

## ORIGINAL RESEARCH

## Deep Learning and Internet of Things Integrated Farming during COVID-19 in India

## Authors' Contribution:

A – Study design;  
 B – Data collection;  
 C – Statistical analysis;  
 D – Data interpretation;  
 E – Manuscript preparation;  
 F – Literature search;  
 G – Funds collection

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## Background and Aim of Study:

## Abstract

Deep learning and Internet of things (IoT) technologies have great potential for their application in various fields, including agriculture. Agriculture is a central pillar of the Indian economy. Agriculture is largest livelihood provider in India. Agriculture employed more than 50% of the Indian work force and contributed 17–18% to country's GDP. Indian agriculture sector has been facing several challenges because of COVID-19 restrictions. Outbreak of corona virus in India and the consequent lockdown, unfortunately, also coincided with the country's peak harvesting time of a variety of crops of the season. Across India, a massive agricultural crisis is due to COVID-19 shutdown.

The aim of the study: to explore the possibilities of using Deep learning and IoT technologies as a tool to handle many problems in agriculture domain such as lack of irrigation infrastructure, market infrastructure and transport infrastructure etc.

## Materials and Methods:

We have studied various problems faced by Indian farmers during this lockdown and various steps taken by Indian government to tackle this global pandemic of COVID-19. This study introduced possible solutions for improvement by using Deep learning based Internet of things ecosystem that helps in gathering information from farmers such location-based information, crop health information and environmental constraints.

## Results:

We proposed an IoT based agriculture framework to monitor and analyse crop health by using Deep learning remotely. This framework promotes a fast development of agricultural modernization, realize smart agriculture and effectively solve the problems concerning agriculture. Our research findings indicate that Deep learning provides high accuracy, outperforming existing commonly used data processing techniques.

## Conclusions:

Data-driven agriculture, with the help of internet of things and Deep learning techniques, sets the grounds for the sustainable agriculture of the future. This study proposed the future advanced farm management systems through Deep learning and IoT technologies to solve various problem faced by Indian farmers during COVID-19 pandemic.

## Keywords:

Deep learning, IoT, COVID-19, irrigation infrastructure, data driven agriculture

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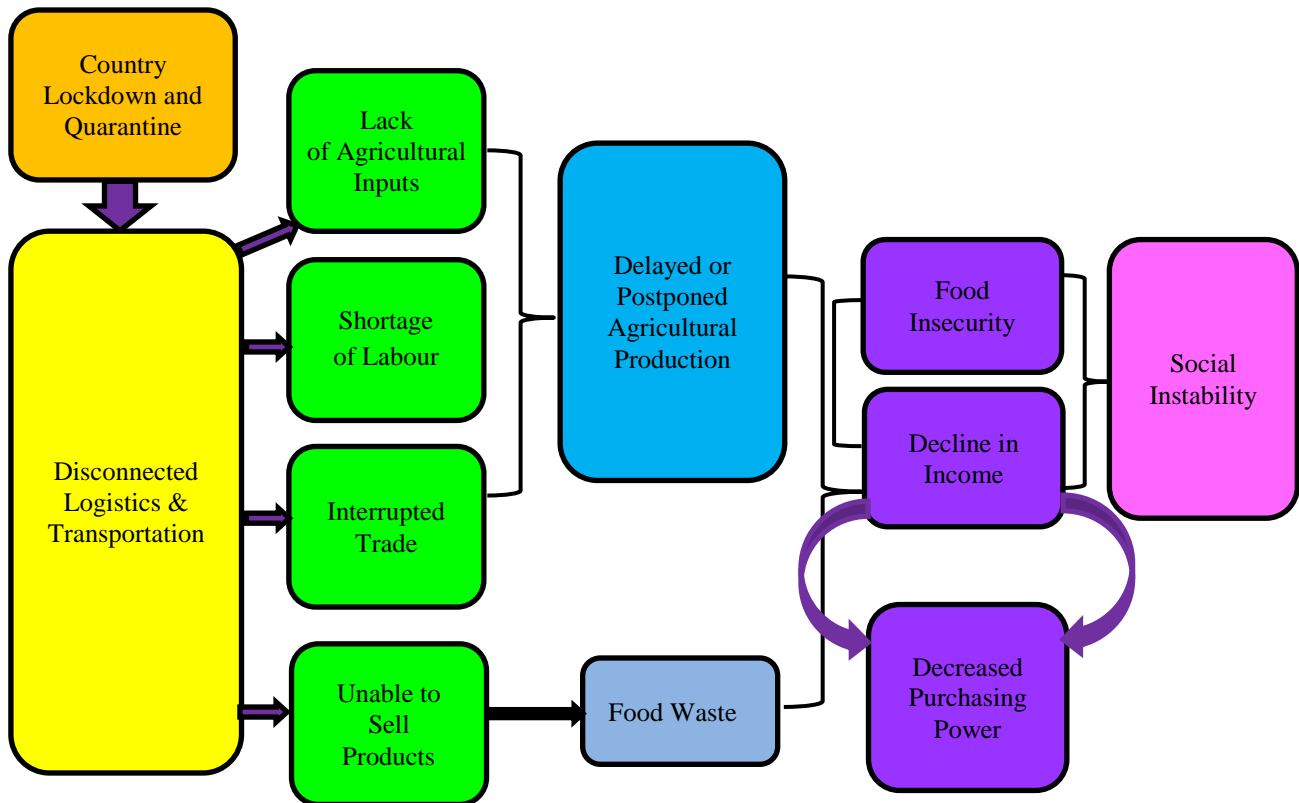
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## Introduction

The ongoing education and health crisis around COVID-19 has affected all walks of life. Protecting lives of people suffering from the disease as well as frontline health responders have been the priority of nations. Governments have swung into actions since the Corona virus attack created an unprecedented situation. India declared a three-week nation-wide lockdown till mid-April in the initial phase, which was subsequently extended for achieving satisfactory containment of the virus spread. During these challenging times, how does Indian Agriculture

respond to the crisis and how do government measures affect 140 million farm households across the country and thereafter impact the economy of a very important country in the developing world. We assess the immediate challenges that COVID-19 has posed to the farm sector and suggest mitigation measures to ensure a sustainable food system in the post-crisis period.

Because of country wide lockdown and disconnected logistics leads lacks of agricultural inputs, shortage of labours, interrupted trade. This caused delay in agriculture production, food insecurity that ultimately leads social instability (Figure 1).



**Figure 1.** Effect of COVID-19 in agriculture.

In view of COVID-19 pandemic and to provide agriculture resilience, the scientist and researchers across the globe are busy to find innovative ways to meet this ever surging demand. In this study we put our emphasis on how Deep learning and Internet of things (IoT) technologies can be applied in the field of agriculture to solve problems of Indian farmers.

*The aim of the study.* To explore the possibilities of using Deep learning and IoT technologies as a tool to handle many problems in agriculture domain such as lack of irrigation infrastructure, market infrastructure and transport infrastructure etc.

## Materials and Methods

In this study a survey is performed on various research papers on applications of Deep learning and IoT in the field of agriculture. A survey based investigation is performed to understand problems in agriculture during COVID-19 pandemic and how Deep learning and IoT technologies can be integrated to solve those problems. In order to answer this research questions a bibliographic analysis in the domain under study was

done, it involved three steps:

1. Collection of related works and.
2. Detailed review and analysis of the works.
3. Proposed a Deep Learning and Internet of things Integrated Farming Ecosystem.

The research paper from 2013-2020 selected for study. In the first step, a keyword-based search using all combinations of two groups of keywords of which the first group addresses deep learning in agriculture and the second group refers to IoT in farming. After analysis of this study it is observed that there is research gap for integration of deep learning and IoT technology in the domain of agriculture. To fill this gap Deep Learning and Internet of things Integrated Farming ecosystem is proposed.

## Results

To solve agricultural problems due to COVID-19 pandemic, immediately after the nation-wide lockdown was announced, the Indian Finance Minister declared an INR 1.7 trillion package, mostly to protect the

vulnerable sections (including farmers) from any adverse impacts of the Corona pandemic. The announcement, among a slew of benefits, contained advance release of INR 2000 to bank accounts of farmers as income support under PM-KISAN scheme. The Government also raised the wage rate for workers engaged under the NREGS, world’s largest wage guarantee scheme. Under the special scheme to take care of the vulnerable population, Pradhan Mantri Garib Kalyan Yojana (Prime Minister’s scheme for welfare of the poor), has been announced. Additional grain allotments to registered beneficiaries were also announced for the next three months. Cash and food assistance to persons engaged in the informal sector, mostly migrant laborers, have also been announced for which a separate PM-CARES (Prime Minister Citizen Assistance and Relief in Emergency Situations) fund has been created.

The Indian Council of Agricultural Research (ICAR) has issued state-wise guidelines for farmers to be followed during the lockdown period. The advisory mentions specific practices during harvest and threshing of various rabi (winter sown) crops as well as post-harvest, storage and marketing of the farm produce.

The Reserve Bank of India (RBI) has also announced specific measures that address the “burden of debt servicing” due to COVID-19 pandemic. Agricultural term and crop loans have been granted a moratorium of three months (till May 31) by banking institutions with 3 percent concession on the interest rate of crop loans up to INR 300,000 for borrowers with good repayment behavior.

The Government of India (GoI) and many state governments have designed several measures to address the problems that farmers face. The GoI has announced the following measures (Table 1).

**Table 1.** Government of India measures in view of COVID-19.

Program	Budget allocated	Program details
PM Kisan Yojana	INR 54,000 crore	The program sends INR 6000 per year as direct cash transfer to farmers account
Agri Infrastructure Fund	INR 1 Lakh crore	This fund will enhance infrastructure at farm gate
Formation of Micro food Enterprises (MFE)	INR 10,000 crore	200,000 MFEs to help farmer to upgrade their technical knowledge
Pradhan Mantri Matsya Sampada Yojana (PMMSY)	INR 20,000 crore	The program works to enhance productivity and production for fisheries
National Animal disease control program	INR 13,343 crore	This program is to achieve 100% vaccination of all large and small ruminants
Setting up animal husbandry Infrastructure development fund	INR 15,000 crore	This fund will support private investment in dairy processing, value addition and cattle feed Infrastructure
Promotion of Herbal cultivation	INR 4,000 crore	This fund will create a network of regional market places for medicine plants and target 1,000,000 hectares land for herbal plants
TOP (Tomato, onion, potato)	INR 500 crore	This fund will help prevent farmers from restoring to distress sales of perishable commodities by subsidizing storage and transpiration services
Promotion of Beekeeping	INR 500 crore	This fund will work to develop infrastructure for beekeeping production, collection, storage and marketing

The GOI has also taken a few important policy decisions, including:

- Amendments to the Essential Commodities Act to deregulate the stock limits and prices of commodities like cereals, edible oils, pulses, onions, and potato to allow farmers to realize better prices.
- Agriculture marketing reforms to remove restrictions and allow farmers to sell to any buyer of their choice in any geography, including through electronic market platforms – thereby diluting the monopoly of the APMCs.

In spite of all these measures taken by state and central government in view of COVID-19 are not enough to fulfil the need of our farmers. Therefore, our agriculture scientists and researchers have to think how science and technology can be used as tool to empower Indian Agriculture and to develop India. With growing population and ever growing demand for food, the scientist and researchers across the globe are busy to

find innovative ways to meet this ever surging demand. Agriculture is one industry where Deep Learning scientists and researchers are working with farmers to help them with their produce. The resources for farming like water, fertilizers, agricultural land etc. are becoming scarce day by day. The growth of urbanization has seen a decline in the area of arable lands in India since the mid-eighties. As the resources are becoming scarcer scientists are using Deep Learning and cloud computing to help farmers make a better and more efficient use of the remaining resources.

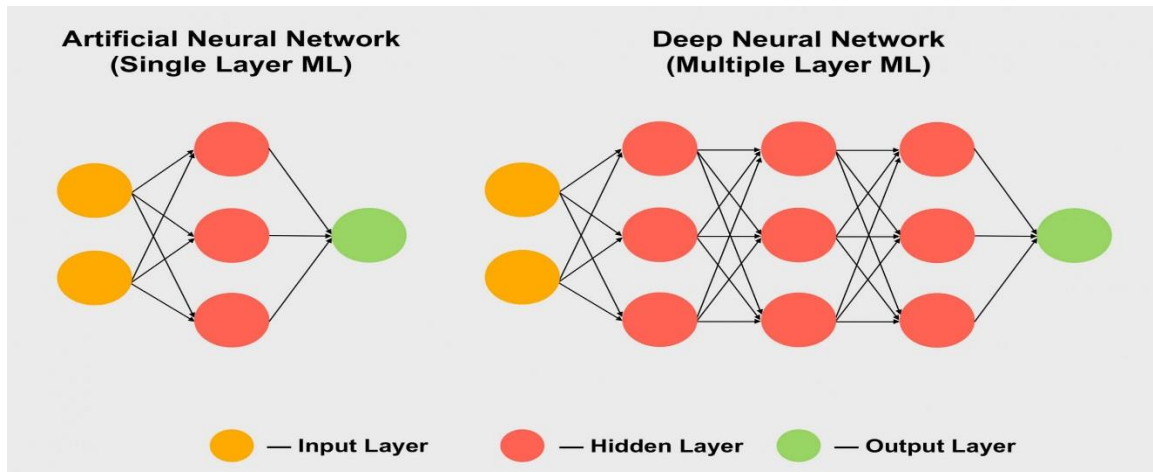
Deep learning is a subset of machine learning in Artificial Intelligence (AI) that has networks which are capable of learning unsupervised from data that is unstructured or unlabelled, also known as Deep Neural Learning or Deep Neural Network. Government can use Deep Learning to help farmers improve their

produce especially in the troubling time of COVID-19. Deep learning has resulted in:

- Improved Efficiency of Farmers;
- Identifying Crop Diseases;
- Reduction of Pesticide usage.

The complex multi-layer Artificial Neural Network (ANN) with two or more hidden layers is known as deep learning network, where the complex problem is hierarchically divided and sub-divided into smaller

specific problems, and are implemented through ANN separately with the concept of layer abstraction. For example the face detection problem is divided into sub-problems such as “is there an eye in top left”, “is there a nose in the middle, is there a hair on the top” etc. which represent the sub-networks for the ANN for face detection as showed in. Each problem is further divided into sub-problems represented by sub-layers such as “is there an eyebrow” as depicted in Figure 2.

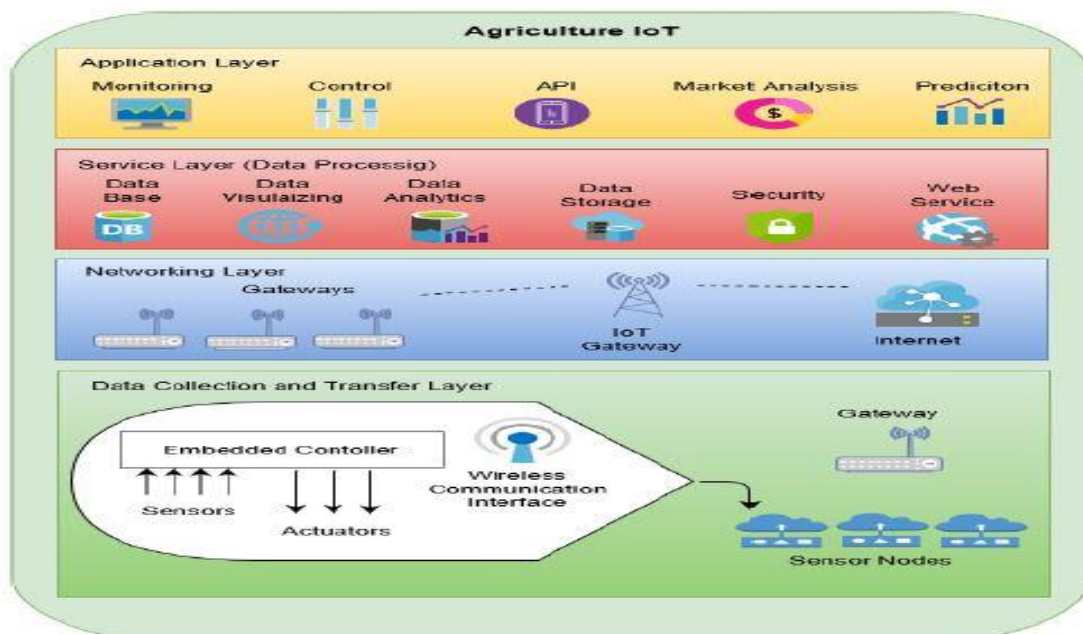


**Figure 2.** Deep neural network.

IoT refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. IoT in agriculture uses robots, drones, remote sensors and computer imaging combined with continuously progressing machine learning and

analytical tools for monitoring crops, surveying and mapping the fields and provides data to farmers for rational farm management plans to save both time and money. One of the benefits of using IoT in agriculture is the increased agility of the processes.

A basic structure of Agri IoT is shown in Figure 3.



**Figure 3.** Agri IoT architecture.

Agri IoT can be broadly classified into four layers Data Collection and Transfer Layer, Network Layer, Service Layer and Application Layer. The data collection layer houses the sensor nodes or WSN, each sensor node comprises of an embedded controller, various sensors

ranging from a simple temperature sensor to camera, actuators like motors, sprinklers, etc. and any wireless communication interface which may can be WiFi, LoRaWAN, Zigbee, etc. The various types of data collected should be made be available in the internet to

make this possible, the local WSN gateways transmits them through an internet gateway which may be either a mobile network or an Ethernet based connection and this constitutes the network layer. To make sense of the collected data in the service layer it is necessary to do some data processing like data visualization, data analytics, data storage and protection, etc. Finally, the application layer is where it all matters here is the end user can monitor and control the various process in the agro-farm and also make important decisions based on the predictions, market trends and local agricultural departments.

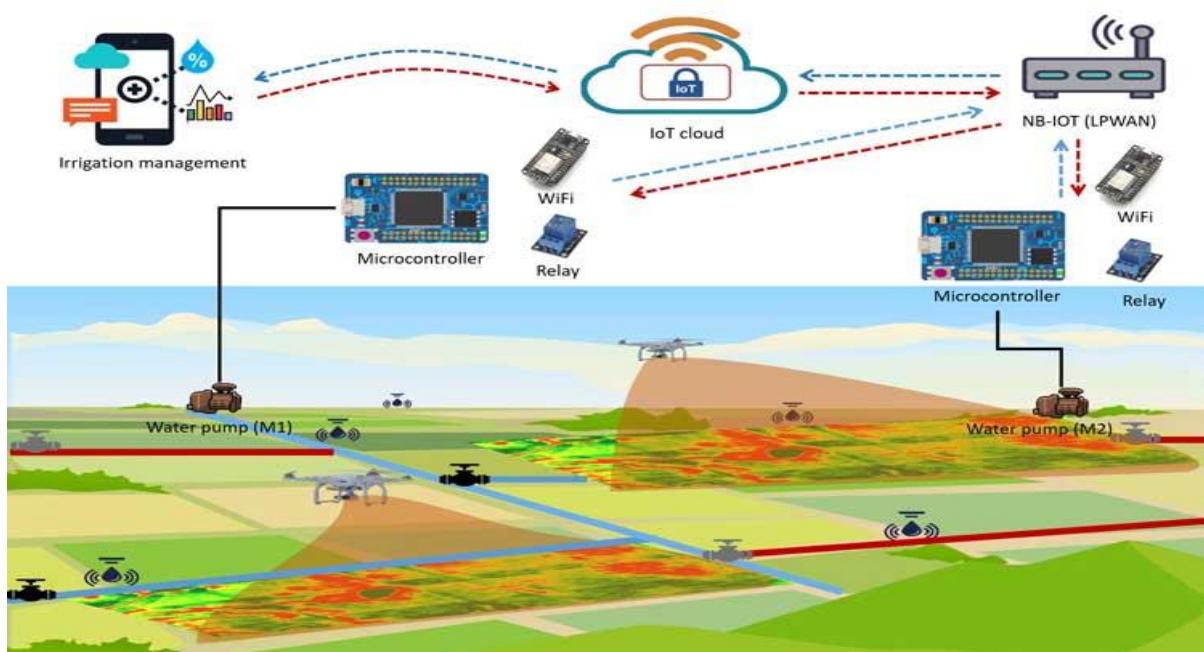
#### *Proposed System – Deep Learning and IoT integrated Farming*

The advent of modern technologies such as IoT and Deep Learning are already transforming several industry sectors. Similarly, advanced technologies like IoT are revolutionizing the agriculture sector by introducing smart farming to reduce hunger problems globally. Smart farming using IoT can:

- effectively improve crop yield;
- enable analysis of climate and soil;
- control pest population to enhance farm production.

This study proposed a Deep Learning and IoT integrated Farming. Because of COVID-19 lockdown movement of farmers to their agricultural fields is restricted. This proposed system will help farmers to work from home and monitor their crops remotely. The Deep Learning and IoT integrated Farming system is completely automated wireless system in which plants are attached with sensors that continuously sense the environmental variables like Dryness of soil, Temperature, Pressure, Soil fertility, pH Concentration of soil etc. and upload these data to respective IoT cloud Provider. These sensors are connected to the cloud via cellular/satellite network. Which lets farmer to know the real-time data from the sensors, making decision making effective. The Major benefit of this

system is that farmer can remotely monitor these environmental variables with the user interface provided by cloud provider. He can on/off water tap if soil is too dry. Farmer can increase or decrease Temperature, pH, Pressure etc. Values depending on the soil need and environmental conditions. Sensor uses deep learning algorithm to calculate amount of water or fertilizer to release which is captured and twisted to the farmer. Deep learning provides high accuracy results, surpassing, with occasional exceptions, alternative traditional image processing techniques in terms of accuracy. The implementation of a Smart farming system for farm automation is laying the wireless sensor network field in which each node is inter connected by Wi-Fi module and lays data over a common server, from where an automated python script can keep polling the data and then send alert/start signal for the required operation. Deep learning-based IoT-controlled operations have the potential to enable optimal, site-specific operations. Single pumps in a system can be activated only when needed in areas where water demand is the highest. High-throughput phenotyping using drones and wireless (WiFi) distributed soil moisture sensors can provide information on which locations require pump operation. Thermal imagery could be a promising method for determining moisture content using drones to collect images from the field. Thermal image processing with an orthomosaic datasets can be utilized to develop water-stress maps, which help in recognizing areas where crops lack sufficient water. In a deep learning system, convolution neural network (CNN) ensures accuracy based on the training datasets. The historical datasets and soil moisture information of large irrigation command areas can be classified based on soil type, organic matter content, and slope. Deep Learning and IoT agrisystem is presented in Figure 4.



**Figure 4.** Deep Learning and IoT agrisystem.

This system provides various services to the farmer over internet.

**Crop related information:** It captures information related to all the crops grown in recent past in different regions. This will help the local farmers of different parts of the nation in crop related decision making.

**Weather information:** It stores the region specific weather information and also the weather forecast for a specific duration. It will benefit the farmers in decision making related to selection of crops.

**Soil Information:** Soil information also plays a vital role in crop related decision making. So, this section provides information on nature of soil of different parts of the country. It can also provide the trend of soil in past and will help in forecasting the future trend of soil.

**Growth progress monitoring:** It monitors and captures data on crop growth in different regions on a regular interval. This will be specifically useful in comparing the crop growth region wise and also comparing it with past data will bring a clearer picture.

**Farmers Data:** It captures the region wise farmer related data, to monitor and study the involvement of local farmers in Indian agricultural sector.

**Expert Consultation:** It provides solutions to common problems that farmers frequently experience. It can also have a provision to post unattended problems seeking for solutions from the experts. It will also have a bundle of frequently asked questions (FAQs) and their answers to make the response reach the farmers faster.

## Discussion

Disha, Khan, and Alam (2020) highlighted various farming problems that can be solved using the synergistic application of deep learning and IoT. They presented a comparison between Deep Learning and Machine Learning, with specific focus on the complete process of applying Deep Learning on agriculture data to make predictions for agricultural applications.

Melnyk and Pypenko (2019) studied the issues of training of future specialists in the education system in a changing environment. They identified the main tendencies and future trends of training specialists in higher educational institutions in IT, technical, economic spheres, etc.

Israni, Meharkure, and Yelore (2015) designed internet of things based sensor network for agriculture use. This sensor network consists of Soil moisture sensor, soil temperature sensor, and ph sensor for soil. These sensors connected to each other by wireless sensor network xbee and will convey data to a station pc in the control room. From control room it will be uploaded to website where farmers can access all the data on his smartphone and tablet.

Patil, Al-Gaadi, Biradar, and Rangaswamy (2012) did a study on cloud computing and IOT it's development and issues. According to them Cloud computing is a pervasive paradigm that is growing by the day. Various service types are gaining increased importance. Internet of things is a technology that is developing. It allows connectivity of both smart and dumb systems over the internet.

Roham, Pawar, Patil, and Rupnar (2015) did a study on Smart Farm using Wireless Sensor Network. According to them Wireless Sensor Networks are used in various areas of agricultural research like Greenhouses, various Climatic Condition Parameters are essential to monitored for regulation of crop production. They developed an automation system to trace down the local climatic condition parameters (like CO<sub>2</sub>, Temperature, and Humidity) at different locations. Wireless Sensor Networks (WSN) does this job to automate and analyse the corresponding parameters.

Ponraj and Vigneswaran (2019) analysed various existing supervised and unsupervised machine learning techniques applied in agricultural domain and compares one technique with another with respects to accuracy and a confusion matrix is plotted for each.

Suba, Jagadeesh, Karthik, and Sampath (2015) explained applications of Sensor based Irrigation system through wireless sensor networks, which uses a renewable energy as a source. In this system Wireless Sensor Networks Plays a major role in Environment monitoring system and provides unmanned irrigation. WSN consists of moisture sensors, Energy harvesting systems, embedded controllers and uses Super capacitors as storage device.

Kareemulla, Ramasundaram, Kumar, and RamaRao (2013) did a study on Impact of national rural employment guarantee scheme in India on rural poverty and food security. They conducted at micro level in four major states viz. Pradesh, Karnataka, Maharashtra, and Rajasthan brought out the following lessons from the view point of people who obtained seasonal employment under the scheme. The observation that a significant proportion of farmers participated in the programmes for wage earning highlights the eroding profitability of agriculture in general and the need for gainful employment even to the farmers. The positive income and employment effects on the landless households are on the expected lines.

DaCosta and Henderson (2013) introduced the idea of "throw away" sensor. I like that we can have sensors that are single use devices. Single use and throw away sensors open up a whole new world for collecting bits of data that otherwise would be too expensive to gather.

Farooq, Riaz, Abid, Abid, and Naeem (2019) did a survey on Role of IoT in Agriculture for the Implementation of Smart Farming. According to them Internet of things (IoT) is a promising technology which provides efficient and reliable solutions towards the modernization of several domains. IoT based solutions are being developed to automatically maintain and monitor agricultural farms with minimal human involvement.

Ray (2017) did an investigations are made on those sensor enabled IoT systems that provide intelligent and smart services towards smart agriculture. They presented various case studies to explore the existing IoT based solutions performed by various organizations and individuals and categories according

to their deployment parameters. Related difficulties in these solutions, while identifying the factors for improvement and future road map of work using the IoT are also highlighted.

Navarro, Costa, and Pereira (2020) did a review to identify the main devices, platforms, network protocols, processing data technologies and the applicability of smart farming with IoT to agriculture. The review shows an evolution in the way data is processed in recent years. Traditional approaches mostly used data in a reactive manner. In more recent approaches, however, new technological developments allowed the use of data to prevent crop problems and to improve the accuracy of crop diagnosis.

Ramya, Swetha, and Doraipandian (2020) proposed a smart irrigation system to predict the irrigation requirement of the field using several environmental parameters along with weather forecasting that assists the growth of the crop. This system proposes the idea of training the ensemble method in ML using the collected real-time data to make an optimized decision. This prediction model helps in reducing the traditional irrigation methods, thereby conserving water, labor and plant nutrients. This system provides a low-cost prototype model with advanced technological features with a fully functional system and the observed results are optimal with 90% accuracy.

Jaiswal, Bhadoria, Agrawal, and Ahuja (2019) aims to design the IoT based system for operation of agricultural activities which is scalable and cost effective so that developing countries and rural areas within the available infrastructure like internet, renewable resources maximize their throughput. The data collected can be further analysed for environmental and climatic conditions and the economically productive crop to be cultivated throughout the year can be planned.

Das, Manisha, and Dash (2019) proposed the smart agriculture system with the help of Internet of Things (IoT). With the use of several sensors and Raspberry Pi, different models are proposed for supervision of soil moisture and pests, building intelligent seeds' corporation and efficient food corporation of India.

Karunakanth, Venkatesan, Jasper, and Kathrine (2018) surveyed different methods of irrigation systems and have proposed a improved system to implement better water management system for home-based garden or any farming activities. A systematic irrigation scheduling algorithm has been developed to improve the climate based irrigation model.

Maduranga and Abeysekera (2020) did a review on existing approaches have been made to the smart agriculture and farming based on IoT and ML separately. They propose novel concepts that how can ML-IoT can be blended in such applications.

Rajeswari, Suthendran, and Rajakumar (2017) studied IoT device is used to sense the agricultural data and it is stored into the Cloud database. Cloud based Big data analysis is used to analyze the data viz. fertilizer requirements, analysis the crops, market and stock requirements for the crop. Then the prediction is performed based on data mining technique which information reaches the farmer via mobile app.

Abbasi, Yaghmaee, and Rahnama (2019) surveyed the research trend, the concepts, fundamental components of IOT, the challenges, and IOT applications in agriculture are examined. Firstly, the numbers of published papers in this field reviewed. Secondly, IOT definition and IOT architecture together with its layers are introduced. Thirdly, some involved technologies in the IOT are compared; finally, the main challenges in IOT and precision agriculture (PA) are considered.

Raju and Vijayaraghavan (2020) discussed introduction to IoT, agriculture IoT, emerging wireless technologies of IoT, architectures and applications of IoT. According to them IoT has set a benchmark in the technologies and has become a backbone to agriculture. This advancement in technology helps in farming automation, which helps in shaping a farmer's workspace, ensuring them with device management, connectivity management, and productivity as a result along with remote management.

### Conclusions

Despite the challenges and hardships caused by COVID-19, the crisis has also shed light on weaknesses in India's Agri food system. This new knowledge can help guide reforms to make the Agri food system and livelihoods more resilient. Key among the needed changes are agricultural market reforms and digital solutions to connect farmers to markets, creation of safety nets and provision of reasonable working conditions, and decentralized food systems, especially for vulnerable communities.

The agriculture industry is becoming increasingly reliant on data, and the growing rate of cloud adoption in agriculture is clear evidence of that. As enormous amounts of crucial agricultural data is stored in the clouds, it becomes easier to process the data and take timely actions to address problems before they turn detrimental to productivity.

An effective implementation of our model will encourage other sectors also, which will lead to optimal benefit of shifting towards cloud.

This will bridge the gap between technology, information and farmers of India. This will have positive and tremendous impact on to face troublent time like pandemic and lead the nation towards technological development especially in agriculture domain.

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## Поглиблене навчання та Інтернет-технологій, інтегрованих у сільське господарство під час COVID-19 в Індії

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### Анотація

#### Вступ:

Технології глибокого навчання та Інтернет-технології (IoT) мають великий потенціал щодо їх застосування в різних галузях, в тому числі й сільському господарстві. Сільське господарство є центральним стовпом індійської економіки.

Сільське господарство є найбільшим джерелом засобів для існування в Індії. У сільському господарстві зайнято понад 50% робочої сили в Індії та внесено 17–18% у ВВП країни. Індійський сільськогосподарський сектор стикається з кількома проблемами через обмеження COVID-19. Спалах вірусу корони в Індії та наслідки блокування, на жаль, також збіглися з піковим періодом збирання врожаю різних культур сезону в країні. По всій Індії масштабна сільськогосподарська криза зумовлена COVID-19.

**Мета дослідження:** Дослідити можливості використання технологій глибокого навчання та Інтернет-технологій як інструмент для вирішення багатьох проблем у галузі сільського господарства, таких як відсутність зрошувальної інфраструктури, ринкової інфраструктури та транспортної інфраструктури тощо.

**Матеріали і Методи:** Досліджено різні проблеми, з якими стикаються індійські фермери під час цього блокування, та різні кроки, зроблені урядом Індії для подолання глобальної пандемії COVID-19. Це дослідження представило можливі рішення для вдосконалення шляхів використання екосистеми Інтернет-технологій на основі глибокого навчання, яка допомагає збирати таку інформацію від фермерів: місцезнаходження, стан врожаю, екологічні обмеження.

**Результати:** Запропоновано систему сільського господарства, засновану на IoT, для моніторингу та аналізу стану врожаю за допомогою дистанційного глибокого навчання. Ця система сприяє швидкому розвитку модернізації сільського господарства, реалізації розумного сільського господарства та ефективного вирішення проблем, що стосуються сільського господарства. Результати наших досліджень показують, що глибоке навчання забезпечує високу точність, перевершуючи існуючі загальнозживані методи обробки даних.

**Висновки:** Керовані дані сільського господарства за допомогою Інтернет-технологій та методів глибокого навчання створюють підстави для стійкого сільського господарства в майбутньому. У дослідженні запропоновано вдосконалені системи управління фермами за допомогою глибокого навчання та технологій IoT для вирішення різних проблем, з якими стикаються індійські фермери під час пандемії COVID-19.

**Ключові слова:** глибоке навчання, IoT, COVID-19, зрошувальна інфраструктура, управління сільським господарством.

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