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Theme

Carbon Dioxide Estimation Using Artificial Neural Networks in Agricultural Greenhouses Case of GHARDAIA

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GRATITUDE

Dedication

I would like to express my gratitude to my very dear parents, KHEIRA AND KADDOUR, I thank them for having, oriented, helping, and advising me.

I extend my sincere thanks to all the professors, especially my cheerful professors, DJEMOUI LALMI and BEN SEDDIK ABDELOUAHAB and SALH BOUHOUN with whom we spent a unique experience, and whom was patient with us in this thesis I thank them for having framed me, oriented, helped and advised me.

I thank my sisters and my brother for stand by me and support me

Finally, I thank my friends who have always been there for me. Their unconditional support and encouragement has been of great help.

I dedicate this thesis to all our heroic martyrs

I offer my thanes, my respect, and my gratitude

“CHOUIREB TOUFIK”

Dedication

To the special man who spent his life in the cause of my happiness and made of his eyes a lamp that illuminates my path, my father.

To my soul and my cause of happiness who encourage me all the time, I ask Allah to give her the happiness and the long life, my mother

To all my dear brothers.

I extend my sincere thanks to all the professors, especially my cheerful professors, DJEMOUI LALMI and BEN SEDDIK ABDELOUAHAB and SALH BOUHOUN with whom we spent a unique experience, and whom was patient with us in this thesis I thank them for having framed me, oriented, helped and advised me.

"BEDJLOUD DAOUD"

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ABBREVIATION LIST

ANN	Artificial neural networks
ML	Machine learning
DL	Deep learning
GAN	Generative adversarial networks
CNS	Central Nervous System
SLP	Single-layer perceptron
MLP	Multilayer Perceptron
CNN	Convolutional neural networks
RNN	Recurrent neural networks
RBM	Restricted Boltzmann machines
DBM	Deep Boltzmann machines
ReLU	Rectified Linear Unit
LSTM	Long Short-Term Memory

Abstract :

To optimize photosynthesis and crop growth in greenhouses, it is essential to predict the concentration and consumption of carbon dioxide. In this study, we aimed to anticipate the CO_2 concentration in two distinct greenhouses: one equipped with a cooling system and the other without. Over a month, we meticulously measured temperature, relative humidity, and CO_2 concentration in these greenhouses at the Experimental Research Unit for Renewable Energies in Ghardaïa, Algeria. To achieve this, we used an Arduino board coupled with various sensors. The collected data were then used to train an artificial neural network, employing the Long Short-Term Memory (LSTM) algorithm for prediction. The analysis of the obtained results demonstrates the model's reliability, with R^2 and MSE parameter values ranging between 0.95% and.1%. Special attention will be given to the potential use of these models for improving agricultural production, economic evaluation, and environmental impact.

Keywords: greenhouse, CO_2 prediction, temperature, evaluation, Artificial neural networks and LSTM

الملخص:

لتحسين عملية التمثيل الضوئي ونمو المحاصيل في البيوت البلاستيكية ، من الضروري التنبؤ بتركيز واستهلاك ثاني أكسيد الكربون. في هذه الدراسة، استهدفنا توقع تركيز ثاني أكسيد الكربون في بيتين بلاستيكيين متميزين: أحدهما مجهز بنظام تبريد والآخر بدونه. على مدى شهر، قمنا بقياس درجة الحرارة والرطوبة النسبية وتركيز ثاني أكسيد الكربون في هذه البيوت على موقع وحدة البحث التجريبي للطاقات المتجددة في غرداية، الجزائر. لتحقيق ذلك، استخدمنا لوحة Arduinoمقترنة بمجموعة متنوعة من الحساسات. تم استخدام البيانات المجمعة لتدريب شبكة عصبية اصطناعية، باستخدام خوارزمية الذاكرة القصيرة الأجل (LSTM) للتنبؤ. أظهر تحليل النتائج المحصل عليها موثوقية النموذج، حيث تراوحت قيم معاملاتR^2 و MSEبين 0.95 % و1%. سيتم إيلاء اهتمام خاص لاستخدام هذه النماذج في تحسين الإنتاج الزراعي، والتقييم الاقتصادي، والتأثير البيئي

الكلمات المفتاحية:البيت البلاستيكي، التنبؤ بغا ثاني أكسيد الكربون، الحرارة، التقييم، الشبكات العصبية الاصطناعية خوارزمية الذاكرة القصيرة الأجل

Résumé :

Pour optimiser la photosynthèse et la croissance des cultures en serre, il est essentiel de prédire la concentration et la consommation de dioxyde de carbone. Dans cette étude, nous avonscherché à anticiper la concentration de CO_2 dans deux serres distinctes : l'uneéquipée d'un système de refroidissement et l'autre sens. Pendant un mois, nous avonsminutieusementmesuré la température, l'humidité relative et la concentration de CO_2dans ces serres, sur le site de l'Unité de Recherche AppliquéeenÉnergiesRenouvelables à Ghardaïa, enAlgérie. Pour cefaire, nous avonsutiliséune carte Arduino associée à divers capteurs. Les données collectéessont ensuite servi à entraîner un réseau neuronal artificiel, en utilisantl'algorithme Long Short-Term Memory (LSTM) pour la prédiction. L'analyse des résultats obtenues a montré la fiabilité du modèle selon les valeurs paramètres R^2, MSE et variaient entre 0.95 % et 1 %. Une attention particulière sera portée au potentiel de l'utilisation de cesmodèles pour l'amélioration de production agricole, l'évaluation économique et l'impact environnemental.

Mots clés : Serre agricole, prédiction du CO_2, température, évaluation, réseaux de neurones artificiels et Long Short-Terme Memory

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Agriculture is critical to human survival since it provides the majority of food and raw resources. As a result, a country's total economic prosperity depends on the expansion and advancement of its agricultural sector.

Greenhouse cultivation provides an ideal setting for the production of vegetables and fruits. It creates controlled settings within which numerous environmental elements can be adjusted. Temperature, humidity, and irrigation, nutrition, carbon dioxide levels, and light intensity may all be carefully monitored and altered in a greenhouse to provide an optimal environment for plant growth. Furthermore, the regulated climate of a greenhouse protects against external elements such as wind, pests, and diseases, allowing for greater control and management.

One of the significant advantages of greenhouse cultivation is the ability to extend the growing season. Crops can be grown year-round regardless of external weather conditions, leading to increased yield and more consistent production. This is particularly beneficial for regions with harsh climates or limited growing seasons.

Greenhouses also support the use of advanced agricultural techniques such as hydroponics and aquaponics. These soilless farming methods allow for the efficient use of water and nutrients, often resulting in faster plant growth and higher yields compared to traditional soil-based agriculture. Additionally, these systems can be designed to recycle water and nutrients, making them more sustainable and environmentally friendly.

Another intriguing aspect of greenhouse agriculture is its potential for urban farming. Greenhouses can be integrated into urban environments, including rooftops and vacant lots, bringing food production closer to consumers. This reduces transportation costs and carbon emissions associated with long-distance food distribution, promoting more sustainable and localized food systems.

In conclusion, agricultural greenhouses serve as an efficient alternative for improving plant growth by providing favorable circumstances and allowing effective control over pollination, disease prevention, and pest management. They offer numerous benefits, including extended growing seasons, the implementation of advanced farming techniques, and the potential for urban agriculture, all of which contribute to a more resilient and productive agricultural sector. [1]

Figure: Indoor greenhouse with organic vegetables [1]

In this study, we will carry out an analytical and comparing study to predict the concentration of CO_2 according to other variables of climate in two greenhouses one with the cooling system from type Pad and the other one without system cooling, using deep learning algorithms.

Initially, in chapter one, we shall cover all the descriptions of the greenhouse and all things about it like definitions of the building materials and the microclimate.

Next in chapter two, we intend to explain artificial neural networks inspired by the way biological neural networks work, define the types of algorithms behind deep learning, and some of the mathematical concepts used in it.

In chapter three, we shall talk about examining the geographical location and ecological factors that characterize the GHARDAIA region. We will describe the greenhouse in which the Master thesis was studied, the greenhouse type of the Canarian greenhouse. A prototype of the Canarian greenhouse was built at the Unit Workshop of Applied Research in Renewable Energies (URAER, Ghardaïa), This Canadian greenhouse was equipped to study its thermal and emission behavior using a cooling system (PAD). The chapter Finally, we will focus on estimating the CO_2 concentration based on data acquired from an Arduino card. We will implement the Long Short-Term Memory (LSTM) algorithm of Recurrent Neural Networks (RNN) to analyze and predict CO_2 levels. This section will include a detailed methodology of the data collection process, the configuration of the Arduino sensors, and the steps involved in training and validating the deep learning model. The performance of the LSTM algorithm will be compared with other prediction models to evaluate its accuracy and reliability.

CHAPTER I:
OVERVIEW OF GREENHOUSES

CHAPTER I: OVERVIEW OF GREENHOUSES

I.1. INTRODUCTION

The agricultural greenhouses, also called the 'environmental chambers', are a contemporary farming method that terminates the loss of crop yield and instead increases the yield by simply utilizing technology. The provision of a regulated atmosphere that cultivates plant growth also helps in the conservation of water sources, contributes to climatic conditions, and the reduction of adverse effects of climate change.

In this chapter, we will discover the history of greenhouses and what greenhouses are for agriculture, also study the advantages of greenhouses for farming, and see what the key aspects of climate are for greenhouses. Besides, we will analyze the several types and categories of greenhouses for agriculture, together with the selection of the most suitable ones, including the cover materials, and discuss the problems that most greenhouse farms face.

I.2. HISTORY OF GREENHOUSES

The historian Columella documents the earliest known endeavors in protected cultivation, dating back to the Roman Empire under Emperor Tiberius Caesar. Smaller structures that could be moved were employed to grow cucumber plants, protected from adverse weather conditions by mica and alabaster sheets. Nevertheless, such events were criticized by the philosopher Seneca as not natural, and so they faded with the fall of the Roman Empire. During the Renaissance time, greenhouses had their beginning in England, The Netherlands, France, Japan, and China. Their structures were made of wood or bamboo and covered with glass or oiled paper sheets. Then, brick-walled greenhouses of the lean-to type emerged in the northern hemisphere, using the brick wall for support and heaters for night protection of the plants. By the 19th century, the gable-frame greenhouses became a norm, allowing the cultivation of different fruits e.g. grapes, melons, peaches, and strawberries, and then tomatoes. The spread of greenhouses around the world was widely practiced during the 20th century, mainly after World War II. Glasshouses multiplied in Europe, while plastic films were used in Asia and the Mediterranean countries to revolutionize the greenhouses. In Europe, the energy crisis and the rise of plastics prompted greenhouse vegetable production to shift to the Mediterranean region, as the inexpensive greenhouses made of plastic allowed year-round cultivation at lower costs. At the same time, the temperate greenhouse industries in Northern Europe started growing cut flowers and ornamental plants instead. Two primary greenhouse concepts emerged: maximum climate control in the greenhouses, developed for enhanced productivity, for example in Northern Europe, and minimum climate control in the Mediterranean-type greenhouses, focusing on cost-effectiveness. The choice of greenhouse types is determined by factors that include climate control needs, crop varieties, geographical location, and socioeconomic settings [2]

I.3. LITERATURE REVIEW

Al Hawari's (2018) research was discussed [1] where we presented how artificial neural networks (ANNs) can be applied to CO2 level prediction in greenhouses. They chose relevant environmental parameters of temperature, humidity, and light intensity to use the ANN model that would be trained using these variables as the input features. The study not only showed the capability of ANNs but also revealed how accurately the model could generate CO_2 concentrations following the presented factors.

Rasouli (2019) [2] submitted a more advanced ANN model that is more adequately suited for CO_2 estimation in greenhouses. They improved the precision of CO_2 control even in a complex environment by taking into account some additional factors such as the presence or absence of plant species in addition to their stage of development and CO_2 injection rates with the ANN model.

Gupta and Kumar (2020) [3] are an example of researchers who specialize in this field by quantifying the computational performances of different neural network models in the context of CO_2 determination in greenhouses. The main focus of their work was comparing deep learning architectures, including CNNs and RNNs, with shallow networks for the computational task of reflecting highly nonlinear relationships between input variables and CO_2 levels. Sensors and ANNs play many crucial roles in real-time monitoring, which is according to published by Chen (2021) [4].

Through establishing a sensor fusion framework that combines different physical sensors into an ANN model, their study portrayed an appealing option of using ANN to explore sensor inputs and real-time CO_2 control in greenhouse applications. Li and Wang referred to an intelligent solution by a combination of Artificial Neural Networks and evolutionary algorithms to enhance the greenhouse climate control systems Li and Wang (2022) [5].

The fusion of the ANNs with evolutionary algorithms was conceived as part of the researchers' effort to provide more refined CO_2 injection strategies, using real-time sensor data and long-term weather records. This resulted in energy efficiency and increased yields of CO_2 management and agricultural greenhouses. In addition to the aforementioned studies, Kumar, Singh, and Sharma (2023) [6] contributed to the advancement of greenhouse climate control by focusing on the optimization of CO_2 levels. Their work, published in the Journal of Sustainable Agriculture, centered on utilizing ANN-based CO_2 estimation to refine greenhouse climate control strategies, thereby enhancing sustainability in agricultural practices.

Furthermore, Gonzalez, Martinez, and Rodriguez (2023) [7] put forward an innovative approach for predicting CO_2 levels in greenhouses under dynamic environmental conditions. Their study, published in the Journal of Applied Horticulture, highlighted the effectiveness of ANNs in accurately forecasting CO_2 concentrations amidst fluctuating environmental parameters, thus facilitating informed decision-making in greenhouse management.

Wu, Li, and Liu (2024) [8] expanded upon the integration of sensor data and ANNs for CO_2 estimation by introducing sensor fusion techniques. Published in the Journal of Agricultural Science and Technology, their research demonstrated the capability of ANNs to forecast CO_2 levels in greenhouses by synthesizing data from multiple environmental sensors, thereby improving the accuracy and reliability of CO_2 monitoring systems.

Zhang, Wang, and Li (2024) [9] proposed an ANN-based control system specifically designed for managing CO_2 levels in greenhouses. Published in the Journal of Control and Decision, their study outlined a comprehensive control framework leveraging ANNs to optimize CO_2 management strategies, ultimately contributing to the efficiency and sustainability of greenhouse operations. These studies collectively highlight the significance of artificial neural networks in advancing CO_2 estimation and management practices in agricultural greenhouses, paving the way for enhanced crop productivity and environmental sustainability.

Finally, Smith (2023) [10] conducted a comprehensive longitudinal study examining the practical application of ANNs for CO_2 estimation in commercial greenhouse operations. Their research provided invaluable insights into the long-term performance and reliability of ANN models in predicting CO_2 levels amidst dynamic environmental conditions and management practices, thus shedding light on the practical challenges and opportunities associated with deploying ANN-based CO_2 estimation systems in real-world greenhouse settings.

We will describe the specific environmental parameters and configurations of the greenhouses, the data collection process using Arduino sensors, and the methodology for training and validating our deep learning models. By comparing the performance of our LSTM model with other existing models, we will evaluate its accuracy and reliability in predicting CO_2 levels. Our study will also explore the integration of real-time sensor data and long-term weather records to enhance the efficiency and sustainability of greenhouse operations. Ultimately, our research aims to contribute to the advancement of greenhouse climate management through the application of advanced data analysis techniques, leading to more efficient and sustainable agricultural practices.

I.4.GENERALITY OF GREENHOUSE

I.4.1. DEFINITION

A greenhouse is a structure designed to provide an ideal micro-climate for growing crops with a lifespan of around 25 years. Those containing high-value equipment and crops should have a longer lifespan of at least 10 years. Agricultural greenhouses are generally made up of four distinct and homogeneous environments: the soil, the plants, the indoor air, and the wall separating the interior from the exterior. To promote plant growth, a greenhouse must provide appropriate levels of light, humidity, and warmth, and maintain a reasonably stable climate.

The primary source of heat in a greenhouse is sunlight, which passes through transparent materials Like glass or clear plastic. When the sunlight hits an opaque surface, some of it is converted into heat. However, some heat loss still occurs even though heat is retained inside a mostly glass or plastic structure.

Therefore, additional heat sources are required to keep the plants, ground, and soil comfortably warm. Maintaining a stable environment is critical for most plants, and this is the key to running a successful greenhouse. Ventilation, heating, cooling, and misting systems are critical considerations when constructing a greenhouse to ensure its durability and longevity. Greenhouses must conform to the same design and construction standards as those used for homes and other small buildings worldwide. Over the past four decades, growers, entrepreneurs, and plant enthusiasts have redesigned greenhouses using various materials.

Stress limits should be considered to prevent potential risks to human life and structural damage. [3]

I.4.2. STRUCTURE AND MATERIALS FOR THE GREENHOUSE

The greenhouse frame can be constructed from different types of material. The selection of the right framing material will depend upon capital investment, the size of the greenhouse, the height of the greenhouse, and the availability of material. The most common materials for greenhouse frameworks are bamboo, wood, mild steel pipes, galvanized pipes, Polyvinyl chloride (PVC) pipes like ours, and aluminum.

The framework should be strong enough to bear wind, snow, and dead load including the load required for the training of plants as well as for the hanging of plant pots. It should allow the maximum amount of light to reach the plants. It should require little maintenance. [4]

I.4.2.1. FRAMING MATERIALS

Greenhouses can be constructed from a variety of different materials. Aluminum, steel, PVC, and wood are among the most popular.

I.4.2.1.1. Metal (steel or aluminum)

It is not a very good insulator, but it is useful for the construction of very large greenhouses because it is mechanically resistant.

By far the most economical and longest lasting. Aluminum may be extruded in various shapes and thicknesses. This material can then be formed into rafters, side posts, and other structural components. [5]

I.4.2.1.2. Wood:

The best thermal insulator and most aesthetic material if wood is used, it is best to obtain pressure-treated lumber that resists decay. Because the wood is less commonly used because it deteriorates quickly in the moist environment of the greenhouse.

I.4.2.1.3. Pvc:

Is also a good insulator, which limits condensation and allows energy savings, in addition, its maintenance is easy. However, you should know that PVC tarnishes over time. [6]

I.4.2.2. COVERING MATERIALS

Greenhouse glazing falls into two categories: glass and plastic, each with strengths and weaknesses. The ideal covering lets in maximum light and deters heat loss. It should also be durable and require minimal maintenance. [7]

I.4.2.2.1. Glass:

The advantage of glass is the material traditionally used for greenhouse glazing, and it remains popular today. It offers excellent light transmission, resists degradation due to ultraviolet (UV) light, and has a long lifespan. It is also nonflammable and, when layered, retains heat well. Double and even triple-pane glass is available. The disadvantage of glass uninsulated single-pane glass offers very little heat retention. Glass is also breakable playing children, tree branches, and hail are all threats to a glass greenhouse. For safety, tempered glass is recommended because it shatters into small, rounded “pebbles” rather than sharp, jagged pieces. Glass is heavy and requires a strong, square frame and foundation or the glass can crack. Although glass offers excellent light transmission, the light is harsh and direct, not diffused, and can easily burn plants. Insulated glass can be costly. [7]

I.4.2.2.2. PLASTIC FILMS

1. Polycarbonate:

The advantages of Polycarbonate glazing is light, strong, and shatter-resistant, and when layered, it retains heat better than glass. It is available in corrugated, double, and triple wall panels. Corrugated polycarbonate provides excellent light transmission equal to that of glass but poor heat retention. Triple wall polycarbonate (16 mm) offers excellent insulation but reduced light transmission. Polycarbonate is impact-resistant and long-lasting (15 years or longer). Unlike glass, it transmits diffused light, which eliminates shadows on plants and protects them from burns. Using twin or triple-wall polycarbonate roof panels can increase heat retention while still allowing good light transmission. The disadvantages Polycarbonate scratches easily, and double- and triple-wall panels reduce light transmission. As with other plastic coverings, polycarbonate is subject to condensation, although it can be coated to reduce this problem. Like glass, it can also be costly, especially layered panels. [7]

2. Acrylic:

The advantages of acrylic offer clarity and light transmission similar to glass but is lightweight and more impact-resistant. Acrylic panels are ultraviolet-resistant and can easily be molded. The material is less expensive than polycarbonate and can be layered for extra strength and heat retention. It is easy to cut and can be shaped with ordinary hand tools. Like polycarbonate, it can be coated to reduce condensation. The disadvantage of acrylic is not commonly used in home greenhouses. Less expensive types of acrylics can be yellow, and even ultraviolet-coated acrylic will eventually need replacement. Unless it's coated, it suffers from condensation problems. [7]

3. HYBRID MATERIAL

a) Fiberglass:

The advantages of fiberglass have improved since its debut as a replacement for glass. It is now more ultraviolet UV resistant and resists yellowing. Its light transmission is almost equal to that of glass, but unlike glass, fiberglass diffuses light. It also offers better heat retention than glass and is much more durable. Good-quality fiberglass can last 20 years. The disadvantages Like other plastics, fiberglass tends to have condensation problems. If corrugated fiberglass is used, dirt can accumulate in the valleys, which detracts from its appearance. Inexpensive fiberglass may have a lifespan of no more than five years. [7]

I.4.3. ADVANTAGES OF GREENHOUSE PRODUCTION

Outdoor farming problems can be overcome by greenhouse production:

- Crop needs are limited in the local climate.
- Greenhouse production is hindered by external climatic conditions.

Managed climatic factors are easy to manage in the greenhouse, unlike outdoor cultivation. We highlight some of the major benefits of greenhouse production:

- Higher production thanks to the possibility of controlling the climatic conditions of the crop and promoting production all year round.
- Increased yield and quality of the harvest.
- Early production.
- Reduced consumption of fungicides and insecticides. [8]

I.4.4. MICROCLIMATE PARAMETERS

Solar radiation, temperature distribution, and relative humidity are the main climatic parameters needed to evaluate the climate suitability in a region for crop growth under protected cultivation. The other climate parameters such as soil temperature air temperature, wind, rainfall, and air composition, influence to a lesser degree. Carbon dioxide (CO_2) and photosynthetically active radiation accumulated over the day, are also two primary variables that affect plant growth in a greenhouse. [9]

I.4.4.1. Internal temperature

Temperature in greenhouses is the most important parameter for crop production under greenhouse conditions. It can be broken down into three types:

- Soil temperature.
- Plant temperature.
- Ambient temperature around the crop.

Temperature has a major influence on vegetative growth, as it is involved in many biological processes such as photosynthesis and respiration. The reaction rate easily increases with ambient temperature. For example, photosynthesis almost doubles when the temperature increases by 10°C.[10]

I.4.4.2. Relative humidity

Humidity in the atmosphere isimportant as it governs most of the metabolic and photosynthesis activities of plants. It has been observed that a relative humidity between 20 and 70 percent is ideal for plant growth.

This is so because, very high relative humidity will provide a better environment for pathogenic organisms making the plant susceptible to diseases. Low humidity is also harmful for plants since it increases the evaporation rate, and at the same time, enhances the water requirement. In environmentally controlled chambers, relative humidity between 55 to 65 percent and temperature between 20 to 25 °C is maintained. [11]

I.4.4.3. Carbon dioxide (CO_2)

The presence of carbon dioxide (CO_2) in the plant environment significantly impacts plant growth because it's essential for photosynthesis. The amount of CO_2 required for optimum plant growth depends on the plant type, state of development, temperature, light intensity, leaf area, air, velocity, humidity, water stress etc. But the CO_2 requirement differs for various plants. Research has shown that controlled environments, such as closed greenhouse system, provide ample opportunity to enhance production by increasing CO_2 levels. Carbon dioxide, which comprises about 0.03 percent (300 ppm) of ambient air, is essential for plant growth.

This level of carbon dioxide in atmospheric air is sufficient to meet the photosynthetic requirement of open field crops. In closed conditions, the level of carbon dioxide rises to nearly 1000 ppm, because respired carbon dioxide remains trapped overnight. As sunlight becomes available, photosynthesis process begins and carbon dioxide from greenhouse air gets depleted. As a result, the CO_2 level in the greenhouse even goes below 300 ppm before noontime. If the greenhouse air does not receive additional carbon dioxide from any other source, the plant would be deficient of carbon dioxide resulting in poor growth. Reports suggest that maintaining CO_2 levels between 1000-1500 ppm inside greenhouses can boost crop yields by 20-30 percent when carbon dioxide level was maintained from 1000-1500 ppm inside the greenhouse. The most common method of CO_2 supplementation is through burning of carbon fuels. [11]

I.4.4.4. Light

The growth and development rate of plants greatly depend on the solar radiation that the crop receives per day. The duration of sunlight is a crucial factor, although some crops react to short days, and others to long days (crop periodicity). Hence, it is important to know the day length throughout the year. Day length can be prolonged using artificial light or shortened by using shading materials (black plastic film). This is especially practiced in tropical countries to allow crops to reach the final stage of development. We need to know the day length to choose the type of crop to plant. The total amount of sunlight determines the growth rate and level of plant development. The variation in day length is strongly linked to seasons. Moreover, the distribution of annual rainfall and cloud cover are also determining factors. The topography of the land and especially the presence of mountains have an effect on the rate of cloud condensation and shading consequences.

I.4.5. CONTROL OF GREENHOUSE OPERATION

Many factors influence greenhouse climate management, including solar radiation, air temperature (T), relative humidity (RH), and carbon dioxide (CO_2) concentration. Controlling and managing these characteristics might result in improved agricultural growth conditions, as well as significant energy savings and water use controls. However, the interplay of the factors that impact each other, as well as their sensitivity to changing ambient environment, complicates monitoring and climate control. For example, relative humidity is determined by the quantity of moisture continually produced by plants, soil evaporation, and temperature, all of which are influenced by solar radiation and weather conditions.

I.4.6. CLIMATE PARAMETERS CONTROL METHODS

Climate control within greenhouses serves primarily to establish optimal environmental conditions for crop growth while minimizing water and energy usage. Various control systems, including manual, automatic, or intelligent control, are employed, and often equipped with Internet data monitoring capabilities. The hardware of these systems comprises sensors, controllers, and actuators. These sensors measure key parameters such as temperature (T◦), relative humidity (RH), CO2 concentration, and airflow rate, positioned both inside and outside the greenhouse at different locations, including at planting levels and inlet and outlet points of control components.

Control components typically include cooling, heating, and ventilation systems, as well as shading and fogging systems. Extensive studies have investigated the interrelationships between these environmental parameters, indicating that for effective control strategies in low-energy greenhouses, understanding their multiparameter coupling is crucial. Numerous control algorithms and numerical models have been developed to simulate the complexities of greenhouse environment control. The accuracy of these models ensures efficient management while minimizing energy consumption and maintaining an optimal growing environment.

Research done by Beveren.Suggested that employing optimal control methods can reduce cooling energy consumption by up to 15% and CO2 injection by up to 10%. Consequently, the adoption of effective control methodologies, particularly through smart greenhouse monitoring, has emerged as a new trend to ensure sustainable crop production. By integrating these advanced methods with renewable resources, greenhouse energy consumption can be significantly minimized.

I.4.7. COOLING SYSTEMS IN GREENHOUSES

Temperature and relative humidity regulation within the greenhouse is managed through various cooling technologies, including ventilation, external cooling systems employing heat exchangers, as well as evaporative and desiccant systems. These cooling processes can be categorized into two primary types: "passive" and "active" systems. "Passive" cooling within the greenhouse primarily involves design strategies (such as shape, covering materials, openings, and passive night cooling of the soil) aimed at reducing internal temperatures without the need for additional water or power consumption. On the other hand, "active" cooling encompasses all cooling systems utilizing electrical equipment such as pumps, fans, and heat pumps. Integrating passive cooling techniques before employing active cooling methods can effectively ensure favorable conditions for crop growth while reducing energy consumption simultaneously.[10]

We have a several systems for cooling in greenhouse:

a. Passive Cooling Systems
b. Ventilation Systems
c. we have two types of systems:
   - Natural Ventilation
   - Forced Ventilation
d. Heat Exchangers

We have two types:

- Air-to-Air Heat Exchangers
- Air-to-Liquid Heat Exchangers

e. Heat Pump Cooling Systems
f. Evaporative Cooling Systems we have three types of systems

I.4.8. EVAPORATIVE COOLING SYSTEMS

Evaporative cooling is a tool that can be used to reduce greenhouse temperatures. A “fan and pad” system uses exhaust fans to pull air through evaporative cooling pads. By utilizing the cooling effect produced when water evaporates and cools the air as it is drawn through the pad, this technique is utilized. The cooling pads cool by generating large surface areas that are exposed to air being drawn into the greenhouse by exhaust fans. Quick evaporation is possible due to the large surface area. [12]

And we find a more technique of evaporative cooling:

- Fogging Systems
- Roof Evaporative Systems
- Fan and Pad Systems

From all their systems we interesting in third type system Fan and Pad Systems.

I.4.9. TYPES OF GREENHOUSES

Greenhouse farming brings together different types of production or cultivation in greenhouses, including the production of horticultural plants (vegetables and ornamental plants, fruit trees or ornamentals) among others. Depending on the type of crop considered, different types of greenhouses are used (Figure I.1). A wide variety of greenhouses exist but two main types stand out: heavy greenhouses, often multi-span glass greenhouses and simple plastic shelters, often tunnel greenhouses. [13] .

- Chinese greenhouses
- Multi-span gutter-connected plastic-film greenhouses
- Horticultural greenhouses
- The round arched tunnel greenhouses
- The Canarian greenhouse

In ALGERIA we find

- The round arched tunnel greenhouses (low and big)
- The Canarian greenhouse
- The metal multi-span greenhouse

FigureI.1: Types of Greenhouses[13]

I.4.10. CHOOSING YOUR GREENHOUSE

- Design of a greenhouse
- Greenhouse Site Selection and Choice of Structure and Cover
- Greenhouse shapes
- Greenhouse Orientation

I.4.11. GREENHOUSE PROBLEMS

Problem of greenhouse can encompass several causes of the greenhouse that is based on construction, operations or greenhouse management.Some common problems include:

a. **Temperature Regulation:** Thefie greenhouses may experience temperature shifts as a result of factors such as insufficient ventilation, substandard insulation, and excessive radiation from the sun. An ideal degree of natural temperature conditions generally depicts the success in growth of plants and the prevention of cold damages as well as heat stress. [14]

b. **Humidity Control:** The necessity of keeping humidity levels within greenhouses correct is associated with plant health. High humidity has a tendency to cause fungal diseases and attract various pests while on its part low humidity can cause dehydration to plants and wilting hence the need to maintain optimum humidity. [15]

c. **Pest and Disease Management:** In greenhouses, pests and diseases have just the right biological habitats to flourish and multiply. Right options like integrated pest management (IPM) and biological control tactics need to be employed to overcome insect outbreaks and diminish crop damage. [16]

d. **Water Management:** Perfect irrigation techniques play a paramount role in the water supply to the plants without having to deal with either too much or too little moisture. For example, varying watering methods, poor drainage, inefficient irrigation system, root rot, nutrient leaching, waterborne diseases, and so on may be results of such problems. [17]

e. **Nutrient Management:** Regulating nutrient levels in the greenhouse and hydroponic culture is essential for plants to grow well and produce in quantity. Tracking for nutrient concentrations, pH adjustment and plants' uptake of nutrients can enable prevention of deficiencies or toxicities. [18]

f. **Structural Integrity:** Greenhouse structures may go out of service if that occurs due to man-made or natural sources such as corrosion, weathering, or physical damage.

Routine repairs and maintain be performed to retain the integrity of the greenhouse, avoid collapses and give the facility a longer life.[19]

g. **Energy Efficiency** Greenhouses rely on a lot of for heating-cooling, lighting, and ventilation. Implementation of energy efficiencies through initiatives like insulation, energy-efficient furnaces and renewable sources, for instance, could lead to the reduction in the utility bills and their impact on the nature. [20]

To address these greenhouse problems, ongoing observation, swift decision-making and application of fit and proper solutions that react to the particular surroundings of the greenhouse and the varieties that are planted is mandatory.

I.5. CONCLUSION

Greenhouses are essential structures designed to create optimal micro-climates for crop cultivation, ensuring the provision of light, humidity, and warmth necessary for plant growth. They predominantly use sunlight as their primary heat source but also require additional heating systems to maintain a stable environment. Constructed from various materials like aluminum, steel, wood, and PVC, greenhouses must balance durability, insulation, and light transmission. Covering materials include glass and plastic films like polycarbonate and acrylic, each with distinct advantages and drawbacks.

Effective greenhouse management involves controlling environmental parameters such as temperature, humidity, CO_2 concentration, and light. Advanced control systems, equipped with sensors and actuators, help maintain ideal conditions, promoting efficient energy and water use. Cooling systems, both passive and active, are crucial for regulating temperature and humidity. Types of greenhouses vary, including Chinese greenhouses, multi-span greenhouses, and tunnel greenhouses, each suited to different climates and crop types.

Despite their benefits, greenhouses face challenges like temperature regulation, humidity control, pest and disease management, water and nutrient management, structural integrity, and energy efficiency. Addressing these issues requires continuous monitoring, appropriate management practices, and technological integration to ensure sustainable and productive greenhouse operations.

CHAPTER II: ARTIFICIAL NEURAL NETWORKS

CHAPTER II: ARTIFICIAL NEURAL NETWORKS

II.1. INTRODUCTION

ANN have been developed as generalizations of mathematical models of biological nervous systems. A first wave of interest in neural networks (also known as connectionist models or parallel distributed processing) emerged after the introduction of simplified neurons by McCulloch and Pitts (1943). [21]

Machine learning (ML) algorithm and deep neural network-based system work towards accomplishing similar goal to the human thought process or behaviors by integrating in the computer systems. AI research goes deep into human thinking, how learning is done, decisions made, and how problems are tackled with a goal of developing smart machines. Machine learning (ML), the component of AI, features the algorithm that automatically detects a score of various patterns within a dataset without any programming instructions. Classification and regression are two main groups of machine learning algorithms. Some of the algorithms used in machine learning include neural networks, support vector machines, decision trees, and random forests amongst others. As a matter of fact, ML includes its own parts that as an example are generative adversarial networks (GANs) which were discovered by good fellow. DL constitutes a hierarchical algorithm for mining experience and produces a useful tool for recognition of visual object or speech and genome or human body studies. It is the structures of the neural networks that are adopted from their biological counterparts, multiple-layered artificial neural networks (ANNs) that are spread across various layers. [22]

Within this chapter we come in the basic concepts to understand NN. Thereafter, we try to describe the bind between biological and ANN. The rest of chapter is dedicated to some notions.

II.2. BIOLOGICAL NEURAL NETWORKS

The nervous system as a network of cells specialized for the reception, integration and transmission of information. It comprises the brain and spinal cord (the central nervous system; CNS) and sensory and motor nerve fibers that enter and leave the Central Nervous System (CNS) or are wholly outside the CNS (the peripheral nervous system; PNS). The fundamental unit of the nervous system is the neuron.[23]

Biological Neural Networks have the following parts. As (Figure II.1)

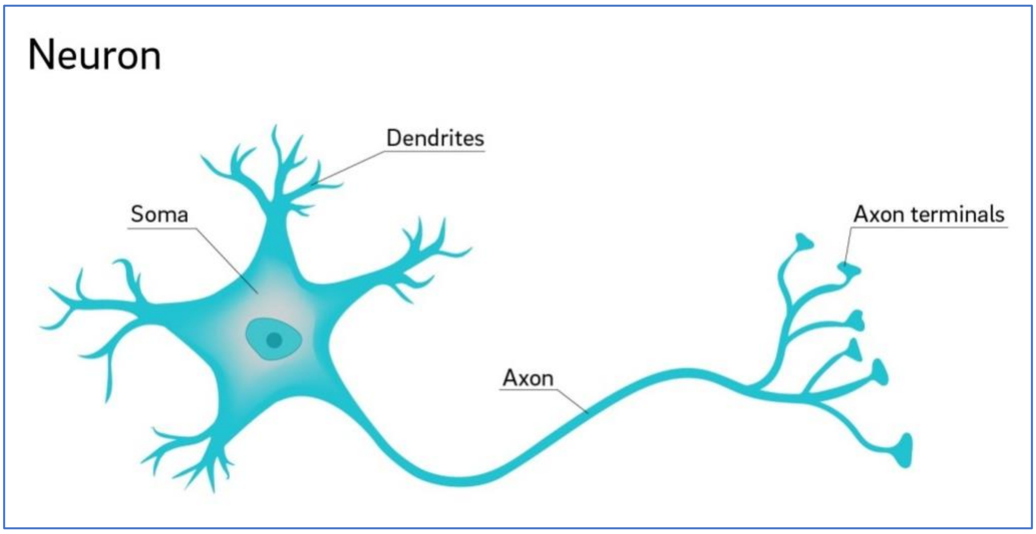


Figure II.1: Biological Neuron from [24]

- **Dendrites:** input canals which receive signals from previous neurons.
- **Body (Soma):** contains the kernel (Nucleus) which is responsible for the conduct of vital cellular activates.
- **Axon:** send signals into the synapse (link between two neurons).

From the above-described mechanism, scientists have modeled a mathematical model that artificially performs the same function of biological neuron. This is the basic element of an artificial neural network.

II.3. ARTIFICIAL NEURON

The artificial neuron serves as a fundamental component within artificial neural networks, drawing inspiration from the structure and behavior of biological neurons found in biological neural networks, such as those in the brain, spinal cord, and peripheral ganglia. (Figure II.2) highlights the parallels between them, depicting a biological neuron on the left with its soma, dendrites, and axon, and an artificial neuron on the right with inputs, weights, a transfer function, bias, and outputs. This comparison underscores the foundational role of artificial neurons in mimicking the functionality of their biological counterparts while adapting them to computational frameworks.[25].

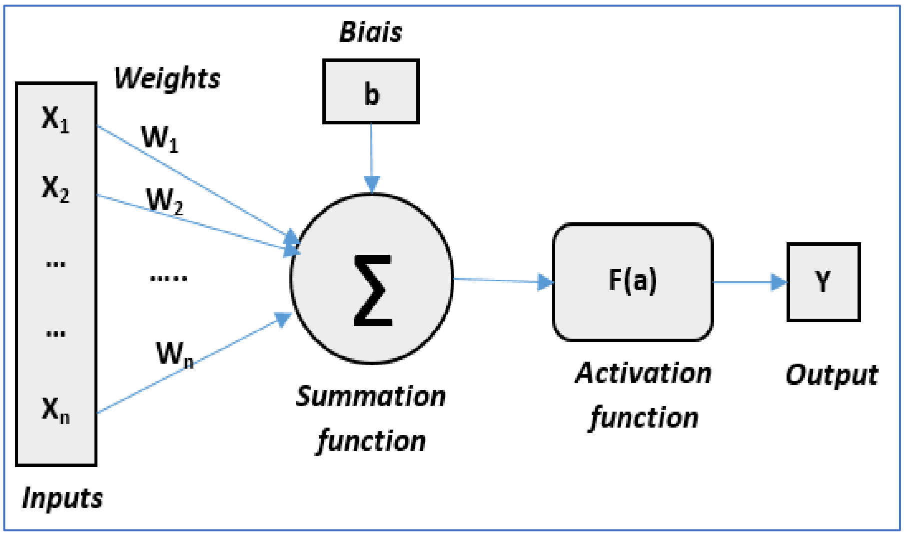


Figure II.2: Artificial neuron from [26]

In the scenario of biological neurons, information enters via dendrites, gets processed within the soma, and then transfers through the axon. Conversely, for artificial neurons, information flows into the artificial neuron's body through weighted inputs (where each input is multiplicatively adjusted by a weight). Subsequently, the artificial neuron aggregates these weighted inputs, along with a bias, and subjects the sum to a transfer function. Ultimately, the processed information is forwarded through output(s). The advantage of the artificial neuron model's simplicity is evident in its concise mathematical representation provided below.

$$y(k) = F\left(\sum_{i=0}^{m} w_i(k).x_i\,(k) + b\right)\text{.............Eq(II) [27]}$$

Where:

- $\boldsymbol{x_i}(k)$is input value in discrete time $k$where$i$ goes from 0 to$m$,
- $\boldsymbol{w_i}(k)$is weight value in discrete time $k$where$i$ goes from 0 to$m$,
- $\boldsymbol{b}$is bias,
- $\boldsymbol{F}$is a transfer function,
- $\boldsymbol{y}(k)$Is output value in discrete time k.

The unseen variables ruling this model are the transfer functions moving from the artificial neuron to its basic equation (1). The transfer function determines what artificial neuron's characteristics are and can be any type of mathematics. Decision on type of the transfer function depends on the problem the artificial neuron (or artificial neural network) needs to solve. Usually, we have the options of just selecting from a number of functions namely, Step function, Linear function, and the non-linear (Sigmoid) function.

Step function is a binary function that only has two possible output values for example zero and one. When the input value is greater than the preset threshold, the output ramifies its value to one and keeps it at zero otherwise. This is, what can be written as equation (2).

$$y = \begin{cases} 1 \;\; if \;\; w_i x_i \geq \; threshold \\ 0 \;\; if \;\; w_i x_i < \; threshold \end{cases} \qquad 2$$

Now when a transfer function such as that used by a perceptron is selected for an artificial neuron, we call the neuron a perceptron. Perceptron's on the contrary are mostly used for solving simple classification problems and they are often employed at the end of a multi-layer neural network. In the instance of a linear transfer function, a neural unit is a straight line and does only one sum of weighted inputs and bias. This type of artificial neuron is not an opposite of the perception threshold and the fiber optic technology which most of the times convinces the first layer of the ANN (artificial neural network).

A non-linear function oftentimes sees a sigmoid function being utilized by the graph. The gradient descents technique is as using the sigmoid function which has the easy-to-calculate derivative that are important the network learning by weight updates. [27]

II.4. ARTIFICIAL NEURONS VS BIOLOGICAL NEURONS

The concept of artificial neural networks comes from biological neurons found in Humans brains .So they share a lot of similarities in structure and function wise.[28] (Figure II.3)

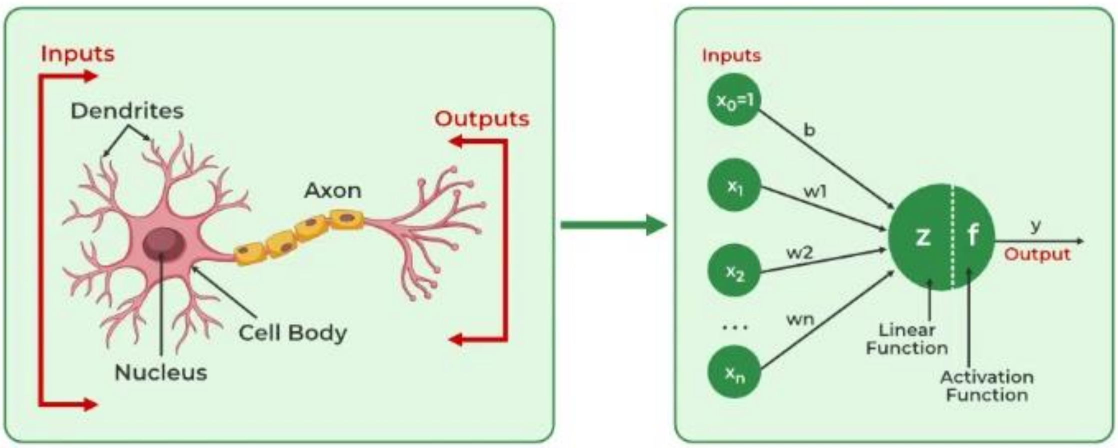


Figure II.3: Artificial neurons vs Biological neurons[28]

In the table below the elements in a biological neural network and their counterparts in an artificial network:

ARTIFICIAL NEURON	BIOLOGICAL NEURON
Inputs	Dendrite
Nodes	Cell nucleus or Soma
Weights	Synapses
Output	Axon

Table II.1: The elements in biological neural network vs Artificial network[28]

II.5. NEURAL NETWORKS NEED ACTIVATION FUNCTIONS

Neural Networks are a network of multiple layers of neurons consisting of nodes that are used for classification and prediction of data provided some data as input to the network. There is an input layer, one or many hidden layers, and an output layer. All the layers have nodes and each node has a weight that is considered while processing information from one layer to the next layer.[29]. (Figure II.4)

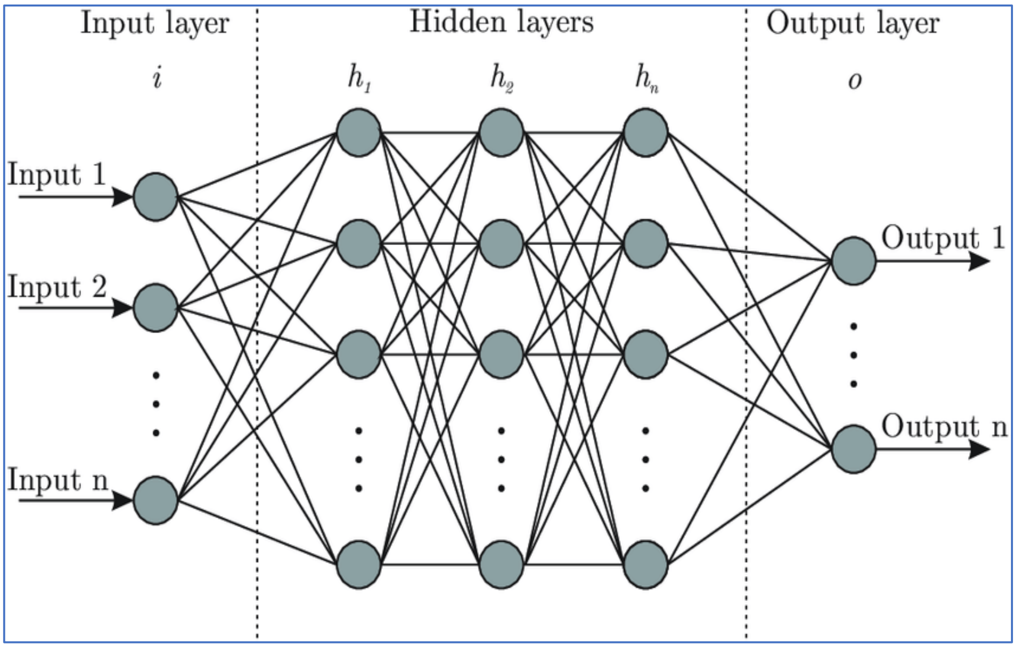


Figure II.4: Neural Network[29]

If a neural network does not employ an activation function, the output signal would simply be a basic linear function, essentially a polynomial of degree one. While linear equations are straightforward to solve, their complexity is inherently limited, lacking the capability to learn and discern intricate patterns from data. A neural network without activation functions behaves akin to a linear regression model, often exhibiting restricted performance and effectiveness. Ideally, a neural network should not only comprehend and compute linear functions but also handle more sophisticated tasks, such as modeling diverse data types like images, videos, audio, speech, and text. Hence, the utilization of activation functions and advanced techniques like deep learning is crucial, enabling neural networks to make sense of complex, high-dimensional, and nonlinear datasets, particularly those featuring multiple hidden layers.[30]

II.6.TYPES OF ACTIVATION FUNCTIONS

Net inputs are the most important components of a neural network. They are processed and converted into an output result known as unit activation by using a function known as the activation function, threshold function, or transfer function, which is a scalar-to-scalar transformation. Squash functions provide for a controlled amplitude of a neuron's output within a defined range. A squashing function decreases the amplitude of the output signal to a certain value. [30]

- Binary Step Function ;
- Linear ;
- Sigmoid ;
- Tanh ;
- ReLU ;
- Leaky ReLU ;
- Parametrized ReLU ;
- Exponential Linear Unit ;
- Swish ;
- SoftMax .

II.7.TYPE OF ARTIFICIAL NEURAL NETWORKS

Different neural networks are utilized for various data and purposes. The various neural network topologies are specially intended to operate with certain sorts of data or domains. Let's start with the most basic and go to more sophisticated ones.

II.7.1. SINGLE LAYER PERCEPTRON MODEL (SLP)

The single-layer perceptron (SLP) serves as the foundational model in neural networks, providing the basis for the development of more complex models in deep learning. Typically applied in classification tasks, SLP assigns labels (binary or multinomial) to data observations based on inputs. (Figure II.5) Input values are directly transmitted from the input layer to the output layer after undergoing multiplication by weights and the addition of a bias to the cumulative sum. This cumulative sum is subsequently subjected to an activation function, defining the output. The final output is determined based on whether this output surpasses or falls below a threshold set by the user. [31]

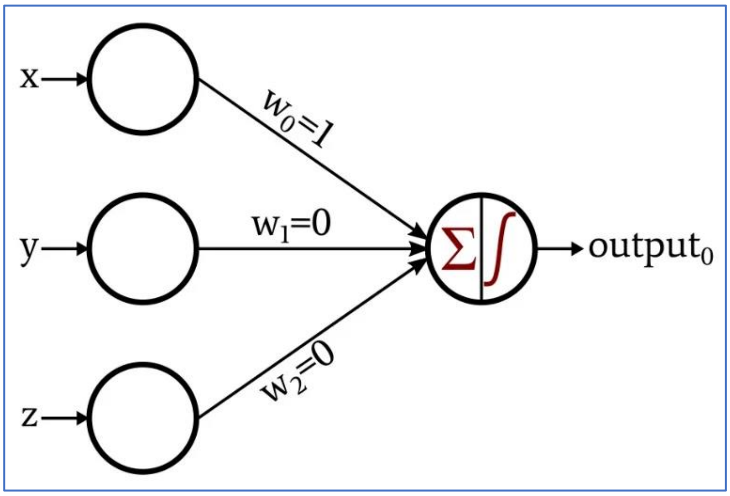
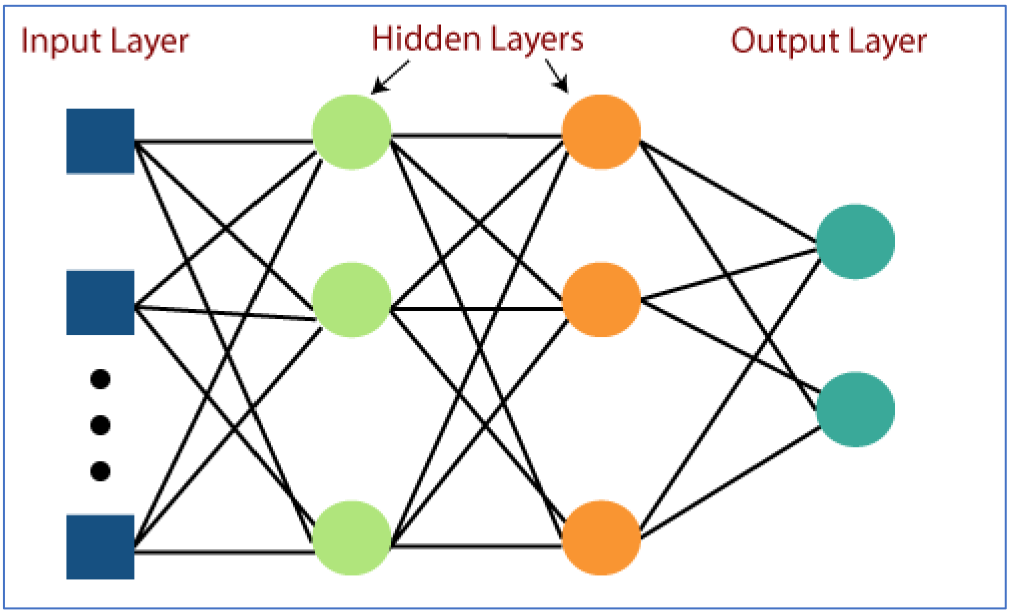


Figure II.5: Single-layer perceptron model [32]

II.7.2. MULTILAYER PERCEPTRON MODEL (MLP)

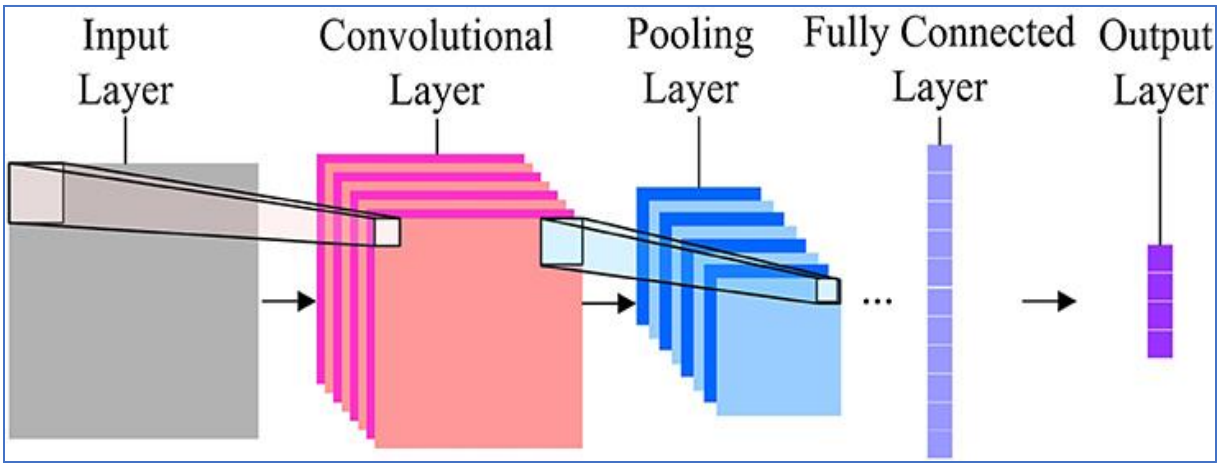
Similar to the single-layer perceptron (SLP), the multilayer perceptron (MLP) model comprises multiple interconnected layers, forming a feed-forward neural network. Each neuron within one layer establishes directed connections with neurons in another layer. A prominent distinction between this model and the single-layer perceptron model lies in the back-propagation algorithm, widely used for training neural networks. Back-propagation involves propagating the error calculated from the output layer back to the input layer, enabling analysis of each layer's role in the error and adjustment of the network accordingly. Gradient descent, a popular machine learning and optimization algorithm, plays a crucial role in this process by determining the extent to which weights should be adjusted in each iteration. Essentially, gradient descent involves calculating the derivative of a function to identify a scalar value indicating the direction of greatest momentum. By subtracting the gradient, the algorithm guides us towards a more optimal solution until we reach a global optimum.[31] (Figure II.6)



FigureII.6: Multilayer perceptron model [33]

II.7.3. CONVOLUTIONAL NEURAL NETWORKS (CNNS)

Convolutional neural networks (CNNs) find their primary application in image processing and computer vision tasks. They are engineered to emulate the structure of the visual cortex in animals, featuring neurons arranged in three dimensions: width, height, and depth. Each neuron within a layer establishes connections solely with a localized region of the preceding layer. CNNs are predominantly employed for tasks related to image processing and computer vision.[31] (Figure II.7).



FigureII.7: The General structure CNN [32]

II.7.4. RECURRENT NEURAL NETWORKS (RNNS)

Recurrent neural networks (RNNs) represent a subset of artificial neural networks (ANNs) characterized by connections between units that create a directed cycle. This directed cycle delineates a sequence wherein the progression through vertices and edges is wholly influenced by the utilized set of edges, thus displaying a semblance of a defined order. RNNs are frequently employed for tasks such as speech and handwriting recognition.[31] (Figure II.8).

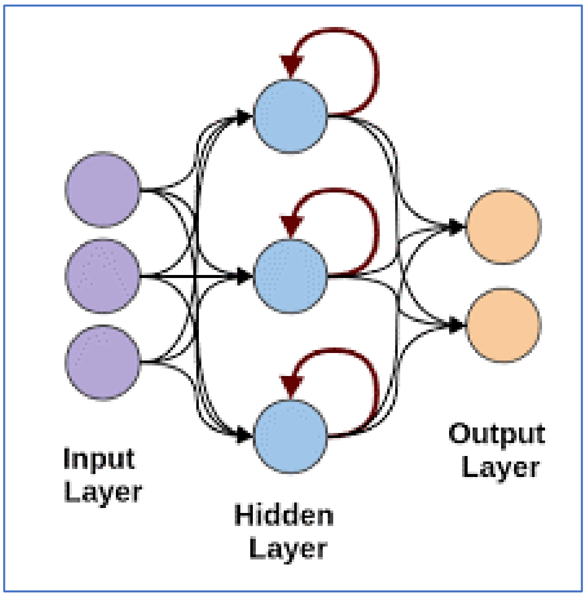
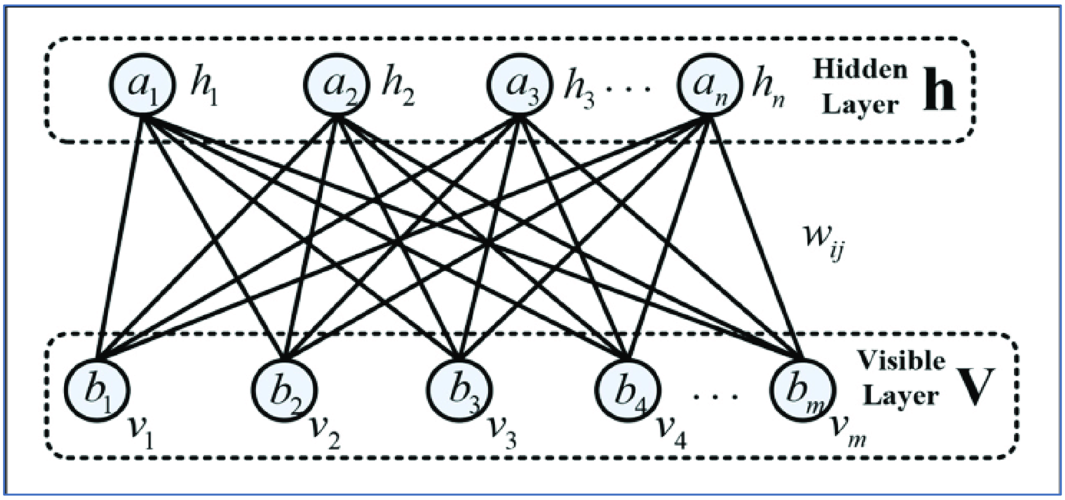


Figure 8: Recurrent neural networks [32]

II.7.5.RESTRICTED BOLTZMANN MACHINES (RBMS)

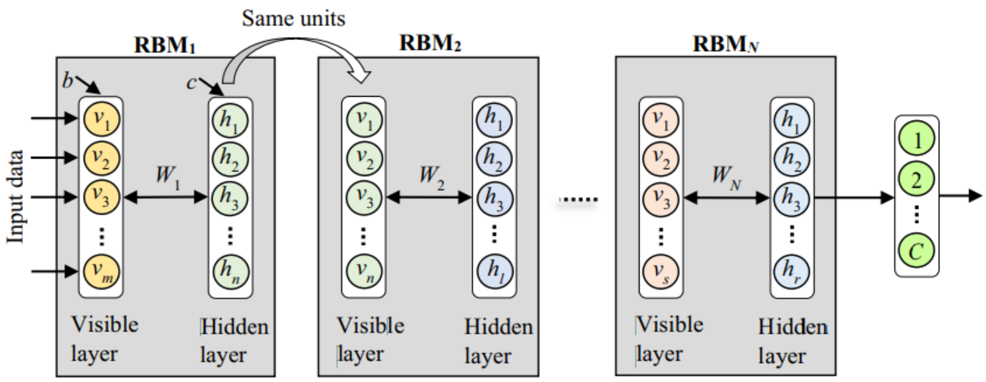
Restricted Boltzmann machines (RBMs) constitute a distinct type of binary Markov model characterized by a unique architecture. They feature multiple layers of hidden random variables and a network of symmetrically connected stochastic binary units. (Figure II.9) Deep Boltzmann machines (DBMs), on the other hand, consist of visible units and layers of hidden units, with no interconnections between units within the same layer. DBMs exhibit the capability to acquire intricate and abstract internal representations, particularly in tasks like object or speech recognition. [31]



FigureII.9: Restricted Boltzmann machine [34]

II.7.6. DEEP BELIEF NETWORKS (DBNS)

A DBN is constructed by stacking multiple layers of RBMs. RBM, a type of artificial neural network, comprises a single visible layer and a single hidden layer, facilitating unsupervised learning. The visible layer corresponds to the data, while the hidden layer captures features indicative of higher-order correlations in the data. In a DBN, each RBM's hidden layer serves as the visible layer for the subsequent RBM, except for the last RBM, which operates differently. RBMs leverage the hidden layer to establish the probability distribution of visible variables.[35] (Figure II.10).



FigureII.10: Deep belief[35]

II.8. ADVANTAGES AND DISADVANTAGES OF NEURAL NETWORKS

II.8.1. ADVANTAGES

- **Adaptability:** Neural networks excel at solving nonlinear problems and can adapt well to varying situations.
- **Speed:** They offer fast execution, suitable for parallel implementation.
- **Robustness:** Neural networks exhibit good noise immunity, making them resilient to disturbances.
- **Transfer Learning:** They can leverage previously trained networks to address similar problems, facilitating efficient knowledge transfer.
- **Fault Tolerance:** Neural networks can continue functioning even if certain information is missing or if there are minor errors within the network.
- **Learning from Examples:** Unlike traditional algorithms, neural networks learn from numerous examples provided to them.

II.8.2. DISADVANTAGES

- **Resource Intensive:** Neural networks require powerful machines due to their structure and the need for parallel processing power to handle large volumes of information.
- **Network Architecture:** The "black box" nature of neural networks makes it challenging to interpret what occurs within hidden layers.
- **Lengthy Learning Process:** Training neural networks can be time-consuming.
- **Risk of Local Minima:** Backpropagation error learning may converge to local minima, resulting in suboptimal solutions.
- **Network Paralysis:** In some cases, the weights within the network may become so large that modifying them does not influence neuron behavior. [36]

II.9. CONCLUSION

This chapter provides a foundational understanding of Artificial Neural Networks (ANNs) by introducing the biological inspiration behind them and explaining how they are modeled mathematically. It covers the basic structure of artificial neurons, activation functions, and different types of neural networks used for various tasks.

The chapter concludes by highlighting the advantages and disadvantages of neural networks. Neural networks are powerful tools for complex problem-solving but can be computationally expensive and require careful design and training.

CHAPTER III: MATERIALS AND METHODS

CHAPTER III: MATERIEL AND METHODS

III.1. INTRODUCTION

This chapter examines the geographical location and ecological factors that characterize the GHARDAIA region. We will describe the greenhouse in which the Master thesis was studied, the greenhouse type of the Canary greenhouse. A prototype of the Canary greenhouse was built at the Unit workshop of Applied Research in Renewable Energies (URAER, Ghardaïa), This canary greenhouse was equipped to study its thermal and emission behavior using a cooling system (PAD). The surface area of our greenhouse is 13.5 m^2 (4.5×3 m, with a height of 1.90 m). The greenhouse was planted. It was covered in plastic Transparent yellow polyethylene.

III.2. DESCRIPTION OF STUDY AREA

Ghardaïa is an arid and dry location located in the south of Algeria, about 600 km south of the capital city (Figure III 1). It is framed by the following geographical coordinates: latitude 32° 36' N, longitude 3° 48' E, and altitude 450 m above the level. The site is distinguished by extraordinary sunlight and a high rate of insolation; the average annual global solar radiation measured on a horizontal plane exceeds 6000 (Wh/m^2), and the sunshine duration surpasses 3000 (hours/year). Winter in Ghardaia is characterized by intense cold due to windblown snow from the highlands. Sandstorms from the southwest toward the end of winter are especially difficult due to significant dustiness. Temperature is high in summer and can exceed 45∘ C. [37]

The Ghardaïa region covers an area of 2,025 km^2. It is limited to the North by the Wilaya of Laghouat (200 km) to the East by Ouargla (200km), bordered by Tamanrasset (1470) km to the South, and to the West by El-Bayad. [38].

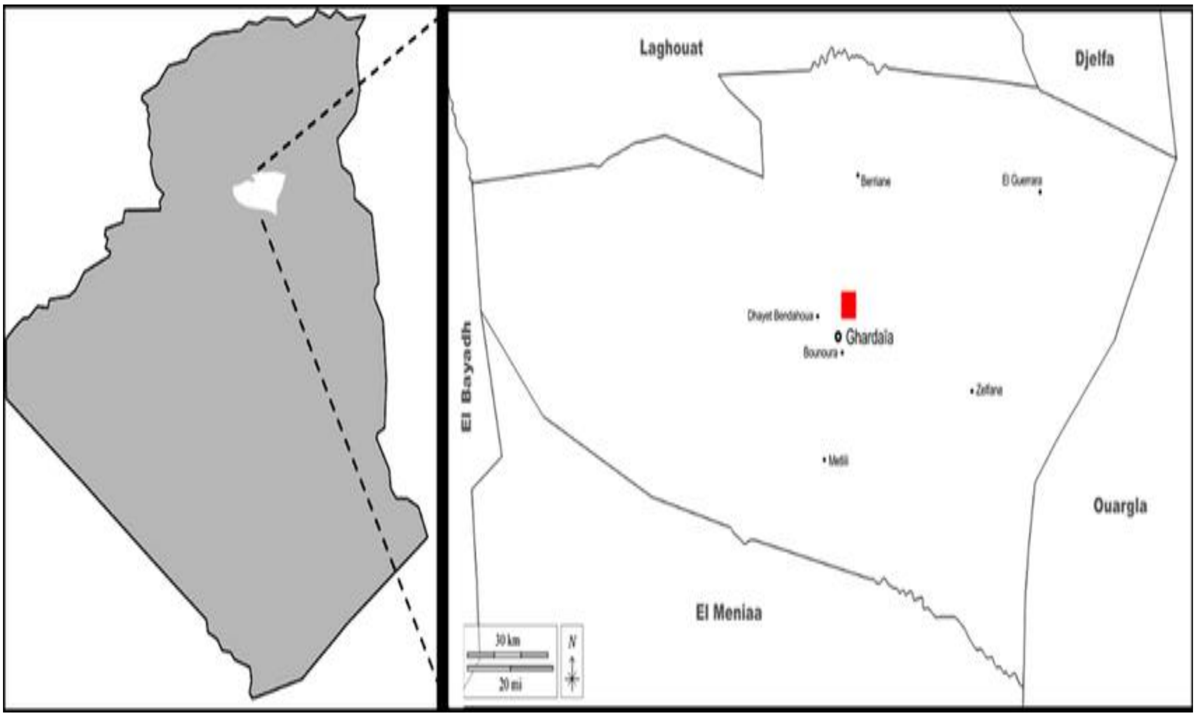


Figure III.1: Geographical location of the Ghardaïa region. [39]

III.2.1. ECOLOGICAL FACTORS

The term ecological factors refer to the different environmental components that impact ecosystem structure, function, and dynamics. These elements can be biotic (living) or abiotic (non-living), and they interact in intricate ways to influence the distribution, number, and behavior of species in an ecosystem.

Ecological characteristics are crucial in influencing the health, resilience, and sustainability of natural habitats.[40]

III.2.1.1. ABIOTIC FACTORS

Abiotic variables refer to all of the physicochemical elements that impact a certain biocenosis. Geological, pedological, and hydrographic features are among the criteria that characterize an ecosystem's ecological attributes. [41]

III.2.1.1.1. EDAPHIC FACTORS

The edaphic aspects of the Ghardaïa region include geology, and pedology, and ecological impact on living organisms.

a) GEOLOGICAL PARTICULARITY

The Ghardaïa area has three distinct types of geomorphological formations.

- The M'Zabchapka
- Dayas
- Ergs

b) PEDOLOGICAL PARTICULARITY

- Sand
- the desert soils
- Clay soils. [42]

III.2.1.1.2. CLIMATIC FACTORS

a) TEMPERATURE

Is the degree of hotness or coldness of an object. It is generally expressed in degree Celsius (ºC). Temperature at a given site depends on wind as well as local factors such as shading, presence of water body, sunny condition, etc.

In Saharan areas, it is the most dominant factor. It is the most important factor among all climatic factors.

We can see in the chart below the records of temperature degrees last third years ,and couple months this years of GHARDAIA. (Figure III .2).[43]

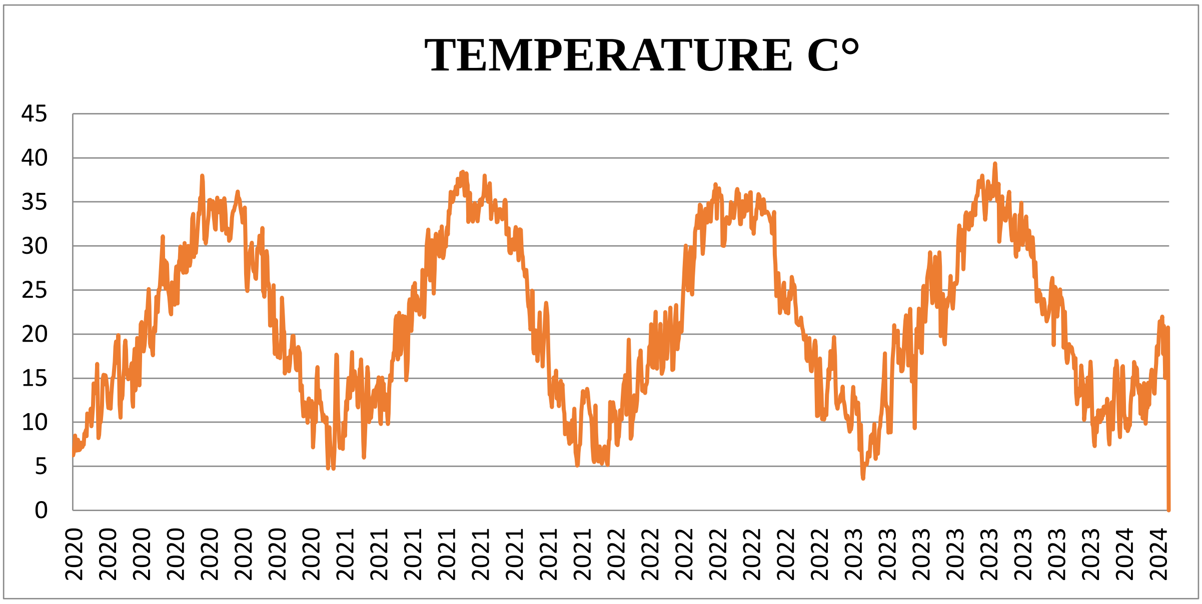


Figure III.2:TemperatureofGhardaïa regionfor last four years (NASA)

b) HUMIDITY

The humidity of air can be described as absolute humidity (AH), i.e. the amount of moisture actually present in unit mass or unit volume of air, in terms of gramme per kilogram (g/kg) or gramme per cubic meter (g/m3).

However, the relative humidity (RH) is a much more useful form of expression, as it gives a direct indication of evaporation potential. The saturation point humidity (SH) is determined by the temperature of the air. The ratio of the actual amount of moisture present to the amount of moisture the air could hold at a given temperature is known as relative humidity. RH = (AH/SH) X 100

Humidity is usually measured with the wet-and-dry-bulb hygrometer. [44]

We can see in the chart below the records of humidity percentage degrees last third years ,and couple months this years of GHARDAIA (Figure III.3). [45]

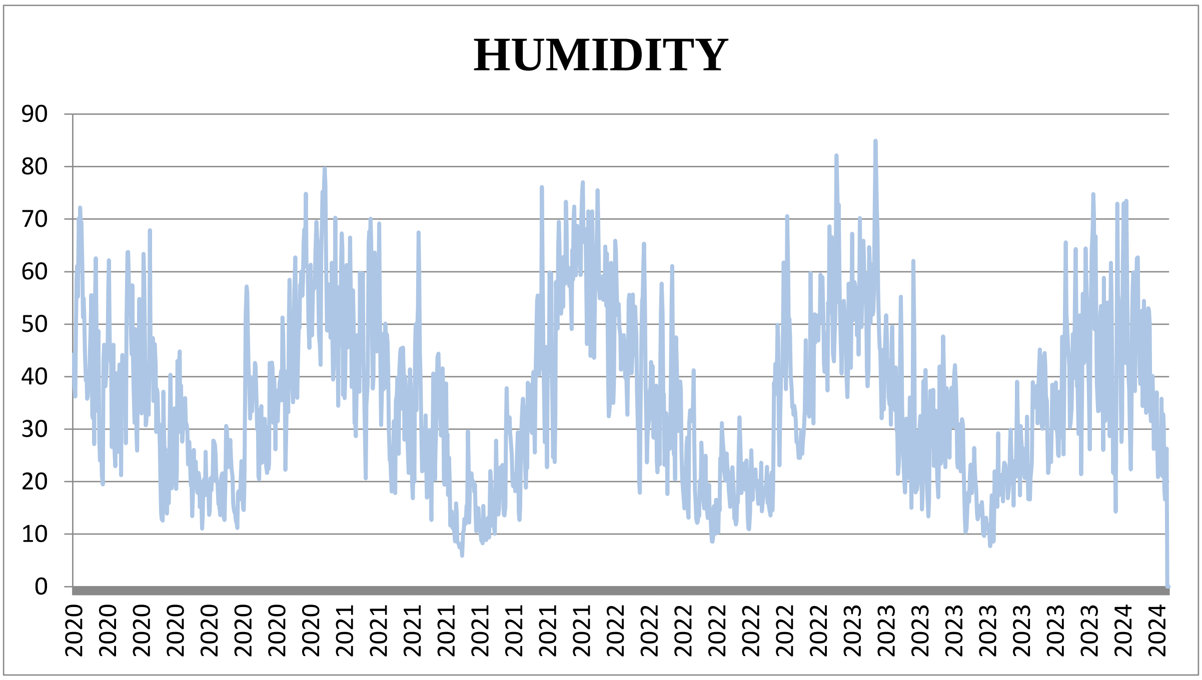


Figure III.3 :humidityof Ghardaïa region for last four years (NASA)

c) PRECIPITATION

Precipitation or rainfall is a collective term used for rain, snow, dew etc. It is measured in RAIN GAUGES and expressed in mm/day. The maximum rainfall data will help predict flood and design the drainage systems. Driving rain is the product of annual rainfall (m) and the average wind velocity (m/s). Thus the unit of driving rain index is (m2/s). [44]

We can see in the chart below the precipitation records (mm/day) last third years, and a couple months these years of GHARDAIA. (Figure III.4).[45]

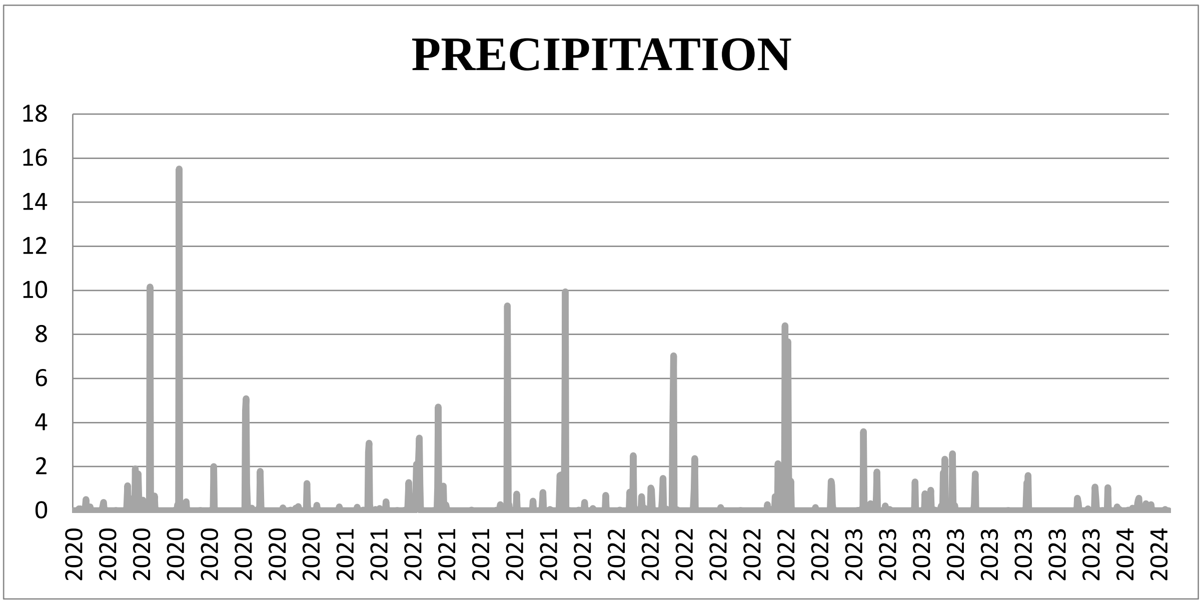


Figure III.4:Precipitation of Ghardaïa regionfor last four years(NASA)

d) WIND

Wind is the movement of air due to a difference in atmospheric pressure, caused by differential heating of land and water mass on the earth's surface by solar radiation and rotation of earth.

the horizontal movement of air relative to the Earth's surface, driven by differences in atmospheric pressure created by the uneven heating of the Earth's surface by solar radiation. This movement occurs in response to pressure gradients, with air flowing from regions of higher pressure to lower pressure.

Wind is characterized by its speed, direction, and variability over time, and it plays a fundamental role in atmospheric circulation patterns, weather systems, and the redistribution of heat and moisture across the planet's surface.[44]

We can see in the chart below the records of **wind**speed (m/s) last third years ,and couple months this year of GHARDAIA. [45] . (Figure III.5)

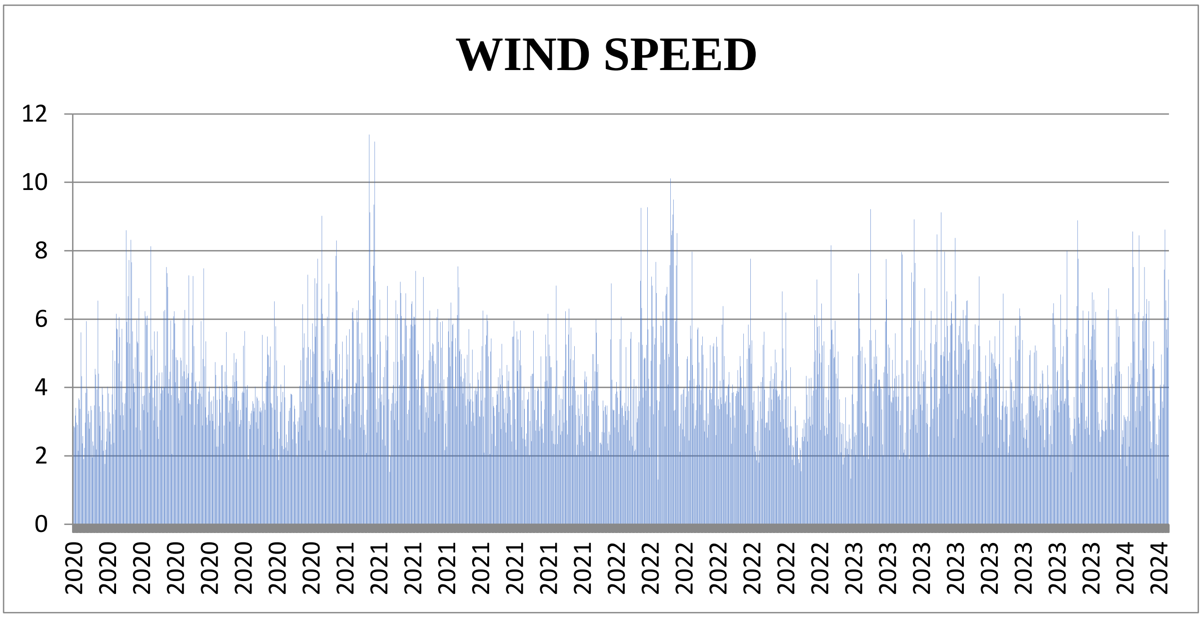


Figure III.5:Wind speed of Ghardaïa regionfor last four years (NASA)

III.3. SITE SELECTION

The URAER experimental platform for renewable energy applications in agriculture was selected as the location for our canary greenhouse prototype. This decision was based on considerations including sun exposure, accessibility, water and electricity availability, also protection against strong winds or adverse weather conditions. (Figure III.6).

Figure III.6: Experimental platform for renewable energy applications in agriculture

III.4. DIMENSION OF OUR GREENHOUSE

- The prototype represents a scale reduction of 1/50.
- The type of greenhouses: canary greenhouse.
- The length: 4.5 m^2.
- The width: 3 m^2.
- The height:1.90 m^2.
- The area: 13.5 m^2.
- The volume:$13.5\times1.90 = 25.65$ m^3.
- Cultivated plant:18 Green Beans plants. Example (Figure III.7) and (Figure III.8)

Dimension of PAD system:

- The length: 1.90 m^2
- The height: 1.10 m^2
- The area: 2.09 m^2

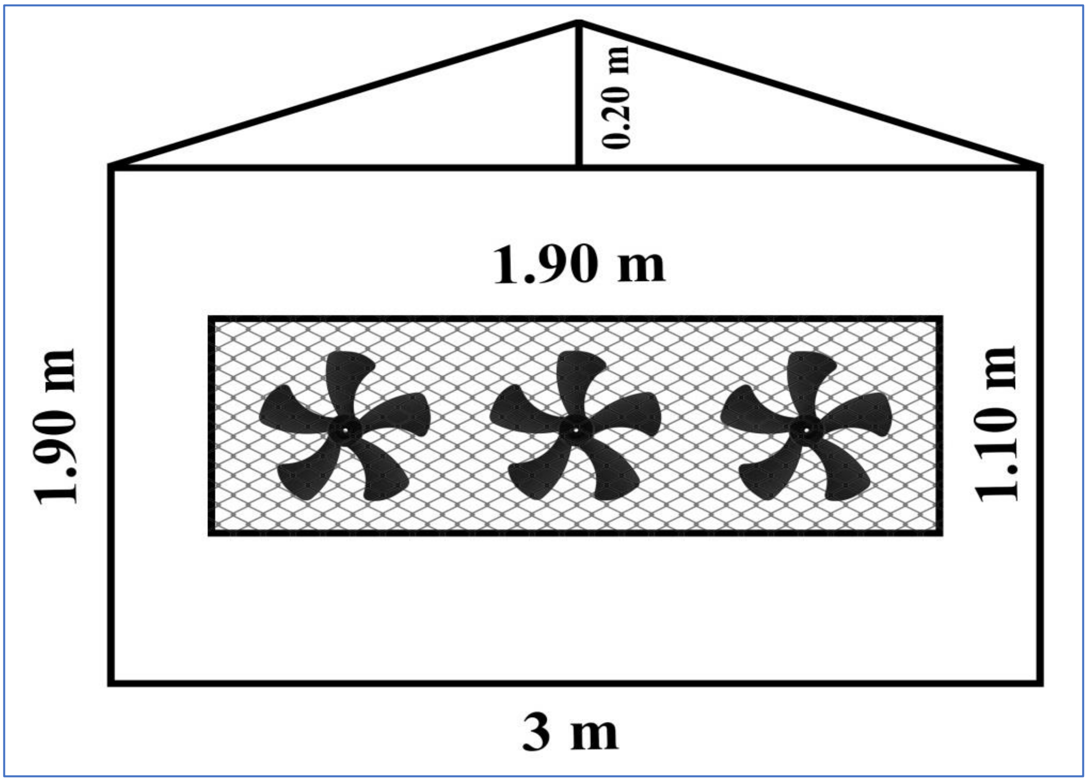
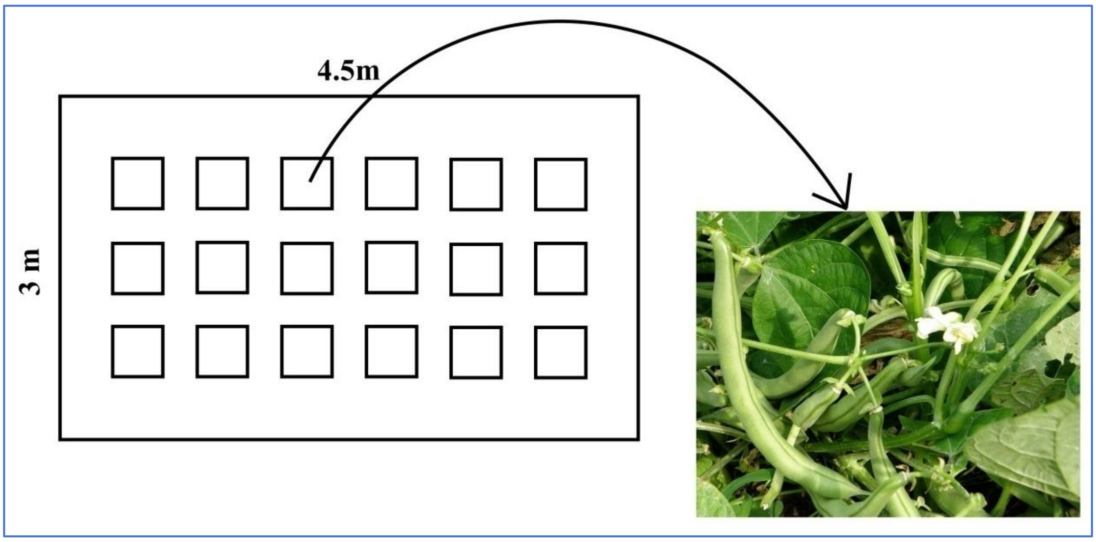


Figure III.7: front sketch dimension of the greenhouse.



FigureIII.8: Above sketch dimension of greenhouse

III.5. DATA ACQUISITION AND PROTOTYPE PROCESSING SYSTEM

III.5.1. HARDWERE PART

III.5.1.1. ARDUINO MEGA

The Arduino Mega 2560 (Figure III.9) is a microcontroller board built around the ATmega2560. It is a popular Arduino development board noted for its wide range of digital and analog input/output ports, as well as its higher memory capacity when compared to other Arduino boards. The Arduino Mega 2560 is ideal for complicated and advanced applications because of its high pin count and processing capability. The device is compatible with Arduino software and may be programmed using the Arduino IDE [46].

Figure III.9: Arduino Mega Board.

III.5.1.2. SENSOR DEFINITION

A sensor is a device designed to gather information by converting one physical quantity into another, typically of a different nature, often electrical. The resulting quantity, representing the sampled parameter, can be utilized for measurement or control purposes [47].

III.5.1.2.1. SENSOR HUMIDITY AND TEMPERATURE

We used two type sensors of temperature and humidity

a) FS200-SHTXX

The FS200-SHTXX (Figure III.10) is a humidity and temperature sensor module designed for measuring environmental parameters in various applications.

Figure III.10: Fs200-shtxxsensor.

Features and specifications:

- **Measurement Parameters:** The FS200-SHTXX sensor module is specifically designed to measure both humidity and temperature simultaneously.
- **Sensor Type:** It utilizes a digital sensor based on the Sensirion SHT series, known for its accuracy and reliability in measuring humidity and temperature.
- **Output:** The sensor provides digital output signals, typically in the form of I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface) communication

protocols, making it easy to interface with microcontrollers and other digital devices.

- **Accuracy:** The FS200-SHTXX sensor module offers high accuracy in both humidity and temperature measurements, typically with ±2% relative humidity accuracy and ±0.5°C temperature accuracy. Operating Range: It operates within a wide range of environmental conditions, making it suitable for various indoor and outdoor applications. The operating temperature range typically spans from -40°C to 125°C.
- **Compact Design:** The FS200-SHTXX sensor module is compact and lightweight, making it suitable for integration into various electronic devices and systems with limited space. Low Power Consumption: It is designed to operate with low power consumption, making it suitable for battery-powered and energy-efficient applications.
- **Applications:** The FS200-SHTXX sensor module finds applications in a wide range of fields, including environmental monitoring, HVAC (heating, ventilation, and air conditioning) systems, industrial automation, agriculture, and weather stations.

Overall, the FS200-SHTXX humidity and temperature sensor module offers accurate and reliable measurements in a compact and versatile package, making it suitable for a wide range of applications requiring precise monitoring of environmental parameters.

b) MQ135 AIR QUALITY SENSOR

The MQ135 air quality sensor (depicted in Figure III.11) belongs to the MQ series of gas sensors and serves to detect, measure, and monitor various gases found in the air, including but not limited to ammonia, alcohol, benzene, smoke, and carbon dioxide. It functions on a 5V power supply, drawing 150mA. A preheating period of 20 seconds is necessary before operation to ensure accurate output reading.

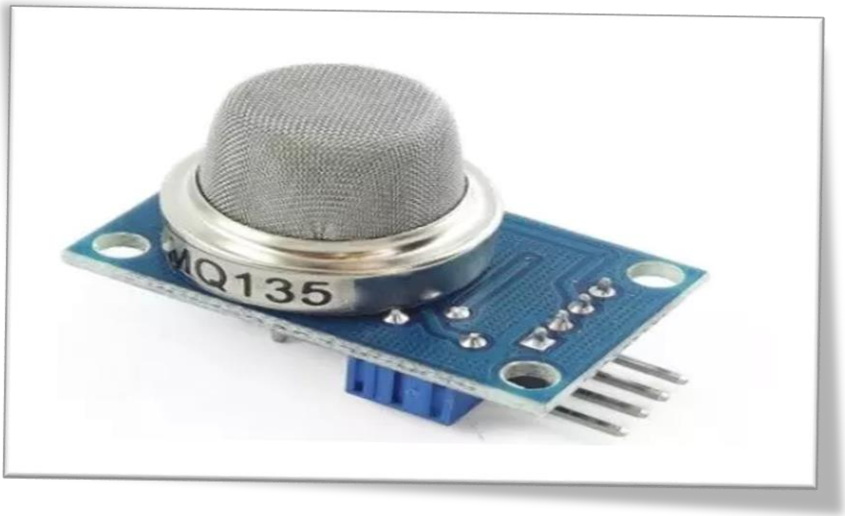


Figure III.11: MQ135 air quality sensor.

Specifications:

- **Gas Detection:** The MQ-135 sensor module is primarily used for detecting and measuring concentrations of gases such as CO2, ammonia (NH3), benzene, and other harmful gases present in the environment.
- **Sensor Type:** It utilizes a semiconductor-based gas sensor element that changes its electrical resistance in response to the presence of target gases.
- **Analog Output:** The sensor provides analog output signals that vary linearly with the concentration of the detected gas. The output voltage typically changes in proportion to the logarithm of the gas concentration.
- **High Sensitivity:** The MQ-135 sensor module offers high sensitivity to CO2 and other gases, allowing for accurate detection even at low concentrations.
- **Operating Range:** It operates within a specified range of environmental conditions, typically at room temperature and moderate humidity levels.
- **Calibration:** The MQ-135 sensor module may require periodic calibration to ensure accurate and reliable measurements over time. Calibration procedures vary depending on the specific application and usage environment.
- **Applications:** The MQ-135 sensor module finds applications in various fields, including indoor air quality monitoring, industrial safety, automotive exhaust monitoring, and environmental pollution control.
- **Compact Design:** The MQ-135 sensor module is compact and lightweight, making it suitable for integration into portable devices, IoT (Internet of Things) applications, and DIY projects.

Overall, the MQ-135 CO_2 sensor module provides a cost-effective solution for detecting and measuring carbon dioxide concentrations in the air, making it useful for a wide range of applications requiring air quality monitoring and gas detection.

III.5.1.3.SD CARD MODULE

We will exhibit the use of an SD card module alongside Arduino (depicted in Figure III.12) to facilitate reading and writing operations on an SD card. This module proves especially beneficial for endeavors necessitating data logging. Arduino, through the SD library, can establish and manipulate files on an SD card for data storage. While there are multiple models offered by different suppliers, they all operate similarly, employing the SPI communication protocol. The Micro SD card adapter, serving as a Micro SD card reader module, interfaces via SPI through the file system driver, enabling the microcontroller system to access and modify files on the Micro SD card.

Figure III.12: Sd card module.

III.5.1.4. DS3231 AT24C32 IIC I2C RTC REAL TIME CLOCK MODULE

The Real-Time Clock (RTC) maintains precise records of seconds, minutes, hours, days, dates, months, and years. It automatically adjusts for months with fewer than 31 days and accounts for leap years. The clock offers both 24-hour and 12-hour formats with AM and PM indications. Additionally, it supports two configurable alarm clocks and features a calendar capable of generating square wave output. Data communication occurs serially via an I^2C bidirectional bus. Moreover, a precision temperature-compensated voltage reference and comparator circuit continuously monitor VCC status to detect power failures. It provides a reset output and seamlessly switches to backup power when needed [48]. (depicted in Figure III.12)

Figure III.13: DS3231 AT24C32 IIC I2C rtc real time clock module

III.5.2. SOFTWARE PART

III.5.2.1. ARDUINO IDE

The Arduino IDE (Integrated Development Environment) is the platform helping Arduino realize its potential. The role of an IDE is to make an Arduino project development easier. It is an interface (UI) that is simple and portable to be used in writing, compiling, and uploading the codes to Arduino boards. With features such as code highlighting, syntax checking, and serial monitor functionality, the Arduino IDE simplifies the programming experience for both beginners and experienced users alike. Hence, the IDE comes with a comprehensive library of pre-written codes and several inbuilt functions which again fast-track the development process of Arduino projects in various applications and industries[49] .

There is a widely use Arduino IDE, Here are a few key features of the Arduino IDE

- Code Editor
- Library Manager
- Sketches
- Board Manager
- Serial Monitor
- code Compilation and Uploading
- Examples and Tutorials

III.6. CONCLUSION

As we can see in this chapter, we did present the study region GHARDAIA, we described the important points about this region like Coordinates and borders of the region, also the ecological factors like climate factors, and we mentioned the site selection of our study. Then, wedid highlight the dimensions of our greenhouse and the type.

Finally, we did talk about the data acquisition and prototype processing system the hardware and software.

CHAPTER IV: METHODOLOGY

CHAPITER IV: METHODOLOGY

IV.1. INTRODUCTION

In this chapter presents the results obtained under variable climatic conditions in the Ghardaia region. This experiment aimed to predict carbon dioxide inside a canary-type greenhouse equipped with an evaporative cooling system using palm fibers. The experiments took place in the platform for experimental applications of renewable energies at the Unit of Applied Research in Renewable Energy (URAER) in Ghardaia. The experiments were designed to reflect the actual operational weather conditions of the Ghardaia region. The main objective of the study was to estimate carbon dioxide using artificial neural networks in greenhouses, where several factors enter into the forecasting process as variables. This was done using an Arduino card and a group of sensors planted inside the greenhouse, such as a temperature and humidity sensor and a carbon dioxide sensor in both greenhouses to record measurements.

IV. 2. DATA

Data was collected using an Arduino card in Excel format to test the performance of the LSTM model.

IV.3. Materials and Methods

IV.3.1.DATA READING AND PREPROCESSING

- The code tries to open an Excel file with the name file path given as the input parameter to the function. After successfully reading the file, it then prints ‘confirm’ and displays the column names in the file. Exception handling techniques deal with the file not found and other exceptions. It removes any trailing spaces from column names to ensure that there is consistency.
- The chosen columns that are needed for the prediction task (temperature, humidity, radiation, etc.) are checked. This is because missing columns will result in an error message being generated.
- A data preparation step involves dividing the feature variables (X) from the target variable which in this case is the temperature in the greenhouse- y.
- If the column name is Heuer, then it is converted to a numerical form that could be understood by the model.

- This is done using the min and max scalar on the features and the target variable as well. This helps to adjust the values of all the parameters within a certain range and enhances the performance of the model.

IV.3.2. SPLITTING DATA

- train_test_split separates the data into training and testing subsets.
- This is because the training set (80%) is employed to make the model learn from the training data and the testing set (20%) is used to monitor the model's performance on data that it has never seen before.
- random_state=42 is used for setting the random seed for the situations when you want to execute the code again.

IV.3.3. Building the LSTM Model

- A Sequential LSTM model is built using the Sequential of Tensor Flow. Keras.

The model consists of

- An LSTM layer with 50 units which is suitable for processing time series data as it can return sequence output.
- They include another LSTM layer with 50 units for the extraction of more features from the input.
- The output layer is fully connected with a high dimension of 1 node to estimate the temperature.
- The model is trained with the Adam optimizer, commonly used for training neural networks, and mean squared error loss function, which is used in regression models that predict continuous outcomes.
- Model summary shows us the architecture of the model that is how many parameters are in each layer.

IV.3.4. RESHAPING DATA FOR LSTM

- LSTMs require 3D data: samples, time steps, and features per time step as the input shape for the model.
- Since the number of instances is of no relevance in the case of images, the training and testing data (X_train and X_test) are reshaped as needed.

IV.3.5. MODEL TRAINING

- The model is trained using the model. The form of the model then used in the training process is as follows; calibrated on the training set which includes the feature matrix X_train and target vector y_train.
- The training process is carried out epoch by epoch (100 epochs in this case) and sample/samples at a time (10 samples at a time, to be precise) to manipulate the weights of the network as required to minimize the loss.
- The data used for test purposes is X_test, y_test, and it is employed to track the progress and do not allow the **over fitting** of the trained model.
- Verbose mode is also available in training where it offers several completion reports (1).

IV.3.6. PREDICTION AND EVALUATION

- To assess the performance of the trained model, the model is applied to the testing set and it predicts the temperature. Predict.
- In this study, the required temperature values in a normalized scale are converted back to the original scale using the inv-transform of the scalar.
- The actual temperature values (y_test_actual) are also calculated from actual test data by using the inverse of Equation 10.
- The following plot is created to directly compare the predicted temperatures with the actual ones. This provides a visual means of determining the degree to which the model as fits the underlying structures.
- An optional addition allows plotting by reference to actual time (Hour) values if available. This offer a much easier way of examining the change in temperature for a given period.
- The statistical measurement technique known as Mean Squared Error (MSE) and coefficient of determination or R-squared (R^2) is also used to measure the efficiency of the model.
- Here, lower MSE implies a stronger fit or says, a lower degree of difference between the actual and predicted values
- R^2 which is closer to 1 indicates a better fit to expected value and these are the actual values that were predicted.

IV.4. RESULTS

IV.4.1. EFFICIENCY CRITERIA

In the aim of evaluating the performances of the LSTM models, 3 widely used efficiency criteria are used: Mean Squared Error (MSE), Root Mean Squared Error (RMSE), (R^2) Score (Coefficient of Determination) .

IV.4.1.1. Mean Squared Error (MSE)

Mean Squared Error (MSE) is a statistical metric used to measure the average squared difference between the actual (observed) values and the predicted values in a regression problem. It's calculated by taking the average of the squared differences between the predicted and actual values. The formula for MSE is :

$$\mathbf{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2$$ **..............Eq (IV.01)**[28]

Where:

- n Is the number of samples.
- y_i And $\hat{y}_i$ are respectively the observed, predicted.

MSE is commonly used in various fields, including statistics, machine learning, and signal processing, as a measure of the quality of an estimator or predictor. The smaller the MSE, the better the model fits the data.

IV.4.1.2. (R^2) Score (Coefficient of Determination)

The R^2score, also known as the coefficient of determination, is a statistical measure that represents the proportion of the variance in the dependent variable (target variable) that is predictable from the independent variables (features) in a regression model. It is a measure of how well the model explains the variability of the data.

$$\boldsymbol{R}^2 = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2}{\frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2}$$ **..............Eq (IV.02)**[28]

- $\bar{y}$It is the arithmetic average of the actual values

The R^2 score, core ranges from 0 to 1. A value closer to 1 indicates that the model explains a large proportion of the variability in the dependent variable and fits the data well. A value closer to 0 indicates that the model does not explain much of the variability in the dependent variable and may not fit the data well.

IV.4.1.3. Root Mean Squared Error

It is the square root of the mean square (RMSE)of the differences, and returns the values to the same unit as the actual values. The smaller the value, the better the model.

$$\boldsymbol{RMSE} = \sqrt{\mathbf{MSE}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2}$$ ....**Eq (IV.03)**[28]

IV.4.2. TESTING THE CODE

In this process we did test the code depends on smalldata. we get the plot below (Figure IV.1)

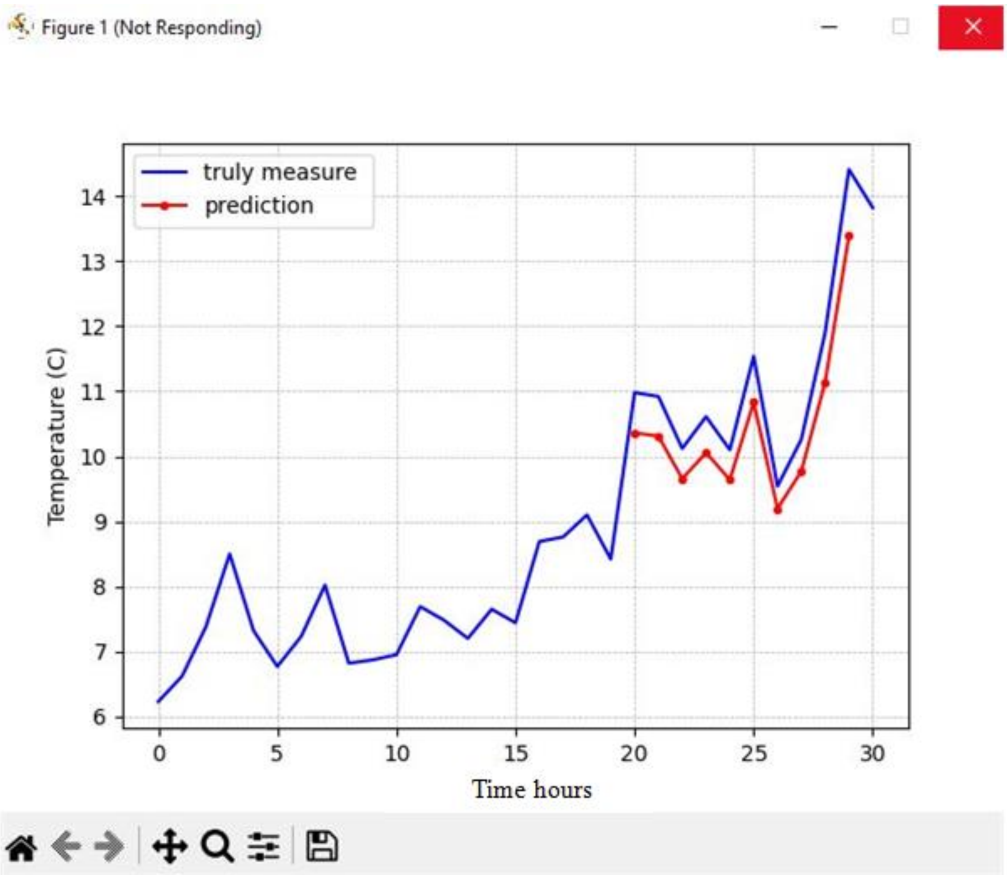


Figure IV.1: The plot of testing code

The chart you sent me appears to show the results of using Long Short-Term Memory (LSTM) code for temperature prediction. The x-axis represents time (hours), and the y-axis represents temperature (Celsius). The chart has two lines:

- A blue line labeled "true temperature" which likely represents the actual temperature measurements.
- A red line labeled "prediction" which represents the predicted temperature values based on the LSTM model.

It seems that the LSTM model adequately captures the overall trend of the temperature data.

There are some discrepancies between the actual and predicted temperatures, particularly for shorter-term fluctuations. For instance, around hour 15, the actual temperature dips slightly, while the predicted temperature remains flat.

It seems that the model is more effective at predicting smoother temperature changes than rapid fluctuations.

From the chart, it appears that the LSTM code is partially successful in predicting temperature. Although the model can capture the general trend, it may have trouble with short-term variations.

IV.4.3. LSTM MODEL

The graph you sent me shows a comparison between actual and projected temperature values. The x-clock axis, and the y-axis represents the temperature in percentage degrees. Actual temperature measurements (blue line) are generally lower than expected temperature values (red line). This means that the model over predicts the temperature. There is a greater discrepancy between actual and projected values at high temperatures. The chart does not show the scope of the y-axis, so it is difficult to determine how different actual and projected values are. It is difficult to say with certainty why the temperature forecast is overestimated without further information about the data and model. However, the reason belongs to the lack of training data. As we can see in (Figure IV.2)

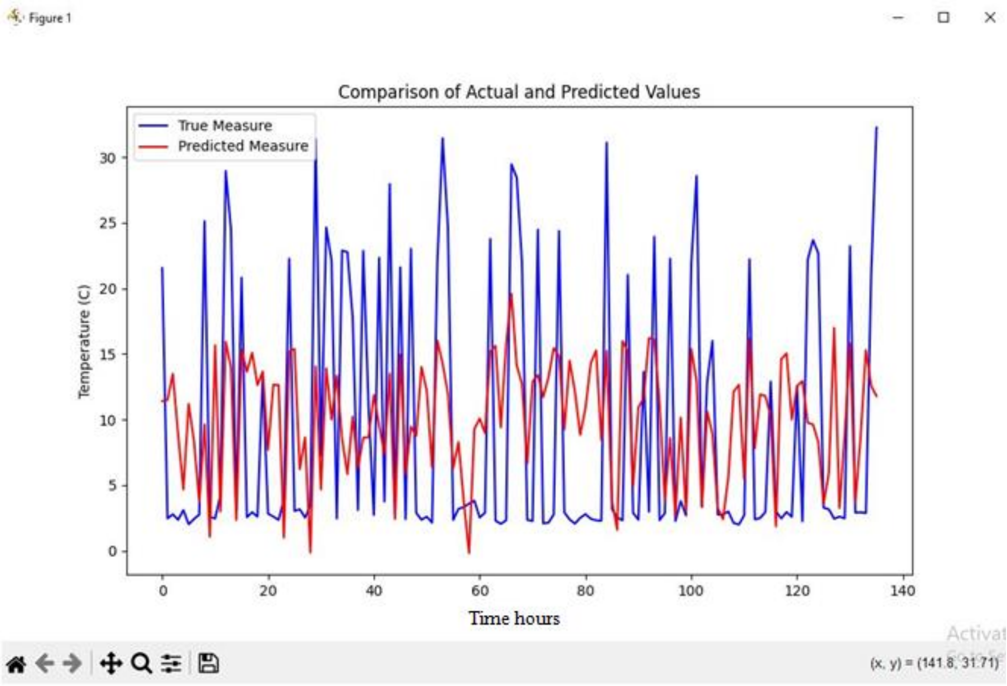


Figure IV.2: The plot of lstm model

IV.4.4.THE MEAN SQUARED ERROR (MSE) AND ROOT MEAN SQUARE ERROR (RMSE)

The chart depicts the mean squared error (MSE) and root mean squared error (RMSE) over epochs, in LSTM algorithm. The epochs are on the x-axis and the error is on the y-axis. The red line shows the average MSE and RMSE, while the blue line represents the validation data. The MSE and RMSE both appear to decrease as the number of epoch's increases, which suggests that the model is learning and improving its performance. The validation error (blue line) is higher than the training error (red line), which is a common occurrence. This is because the validation set is not used to train the model, so it provides a more objective measure of how well the model is generalizing to unseen data. Overall, the chart suggests that the model is making progress on the training task. However, it is important to monitor the validation error to ensure that the model is not overfitting to the training data. See the chart below (Figure IV.3).

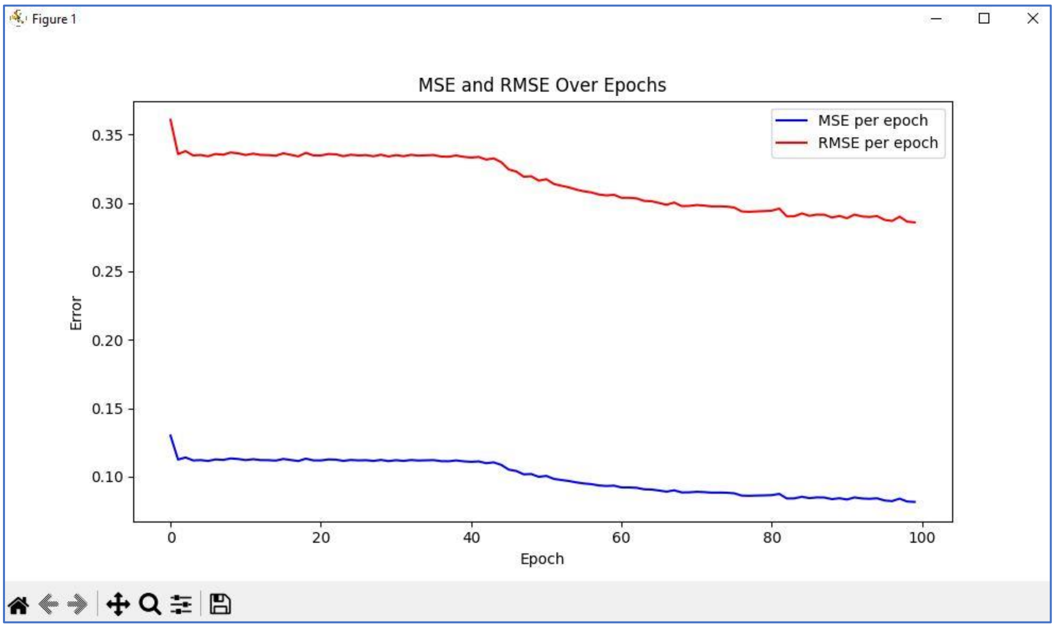


Figure IV.3: The mean squared error (mse) and root mean squared error (RMSE)

IV.5 CALCULATE CO_2 CONCENTRATION BASED ON TEMPERATURE AND HUMIDITY

Calculating the concentration of CO_2 based on temperature and humidity in an agricultural greenhouse necessitates a detailed grasp of the relationships between these factors. A straight mathematical formula for this connection might be difficult to develop since it is influenced by several physical and biological variables. However, empirical formulae and models may be employed to determine CO_2 levels. Here's a basic way to model this relationship:

IV.5.1 FORMULA FOR CO_2 CONCENTRATION

Ventilation, plant respiration, and external sources may all affect the concentration of CO_2 (CCO_2) in a greenhouse. In general, an equation differential may be used to approximate CO2 concentration, but for a more straightforward approximation, we can utilize an empirical calculation based on observations and data modifications.

IV.5.2. EQUATION

$$C_{CO2} = C_{initial} + \alpha \times (T - T_{ref}) + \beta \times (R_H - R_{Href}) \text{........Eq } (\textbf{IV.03})$$

R_H **Where:**

- C_{CO_2} isthe concentration of CO_2 in ppm (parties per million).
- $C_{initial}$ is the initial concentration of CO_2 (sans adjustment for temperature and humidity).
- T is the actual temperature in the greenhouse at °C.
- T_{ref} Is the temperature of the recovery (a temperature or the initial conditions of CO_2weremeasured).
- R_H Is the relative humidity at %.
- R_{Href} Is the relative humidity of the reference (the humidity or the initial conditions of CO_2 are monitored).
- αα is an adjustment coefficient for the temperature (ppm/°C).
- β is an adjustment coefficient for humidity (ppm/%RH).

From our data in excel folder after we did normalize it,weappliedthe previous equation and we get the chart below (Figure IV.4).

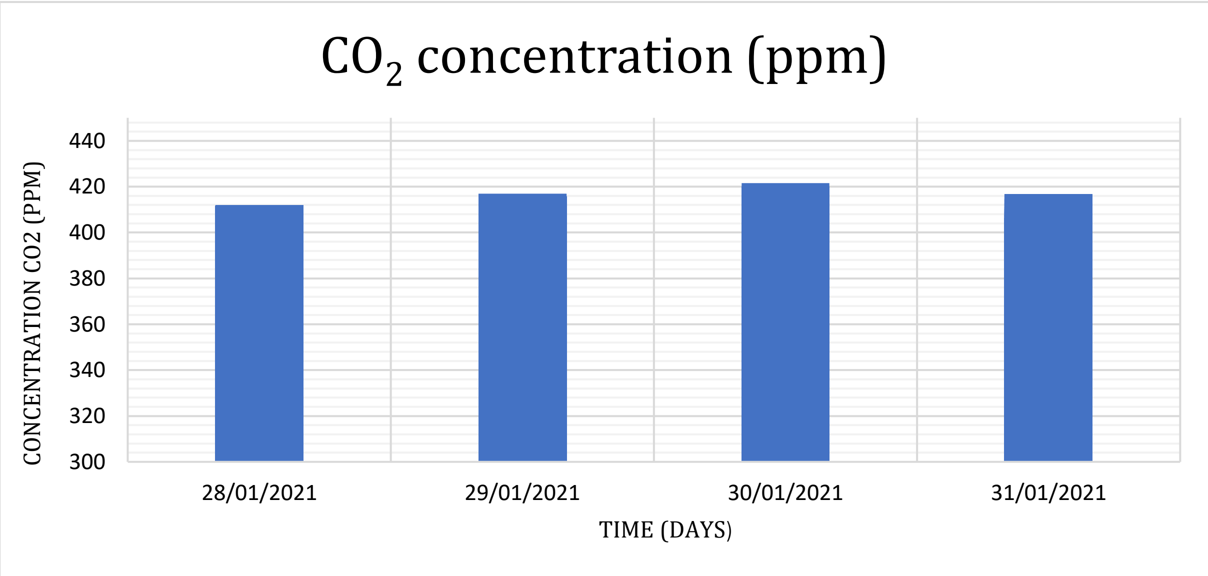


Figure IV.4:Graph of carbon dioxide concentration of CO2 basic formula for CO_2 concentration

The graph shows carbon dioxide "concentration of CO_2 " according to date. The x-axis is called "Date" and appears to range from 1/28/2021. The y-axis is labeled “CO_2 concentration (ppm)” and ranges from 300 to 440(ppm) .as we can see the maximal value is 421.5 in day 1/30/2021 and the minimal value long of four days is 312 (ppm), the maximal value indicates the plants were active during the day, the activity is the process of photosynthesis, and the minimal value indicates the planets were inactive during the night, where the plants release the oxygen.

IV.7. CONCLUSION

In this chapter we did try to make anestimation of CO_2 Bay using the algorithm of LSTM but we did face some problems in our experimental in GHARDAIA we did solve that with using anequation calculate CO_2 concentration based on temperature and humidity

GENERAL CONCLUSION

GENERAL CONCLUSION

Greenhouses play a vital role in modern agriculture, providing controlled environments for crop cultivation. They leverage various materials and technologies to optimize growing conditions, but their potential extends far beyond traditional farming methods.

In addition to their fundamental functions of maintaining optimal micro-climates, greenhouses are increasingly integrating digital applications and smart technologies. These innovations are revolutionizing greenhouse management, enabling real-time monitoring and precise control of environmental parameters. From automated irrigation systems to sensor-based climate control, digital solutions enhance efficiency, reduce resource consumption, and improve crop yield and quality.

In our study, the Mean Squared Error (MSE) is 0.01, indicating the accuracy of our predictive models, and the R^2 score is 0.95, suggesting that 95% of the variance in crop yield can be explained by our model. These high-performance metrics underscore the effectiveness of digital applications in greenhouse management, ensuring reliable and optimized crop production.

Moreover, digital applications extend beyond environmental control to encompass crop health monitoring, yield forecasting, and resource management. Remote sensing technologies, drones, and satellite imagery provide valuable insights into crop growth and health, allowing growers to make informed decisions and optimize resource allocation.

Looking ahead, the future of greenhouse farming holds promising opportunities. Advancements in data analytics, artificial intelligence, and Internet of Things (IoT) technologies will further refine greenhouse operations. Predictive analytics can anticipate crop needs, while IoT-enabled sensors and actuators enable remote monitoring and autonomous management. Such integration not only maximizes productivity but also minimizes environmental impact through optimized resource utilization.

However, challenges persist, including sustainability concerns, structural durability, and energy efficiency. Overcoming these challenges will require continuous innovation and collaboration across disciplines. Emerging trends like vertical farming, hydroponics, and aeroponics offer alternative approaches to conventional greenhouse farming, emphasizing resource efficiency and scalability.

In conclusion, while greenhouses face multifaceted challenges, the integration of digital applications and innovative technologies, coupled with our high-performance predictive models (MSE: 0.01, R^2 : 0.95), holds immense potential to address these issues. By embracing these advancements and adopting sustainable practices, greenhouse farming can evolve into a cornerstone of future food production, ensuring food security, environmental stewardship, and economic viability in the face of global agricultural challenges.

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