Impact of Adopting Machine Learning Methods on Indian Agriculture Industry- A Case Study

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ABSTRACT

Background/Purpose: *Machine learning in today's world is the driving mechanism for achieving sustainable agriculture. A study of existing literature on applying Machine learning in the agriculture sector and the impact of these methods on the Indian agriculture sector is presented in this paper. Based on the agriculture market and analysis of agriculture trends using Machine Learning and also government initiatives to support Artificial Intelligence-powered agriculture in India, the strengths, weaknesses, opportunities, and challenges are identified and a broader analysis is given in this paper.*

Design/Methodology/Approach: *The data required for this study on the adoption of Machine learning solutions in the agriculture sector of India are collected from secondary resources including scholarly publications, research articles, web reports, and government websites. The qualitative research method is adopted in conducting the study.*

Findings/Result: *The study has given insights into various machine learning methods and their applications in the agriculture domain. The knowledge-based agriculture practices could improve overall agriculture productivity. The facts and figures explored during the study of Indian agriculture are analyzed and it is seen that predictive analytics using Machine Learning has great potential in making significant advances in agricultural production.*

Research limitations/implications: *Machine Learning approaches can be adopted in all the allied sectors of agriculture. The study is limited to improvising farming practices using machine learning methods for better productivity and contributing to the growth of the Indian economy.*

Originality/Value: *This paper presents a study of the Indian agriculture sector and the scope of incorporating data-driven approaches using machine learning algorithms that help in supporting the growth of the industry.*

Paper Type: *A case study*

Keywords: Artificial Intelligence(AI), Machine Learning(ML), Agriculture Industry, Industry Analysis, SWOC analysis, Internet of Things(IoT)

1. INTRODUCTION :

The agricultural industry is the most important field for humanity. A sustainable development goal in the agriculture field is required to feed the ever-growing population. The agriculture industry of India has many sub-sectors. Some of them are farming, seeds, fertilizers, pesticides, food processing, dairy market, bio-agriculture, etc. The success of the agriculture and food industry is impacted by using information, technology, and communication. The machine learning models are used by individuals, businesses, and government agencies for learning from agriculture data and making predictions.

Machine Learning is a branch of artificial intelligence. It is the study of computer algorithms that enable computer programs to be automatically improved through experience [1]. Machine learning is a predictive technology that can identify the most probable key inputs within a training set function to make better predictions. One can combine multiple inputs of different types to predict a single variable. This helps us get closer to reality, as opposed to a mechanical approach that relies on mathematical

methods to model biophysical processes. These methods are well equipped to use large amounts of data efficiently.

Industry analysis assists students and researchers to survey and explore the different aspects of the industry and its components [2]. This paper gives a study of the agriculture industry and an analysis with the main focus on the applications of Machine Learning methods in this domain.

2. REVIEW OF RELATED WORKS :

This section outlines a summary of the research work available in the literature on applying various Machine Learning algorithms in the agriculture sector to help farmers and increase agriculture production. The article [3] gives a complete review of how Machine Learning techniques can be effectively used in agriculture. The authors have reviewed 40 articles published in standard journal papers covering crop quality, yield prediction, water and soil management, disease prediction, animal welfare, weed detection, and livestock production. They have implemented eight machine learning models for analyzing the reviewed articles. They have shown that the usage of machine learning models in multiple applications for crop management is 61% out of which 20% are on yield prediction and 22% are on disease detection. They have shown the trend in the application of distribution within crop data and the high usage of images. The authors of the paper [4] surveyed machine learning applications in this domain to reduce the problems in pre-harvesting, harvesting, and post-harvesting areas and concluded that it supports methodical and accurate farming and achieves high-quality production by reducing human resources. The paper [5] gives a comprehensive review of the latest research work done using deep learning in the area of plant leaf disease detection using hyperspectral images. It is found that collecting large image data sets with high variability plays a major role and data augmentation; transfer learning and visualization of CNN activation contribute to the improvement of classification accuracy. The article [6] gives a perception of the reality of smart agriculture using Big Data Analytics and highlights the fact that Convolutional Neural Network methods and Analysis of Big Data help in achieving higher precision and better performance. The authors of the paper [7] thoroughly reviewed and validated through experiments the major research work in the agriculture domain using Machine Learning along with Deep Learning and Big Data and found the importance of processing hyperspectral remote sensing data including spatial and spectral information. The authors of [8] made a study on the impact of machine learning on various domains such as agriculture, healthcare, and management and the paper gives a better understanding of employing machine learning methods in these areas. Table 1 summarizes the articles reviewed on various approaches to applying machine learning in agriculture and also the Indian Government Policies to support startups in the technology-based agriculture sector. The recent articles from 2019 to 2022 containing the related work are collected using the keyword search method in Google Scholar using the keywords such as Machine Learning, Applications, Deep Learning, Artificial Intelligence, and precision agriculture.

Table 1: Publications on applying machine learning techniques in agriculture.

Sl No	Field of Research	Focus	Outcome	References
1	Neural Network	Predictions in crop yield	This paper presents a Long Short Term Memory model that is based on a Recurrent Neural Network. Weekly meteorological parameters and origin-relatedness measures are used in the study. The model can analyze and make genetic predictions in multiple environments.	Shook et al.,(2021). [9]
2	Deep Learning	Rice yield prediction using deep learning	The authors of this paper have developed a model using rice yield, area data, and time-series meteorology data. The model can learn the deep spatial features. A back propagation neural network	Chu & Yu,(2020). [10]

			with an independently recurrent neural network is implemented to predict the rice yields in summer and winter.	
3	Machine Learning	Soil fertility prediction using machine learning algorithms on X-Ray fluorescent data.	X-ray fluorescence data is used to determine the total elemental concentration in soil. Best performing models are selected out of the Random Forest models and the Generalized Linear model to create soil fertility maps as the spatial application of the fertility prediction of soil samples.	Benedet et al. (2021). [11]
4	Machine Learning	Fertilizer recommendation	A fuzzy system is used to evaluate the values of three micronutrients Nitrogen, Phosphorous, and Potassium. The system computes the requirement for fertilizer for wet and dry seasons.	Haban et al.,(2020). [12]
5	Image Processing	Plant disease prediction using image processing	An adaptive learning algorithm for selecting a suitable classification technique with high accuracy in crop image detection. Efficient in handling plant data sets with different dimensionalities.	Patel & Sharaff, (2021). [13]
6	Recurrent Neural Network	Precision Agriculture	Soil moisture prediction model based on a recurrent neural network to generate an intelligent irrigation system. This feedback-integrated system resulted in achieving efficient usage of water.	Kashyap et al.,(2021). [14]
7	Image Processing with Deep learning	Nitrogen deficiency detection in cornfields using Deep Neural Network	Images collected by drones are used to detect nitrogen deficiency in maize fields. A deep neural network trains the data.	Zermas et al.,(2021). [15]
8	Machine Learning model development	Emerging trends	The factors influencing crop yield and yield prediction models using machine learning are highlighted. The paper also discusses the continuing development of adopting machine learning mechanisms in the agriculture sector.	Bali & Singla, (2022). [16]
9.	Machine Learning	Digital farming techniques	This paper focuses on a precision irrigation decision management system by integrating various machine learning models. It also discusses the applications and benefits of using data-driven machine learning solutions.	Abioye et al., (2022). [17]

10.	IoT and machine learning	Adopting automation in agriculture to improve productivity in the Indian context	This report gives an outline of applications of trending technologies including machine learning, IoT, and cloud computing in the Indian agriculture sector.	Balakrishna & Moparthi, (2020). [18]
11	Digitization of the Agriculture Sector	Indian AgriTech startups and Government policies	The paper gives a glimpse of the major sectors where Agri startups are emerging. It also describes the artificial intelligence startups impacting the agriculture sector and also the Indian Government policies for startups.	Anand & Raj,(2019). [19]
12	Artificial Intelligence	Public-private partnerships in India give AI-driven farming solutions.	This article addresses the main areas where AI can help agriculture and also the major private-public collaborations in India that have become successful by providing AI-based solutions to the agriculture sector.	Fernandes,(2020). [20]

2.1 Research Gap:

The study reveals that almost all sectors of agriculture can adopt AI or ML-based solutions. It is found that the major focus is given on the technical aspects and there is a need to study the factors influencing the acceptance of this technology in the agriculture domain and mainly in the context of Indian agriculture.

2.2 Research Agenda:

To study the need for adopting ML-based solutions for enhancing the productivity of agriculture and the challenges in adopting the same with the help of SWOC analysis concerning the Indian context.

3. OBJECTIVES OF THE STUDY :

(1) To study the Government initiatives on applying trending technology to the agriculture sector.
(2) To analyze the global trend of AI in agriculture
(3) To study the effect of Covid 19 on the agriculture sector and the ML-based solutions
(4) To study the agriculture economy in India.
(5) To study the impact of Machine Learning in agriculture by SWOC Analysis.

4. METHODOLOGY :

The study presented in this paper is based on the data compiled from various secondary resources including articles published in standard journals and reports published on websites.

5. GOVERNMENT INITIATIVES :

The government of India has taken appropriate steps to assist in improving the farming sector with advanced technology and support plans throughout these years. The technologies like Artificial intelligence (AI) and machine learning (ML), remote sensing, big data, blockchain, and IoT technologies in agriculture will further enhance growth by improving stability by reducing water consumption and pesticide use. Under the Digital Agriculture Mission 2021-2025, Government has signed MoUs for projects based on AI and ML for transforming the agriculture sector into a digital ecosystem. Table 2 summarizes the projects selected for this Mission.

Table 2: Initiatives under Digital Agriculture in India 2021 [21]

Company Name	Projects
JIO	Give recommendations by using standalone data on apps.

	The data collected from different resources are used in implementing AI/ ML algorithms to give accurate personalized advisory.
ITC	Design of a digital crop monitoring platform providing Site-specific crop advisory service.
CISCO	Design of a Smart Agriculture Platform to collect and integrate data from sensors, available data from the Department, and Satellite Data processing solution on a single dashboard providing immediate status in real-time for enhancing farming and knowledge sharing
NeML	A digital marketplace for enhancing the livelihood of farmers and promoting sustained social and economic progress
Ninjacart	Agri Marketplace platform to bring all the participants together in the after-the-harvest market connection.

Microsoft in collaboration with ICRISAT has come up with an AI Sowing App that gives the optimal date of seed-sowing. NITI Aayog and IBM have developed a model for crop yield prediction. Machine Learning-based Blue River project helps in maximizing the farm inputs [22].
The government is taking various smart agricultural initiatives, including yield prediction models, AI sensors for smart farming, and Drones for monitoring soil and crop health. The government has taken initiatives on spreading agriculture-related details to farmers by designing and releasing mobile apps for them. Under the Digital India Programme[23], the Government has launched various mobile apps such as Kisan Suvidha, MKisan Application, Pusa Krishi, Farm-O-Pedia App, Shetkari Masik App, and Agriculture Insurance, AgriMarket App, etc. which are encouraging farmers to move towards smart farming practices.

6. GLOBAL TREND ANALYSIS OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE :

Artificial Intelligence in the agriculture market concerning the global scenario is estimated to be US $ 608.9 million in 2018 and is estimated to reach a CAGR of 25.4% between 2019 and 2025[24]. According to the summary of this trend analysis report on the Artificial Intelligence Agriculture market, the productive capacity and yield could be improved by adopting Artificial intelligence technology in agriculture. Agribusiness companies are providing solutions that are based on predictive analytics. Some technologies with applications based on AI help in pest control, monitoring soil, improving agricultural tasks, and producing healthier crops throughout the agriculture food chain. The report gives details about the technology subdivisions in this domain including machine learning, deep learning, computer vision, and predictive analytics. Some agriculture business enterprise groups such as AgEagle Aerial Systems Inc., Microsoft, and Granules Ect are working on developing AI-based solutions and platforms for agriculture. The report gives the analysis made on Asia pacific AI in the agriculture market size and by the application that is shown in Fig 1.

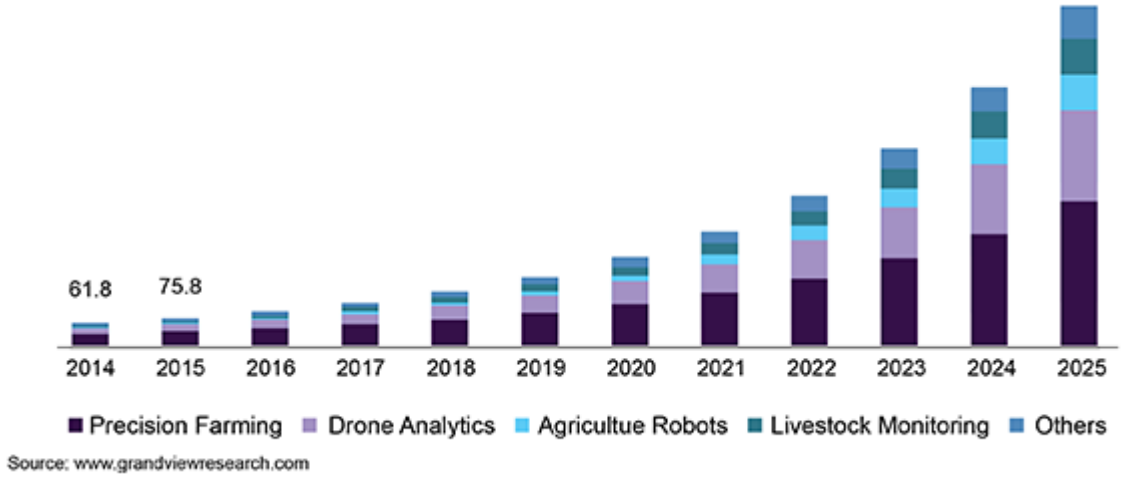

Fig. 1: AI in agriculture market analysis

7. IMPACT OF COVID 19 ON THE AGRICULTURE SECTOR AND ML-BASED SOLUTIONS :

COVID-19 has made a disastrous impact on the economy, due to which the Government, private sectors, and individuals including the small holding farmers are focusing on binging on sustainable digital farming techniques. The price of food has drastically increased and many have lost jobs during the Covid pandemic. The educated youth have found agriculture appealing and started exploring in terms of providing data-driven solutions for agriculture problems. The paper [25] discusses the impact 0f Covid 19 on the agriculture sector and how technology-driven agriculture can improve the productivity of this sector. Authors have also given detailed information on the application subdivisions of Artificial Intelligence in this sector by using Machine Learning, Deep Learning, and Neural Networks.

8. AGRICULTURE AND ECONOMIC DEVELOPMENT IN INDIA :

India has a large agricultural sector. According to the report [26]**,** agricultural production growth has been strong over the last three decades, and more importantly, agricultural production has almost caught up with the growing population's demand. The agriculture sector of India accounts for only about 14% of the economy of our country and it is estimated to account for 42% of entire employment. Rainfall and other climate factors are very important for economic activity. About 55% of arable land in India depends on rainfall. The GDP from Agriculture depicted in this report is shown in the following graph shown in Fig 2.

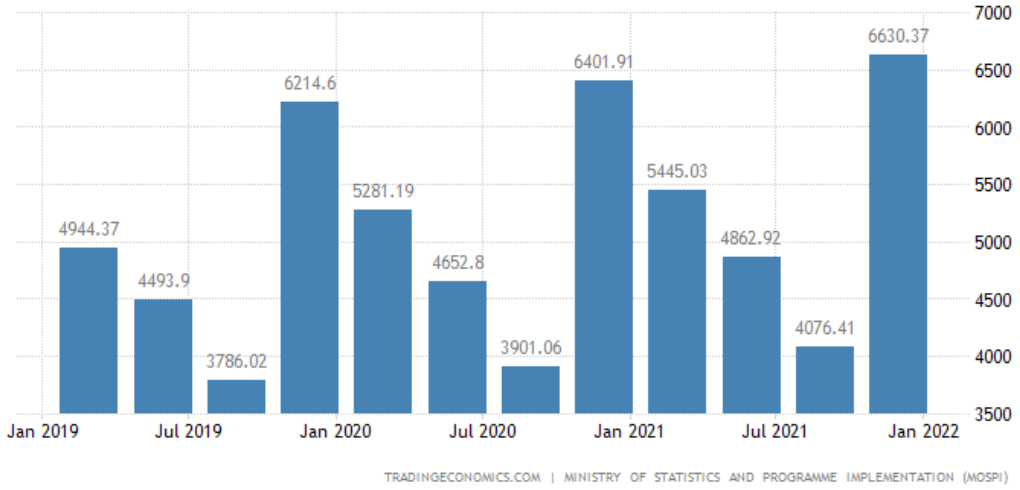

Fig. 2: India's GDP from agriculture

The article [27] gives details about the major developments in Indian agriculture. The policies on land distribution, productivity gain, and integration with global food markets are discussed in this reticle.

9. SWOC ANALYSIS :

There are many reliable and adaptable applications of Machine Learning which are in practice in the field of agriculture and the scope of ML in India is found to be promising. This section highlights the SWOC analysis focusing mainly on the agriculture sector employing ML-based methods for farming solutions. The article [28] discusses the various techniques used for the systematic analysis of business models. It also presents an innovative approach called ABCD analysis and discusses how a specific framework could be implemented for a business model. The strengths and weakness analysis of a specific case study is presented in the article [29] and discusses how to improvise the model by considering the key factors identified. The authors of [30] have applied the SWOC analysis framework to higher education systems by identifying the factors that impact the success of the organization suggesting how it could be effectively used for predicting the changing trends.

Strengths:

(1) Government support for Machine Learning projects and startups: The study shows that the government of India provides financial support to agricultural technology start-ups and encourages

the adoption of Machine Learning and AI to revolutionize agriculture and agricultural trends. The major focus of Budget 2022 is on smart and modern agricultural practices. According to the Prime Minister of India, farm credit has increased 2.5-fold over the past seven years. These loans will help to significantly modernize agriculture and improve natural farming, with an emphasis on agricultural waste management [31].

(2) **Machine learning has the potential to improve the growth and productivity of agriculture:** The articles reviewed in this study including the major categories such as yield prediction, plant disease detection, soil management through fertilizer recommendation, and precision agriculture show that Machine Learning methods can be effectively used in agriculture domain to improve the agricultural efficiency.

(3) **Reduction in labor effort and cost:** Many processes of farming can be automated. Farm automation using Machine Learning and AI techniques reduces human labor. Machine learning algorithms can be effectively used to process data collected from remote sensing systems to estimate plant needs such as light, water, space to grow, nutrients, etc. These techniques are also used to predict production. Robots can be used for keeping track of the farming process and for weed control.

(4) **Global AI Market trend**: The report [32] also reveals the fact that the total AI market in agriculture is expected to increase from an estimated US $ 1 billion in 2020 to the US $ 4 billion in 2026, with a CAGR of 25.5 during 2020 and 2026. The global forecast highlights the opportunities for AI and Machine Learning in the Agriculture market, recent developments, and the key market players. Machine learning solutions and predictive analysis are widely used by agricultural organizations and farmers around the world to increase farm productivity and gain a competitive advantage in business operations. Over the next few years, machine learning applications in various agricultural practices are expected to grow exponentially.

(5) **Growing opportunities for adopting Machine Learning methods in agriculture:** Machine Learning applications in the agriculture domain are rapidly growing and due to this the scope and opportunities in this field are increasing. The broad categories of Machine Learning methods in the agriculture industry are listed in the following Table 3.

Table 3: Possibilities of Machine learning in agriculture [33]

Managing Species and habitats	Reproducing Plant Species
	Plant species identification
	Plant Science
Field preparation and Conditions Management	Water management
	Soil health management and weather prediction
Crop production and management	Yield prediction
	Crop disease detection
	Weed detection and control
	Crop quality
	Crop row detection
	Crop mapping
	Quality assessment
	Farmers decision
	Intelligent harvesting
Livestock management	Livestock production
	Animal welfare

Weakness:

(1) **The technology adoption process is complicated:** It is a challenge to collect and interpret data related to smallholder farmers and to give them the technical knowledge required to handle the tools that are used for decision-making. Many Indian farmers lack expertise and they do not have the experience in using the new technologies.

(2) **Unavailability of timely and accurate data:** There is no specific format or standard for maintaining the data in the agriculture domain. It is possible to monitor plant health in real-time which requires real-time data. Disseminating the updated real-time statistics of various aspects of agriculture is very important to get accurate and reliable results.

(3) **Ethical and social issues:** Machine Learning solutions require a large amount of data collected from various sources. There should be a proper policy for sharing agriculture data as there is no proper code of conduct on sharing such data that will be used for analysis. There will be an impact on society due to the reduction in employee requirements due to automation in this sector. And also the replacement of manual labor with robots would damage the labor market.

(4) **Privacy and security issues:** Security and safety are the major concerns to be addressed during data exchange. There is a need to build open space with proper data sharing policy that would help in connecting the existing platforms and providing data-driven solutions in the agriculture sector.

Opportunities:

(1) **Scope for research in Machine Learning**: Integrating Information and Communication Technology with Machine Learning seems to be our greatest hope to face future challenges in agricultural applications. The research article [34] provides an overview of the status and scope of research work in the context of Machine Learning in agriculture. This study gives awareness of the benefits of using machine learning in the agriculture sector and helps for a systematic study on this subject. This paper provides the temporal distribution of research publications giving attention to machine learning in agriculture which is shown in the following Figure 3.

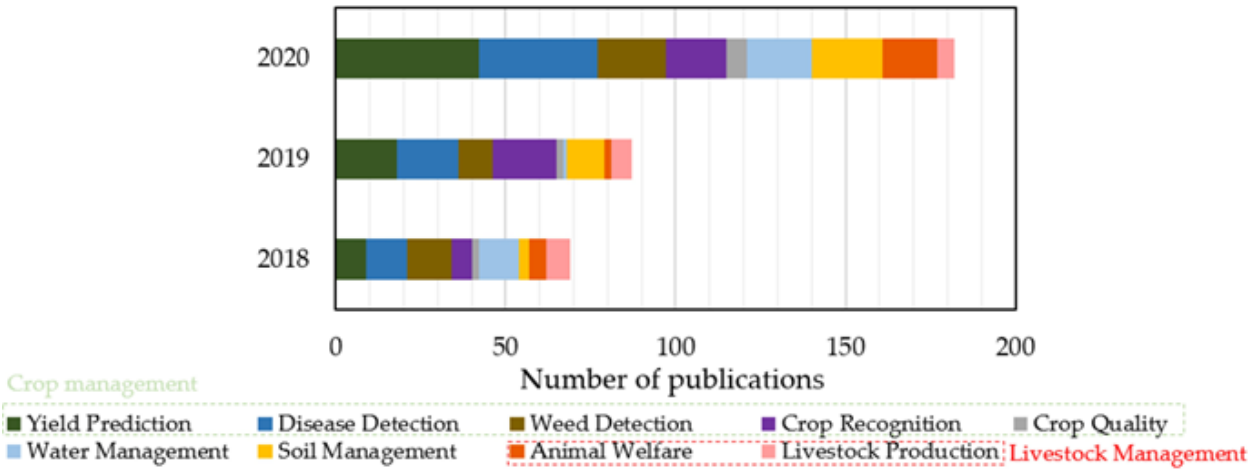

Fig. 3: Research publications published in 2018-2020 on machine learning research in agriculture

(2) **Farm Automation**: There is scope for developing Machine learning applications that can automate complex tasks. The current problems that are faced by Indian farmers including labor shortage, irrigation, pesticide control, weed management, cropping pattern, agricultural marketing, etc can be addressed by implementing smart farming techniques in agriculture. Different techniques can be implemented as automation in agriculture using Machine learning algorithms which help in reducing human intervention and effort [35].

(3) **Employment opportunities:** As the agriculture sector is moving towards smart and precision farming, there are a lot of employment opportunities arising in terms of application development.

(4) **Entrepreneurial opportunities for youth**: There is growing interest in Machine Learning around the world. Governments and Private sectors investing in AI startups are good indicators of this. Most AI startups use ML technology as a technology to enhance their business. Young farmers are showing interest in making investments in agricultural automation. There are endless possibilities for the industries in coming up with innovative ideas connecting to the surrounding smart environment.

Challenges:

[1] **Lack of availability of digital Data for Machine learning solutions:** The agriculture-related data is not well documented. The data needed for analysis has to be collected from farmers, weather stations, and agriculture agencies. The quality of the documented data may not be reliable.

[2] **Data collection and Handling heterogeneous data:** Machine learning models are data-driven models. Agricultural datasets contain a variety of information on weather, soil, seeds, irrigation equipment, fertilizers, pesticides, weeds, reaping, farming practices, etc. that are available in research institutions, government, and agricultural companies including production, marketing, insurance, etc. Data required for analysis has to be collected from different sources which may be in different formats.

[3] **Handling large volumes of data:** The historical data required for analysis in the agriculture domain is large. To handle the rapidly growing data efficiently there is a need to use a suitable strategy in data collection and preparation.

[4] **Domain-specific expertise to design solutions:** To provide useful data-driven solutions in agriculture design, the data scientist requires to have domain-specific knowledge.

[5] **Language barrier:** Developing a common platform for all Indian farmers to give technology-driven farming solutions is a challenge.

[6] **Accuracy:** The major challenge of developing Machine learning models is accuracy. The accuracy of the data-driven models depends directly on the data used for training the model. Collecting and preparing reliable data in the required format for analysis would give good results.

10. FINDINGS :

The survey opens up the fact that the need for increased productivity in the agriculture sector in India can be met with the use of using digital technology in agriculture. Various machine learning methods are effectively used and many applications and services are available to solve the problems in this sector. As many problems in the domain are interdisciplinary, such models using IoT, cloud concepts, various sensors, and data processing and analytics are becoming popular. The government is showing interest in investing a large amount of money in agriculture and supporting the adoption of digital technologies. The pandemic Covid 19 and the unpredictable climate have opened up new challenges in this sector which could be handled by using machine learning and deep learning approaches. Artificial Intelligence, Machine Learning, and automation have shown a greater positive impact on achieving sustainable agriculture. India is dreaming about bringing in Smart agriculture to address the challenges in the agriculture domain.

11. RECOMMENDATIONS :

The technologies including machine learning and data visualization, and satellite monitoring help in increasing farm sustainability. Agricultural companies, farming enterprises, banks, insurance companies, and government bodies also benefit along with farmers in their business operations. The following recommendations are proposed based on the literature review and SWOC analysis.

(1) Almost every stage of the agriculture process can take the benefit of Machine learning and Artificial Intelligence for making decisions and improving production.

(2) Real-time recommendation systems or models can be built to solve real-time recommendation problems in this domain.

(3) There is scope for developing accurate and high-quality Machine Learning models.

(4) There is a need for reliable data sets that could be used effectively for training the Machine Learning models which can be made available to the public for research purposes.

(5) There is a need in India to use Technology in agriculture to feed the increasing population.

(6) Implementing digital technology in agriculture would transform agriculture even though practical implementation is quite challenging.

12. CONCLUSION :

Systematic computational analysis of agriculture data gives valuable insights in terms of plant health and crop yield which improves agricultural practices and enhances productivity. The study shows that Machine learning algorithms can be effectively used in the agriculture domain and predictive and exploratory data analytics contribute to achieving sustainable agricultural practices. AI and ML provide

the best solutions for overcoming the problems of farmers. IoT and data analytics using machine learning help farmers in taking better real-time decisions on farming practices and smart farming provides efficient farming solutions. Data scientists are helping the agriculture industry by providing solutions for improving crop yield, managing pests and crop diseases, and managing climate change-related issues. The agricultural sector has witnessed substantial changes and improvements by adopting machine learning and Artificial Intelligence. The conventional farming techniques in India can be reformed by applying machine learning in the farming sector. This cost-friendly approach is found to be the need of the hour in the Indian agriculture sector.

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