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Vertical AgriTech: Revolutionizing Agriculture with Intensive Cultivation and Artificial Illumination

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Dedication

Thank God with love, gratitude, and thanks for the beginning and the end.

I see the master's phase nearing its completion already, after five years of toil and hardship in pursuit of dreams and knowledge. Within its folds, it carried the wishes of nights, and today my labor becomes a delight to the eye.

Here I stand at the threshold of my graduation, reaping the fruits of my labor and proudly tipping my hat.

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To the one who adorned my name with the most beautiful titles, who supported me endlessly and gave without expectation, my father Ibrahim, without forgetting the pure souls of my uncles Ahmed, may God have mercy on them.

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Dedication

In the name of Allah, my Creator, yesterday's effort was not wasted in a day or in vain , neither the journey was short, and it shouldn't be, nor the dream was close, nor the road was easy, but whoever said, I'm for it he got it, and I am for it, and even if it declines against my will, I'll reach it anyway.

I dedicate this great piece of success:

To the one whom Allah has endowed with prestige and dignity, to the one who gave my name the most beautiful title, to the one who was the strongest motivator to pursue the journey of a thousand miles My dear father, my pride may God keep you my greatest hero .

To the one whom God honored with a heart full of love and tenderness, to the one whom God made my paradise under her feet, to the one whose prayers were the secret of my success and happiness, to My dear mother may God save you, you are the paradise of my heart .

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Abstract

In the current era, introducing technology into daily life has become very common in modern societies, where technological developments are advancing day by day and spreading in all areas of life. This thesis deals with the thesis of a miniature smart indoor and outdoor farms project in the context of smart agriculture.

This thesis aims to utilize Internet of Things (IoT) technologies, by designing a small-scale automatic hydroponic irrigation system, to facilitate the irrigation of agriculture. The aim is to design and implement a prototype of an automatic hydroponic irrigation system for indoor and outdoor use, to reduce excessive water consumption, increase the efficiency of old irrigation systems, facilitate water saving and keep plants moist, thus reducing the manual labor burden and inefficient use of water. Small farms are a solution for people with limited space at home. Automated smart farms provide an effective way for people to control and supervise climatic factors, promoting healthy crop growth and more efficient use of resources. By taking advantage of height, a vertical hydroponic system can be set up in warehouses, containers, and backyard kitchen gardens. Compared to the productivity of a regular hydroponic system per unit area will be 5 to 20 times higher depending on the hydroponic infrastructure

KEYWORDS: Hydroponic, Automation, Sensors, Control, Garden.

Résumé

À l'ère actuelle, l'introduction de la technologie dans la vie quotidienne est devenue très courante dans les sociétés modernes, où les développements technologiques progressent jour après jour et se répandent dans tous les domaines de la vie. Cette mémoire traite de l'étude d'un projet de mini-fermes intelligentes intérieures et extérieures dans le contexte de l'agriculture intelligente.

Le mémoire vise à utiliser les technologies de l'Internet des objets (IoT) en concevant un système d'irrigation hydroponique automatique à petite échelle, afin de faciliter l'irrigation de l'agriculture. L'objectif est de concevoir et de mettre en œuvre un prototype de système d'irrigation hydroponique automatique pour une utilisation intérieure et extérieure, afin de réduire la consommation excessive d'eau, d'augmenter l'efficacité des anciens systèmes d'irrigation, de faciliter l'économie d'eau et de garder les plantes humides, réduisant ainsi la charge de travail manuel et l'utilisation inefficace de l'eau. Les petites fermes sont une solution pour les personnes disposant d'un espace limité à la maison. Les fermes intelligentes automatisées offrent un moyen efficace pour les personnes de contrôler et de superviser les facteurs climatiques, favorisant une croissance saine des cultures et une utilisation plus efficace des ressources. En tirant parti de la hauteur, un système hydroponique vertical peut être installé dans des entrepôts, des conteneurs et des jardins de cuisine arrière. Comparée à la productivité d'un système hydroponique régulier, la productivité par unité de surface sera de 5 à 20 fois supérieure selon l'infrastructure hydroponique.

MOTS-CLÉS : Hydroponique, Automatisation, Capteurs, Contrôle, Jardin.

ملخص

في العصر الحالي، أصبحت إدخال التكنولوجيا في الحياة اليومية أمرًا شائعًا جدًا في المجتمعات الحديثة، حيث تتقدم التطورات التكنولوجية يومًا بعد يوم، وتنتشر في جميع مجالات الحياة. تتناول هذه المذكرة دراسة مشروع مزارع داخلية وخارجية ذكية مصغرة في سياق الزراعة الذكية.

تهدف هذه المذكرة إلى استخدام تقنيات الإنترنت الأشياء، من خلال تصميم نظام للري الهيدروبوني التلقائي بمقياس صغير، لتسهيل عملية ري الزراعة. الهدف هو تصميم وتنفيذ نموذج أولي لنظام ري هيدروبوني تلقائي للاستخدام في الأماكن المغلقة والمفتوحة، لتقليل الاستهلاك المفرط للماء، وزيادة كفاءة أنظمة الري القديمة، وتسهيل توفير الماء والحفاظ على رطوبة النباتات، وبالتالي تقليل العبء اليدوي للعمل والحد من استخدام الماء بشكل غير فعّال. تعتبر المزارع الصغيرة كحل للأشخاص الذين يعانون من ضيق المساحة في البيوت. توفر المزارع الذكية بشكل آلي وسيلة فعالة للأشخاص في التحكم والاشراف على العوامل المناخية، مما يعزز نموًا صحيًا للمحاصيل واستخدامًا أكثر كفاءة للموارد. وذلك من خلال الاستفادة من الارتفاع .يمكن إنشاء نظام الزراعة المائية العمودي في المستودعات والحاويات وحدائق المطبخ في الفناء الخلفي. مقارنة بإنتاجية نظام الزراعة المائية العادي لكل وحدة مساحة ستكون أعلى بنسبة 5 إلى 20 مرة اعتمادًا على البنية التحتية للزراعة المائية.

الكلمات المفتاحية: الزراعة المائية، الأتمتة، المستشعرات، التحكم، الحديقة.

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List of abbreviations

$: dollar.

% : percent.

°C : degrees Celsius.

10 ech/sec : 10 Hz.

3D : three Dimentional.

A : Ampers.

AC : Alternating Current.

AD : Anno Domini (In the year of our Lord).

ADC : Analog To Digital Converter.

AOAD : Arab Organization For Agricultural Development.

CE : Conductivity Electrical.

CO_2 **:** Carbon Dioxide.

CSA : Climate Smart Agriculture.

DAC : Digital To Analog Converter.

DC : Direct Current.

DHT11 : Digital Humidity Temperature type 11.

DMA : Direct Memory Access.

Drs : Doctor.

EC : Electrical Conductivity.

ENSA : NHSA : National Higher School Of Agronomy In Algeria.

ESP32 : Espressif Systems Part 32.

FAO : Food And Agriculture Organization.

G : Grams.

GMO : Genetically Modified Organism.

GND : Ground.

GPIO : General Purpose Input/Output.

GPS : Global Positioning System.

GSA : Global Smart Agriculture.

h : hour.

N_3PO_4 **:** Acide Phosphorique.

I2C : Inter Integrated Circuit.

I2S : Inter-IC Sound.

IDE : Integrated Development Environment.

INRA :NIAR: National Institute Of Agronomic Research .

IoS : Internet of Services.

IoT : Internet of Things.

ITCMI : Technique Institute Of Vegetable And Industrial Crops In Algeria .

KB : KiloBytes.

KHz : KiloHertz.

L : Liter.

LDR : Light Dependent Resistor.

LM393 : Linear Monolithic 393.

MAC : Media Access Control.

MB : MegaByte.

mm : :millimeter

MMC : Multi Media Card.

MMU : Memory Management Unit.

MPU : Memory Protection Unit.

mΩ : milliohms.

NASA : National Aeronautics And Space Administration .

NFT : Nutrient Film Technique .

NH_3 : ammonia.

NOx : nitrogen oxides.

O_2 : Oxygen .

PH : Potential of Hydrogen .

PPM : Parts Per Million.

PWM : Pulse Width Modulation.

Q : Coulomb.

QSPI : Quad Serial Peripheral Interface.

RFID : Radio Frequency Identification .

RH : Relative Humidity.

ROM : Read Only Memory.

SD : Secure Digital.

SDIO : Secure Digital Input/Output.

SPI : Serial Peripheral Interface.

SRAM : Static Random Access Memory.

ST045 : Sensor ,T : Tank or Type.

TDS : Total Dissolved Solids.

TOR : Toggle On / Off Relay.

TTL : Transistor-Transistor Logic.

UAE : United Arab Emirates.

UAN : Unmanned Aerial Vehicle.

UART : Universal Asynchronous Receiver Transmitter.

UK : United Kingdom.

V : Voltage.

VCC : Positive Power Supply Voltage.

General Introduction

If there is something that all beings on this planet have sought from time immemorial, and have done so throughout time, it is water. This resource is fundamental to life due to its simple chemical composition of two atoms of hydrogen and one atom of oxygen, from which everything and everyone arises, it is the common element of all living beings. Since time immemorial, we have been interested in storing it and directing it to our liking, we have created countless wonders that enable it to be transported anywhere, countless structures have been built to supply water that today give us the opportunity to have water for all our needs, we use it however we want, it cleans us, nourishes us and helps us grow, we know it is synonymous with life, health, beauty and purity, it is a natural resource that we must preserve.

Approximately two-thirds of all water used in the world is used in agriculture, and the proportion is higher in arid and semi-arid regions with strong agricultural development. In the near future, the growing need for food, as a result of the expected increase in the world's population and the improvement of their quality of life, will increase the demand for water to irrigate crops and increase competition for this ever-decreasing resource. In this context, there is a growing social demand for more productive and sustainable use of water and better knowledge of its use in agriculture.

Irrigation systems are fundamental to agricultural development, so their improvement is essential. Improving the performance of these systems is no longer a luxury but a necessity, as it allows to alleviate part of the water wastage that arises in most non-technical irrigation processes. Currently, various types of irrigation systems can be found, which, despite the passage of time, are subject to constant revision, as they extend with the development of society. Green spaces are not a luxury but a necessity, and irrigation is the most important and necessary way to maintain them. Although in recent years automatic control and management systems have been developed, the few systems that have found great acceptance in application are due to the consumption of labor, time and training to operate them and provide them with data and information, in addition to the lack of sufficient knowledge about the results they achieve on water consumption and crop or plant yields.

This thesis aims to design a smart indoor and outdoor farm by exploring different aspects of smart hydroponic farming with a focus on designing an automated and manual control and monitoring system for environmental parameters. We will use sensors, microcontrollers, and mobile applications to collect and analyze data, enabling precise control of plant growth conditions.

This thesis is divided into four chapters, each of which addresses an important aspect of the thesis of smart garden. In this general introduction, we provide an overview of the context, objectives, method, results, and structure of the thesis.

The methodology of this thesis includes building a model of an automated indoor and outdoor smart farm, integrating sensors and actuators, developing a mobile application, and conducting tests and experiments to evaluate the efficiency of the system. The results of this thesis will be presented in the chapter dedicated to implementation and development, we will discuss the performance of the monitoring system, features of the mobile application, and potential benefits of indoor and outdoor miniature farms in smart farming.

Regarding the structure of the thesis, we have four main chapters, covering respectively the general aspects of hydroponic agriculture, the description of smart agriculture, Smart Mini Farm Model, the materials and software used, as well as the implementation and development of the system. Each chapter provides specific information to deepen the understanding of the topic.

Overall, this thesis aims to explore the potential of smart indoor and outdoor farms in modern agriculture, focusing on the benefits of precise (automatic and manual) control of environmental parameters to optimize productivity.

Chaptre I:

Generalities of

Hydroponic Agriculture

Chaptre I : Generalities of hydroponic Agriculture

I. 1 introduction

This chapter provides an introduction to hydroponics in particular, including its definition, objectives, importance in the world and in Algeria, different types of hydroponic systems and their components, as well as their requirements and favorable conditions these guidelines have been defined to achieve two objectives: Maximize the production of the mini-farm and protect the crop from diseases during its growth.

I. 2 Definition

The word "hydroponics" is derived from two Greek words: "hydro" meaning water, and "ponos" meaning labour[1].

Figure I-1: Hydroponic garden[1].

Simply put, hydroponics is the art of growing plants without soil (Figure I-1). Usually, people imagine growing plants that grow with their roots suspended in water without soil, and this is only one form of hydroponic gardening known as the Nutrient Film Technique (NFT). There are different form of hydroponic gardens used all over the world, and it is a popular method of hydroponics[2].

Another benefit is that there is no need for crop rotation, only one type of plant can be grown for years with the same production efficiency, and it is impossible to achieve elimination of seasonal or seasonal production with traditional methods, such as picking strawberries in the winter. Hydroponics requires less water than conventional farming, as water is recycled in a closed cycle and used over and over again for the plants[2].

I. 3 History

Hydroponic gardens, a marvel of modern science, now yield abundant harvests of fruits, vegetables, grains, herbs, and flowers in previously inhospitable locations. These gardens produce the healthiest crops with optimal yields and vitamin content, thanks to precisely balanced nutrient solutions and controlled environments. They play a crucial role in feeding millions worldwide, offering superior-quality produce year-round. Though some American consumers remain wary due to past experiences, modern hydroponics has evolved into a premium product. Even NASA has developed advanced hydroponic methods. Despite appearing as a recent innovation, hydroponics has ancient roots [3].

Hundreds of years ago, people in China, India, and Egypt would put animal dung in bowls of water, let the dung ferment in the water, and then use those bowls by putting vegetables and fruits like cucumbers and carrots in them for planting. This is also done in the hanging gardens of Babylon to grow plants. Hydroponics was discovered in its modern concept in 1919 when a student at the University of California succeeded in growing a tomato plant in a nutrient solution, and since then the name of agriculture in water or hydroponics has gained later during the years 1961 and 1971 AD, commercial nurseries that follow this method of cultivation began to spread in many countries such as the UAE, Belgium, Germany, Denmark, Norway, the United States of America and others.

It is worth noting that this type of cultivation has existed since ancient times, as the rules of hydroponic gardening have been proven to have been used since ancient times, then it was recognized in the United States of America and gained popular interest there by a doctor in 1937.

He introduced the word hydroponics through the Greek words for water and labor to demonstrate the validity of his vision. He presented large tomato plants grown through hydroponics. Hydroponics was briefly enthusiastically embraced, but scientists developed and studied methods of cultivation despite the lack of public interest, and in World War II, soldiers on Pacific islands grew the vegetables they needed for lunch using hydroponics.

In the 1960s, large commercial greenhouses and large-scale hydroponic farms were established in several regions across the United States[4].

I. 4 Comparing Hydroponics to soil cultivation

Soil-based cultivation is the more traditional of the two methods. In fact, it's the one that most closely mimics the natural process. In practice, this means that growers have fewer parameters to control, as the soil does most of the work. Naturally occurring nutrients help maintain the plant's pH levels. These nutrients can also be added to the soil manually, allowing it to act as a buffer for the plant's pH. Depending on what you're growing, the taste of the plant may be influenced[5].

Hydroponic systems, on the other hand, don't use soil at all, but rather water, as the name suggests. Plant roots are suspended in a liquid solution containing a balanced mix of the nutrients they need to grow. This offers greater control over nutrients, which the plant does not need to search for, as they are directly accessible to it in highly soluble form. This technique is known as the "nutrient filter".

There are other methods of setting up a hydroponic system, where plants are not simply suspended in water without a substrate (such as sand, gravel or coconut fiber, for example). The choice of substrate depends on the type of cultivation. The substrate itself provides no nutrients to the plant, as it is the hydroponic drip system that controls the plant's pH and nutrient levels[5].

I. 5 Different hydroponics system

The difference between active and passive hydroponic systems lies in the way water (or air) is transported :

I. 5. 1 Active and passive hydroponic systems

I. 5.1.a) Passive hydroponic system:

The properties of the substrate (or a wick) are used by a passive hydroponic system to transport water and nutrients to the roots by capillary action. Distracted plant lovers will appreciate these systems, as water is always delivered to the plants, and all they have to do is refill the nutrient solution reserve As shown in Figure I-2 [6].

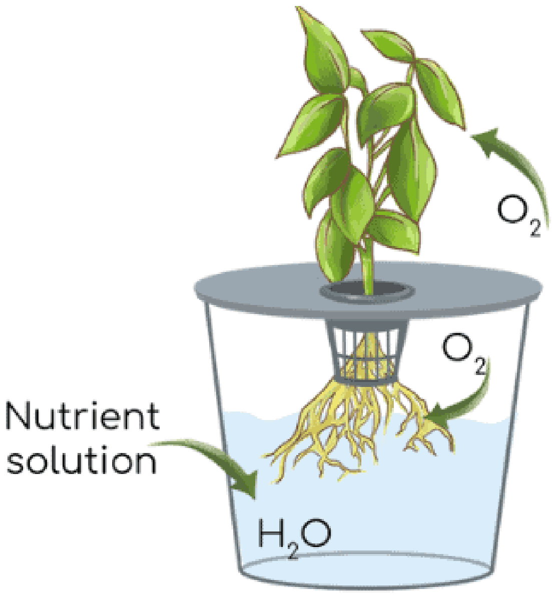

Figure I-2 Passive hydroponic system[2].

I. 5.1.b) Active hydroponic system

To distribute the nutrient solution, it is necessary to use pumps that convert electrical energy into mechanical energy.

Active hydroponic systems are the most efficient irrigation is activated when necessary and in the right quantities, according to the plants' needs. In an active system, the circulation of the nutrient solution promotes an increase in oxygen (O_2) concentration and homogenization of the nutrient soup. Unlike passive systems, they also offer the possibility of water saturation/dry substrate cycles. Plants such as the Rose Laurel and Nerium oleander require alternating periods of irrigation and drought in order to flower As shown in Figure I-3 [6].

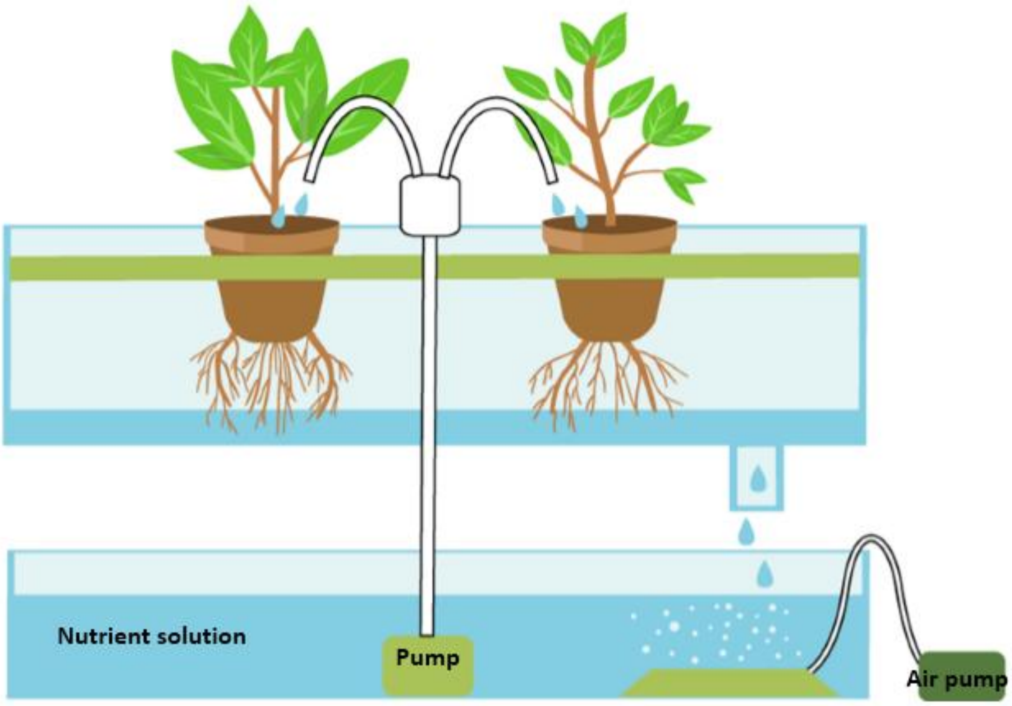

Figure I-3 : Active hydroponic system[3].

I. 5. 2 Hydroponic systems with and without substrate

I. 5.2.a) Systems without substrate (liquid culture)

Plants rest on roots, cardboard, plastic, wood or wire, and the roots are constantly or temporarily immersed in a nutrient solution.

These systems include tube culture, nutrient film technique (NFT) and hydroponic flooding ,most of which reuse the nutrient solution[7].

a.i Aquaculture

In aquaculture, the nutrient solution is stored in a tank (Figure I-4).

Figure I-4 : Aquaculture system [4] [5].

To avoid smothering the roots, the nutrient solution must be enriched with oxygen using complex technological processes, so aquaculture remains a useful system for research purposes and less developed in practice[7].

a.ii Nutrient film technique (N.F.T.)

NFT uses a constant spray or drip of water to irrigate the roots with the nutrients they need. So that In theory, providing optimal conditions for the roots enables faster growth as long as the plant can tolerate it (Figure I-5).

Nutrient film technique was developed in the late 1960s by Drs. Allan Cooper of the Greenhouse Research Institute, Little Hampton, UK, in parallel with numerous other improvements.

The main advantage over other NFT systems is that less nutrient solution is needed ,This makes it easier to heat the solution in winter to achieve optimum temperatures for root growth, and to cool the solution during hot summers in arid or tropical regions[5].

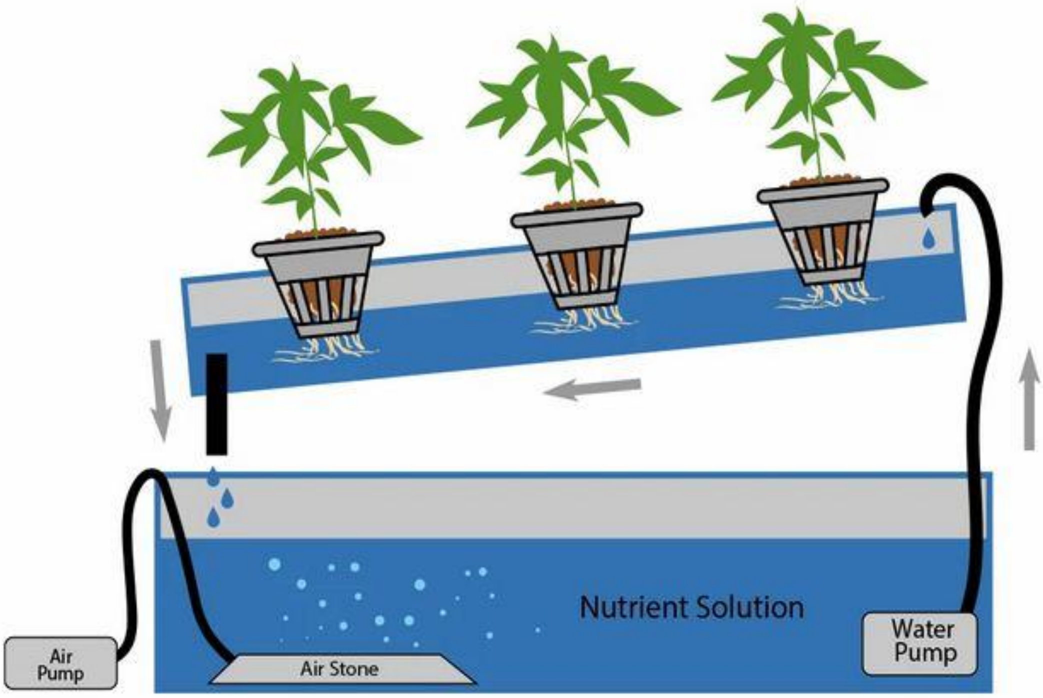

Figure I-5 : Nutrient film technique[6].

I. 5.2.b) Systems with substrates:

This technique is the closest to what happens in the soil in traditional cultivation, with alternating irrigation and drainage.

Moreover, unlike non-substrate techniques, the substrate also provides water and nutrient reserves, and uses a solid support to help supply oxygen, In addition there are numerous disadvantages when it comes to renewing and recycling the substrates used[8].

b.i Tidal table system (Flux-reflux):

Also known as "flood gutters", they consist of a watertight table with a rim, The table is periodically flooded with water from a reservoir when the table is full, water is supplied to the board and the pump automatically stops and drains the water (Figure I-6).

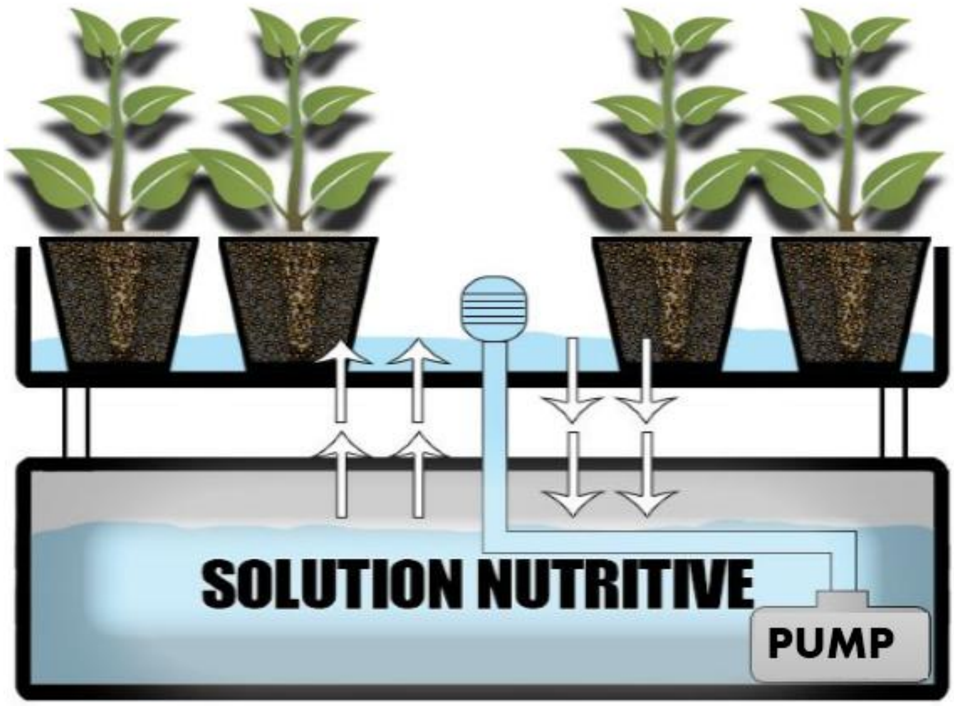

Figure I-6 : Tidal table system (Flux-reflux)[7].

This type of small system is available from brands specializing in hydroponics. Buying a complete system is easier than searching for individual parts.

Of all living-water hydroponic systems, tidal cards are the least expensive to install and require minimal maintenance, They rarely pose plumbing problems, Since only relatively thick pipes are used, the risk of clogging is lower[8].

b.iiDrip systems

These configurations employ a pump to transport water over the substrate via a drip system. The water flows through the substrate, returns to the reservoir, and is ready for reuse. Drip systems are simple to install. Water is pumped from a reservoir, usually placed under the planting area, to the drippers, one for each plant (Figure I-7). Plants can be placed in individual pots or on a common tray. Water flows through the pots and back to the reservoir. Reservoir capacity should be around 40 L/m² of planting. Companies specializing in hydroponics offer a variety of innovative drip systems. Some reuse water from each pot, with one plant per pot. Others reuse water from a central reservoir. Both methods work efficiently[8].

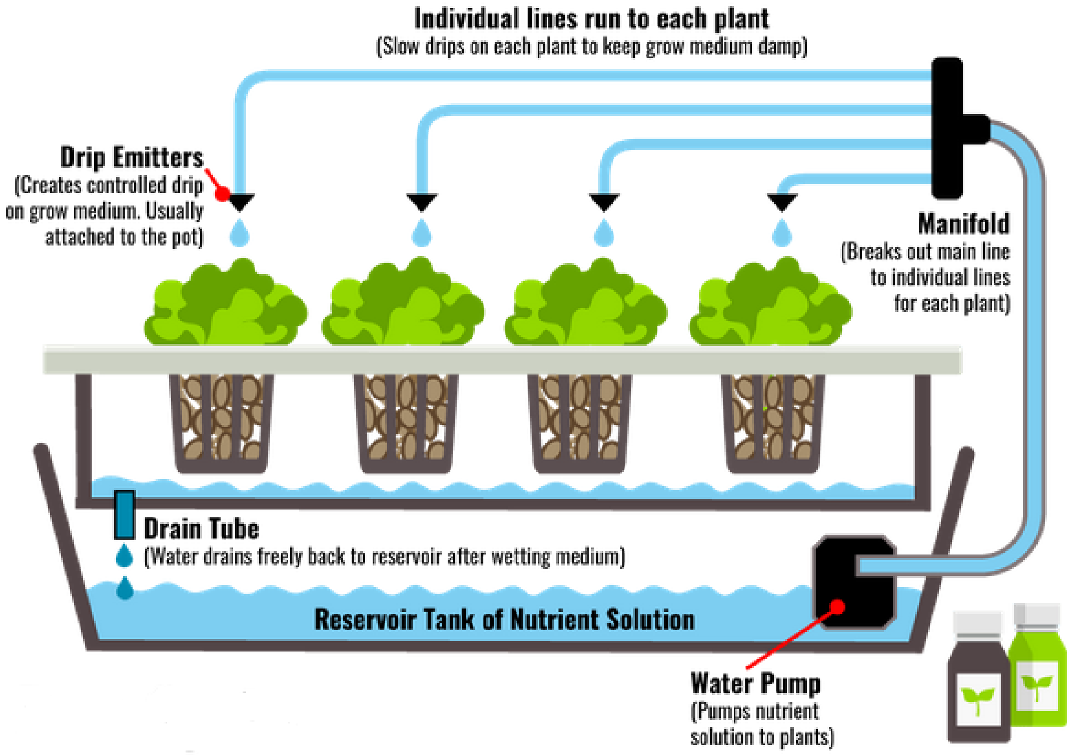

Figure I-7 : Drip systems[8].

b.iii Continuous-flow system

This system is generally small-scale, consisting of several small units. It has a wide range of applications, mainly in the cultivation of culinary or aromatic plants. Plants are grown in opaque containers, usually filled with clay balls, as this substrate reduces waste production and prevents clogging of the reservoir below. To protect the roots from damage, an air pump sends the nutrient solution through a pumping column, then distributes it via a distribution ring[8].

b.iv Mineral origin

- Natural (extracted): gravel, sand, pozzolan.
- Manufactured: rock wool, glass wool, expanded clay, vermiculite, perlite.

b.vOrganic origin

- Natural: peat moss, potting soil, red cedar, pine bark, coconut fibres.
- Synthetic: expanded plastic materials, polystyrene beads, polyurethane foam, water granules.

Table I-1: The principal substrates used in hydroponics.

Organic substrate	**Mineral substrates**
Coco Coir [9]. 	Expanded clay[12]. 
Peat[10]. 	Rock wool[13]. 
Potting soil[11]. 	Vermiculite [14]. 

I. 6 Hydroponic requirements and supplies

Hydroponics needs supplies and tools to be successful. It differs from land-based farming with soil in that if we don't have all the supplies, we can't do hydroponics(Figure I-8). That's why hydroponics is expensive to set up. Here, we will introduce you to the tools and supplies needed to grow plants with water (hydroponics).

Figure I-8 : Hydroponic ponds[15].

The practice of hydroponics, often carried out in soilless systems, generally requires a higher level of care and maintenance than that observed in traditional open-ground cultivation. When using hydroponic growing techniques, mainly in greenhouses or shelters, it is imperative to consider the whole system rather than focusing on isolated elements or parameters. The success of hydroponic cultivation depends on total control of Appropriate lighting, including artificial devices and timers[7].

- A controlled and maintained cultivation and irrigation system, including containers, submersible or conventional water pumps, control and disinfection devices, and suitable substrates.

- Rigorous environmental control, including ambient and solution temperatures, relative humidity and carbon dioxide enrichment.
- Monitoring of nutrient concentration levels using a conductivity meter (EC meter).
- Regular monitoring of water and nutrient solution pH using a pH meter.

I. 6. 1 The nutrient solution

Scientific research by agronomists and biologists has led to the development of a nutrient solution (Figure I-9)and an optimal environment for crop growth[9]. This includes :

Figure I-9 : Nutrient solution[16].

- A balanced supply of mineral and organic elements for plants.
- Water supply adjusted to plants' specific needs.
- Good oxygenation of the root system.
- Permanent air circulation around foliage.
- The use of natural bio-stimulants, such as seaweed extracts, to promote plant growth.

Certain organic compounds, such as iron chelates, may also be present in the nutrient solution. Each organic element plays a crucial physiological role, and its absence can compromise the life cycle of the plant as a whole ,There are two main categories of nutrients.

- Mineral salts: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Chlorine (Cl), Magnesium (Mg), Sodium (Na), Sulfur (S), etc.

- Trace elements : Iron (Fe), Copper (Cu), Bromine (Br), Cobalt (Co), Zinc (Zn), Aluminium (Al), Silicon (Si), Manganese (Mn), Molybdenum (Mo), Iodine, Selenium, Vanadium, etc.

Among the various factors influencing hydroponic systems, the composition of the nutrient solution is widely recognized as one of the main determinants of crop yield and quality. A hydroponic nutrient solution consists of an aqueous solution containing mainly inorganic ions derived from soluble salts containing the elements essential for higher plants. In addition to these ions, certain organic compounds such as iron chelates may also be present. An element is considered essential if it plays a clear physiological role, and its absence completely hampers the plant's life cycle.

Currently, 17 elements are recognized as essential for most plants(Table I-2), including carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel. With the exception of carbon (C) and oxygen (O), which are supplied by the atmosphere, the other essential elements are obtained from the growth medium. In addition, elements such as sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine, among others, are considered beneficial because some of them can stimulate growth, offset the toxic effects of other elements, or even replace essential nutrients in less specific roles. Basic nutrient solutions generally contain nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, supplemented by micronutrients.

The nutritional composition of the nutrient solution influences the solution's electrical conductivity and osmotic pressure, while other parameters such as those detailed below also play a crucial role in defining an optimal nutrient solution.

I. 6.1.a) Nutrient solution management

When it comes to nutrient solution management, although achieving optimum nutrition is relatively straightforward in soilless cultivation, incorrect management can lead to plant damage and even total crop failure. It's crucial to carefully monitor the pH, temperature and electrical conductivity of the nutrient solution, and to replace the solution whenever necessary. This meticulous approach will guarantee the success of an above-ground garden[9].

Table I-2 : Nutrients and their concentration in the nutrient solution (ppm)[1].

Element	Minimum	Upper limit	Optimal limit
Nitrogen	50	300	150-200
Phosphorus	20	200	50
Potassium	50	800	300-500
Magnesium	25	100	50
Calcium	125	400	150-300
Iron	3	12	5
Manganese	0.5	2.5	1
Zinc	0.05	2.5	0.1
Copper	0.05	1	0.1
Boron	0.1	1.5	0.3-0.5
Molybdenum	0.01	0.1	0.05
Chlorine	--	400	--
Sodium	--	250	--

I. 6. 2 PH and EC

The pH and EC are two of the main tools required for successful hydroponics (Figure I-10), each of which determines the level of success or failure in this field. The balance of a nutrient solution is essential for plants to benefit from it, as plants cannot absorb a nutrient solution in water with excessive salinity, nor can they utilize nutrients in an acidic environment. Adjusting the pH and EC level is essential in any hydroponic farm[1].

Figure I-10 : Measuring device PH and EC[17].

I. 6.2.a) Adjusting the PH level

Is vital, as a pH-neutral medium is the ideal medium for plant growth. Each plant has its own pH level, and the ideal value for most plants is between 6 and 7.5. When the pH level drops below 6 or rises above 7.5, certain elements can begin to precipitate and not dissolve, leading to plant poisoning and death [1].

The pH level can be adjusted using acids such as phosphoric or nitric acid if the pH level is too high. If the pH level is too low, it can be adjusted with potassium or calcium carbonate.

Nowadays, there are many ready-made solutions that are used to adjust the pH level in an easy and effective way.

I. 6.2.b) Adjusting the EC level

Is essential to the success of hydroponics. It is difficult to use water with high salinity because it is impossible to dissolve fertilizers in it and deliver them to the plants, since fertilizers are salts, and using salty water will lead to the accumulation of these salts and poison the plants. Therefore, you should use non-salt water as much as possible to increase the possibility of adding fertilizers [1].

The ideal salinity level for hydroponic irrigation water is around 250-750 parts per million (ppm). Plants vary in their tolerance to salinity, so the salinity level can be adjusted by adding more water and reducing the amount of fertilizer added.

I. 6. 3 Feeding trough

It is the essential part of a hydroponic system, as it is the point where the nutrient solution enters and exits the system. The basin should be clean and free of sediment, should be a dark light color, and should be of sufficient capacity and compatible with the size of the farm. Through this basin(Figure I-11), irrigation lines are connected to the planting system to distribute the nutrient solution to the plants[1].

Figure I-11 : Nutrient solution container[18].

I. 6. 4 Pump

A device used to push water from the feed trough to the plants in the system(Figure I-12), varying in size and power depending on the size of the farm and irrigation needs. The pump may be non-submersible, connected externally, and installed in the feeder box or in a customized outdoor location.

Figure I-12 : Submersible water pump[19].

When purchasing a pump, it is essential to know several pieces of information such as the amount of water it pumps per hour (in liters/hour or gallons/hour), its power (in watts or horsepower), and any other relevant information. This information helps ensure that the pump provides continuous access to water to the plants and effectively returns it to the feeder basin [1].

I. 6. 5 Tubes and troughs

Depending on the nature of the plants and the choice of the designer, the system may be vertical, tiered, or include troughs, and this form does not significantly affect the overall quality of the plants. The main thing is to build a system that facilitates the flow of water and oxygen to the plants. In systems that use tubes(Figure I-13), the system is naturally aerobic, where the tubes are not filled with water but only touch the roots of the plants, allowing air and oxygen to flow naturally. In systems that use ponds, the movement of the water may be limited, so it may be necessary to use devices to move the water or provide an oxygen-generating device [1].

Hydroponic systems come in a variety of shapes and designs, but the basic idea is to provide easy acc.

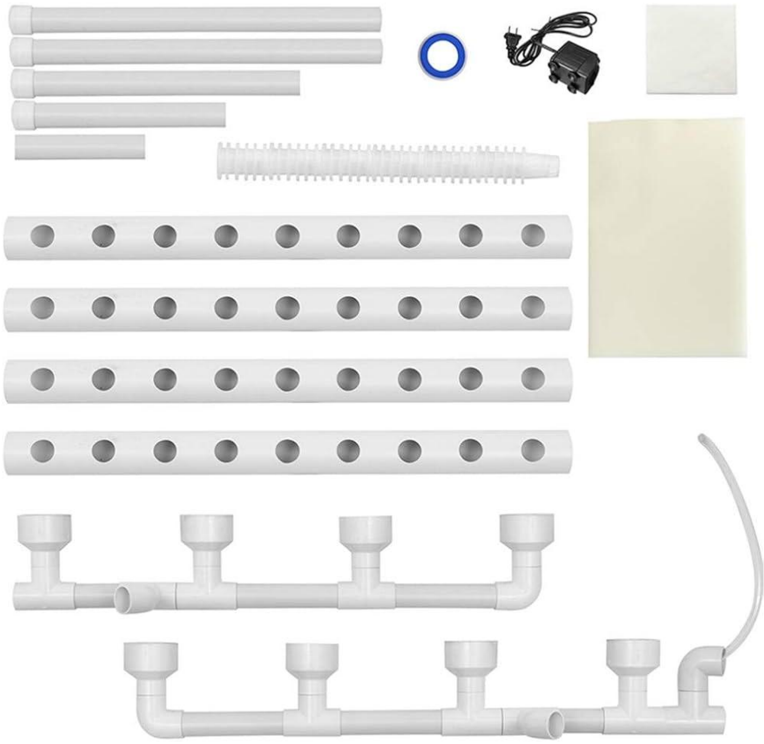

Figure I-13 : Hydroponic tubes[20].

I. 6. 6 Seedling cups and stabilizers

In a hydroponic system, where there is no soil, a means of stabilizing the seedlings is required (Figure I-14). For this purpose, seedlings are placed in perforated cups surrounded by a stabilizing medium such as wool stone or pearlite. These cups offer a variety of sizes depending on the nature of the plants and their stages of growth, and are practical and economical.

Figure I-14 : Seedling cups and stabilizers[21].

The seedling cups are installed in pre-prepared holes in pipes or tubs, and this is done at appropriate dimensions that correspond to the nature and needs of each plant. This system facilitates a stable environment for seedling growth and development without unwanted movement [1].

I. 6. 7 Irrigation Connections

These are the lines used to transport the nutrient solution from the feeder basin to the plants and back without any issues (Figure I-15). These connections can be controlled according to the conditions of the farm and the way it is built, and the main goal is to ensure that the nutrient solution efficiently reaches the plants and returns without any disruptions.

These connections come with special pieces that are used to extend them, making it easier to connect and control irrigation. These pieces can be customized according to the needs of the farm, and can be used to expand the system and improve overall irrigation performance[1].

Figure I-15 : Irrigation connections[22].

I. 7 Influencing factors

There are many factors that affect the composition of the nutrient solution[9]:

I. 7. 1 Plant type

The choice of nutrient solution is greatly influenced by the type of plant grown. For example, leafy plants need more nitrogen than other plants such as tomatoes and cucumbers. This is due to the plants' different needs for nutrients[9].

I. 7. 2 Climatic conditions

Climatic conditions affect the amount of potassium and nitrogen required in the nutrient solution. On long, sunny summer days, the plant needs large amounts of nitrogen and smaller amounts of potassium, while in short, dark winters, the ratio changes so that the ratio of potassium to nitrogen is high[9].

I. 7. 3 Type of ions added

Although nitrogen is effectively absorbed by the plant as an ammonium cation and nitrate anion, the ammonium content of the solution should preferably not exceed 11% of the total nitrogen. Adding ammonium nitrogen in the form of ammonium sulfate helps maintain the acidic pH of the solution, because the plant absorbs ammonium ion faster than other ions[9].

I. 7. 4 Behavior of ions in solution

Thesis that phosphorus in the nutrient solution is present as H_3PO_4, and this leads to precipitation of other ions, especially small ions, reducing their suitability for the plant. For this reason, the concentration of phosphorus in the nutrient solution is kept as low as possible.

I. 7. 5 Plant tolerance to high certain element concentrations

In the previous examples of solutions, the concentration of sulfur was not mentioned; this is because sulfate constitutes a large part of the salts used in the preparation of nutrient solutions, making the concentration of sulfate exceed the adequate limit. However, plants have the ability to tolerate relatively high sulfate concentrations[9].

I. 7. 6 The plant's need for microelements in trace amounts

Keep in mind that micronutrients are toxic to the plant if their concentration exceeds a certain limit. Therefore, the concentration of these nutrients in the nutrient solution should be adjusted with special care (Table I-3). Therefore, it is preferable to prepare a concentrated micronutrient solution and add 1 liter of this concentrated solution for every 100 liters of diluted nutrient solution[9].

Table I-3 : Prepare a concentrated solution of trace elements[2].

Salt	25g/L salt weight	Element	The concentration after dilution in ppm
Clawed iron	80	Fe	4.5
manganese sulfate	10	Mn	1
boric acid	4	B	0.3
copper sulfate	0.8	Cu	0.08
Zinc sulfate	0.8	Zn	0.07
Ammonium sulfate	0.2	Mo	0.04

I. 8 Environmental conditions for hydroponics

Arable environmental conditions are the factors surrounding crops that directly affect their growth and productivity. This includes several factors to acclimatize young plants in all conditions, especially in desert conditions to control moisture, radiation, and nutrition to enhance survival rates and growth vitality compared to traditional methods.

I. 8. 1 Temperature

The hydroponic device maintains an air temperature of 23°C to 26°C and a constant flow rate of nutrient solution, creating optimal conditions for growing feed for livestock in a controlled environment[10].

I. 8. 2 Water quality

Most plants need water with a pH of around 6 to 6.5. You can adjust the acidity of the water using solutions available in hardware or hydroponic stores, without the need for a prescription[11].

I. 8. 3 Oxygen

In conventional farming, plant roots can get the oxygen they need to breathe from the air in the soil pockets. But in hydroponics, you need to adequately supply oxygen to the roots so that they are not completely submerged. This can be done by leaving a space between the base of the plant and the water tank, or by using an oxygen container such as a specially designed air pump. You can achieve this by purchasing an air stone or installing an air pump to generate bubbles in the water tank, which helps keep oxygen available to the plant's roots [12].

In closed hydroponic systems, oxygen levels vary with different substrates, showing high CO_2 and low O_2 in organic substrates. Excess oxygen supports optimal plant growth without hypoxia.

I. 8. 4 Root Support

Although soil is not required, your plant's roots need some materials to help stabilize them and provide a suitable environment for growth. Typical materials include vermiculite, perlite, peat moss, coconut fiber, and rock wool. It's best to avoid using materials that may compress, such as sand, or that don't retain moisture, such as gravel. Using these materials will help support the plant's roots and provide optimal conditions for its growth[13].

The natural hydroponic technique for plants requires clean roots, drought control, root stimulation, and water changes every 3 to 7 days initially.

I. 8. 5 Nutrients

A plant needs to be provided with essential nutrients such as magnesium, phosphorus, calcium, as well as other nutrients to ensure optimal health and production, just as plants growing in natural soil receive nutrition from fertilizers. When growing plants without soil, this "plant food" must be supplied through the water that is used to feed the plants. Although you can make your own nutrient solution, it's easier to buy pre-made mixes, either online or in stores[14].

I. 8. 6 Light

Light is a type of radiant energy, a key factor in determining the primary productivity of plants, on which all other organisms depend (Figure I-16), either directly or indirectly[15].

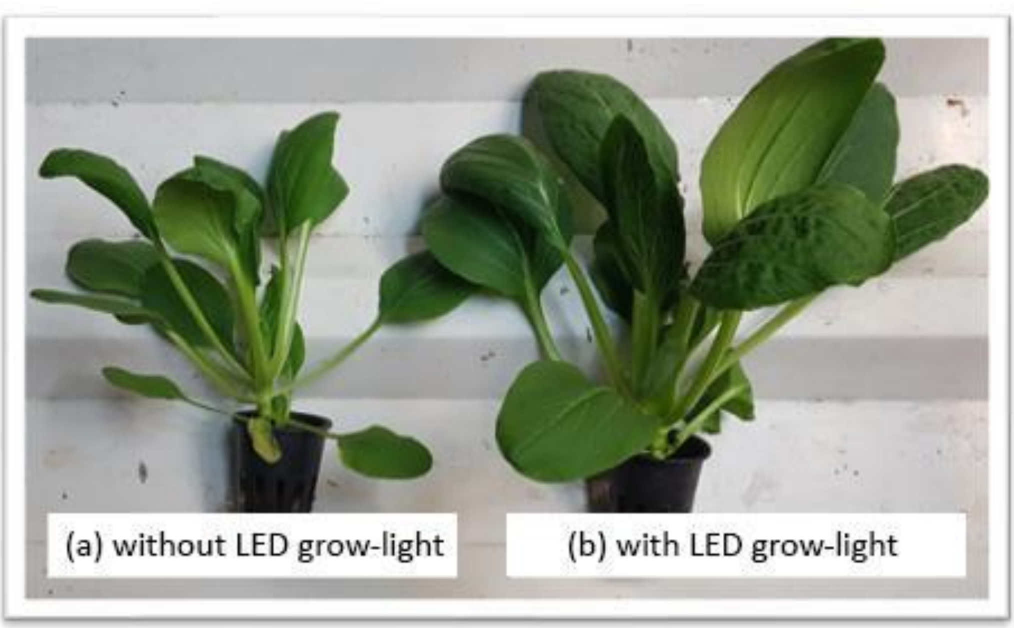

Figure I-16: Artificial light effect[23].

The photosynthesis process in plants necessitates a minimum of four hours of sunlight daily. Insufficient sunlight results in etiolation, wherein plants exhibit abnormal growth characterized by rapid elongation, fragile stems, pale coloration due to chlorophyll deficiency, imperfect leaf development, and heightened vulnerability to disease. Consequently, this diminishes productivity levels[16].

I. 8.6.a) The importance of light

The importance of light in an ecosystem is due to multiple factors, including[17]:

- Artificial light offers the possibility of providing light at any time, which promotes plant growth.
- Increases productivity by providing light in specific and appropriate quantities.
- Crops can be grown more densely without the need for a large area.

- Contributes to sustainability by saving energy and reducing dependence on traditional energy sources.
- Light plays a role in the formation of chlorophyll and other pigments, which affects the coloration of plants.
- Light influences plant growth by affecting processes such as seed germination, location and number of chloroplasts, stomatal closure and opening, transpiration, and flowering.

To understand light as an important environmental factor, three main aspects must be emphasized: First, the intensity and quantity of light, second, the quality of light, and third, the length of the photoperiod:

a.i Light intensity and quantity:

- Light intensity: Light intensity depends on the amount of light energy reaching the plant. Sufficient light intensity must be provided to stimulate photosynthesis and healthy plant growth[15].
- Amount of light: This depends on the duration of light exposure. The periods of light used in hydroponics must be properly balanced with periods of darkness to enable plants to photosynthesize effectively[15].

a.ii Light quality:

This refers to the wavelength of light used. Plants need a variety of wavelengths of light to perform different processes, such as growth, photosynthesis, and regulation of hormonal production[18].

In hydroponics and artificial light, lamps that mimic the natural light spectrum can be used to meet the needs of different plants.

a.iii Length of photoperiod:

The length of the light period depends on the type of plant and its stage of growth. The duration of lighting must be properly determined to meet the needs of the plants. For example, in the active growth stage, plants may need longer light periods to promote growth and production[19].

In hydroponics and artificial light, these factors must be carefully considered to ensure an optimal environment for plant growth. Using artificial lighting systems such as LEDs can be precisely adjusted to provide the optimal intensity, quality, and length of light period for each type of plant according to its growth stages.

I. 9 Benefits of hydroponics

The benefits of hydroponics include:

I. 9. 1 Saving space

In traditional farming, a plant needs a lot of space to grow its roots and search for water and nutrients. However, in hydroponics, water and nutrients are provided directly to the plant without the need for its roots to spread, allowing more plants to be grown in the same space[2].

I. 9. 2 Water conservation

Conventional farming consumes large amounts of water due to evaporation and leakage. In hydroponics, about 11 times less water is used, thanks to controlled delivery and the use of water recycling systems[2].

I. 9. 3 Less chemicals are used

While hydroponic systems don't completely eliminate pest-related issues, they reduce the likelihood of them occurring, minimizing the need to use pesticides and herbicides. By carefully controlling the growing environment, the risk of pest infestations can be minimized, thus reducing the need for pesticides and herbicides[2].

I. 9. 4 Faster growth

Plants in hydroponic systems grow 31% to 51% faster than those grown in soil, due to optimal amounts of nutrients and a less environmentally stressful environment[2].

I. 9. 5 Nutrient monitoring

Hydroponic systems provide farmers with better control over the nutrients that crops receive, helping to improve the quality and quantity of production[2].

I. 9. 6 Indoor growth

Growing indoors allows full control over environmental conditions, increasing the efficiency of the cultivation process and minimizing pest and disease issues[2].

I. 9. 7 Healthier plants

Thanks to the absence of soil that can be a source of disease, plants grow healthier and more mature in hydroponic systems. In addition, plants don't have to spread their roots in search of nutrients so they spend more energy on growth[2].

I. 9. 8 Higher yields

Because more plants can be grown in smaller spaces with hydroponics, hydroponic systems typically produce more crops per square foot. Thanks to the ideal conditions within hydroponic systems, plants are healthier and grow faster, dramatically increasing their productivity. Continuous year-round growth also allows for more frequent harvesting of crops, increasing the overall yield[2].

I. 9. 9 Less resources

In fact, we can confirm that hydroponic systems consume fewer resources than traditional soil-based systems. This is because less water is used, as closed systems minimize evaporation. In addition, water in hydroponic systems is continuously filtered and reused, which greatly reduces waste. For example, in our system we use up to 92% less water than traditional soil-based systems[2].

I. 9. 10 Easy troubleshooting:

With a hydroponic system, it's easy to troubleshoot quickly. In cases where one plant appears to be thriving while its next-door neighbor is struggling, it can be difficult to determine the reason behind the difference. Is the plant suffering from pests? Is the nutrient composition of the solution different at that point?

With a hydroponic system, you have complete control over the conditions in which the plant grows. This allows you to easily isolate variables and conduct experiments. Once you determine the ideal conditions in terms of lighting, pH balance, and nutrients, you can apply this successful formula over and over again without having to face constant issues.

In addition, indoor hydroponic plants do not need additional resources such as pesticides and other potentially harmful chemicals. These crops are effectively protected from plant pests and diseases that are found outdoors in traditional soil-based farms[2].

I. 10 The importance of hydroponics

Hydroponics, or soilless cultivation, has experienced rapid growth in recent years. In what follows, we discuss the importance of this growing method both on a global scale and in Algeria[20].

I. 10. 1 On a global scale

In Europe, the bulk of soilless greenhouse cultivation is concentrated in four countries, mainly the Netherlands, which has vast areas dedicated to this method, followed by France, Belgium and Great Britain. Hydroponics is also present in Switzerland and some Eastern European countries. Other parts of the world, such as Japan and South Africa, also have large areas dedicated to this practice[20].

I. 10. 2 In Algeria

The first soil-less cultivation experiments were carried out in Beni-Abbes, with the aim of making the most of local sandy substrates. Subsequently, further studies were carried out at INRA, ENSA and ITCMI in Mostaganem, but these were not implemented in the field, despite the country's considerable potential for hydroponic crops, their development remains limited. Some work has been undertaken in Biskra, Tlemcen and El Oued, but its scope remains limited[20].

I. 11 Advantages of hydroponics:

Hydroponics offers many benefits that address current agricultural challenges [21]making it more efficient and sustainable to meet the growing demand for food [22]. In addition, it eliminates soil-borne diseases and pest attacks, provides year-round production, and reduces labor-intensive tasks such as weeding and irrigation [23]. Despite the initial investment costs and technical requirements, careful evaluation of their advantages can lead to improved systems for future agricultural practices.

- The possibility of agricultural production in areas unsuitable for farming, such as soils affected by salinity The need to provide fresh water for irrigation.
- The possibility of being absent for a few days is made possible by the relative automation of the system.
- Yields are often higher than those of soil cultivation, depending on experience of course.

- Treatment of deficiencies, diseases or fungi is simplified compared to soil cultivation.
- Optimum cleanliness.
- The substrate used, such as clay balls, is infinitely reusable.
- Eliminates the need for over- or under-irrigation.
- Only one system is needed for the entire growing cycle.
- Reduced risk of soil-borne pests.
- Better control of early harvests.
- Enables intensive farming with high yields at harvest.
- Increase productivity per unit area
- Early maturity.
- It can grow anywhere.
- Your environment is sterile, which means no pesticides.
- No mulching, ploughing, soil changes or weeding.
- It can grow all year round if kept indoors.

I. 12 Disadvantages of hydroponics

There are some potential disadvantages of hydroponics despite its benefits. Among these are[24]:

- A high initial investment is required, due to the cost of purchasing the equipment.
- Regular monitoring of pH and EC (electrical conductivity) is required.
- Extra vigilance is required in terms of safety, due to the proximity of water and electrical cables.
- It is essential to use containers of sufficient quality to avoid leaks in the absence of the grower.

I. 13 Conclusion

In conclusion, this chapter allowed us to familiarize ourselves with hydroponics, types of systems, requirements, environmental conditions, importance, advantages and disadvantages. We have seen that hydroponics instead of traditional agriculture offers advantages of saving space, conserving water, using less chemicals, faster growth and higher yields.

We also found that hydroponics is among the miraculous solutions, but it requires careful planning and realistic analysis to thesis the appropriate situation for the crops to be planted before making an investment.

Chaptre II :

Smart Agriculture

Chaptre II : Smart Agriculture

II. 1 introduction

Smart agriculture offers a sophisticated approach to developing the agricultural sector, a term that emerged in the second decade of the current century as a solution to the challenges of climate change and ensuring food security globally. This reflects the movement of concerned bodies and organizations towards seeking innovative solutions to the issues of agriculture and food, in light of the worsening food situation at the local and international levels. The Global Smart Agriculture Alliance (GSA) launched this vision in 2014, emphasizing the importance of adopting technology to achieve food security and sustainability. In this context, smart agriculture is a key sector that is heavily influenced by the development of advanced technologies, making research and innovation in this field one of the most important paths to follow. In smart agriculture, traditional farming and modern technology converge, opening up new horizons to improve the efficiency of agricultural production and crop quality, and balance the use of natural resources. This shift from concepts to reality is an important step towards enhancing sustainability and developing the agricultural sector. In this chapter, this chapter reviews the principles and areas of application of smart agriculture, analyzes the challenges it faces, and envisions the future of this fascinating field.

II. 2 Definition of Smart Agriculture

The concept of climate-smart agriculture is defined by the Food and Agriculture Organization (FAO) as an approach that aims to sustainably increase productivity, enhance the resilience of livelihoods and protect ecosystems, to reduce or eliminate greenhouse gas emissions and to promote the achievement of food security and development goals. As defined by the Arab Organization for Agricultural Development (AOAD), CSA is an approach that uses modern communication and information technologies to develop sustainable agricultural practices (**Erreur ! Source du renvoi introuvable.**). Climate-smart agriculture is an approach used in agriculture with the aim of maximizing agricultural productivity while preserving natural resources. Smart agriculture can be defined as a system that relies on advanced technology to grow food in sustainable and clean ways, and rationalize the use of natural resources, especially water. Smart farms are characterized by their ability to achieve greater productivity and sustainability by using resources efficiently, through the use of information management and analysis systems to make informed production decisions at low costs, in addition to automating agricultural processes such as irrigation, pest control, soil and crop monitoring[25].

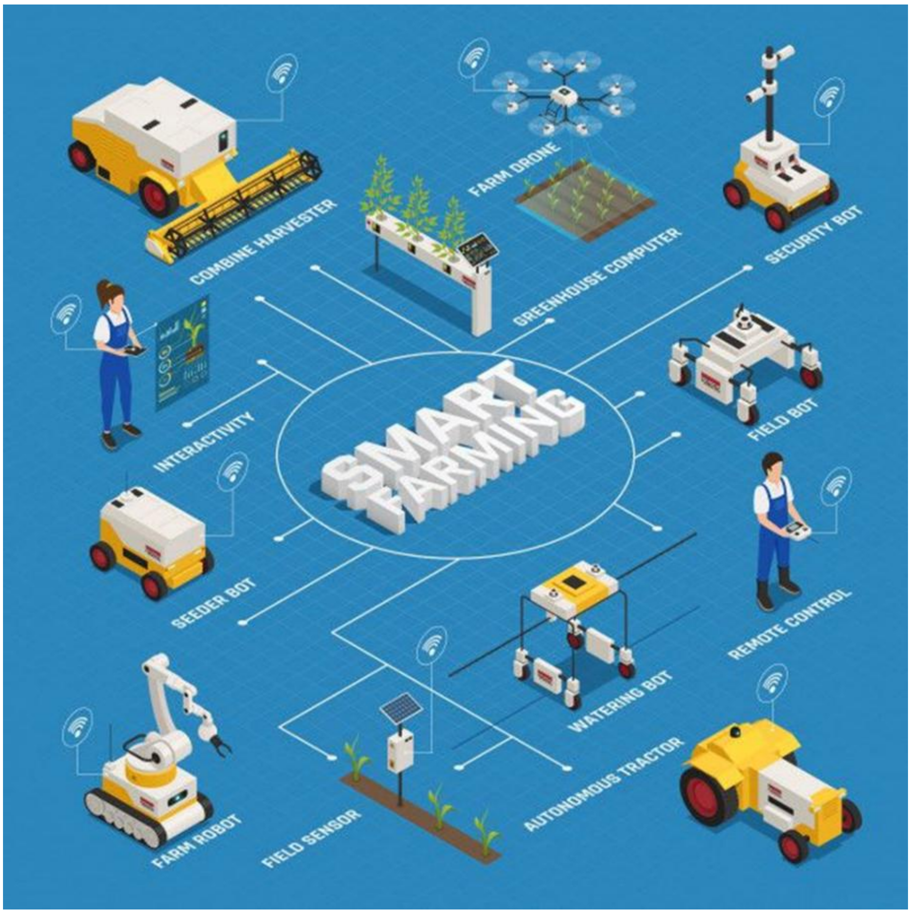

Figure II-1 : Isometric smart farming flowchart[24].

II. 3 The Foundations of Smart Agriculture

Smart agriculture is characterized by the use of advanced technologies such as remote sensing, artificial intelligence, the Internet of Things, and big data analysis to improve production efficiency and agricultural management. These technologies aim to collect data from farms accurately and continuously, and analyze it effectively to make smart decisions related to agriculture such as irrigation schedules, fertilizer management, and pest and disease control.

In addition, smart farming includes new methods such as vertical farming and soilless farming, which allow for more efficient use of agricultural space and less consumption of natural resources. By using robots and automated systems, farming operations can be optimized and the human labor required can be reduced[3].

II. 3. 1 Sensing and Monitoring Systems

Smart agriculture relies on sophisticated sensing and monitoring systems as its cornerstone. These systems harness a network of sensors and IoT devices to collect data on essential agricultural parameters. Examples include soil moisture sensors, weather stations, and aerial drones equipped with high-resolution cameras. They offer valuable insights into soil conditions, weather trends, pest infestations, and other critical information crucial for efficient farm management[3].

II. 3. 2 Data Analytics and Predictive Models

The wealth of data gathered from sensing and monitoring systems becomes truly beneficial with robust data analytics and predictive models. Leveraging AI algorithms and machine learning techniques, farmers can analyze intricate datasets and extract meaningful patterns and forecasts. These models offer recommendations on optimal irrigation schedules, strategies for disease prevention, and even predictions on market demand. This empowers farmers to make informed decisions and mitigate risks effectively[3].

II. 3. 3 Automated Systems and Robotics

Automation is pivotal in smart agriculture, streamlining labor-intensive tasks and minimizing human error. Automated systems and robotics are employed for activities like planting, harvesting, and livestock management. For example, self-driving tractors with GPS technology can precisely plant seeds and apply fertilizers, while robotic milkers ensure efficient and stress-free milking processes. By automating repetitive tasks, farmers save time, cut costs, and allocate resources more efficiently[3].

II. 3. 4 Precision Application Techniques

Precision application techniques optimize resource usage and reduce environmental impact. By precisely delivering fertilizers, pesticides, and water, farmers can minimize waste and environmental harm. Variable-rate technology allows inputs to be applied based on specific crop needs, identified through analysis of data collected from sensors and predictive models. By customizing resource application, smart agriculture fosters sustainable practices and minimizes wastage[3].

II. 4 Smart Agriculture Goals

The use of technology in agriculture enhances productivity and reduces the use of chemicals, leading to safer and cleaner agricultural products and minimizing the negative environmental impact of traditional practices. In addition, smart agriculture can contribute to enhancing farmers' resilience to climate change and improving crop quality, which enhances food security and increases the income of farming families[26].

- Smart agriculture achieves many benefits and goals, including
- Promoting innovation in agriculture.
- Creating sustainable job opportunities.
- Preserving and protecting the environment through effective management of natural resources.
- Contribute to the fight against climate change by reducing greenhouse gas emissions.
- Reducing hunger and poverty.
- Increase productivity and improve crop quality.
- Implementing sustainable management of natural resources.
- Improving soil management and fertility.
- Efficient utilization of energy and conversion of animal waste into alternative energy sources.
- Encouraging fish and aquaculture that is resilient to climate change, such as using storm-resistant cages and ponds and managing regenerative fisheries.

Concisely, the adoption of technology in agriculture is an important development that contributes to agricultural sustainability and improves the quality of life for farmers and communities.

II. 5 Challenges Facing the Agricultural Sector

The agricultural sector is a vital component of our global economy (Figure II-2), but it is currently facing numerous challenges that threaten its sustainability and productivity. These challenges range from environmental concerns such as climate change and water scarcity to economic issues like fluctuating market prices and access to resources. Additionally, technological advancements and changing consumer preferences present further complexities for farmers and stakeholders in the industry, Despite these challenges, there are also opportunities for innovation and growth within the agricultural sector[27].

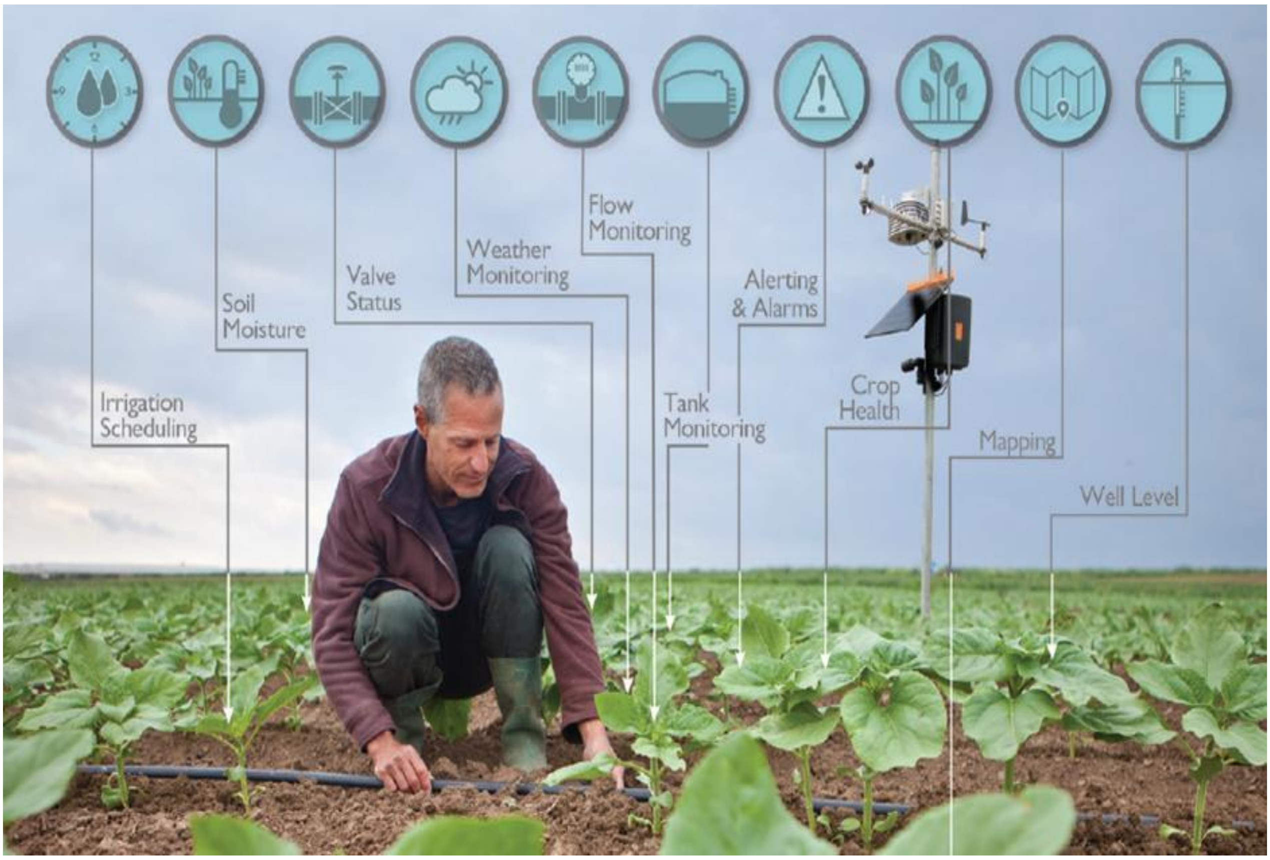

Figure II-2: The Challenges of the Agricultural Sector in the Modern Era[25] .

II. 5. 1 The agricultural challenge of growing populations

Rapid population growth is one of the main challenges facing agriculture in the current era, with growing demographic data predicting a population increase of up to 33% by 2050 (Figure II-3). This massive growth in population means a huge increase in demand for food, putting enormous pressure on the agricultural sector to meet this growing demand.

Under these circumstances, agriculture must adopt new and sophisticated strategies to sustainably increase its productivity, in order to meet the needs of a growing population without negatively impacting natural resources and the environment. In addition, climate change and water scarcity increase the challenges faced by agriculture, as it becomes necessary to develop advanced and sustainable farming techniques that enable high productivity under difficult environmental conditions.

Moreover, efforts should focus on strengthening agricultural infrastructure and providing financial and technical support to farmers, in addition to providing training and continuous education to improve their skills and adopt new technologies. Efforts should also focus on developing the food chain to ensure fair and equitable distribution of food resources and minimize food waste[27].

Figure II-3: The rate of increase in food production by the year 2050[26].

II. 6 Ensuring Agricultural Sustainability in the Face of Challenges

Ensuring agricultural sustainability is a major challenge in light of climate change, increasing global demand for food, and diminishing natural resources. To ensure the sustainability of agriculture and address these challenges, there are several elements to consider[28]:

II. 6. 1 Transitioning to Sustainable Agriculture

To ensure the longevity of agriculture, there is a pressing need to transition towards sustainable farming practices. Practices like organic and hydroponic farming, prioritizing environmental preservation and minimizing harmful chemical use, are crucial for achieving sustainability. Additionally, promoting biodiversity-preserving practices is vital for maintaining ecosystem balance and ensuring long-term agricultural productivity[28].

II. 6. 2 Adapting to Climate Change

Modern agricultural techniques and technological investments can facilitate adaptation to climate change (Figure II-4). This encompasses developing drought-resistant crops and smart irrigation technologies. Leveraging these advancements enables farmers to mitigate climate variability's impact on crop yields, ensuring food security amid changing environmental conditions[28].

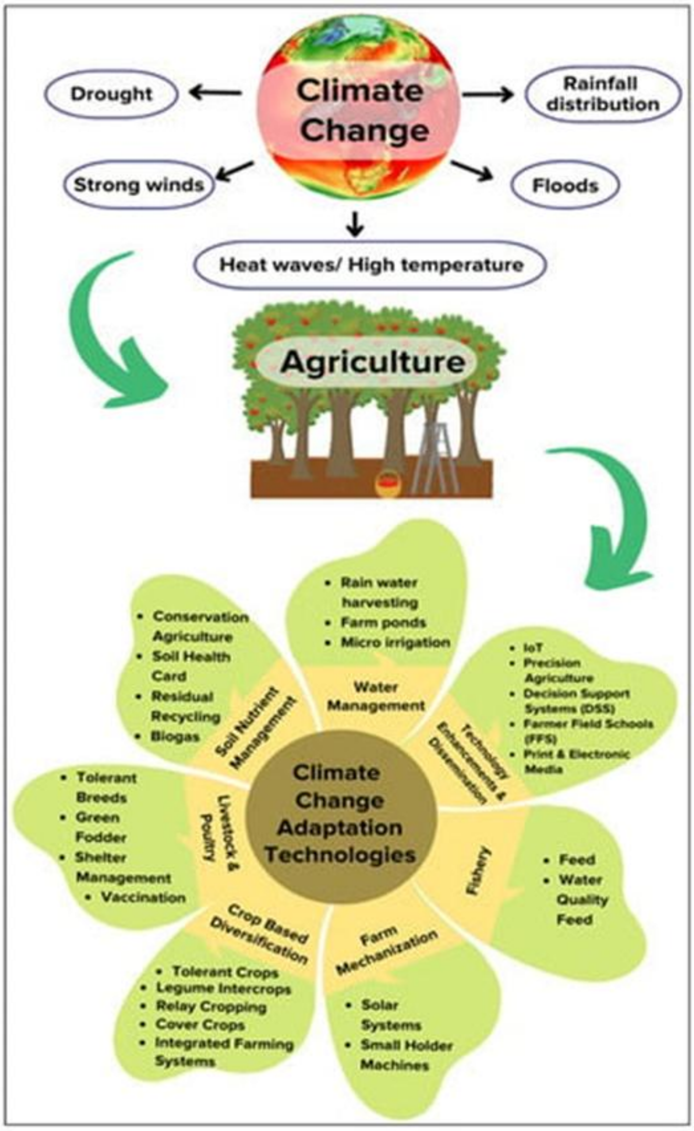

Figure II-4: Climatic impacts on agriculture and adaptation technologies to combat climate change[27].

II. 6. 3 Reducing Food Waste

Addressing food waste forms a critical part of the solution. Efforts to minimize food waste through public awareness campaigns and policy implementations aimed at redistributing surplus food to those in need are paramount. By reducing food waste, we optimize resource utilization and bolster food security for communities worldwide[28].

II. 7 Food Production Innovations

Production is undergoing a transformative shift towards new methods, such as hydroponic farming, which is a significant subset in this context. Innovative technologies, exemplified by companies like "Sundrop" in Australia, reflect the use of solar energy and desalination to sustainably cultivate vegetables. This approach reduces reliance on limited natural resources and enhances agricultural output.

Additionally, algae serve as alternative and sustainable raw materials, efficiently utilized in aquaculture, thereby reducing costs and improving environmental sustainability in production processes.

In desert environments, universities and research institutions, such as King Abdullah University of Science and Technology in Saudi Arabia, strive to develop techniques for crop cultivation in harsh environments, thus enhancing food security and sustainability.

In the realm of packaging, innovative companies like "TIPA" seek to develop eco-friendly alternatives to plastics that biodegrade naturally, reducing plastic pollution and contributing to environmental preservation.

These innovations are part of a comprehensive shift towards more sustainable and efficient food production, addressing the needs of a growing population while safeguarding the environment simultaneously[27].

II. 8 Integrating Applications and Technologies Across Sectors

II. 8. 1 Integrating Drone Technology Across Sectors

While unmanned aerial vehicles (UAVs), or drones, aren't a new technology, their utilization has been steadily increasing due to investments and some regulatory leniency. Reports suggest that the value of UAV-based solutions across various sectors could exceed 127$ billion. One of the most promising sectors is agriculture, where drones can address numerous key challenges.

Drones can revolutionize agriculture by utilizing technology. Here are six ways drones can be used throughout the crop cycle[27]:

II. 8.1.a) Soil and field analysis

Drones can play a vital role in planning seed planting by creating accurate 3D maps of soil analysis and collecting data for irrigation management and nitrogen levels[27].

II. 8.1.b) Planting

Startups have designed drone planting systems that reduce agricultural costs by 85%. These systems release seed-filled pods into the soil, providing all the necessary nutrients for crops[27].

II. 8.1.c) Crop spraying

Drones can survey fields and spray in real-time, providing even coverage and spraying crops five times faster than traditional methods[27].

II. 8.1.d) Crop monitoring

Inefficient crop monitoring poses a significant obstacle. Images captured at regular intervals by drones can track crop development and reveal any production issues, allowing for better management[27].

II. 8.1.e) Irrigation

Drones equipped with sensors can identify dry areas in the field or those needing improved irrigation[27].

II. 8.1.f) Crop health assessment

Visual and near-infrared inspections via drones can track plant changes, health indicators, and alert farmers to any diseases.

The future of agriculture involves integrating UAVs, including self-driving UAV swarms that collect data and perform tasks. However, the main challenge lies in sensor devices capable of collecting high-quality data and software capable of analyzing it[27].

II. 8. 2 Blockchain Technology for Secure Agricultural Value Chains

Blockchain technology, known for its distributed ledger system underlying cryptocurrencies like Bitcoin, can secure digital transactions and preserve records. Although primarily used for virtual currencies, blockchain can be applied to other types of transactions, including agricultural ones.

Blockchain technology can mitigate inefficiencies and fraud, enhance food security, facilitate farmer payments, and streamline transaction times. Improving product traceability within the supply chain enables regulators to track contaminated foods and identify affected products during contamination incidents, reducing waste by identifying bottlenecks leading to food spoilage.

Blockchain's transparency can combat food fraud. With consumers increasingly demanding organic, non-GMO, and antibiotic-free foods, the number of food fraud cases has also risen. Monitoring even the smallest transactions in farms, warehouses, or factories efficiently and transmitting their details along the supply chain when paired with the Internet of Things technology such as sensors and RFID tags. For example, Maersk, a shipping and logistics company, operates cross-continental supply chains with dozens of employees and hundreds of transactions. The company estimates potential savings in the billions by using blockchain technology to improve efficiencies that reduce fraud and human errors.

The benefits of this openness extend to all honest parties in the market. Blockchain technology can prevent price manipulation, payment delays, eliminate intermediaries, and reduce transaction costs, leading to fairer pricing and helping small farmers gain a larger share of their crop's value[27].

II. 8. 3 Nano-Technology and Precision Agriculture

The Green Revolution of the 20th century relied on irresponsible use of pesticides and chemical fertilizers, resulting in soil biodiversity loss and increased resistance to pathogens and pests.

The new revolution focuses on precision agriculture, supported by nathesischnology. These new revolution technologies will introduce nanomaterials into plants and advanced biosensors to enhance precision agriculture. Nanoscale fertilizers, insecticides, and herbicides will be released slowly and sustainably to provide crops with precise doses[27].

The benefits of using nathesischnology in precision agriculture include reducing approximately 60% of the fertilizer wasted in the environment, causing pollution, aiding slow and sustainable release of agricultural chemicals, better plant protection and disease management, and improved detection of pesticides in crops to help decision-making based on information[27].

II. 8. 4 Shared Food and Agriculture

Collaborative and communal economics are key to reducing food waste. Technology has enabled communities to share surplus food and services. This concept first emerged in car-sharing and home-sharing sectors, now being applied to the food industry.

Olio, founded by social entrepreneurs, launched an app connecting individuals with their neighbors and local stores to share surplus food instead of disposing of it. Another pioneering social project, Carmen del Naranjas, developed the concept of communal agriculture, where individuals collectively own trees and land, ensuring a direct link between production and consumption to avoid waste and surplus production along the value chain[27].

II. 9 Conclusion

In conclusion, this chapter allowed us to learn about smart agriculture and the importance of shifting towards smart agriculture and the use of advanced technology and the Internet of Things in enhancing agricultural productivity and facing the challenges of climate change. This chapter presented many modern strategies and technologies that can be applied in managing crops and optimizing productivity in sustainable and effective ways. Through continuous efforts to adopt and develop these technologies, we can achieve greater sustainability in agriculture and improve the quality of life for farmers and communities.

Smart agriculture represents a promising path toward food security, environmental sustainability, and rural economies. Faced with new challenges and increasing constraints, we need to overcome barriers and work together to implement these smart technologies in agriculture, in order to realize a better and more sustainable agricultural future for generations to come.

Chaptre III:

Smart Mini Farm Model

Chaptre III : Smart Mini Farm Model

III. 1 Introduction

Agriculture is one of the oldest arts known to man, as he has relied on it since ancient times to meet his food needs and sustain his life. With the development of technology and increasing pressure on natural resources, it has become necessary to look for innovative solutions to enhance the efficiency of agricultural production and improve its sustainability.

This project comes as part of a futuristic vision to develop agriculture into a smart and sustainable process. The project aims to design and implement a smart hydroponic farm, where plants are grown in a fully managed environment, using the basic elements of growth such as water and artificial light, as well as an automated control that allows us to use data analytics to obtain maximum efficiency and productivity.

III. 2 Problems

- Water waste: Water wastage is one of the main challenges in conventional agriculture, where large amounts of water are used to irrigate crops without actually needing it. This is due to traditional irrigation systems that can be inefficient and allow water to be wasted or lost through evaporation or leakage.
- Lack of space: The lack of space in homes and urban areas is a major barrier to implementing traditional agriculture and achieving high productivity.
- Consumption of natural resources: Traditional agriculture consumes large amounts of water and soil, which leads to the depletion of these resources and high production costs.
- Climate change and unstable weather conditions: Climate changes and extreme weather conditions can affect the productivity of traditional agriculture and cause significant losses for farmers.
- Environmental pollution and heavy use of pesticides: Traditional farming involves the use of large amounts of pesticides and harmful chemicals that can negatively impact the environment and human health.
- Market volatility and high production costs: Farmers are exposed to risks related to market price fluctuations and high production costs, which negatively affects the stability of their income.

- Negative impact on public health: Conventional agricultural products can contain harmful chemicals that affect the overall health of consumers.
- Poor control of growth factors: In conventional farming, control over growth factors is limited, resulting in an inability to effectively meet the needs of the plants. For example, plants may be susceptible to fluctuating weather conditions or changes in moisture and soil levels. Thanks to the direct and precise control available in smart farming projects, environmental factors such as temperature, CO_2 concentration, and moisture levels can be adjusted with high precision, ensuring an optimal growing environment for plants and contributing to increased productivity and improved crop quality.
- Mobility constraints in traditional farming: In traditional farming, farmers may face restrictions in moving between different locations to grow their crops, which can affect the possibility of making the most of favorable climatic conditions or commercial opportunities. In addition, conventional farming may require the allocation of large tracts of land and heavy investments in infrastructure, which increases the cost of operation and reduces flexibility in mobility and adaptation to market and demand needs.

III. 3 Solutions

By exploring these issues, we seek to illustrate the urgent need for automated smart farms that can provide sustainable and effective solutions to these complex challenges.

One potential response to these challenges is the mobile smart automated mini-farm project for hydroponics and artificial light. This project aims to provide solutions:

- Water :Using water instead of soil allows for greater water savings and less waste due to seepage.
- Artificial lighting:
  - To extend the daily hours of light available to plants.
  - Improves the quality of plants in terms of color, taste, and growth time. For example, the spectrum of light used can be precisely controlled to optimize the chlorophyll content and thus increase photosynthesis.
  - To provide uniform conditions for growth regardless of external weather conditions, increasing production stability and crop quality.

- Reduce manual labor: Reducing the need for traditional tillage, fertilization, and soil management processes can save manual labor.
- Saving space: Compared to traditional farming, hydroponics does not require a large amount of land, which can be used in places where there is not enough space for traditional farming.
- A smart system that allows for customized lighting and restroom separation while regulating light intensity, temperature, and water supply.
- Convenient indoor and outdoor gardening Multiple use Home Apartment Kitchen... With year-round freshness and cleanliness, you can enjoy fresh produce all year round.
- Reduce pollution: By reducing the use of pesticides and fertilizers, the negative environmental impacts associated with agriculture can be reduced.
- Diverse cultivation of many types of vegetables, fruits and herbs ....
- Beautiful design to match the home decor.
- Expandable by combining the gardens.
- Android application: Allows remote control by using the automatic or manual mode for convenience.
    - Automated judgment allows a solution to the issues of watering plants, providing nutrition and lighting by providing them automatically at the right time without human intervention.
- Automatic diagnostics to find the fault in the system without having to search for it.

III. 4 Designing Smart Mini Farm Model

The mini-farm project aims to rationalize the use of irrigation water while increasing production efficiency as well as optimizing the use of small and narrow spaces. As well as controlling the climatic conditions favorable to plant cultivation.

Figure III-1: Mini-farm hydroponic smart automated vertical garden.

The proposed solution to achieve this was the Mini Farm, a mobile smart farm that integrates hydroponics technology with automation and the use of artificial lighting:

- Hydroponics strategy with artificial lighting without the need for soil and sun.
- Vertical farming strategy that saves space and is suitable for small spaces.
- Facilitate the possibility of controlling the system through a mobile application in two different modes: Automatic mode and manual mode.
- The strategy of recognizing system malfunctions without the need to search.
- The ability to control the light intensity that each plant needs.
- Easy mobility.
- Beautiful modern design that complies with various decorations for homes, restaurants, hotels…

Figure III-2: The prototype of a smart hydroponic vertical garden.

III. 5 Principle of Operation of a Mini Farm

The Smart Farm Device is a mobile, intelligent small farm that integrates vertical farming technology with automated control and the use of artificial lighting. Plants are grown in multiple layers within the device, allowing for highly efficient space utilization. These layers are equipped with trays or special hydroponic systems to hold the plants. Water is pumped through pipes from the bottom of the tank to the top, flowing through the layers from the lowest to the highest and back to the tank directly. The water is filtered in each cycle. Plants are grown in nutrient-rich solutions instead of soil, allowing them to absorb nutrients more efficiently.

A dedicated application is used for control and data analysis to enhance farm performance and user convenience. The application includes the ability to control the device in both manual and automatic modes, monitor environmental factors, adjust light intensity, and detect device malfunctions.

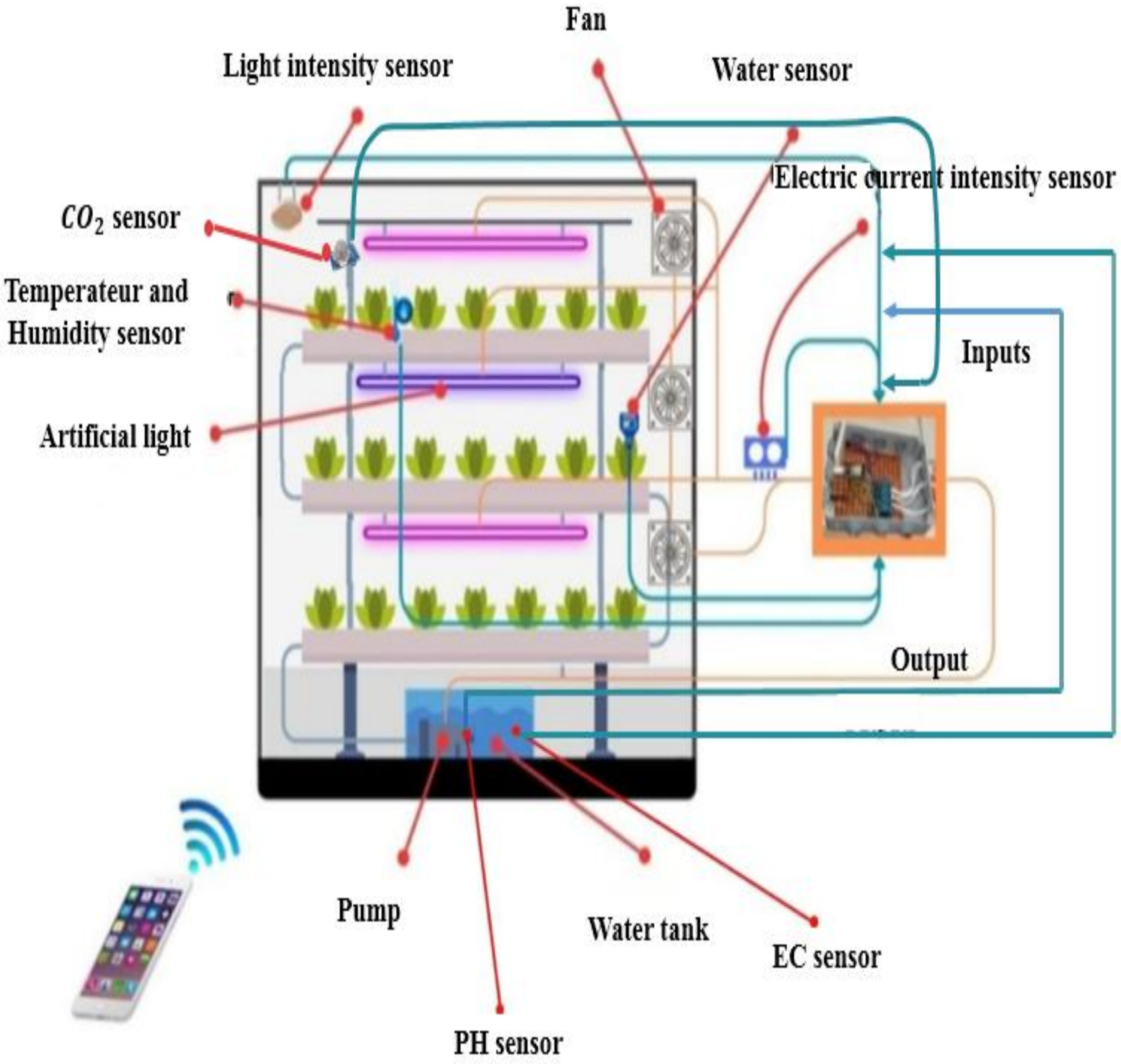

Figure III-3 : Principle of operation of a mini farm.

The Smart Farm Device is equipped with sensors that continuously monitor the environmental conditions inside the unit, as shown in Figure III-3, such as:

- Temperature and humidity sensors: These maintain an appropriate temperature and humidity level to ensure the health and growth of the plants. In automatic mode, the fan activates as soon as the temperature exceeds the set value.
- Water level sensor: This ensures an adequate water supply for the plants and the hydroponic system in general. In automatic mode, when the water level drops to a certain point, the sensor signals the control system to activate the water pump to recirculate the water through the pipes.

- Carbon dioxide (CO_2) sensor: This regulates CO_2 levels to enhance photosynthesis. In automatic mode, when the CO_2 level rises, the fan activates to change the air cycle and prevent plant suffocation.
- Light sensor: This provides specific lighting conditions that aid in particular growth stages. In automatic mode, if the ambient light intensity drops, the lights turn on when used indoors and turn off upon detecting sunlight when used outdoors.
- pH and electrical conductivity (EC) sensors: These monitor and adjust the quality of the water and nutrient solutions used to irrigate the plants. In automatic mode, when the nutrient concentration is outside the optimal range, the system adds more nutrients or dilutes the solution with water to achieve the required balance. This is done through a control unit that sends commands to activate pumps or valves to add chemicals or nutrients to the solution.
- Current sensor: This detects abnormal changes in power consumption, which may indicate device malfunctions or electrical leaks. It also helps identify potential issues before they lead to significant breakdowns, reducing downtime and increasing system reliability. In automatic mode, when the current value drops below the set threshold, an alert is sent by activating a light in the application.

The Smart Farm Device relies on the integration of vertical farming technologies, artificial lighting, automated environmental control, and smart technology. This integration creates a closed and sustainable ecosystem capable of producing food with high efficiency in small spaces, making it ideal for use in urban environments or areas lacking traditional agricultural land.

III. 6 conclusion

In conclusion, this chapter allowed us to explore the smart mini-farm project, its benefits and the problems it has resolved, and the principle of operation of the mini-farm. We also reaffirmed the significance of agriculture as an ancient art that represents an integral part of human history, as well as the necessity to develop and improve it in the face of modern challenges. This project reflects a forward-looking vision of transforming agriculture into a smart and sustainable process. It enhances the efficient use of space and small areas, reduces water and resource wastage more effectively, and contributes to meeting the growing food needs of humanity in a sustainable manner through the use of technology and innovation.

The project aims to achieve an ideal balance between productivity and sustainability, paving the way for a promising and sustainable future for the coming generations.

Chaptre IV:

Hardware and Software System Design

Chaptre IV : Hardware and Software System Design

IV. 1 Introduction

This chapter presents the design of the mini-farm and covers the components needed to create it, its control application, SolidWorks engineering design, electrical design scheme, the implementation of the proposed design is described and the connections to the sensors are illustrated.

IV. 2 Mini-farm parameter detectors

IV. 2. 1 The sensor

A sensor is a device that detects changes in the environment and responds by producing an output to another system (Figure IV-1). A sensor converts a physical phenomenon into a measurable analog voltage (or sometimes a digital signal) which is then converted into a human-readable display or transmitted for further reading or processing[4].

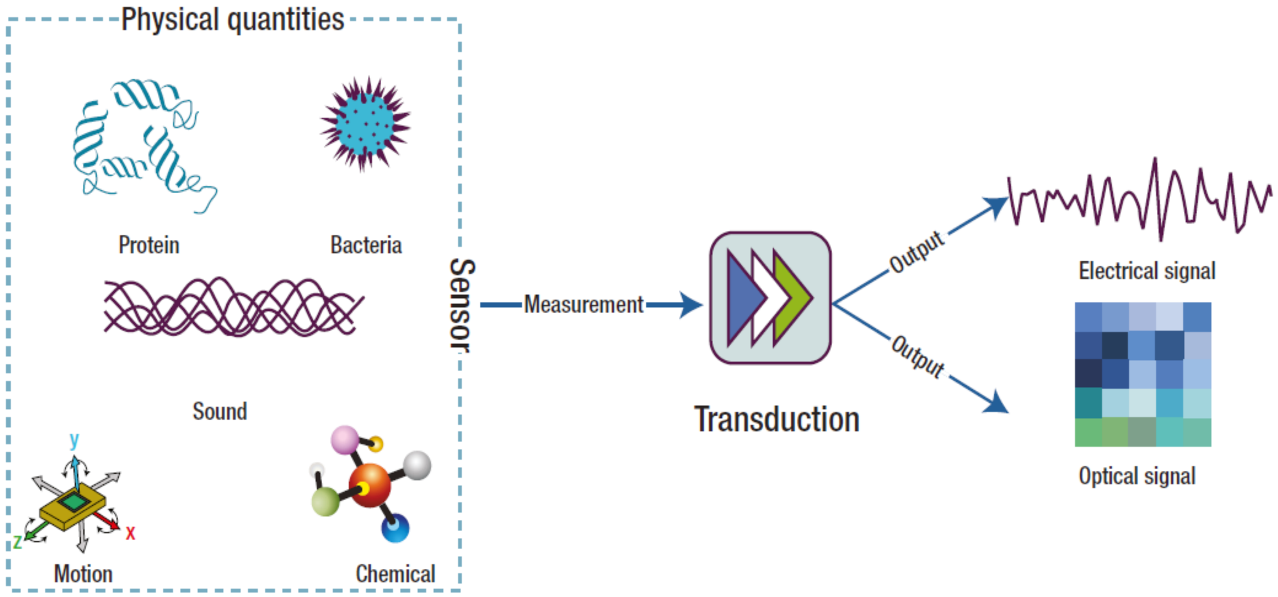

Figure IV-1: The sensing process[28].

The accuracy of the sensor is affected by several factors, such as environmental parameters like temperature. We must consider this point along with anything else that could disrupt the measurement[29].

IV. 2. 2 The different types of sensor

IV. 2.2.a) Passive sensors

In most cases, passive sensors require an external energy source to function (as is the case with strain gauges, thermistors, etc.), and they are often modeled by an impedance. A change in the physical phenomenon being studied (measured) causes a change in impedance. To obtain an output signal, a voltage must be applied to them[30].

The sensor behaves at the output like a passive dipole, which can be resistive, capacitive, or inductive.

Depending on the measurand, various effects are utilized to perform the measurement.

IV. 2.2.b) Active sensors

When the physical phenomenon used to determine the measurand directly transforms into an electrical quantity, it is considered an active sensor. It is the physical law itself that links the measurand to the electrical output quantity.

The sensor output is treated as a generator, It is an active dipole that can be of the current, voltage, or electric charge Q type, measured in coulombs[30].

IV. 2. 3 Signal classification

IV. 2.3.a) Analog signal

A signal is said to be analog if the amplitude of the physical quantity representing it can take on an infinite number of values within a given interval[31].

- Continuous signal: A signal that varies 'slowly' over time: temperature, flow, level.
- Form: It's the form of this signal that's important: cardiac pressure, chromatography, impact.
- Frequency: It's the frequency spectrum that carries the esir'ee information: voice analysis, sonar, and spectrography.

IV. 2.3.b) Logical signal

A logical sensor is like a machine that indicates whether or not the measured phenomenon has occurred. It gives only two answers: "yes" or "no". Some logic transducers only work if the measured phenomenon occurs completely, and some only work if nothing occurs at all[5].

IV. 2.3.c) Digital signal

A signal is digital if the amplitude of the physical quantity representing it can only take on a finite number of values. In general, this finite number of values is a power of 2 [31].

- On/Off (TOR): Provides information on a system's bivalent state.
- Pulse train: Each pulse is the image of a change of state. Incremental gives a known, finite number of pulses per revolution.
- Sampling: This is the digital image of an analog signal.

IV. 2. 4 Internal structure of a sensor

The internal structure of the sensor (Figure IV-2)consists of 3 elements[32]:

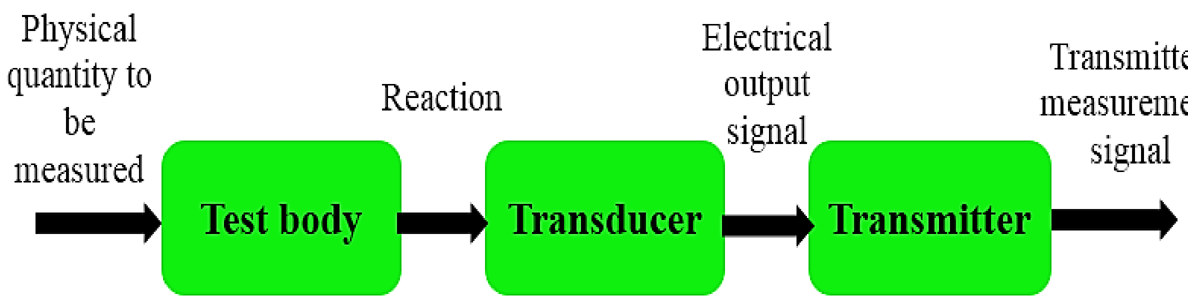

Figure IV-2: Internal structure of a sensor.

IV. 2.4.a) The test body

Is a component that reacts specifically to the quantity to be measured, converting this quantity into another physical quantity that can be measured.

IV. 2.4.b) The transducer

converts the test body's reactions into an electrical signal, forming the output signal.

IV. 2.4.c) The transmitter

Amplifies, filters and standardizes the output signal for remote transmission. It may be integrated into the transducer or be a separate component.

IV. 3 Components

IV. 3. 1 ESP-WROOM-32

The ESP32 is an electronic board (Figure IV-3) that can be used to implement IoT projects quite easily, and is easy to learn because it's a cousin of the Arduino board. It can therefore be used in the same way as the Italian microcontroller board, using the same programming language, the same add-on modules and, above all, the same compilation software (Arduino IDE),No fundamental change to the user interface, which makes it all the simpler to use, and it is without doubt the microcontroller board with the best compromise between size, connectivity, inputs and outputs. Its miniature size is also a considerable advantage: it measures less than 3 cm by 5 cm, despite the technologies it uses[33].

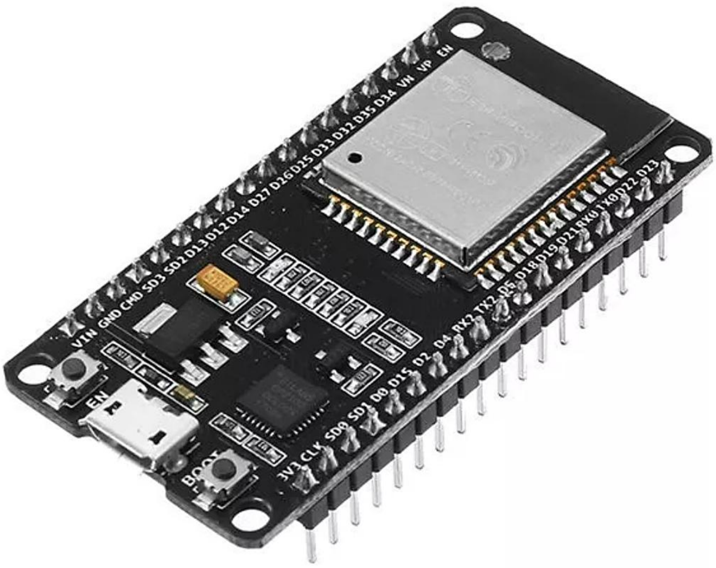

Figure IV-3: ESP-WROOM-32[29].

- Comprehensive Features of the ESP32 Microcontroller[6]:

  -Wireless Connectivity**:** Wi-Fi 802.11 (b/g/n) and Bluetooth version 4.2.

  -Processor and Memory: Xtensa single-/dual-core 32-bit LX6 microprocessor(s), 448 kB ROM, 520 kB SRAM internal memory. Supports up to 4 x 16 MB external memory via QSPI interface. Includes cache memory, MPU, and MMU for memory protection.

  -Internal Sensors: Temperature sensor (-40°C to 125°C), 10 capacitive sensing pins, Hall effect sensor.

-Peripherals: 34 GPIOs, 18 channels of 12-bit ADC, 2 channels of 8-bit DAC, Ethernet MAC interface, SD/SDIO/MMC host controller, SDIO/SPI Slave Controller, three UART serial interfaces, two I2C interfaces, two I2S interfaces, eight IR channels, pulse counter, PWM, DMA controller, and two sets of counters (each group is 2 x 64-bit).

IV. 3. 1 Temperature and humidity sensor (DHT11)

DHT11 is a digital temperature and humidity sensor (Figure IV-4), the composite sensor contains a calibrated digital signal output of temperature and humidity, application of dedicated digital module collection technology and temperature and humidity sensing technology, the sensor includes a resistive wet component sense and temperature measurement device, and connected with a high performance 8-bit microcontroller[34].

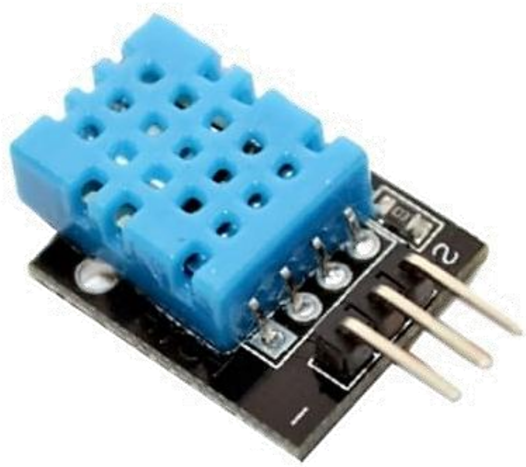

Figure IV-4: Temperature and humidity sensor (DHT11) [30].

The only real disadvantage of this sensor is that you can only get new data once every 2 seconds, so when you declare the sensor library in the program, reading this sensor can take up to 2 seconds.

- Principal characteristics of DHT11[35]:

This temperature and humidity sensor based on the DHT11 circuit communicates with an ESP32 or compatible microcontroller via a digital output.

- Power supply: 5 VDC.
- Measuring range :temperature: 0 to 50°C (± 2°C).
- Humidity: 20 to 90% RH (± 5% RH).

- Connectors : 3pin (Vcc, GND and Signal).
- Dimensions: 23 x 17 mm.

IV. 3. 2 light sensor

The light sensor (Figure IV-5)is an electronic component whose resistance depends on the lux of light to which it is exposed. They are also called LDR (Light-Dependent Resistor) or photoconductive cells[36]. On the left is the light-sensitive LDR resistor (type GL5516), and the LM393 comparator, which compares the voltage across the LDR with an adjustable reference voltage. The potentiometer adjusts the trigger threshold according to the light level. Turned clockwise, it increases sensitivity. Counter-clockwise, sensitivity is reduced[37].

Figure IV-5: Light sensor[31].

- LED D1, located close to the potentiometer, lights up when the module is powered.
- LED D2 indicates the output level on pin D0, it lights up when the light intensity exceeds the threshold set by the potentiometer.

- The pins are, from top to bottom:
  - A0 Analog output, reflects the light intensity received by the LDR.
  - D0 Digital output, switches to 1 (+3.3v or +5v) when light intensity exceeds the threshold.
  - GND Ground.
  - Vcc Power supply +3.3v.

The module operates from 3.3v to 5v. This is interesting because the ESP32 GPIOs use 3.3v, by supplying the module with 3.3v, you can connect output A0 directly to a GPIO.

IV. 3. 3 current sensor(ACS712)

The ACS712 is a Hall effect current sensor (Figure IV-6). This device features a precise linear Hall detection circuit with a copper conduction path located near the surface of the die. The current flowing through this copper conduction path generates a magnetic field, which is detected by the integrated Hall cell and converted into a proportional voltage. The device's accuracy is optimized due to the proximity of the magnetic signal to the Hall transducer. It can detect both positive and negative currents in the range of -5A to +5A with a sensitivity of 185 mV/A. The sensor operates with a Vcc of 5V DC and has an offset of Vcc/2 or 2.5V. The ACS712 includes a low-pass filter with a cutoff frequency of 80 kHz, making it suitable for both AC and DC currents. The internal resistance of this conduction path is typically 1.2 mΩ, ensuring low power loss[38].

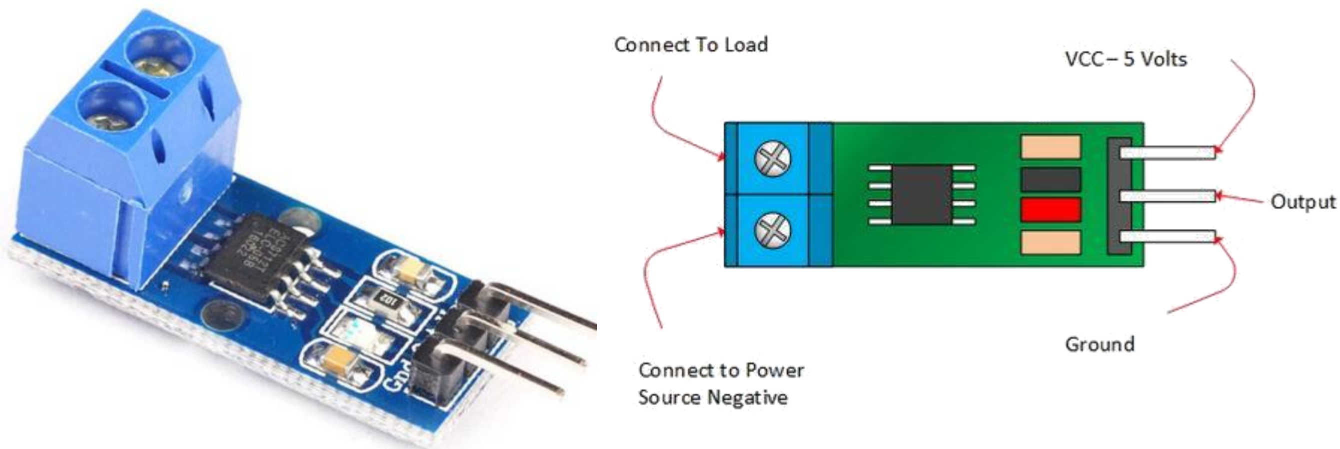

Figure IV-6: Current sensor(ACS712)[32][33].

- Principal characteristics of ACS712:
  - Dimensions: 31x13x15mm.
  - Power: ACS712ELEC-30A.
  - Measured current range: -30A to +30A.
  - Vref A0: Vcc/2 i.e. 2.5V.
  - Sensitivity: 66mV/A.
  - Isolation: 2.1KV.
  - Current consumption: 10mA.
  - Error: 1.5% / 25°C.
  - Power supply: 5V DC (4.5-5.5V).
  - Weight: 2g.

IV. 3. 4 water level sensor (ST045)

ST045 is an analog water sensor (Figure IV-7), working on the principle of measuring the size of water droplet traces across the line with a series of parallel wires exposed to the quantity of water to simulate the second plasticity based on the analog output values of the high-sensitivity, low-power, third-power sensor directly connected to a microprocessor or other logic circuitry[39].

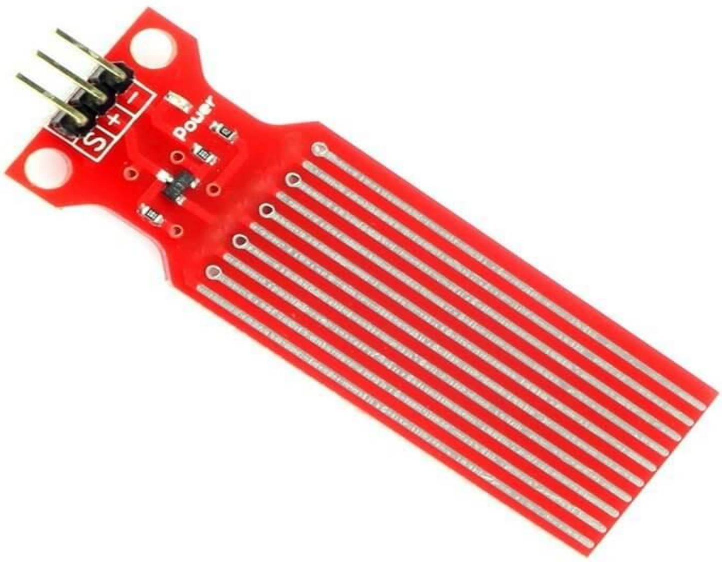

Figure IV-7: Water level sensor (ST045) [34].

- Principal characteristics [40]:
  - The sensor delivers "700" when the level is high and "400" when it is low.
  - Power supply: 5V DC.
  - Connectors: 3 pins (Power, GND and Signal).
  - Dimensions: 60 x 21 x 7 mm.

IV. 3. 5 Relay Module

This is a low-level 5V 4-channel relay interface board (Figure IV-8), with each channel requiring a 15-20mA driver current ,It can be used to control various high-current appliances and equipment. The board is equipped with high-current relays that operate at 250V AC 10A or 30V DC 10A, It has a standard interface that can be directly controlled by a microcontroller, The module is optically isolated from the high-voltage side to meet safety requirements and prevent ground loops when interfacing with a microcontroller[41].

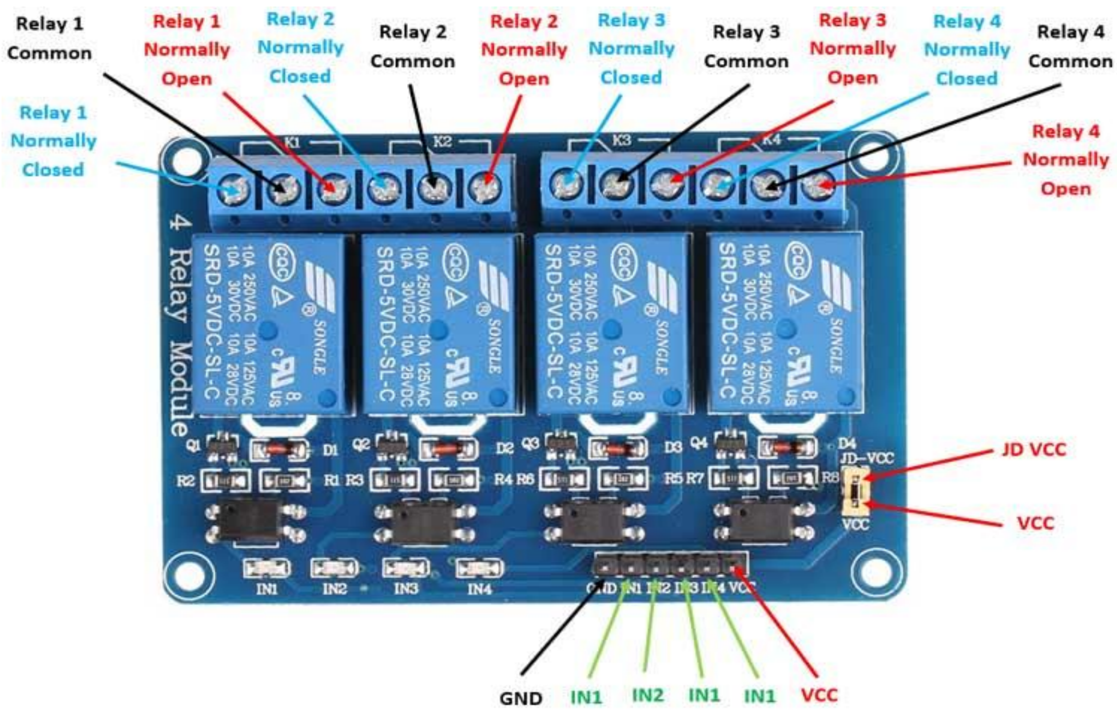

Figure IV-9: 4 channel relay (5V)[35].

IV. 3. 6 CO2 Sensor (MQ-135)

The (MQ-135) gas sensor utilized for air quality and are detecting or measuring of NO_x , NH_3, CO_2, Benzene, Alcohol ,Smoke, and other hazardous chemicals in the air greatly affects its sensitivity (Figure IV-10). The (MQ-135) sensor comes with a digital pin that makes this sensor work with or without micro-controller, which is good use when trying to discover one particular gas. To measure the gases in PPM (part per melon) the analog pin need to be used. The analog TTL is operated and operates at 5 volts and so can be used with most common microcontrollers [42].

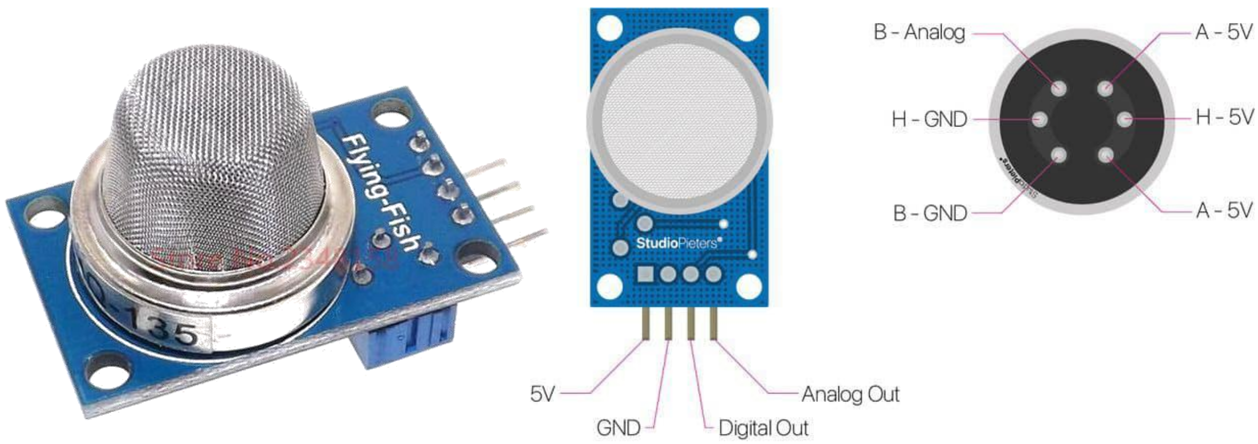

Figure IV-10 : CO_2 Sensor (MQ-135)[36].

The digital output pin goes high if the air's gas concentration is more than the threshold limit. The sensor's potentiometer can be used to adjust the threshold value[43].

The analog or digital pin can be used to operate the (MQ-135) sensor by connecting 5V to the module, which will power on the LED indicator. When no gas is detected, the output LED remains off and the digital pin stays at 0V. After the preheating period, the output LED and digital pin will light up when gas is detected; if not, the potentiometer can be adjusted. The digital pin goes high (5V) when gas is detected at a certain concentration. The analog pin can also be used to read values (0-5V) using a microcontroller, and this value will be proportional to the amount of gas detected[43].

IV. 3. 7 PH sensor

This sensor is capable of measuring pH levels (Figure IV-11) from 0 to 14 in various experiments in Biology, Chemistry, and Environmental Sciences. It can replace a traditional pH meter. It automatically collects pH data and records pH variations during chemical reactions, displaying them on a graph. The probe is temperature-compensated, Typical experiments include measuring the pH of water bodies over extended periods, diffusion in liquids, milk acidification, and acid-base titrations[44].

Figure IV-11: PH sensor [37].

- Principal characteristics of PH sensor :
  - Range: 0 to 14 pH.
  - Accuracy: ±2% over the entire range, after temperature compensation.

- Temperature-compensated: yes.
- Operating temperature: 0 to 50°C.
- Response time for 95% of final value 10 seconds.
- Default sampling rate: 10 ech/sec.
- Storage solution: yes.
- Essential accessory: FRE CBL022 connection cable.
- Resolution (12 bits): 0.004 pH.

IV. 3. 8 EC sensor

The ability of a solution to conduct or carry an electric current (Figure IV-12) is called its conductivity. Measuring specific conductivity is important for determining impurities in water. Total dissolved solids (TDS) in water determine the quantity of salts and minerals present in the water[45].

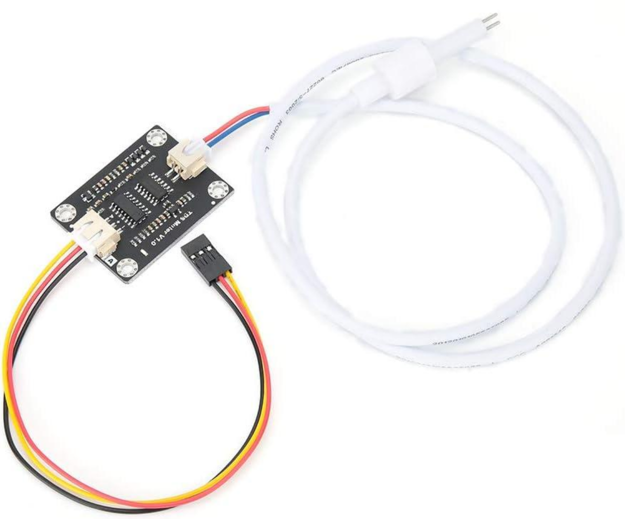

Figure IV-12:EC sensor[38].

IV. 3. 9 Water pump

A water pump is a device that pumps liquid through pipes using an electric motor or gasoline engine. Used in many applications such as irrigation, water distribution, cooling and fluid transport.

Electric water pumps (Figure IV-13) are generally energy-efficient and quiet, but they do require a power source. Water pumps are used in a variety of fields, including agriculture, construction, industry and households. They are often used to pump liquids over long distances or to transport large volumes of liquids under high pressure.

Figure IV-13: Water pump (220V)[39].

Water Pump (Q-1200) 18W ,1200 l/h ,1.2 m this water pump is suitable for small ponds, fountains and aquariums. The water pump is quiet and reliable. The parts and materials from which the product is assembled are safe for aquatic life[7].

IV. 3. 10 Fan

A fan is an electrical device consisting of cooling blades or rotating vanes (Figure IV-14), enclosed in a housing. Which operates at a voltage of 220 Volts, It is designed to create an airflow by generating a controlled and directed movement of ambient air. It is often used in electronic projects to circulate and exchange air in a confined space, in order to regulate temperature, humidity and air quality[46].

Figure IV-14: Fan (220V) [40].

In this project, fans can be used in conjunction with an ESP32 microcontroller to automate and control the ventilation system.

IV. 3. 11 Artificial light

Artificial light enables lighting control, providing an ideal environment for plant growth throughout the year, regardless of climatic or seasonal conditions. Technologies such as advanced LED lighting (Figure IV-15) allow light spectra to be customized according to the needs of different plants, enhancing their growth and increasing crop yields. In addition, artificial light helps reduce dependence on natural conditions that may be unpredictable or unfavorable.

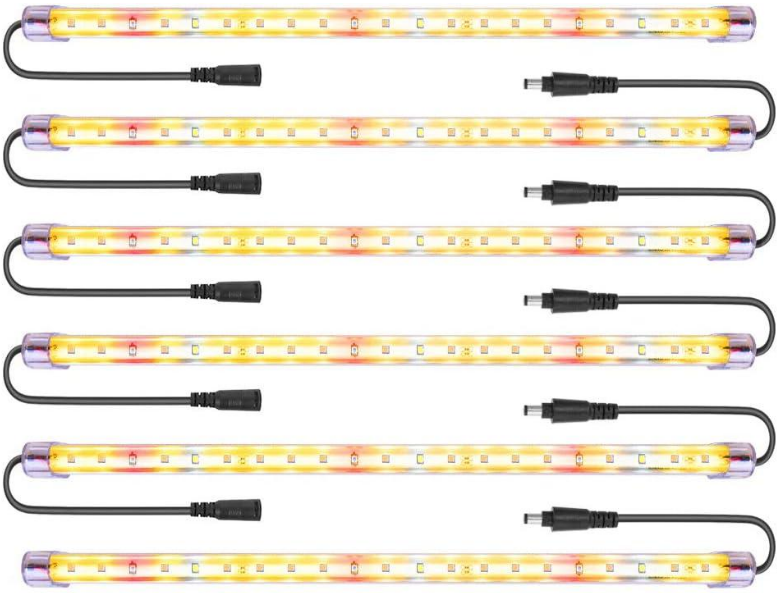

Figure IV-15: Artificial light (220V)[41].

IV. 4 Software requirements

Programming the ESP32 board and creating an application are essential for controlling mini-farm components, enabling optimum automation and monitoring of the plant-growing environment. This requires the use of specific software.

IV. 4. 1 The Arduino IDE

The Arduino IDE (Integrated Development Environment) is a software package for programming microcontrollers from the Arduino family (Figure IV-16). It is designed to be simple and accessible, even for beginners in programming and electronics, It is an open source software platform that provides a set of tools for writing, compiling and uploading code to the board (Arduino,ESP32...).The Arduino IDE offers a user-friendly interface with features such as autocompletion, debugging and code verification, making the programming process easier for users[8].

Figure IV-16: The Arduino IDE[42].

IV. 4.1.a) Electronic board development

The automatic and manual control system uses DHT11 sensors to measure temperature and air humidity, MQ-135 sensor to measure CO_2, ST045 sensor to measure water level, light sensor to measure light, and pH and EC sensor to adjust the level of nutrients. The data is customized by an electronic card that adjusts the light and ventilator to maintain optimal conditions. The water pump also serves for irrigation.

In this scheme (Figure IV-17), the mobile application uses the Wifi module to send commands and receive real-time data for operation, and the ESP32 card collects sensor measurements (Light Sensor, ACS712, ST045, PH, EC ,DHT11, CO_2).

DHT11, MQ-135 to regulate fan-assisted ventilation, optimal lighting is ensured by an artificial light when the light ratio is low or non-existent, irrigation is ensured by an active pump when the water ratio is insufficient, and the pH, EC sensor ensures an optimal amount of nutrient solutions when it is lacking from the water tank.

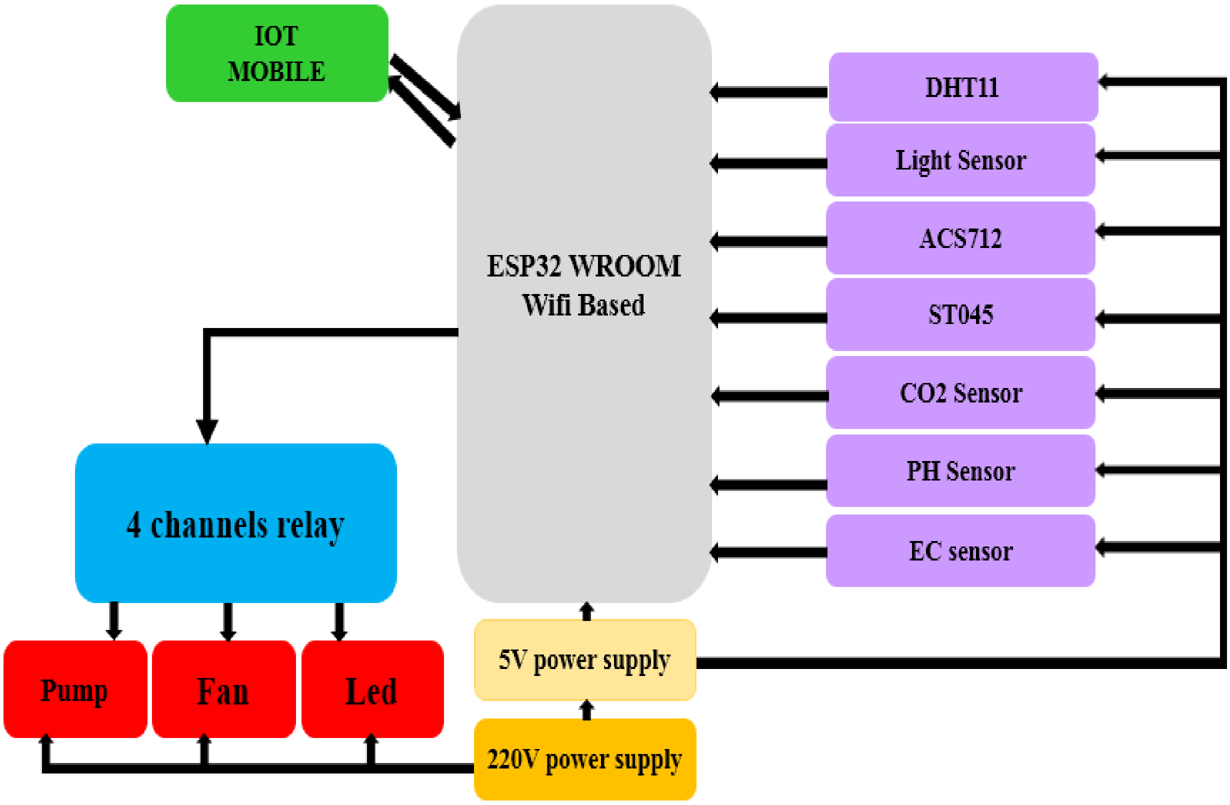

Figure IV-17: Block diagram of system.

a.i System organization chart

The flowchart in (Figure IV-18) represents the general operation of our board, and fully translates the content of the specifications described .

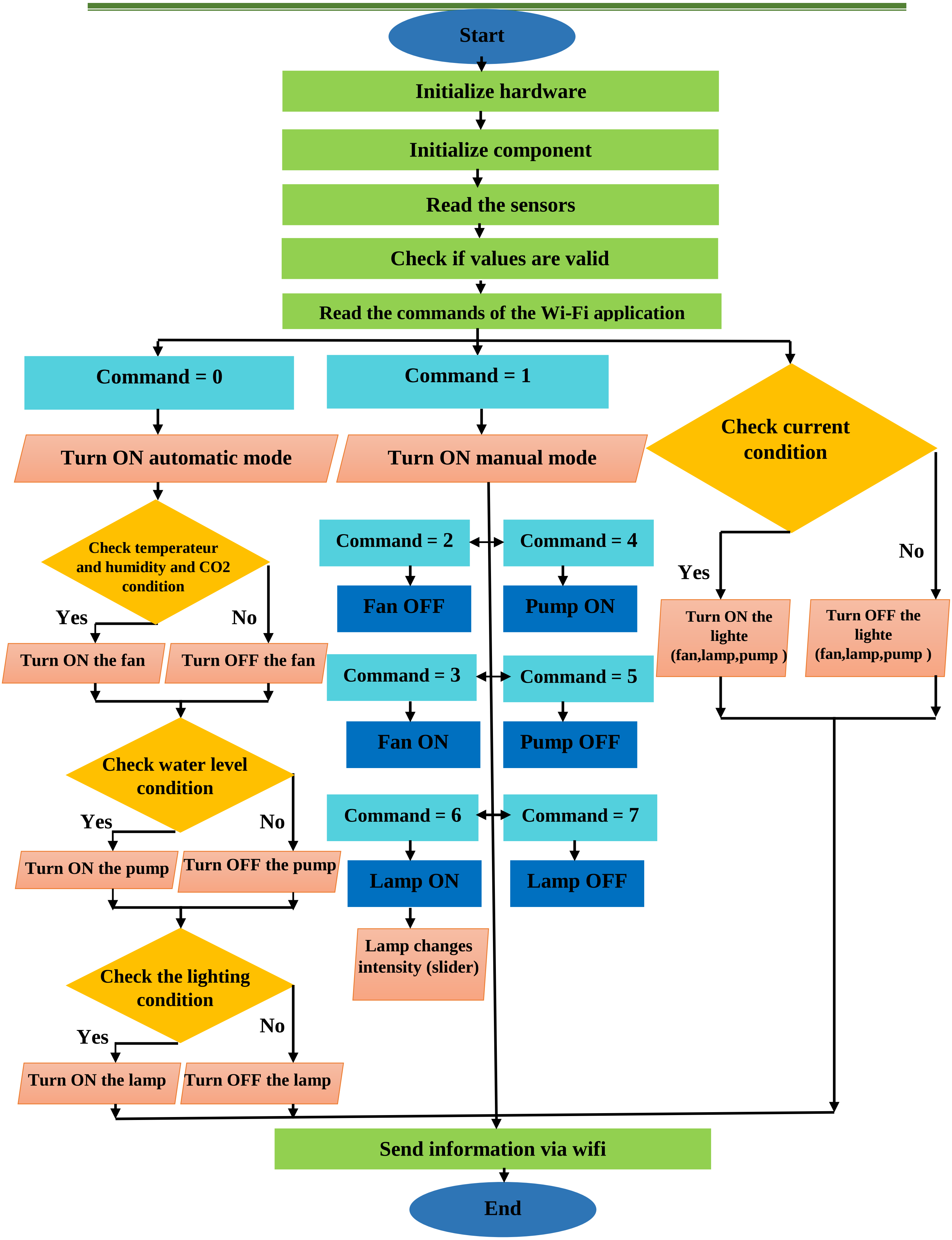

Figure IV-18: System Organization Chart.

IV. 4. 2 Blynk

Blynk is a comprehensive software suite that facilitates the prototyping, deployment, and remote management of connected electronic devices at any scale, Whether for personal IoT projects or commercial connected products in the millions (Figure IV-19), Blynk empowers users to connect their hardware to the cloud and create IoS, Android, and web applications, analyze real-time and historical data from devices, control them remotely from anywhere, receive important notifications, and much more[9].

Figure IV-19: Blynk [43].

IV. 4.2.a) Developing the application

As part of the Android app development, we used blynk to design and create a user-friendly user interface. The app provides features for controlling and monitoring the mini-farm (automated and manual), allowing the user to adjust parameters and view real-time data. blynk streamlined approach makes it easy to develop applications quickly and efficiently, providing a smooth and intuitive user experience.

The Figures (Figure IV-20,Figure IV-21,Figure IV-22,Figure IV-23) below show the data of applications built with blynk. These datasets help define the logic and behavior of an Android app to control and monitor (automated and manual) a mini- farm system. With a user-friendly interface, blynk makes it easy to create customized apps without the need for extensive programming knowledge.

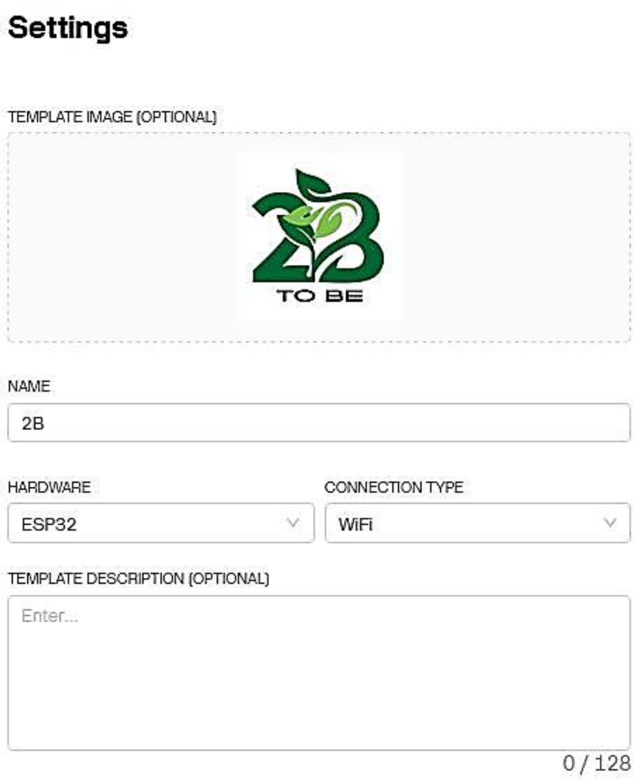

Figure IV-20: Template.

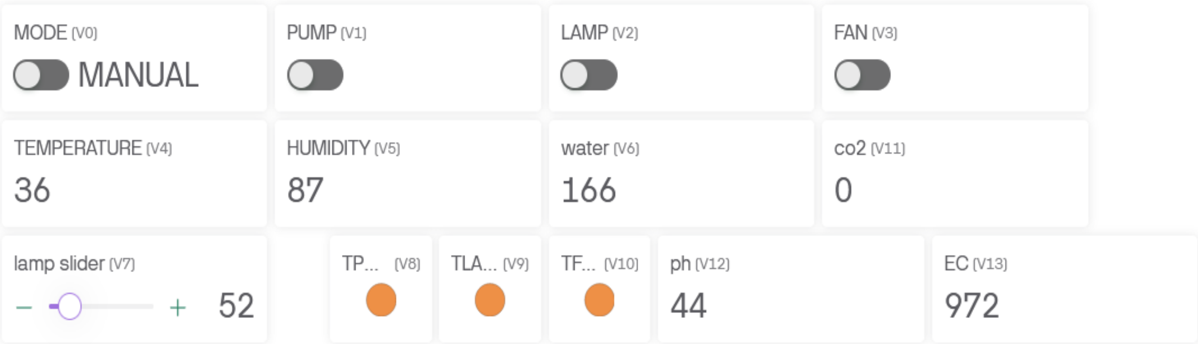

Figure IV-21: Web dashboard.

Figure IV-22: Firmware configuration.

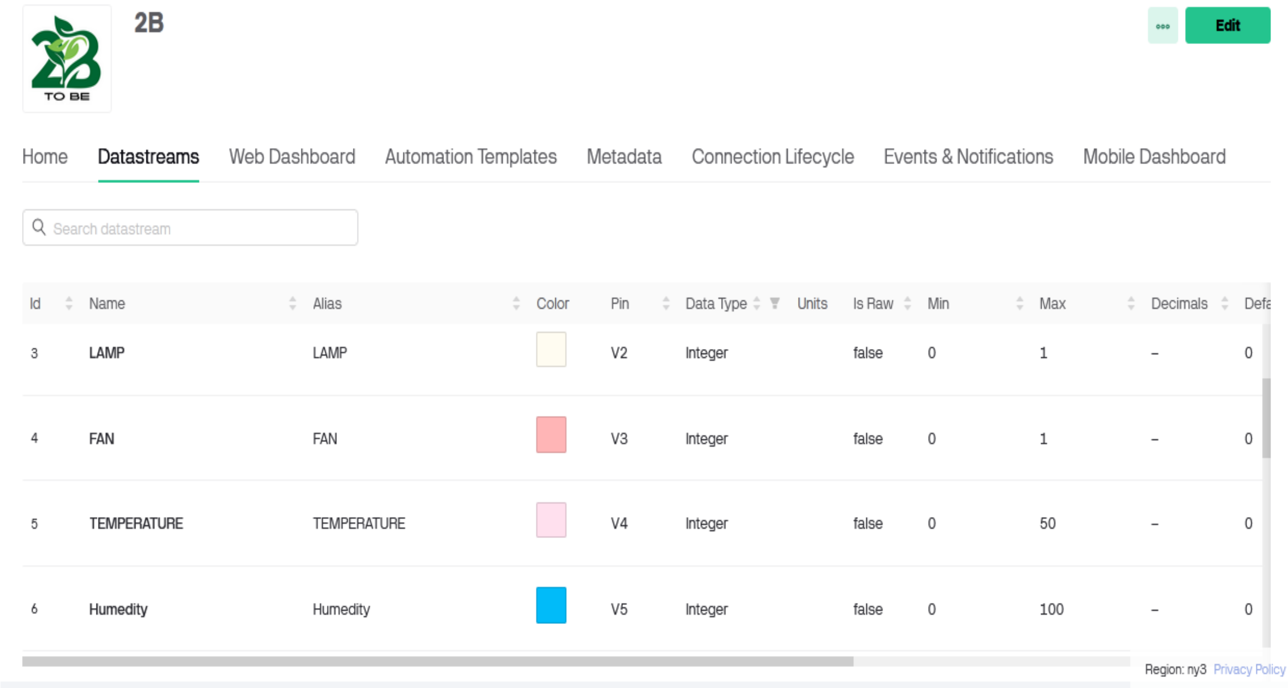

Figure IV-23: Datastreams.

Using the mobile app, we can manage the controls (automatic or manual) on the mobile phone (Figure IV-24) such as:

- Control Panel: This part is used to monitor climatic factors, temperature, humidity, water level, carbon dioxide, pH, electrical conductivity, and system malfunction.

- For actuators: Fan, pump, light, controlled automatically or manually via the control app and by pressing the control button after activating one of the two modes (automatic or manual).

- The following image represents the application interface:

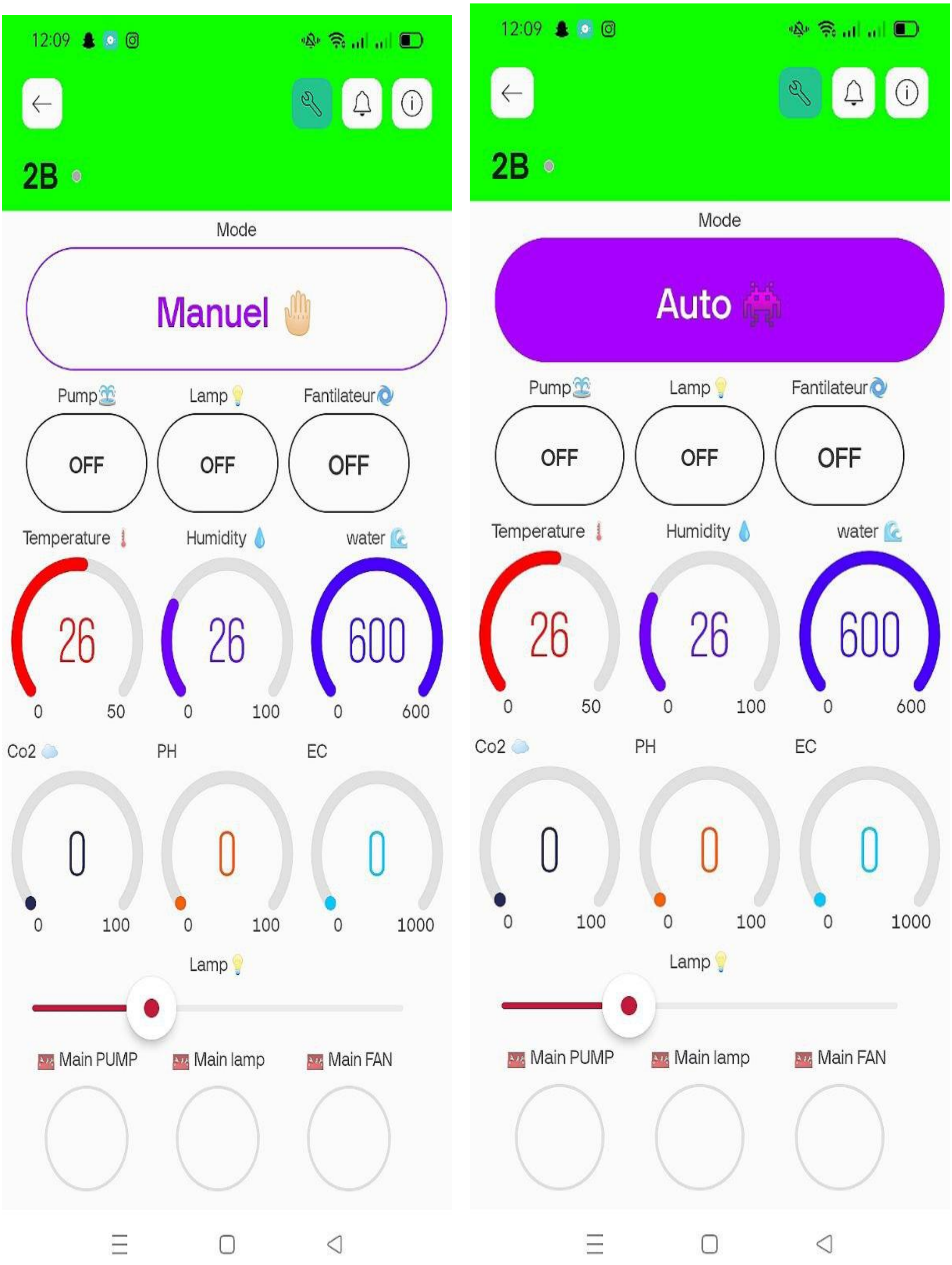

Figure IV-25: Application interface.

IV. 5 Design development

IV. 5. 1 Pipe design

The design of the piping in a mini-farm hydroponic system (Figure IV-26) is an important part of ensuring an adequate supply of water and nutrients to the plants. To perform this design, SolidWorks design software can be used.

The first step in pipeline design is to create a two-dimensional diagram of the hydroponic system. Various drawing tools, such as lines, circles, and arcs, can be used to plot the pipes location and route. It is important to take into account the floor distribution and elevations of each vertical system to determine the pipe layout.

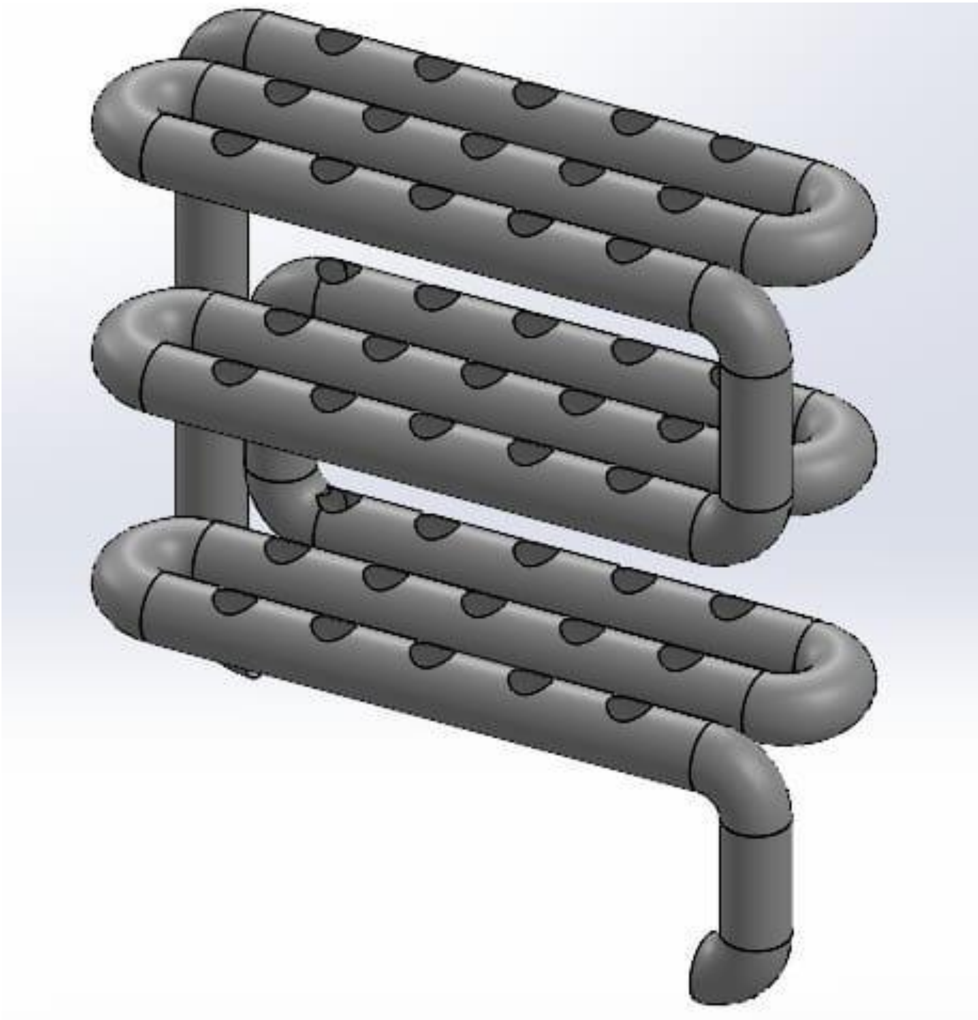

Figure IV-26: Pipe design (SolidWorks).

Once the drawing is created, SolidWorks extrusion and rotation functions can be used to convert the drawing into a 3D model of the pipe as shown in (Figure IV-26),These functions allow you to adjust the thickness and shape of the pipe as necessary.

IV. 5. 2 Shelf design

A shelf is an essential element of a hydroponic system (Figure IV-27), providing the support and structure needed to accommodate plants at different levels. The design of the rack must be efficient, safe, and maximize the space available for cultivation. Design tools such as SolidWorks can be used to create a 3D model of the shelf.

Using SolidWorks, a structural design of the shelf can be created in 3D. This includes creating frames, trays, and supports that can be easily assembled and disassembled for easy maintenance and crop harvesting. SolidWorks extraction, cutting, and assembly functions can be used to shape the different parts of the rack and ensure a strong and stable structure.

It is important to take available space and planting optimization into consideration when designing the rack. Multi-part racks can be created that allow for vertical expansion of the system, maximizing planting capacity in tight spaces.

In addition, trays can be designed with slots or holes to facilitate water drainage and allow plant roots to grow freely.

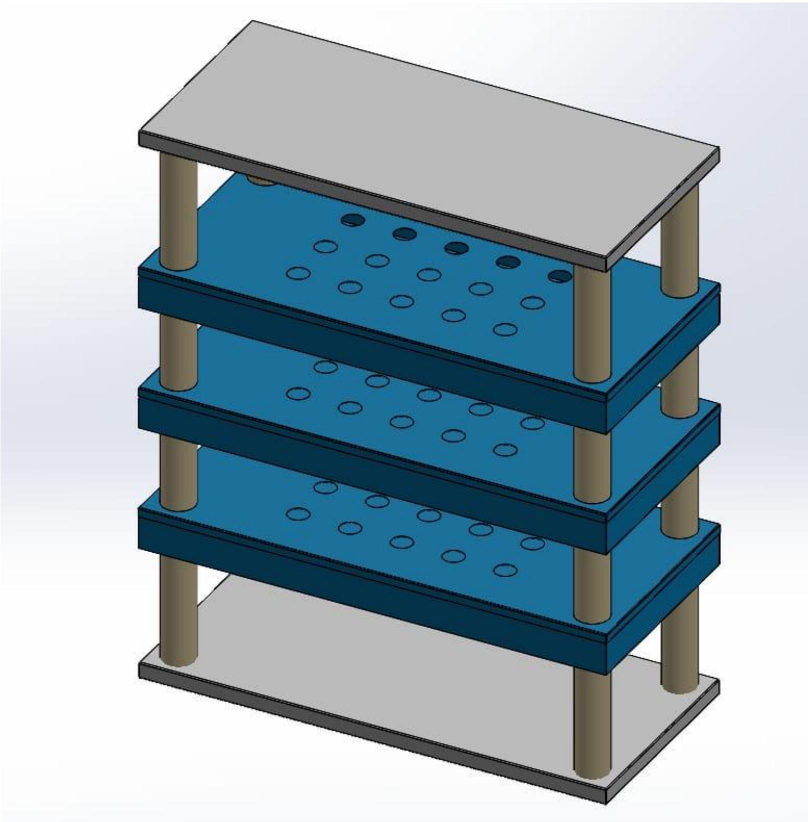

Figure IV-27: Shelf design (SolidWorks).

IV. 5. 3 Assembling the design

Assembling the pipes, cabinet, and rack is an essential part of building a hydroponic system for a miniature farm (Figure IV-28). This process involves properly connecting the pipes, installing the control cabinet, and installing the rack to create a complete and efficient system.

First, the water supply and drainage pipes must be connected. Using accessories such as elbows, couplings, and adapters, the pipes are assembled to ensure proper water flow throughout the system. It is important to ensure that the connections are tight to prevent leaks and wasted water. Clamps or strips can be used to stabilize and prevent unwanted leaks.

Next, the control cabinet is installed which contains the electrical and electronic components of the system such as pumps, relays, sensors, and the ESP32. The cabinet is placed in an accessible and safe location, preferably near the planting area. The installation instructions provided by the cabinet manufacturer must be followed and proper electrical connections made.

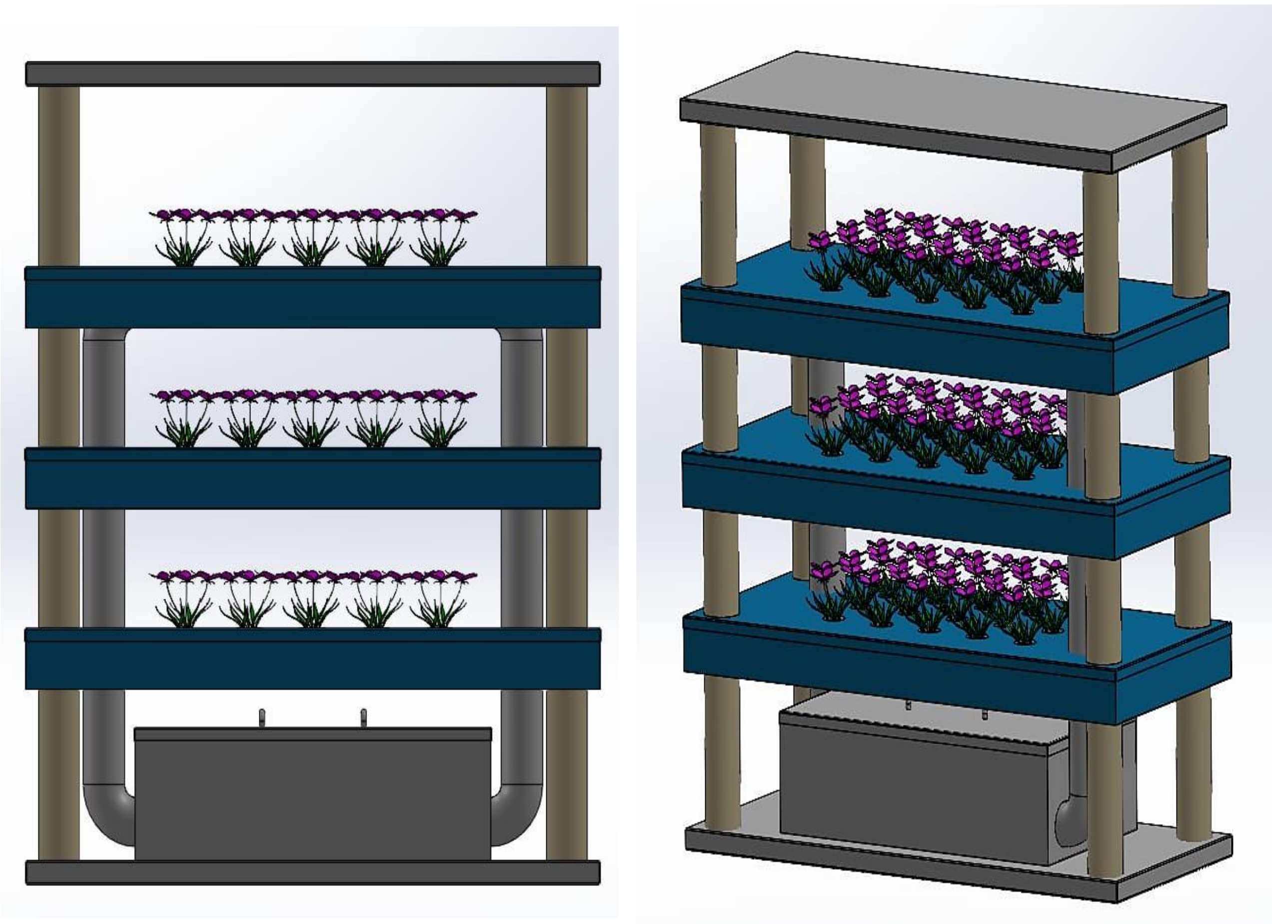

Figure IV-28: Design for prototype (SolidWorks).

IV. 6 Electrical Design

During the prototype assembly process, it is necessary to install the electrical and electronic components in the control cabinet (Figure IV-29), which is then attached to the model to accommodate and protect the various devices needed to operate the miniature farm, which includes an ESP32 controller, relay, and current sensor.

- The humidity and temperature sensor and CO_2 is used to control the operation of the fan.
- The pH and conductivity sensor (EC) controls the amount of nutrients in the water.
- Light sensor to control the operation of the artificial light.
- Water level sensor to control the pump.
- Current sensor to control the operation of the lamp located within the phone application.

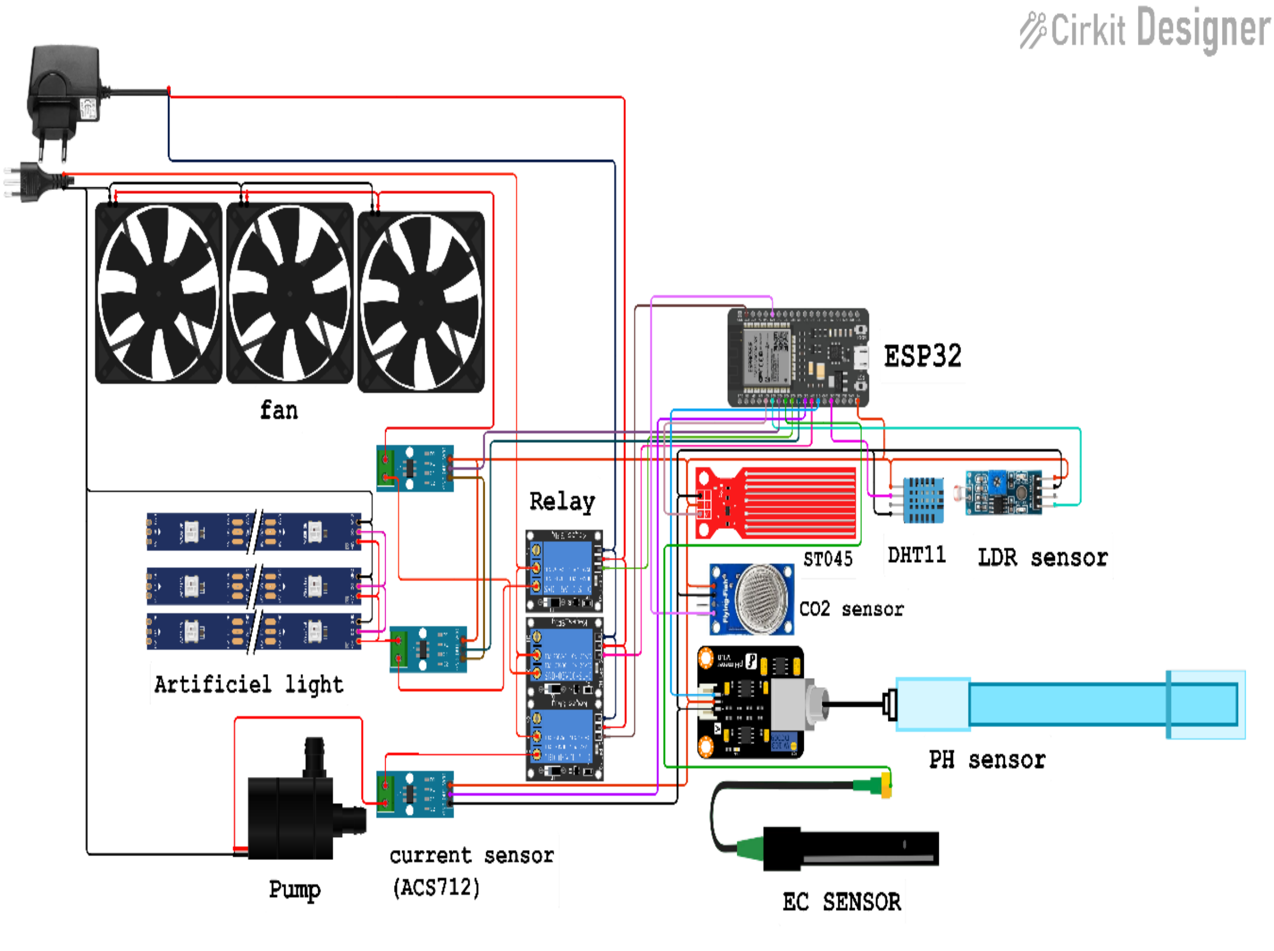

Figure IV-29: Circuit diagram(Cirkit Designer).

IV. 7 Implementation and principle of operation

The figures(Figure IV-30,Figure IV-31,Figure IV-30,Figure IV-31) below show the smart Mini-Farm prototype is a prototype version of a product or service that is used as a basis for development towards a final product that is officially marketed.

The prototype was made using materials available to us. The device was tested and verified in the laboratory of the Department of Automation and Electromechanics at the University of Ghardaia.

IV. 7. 1 Android application for manual and automatic control

The device can be controlled via two modes: Manual Mode and Automatic Mode.

IV. 7.1.a) Manual Mode

Once in manual mode, you can turn off and on the pump, fan, and artificial light (Figure IV-30Figure IV-31).

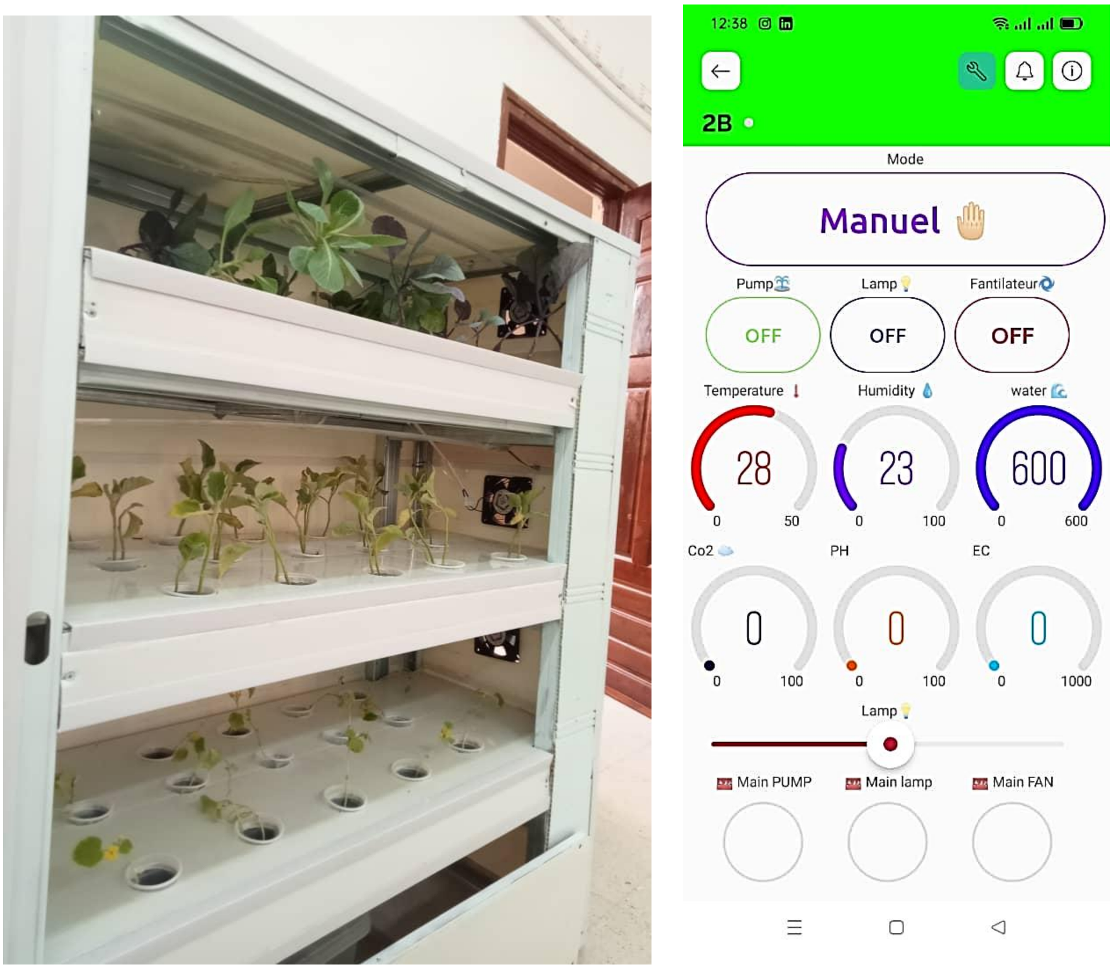

Figure IV-30: Turn off the smart mini-farm (manually).

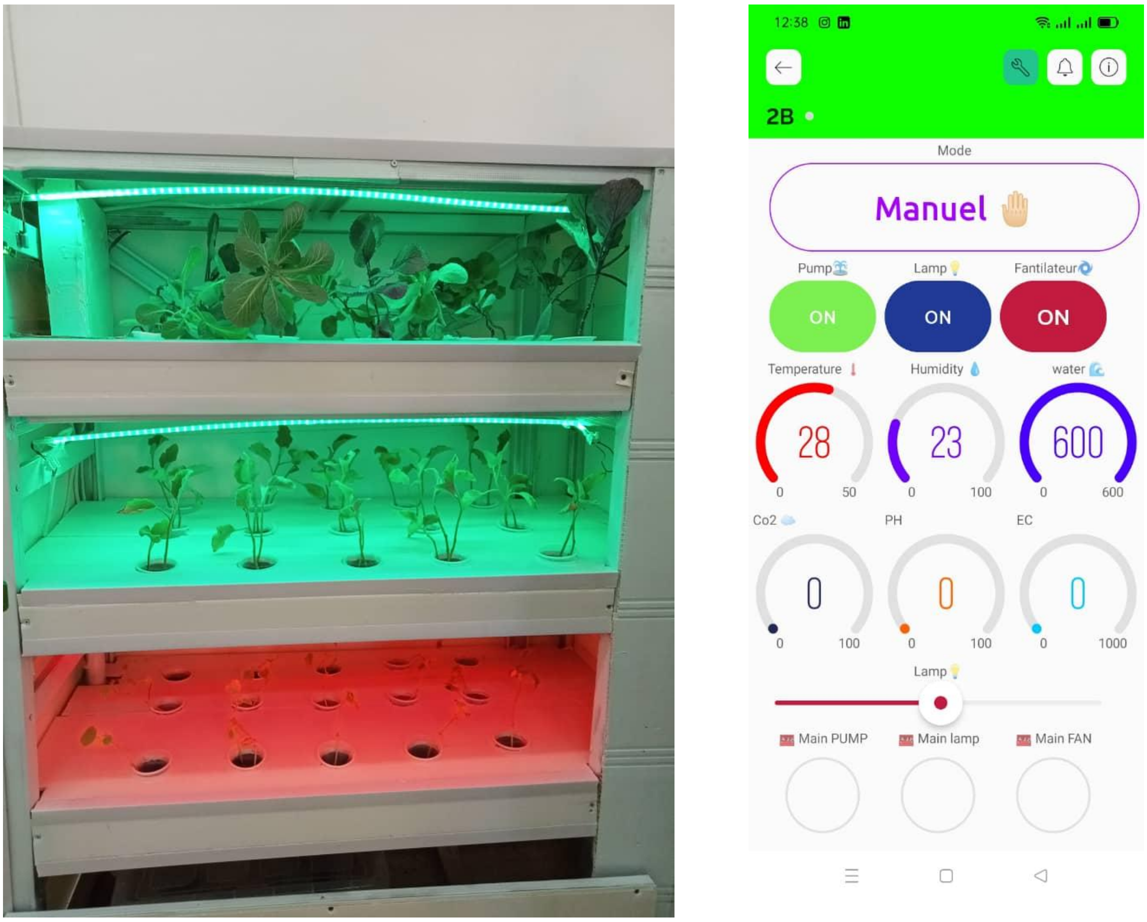

Figure IV-31: Running the Smart Mini Farm (manually).

IV. 7.1.b)Automatic Mode

Once you press the control button for the automatic mode as shown in the (Figure IV-30, Figure IV-31):

- With the DHT11 sensor and a carbon dioxide sensor, the fan operates automatically when the temperature exceeds 26 °C, humidity levels rise above 60%, or carbon dioxide levels exceed 1500 ppm. It turns off when these conditions fall below the specified thresholds.
- With the ST045 water level sensor, the pump automatically turns on when the water is low and turns off when the water reaches a certain percentage.
- With a light sensor that measures the percentage (intensity) of light in the environment so that the artificial light is automatically turned on for lack of light or lack of sunlight and turned off as soon as sunlight is present.
- Slider to control the intensity of the light when it is turned on in both modes (automatic and manual).
- 3 lights that turn on automatically in the event of a malfunction in one of the system devices.

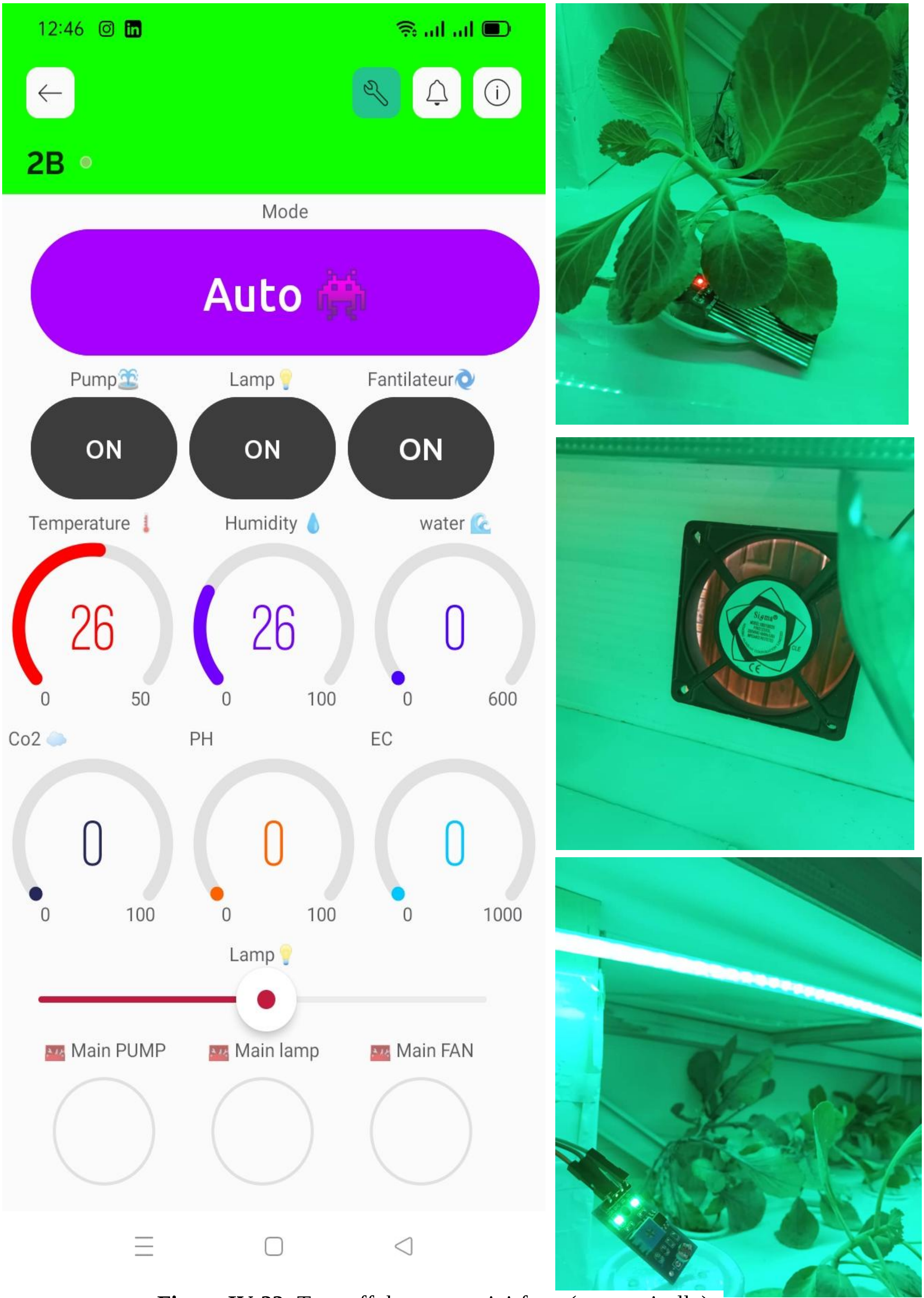

Figure IV-32: Turn off the smart mini-farm (automatically).

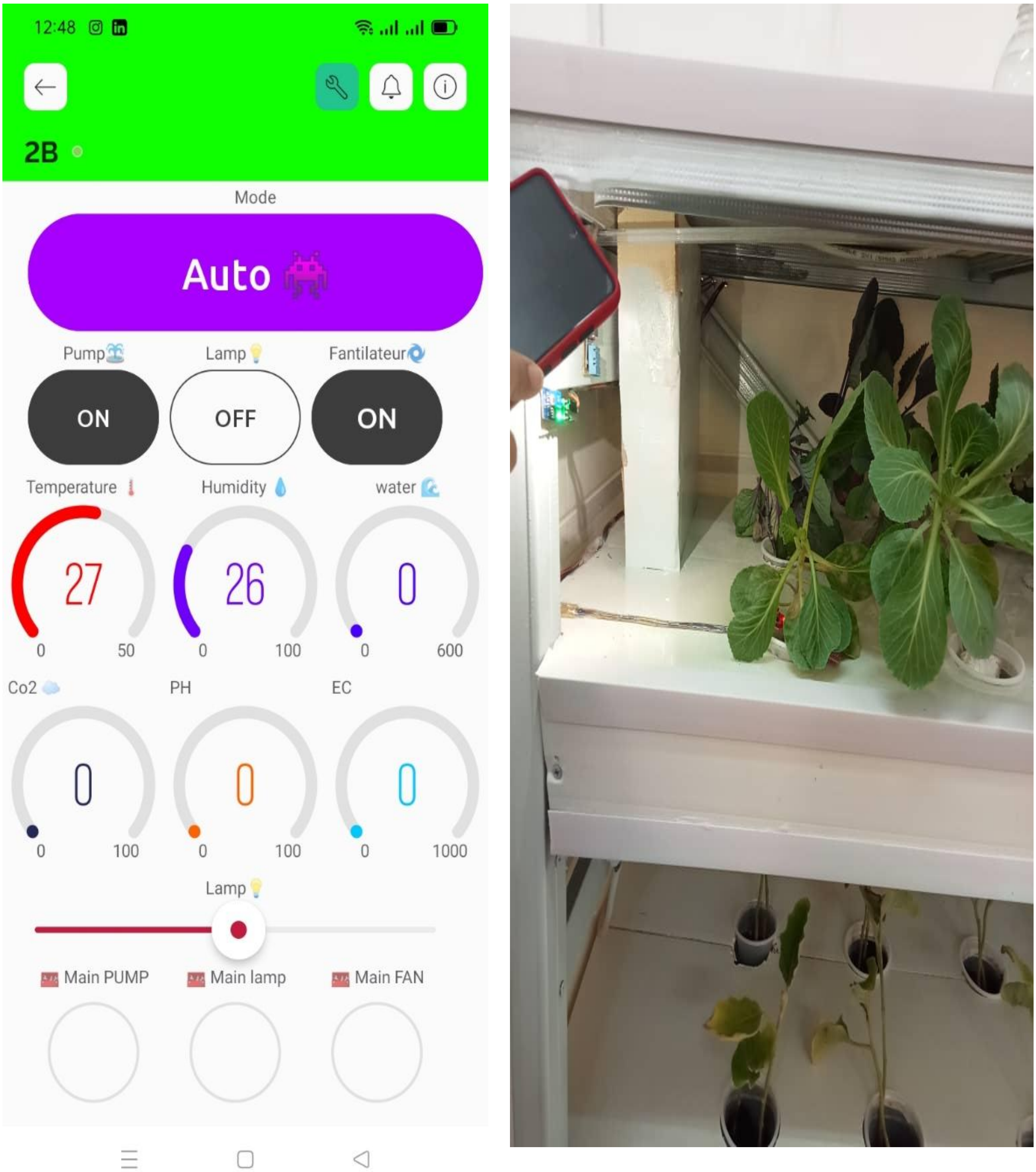

Figure IV-33: Smart Mini Farm artificial light is turned off (automatically).

IV. 8 Conclusion

In conclusion, this chapter has shown that an automated mini-farm management system can be created and developed through the use of smart sensors, a microcontroller, and an Android application. This system gives users the ability to effectively monitor and manage the climatic parameters of the mini-farm, helping to maximize production and ensure optimal crop health and growth.

The Android application is easy to use and offers advanced features such as automated or manual mode operation, remote monitoring, and system electrical fault detection, facilitating management even outside the micro farms footprint. By combining technological advances and agricultural knowledge, the automated management of the micro farm with water and artificial light opens new horizons for modern agriculture, improving food production efficiency, productivity, and sustainability.

In general, this chapter represents an important stage in the realization of our project, high lighting the concrete results obtained and illustrating the advantages and opportunities offered by the automated and manual management of miniature farms via an Android application.

General Conclusion

General Conclusion

The Smart Mini Farm Project (indoor and outdoor) opens new horizons in agriculture using water and artificial light with an irrigation, lighting, and cooling system that operates in both automatic and manual modes. This innovation addresses the inefficiencies of traditional irrigation systems and excessive water usage. Additionally, it optimizes the use of small and narrow spaces for those who lack sufficient space in their homes. This innovative project tackles these problems and enhances food production by ensuring optimal environmental conditions for plant growth while reducing reliance on external weather conditions.

Working with automated crops allows for intelligent control of environmental conditions, which are often uncontrollable in other agriculture. The data collection process allowed the use of automation in crop management to be identified and a list of variables to be monitored and controlled was created; as well as variables that could be included in future updates to the prototype. Using the Arduino™ platform and low-cost sensors, an automated system to monitor and control a prototype hydroponic farming system was developed.

By ensuring physical and chemical conditions in the germination and growth of plants, other elements that contribute to quality and development time can be incorporated, and the implemented automated system is a clear example of this. By using this system, the producer will significantly reduce the loss of seedlings due to mismanagement. Since when this automated system is implemented, immediate corrective actions will be implemented when one of the variables is outside the desired range, maintaining the crop in an optimal state of growth.in addition, it will allow reducing the labor cost dedicated to direct work on the crop.

In conclusion, the mini-farm is a solution for many users who are interested in farming with automated management via an Android application and represents a promising technological advancement for modern agriculture. By combining traditional agricultural knowledge with the benefits of technology, this approach offers great potential to increase productivity, optimize resource utilization, and ensure sustainable food production. In the era of digitization and innovation, mini-farm automation is a future solution to address global food challenges and promote more efficient and resilient agriculture.

Future Work

As part of the future development of the mini-farm project, the scope of crops can be expanded and artificial intelligence and solar energy technologies can be adopted to enhance innovation and efficiency in agriculture. The system can be designed to rely on high-efficiency solar panels to generate the necessary energy to operate all farm components, including the lighting system, pumps, and control devices, with batteries used to store excess energy for use during periods of low sunlight. Artificial intelligence will play a key role in analyzing sensor data to automatically manage light, water, and nutrient levels for any type of crop to be grown and predict harvests using machine learning algorithms to forecast optimal harvest times and potential productivity based on historical data and current growing conditions. This improves plant health by analyzing images for early detection of diseases or nutrient deficiencies, as well as analyzing plant health by introducing computer vision technologies to analyze plant images and identify any signs of disease or nutrient deficiencies.

A voice control interface can be developed and various farming modes can be customized to meet the farm's specific objectives, such as rapid growth, water conservation, or increased agricultural density. The use of energy-efficient LED lighting and an intelligent energy management system will ensure high efficiency and sustainable operation while reducing operational costs and reliance on conventional electricity. These improvements make the system more sustainable and reliable, increasing the farm's productivity and attractiveness to both consumers and investors. These future initiatives will contribute to enhancing smart and sustainable agriculture and providing innovative solutions to global food security challenges.

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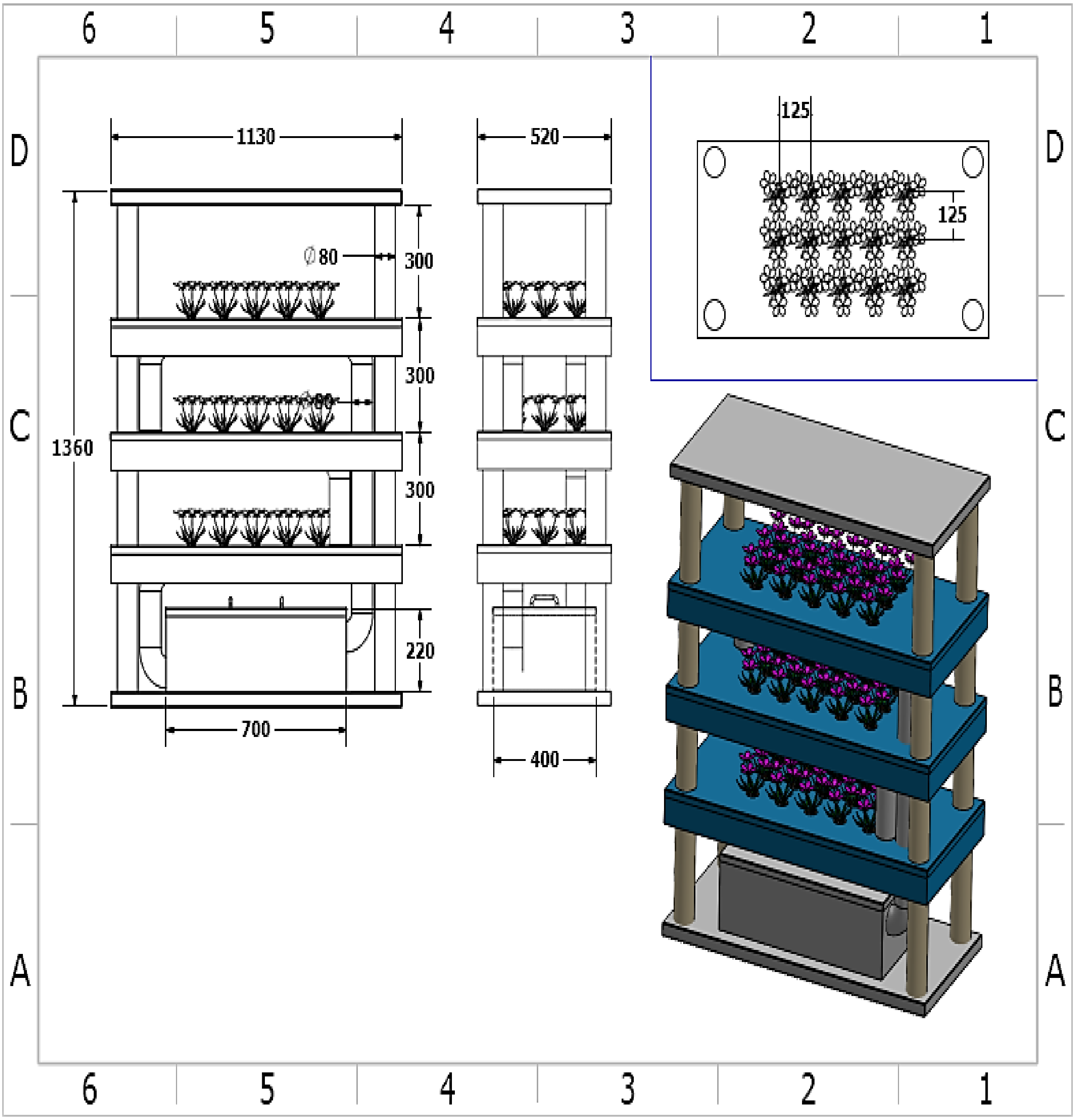
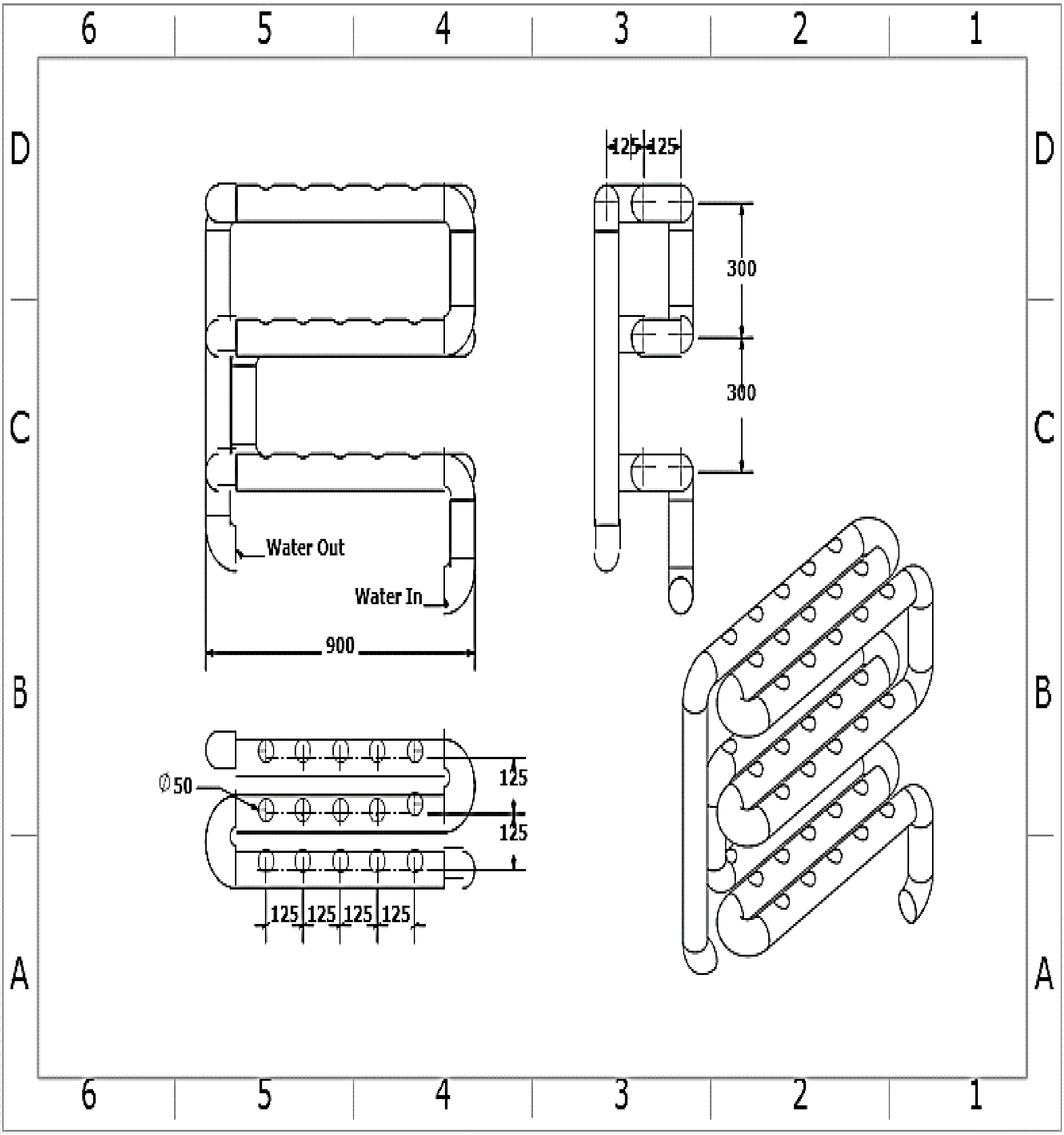
Appendix

Appendix- Design development (SolidWorks).

Modeling these measurements in SolidWorks in millimeters.




6
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300
Water Out
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125
125
125
125

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Faculté des sciences et Technologies

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