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AI BASED VERTICAL HYDROPIC SYSTEM : A SURVEY

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Abstract
With the world's population expanding, there is a greater demand for food globally, which has led to requests for new sustainable agriculture practices. A big problem now is the lack of arable land and fertile soil worldwide. An innovative approach and a more effective and sustainable alternative to conventional farming could come from combining hydroponics farming with vertical farming. This paper has discussed various research papers in which farming systems developed based on the IoT, embedded systems, wireless sensor networks and some other advanced technologies are covered. This paper highlighting the ever-growing need of Hydroponics along with Vertical farming in the agriculture field. Moreover, this paper is also focusing on artificial intelligence's importance in Hydroponics Farming. The study in this paper will definitely help researchers and readers in their work.
Keywords—Smart Farming, Hydroponics Farming, Vertical Farming, IOT, Artificial Intelligence

INTRODUCTION
The word "agriculture" is derived from the Latin terms "Ager" and "Culture," which both mean "cultivation." It is one of the benchmark regions and the field that represents the pinnacle of human civilization. The agriculture industry is the foundation of the economy in various developed and emerging countries. This sector greatly boosts the GDP, or gross domestic product, of emerging countries, some of which are depicted in Table 1 [1].

Table 1. List of Countries having major Agricultural GDP contribution

Sr. No.	Name of the Country	GDP in %age
1)	Liberia	76.9
2)	Somalia	60.2
3)	Guinea-Bissau	55.8
4)	The Central African Republic	53.1
5)	Chad	52.7
6)	Comoros	51.6
7)	Sierra Leone	51.5
8)	Toge	46
9)	Ethiopia	41
10)	Niger	39
11)	Mali	38.8

Catalyst Research Volume 23, Issue 2, August 2023 Pp. 468-499

12)	Burma (Myanmar)	38.2
13)	The Democratic Republic of the Congo	37.5
14)	Benin	36
15)	Nepal	34.9
16)	India	23

In India, the agriculture industry provides jobs for 53.3% of the population and is the source of income for 61.5% of the people [1]. Figure 1 compares the contribution of agriculture to India's overall economic development with that of other sectors.

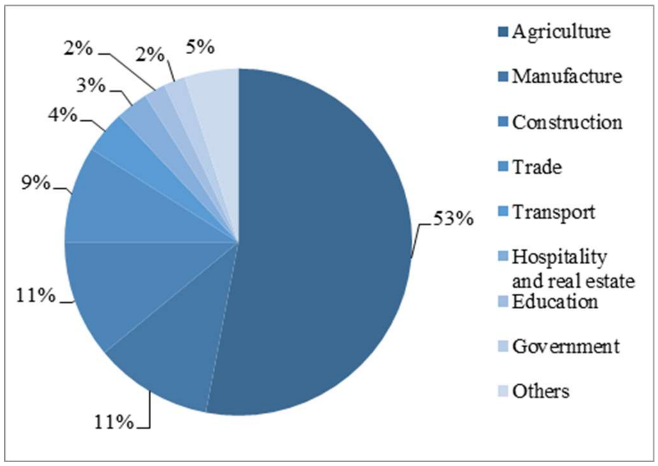

Fig. 1. Contributions of different industries to the Indian economy

A. Smart Farming

Farmers do not find it convenient to use conventional farming methods. Farmers are facing many practical problems like inadequate fertilizers, manures, and seeds, as well as a lack of effective implementation etc. One of the most important problem faced by farmer is soil erosion which results into less agricultural production and desertification. So there is a need of major shift from conventional farming to modern farming by incorporating smart farming. IOT is incorporated in Smart Farming alongwith advanced technology. IOT is giving solutions to many issues which are in conventional farming.

B. Vertical Farming (VF) and Hydroponics

Many researchers are working on soilless farming and one of soilless farming is hydroponics. Crops are grown using water and nutrients in hydroponics. Growing plants without soil has become popularized through hydroponics, and numerous studies have demonstrated that plants produced this way are of higher quality and use fewer resources than those grown using more conventional techniques. The cultivation of plants without soil has two main advantages. First, using hydroponics could result in much increased agricultural yields. Moreover, hydroponics can be employed in locations where traditional agriculture or gardening is impractical, particularly in those with unfavorable climate, light, or soil conditions [2]. In addition to this VF will meet the challenges of water and land shortage and also suitable to adopt near the cities. To expand the amount of arable land without affecting the forests as well as other natural wildlife habitat, innovative and cutting-edge methods are needed in addition to hydroponics and VF. The deserts, which make up one-third of the Earth's land surface, must be our main focus in this [3].

C. Importance of Artificial Intelligen / Machine Learning (AI/ML) in Agriculture

The data generation and storage globally is increasing at an exponential rate, making data an increasingly significant economic asset. Of course, gathering data is useless if you don't do anything with it, but these massive influxes of data are just impossible to handle without assistance from automated systems.

By utilising artificial intelligence, machine learning, and deep learning, organisations may benefit from the huge amount of data they gather. These technologies generate business insights, automate activities, and enhance system capabilities. AI/ML has the potential to completely revolutionize a business by assisting with the achievement of measurable results like Enhancing customer satisfaction, Providing differentiated digital services offers, Improving current business services, Automating business procedures, Increasing income and Lowering costs etc.

Technology has altered farming practises over time and has had a wide range of affects on the agriculture industry. By 2050, when the population will rise from 7.5 billion to 9.7 billion, only an additional 4% of the planet's surface will be cultivated, placing further pressure on the land. In many countries around the world, agriculture is the main source of employment. As a result, farmers will have to exert more effort while using fewer resources. According to the same report, food production would need to increase by 60% in order to feed an additional two billion people. Traditional methods, however, fall short of this huge need. Farmers and agricultural businesses are being compelled by this to create novel methods for increasing output and decreasing waste. Following that, artificial intelligence (AI) is progressively becoming a part of the agricultural industry's technological development. To feed an additional two billion people, it is intended to raise world food output by 50% by 2023. Farmers will be able to work more productively while also improving crop quality and quantity and assuring a faster time to market with the aid of AI-powered technologies.

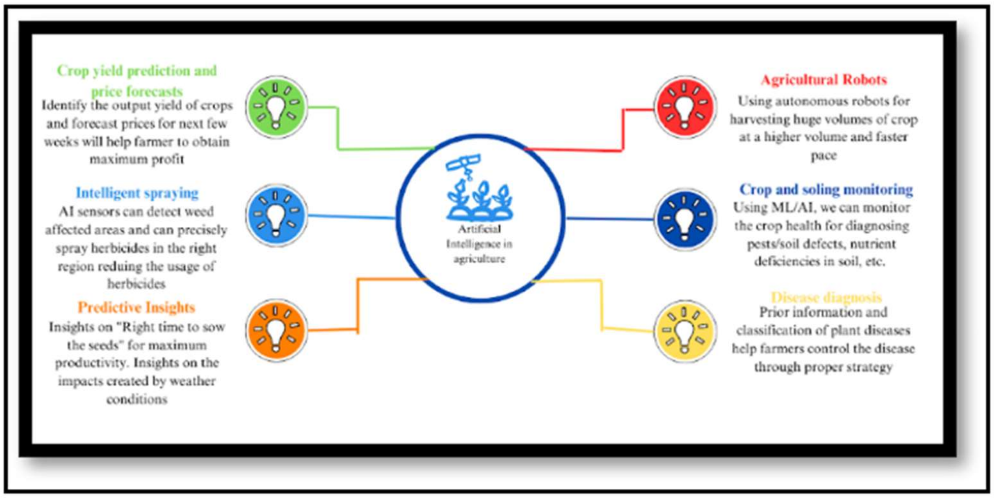

Fig. 2. shows use of Artificial Intelligence in Agriculture.

D. Sources and Search Method

Table 2 displays a list of the web sources from which the research materials were chosen. The survey method requires reading papers that discuss how IoT, AI/ML and similar technologies have helped to grow and expand the agriculture industry. The data and carefully selected studies were used to develop the overall framework of this paper.

Table 2. List of the web resources for finding the related research papers

Sr. No.	e-Resources	Bodies
1	ScienceDirect	Journals, Conferences,
2	Springer	Magazines,
3	IEEE	Databases,
4	Hindwi	Transactions,
5	Academia	Book Chapters, Books,
6	MDPI	Proceedings and
7	IOPscience	Special Issues.
8	NEWTON	
9	Novateur	
10	Google Scholar	

All of the papers taken for survey are sorted from 2016 to 2022. By studying the previous literature, a sustainable structure has been planned to reduce the effects of the current challenges in the field.

The further sections of this paper includes: Hydroponic farming has been covered in Section 2 for a more thorough understanding of the numerous concepts, theories, and tools connected to the application of smart farming. In Section 3, discussion on all papers survey is mentioned. The paper concludes with a conclusion in Section 4, which provides the many research linked to problems, limitations, improvements, future work, etc.

2. RELATED WORK

This section includes the documentation of various researchers working on IOT based Smart Farming, Precision Agriculture, Soilless Farming and Hydroponics etc. Still research is going on different issues of agriculture to shift it from soil farming to soilless farming. It will discuss about different approaches, concepts, techniques and methodology used by various researchers. This section is including the survey based on different issues in the agriculture like Crop growth, disease detection and Remote monitoring etc.

Table 3 summarizes the approaches that have been created for crop growth and goes into further detail. For estimating crop productivity and drought, authors in [4] have devised a wrapper feature selection approach and PART classification technique.

For crop growth monitoring and diagnosis (CGMD), authors in [5] devised an active light source apparatus taking into account the spectral monitoring mechanisms of row-cultivated crops and canopy shape parameters.

Many techniques such as Edge and cloud computing, Convolutional Neural Network, Big Data Analysis, 3-D Point Cloud Data from Registered Camera Data and Terrestrial Laser Scanning are used for determining the crop growth. But the use of artificial intelligence technique and applying the final results will benefit farmers achieve automatic environment control and cultivation [6-9].

Challenges in Vertical farming are related with operational costs, monitoring, and management which are addressed using IoT, Low edge computing, big data analytics etc. [10-14].

A solar photovoltaic (PV) panel combined with an energy storage device totally meets the system's energy needs [15].

The authors in [16], have proposed the dual-axis solar tracking system which will produce power more effectively by spinning in every way. The generated energy is stored in a battery and then used as a hydroponics energy source for lighting and irrigation. It also includes a weather sensing unit that measures humidity and temperature.

The LAI ie Leaf Area Index is a useful tool in [17] for site-specific management that tracks crop growth and health. Data from proximal and multispectral remote sensing are utilized to determine LAI. Semantic segmentation is used to estimate crop LAI and weed LAI from a small number of high-resolution ground photo samples. Using data from proximal and remote sensing, these constrained LAIs are expanded across the entire field.

Pixel-based methods are used to classify crops from weeds, especially in complex situations where there are overlapping plants and partial occlusion. HOG is used for object detection. Crop and weed classification use attribute profiles, which are multiscale and content-driven morphology-based descriptors [18].

Random Forest Algorithm is implemented in Hydroponics farming and Nursing System for key parameter identification. The use of Wi-Fi technology is for communication. To reduce energy requirements and the number of sensors, the Random Forest algorithm makes sure that just a few electrical actions are carried out [19].

The Hydroponics expert system incorporates mobile application-integrated artificial intelligence. The DLCNN cloud platform has an AI system installed that continuously assesses sensor data, plant disease conditions, and notifies farmers via the Agri-Hydroponic application [20–21].

Based on the hydroponics machine learning paradigm, a framework for predicting absolute Crop Growth Rate is suggested in [22]. Microcontrollers, sensors, and pumps are employed in hydroponics systems to automate the system [23–28].

The hydroponic automation system is monitored over by a chatbot on Telegram. The chatbot can get data from each and every sensor. The results of the Telegram bot testing were positive; the average of time required to receive information was only 1.44 seconds. The smart hydroponic system design results identified certain challenges while capturing photos that still couldn't be displayed because messages from Firebase to Telegram couldn't be translated into images [29]. As a result, string data photos were transferred and shown on Telegram.

By using less water, fertilisers, and space for farming, the designed system was able to produce plants and crops more effectively. The "IoT MQTT Panel" mobile application, which enables easy monitoring and control of plant condition, displays the data from the proposed system that was collected on ThingSpeak [30].

Data is transferred from the NodeMcu ESP8266 to the cloud (NodeRed) in the proposed system utilizing a designed secure MQTT server and Mosquitto. Both an email and an SMS have been received by farmer. However, there are a number of issues that can be resolved in subsequent studies, such as the application of artificial intelligence and data science to further improve crops [31].

Farming data can be gathered and analysed using IoT, machine learning, fuzzy logic, deep neural networks, and Bayesian Network (BN) approaches, which will aid farmers in increasing agricultural yields. Intelligent devices on the ground can better manage the crop fields. The development of hydroponics, greenhouse farming, and seawater greenhouse as alternative agricultural ways to build sustainable agriculture is strongly motivated by the lack of agricultural land and water availability. [32-52].

To quickly diagnose and debug the system, an automatic data acquisition system (DAQ) based on an Arduino was developed [53]. A pipeline is digitally fabricated using 3D Model for hydroponic system in [54]. In contrast to typical hydroponic substrates, a porous SBS material results in more consistently healthy plant development. In IOT based smart farming system, The camera is connected to the CC3200 so that pictures can be taken and sent through MMS to farmers' cellphones over Wi-Fi [55]. In Arduino UNO system, based on sensed temperature and moisture values actuators are controlled. Furthermore, the same values are stored to ThinkSpeak cloud for further data analysis by farmers as well as researchers in [56].

Temp and humidity readings are sent to ThinkSpeak's cloud platform for later monitoring and analysis. Users can observe the data on System in the web browser as well as on android mobile phone. Additionally, the same data can be exported to excel file which can be analysed using MATLAB [57]. The amount of alkalinity, acidic content present in the soil and the usage of fertilizers are notified to the farmers using user friendly Mobile-app [58].

The proposed system in [59] notifies motor pumping when motor is ON and Raining when rain detection sensor detects it. The humidity and temperature values are also notified to farmers in the Blynk App. Speaker is used to alert and announce the user about the conditions. In addition to this, Push Notification facility is also provided to alert the user about farming condition in [60].

Table 3. List of developed techniques for Crop Growth

Authors	Area	Type of Crop	Tools / Techniques	Parameters	Applications
Rezk et al. [4]	Smart Farming	Crops like Jowar, Sugarcane, Soybean, and Bajra.	An effective prediction technique, known as WPART, was developed in this study.	Feature selection and classification for crop productivity and drought prediction.	For assessing crop productivity and drought, the PART technique and wrapper feature selection have been developed.
L. Yao et al. [5]	Smart Farming	wheat and rice	Signal conditioning circuit, Module: an ATmega32 processor, Const current source drive module, LCD Display Module, Keyboard input module and Temp and Humidity Sensor Module	The leaf area index (LAI), leaf nitrogen accumulation (LNA), leaf dry weight (LDW), and leaf nitrogen content (LNC) are among the parameters used to gauge crop growth. Additionally, the normalized difference	Authors have developed an active light source apparatus which is useful for crop growth monitoring and diagnosis.

				vegetation index as well as the ratio vegetation index are both used.	
Zamora-Izquierdo MA et al. [6]	Precision Agriculture	tomato crop (in a greenhouse in the South-East of Spain)	Low-cost Hardwares: Climate unit, nutrient solution unit, irrigation unit, purification unit, and disinfection unit. Different Sensors, FIWARE, Cloud Server & HTML5	All the environmental parameters	To provide advances in Precision agriculture using IOT and Cloud computing. This system is also suitable for extreme climatic environments.
Lingxian Zhang et al. [7]	Greenhouse	greenhouse lettuce	This paper offered a technique for tracking the growth of greenhouse lettuce with digital images and a convolutional neural network method.	Leaf Area (LA), Leaf Area Fresh Weight (LFW), and Leaf Dry Weight (LDW)	It has high potential for use in the application of growth monitoring and is a trustworthy tool to evaluate the growth-related features of greenhouse lettuce.
F. -H. Tseng et al. [8]	Smart Farming	green beans, celery, water spinach, and daikon	Hardware includes a 3-in-1 soil sensor, an illumination sensor, a temperature and moisture sensor, and a solar power system with IOT development board SIM5320E. Software :Python, the XMPP Web Platform, and the MySQL Server	All the environmental parameters	When the system observes and analyses crop cultivation behaviour, farmers may gain a better knowledge of whether a crop is fit for their farm by taking into account variables like temperature and soil moisture content
L. Xu. et al. [9]	Smart Farming	Corn	Integrating terrestrial laser scanning (TLS) and camera data makes it possible to detect corn seedlings in cropland with great accuracy.	A method of piecewise linear interpolation to separate corn seedlings from the ground and remove the distance for intensity attributes of scanned targets	Corn Seedling Monitoring Using TLS and Camera Data from the Cloud
Jandl, Adrian et al. [10]	Vertical Farming	-	A host with an RPi2 ModelB of 900MHz quad-core ARM Cortex-A7 CPU; 1GB	Challenges in Vertical farming are related with operational	Authors have demonstrated that integrating service-oriented design,

			RAM and an AMD Ryzen 5 3600X processor with 6 CPU cores at 3.80GHz are the two types of computing devices that are used. Edge computing and IoT-based vertical farm management technologies.	expenses, management, and supervision.	improvements in IoT network, and cheap edge computing technology can overcome issues in vertical farming.
Shrivastava, Anurag et al. [11]	Vertical Hydroponics Farming	-	Arduino Microcontroller, Sensors and Android App	Water Levels and other parameters	Employing an IoT platform, develop and apply automated vertical hydro farming techniques are described in this research article. Big data analytics will be used for their analysis.
Kumar, MR Sundara et al. [12]	Vertical Hydroponics Farming	-	Sensors are used in the hydroponic farming method to continuously observe the status and health of the crops.	Water Levels and other parameters	According to the seasons, big data analytics assists farmers in deciding which crops (vegetables and fruits) should be grown. Small farmers may monitor their farms using a mobile app and centralized server due to the IOT technology.
Muhammad E. H et al. [13]	Indoor Vertical Hydroponics Farming	Crops that are frequently used as a food source inside Gulf region houses.	The following subsections make up the design of the system: NFT structure and key components, Internet of Things (IoT) platform, nutrition and pH control system, and water flow path Application of Deep Learning and Machine Learning Algorithms	Wavelength of appropriate light, pH, EC, temperature, and the amount of water the system requires.	User can monitor the farm remotely.

Catalyst Research Volume 23, Issue 2, August 2023 Pp. 468-499

Rahul G. Mapari et al. [14]	Hydroponics Farming	Sprouts vegetables	Spectrum/Light, an Arduino Uno Light intensity sensors, moisture sensor, humidity sensor, pH sensors, water-level sensors, water pump controls and actuators. Softwares: Fuzzy Logic Algorithm, MATLAB, the Arduino Integrated Development Environment (IDE), and Windows OS	Moisture, pH, humidity, water level, and spectrum availability.	The stimulation of light accelerates the growth of sprouts in the farm, and sensors in an IOT-based system assist to continuously monitor all the parameters.
Yemeserach Mekonnen et al. [15]	Smart Farming	-	Electrical System Units, Wireless Sensor, Irrigation System Unit: Arduino Mega and the power meters and Zigbee Protocol	agricultural and environmental parameters	Network approach useful in using food, energy, and water for growing crops as efficiently as possible.
Yashas G et al. [16]	Hydroponics Farming	-	Arduino UNO, LDR, DHT-11, Rain Sensor, Servo Motor, Solar Panel and Battery. Hydroponic Food Chamber	Light, Temperature and Rain	In addition to being turned into electrical energy, solar energy is also stored in batteries. In hydroponic farming, the stored energy is used to pump the water.
M. H. Asad et al. [17]	Smart farming	-	Machine Learning - Deep Learning Model Training using Multi Source Data	CLAI, WLAI	The Leaf Area Index (LAI) is a helpful technique for site-specific management that tracks crop growth and health.
P. Bosilj et al. [18]	Smart Farming	-	Object detection is done using HOG. Pixel-based methods for classifying crops from weeds are especially useful in complex situations when there are touching plants and partial obstruction. The benefits of multiscale, content-based attribute profiles that use morphology-based	Image	A pixel-wise plant-type classification improved system is designed. Helps to determines types of vegetation in the farm through image.

			descriptors are determined.		
Y. V. Bhargava et al. [19]	Hydroponics Farming	Spinach plant	Monitoring devices include the LDR, the DHT11 Sensor for Humidity and Temperature, the MAX6675 ie Water Temp Measurement Sensor, the EC201 pH Value Measurement Sensor and EC-3190 - Water Depth measuring sensor. It uses the Random Forest algorithm.	Temp. pH, Electrical Conductivity, Water and Light Intensity	The spinach plant growth is monitored using proposed Hydroponic System.
Ramakrishnam Raju, S. V. S. et al. [20]	Hydroponics Farming	-	Raspberry PI, Camera, Sun light sensor, Air Temp. and humidity, Water Temp. Sensor, Water PH Sensor, Turbidity & NPK Sensor. Screen of Data, Fresh Water Pump, Drain Water Pump, Cooler and Motor for Sun ray controlling	Image, Water, Light & Air	IOT based using AI Hydroponic system is communicating with farmer through mobile application and helps to control nutrients in automatic as well as manual mode remotely.
G. Dbritto et al. [21]	Hydroponics Farming	Tomato F1 Hybrid Suhyana crop	Raspberry Pi 3 with Micro controller, Temperature sensor, Light Red and blue color, Water level sensor, PH Sensor, Light intensity sensor	Time, Temp, pH Level, Light and Water Level	The Hydroponics system is used for automating crop plantations in a closed environment.
Swapnil Verma et al. [22]	AI and Smart Systems (ICAIS)	Tomato	The entire arrangement is broken down into three primary components: data collection, analytics, and prediction results.	Nutrient Analysis	The work in this paper helps to provide useful insights into the hydroponics field using a machine learning and reduce the difficulties in the process.
Vanipriya, C. H. et al. [23]	Hydroponics Farming	-	pH sensor (SEN0161), moisture sensor, temperature sensor (DS18B20), ultrasonic sensor (HC-SR04), Arduino Mega 2560,	Water level, temperature, humidity, and pH	The device monitors the plant status in real time and gives early predictions along with control actions.

			ESP8366 and Cloud (i.e., Adafruit).		
Shetty, Hariram M. et al. [24]	Smart Farming	-	PIC16F877A microcontroller and four pumps	Temperature, Humidity, pH, and EC	Traditional farming required a lot more manual labour, and this technology used less labour while producing more food with less water than conventional farming techniques now in use. automatically without the farmer present.
C. Ramos et al. [25]	Hydroponics Farming	-	Hardware: HL-69 sensors for detecting root moisture, DHT 22 and DHT 11 sensors for measuring inside and outside temperature and humidity, and a photoresistor for monitoring brightness. Raspberry Pi Technology: IOT and Deep Neural Network	Temperature, humidity, and brightness both indoors and outside, as well as root moisture	A water flow problem is crucial in hydroponics since it can harm the plants and easily result in the loss of all production. This study demonstrates that the NFT system does not require constant watering, which saves energy.
Tagle Sean et al. [26]	Urban Farming	-	CAD Model of the Indoor Hydroponic Tower Prototype. Microcontroller, all sensors, SD card and LCD display	Environmental Conditions	The system which occupies only 4.84m2 of space but with a capacity of 52 plants proved to be suitable for the urban setting due to its compact structure.
Sihombing, P. et al. [27]	Hydroponics Farming	--	Arduino Uno Microcontroller and Sensors	Height of Water Nutrient, temp and other parameter	According to the needs of the hydroponic system, the water level can be automatically changed.
Mr. Rahul Nalwade et al. [28]	Hydroponics Farming	Tomato	LCD, Solar panel, pH sensor, Temperature sensor LM35, Temperature sensor waterproof (DS18B20), Operating voltage, GSM module, GSM module and	pH, Temperature, Light and EC	This is system helps to automate the growth monitoring and increase the tomato yield.

			Arduino Uno Atmega 328 microcontroller. Arduino programming environment		
Hariono Tholib et al. [29]	IT in Agriculture - Hydroponics Farming	-	Arduino Uno, ESP8266, temperature, pH, and water-level sensors, as well as battery and charge sensors. Waterfall Model, Firebase and Telegram bot	Image	Telegram bot-based application helps to monitor the plant growth using hydroponic system remotely.
Patil Nivesh et al. [30]	Hydroponics Farming	-	Microcontroller, PH Sensor, DHT11, EC ckt, Dispenser, MQTT App and ThingsSpeak	pH Level, Temp, Humidity and EC Level	A farmer can monitor plant health with the aid of the mobile app "IoT MQTT Panel".
Lakshmanan Ravi et al. [31]	Hydroponics Farming	-	Sensors, NodeMcu, Node Red, and MQTT	Temperature and humidity in the room, water temp., pH level, and fertilisers level.	The automated smart hydroponics stock supply chain uses email and SMS to convey messages.
Anneketh Vij et al. [32]	Agriculture	-	Raspberry Pi 3 and Arduino Mega micro-controllers, as well as other sensors	All the environmental parameters.	The method aids in predicting the kind of soil, the type of crop, and the quantity of irrigation needed by the targeted crops.
Manav Mehra et al. [33]	Automated Agriculture	Tomato	Arduino, Raspberry Pi3 and Tensor Flow.	pH, Temp, Humidity, Level, and Lighting	Deep neural networks and IOT implementation combine to create intelligent systems.
A. F. Subahi et al. [34]	Agriculture	Greenhouse	The complete system is broken down into three primary subsystems: data conversion, temp control and monitoring subsystem and greenhouse management information system.	Greenhouse environmental parameters	PN model is used to supervise the greenhouse environment.
Palande Vaibhav et al. [35]	Agriculture – Hydroponics Farming for Indoor	-	Arduino microcontrollers, NRF24L01+ radios, Raspberry Pi, LED’s, camera mounted on the system, a pH sensor, an electrical conductivity	Temperature, humidity, EC and pH	In this paper, the developed system can produce typical plants and vegetables using a method called Hydroponics. Domoticz software

	Plant Growth		probe, a water temperature sensor, an air temperature/humidity sensor and an air temperature/humidity sensor, EC and pH probes Domoitcz software		allows remote monitoring and control if required.
H. Fakhrurroja et al. [36]	Hydroponics Farming	-	Humidity sensor, PH sensor, DHT22 sensor, Arduino Nano, Raspberry pi, Relay, Exhaust Fan and Web server. Fuzzy Logic	pH and Humidity	pH and Humidity are automatically controlled in this Hydroponic system where fuzzy logic has been added.
Mishra Piyush et al. [37]	Hydroponics Farming	-	Peristaltic pumps with a 12 V, 60 ml/min motor. Data collection: OS, CPU, and PC Normalisation: Drainage solutions, 5 L of water in the tank Tank - 6 L ISE sensors as a sensor array Holder for samples: Rotary disc A signal conditioning board serves as the amplifier's power supply controller.	Ca, NO3 and Ki	The modeling of an IoT-based monitoring system can be tracked together with Calcium (Ca), nitrogen oxides (NO3), and Potassium (K) concentrations in hydroponic solutions with the appropriate level of sensitivity.
A. Muniasamy [38]	Desert Agriculture	-	The three phases of the ML conceptual framework for smart farming are as follows. 1. Generation of Smart Farming data 2. application of machine learning techniques 3. Analysing and making decisions about farming-related tasks	-	IoT and ML techniques are proposed to improve the crop yield.
H. K. Srinidhi et al. [39]	Hydroponics Farming	-	Hardware & Software Requirements: Raspberry Pi - Android Studio IDE, Water Temp sensor-Adobe XD, EC sensor - OpenCV, DHT11 sensor-Anaconda IDE, pH sensor - Raspbian	Water, temp & pH	Comparatively, hydroponic farming uses 90% less water than conventional farming.

			OS, Arduino Uno - Arduino IDE.		
Herman and N. Suranth a [40]	Hydroponics Precision Agriculture	-	ESP8266 (microcontroller module), pH sensor module, EC sensor module, water level sensor, relay and pumps, and humidity sensor module design IOT Technology	pH value, Neutritional value, Water and Humidity Level	In this research, authors suggest an IoT- fuzzy logic based monitoring and control system for hydroponic precision agriculture. IoT is used to make it possible to regularly check the nutrition and water requirements of plants, and fuzzy logic is used to manage how much of each is provided.
Kularbp hettong Kunyan uth et al. [41]	Hydroponics Farming	Vegetables	Hardware: Arduino, Relay Module, Ultrasonic, the pH and Ambient light sensor, Solenoid valve, MCU. Software: Arduino IDE, Edge Computing, Message Queuing Telemetry Transport (MQTT, Prototype model and Firebase Technology: IOT	Temperature, humidity and water	An automated hydroponics system is used to control plant growth using environmental parameters.
R. Perwirat ama et al. [42]	Smart Hydroponic Farming	-	Water flow and its level, pH, EC, humidity, and lux sensors are among the sensors that are used with a NodeMCU controller.	Water flow and its level, pH value, EC, humidity and light	The monitoring conducted by a variety of sensors, which is then analyzed by computers, will serve as the foundation for manipulation in an IoT-based system.
Sudharsan, S. et al. [43]	Smart Hydroponic Farming	-	IOT, Cloud Database, Mobile Application and e digital image processing	Water, pH and Camera captured image	To keep users updated on the growth of the crops, a mobile application is created and the user is informed by the digital picture processing if a disease or infection is spreading among the plants.

S. Pawar et al. [44]	Hydroponics Farming	-	NodeMCU ESP8266 Wi-Fi module, sensors, Raspberry Pi and other hardware	Humidity, temperature, light intensity and pH Level	Both manual and automatic working modes are available. We can regulate the duration of time by using the manual mode.
K. Veloo et al. [45]	IOT based smart agriculture and urban agriculture	Radish sprouts	Hardware used: RaspberryPi Camera Module v2 and Raspberry Pi3 Model B+, Temp. and Humidity module (DHT 11), Light sensor (GL5528) and 3W High-Power LED (OSW4XNE3C1S) Paddy Drone	Temperature, Humidity, Light Intensity and Growth condition	Authors have created an interactive agriculture sensing system using Kaiwalingual integrated IoT-based technology to help farmers produce their crops.
Mehra Manav et al. [46]	Hydroponics Farming	Tomato Plant	Technology: IoT hydroponics, Data analysis using Deep Neural Networks Hardware used: Raspberry Pi Water Level and DHT11 sensor, LDR module or Photo resistor, Two DC motors with propellers, DC water pump, LED Bulb, Arduino UNO and Raspberry Pi Software's: Raspbian Jessie, Arduino IDE, Python 3.6, Nanpy, Tensor flow, Pandas and Google Firebase	PPM, Water Level, Temp, Humidity and Light	Authors have developed an Intelligent IOT-based Hydroponic System where Deep Neural Network (DNN) model is used for generating the predicted output.
P. Belhekar et al. [47]	Hydroponics Farming		Raspberry pi and Sensors	Temp, Moisture and pH value	The farmer can grow any crop in any season with the aid of this technique.
S. Mashumah et al. [48]	Hydroponics Farming		Computer, Camera, Sensors and Microcontroller Box HSV Histogram image processing and Fuzzy logic control for the plant age	Image, Water, Neutrient Solution and EC	The fuzzy logic control of this system has proven successful in providing nutrients in accordance with the age of the plant, having a rate of error of 8.9%.

T. Changmai et al. [49]	Hydroponics Farming	Lettuce crop	IOT technology Hardware: I) NFT hydroponic planting devices II) Internet of Things devices III) PC and its Software: Apache Web Server Version 2.4.20, Windows 7, Arduino 1.8.5 and Visual Studio 2015	-	In this study, the authors built a Smart Hydroponic farm utilising the Internet of Things to examine its advantages over a conventional hydroponic farm.
D. Saraswathi et al. [50]	Hydroponics Farming	-	Sensors: Temp, Humidity, pH and Pressure sensor, IOT & Mobile App and Raspberry Pi board	Temp, Humidity, pH Value and Pressure	IOT is utilised to communicate the received data to the net and mobile apps are used to inform users of the current status via the internet to their mobile phones in order to simplify monitoring and maintenance.
M. I. Alipio et al. [51]	Hydroponics Farming	-	i) Construction of Hydroponics Farm using NFT technique. ii) Sensors: water temperature (WT), electrical conductivity (EC), pH level (PH), relative humidity (RH) and light intensity (LI). All sensors are interfaced to a microcontroller using Raspberry Pi. iii) Cloud Server and Web Interface iv) Use of Bayesian Inference for Data Analytics	RH, LI, WT, PH and EC	The authors designed a smart hydroponics system that uses Bayesian Network (BN) precise inference to run the process of growing crops automatically.
J. Pitakphongmetha et al. [52]	Hydroponics Farming	-	Hardware requirement: Temperature and humidity DHT11 sensor, Ultrasonic Sensor Module, 8 channel Relay Board and Greenhouse Architecture Software requirement: Blynk app	Temperature and humidity, Ultrasonic Sensor Module, Relay Board, Soil Moisture Sensor and Greenhouse Architecture	This study helps the farmers in the different stages of crop growth

S. Tagle et al. [53]	Hydroponics Farming	-	Microcontroller, SD Card, Water Temperature Sensor, Water Level Sensor, pH Level sensor, Light Intensity sensor, Ambient Temp, Humidity Sensor and Display	Environmental parameters	DAS was created by the authors with the intention of automatically measuring and logging various conditions for growing in the hydroponic system in outdoor.
Y. Takeuchi [54]	3D printing in Hydroponics Farming	-	Digital 3D Model	3D Computer data	The authors of this study have detailed a pipeline for digitally fabricating hydroponic systems, which allow for the soil-free growing of a variety of plant species.
S. R. Prathibha et al. [55]	Smart Agriculture	-	1) CC3200 includes network processor, microcontroller & Wi-Fi unit.2) Temperature infrared thermopile sensor- TMP007 3) humidity sensor- HDC1010 4) Camera 5) Power Supply	1) Temperature 2) Humidity 3) Images	It uses IOT and Smart Agri. using Automation includes monitoring temperature and humidity in farming.
M. Ashifud dinMondal and Z. Rehena [56]	Smart Agriculture	-	Arduino UNO, Temperature sensor (LM35) and Soil moisture sensor (VL95), Stepper motor and fan, Wifi module and ThinkSpeak cloud	Environmental Temperature and soil moisture	In this study, based on sensed temperature and moisture values actuators are controlled. Furthermore, the same values are stored to ThinkSpeak cloud for further data analysis by farmers as well as researchers.
T. Wiangtong and P. Sirisuk [57]	Precision Farming	-	1. Hardware and sensors: - Arduino Mega2560, ESP2866 2. Cloud Services 3. Clients 4. Implemented hybrid control techniques in this work include loop time control and specific	Environmental parameters	In this study, the hardware receives data from sensors and decides whether to activate the system actuator at predetermined intervals. Users can observe the data on

			time control, Control of temp hysteresis, Conditional control, along with controls for humidity hysteresis.		System in the web browser as well as on android mobile phone. Additionally, the same data can be exported to excel file which can be analysed using MATLAB.
R. Deepa et al. [58]	Smart Farming	-	Arduino Uno based on ATmega328P microcontroller, Sensors: Soil Moisture EC-05 sensor, DHT-11 sensor, pH Sensor and Solar Cell	Moisture, Temperature, Humidity and pH Value	The authors have offered a useful way for assessing the soil's alkalinity and acidity levels. Farmers can get real-time soil characteristics and information about fertiliser use due to the user-friendly mobile app.
M. S. D. Abhiram et al. [59]	Smart Farming	-	A DC motor, a Deek robot, a microcontroller with an Wi-Fi module, a smartphone with the Blynk app, a soil moisture sensor, a humidity and temperature sensor (DHT11) and sensors for rain detection.	Moisture, Temperature, Humidity and rain detection	The proposed system notifies motor pumping when motor is ON and Raining when rain detection sensor detects it. The humidity and temperature values are also notified to farmers.
G. A. Rao et al. [60]	Agriculture	-	A. Controller B. Sensors: i) Temperature and Humidity ii) Soil temp iii) Capacitive soil moisture iv) Rain sensor C. Actuators 1). Fans 2). Drip System 3). Grow Lights 4). Fog System 5). Nutrients Servo D. ThingSpeak E. Big-ML F. Display G. Speaker H. Push Notification	1) Temperature and Humidity 2) Soil temperature 3) Soil moisture 4) Rain	In this paper, speaker is used to alert and announce the user about the conditions. In addition to this, Push Notification facility is also provided to alert the user about farming condition.

The list of approaches for Crop Disease Detection is detailed in Table 4. Image processing is utilised to detect crop diseases. The camera is positioned close to the crop in order to get an image of a leaf. But the results are not correct in the night time and if the sunlight is too sharp. Camera resolution is also important to recognize the colour of leaf [61].

Machine learning methods are advised for tomato plant leaf disease in the initial prediction and diagnosis. The authors worked on a dataset and carried out numerous operations on it, such as feature extraction and testing, etc., using various 8 machine learning methods. For the purpose of detecting diseases in tomato plants using photos of tomato leaves, the performance of different classification algorithms is examined, such as KNN, Nave Bayes, Random Forest, etc. [62].

In order to monitor onion crops, the IOT-based Smart Farming Monitoring System (SFMS) prototype was set up both outdoors and within a greenhouse. According to sensor data, the percentage of onions that bolted was 16.70 % and 3% in an open and a closed environment respectively proved by authors in [63].

To ensure the real-time implementation of the intelligent agricultural disease monitoring system, authors in [64], does comparative analysis amongst various ML algorithms, including SVM, naive Bayes, K-nearest neighbours and CNN. While the rice blast may have already spread to all remaining plants, image detection is frequently too late. The spore germination prediction function was developed by the RiceTalk project's authors [65], and used as an extracted feature to boost the CNN model's optimistic forecast. The IoT soil cultivation platform used by RiceTalk was designed to detect rice blast using IoT non-image instruments.

Deep learning-based IoT systems can automatically identify crop disease and provide farmers with diagnostic information. However, it is difficult in this system to identify the reasons why recognition fails in some instances [66].

It is suggested to use deep learning to detect and categorise bean leaf disease. This is accomplished by utilizing the TensorFlow open-source framework, the MobileNet model, and a public dataset of leaf picture data. This study's findings showed that the classification training accuracy value reduces as the batch size grows larger and the learning rate slows [67].

The suggested system analyses the image, uses ML algorithm (with DNN) to classify the insects in the trap, and then, if it identifies a codling moth, notifies the farmer [68–69].

Using the Pepper crop dataset and the publicly accessible PlantVillage dataset, which employs effective convolutional neural networks with stepwise transfer learning, the proposed Plant Disease Detection classification system is assessed [70].

Table 4. List of approaches for Crop Disease Detection in agriculture

Authors	Area	Type of Crop & its Disease	Tools/Techniques	Parameters	Applications
A. Thorat et. al. [61]	Smart Farming	Any Plant Leaf Disease Detection	Hardwares: RaspberryPi Sensors, Soil moisture, Temperature - Humidity sensor (DHT11) and camera	Soil moisture, Environment Temperature - Humidity	The system gives alert messages depending upon the status that "Leaf has no

			Softwares: Installation of the operating system, OpenCV for image processing and all camera drivers, SERVER and Language - Python	and leaf images	disease." or "Leaf has disease."
H. Baheti et al. [62]	Smart Farming	Tomato plant Leaf Disease Detection	To compare the performance for the same database, 8 machine learning algorithms are compared with one another.	Image	In this system, system performs predicting and finding tomato leaf disease early.
Z. Khan et al. [63]	Smart Farming	Bolting reduction in Onion Farms	Hardwares: Arduino Nano platform, DHT11 Humidity Sensor, LDR Sensor and Temp Sensor BMP180, Wi-Fi Module 8266, Softwares: The Sketches, IoT Analytics Platform, and Channel Creation in ThingSpeak for Arduino.	Temperature , Humidity & Light	The SFMS was installed in both open and closed environment for onion crops monitoring. But it works more effectively in green house environment leads in better onion production.
G. Nagasubramanian et al. [64]	Smart Farming	Leaf Disease and Crop Disease Detection	This proposed system consists of three modules. These three modules are: (1) hardware; (2) analysis; and (3) decision-making. IOT Components are Arduino Uno Microcontroller Unit, Relays, Sensor Unit, ECPRC Engine, Hyper Spectral Cameras and Communication Technologies	Image	IOT based infrastructure is used to capture the image in hyperspectral mode and this image is stored in cloud to be monitored by CNN & ENSVM to detect the disease. In ML techniques are also used to detect the disease.
W. -L. Chen et al. [65]	Smart Farming	Rice Blast detection	AgriTalk IoT platform, RiceTalk application	Non image data	RiceTalk application utilizes nonimage data for Rice blast detection.

W. -J. Hu et al. [66]	Agriculture	Species, fine- and coarse-grained diseases	To create an IOT system for agricultural disease diagnosis, authors integrated deep learning technology with IOT technology.	Dataset	The authors created the MDFC ResNet ie Multidimensional Feature Compensation Residual Neural Network model to find minor diseases in the system.
E. Elfatimi et al. [67]	Agriculture	Beans Leaf Disease	Components of the MobileNetV2: Dataset, Separating the data, MobileNetV2, Training the data, Calculate Performance Metrics and Classification of beans leaf.	Public dataset with one healthy class and two unhealthy classes	A deep learning method is suggested to recognise and categorise bean leaf disease utilising a public collection of leaf images, a MobileNet model, and the free and open-source TensorFlow library.
D. Brunelli et al. [68]	Agriculture	Pest detection in apple	Raspberry Pi, Modividius, Image Processing and Deep Learning	Codling moth and generic insects are the two categories shown in the dataset.	It focuses on an automated technique for keeping track of parasitic insects using pictures captured by pest traps.
A. Albanese et al. [69]	Agriculture	Pest detection in fruit orchard	Sony IMX219 image sensor, Raspberry Pi, energy harvester for charging Li-Po battery, RFM95W transceiver. Deep Neural Networks: 3 DNN Architectures	Image	This research describes an embedded system with machine learning capabilities that continuously monitors fruit plantations for insect infestation.
M. Ahmad et al. [70]	Agriculture	Plant Disease Detection	Convolutional neural networks are used to	2 datasets: the pepper disease	Using Efficient Convolutional Neural

Catalyst Research Volume 23, Issue 2, August 2023 Pp. 468-499

			classify the signs of plant disease.	dataset and the publicly accessible dataset PlantVillage	Networks (CNN) with Stepwise Transfer Learning, diseases of plants are detected in two datasets.

Table 5 discussed about the work done based on remotely tracking and controlling farm in agriculture.

A smart farming system based on LoRa technology is utilised to get beyond wireless sensor network limitations in terms of bandwidth, power, and coverage in [71]. Here, sensor-enabled end nodes are used, which communicate detected data to a reception node. The data is received, stored in the IBM cloud database, and monitored by the IBM Watson IoT Platform. Further prediction models and data mining techniques must be added to the data analytics service.

An automatic IoT based mushroom cultivation monitoring system 'SENSPACK' is created by authors in [72]. A dedicated application monitors and controls the environment of mushroom which also turns on/off the external devices interfaced with it depending upon the requirement. An IoT-based application can handle the entire procedure remotely.

The startup Hydrolite has an online marketplace where it sells hydroponically grown veggies as well as all the necessary farming supplies [73].

The Android software on a smartphone functions as a subscriber to the MQTT cloud, allowing it to access sensor data that is stored there. This will aid in system enhancement by providing data from numerous hydroponic farms [74].

A hydroponic smart crop cultivation system that can be monitored online via Telegram Chat (CPSS) is developed in [75] employing Cyber Physical Social System. Python programming has been used to develop a Telegram-Bot for communication between users and physical systems.

Table 5. List of concepts for remotely tracking and controlling farm in agriculture

Authors	Area	Type of Crop	Tools/Techniques	Parameters	Applications
R. K. Kodali et. al. [71]	Smart Farming	-	ESP_32 LoRa device, Sensors : DHT-11 and Soil Moisture Sensor, IBM Watson IOT platform, IBM cloud DB and LORA Technology	Temperature, Humidity and Soil Moisture	IBM Watson IoT platform monitors the data and it is stored in IBM cloud DB using LORA modulation scheme to receiver side.

Catalyst Research Volume 23, Issue 2, August 2023 Pp. 468-499

A. A. Shakir et al. [72]	Smart Farming	Mushroom	ESP12E Devkit UART WiFi Module, Temp. and Humidity Sensor, LDR Light Sensor, Gas Sensor (MQ-135), Arduino Mega Microcontroller, Transistors (BC 547), Relay (220V to 5V), Display (OLED), Real Time Clock, BC 547 NPN transistor, BD 135 NPN transistor, 1N4004 Diode, L7805 DC voltage regulator, Resistors Circuitry, LED On Board Status Indicators	Environmental factors: the nursing room's temperature, humidity, CO2 level, and light intensity	IOT based SESPACK system is developed for monitoring mushroom cultivation.
A. A. Permana et al. [73]	Hydroponics Farming	-	Android OS, version 4.1.1 Jelly Bean, 2 GB of RAM, a quad-core Cortex-A9 processor, an 8 MP camera, 15.7 MB of space storage, and a screen resolution of 720x1280 to 2560x1600 are all included in the device.	-	Hydrolite is a online sales media which is only for Hydroponic products. It sells all vegetables which are grown hydroponically and the equipment needed in hydroponic farming.
N. K. Bharti et al. [74]	Hydroponics Farming	Tomato	Android Application by IOT and MQTT Broker; sensors and micro-controller	Humidity, Temperature and pH	In this work, IOT based Hydroponic system related all the parameters are monitored using Android Application. It may help to monitor multiple hydroponic farms at a time.
R. E. N. Sisyantoet al. [75]	Hydroponics Farming	-	Raspberry Pi, LDR sensor, pH sensor, EC and temp sensor, DHT11	pH, EC, temp and Light	Cyber Physical Social System (CPSS) based Telegram Messenger is heling farmers to monitor the Hydroponic farm anytime.

DISCUSSION

Agriculture depends on a number of factors, including temperature, moisture, humidity, wind speed, and wind direction. Due to the weather, these characteristics are impacted, which ultimately leads to plant growth issues and a lower output. Real-time monitoring is therefore the essential step. Most of the systems based on IOT are implemented to reduce manual farming methods to increase the automation in agriculture fields. It is observed that many researchers have been worked on IOT based Smart Farming. But still soil farming is having many issues related to soil and environment, a shift from soil to soilless farming is necessary. Hydroponic has become popular to grow crops than traditional farming which is already discussed in the last section.

Some of the countries that have benefited from implementing smart farming practices and their agricultural success stories are discussed.

USA: To meet the need for food, the USA has made significant investments in present farming technologies. National Institute of Food and Agriculture is working on IOT and to facilitate smart farming in their country. The United States Dept. of Agri. (USDA) has started a project to solve water management challenges and provide an alternative approach to those problems that are affecting agriculture.

China: In order to increase agricultural productivity, China's 13th five-year plan, which was released in 2016, included IoT integration in the agribusiness sector. Huawei Company in China developed the NB-IoT technology, which can solve the issue of irregular agricultural data.

Malaysia: There are two different agricultural policies in Malaysia, the pre and post independence policies. The policies were implemented in order to guarantee the superior advancement of farming and the reduction of poverty. Malaysian Institute of Microelectronic System (MIMO) introduced various solutions in the field of agriculture. MIMO designed a farming framework that connects providers, dealers, and agricultural producers altogether.

France: The Agricultural Innovation Project 2025 now counts the Ministry of Agriculture of the French Government as a major partner. The superior improvement of agricultural land is the project's fundamental idea. Farmers are provided access to the information obtained by the ministry of agriculture in order to propose fresh approaches to the sector.

Australia: The Australian government has committed 134 million Australian dollars (AU dollars) to boosting the agricultural industry. In order to build a cooperative framework for a broad-based movement in the Australian agribusiness, an Advanced Network for Precision Agriculture was started in 2014. In order to maintain security and privacy, a well-known farming bureau in the USA took the initiative to develop a security and privacy framework for farming data in 2015.

India: The Indian government has implemented a number of IoT policies in order to strengthen their agricultural sector globally. India's primary goals include keeping track of the earth's density, temperature, and soil quality, as well as warning farmers about pest-related problems. The Ministry of Communication and Information Technology announced an IoT strategy for India in 2015 with the goal of transforming the digitised environment.

Catalyst Research Volume 23, Issue 2, August 2023 Pp. 468-499

RESEARCH CHALLENGES

It is believed that new applications or research fields would emerge with the development of IoT and other technologies. Following a review of the literature, the following list and discussion of prospective concepts and forward-looking research challenges is provided:

- Future work for automated hydroponic system enhancement must involve incorporating data analytics into the system or using machine learning to create algorithms to forecast results.
- Designing platforms combining artificial intelligence and several learning tools in a user-friendly way i.e. from the ease of use and farmers' perspective for remotely assessing the health of plants and crops.
- To develop concepts and methods based on various factors, such as science, technology, experience, industry, etc.
- To introduce cloud sources for accurate, methodical, and scientific data collection and processing.
- Use of historical and current scientific data for the creation of agricultural decision support systems.
- Use of Supply Chain management method in Hydroponics farming.

CONCLUSION

All over the world, many researchers are still working on different agricultural issues to improve crop productivity and reducing the manual efforts taken by farmers. Moreover, farmers are also facing issues in soil farming which need shift from soil farming to soilless farming. This article gives a comprehensive review of the most recent and ongoing innovations in soil and soilless IoT agricultural systems using hardware/sensors, communication protocols, and several many more. With the increase in population all over the world and shortage of soil, water and fertilizers, Hydroponics Farming is the need of society. Use of Vertical farming and Artificial Intelligence in Hydroponics farming will definitely help farmers to automatically control the farm and increase the crop productivity. In the end, it is expected that this exhaustive survey will yield incredibly useful data for researchers, experts, agriculturalists, and decision-makers who are active and working in the IoT industry and agricultural technology.

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