in projects to monitor environmental conditions, such as UV index.

Table 2. Characteristic of ultraviolet radiation sensor ML8511

Model	ML8511
Power supply	5 VDC
Operating range	280 a 390 nm
Voltage output	analog
Linear output	mW/cm2

Table 2 indicates that the sensor is processed by means of an analog signal to detect UV radiation in established ranges from 280 to 390 nm, referring to the UVA and UVB spectrum [15], [16].

Soil Moisture Sensor

The FC28 sensor allows measuring soil moisture through 2 resistive electrodes. Table 3 shows that it has a digital output, which works with an OPAM in comparator mode; that is, the digital signal is activated when the level of humidity is less than the desired level, and the Threshold level is regulated by means of a potentiometer; while the analog output works through a voltage divider between a stable resistance [17].

Table 3. Characteristics of the soil moisture sensor FC 38

Model	FC 38
Power supply	3.3 - 5 VDC
Operating current	35mA
Voltage output	Analog / Digital
Additional	Opamp LM393

pH-Sensor

The PH-4502C sensor normally works with an E201-BNC electrode. It is compatible with any TTL technology, and since it has an analog output, it can work with educational microcontrollers found in the Peruvian market, such as Arduino, Pic, and Esp32, among others [18, 19]. Next, Table 4 shows the technical characteristics of this sensor.

Table 4. Characteristic of the pH sensor 4502C

Model	PH-4502C
Power supply	5 VDC
Operating range	0 – 14 pH.
Precision	± 0.1pH
Measurement temperature	0-80°C
Response time	≤ 5s

3.2.2. System Process

After visualizing the main characteristics of the 4 sensors that will be used for this project, the system's operation will be briefly explained. In, it is known that each device has a way of converting a physical magnitude to an electrical one, either analog or digital. For this, these sensors require a platform that processes the data and transmits it to a graphical environment through wireless communication, such as Wi-Fi or Bluetooth, which will depend a lot on the study area where you want to monitor. Next, Figure 3 shows the block diagram of the system's operation that will be detailed in greater depth in the following lines.

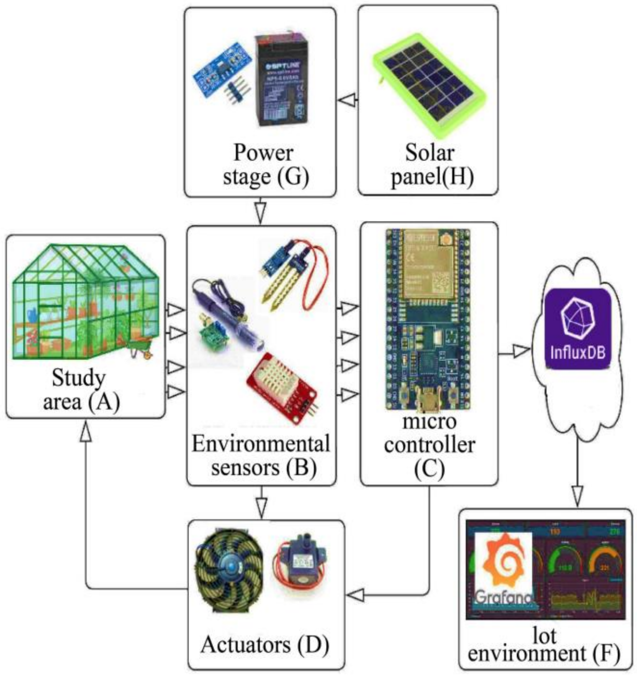

Fig. 3 Block diagram

Figure 3 shows the operation of the system established by means of a block diagram, in which a closed-loop system was made to automate and process using IoT technology. At point A, ornamental plants of 2 species, such as Fern and Carnation, from the study area were determined.

These plants will be monitored by 4 environmental sensors, 0indicated at point B, the sensor for temperature, soil humidity, ultraviolet radiation and PH. Then, the data established by the sensors will be sent and processed to the ESP32 platform shown in point C, which will be in charge of automatically establishing the Wi-Fi wireless connection to the Influx db database.

Likewise, the ESP32 will also be in charge of carrying out the conditions of the temperature sensor (X1) and soil humidity (X2) shown in Figure 2 for operating the ventilation and automatic irrigation system. That is why Table 5 shows the conditions established to turn the 2 indicated actuators on and off automatically.

Table 5. System actuator on and off conditions

Temperature	Soil humidity	water pump	cooler
>28	< 40 %	ON	ON
< 27	> 60%	OFF	OFF

On the other hand, Figure 4 shows the system simulation in the Fritzing software, which gives us a clearer idea regarding the system's operation.

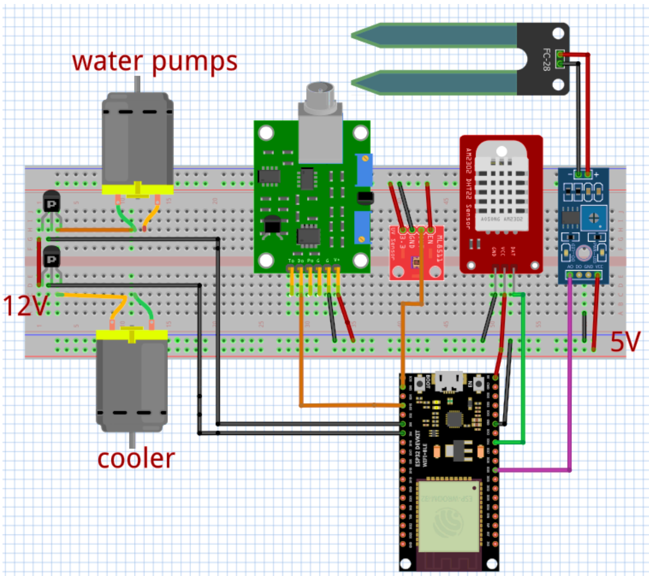

Fig. 4 System simulation in fritzing

At point E of Figure 3, the data is sent wirelessly via WIFI from the ESP32 platform to the time series database, such as Influx dB, which will be in charge of storing the data periodically for future reports. Likewise, it is observed at point F the transmission of the Influx dB database to the IoT environment that is GRAFANA, which will provide various statistical graphs to monitor the study area through the Internet of Things [20].

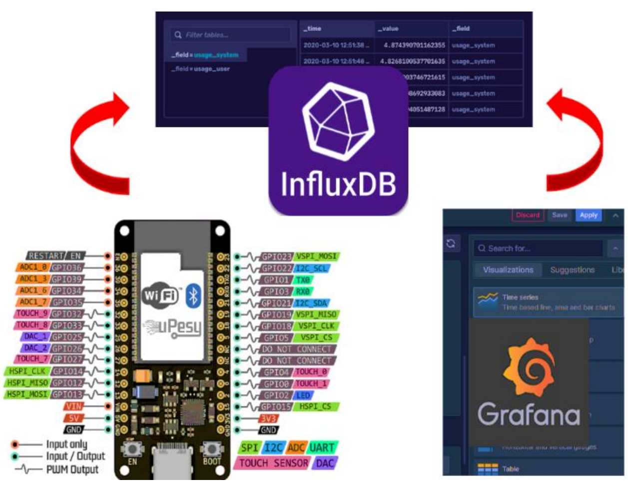

Fig. 5 Communication of the ESP32 in the cloud

Below, Figure 6 shows the various options GRAFANA has. For this, point 1 indicates that the proposed system has a user ID and password to view the monitoring. In addition, point 2 shows the option to change the resolution of the monitoring time and date, in which, through this option, you can see the previous days of system monitoring thanks to the storage we have in the Influx DB database. On the other hand, in point 3,4,5, the data export process is shown in simple steps in an Excel table, in which individual and group magnitudes can be exported [21].

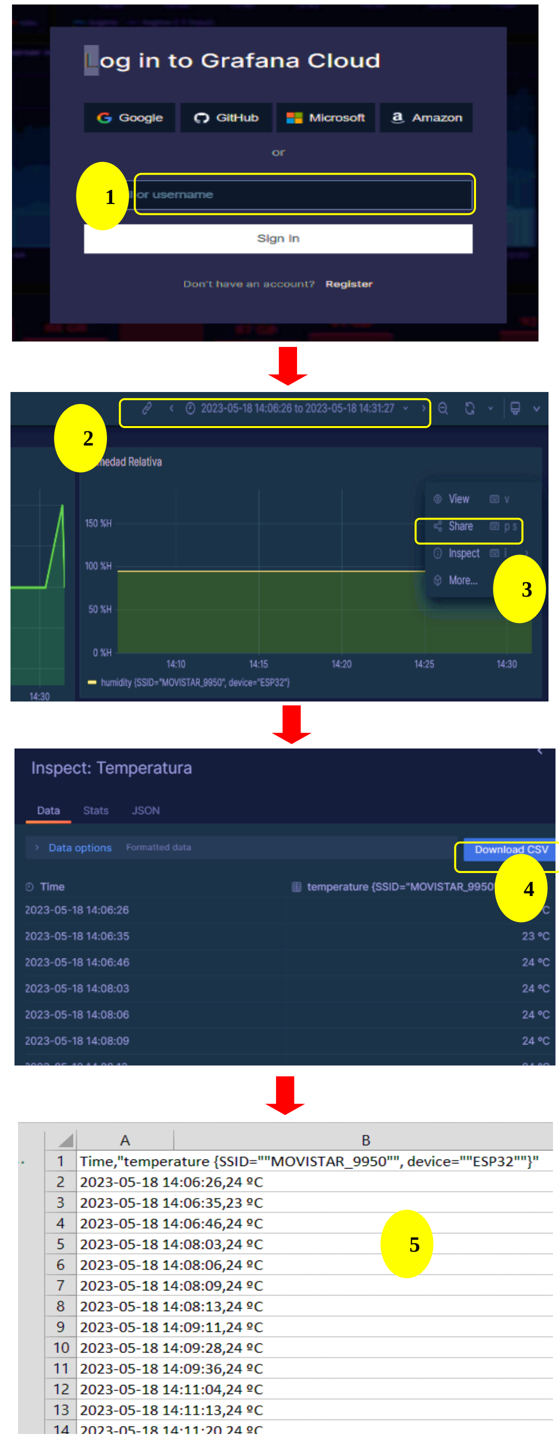

Fig. 6 Export system data in GRAFANA software

On the other hand, at points G and H, the power stage of the system shows a renewable energy generator is used, such as an 18V solar panel and an MPPT charge regulator, which will feed the 6v 4Ah battery, to energize the entire stage of the control system of the proposed prototype [22, 23]. Next, Figure 7 shows the diagram and connection of the power stage.

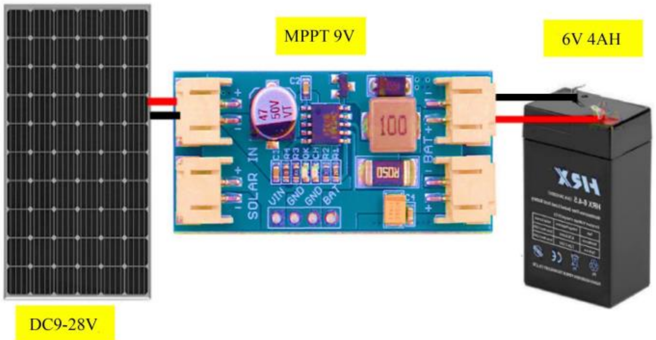

Fig. 7 System power stage diagram

4. Results and Discussion

4.1. Results

At this stage, mention is made of the results obtained in the implementation process of the automatic system, in which the following simulation tests were carried out to be later mounted in the study area and obtain the various efficiency results. Next, Figure 8 shows the simulation of the control stage to verify the operability of the sensors and microcontroller before being assembled to avoid early failures that can be found in the various tests that will be detailed later.

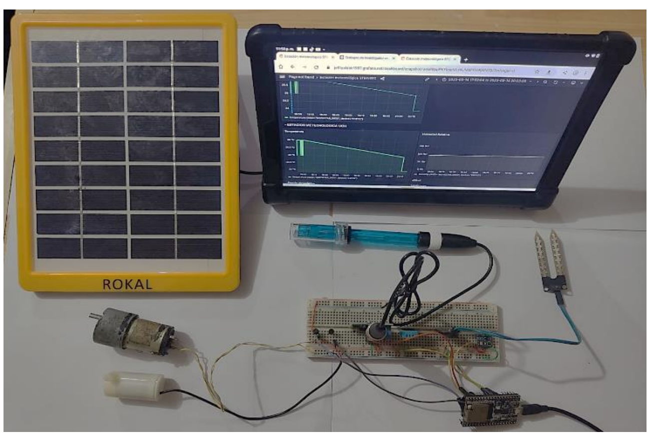

Fig. 8 Hardware simulation of autonomous systems

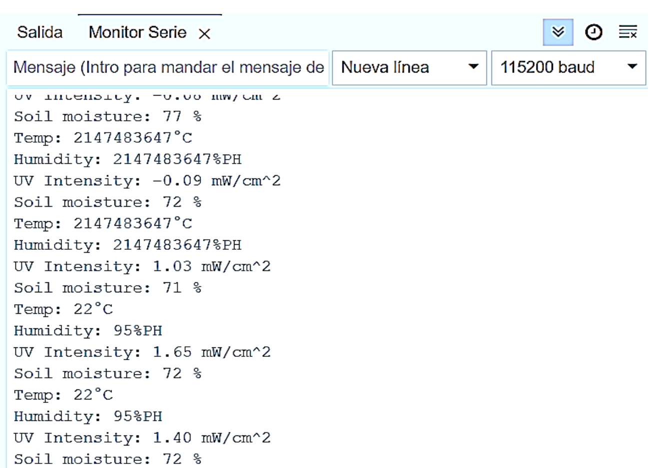

Fig. 9 System verification via serial monitor

As can be seen in the simulation, the operation of the system is verified through the serial monitor that has the Arduino IDE programming environment shown in Figure 9, which will help to verify that the sensors, the Influx DB database, and the WIFI communication of the ESP32 are monitoring correctly. In the same way, it was also verified that the communication of the INFLUX DB database and the WIFI of the ESP32 communicate correctly.

Figure 10 shows the design of the system's structure, where the various horticultural and ornamental plants will be monitored through WIFI, and the monitoring of the plants will be observed through the GRAFANA software.

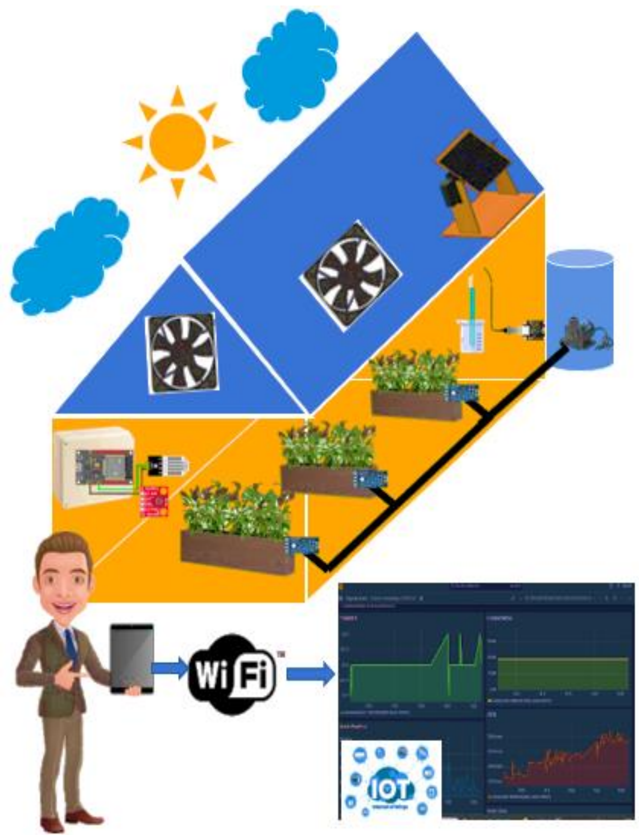

Fig. 10 Design of the structure of the automatic system

After visualizing the structure's design in general, Figure 11 shows the final assembly of the prototype, where 1 ornamental plant is monitored for the verification and efficiency of the proposed system, which will then be shown in the following tables for their respective analysis.

To carry out the efficiency test, conventional laboratory instruments were used, as shown in Figure 12, where the HTC-2 thermohydrometer, the YH-SOIL4 pH meter, and the UVA 365 meter are located, which will help us compare with the system suggested [24], [25]. That is why a comparison is made in Tables 7 and 8 with the instruments shown in Figure 12 and the system proposed in the present work.

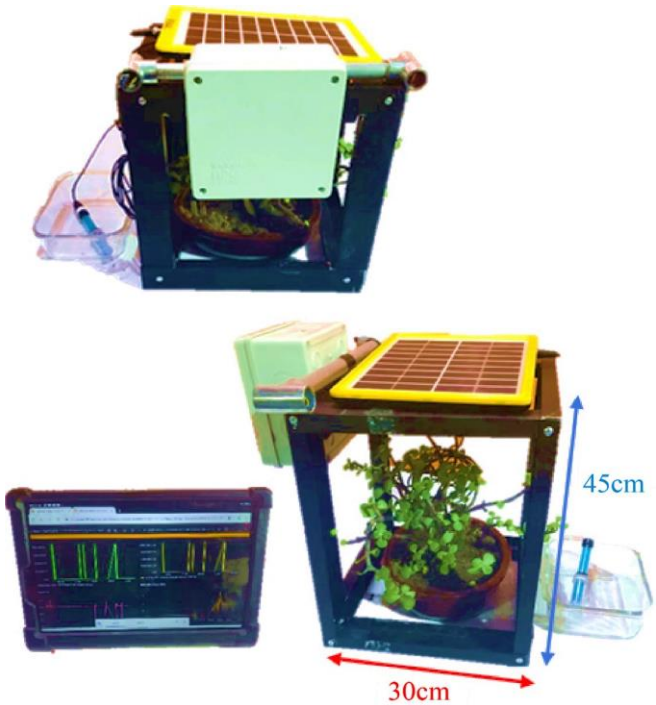

Fig. 11 Installation and assembly of the proposed system

Fig. 12 Conventional instruments for nursery monitoring

Table 6. Final result of the system for monitoring the green nursery

Automatic system	Resulted
Operation days	1 week
Supply voltage to the circuit	5VDC - 1A
Temperature operated in the simulation	18ºC - 27ºC
ML8511 sensor reading (index)	1.5- 6.2
DHT22 sensor reading (%)	75 - 85%
FC38 sensor reading (%)	30 - 90%
Ph – 4502c sensor reading (Ph)	3 - 6 .9 pH
water pump range	5 – 10 Liters

Likewise, by recommendation of the manufacturers, the digital and analog sensors were kept on for 24 hours to obtain more stable data and with the minimum possible error. Therefore, after stabilizing the sensors, Table 6 shows the overall results during the 1-week test period of the installed prototype. On the other hand, in the effectiveness test, the relative error of each magnitude will be found, which is the positive difference between the real value (conventional instrument) and the estimated value of the instrument that we propose, shown in Tables 7 and 8, which shows independently each environmental magnitude.

As can be seen, Table 7 indicates the monitoring of the DHT 11 sensor of the magnitudes of temperature and humidity, in which, when compared with a conventional HTC-2 thermohydrometer, it can be observed that there was a relative error of no more than 1 ° C and 1%. HR. Thus verifying that the proposed instrument is effective in its precision since it is within the range allowed by the DHT 11 family sensor manufacturer.

Table 7. Monitoring of the temperature and humidity of the proposed system

Temperature (°C)			Ambient humidity (%)		
True value	**Middle value**	**Absolut mistake**	**True value**	**Middle value**	**Absolut mistake**
23	23	0	77	78	1
22	23	1	77	78	1
22	23	1	79	79	0
21	21	0	79	79	0
21	22	1	80	80	0
22	23	1	83	82	1
21	22	1	83	82	1
21	21	0	82	82	0

Similarly, Table 8 shows the monitoring of the pH and ultraviolet radiation sensors. Where it was determined that the pH of the water during the test period obtained an average of 6.55 pH, which is in the established range so that the plant can absorb more nutrients from 6.5 to 7.5 pH, as can be seen in the pH levels from Figure 13.

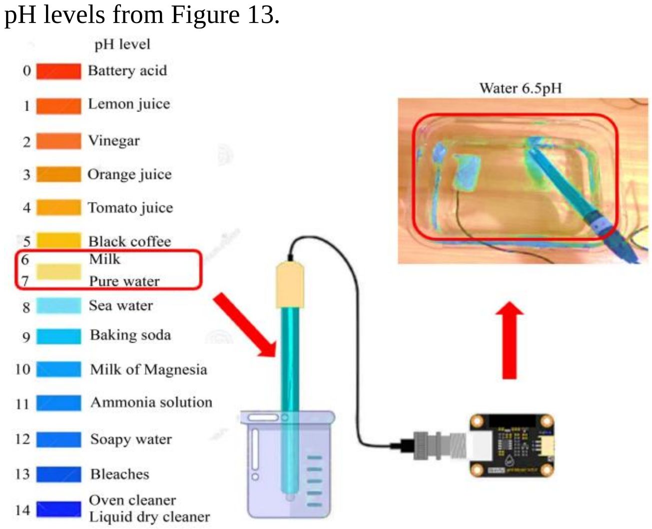

Fig. 13 pH levels

Table 8. pH and UV monitoring of the proposed system

Acidity or alkalinity (pH)			Ultraviolet radiation (Index)		
True value	**Middle value**	**Absolut mistake**	**True value**	**Middle value**	**Absolut mistake**
6.55	6.53	2	4.9	5.0	1
6.55	6.55	0	5.1	5.0	1
6.53	6.54	1	4.9	4.9	0
6.56	6.55	1	4.7	4.7	0
6.55	6.55	0	4.6	4.5	1
6.55	6.56	1	3.5	3.5	0
6.57	6.56	1	2.9	2.9	0
6.56	6.56	0	2.6	2.4	2

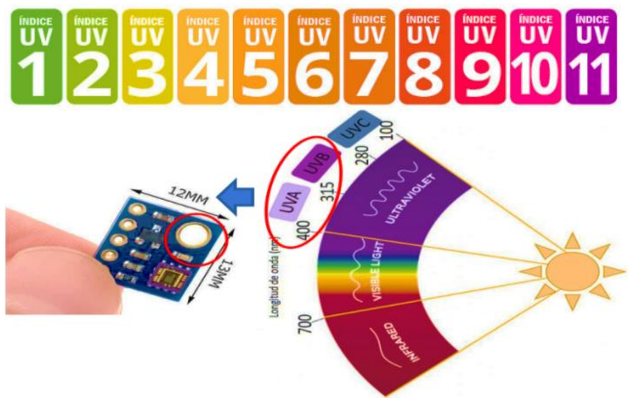

Fig. 14 UV levels

Furthermore, Table 8 shows that the pH sensor obtained an absolute error of no more than +-2, within the range established by the manufacturer.

Additionally, Table 8 also shows the monitoring of ultraviolet radiation, which is established in a range from 1 to 11, as seen in Figure 14, where it shows us the UV levels, as low 1 to 2, moderate 3 to 5, high 6 to 7, very high 8 a 10 and extreme 11 a plus. Likewise, regarding the analysis, it can be observed that the UV had an absolute error of no more than +-2. Likewise, it was verified that work was done at a moderate index level during the test period, representing an average of 4.1.

On the other hand, the test of the solar panel was carried out, where it was agreed to work with a solar panel that generates 9v and 600mA according to the manufacturer, in which, in the respective tests, it was possible to verify that the panel works 100%—generating approximately 10V as shown in Figure 15, reaching the established range to generate a power not greater than 5W that is shown in the manufacturer's characteristic.

Fig. 15 Solar panel test

Fig. 16 IoT system with GRAFANA software for monitoring the municipal green nursery of Mi Perú

Finally, after the respective test, the GRAFANA platform was installed. Figure 16 shows the general statistical tables of environmental magnitudes such as temperature, soil humidity, pH and ultraviolet radiation that will be used in the present monitoring project of the municipal nursery. For this, after observing the statistical graphs, an efficiency comparison was made, already shown in Tables 7 and 8. In addition, it was also possible to verify that the update time for sending data of the ESP32 magnitudes to GRAFANA was not greater than 5 seconds, in which an efficient transmission is considered; if we compare with another IoT environment that its transmission time is slower and does not have the various functions that this software shares with us, which was already shown in Figure 6.

4.2. Discussion

This research work emphasizes an autonomous monitoring system for nurseries and greenhouses, intending to promote afforestation through cheap and easy-to-install electronic systems, as also promoted by the authors of the article [10], who propose a system for the control of domestic plants, through an Arduino uno and sensors such as the DHT 11, LDR and water pump, while our system proposes more sophisticated and up-to-date devices such as the ESP32 that provides us with wireless communication through WIFI, facilitating monitoring through the cloud and using an IoT environment, such as GRAFANA and the Influx db database.

Likewise, in the article [8, 9], the author proposes an automatic irrigation system to improve the productivity of crops in Indonesia, which uses GSM technology and embedded systems; in the first instance, it is known that this system allows the plate to Arduino connect to the Internet, send and receive SMS to monitor the study area. However, currently, some tools facilitate the most optimal process, as proposed in this research work, which uses the IoT to monitor and control the system anywhere in the world. In addition, today, with the help of free tools, it can be monitored in real-time and stored in a database as proposed in the present investigation, where the most appropriate software was selected so that the user or operator can better monitor the study area.

On the other hand, articles [10] and [12] propose a system using Arduino, temperature, relative humidity and soil humidity sensors such as the FC-28, in which this last sensor is commonly used for automation. However, they do not use some sensors that are also used for the correct monitoring of plants in general, such as measuring the pH of the water, which is very important to be in the range of 6.5 to 7.5 pH so that the plants absorb nutrients. In the most optimal way possible at the time of automatic watering. Likewise, it also occurs with the importance of using a UV sensor to control plants' growth and development. For this reason, in the present work, these magnitudes are proposed to generate a multiparameter system. It should be noted that in the article [10, 11], the calibration of the soil moisture sensor is shared as a guide, where it works in different ranges to automate irrigation through the pump and the automation of the cooler through the DHT 22 sensor.

Finally, in the article [13], the author shares his initiative to use the ESP8266 platform, an old version of ESP32, in which he seeks to monitor water quality through a smartphone, using a 4502C pH sensor and a turbidity sensor. In the respective tests, the alkalinity and acidity sensor monitored 6 pH with respect to water quality, as also happened in the system proposed in this work, which averaged 6.55pH with an absolute error of +- 2. Likewise, with respect to the test of other magnitudes, such as temperature and relative humidity, other mean values were obtained since the study area where the monitoring is carried out is located in a different area from that of the article [13]. In addition, it was observed that in the municipal nursery of Mi Perú, there is a high concentration of relative humidity, reaching an average of 80% in the test time, and this is due to the fact that the nursery is located near the Ventanilla wetland that is located in a range of 110 m.s.n.m.

After having made a comparison of various research papers related to monitoring systems for nurseries and greenhouses. It is important to indicate that there are currently several more sophisticated systems, but their cost is very high, both in the installation and in the maintenance and calibration of the sensors, unlike the proposal proposed in the municipal nursery. That is why this article proposes the implementation of an economic system that is easy to install and uses renewable energy through a solar panel, in addition to having a free access IoT platform that will provide better control in the study area. Finally, it seeks to promote this prototype for the correct monitoring of horticultural and ornamental plants produced by the Mi Perú municipal nursery, which seeks to promote afforestation, a very important point to contribute to sustainable development due to excess emissions of CO2 that currently exists on the planet.

5. Conclusion

It is concluded that the system generally works correctly, monitoring the essential environmental magnitudes to correctly control the ornamental plants that inhabit the municipal nursery of the district of Mi Perú.

In addition, it was possible to verify the efficiency of the sensors, compared with other conventional instruments shown in Figure 12, where the system responded in the best way, obtaining an absolute error of no more than +- 2 in each environmental magnitude shown in Table 7. and 8, in which it did not exceed the allowable ranges that the manufacturers indicated for each environmental sensor that was used.

In the same way, regarding the use of ESP32, it was found that it could improve wireless transmission to the cloud using a 3dB amplifying antenna, but everything will depend on where you want to monitor to avoid interference with respect to data transmission in the IoT platform.

Also, the IoT platform performed the best, proving that the data can be exported in an Excel file in easy steps, as shown in Figure 6. Also, the GRAFANA software proved to be very efficient in updating the sensors' data. It takes a maximum of 5 seconds to transmit the data, which, unlike other environments, the GRAFANA software transmits quickly in its free version, which has several options enabled to monitor the study area.

On the other hand, it is recommended that, when installing the system, it is very important to verify that the sensors are correctly calibrated 24 hours before to have a better reading. It is mainly recommended to calibrate the PH 4502C sensor since it must be calibrated with at least 2 solutions for correct monitoring. In addition, working with good quality internet is recommended to monitor the nursery plants in real time. Additionally, regarding the power stage, it is recommended that the solar panel be tilted 90° towards the sun to operate correctly and maintain a power of 5W to charge the 6V 4Ah rechargeable battery constantly.

Finally, as future work, it is sought to make a mobile application that works through Bluetooth so that this platform is a monitoring alternative when there is a problem with the internet, which is the means to monitor the GRAFANA platform. Likewise, since the system is a scalable prototype, for a future project, it is intended to use or add the NPK sensor, which, due to its monitoring characteristics, is considered to be of great help to the agricultural sector. Therefore, it is also sought to modify the system so that it works as a portable system and can be used in different places without much need to install devices. In addition, it seeks to add UV lamps to better monitor plants with artificial lights to promote installing these systems in homes or different parts of the country to contribute to afforestation and sustainable development, which is the purpose of this project.

References

[1] Vasanthakumari Roshni, and Variampally Sankar Harikumar, “Fluoride Contamination in Wetlands of Kuttanad, India: Predisposing Edaphic Factors,” *Eurasian Journal of Soil Science*, vol. 10, no. 1, pp. 61-68, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Villegas Yarleque Mario, Hidalgo Armestar Ronald, and Gretel Fiorella Villegas Aguilar, “Effects of Climate Change on the Production and Yield of Two Agricultural Crops in Piura, Peru 1973-2018,” *Universidad Ciencia y Tecnología*, vol. 24, no. 106, pp. 27-33, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] Chavez Quispe Alejandro, “*Determination of Lead Levels in Adult Residents of the "Virgen de Guadalupe" Human Settlement, MiPerú District, in the Constitutional Province of Callao*,” Thesis EP Toxicología, Universidad Nacional Mayor de San Marcos, 2018. [Google Scholar] [Publisher Link]

[4] Maria Custodio et al., “Ecological Risk due to Heavy Metal Contamination in Sediment and Water of Natural Wetlands with Tourist Influence in the Central Region of Peru,” *Water*, vol. 13, no. 16, p. 2256, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[5] Asmae El Mezouari, Aziz El Fazziki, and Mohammed Sadgal, “Smart Irrigation System,” *IFAC-Papers Online*, vol. 55, no. 10, pp. 3298–3303, 2022. [CrossRef] [Publisher Link]

[6] Jens Breckling, *The Analysis of Directional Time Series: Applications to Wind Speed and Direction*, Lecture Notes in Statistics, Springer-Verlag Berlin Heidelberg, vol. 61, 1989. [CrossRef] [Google Scholar] [Publisher Link]

[7] Nugroho Adi Pramono et al., “Application of Arduino Programming Using ML8511 UV Sensor Hookup Guide to Learning the Effect of Ultraviolet’s Level,” *Journal of Disruptive Learning Innovation*, vol. 2, no. 1, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[8] Sakshi Lahabar, Ajinkya Barapatre, and Lokesh Heda, “IOT - Powered Smart Photovoltaic Charge Controller,” *SSRG International Journal of Electrical and Electronics Engineering*, vol. 10, no. 1, pp. 219-225, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] Salgado José Alberto Fernandes et al., “Design and Experimental Validation of a Compact LowCost Weather Station for Solar Photovoltaic Applications,” *EAI Endorsed Transactions on Energy Web*, vol. 8, no. 34, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[10] M. Anisha et al., “Arduino-based Low-Cost Greenhouse Monitoring System for Small Scale Farmers,” *Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)*, pp. 1120-1127, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[11] T. Godhavari et al., "An Intelligent System for Monitoring Various Parameters in Irrigation System using IoT," *SSRG International Journal of Electrical and Electronics Engineering*, vol. 9, no. 12, pp. 120-125, 2022. [CrossRef] [Publisher Link]

[12] Alem Huayta Uribe et al., “Nursery with Automation and Control Systems to Produce White Chuño (Tunta),” *IEEE International IOT, Electronics and Mechatronics Conference*, pp. 1-5, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] C. T. Kalaivani et al., “Environmental Monitoring and Control System for Greenhouse with Node MCU and GSM Using IoT Devices,” *8th International Conference on Smart Structures and Systems*, pp. 1-4, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Namrata P. Mohanty et al., “Cultivation of Cash Crops under Automated Greenhouse using Internet of Things (IoT),” *International Conference on Communication and Signal Processing*, pp. 235-239, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[15] Kamweru Paul Kuria, Owino Ochieng Robinson, and Mutinda Mutava Gabriel, "Monitoring Temperature and Humidity using Arduino Nano and Module-DHT11 Sensor with Real Time DS3231 Data Logger and LCD Display," *International Journal Of Engineering Research & Technology*, vol. 9, no. 12, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] Rajendra Akhil Kumar et al., "Crop Monitoring using Visual Sensors and IOT," *SSRG International Journal of Electronics and Communication Engineering*, vol. 4, no. 4, pp. 42-47, 2017. [CrossRef] [Publisher Link]

[17] M. Hafizuddin et al., "Development of UV Monitoring System Using Metal Oxide-Based Sensor," *8th International Conference on Mechatronics Engineering*, pp. 120-124, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Murry Raditya et al., "Schematics Monitoring System Temperature, PH and Turbidity Based on LORA (Long Range) to Improve the Quality of the Harvest," *3rd International Conference on Research and Academic Community Services*, pp. 7-11, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[19] Ruby Jon M. Kagalingan, Bernard Piolo M. Tolentino, and Jessie Jaye R. Balbin, "Aiding Plant Growth Difference for Indoor Vertical Garden against Traditional Outdoor Vertical Garden Setup using DHT11 and Capacitive Soil Moisture Sensor," *IEEE International Conference on Automatic Control and Intelligent Systems*, pp. 96-101, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[20] Levente Manases, and Daniel Zinca, "Automation of Network Traffic Monitoring using Docker images of Snort3, Grafana and a Custom API," *21st RoEduNet Conference: Networking in Education and Research (RoEduNet)*, pp. 1-4, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[21] Matsobane K Mahomela et al., "Self-Diagnostic Vital Sign Monitoring System," *International Conference on Electrical, Computer, Communications and Mechatronics Engineering*, pp. 1-6, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[22] Yuliya Zatsarinnaya, Denis Amirov, and Maksim Elaev, "Solar Panel Cleaning System Based on the Arduino Microcontroller," *Ural Smart Energy Conference*, pp. 17-20, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] Anshu Behera, and Prakash S. Kulkarni, "Smart Temperature-Dependent Cooling of Solar Panel using Arduino," *2nd International Conference on Paradigm Shifts in Communications Embedded Systems, Machine Learning and Signal Processing*, pp. 1-6, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[24] Seok-Oh Yun et al., "Flexible pH Sensor and System Fabricated using PET Film," *IEEE Sensors*, pp. 1-3, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[25] Chenglang Li et al., "A Design of Batch Electronic Thermometers Automatic Verification System Based on LabVIEW," *IEEE 11th Conference on Industrial Electronics and Applications*, pp. 1365-1368, 2016. [CrossRef] [Google Scholar] [Publisher Link]