Smart Farming for a Sustainable Future: Automating Hydroponics

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Abstract - **As the population grows, so does food consumption, but the planet has a limited capacity for growing fruit or vegetables. Moreover, there are vast areas of challenging soils worldwide where traditional farming is not feasible. Hydroponics plays a vital role in those areas where crops cannot be grown due to the absence of suitable soils. In a worldwide context, the United Nations called to action through the Sustainable Development Goals. Target 12.1 aims to implement programs on Sustainable Consumption and Production in many countries. Argentina is a country where there is a wide variety of soils, but not all soils are suitable for agriculture. For this reason, the automated hydroponics system is implemented, enabling cultivation in difficult terrain. This paper aims to highlight the significant promise of automated hydroponics for a more sustainable, efficient, and resilient future of agriculture in Argentinian sterile soils. The structure of the paper is organized as follows. Section II presents the problem description, focusing on the challenges posed by sterile soils in Argentina. Section III explores the sensors and Arduino-based boards used in automating hydroponics. Section IV discusses the automation process involved in hydroponics. The anticipated impact of this work is considerable because it addresses critical challenges in agriculture as the global population expands. With traditional farming facing limitations in challenging soils worldwide, hydroponics emerges as a key solution. The use of this type of vertical farming approach has the potential of maximizing land utilization.**

Keywords: **Arduino-based boards, automated agriculture, Deep Flow Technique, hydroponics, soil challenges in agriculture, sustainable and efficient farming.**

Resumen – **A medida que la población crece, también lo hace el consumo de comida, pero el planeta tiene una capacidad limitada para cultivar frutas o vegetables. Además, existen áreas extensas de suelos desafiantes en el mundo donde la agricultura tradicional no es viable. La hidroponía juega un rol vital en esas áreas donde los cultivos no pueden crecer debido a la ausencia de suelos propicios. En un contexto mundial, las Naciones Unidas llamó a la acción a través de los Objetivos de Desarrollo Sostenible (ODS). La meta 12.1 apunta a implementar programas sobre Consumo y Producción Sustentables en varios países. Argentina es un país donde existen una gran variedad de suelos, pero no todos son adecuados para la agricultura. Por esta razón, el sistema de hidroponía automatizada es implementado, habilitando cultivos en terrenos difíciles. Este artículo tiene como objetivo resaltar la importancia de la hidroponía automatizada para un futuro más sostenible, eficiente y resiliente de la agricultura en suelos estériles argentinos. La estructura de este artículo se organiza como sigue. La Sección II presenta la descripción del problema, enfocándose en los desafíos planteados por los suelos estériles en Argentina. La Sección III explora el uso de sensores y placas basadas en Arduino en hidroponía automatizada. La Sección IV discute el proceso de automatización involucrado en la hidroponía. El impacto anticipado de este trabajo es considerable porque trata desafíos críticos en la agricultura a medida que la población mundial se expande. Con la agricultura tradicional enfrentando limitaciones en suelos desafiantes alrededor del mundo, la hidroponía aparece como una solución clave. El uso de este tipo de enfoque de agricultura vertical tiene el potencial de maximizar la utilización de la tierra.**

Palabras Clave: **Placas basadas en Arduino, agricultura automatizada, Técnica de Flujo Profundo, hidroponía, desafíos del suelo en la agricultura, agricultura sostenible y eficiente.**

I. INTRODUCTION

As the population grows, so does food consumption, but the planet has a limited capacity for growing fruit or vegetables. Moreover, there are vast areas of challenging soils worldwide where traditional farming is not feasible.

Hydroponics plays a vital role in those areas where crops cannot be grown due to the absence of suitable soils. Hydroponics is a method of vertical agriculture that eliminates the need for soil by using water-based mineral nutrient solutions [1]. It enables multiple harvests one above the other, optimizing the occupied land area.

In a worldwide context, the United Nations (UN) called to action through the Sustainable Development Goals (SDGs), which are 17 global objectives [2]. Target 12.1 aims to implement programs on "Sustainable Consumption and Production" in many countries, because it is not difficult to do it [3, p. 37]. The low-cost and ease of maintenance associated with automatic hydroponics make it a perfect fit for the Target 2.4 which focuses on the 'implementation of resilient agricultural practices' [3, p. 5].

Furthermore, thanks to photosynthesis, the plants feed on CO_2 and produce O_2. Therefore, they play a vital role in our ecosystem [4]. Although the focus of this paper is on the country of Argentina, it is important to address the global situation at the moment.

Argentina is a country where there is a wide variety of soils, but not all soils are suitable for agriculture. For this reason, the automated hydroponics system is implemented, enabling cultivation in difficult terrain. This system uses Arduino based- boards, which are cheap and versatile, which allows for the automation of the cultivation process through sensors connected to these devices [5].

This paper aims to highlight the significant promise of automated hydroponics for a more sustainable, efficient, and resilient future of agriculture in Argentinian sterile soils. It is essential to continue research, development, and knowledge sharing to unlock the full potential of automated hydroponics, contributing to a sustainable agricultural sector not only in Argentina but also worldwide.

The structure of the paper is organized as follows. Section II presents the problem description, focusing on the challenges posed by sterile soils in Argentina. Section III explores the sensors and Arduino-based boards used in automating hydroponics. Section IV discusses the automation process involved in hydroponics.

The anticipated impact of this work is considerable because it addresses critical challenges in agriculture as the global population expands. With traditional farming facing limitations in challenging soils worldwide, hydroponics emerges as a key solution. The use of this type of vertical farming approach has the potential of maximizing land utilization.

II. SOIL SITUATION IN ARGENTINA

Argentina has a wide range of soil types, as can be seen in Figure 1, which are suitable for various agricultural practices [6]. This project focuses on two significant areas of soil classifications, entisols and aridisols, located mostly in the Patagonia and Cuyo regions.

These distinct soil types' characteristics make them the perfect place for implementing hydroponic cultivation. These soils exhibit low natural fertility and water holding capacity. Additionally, they face challenges such as limited rainfall, high evaporation rates, and low water-holding capacity. The low organic matter content in these soils further complicates traditional agricultural practices [7].

In these regions, not all types of vegetables and fruits can be grown. Since not all crops adapt to these types of soils, the regional production becomes extremely difficult. While entisol soils are suitable for citrus cultivation, forestation with pines, eucalyptus and blueberries, aridisol soils are only conducive to the production of ephemeral grasses, shrubs and cacti. Therefore, the production of leafy vegetables, such as lettuce, arugula, basil, among others, is very scarce [8].

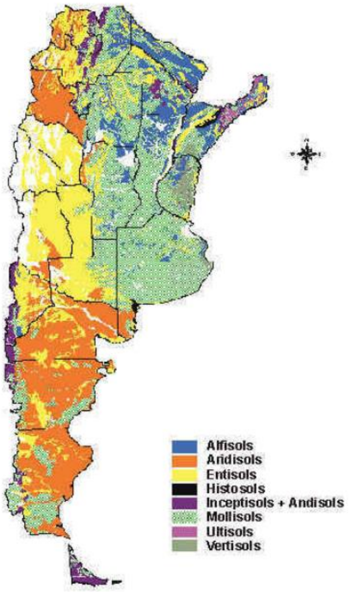

Fig 1. Dominant soil orders in Argentina according to the Soil Taxonomy. [6]

III. AUTOMATED HYDROPONICS SYSTEM DESIGN

Automated hydroponics is important for utilizing these complex soils, considering the constraints in fertility and water retention. It provides a controlled and precise supply of nutrients and water while allowing for optimal environmental conditions for plant growth. This results in increased crop yield and resource efficiency.

In the implementation of automated hydroponics, sensors are connected to an Arduino board. This process is automated and the system is connected to the Internet of Things (IoT) so the automated hydroponics can be operated from homes, offices or any other location.

A. *Arduino*

The Arduino motherboard is widely sold around the world for its ease and practicality. Figure 2 shows this prototype, which is used for the creation of electronic projects since the use of hardware and software is very easy to use [9]. Broadly speaking, this is made up of an 8-bit microcontroller where the pins correspond to both inputs and outputs. These are used to read and write information; the analog pins can detect input voltage values from 0V to 5V, which is translated between the values 0 and 1023. These represent 0 when there is no potential difference at the input and 1023 when there is 5V. As for the digital pins, they can be used to receive or transmit information either in parallel or in serial format.

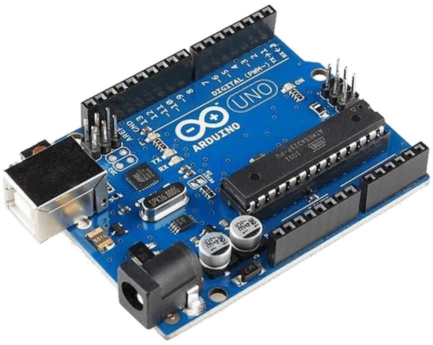

Fig 2. Arduino Uno. [9]

B. *Sensors*

The sensors used in this project are three: DTH11, TEMT6000 and SEN0161. These were chosen for their cost-effectiveness and efficient performance. The DTH11 sensor (Fig. 3) is responsible for controlling both temperature and humidity. It is powered with a 5V supply and has four pins. Pins one and four are designated for power, pin two is used to transmit serial data and pin three is not usually connected. The transmitted data consists of 40 bits, with the first 16 bits representing the humidity value, the next 16 bits representing the temperature values and the last 8 bits being the check-sum. The check-sum is a method used to verify that the data transmitted is correct. In other words, it ensures that the data is correct in case of any errors [10].

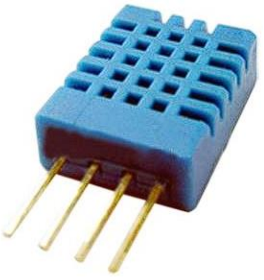

Fig 3. Sensor DTH11. [10]

Figure 4 depicts the TEMT6000 sensor. This sensor is used to measure light intensity, and it works in a simpler way. Since this sensor uses a phototransistor and a resistor, the phototransistor works as a variable resistor when it is excited by light at the base, so its impedance varies, generating a variation in current.

Fig 4. Sensor TEMT6000. [11]

This combination between the phototransistor and the resistor generates a resistive divider which is used to obtain potential differences ranging from 0V to 5V. This sensor has three pins (Fig. 5): VCC and GND for power, and OUT for the measured value [11].

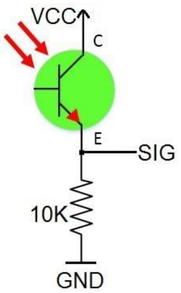

Fig 5 Circuit of the Sensor TEMT6000. [11]

The SEN0161 sensor is used to measure pH. To power the sensor, it is connected to a 5V source. After that, the pH electrode is connected to the pH meter board, and the board is connected to the analog port of Arduino. Immerse the pH electrode in a solution with a pH value of 7.00 or cut off the BNC connector and open the serial monitor in the Arduino IDE to check the pH value [12]. Calibration is essential for the correct operation.

Fig 6. Sensor SEN0161. [12]

C. *Bluetooth Module*

Communication between the main Arduino board and sensor is critical, and efforts must be made to minimize errors. There are two main factors to have in mind, one is the connection technology and the other is the protocol. Bluetooth has been chosen as the technique used to link the main board with the sensors over long distances, due to the fact that wired connections produce data error when the distance is longer than 10 centimeters [10].

The module implemented is the HC-06 which has a relative good linking distance, around 100 meters of radius which guarantees a broad coverage area [12]. Its installation is relatively simple. It is only necessary to connect one module in the master configuration on the main board and one for each area to be scanned in the slave configuration. With the implemented code, the master Bluetooth module will send a signal that the slaves will react to by sending back the sensor data.

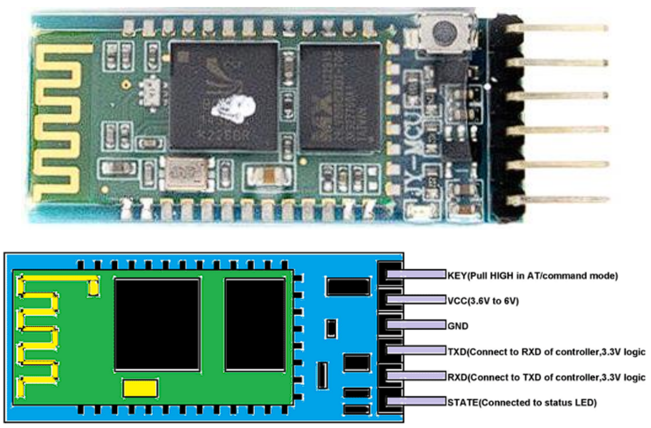

Fig 7. Bluetooth Module HC-06. [13]

D. *Connection*

With long-range communication covered, now it is time to delve into the protocol. The Inter-Integrated Circuit (I^2C or I2C) is an advanced communication method designed by Phillips Semiconductors that allows messaging between various masters (controllers) and slaves (targets) as can be observed in Figure 8 [14].

Figure 9 shows that in this protocol, “messages are broken up into frames of data. Each message has an address frame that contains the binary address of the slave, and one or more data frames that contain the data being transmitted” [15].

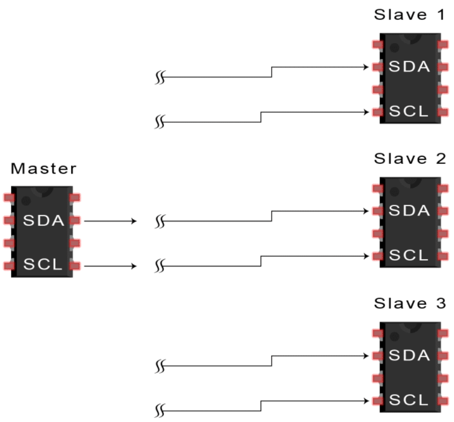

Fig 8 Example of master-slave communication. [15]

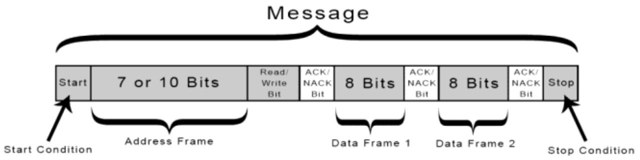

Fig 9. Message composition. [15]

IV. CULTIVATION TECHNIQUE AND AUTOMATION

Hydroponics involves a constant flow of a mix of water with liquid and soluble nutrients, including Nitrogen, Phosphorous, Iron, Potassium, among others. Therefore, this kind of cultivation requires a pump system [16].

To control this flow, [17] indicates that it is common to use the Nutrient Film Technique (NFT), which consists in having the plants held on a sloped stray. However, the Deep Flow Technique (DFT) is recommended in this paper, which differs from the previous one in the amount of liquid flowing through and its excess, mostly water with little few nutrients, comes back to the solution tank.

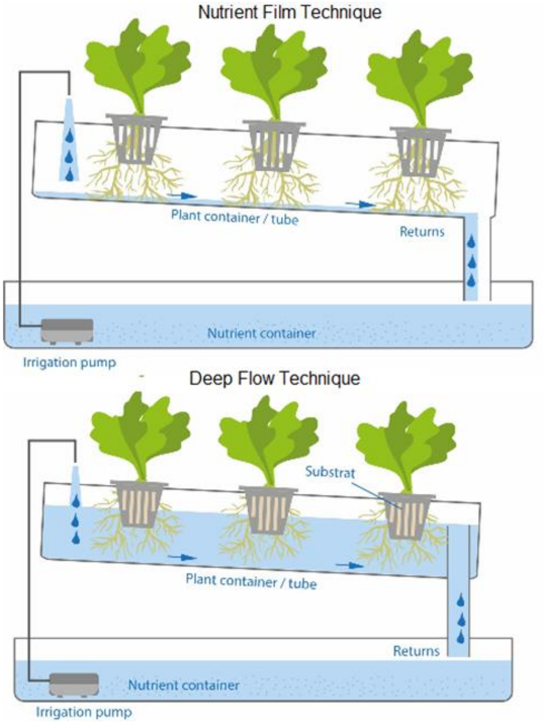

Fig 10. Hydroponics techniques. [17]

With this in mind, the Arduino main board is set to activate the pumps at calculated time lapses, according to the volume of the solution flowing and the return rate, or when the sensors detect an unusual behaviour like low PH or high temperature. Also, this process could be manually interrupted through an interface accessed by the user through the Internet of Things (IoT) or through simple manual labour. All sensor data are stored for user analysis. Therefore, farmers could use this information to increase their productivity.

V. CONCLUSION

Smart hydroponics aims to create a fully automated system that is low-cost and user-friendly that can facilitate the cultivation of plants that are not suited to the challenging environments of the Patagonia and Cuyo regions. Through the use of Arduino boards, open-source software and diverse sensors, this goal can be accomplished, transforming this dessert kind of lands into a source of food for locals and people in the country. The automated hydroponic system maintains the parameters needed for the test plant to thrive and is able to incorporate an IoT network for remote monitoring and control.

A few advantages of this system include complete control over the aspects that allow a plant to grow, customization to suit the needs of various plants, and independence from the external atmosphere or environment to succeed.

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The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar