A Controlled Environment Agriculture with Hydroponics: Variants, Parameters, Methodologies and Challenges for Smart Farming

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***Abstract*—Soilless agriculture, hydroponics can be implemented efficiently with a Controlled Environment Agriculture System (CEA). The technological progress and improvements in smart farming have provided a platform for successful deployment of CEA. With more and more advances, the use of complex mathematical models by the hardware-software interfacing, artificial intelligence and adaptive data analysis are providing the CEA with versatile design and control strategy to implement the broader level of automation. The review is an attempt to highlight the different hydroponic techniques their pros and cons in building an economic system. This study reviews various physical and environmental variables that influence the plant growth for the sustainable and efficient farming system. This research also highlights the methodologies that are used to automate, monitor and control the parameters for optimal plant growth. The research ultimately proposes the prediction models using machine learning techniques to understand the correlation analysis with plant growth dynamics. Finally, the research also focuses on the challenges that are to be identified while integrating smart farming in a CEA to minimize the energy inputs, enhancing productivity for higher quality crops.**

***Index Terms*-Controlled Environment Agriculture System; Hydroponic; Internet of Things; Smart Farming;**

I. INTRODUCTION

The various challenges and issues in agriculture are escalating with urbanization, scarcity of food, food insecurity and unpredictable climate. An alternative to conventional farming, to increase sustainable production, is Hydroponics, a soil-less culture. This system efficiently utilizes water and nutrients for optimal plant growth. Hydroponic has expanded worldwide in recent years as a sustainable model for the controlled environment and precision agriculture system. The advancement in technology has gained importance to automate agriculture system and efficiently utilize resources like water, fertilizers. Instead of conventional farming methods, the urban farmers can adopt farming with CEA methods without pesticides and Genetically Modified Organism (GMO) methods. The researchers have documented about the steady decline in the nutrient contents like iron, phosphorus, calcium, protein, etc., in today's crop productions compared to earlier decades of agricultural methods. There are many nutrient insecurities that leads to poor farming [1]. Developing countries like India, where resources are extremely scarce, population explosion, climate intervention, and urbanization have tremendously affected the urban people. The supply of food has severe implications for food insecurity and undernourishment of food intake which constitutes an enormous threat to the food supply. Besides, the agricultural lands are degraded by over-exploitation of natural resources, leading to soil erosion, land degradation, deforestation and global climate changes which have resulted in the fall of food productivity [2].With urban farming captivating innovative scientific methods, we can naturally produce high-quality food using natural pesticides and bio-degradable waste. The latest advancement in the technology, a smart and intelligent models have worked the great way with urban and indoor farming in a more efficient way and all year around. Many academic researchers and practitioners have come out with several agricultural kits and framing devices which can adequately monitor and precisely control the plant growth. The system could also create climate recipes for specific crops with computer-based algorithms as a remarkable precision for non-farmers. This modern technique is uniquely characterized by a higher degree of environmental control, integration of technologies, utilization of less precious water resource and no pesticides for the sustainable growth of plants.

A. Urban Farming and its Classifications with Controlled Environment Agriculture (CEA) system

CEA is a farming technology that empowers the cultivator to produce crops and control the growth with the desired climatic conditions [2]. There are different approaches to urban farming with CEA system like rooftop farming, greenhouse farming, vertical farming and indoor farming. The classification of CEA system for urban agriculture [1] where plants can be cultivated using either of these techniques are aquaculture, hydro culture, aero culture and mistponic. The purpose of this paper is to discuss the review on different farming techniques under CEA system is presented. The rest of the paper is organized as follows: Section 2 describes the overview of different techniques of hydroponic system, their merits and demerits including the stages in the life cycle of a plant. In Section 3, the various factors that are involved in plant growth are presented. In Section 4, the technological aspects of a CEA system, the available smart devices in the market and their capabilities are analyzed. Section 5 emphasizes the challenges and issues faced with respect to CEA hydroponic system and Section 6 concludes the paper with the scope for future work.

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II. CONTROLLED ENVIRONMENT HYDROPONIC SYSTEM

The CEA system emphasized in this article is a hydroponic farming system which is characterized as the science of growing plants in the absence of soil. This system has been utilized all through history by the Babylonians, the Aztecs, and even the old Egyptians, and further a lot of new methods, innovations and technicalities have been embedded more to it [3]. The main objective of the CEA hydroponic system is to reduce the energy cost per unit and increase the yield of crops. The key to success is to implement best climate recipes, design of dynamic models, and several control methodologies with the use of complex analysis algorithms and intelligence to the system. With the technological innovations as a significant contributor in this system, there has been a wider improvement in social and economic wellbeing of the society and sustainable agricultural production.

A. Variants of CEA Hydroponic System

The hydroponic system depends on the nutrient solution to supply and distribute the most essential macro and micro-nutrients to the plant for their effective growth. There exist six distinct sorts of hydroponics namely Ebb and Flow (Flood & Drain), Wick, Deep Water Culture(DWC), Drip (Reuse and non-reuse), NFT (Nutrient Film Technique) and Aeroponic have several advantages over conventional farming systems [4]. The schematic diagrams of these techniques can be seen in Fig. 1.

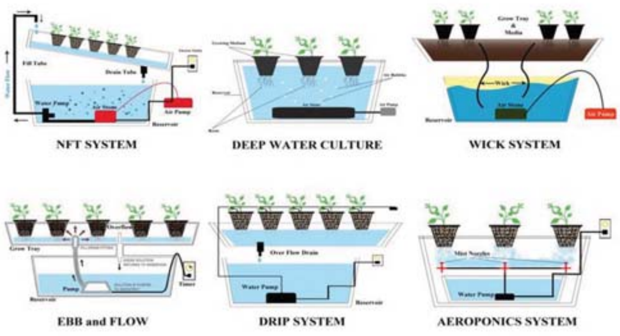

Fig. 1: Schematic demonstration of different hydroponic cultivation system

1) Wick Hydroponic

In the wick framework, the nutrients are kept in the reservoir and moved up with the wick or string into the system through capillary movement which uses the growing medium like Coconut Fiber, coco coir, Vermiculite, Perlite, Pro-Mix etc. NASA [5] has set-up sustainable agricultural methods for space mission and has experimented on crops like soybean, wheat, tomatoes and lettuce. The plants were germinated with nylon-based wick hydroponics in a CEA system. The yield of the crops was highly dependent on the artificial light radiation with high photosynthetic effect. NASA has established a life support system in space and analyzed that for a 20-25 square meter of crops grown, could support Oxygen for a single person in space.

2) Ebb and Flow system

The research conducted by the authors [6] made an experimental study on the ebb and flow system which used two distinctive frameworks called Flood and Drain with a nutrient-rich solution for a stipulated period. The system was flooded periodically and continuously monitored. So, to build the viability of plant development in an ebb and flow framework, the blend of Aquaponic [7] or nutrient film technique [6] can be adopted. However, the drawback with this system [7] was the reduction of Oxygen level, with an increase in the conductivity. A product of Freight Farms, “Leafy Green Machine™” [8] is an innovative and fully automated technology based ebb system. Water floods in segments of 12 trays, and are drained with nutrient-rich water solution numerous times each day.

3) Drip System

Nutrient water is provided gradually drop by drop, by means of little spaghetti lines and emitters from the base channel by installing timers. The greatest challenge with the system is sufficient dampness in the root zone has to be well maintained. The Freight Farms hydroponic organization have also designed to use recirculating drip systems onto the top of 256 crop segment container [8] which utilizes the water in an efficient way, less than 5 gallons per day for around 5000 crops. The drip system utilizes water effectively and economically where water is delivered uniformly at periodic intervals without causing stress to plants [9].

4) DWC & NFT

DWC is equally known as the floating raft system, is ideal for both small and extensive scale production systems [10]. This technique provisions water, which contains essential nutrients directly to the roots of the plant constantly and guarantees that the foundations of the plants are always immersed in water filled with adequate oxygen. In DWC, monitoring the level of water and controlling the in-flow and out-flow in a reservoir is significant. The automation with sensors and actuators help in this periodic monitoring for efficient plant growth [11]. The major challenges in DWC are optimizing the consumption of electricity, less utilization of water, high oxygenation for the plants, accuracy and time management in the process of automation.
The NFT framework utilizes long and small width plastic tubes with a thin film of water constantly flowing through them. An outright advantage of the NFT system is to carefully outline and assemble the framework vertically, making the exceptional utilization of the possible developing area [4]. NASA [5] experimented on several crops with a closed system demonstrating the recirculating hydroponic technique. The organization collected and analyzed the dataset to identify the sole source of nitrogen which was utilized by plants as nitrate. This experienced profound impact in the variation of pH value.

5) Aeroponics

During the 1990s, National Aeronautics and Space Administration (NASA) were keen on finding proficient approaches to develop plants in space named it as "Aeroponics," characterized as "developing plants in an air/fog condition with mist water but without soil. With almost 90% less water this farming technique would obtain the more efficient hydroponic plant growing system. The productive farming organization AeroFarms [12] which was started by Ed in 2004, is one of “Fast Company’s Most Innovative Companies of 2018”. This commercialized

Aeroponic system is designed to be a completely automated and controlled, indoor and closed system, where it utilizes 95% less water than conventional farming and 40% not as much as hydroponics. Apart from growing, this Organization has developed a smart recycled cloth substrate for the distinct phases of the plant growth along with smart pest management and highly customizable farming environment. Plants developed in these Aeroponic frameworks [13] have additionally been appeared to take-up more minerals and vitamins, making the plants more beneficial and possibly more nutritious.

III. Parameters need to be controlled in CEA with Hydroponics

The key challenge with hydroponic farming techniques and optimal plant growth depends on many parameters for CEA system. The authors [14] prioritized and evaluated twelve crop features that play a major role in optimal plant growth using a fuzzy logic approach. The challenges include Light intensity, water quality, air quality, water and air temperature, nutrient level, growing media, humidity, air flow, crop layout, crop species and CO2.

A. Artificial Sunlight-Light Intensity (Light Emitting Diode (LED) Lights):

Light quality plays a noteworthy part in the appearance and yield of food plant species. Studies on indoor farming using LED as a light source for plant photosynthesis had turned out to be high because of the uncertainty of climate and pest mortality. In an indoor farming system compared to conventional sources of lights, LED lights have been proven to be the most efficient and one of the finest techniques to reduce power consumption. The authors [15] explored and analyzed a modern technique with solid state and LEDs which are dimmable. A relative study on "Brassica Chinensis" plant with Red Blue White (RBW) LEDs without a Far-Red treatment of ratio 16:4:2 and RB LEDs with a Far-Red treatment of ratio 16:4:16 for photosynthesis effect had successfully experimented. These experimented findings on a small-scale hydroponic system have proven that Far-Red treatment has appeared to defer the blooming process and with more consumption of power. With a varying intensity of LED light, the plant's growth accelerated a bit faster than the other. However, the authors are continually striving to improve the yield of the crop and reduce the time of harvesting.

NASA, the Government Research Center of America, has done research on LEDs for life support activities and plant growth since the 1980s for CEA. Several combinations of light recipes of Red, Blue, Green and Far Red light of different wavelengths have been analyzed to decide on excellent light conditions for optimal plant growth [16]. For the growth of specific plants, if the blend of Red and Blue Lights based on some rubrics are implemented, then it is easier to automate the light intensity [17].

LED lighting appliances are more proficient compared to the lighting sources used in conventional lights generally in agriculture. This enables light spectrum and intensity modulations to improve the light utilizes effectiveness for plants [18]. By fluctuating the light radiating from the distinctive shading LEDs the temperature, as well as the spectrum of the light, can be controlled and optimized for plant development. The authors [19] have made a comparative study that proves LED lights have more efficiency than traditional High Pressure Sodium (HPS) lights where light spectrum can be monitored and controlled for better photosynthesis. Most of the LED glow lights are either Far-Red or Blue light because of their absorption spectrums by chlorophyll. With multi-layer production framework, lights can be effectively deployed and delivered to leaves with close proximity at each canopy [13].

B. Nutrient Solutions:

Most of the crops produced in a hydroponic system, which use Deep water culture or Nutrient Film Technique are replaced with a soilless nutrient solution. The primary factors that influence the optimal growth and higher yields depend on the balance and concentration of nutrients. Hence, the authors of [20] have analysed the difference in the concentration of nutrients for four weeks. The highest nutrition deficiency was found at week 4 with 23.81% which has affected the plant growth. Electrical conductivity (EC) is the primary indicator of nutrients which will be in the form of chemicals.[21] The authors have come out with EC and Potential of Hydrogen (pH) adjusting linear regression models with some standard error estimation of S= 42.1 and S=0.32 respectively.

The conductivity of the nutrient solution in terms of parts per minute (ppm) was analyzed using Total Dissolved Salts [TDS] sensor at a prototype-scale. This NFT based system was automated for nutrient uptake which proved an accuracy of 97.8% [22] compared to TDS meter. A dosing algorithm was designed for automated nutrient management system by the authors to measure and test the concentration of macronutrients [23]. The algorithm has shown the linear relationship between the standard analyzers and dosing model proposed. However, the algorithm was focused on very few macronutrients concentrations. Similarly the individual ion concentration of nitrate was measured using an automated system with the help of electrodes which showed fewer errors compared to standard electrode instruments.

C. EC and PH Level:

The plant development highly depends on the EC and pH value. It is essential to monitor the nutrient solution regularly using EC and pH sensors and adjust the values for the growth of plants. The optimal pH range in soilless agriculture is 5.5 and 6.5. The essential constituents of alkalinity in nutrient solution are to the greatest extent bi-carbonates (HCO_3^-) and to slighter degree carbonate (CO_3^{2-}). This acid requirement relies upon the target pH value and absorption of dissolved bi-carbonates [25]. EC ($dS\ m^{-1}$) value is accurately calculated based on the aggregate of Ion concentration which can be effectively measured using EC meters which is highly influenced by temperature. The plant growth was adequately tested across several EC treatments from lower to higher range which influenced the profound effect of photosynthesis effect on leaves and its biomass. The range between 1.8- 2.4 EC treatment has yielded with better quality crop [26]. The EC and pH sensors are connected to the microcontroller for analysing the plant growth and are precisely controlled by exploiting and implementing the technology of artificial intelligence and machine learning [21] which serves as a tool for an automated hydroponic system. The authors of [27] have proposed an intelligent Fuzzy Logic control methodology for NFT hydroponic culture to control EC and pH values by efficiently reducing the response time.

D. Temperature

The temperature of the nutrient solution considers an explicit association with the amount of oxygen absorbed and has a converse association between the amounts of oxygen dissolved in it. Temperature likewise influences the solvency of manure and take-up capacity of roots, being obvious the significance of controlling this variable particularly in extraordinary climates. The scholars [28] experimented by harvesting lettuce crops to automate the monitoring of temperature using wireless sensor networks in a closed system. The system has also been deployed with a fan-circulating system to create a precision cultivation environment for plants. The plant growth was analysed and compared with and without deploying the fan based system which proved that there is a significant decrease in the average temperature, and the harvested lettuce crop was 61-109% weightier than without fan-circulating system. The temperature of root-zone portrays a significant impact not only on the growth of plants but also the composition of chemicals in a nutrient solution.

E. Humidity

There exist different variations in determining humidity which is relative, specific and absolute humidity. Generally, the plant growers consider relative humidity (RH) which measures the content of moisture in the air. One of the case studies carried out by Nebula and Sirius for growing cannabis in hydroponic culture demonstrates that the optimal relative humidity during clones rooting can be 70-80%. During the transition from germination to vegetative phase the RH values is 40-60% and during blossoming phase the RH 40-50% [29].

F. CO_2

The photosynthesis of plants is dependent on the CO_2 concentration. The essential research conducted by [30] having identified the physiological disorders at the stage higher than 1200 ppm concentration. In a closed environment, the parameters like temperature, light intensity, nutrients, and pH affect the levels of CO_2 for optimal plant growth and sufficient metabolism depending on plant species. The growth rate increased with a controlled CO_2 concentration within the range. The study on tomato species also reveals that the ambient CO_2 concentration to 400-500 ppm controls the rate of the chlorosis kind of physiological disorder to the maximum extent and improves the growth rate. A recent study on tomato cultivation revealed that the elevated CO_2 and the source of macronutrient i.e., Nitrogen affect the size and life structures of various root [31].

G. Substrates:

The most commonly used substrate in soil-less culture is Coco-peat [32] because of its stability, safety, lightweight and capable of exchange of cat-ions. The authors of [33,34] have introduced and implemented a novel and promising way of using biochar and hydrochar obtained from organic wastes as substrates in tomato plant cultivation. A smart substrate designed by Aerofarms [13] which is a fully sanitized cloth medium prepared out of Bisphenol-A, and reusable plastic product, with reduced risk of contamination, would take 350 (16.9 oz) water bottles out of the waste stream.

IV. TECHNIQUES & METHODOLOGIES FOR CONTROLLED ENVIRONMENT AGRICULTURE

Several modern technologies that are identified by growers and organizations to innovate and automate the growing system are the integration of Internet of Things, Artificial Intelligence, Machine Learning, Data Analytics methodologies, Cloud, Wireless Sensor Networks and many more. Several modernized techniques have been implemented to design a controlled system which is depicted in Fig. 2. The hydroponic system is a rigorous method for farming by controlling the humidity, light, temperature, water system, nutrient and fertilizers to the plants that are developing in an inert substrate that can be clay pebbles, rock wool, vermiculite, coco, perlite peat and others [35].

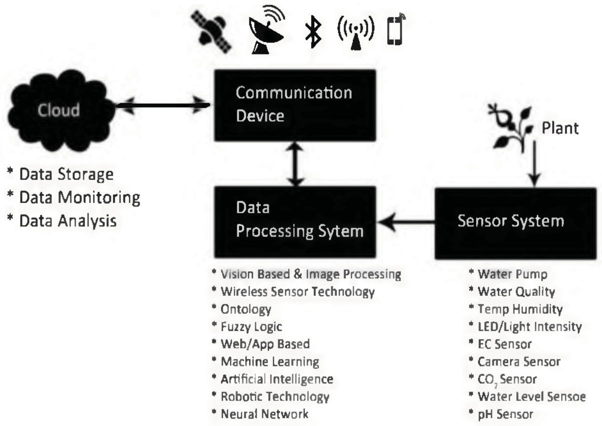

Fig. 2: The proposed Architecture of Technology based CEA

Many relevant works for Smart farming applications have been designed and published with the integration of more generic sensor network and with its grounded frameworks [27, 36-40]. Hydroponic Farming Ecosystem (HFE) [40] utilizes IoT gadgets to screen and record humidity, temperature, air temperature, pH, nutrient solution, light and Electrical Conductivity. This eases and supports non-professional farmers in cultivating their own crops and monitors using android applications. The authors [41] had designed a prototype "Intelligent Plant Care Hydroponic Box-IPCH" to monitor and control the environmental parameters which are highly configurable, responsive and scalable with the actuators and sensors embedded in the box. The plant growth was well monitored. However, this prototype was developed for a small-scale system which has to be improvised for large-scale in the future.

A NFT based smart farming was developed to monitor and automate the system with sensor-based technology built using Arduino Uno microcontroller and microcomputers "Raspberry Pi 2 Model B ARM Cortex-A7" [42]. The web-based interface management system called, "Hommons" of the dimension 90 cm × 45 cm × 120 cm was efficient to monitor and control the major parameters using sensors. The data collected from automated sensors and manual testing had a difference of an average error rate of 0.25. However, the authors can enhance the model to automate and build intelligence to the system. A similar study was made about the lettuce crop which emphasized on quality and quantity of crop production. [43].

An Open Ag Personal Food Processing system [44] deployed by Massachusetts Institute of Technology (MIT) has modelled a system that allows the user to create, share and stock the data generated during the plant growth phase. This device embeds climate recipes that help in monitoring and controlling environmental parameters for plant growth by using robotic technology. The system is highly adaptable, customizable and less expensive and efficient when compared to many commercial devices in the market. It was found that the researchers had to face few challenges with the customization in the design & control of hardware, adaptability and scalability of the system.

With the implementation of computational intelligence (CI) methods to anticipate the most essential and broadly utilized plant morphological parameters, for example, plant development, behaviour or fruit growth behaviour for modifying the operation of indoor hydroponic techniques, a CEA system that automates the plant production is required. The key challenge in automated hydroponics apart from the smart, intelligent and self-controlled system is a self-sustained crop production with proper analysis for optimal plant growth is required. A model developed for smart farming hydroponics accomplished great financial and environmental advantages in modern agriculture system. The data read from the sensor network performed the predictive analysis using Bayesian Network, which ascertained that the yielded crop gave 66.67% effective result that manual control [34]. However, the learned algorithm has to be improvised for longer and larger data analytics for more accurate results. A model was designed for an NFT based hydroponic system to control pH and EC values using fuzzy logic for efficient use of water and nutrient solution [27]. However, the automation in controlling the variations of pH and EC values are directly proportional to the throughput of the system. Higher the pH and EC, greater the response time.

The authors of [45] designed the computer vision-based system for the production of lettuce with nutrient film technique based hydroponic system. The system could continuously monitor, control, extract images and collect the data of crop features to analyse the changes in plant color, temperature, crop indices, and texture from crop canopy and also determines the plant health status. A similar plant growth cabinet was proposed by [37, 46] using the Internet of things with the integration of Android based software to analyse plant phenology implemented using Artificial Neural Networks (ANN). The sensors collect the data in plant growth cabinet and control various parameters like temperature, air temperature, nutrient solution, humidity, a concentration of CO2 and light intensity in hydroponic to ensure sustainability, closed environment and energy efficient plant growth. One of the researchers [47] had aimed to design a model with image processing technique using multi-cameras to monitor the growth of a plant and observe plant age and fresh weight of a mustard plant implementing ANN.

TABLE 1: REVIEW AND ANALYSIS OF CONTROLLING PARAMETERS WITH DIFFERENT MICROCONTROLLER CHIPS

Microcontroller	**Positivity**	**Technique Used**	**Shortfalls**	**Accuracy**
SK 40C [11]	Automation of pH control	-	Focus only on automation of controlling pH	90%
Raspberry Pi [36]	An intelligent system with ecological benefits	Bayesian Network & Machine Learning	A fewer data set for data analysis	66%
[37]	Highly accurate in prediction	ANN and fuzzy logic	Expensive system	97%
Arduino Yun [41]	Good scalability and configurability	IoT Talk	Can improvise on larger systems	38%
Arduino Uno & Raspberry Pi 2[42]	Has improved efficiency with CEA	Web Based Analysis	A simple data collection system with no intelligence	90%
Arduino Mega, Raspberry Pi[50]	Real time Data Acquisition	Deep Neural Network	analysis based on small scale productions and smaller datasets	88%

With automated and controlled hydroponics, there are lots of challenges to be addressed to monitor, analyze and process real-time data. One of them is to identify the current technology and how it can be integrated to work in a smart and intelligent fashion. Several researchers have used different kinds of microcontrollers that automate the system in hydroponics to optimize the plant growth. The real-time data acquisition has been implemented using low cost "Atmel's AVR (Advanced Virtual RISC) microcontroller" [48]. However, the simulation of this work has to be implemented to verify with real-time data. The project experimented for the Deepwater Culture system used SK 40C microcontroller to monitor the parameters of plant growth [11] to automate the system. In the same way, an Arduino mega 2560 microcontroller [49] was used to automate and control pH values in the DWC hydroponic system. The table 1 above shows the remarks review of the microcontrollers used in different systems.

V. FUTURE ENHANCEMENTS- PROPOSED MODEL FOR CO-RELATION ANALYSIS

The Machine Learning (ML) prediction algorithms present a scalable and multidisciplinary approach for data analysis which can make a huge impact on agricultural production. The ML approaches act as a tool in agricultural research for precision farming with spectacular results. The effective modelling of the dynamics of plant growth and crop yields are very essential in hydroponic agriculture system as well, with effective resource management. The possible target outcomes with hydroponic farming are fresh weight, plant height and number of leaves, stem's diameter and healthiness of the plant.

With ML prediction models like Regression Algorithms, Neural Network models and optimization models, the accurate crop prediction, impact of environmental parameters and crop management can be implemented for high yield. Prediction and Analysis of plant growth based on environment parameters can be shown in the Fig. 3.

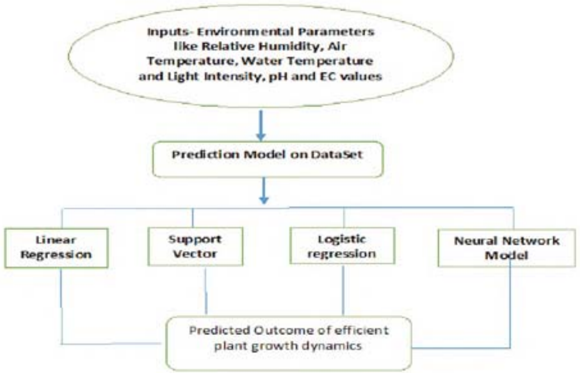

Fig. 3: Proposed prediction Algorithms for prediction of plant growth dynamics

The plant growth rate can be effectively analyzed based on the environmental parameters along with pH and EC values for high yield production. Hence, there is a need to analyze the correlation with these parameters towards plant growth and health by effectively implementing statistical and supervised machine learning models. These models are trained and tested to predict the dynamics of plant growth and plant health. The model should be able to predict the further plant growth by considering the future weather conditions.

A. Linear Regression Model:

A simple and multivariate linear regression models can be implemented on the hydroponic time-series dataset to analyze the dynamics of plant progress from the single and multiple independent variables respectively. With correlation matrix, the significant parameters are chosen which produces less cost function. The multivariate regression equation 1 is shown below

$$Y = \alpha + w_1 a + w_2 b + w_3 c + \ldots \quad (1)$$

Where, a,b,c.., are independent variables, α is a constant, w_1, w_2, w_3… are reggression co-efficients and Y is a dependent variable. By applying the correlation co-efficient between dependent and independent variables, the hypothesis can be formulated and plant height can be observed. The accuracy of these models are calculated using cost functions Root Mean Square Error(RMSE), Mean Square Error(MSE) and Mean Absolute Error(MAE). The best fit line can be drawn to minimize the sum of square errors.

B. Support Vector Regression Model (SVM):

This model aims towards non-linear mapping of predictor parameters from lower dimension to higher dimensional space. The SVM kernel function Radial Basis Function (RBF) is used to project the input parameters into higher dimensional space. The Gaussian RBF function is given in the equation 2.

$$K_{rbf}(x_1, x_2) = \text{exponent } (-\gamma \, ||x_1 - x_2||^2) \quad (2)$$

Where $||x_1-x_2||$ determines the Euclidean distance between x_1 and x_2 and γ determine the model fitting for RBF kernels. The margin of tolerance is determined using the threshold value € and cost function c. The trade-off complexity c with number of support vectors should regularize in minimizing the errors and maximizing the margin between the hyper plane and data points. Choosing a high predictor variable can be achieved by using Principal Component Analysis with evaluation based on the performance.

C. Logistic regression Model:

This model can be applied if the data sets are continuous or dichotomous. The datasets are analyzed based on binary regression using sigmoid function. The cost function is determined to minimize the errors which is called cross-entropy in the binary form of 0 or 1 of a target variable.

D. Neural Network Model:

The neural network model is the cost-effective prediction model which can be used to predict the plant growth dynamics using feed forward technique. The input parameters act as neurons which are forwarded to the next hidden layers. Finally the output layer forecasts the required target variable. Later, with back propagation technique the actual outputs are compared with predicted outputs, estimate the error and adjust the weights to gain higher performance. The Neural network model can handle complex and nonlinear problems in a better way.

VI. Challenges with Controlled Environment Agriculture System

The challenges with conventional agricultural practices are confronted by true indoor farming agricultural systems by being more efficient with time, resources, space, energy and being more ergonomic and conducive for easier and faster cultivation of plants. In recent years there has been a greater struggle for the sustainability of agriculture, farming [51]. The major concerns with respect to small scale and large scale hydroponic agriculture include Food Safety, Nutrient Management and pest management. On the other hand, in large scale, the other concerns include financial sustainability, production management, time management, water conservation and recycling, wastewater management, Energy and climate [2].The key challenges for CEA with hydroponics are:

A. Power Optimization-

For a CEA system power optimization is to be considered as a major challenge when the photosynthesis of plants is made possible in an indoor system using artificial light. NASA's [5] life support system with CEA for hydroponic plant production, the power optimization was the foremost concern. Reducing the consumption of power to maximize plant growth can be achieved using various methodologies in Artificial Intelligence such as fuzzy logic, neural networks, machine learning, and genetic algorithms [16].

B. Energy Saving and Recycling-

It is one of the challenges that have to be considered with indoor Hydroponics. The countries which are deprived of natural sunlight, make use of numerous hydroponic solutions by utilizing artificial light as an alternative to grow at indoors and outdoors. The source of lightning is through LEDs. The LED light treatment influences the growth of plants and shortens the period of harvesting. The cost-effective LED lighting frameworks require an accurate design, implementation and management practices to acquire the best performances in the CEA system [18, 19]. In future studies with respect to smart lighting systems are required to enhance and optimize the indoor farming system with higher energy saving, recycling and sustainability. However, energy saving with artificial lightning still remains a huge challenge.

C. Water conservation and recycling:

In this soil-less culture, the plants are more dependent on water and nutrient solution. A lot of studies have been done to increase the efficiency of water conservation and recycling in closed systems which is a top priority in the today's need. The researchers are studying the reuse of the Hydroponic waste solution to grow vegetables and fruits which can reduce the water consumption. The authors of [52] having made a rigorous review of wastewater reuse with a hydroponic solution and positively identified several ways of gradual reduction of consumption of irrigation water to overcome the water crisis. This can have a potential change in the food quality with more environment sustainability [53]. NASA [5] has used a life support technology for purifying and recycling the waste water in a closed CEA for a plant factory system in space.

D. Pest Management-

With conventional farming, the plants are exposed to air and soil-borne pathogens, disease and pests due to several environmental factors. However, in a CEA hydroponic, with integrating modern methodologies like image processing or computer vision, intelligent and integrated pest management system has to be adopted. The use of organic pesticide and chemicals may help in effective pest management, which has a more enormous benefit to the health and quality of crops. These organizations [8, 13] have come out with hydroponic solutions to grow pesticide-free plants. Effective measures have to be considered to optimize the health of plants grown with indoor/outdoor hydroponics. The focus is on pesticide-free farming or minimal and safe use of pesticides. One of the challenges with hydroponic CEA is that there is threatening for the feasibility of plants by pathogens that harm the plant growth food, and fungal infections, however, exist [4]. With the use of several beneficial bacteria that can control the phyto-pathogens, quality and quantity can be improved. The study has been made by the author to identify the plant diseases and controlling mechanisms to reduce it.

VII. CONCLUSION

A Hydroponic farming system with an integration of technology helps the growers to create a precision environment for crop cultivation. The automation and intelligence to the system have got numerous benefits to this type of farming to enhance crop production with limited resources. This type of indoor farming methods helps hobbyists or any individual to grow their own crops with limited resources. Compared to conventional farming the modernized, automated CEA hydroponic has numerous advantages which include higher efficiency, higher crop yields with large-scale, ecological benefits. Apart from all these benefits waste management is the most crucial part of the CEA system that needs to be explored more.

Several organizations have explored to come out with Food Processing Computers that is implemented using some modern technologies. These kits can automatically sense and intelligently control the environmental parameters in closed/open systems that can affect the plant growth. This research review has highlighted the need to analyse parameters like temperature, pH, EC many more that has a linear relationship with the optimal plant growth. Many intelligent algorithms and technologies like fuzzy logic, linear regression, machine learning, image processing can be implemented on the datasets to understand the correlation analysis between the growth rate and input parameters. Urban farming still remains an experimental stage in developing country like India as less research work has taken place on Indian climate based crops. In the future, with the scarcity of resources, by incorporating the smart-farming techniques that could yield to high-quality crops. Further, there is a need for directing quantitative research that gives exact evaluations of the ecological, environmental and social benefits.

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