MACHINE LEARNING APPLICATIONS IN AGRICULTURE 4.0 –A RENAISSANCE IN THE FIELD OF AGRICULTURE, IMPACT ON THE PRECISION AGRICULTURE AND REVOLUTION IN CROP MANAGEMENT

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ABSTRACT

The paper focuses on the growth of the agricultural sector from the past to current trends and its growth in smart farming. The agriculture sector in India has successfully met the production targets set by the government and has also set new production records in almost all commodities. The paper is a bibliometric analysis of the systematic literature review of precision agriculture, including technical terms like IoT, precision agriculture, machine learning, artificial intelligence, and traditional farming. The paper discusses the various phases in the agricultural management system, including advancements from the past centuries to current trends. The study compares different machine algorithms for agriculture management in precision agriculture. The different sectors include crop disease detection, weed detection, yield prediction, crop recognition and recommendation, water management, animal welfare, livestock production, and soil management. The challenges faced by farmers are a matter of concern and have been highlighted in this paper. The future prospects are also discussed, giving India a new edge in the world.

Keywords: IoT, precision agriculture, machine learning, artificial intelligence, traditional farming, crop disease detection, weed detection, yield prediction, crop recognition, soil management.

JEL Codes: C32, E31, E52, H62

INTRODUCTION

The research for Precision Agriculture began more than two decades ago. The project being described in the study uses a variety of machine learning techniques to address issues in

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horticulture and agriculture. India is a country where the prime source of income is vegetation or the agriculture sector. The time has come when innovations and advancements are taking place. Keeping in view the processes involved in agriculture, the induction of technologies such as IoT's, Artificial Intelligence, Machine learning, Image processing, and Deep learning are now commonly used in smart farming. The bibliometric study for Systematic Literature Review has been analyzed. The papers with keywords like precision agriculture and machine learning from different journals from the year 2015 to 2024 have been searched and the results have been filtered and shown in the results section.

LITERATURE REVIEW

Machine learning research techniques, including a software workbench for testing various strategies based on actual data sets and a case study on dairy herd management, where culling criteria were taken from a medium-sized herd registration database (Singh, 2020). This paper studies the Machine Learning for Soil Fertility and Plant Nutrient Management, focusing on the analysis of soil characteristics, including organic matter, vital plant nutrients, and micronutrients that influence crop growth, and using supervised learning to determine the appropriate proportion relationship between those characteristics. With reference to crops' growth properties, available nutrient grades, and capacity to supply nutrients from its own resources, Back Propagation Networks (BPN) are trained. BPN will ascertain and suggest the right correlation proportion between those features using outside crop production applications.

The first stage of this machine learning system involves sampling (various soil with the same amount of properties but different settings), followed by the Back Propagation Algorithm and Weight update. Test data will be used to assess the Back Propagation Neural Network model's performance.

When it comes to predicting a realistic result as an output and establishing correlations and abstracting patterns between diverse data sets, machine learning techniques are especially helpful. It can be successfully applied to boost efficiency in the Indian agriculture sector. We have discussed the application of machine learning techniques to soil fertility assessment in the Indian agriculture sector. One of the most interesting subjects for analysis and study has always been agriculture. The objective of this study is to evaluate soil data according to various attributes, categorize it, and enhance the effectiveness of every model by employing various terminologies and classifications. The goal of the study was to analyze the soil data by collecting it from different sources (Kanade, 2023).

The accuracy of predictions and outperforms conventional techniques based on automatic processing of weight updates. The paper's potential scope is to develop a self-trained function for predicting soil properties with parameters in Back-propagation network (McQueen et.al., 1995).

The paper titled "Crop Selection Method for Maximizing Crop Yield Rate by using ML Technique" (Rakesh Kumar et al.) has mentioned that in an agro-based country, agriculture plays a significant role in economic growth and food security. The selection of crop(s) is an important issue that depends on various other parameters such as production rate, the market price of crops, and government policies in every five-year plan. Researchers advise employing statistical and machine learning approaches to anticipate high rates of crop yielding, forecast the weather, and classify crops and soil for agricultural planning. It becomes a difficult and tough decision for having more options to plant crops at a time by using limited land resources. The paper proposes a methodology named the Crop Selection Method (CSM) to bring about the resolution of the crop selection issue, which maximizes crop production yield and rate from one season to the next and, as a result, leads to the nation's ultimate economic growth. A strategy is created that has the potential to raise crop net production.

The method known as the Crop Selection Method is employed to determine the arrangement and order of crops to be planted on a seasonal basis.

The method possibly will improve the yield rate of crops to be planted over the season. The suggested approach determines crop selection by forecasting production rate, which is impacted by key factors like climate, crop type, soil type, water density, and weather. It finds a sequence of crops whose daily output is greatest throughout the course of the season by taking into account the crop, their sowing time, planting days, and expected yield rate for the season. The predicted values of the affected parameters determine the performance and accuracy of the CSM technique, so a prediction method with higher performance and accuracy must be used.

The paper titled "Machine Learning Applications for Precision Agriculture: A Comprehensive Review" (Abhinav Sharma et al., 2021) states that crop yield forecast and methods for increasing yield are critical pieces of knowledge for any farmer. Predicting crop production involves a number of critical factors, such as soil type, pH level, and quality; weather patterns, such as temperature, humidity, rainfall, and sunshine hours; fertilizers; and harvesting schedules.

The crop yield depends on the efficiency of the optimal utilization of resources. If there is some kind of variance that goes unobserved in the initial stage, it may harm the crop yield in an exceptional way and the recovery might be difficult and tedious. According to the report, farming households in peripheral areas frequently incur debt as a result of poor income prospects, may lack the skills necessary to employ inputs, and may necessitate substantial government help. Accurate weather forecasts might prove to be extremely beneficial for farmers in a country such as India, where resources for storing produced crops are scarce and storage conditions are erratic. When ML models are consistently used in a system, they function as feedforward control. Innovation and machine learning algorithms are what allow for precise prediction (Sharma et al., 2021).In addition to the decision-support question and a few other crucial research difficulties, there are a number of other significant issues that need immediate and continuing attention by researchers in order to fully develop the PA idea. The remaining concerns are listed with an approximate ranking of importance. The acceptable criteria for economic assessment in precision agriculture are as follows: (a) It is not enough to recognize temporal variation. (b) Neglecting the farm. (d) The techniques for evaluating crop quality for maximum yield. (e) Traceability and product tracking. (f) Environmental auditing is the right standard for economy.

The use of Precision Agriculture - It was studied earlier that the variability in soil fertility led to the concept of precision agriculture. The agricultural production system is an integrated output of soil-water-nutrient-plant-atmospheric interactions, and if this system is to be optimized, then all the individual components like soil, water, nutrients (fertilizer), plant (crop), and atmosphere (weather) have to be monitored. Each of these components has to be characterized through different parameters reflecting different properties.

Precision Agriculture's Necessity -The potential benefits of precision agriculture, both economically and environmentally, can be seen in the decreased use of pesticides, fertilisers, water, and herbicides in addition to farm equipment. As previously said, a precision agricultural strategy detects variations within fields specific to a site and modifies management activities accordingly (Goovaerts, 2000). Most farmers are aware that the yields in their farms vary depending on the terrain. These differences can be linked to environmental factors, soil qualities, and/or management techniques. A soil's texture, structure, moisture content, organic matter content, nutrient status, and landscape orientation all have an impact on yields. Weeds, insects, illnesses, and weather are examples of environmental features. IoT Application in Agriculture An essential component of agricultural IoT infrastructure are sensors.

Numerous uses in agriculture are possible for it, such as assessing crop development using spectral vegetation indices (Travlos et al., 2021), identifying weeds (Khan et al., 2021), pests (Schrader et al., 2022), and diseases (Gonzalez-Huitron et al., 2022), machine guidance (Conesa-Munoz et al., 2016), real-time spot spraying (Alam et al., 2020), and robotic weeding (Kunz et al., 2015). Additionally, there are RGB-D cameras, which can greatly improve detection accuracy by providing depth information in addition to RGB spectral bands (Zbiciak et al., 2023) and therefore the control of pests (Utstumo et al., 2018). Because soil sampling is a labor-intensive and costly process, the conventional approach involves taking a limited number of samples from a field and analyzing them in a lab. Geostatistics has been shown to be a useful technique for assessing soil variability since it may give a broad picture of the analyzed soil attribute throughout the entire area. The most popular geostatistical method for estimating values at unsampled sites from a set of observed values at nearby locations is kriging. The variogram, a mathematical model that quantifies the degree of similarity between data values as a function of distance, is used by the Kriging technique to characterize the spatial autocorrelation of the data. Kriging has been extensively used in PA to map the spatial (Dorijan Radocaj et al., 2023). Utilizing multispectral cameras was the second most popular kind of recording equipment. Compared to spectral vegetation indices based only on RGB bands, those based on other spectral bands, such as the Near Infrared and the Red Edge, have demonstrated a stronger correlation with crop vitality, meaning that multispectral cameras can provide richer information than RGB cameras (Prey et al., 2018). In nearly every year except 2013–2015–2017, just 14 research articles employed hyperspectral cameras. Because it can gather data in over 50 bands, this kind of recording equipment can provide the most information. As a result, weed identification has been done using hyperspectral cameras(Liu et al., 2019), weed resistance to herbicides (Scherrer et al., 2020), disease detection (Pineda et al., 2022), and thermal micro-dosing (Zhang et al., 2012). Nevertheless, the high acquisition costs of this technology limit its application in agricultural research. Between 2015 and 2024, just three research articles used thermal cameras. This is explained by the fact that, should they be employed with airborne platforms, thermal cameras may be affected by weather and altitude changes and that, in any event, they must have sufficient spectral or measurement resolution for suitable data.

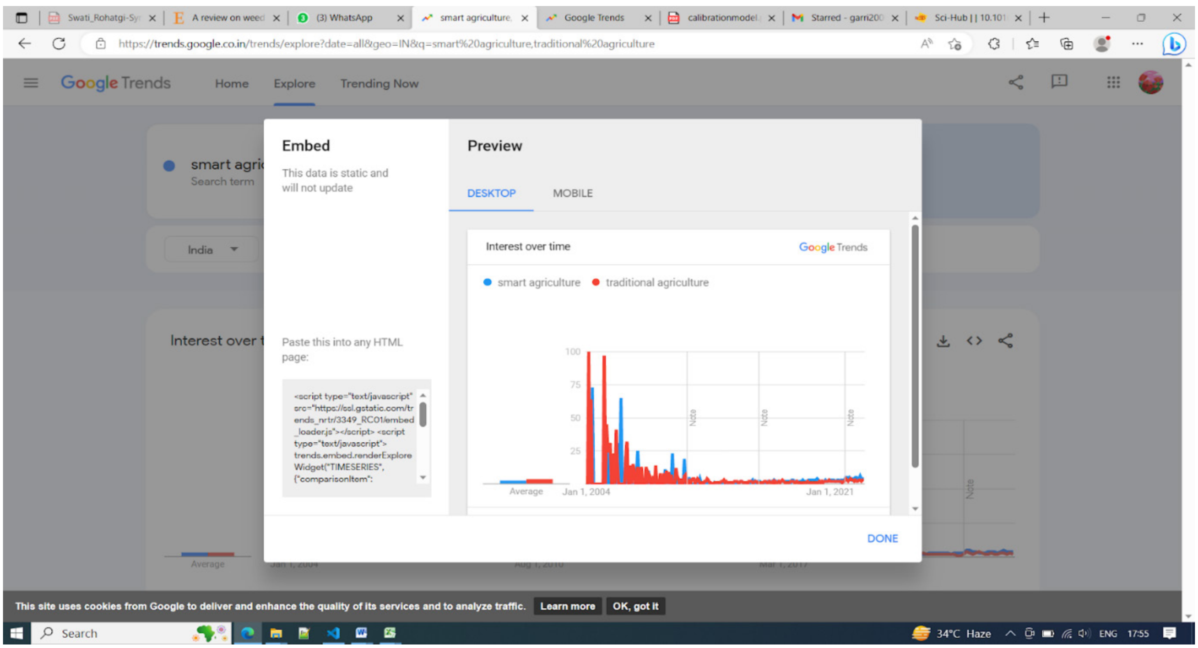

Fig.1: Google trend for comparison smart agriculture Vs Traditional agriculture in India.

Source: Google Trends as showing trends for past 15 years India.

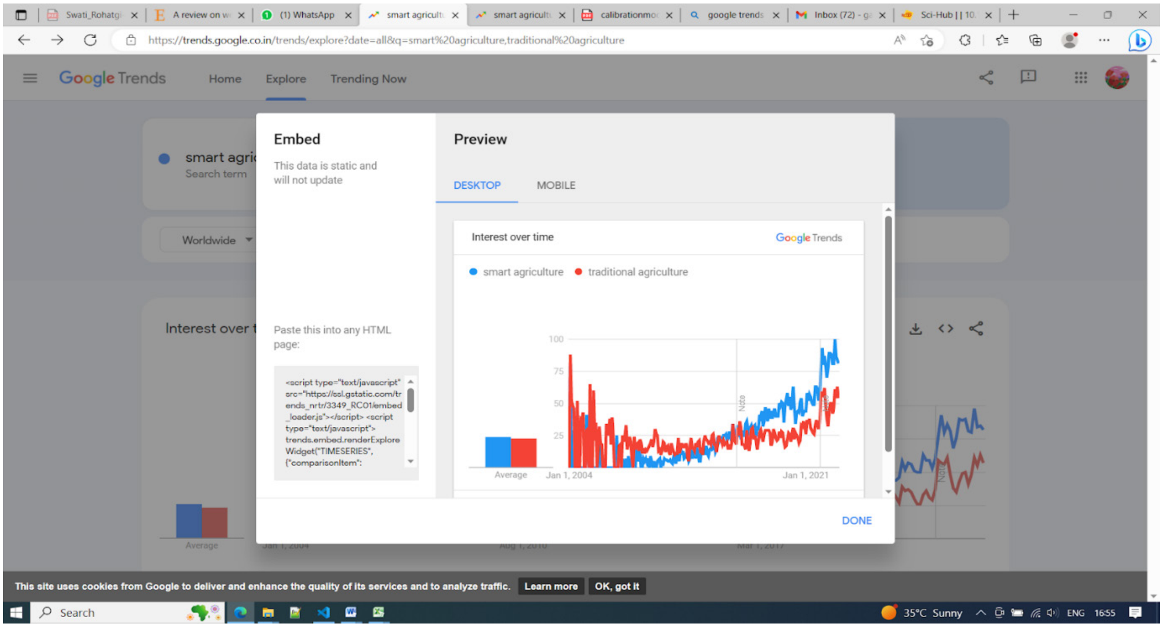

Fig.2: Google trend of smart farming Vs Traditional Farming Worldwide

Source: Google Trends as showing trends for past 15 years Worldwide.

The number of searches regarding the two keywords, smart agriculture and traditional agriculture, has shown a spike in the year 2021 worldwide, whereas the case is not the same in India. The current trend shows that there is not much awareness about precision agriculture or smart farming in a developing country like India.

Smart agriculture is a field where research is going on at an utmost pace in order to make agriculture, which is considered to be one of the most important occupations in India, a chief occupation. Many emerging entrepreneurs have left their reputed corporate jobs and have moved into the agricultural sector, particularly in organic farming. There is a need to develop certain tools or equipment to enhance the process of e-farming. The following are different government sites where data repositories are maintained, and where data about the soil maps of India is depicted.

1. Soil and Land Use Survey of India (dacnet.nic.in)
2. data.gov.in
3. bhoonidhi.nrsc.gov.in
4. www.ibef.org
5. github.com
6. soilgrids.org

RESEARCH METHODS

The tools used for the Systematic Literature Review are the Dimensions database and VOS viewer for conducting the bibliometric analysis.

The number of journals is pictorially listed categorically based on Environmental Sciences, Earth Science, Soil Science, and Agricultural Sciences, numbered as follows: 146, 117, 112, 108, and 70. There is a surge in citations from the year 2019 until 2024. Figure 3 shows the Analytical Views of the SLR.

Fig.3: Shows Analytical Views

The chart represents the number of publications in each research category from the time period of 2020-2023. Given below are the research papers showing the systematic literature review of the research carried out in the emerging field of Precision Agriculture using Machine Learning.

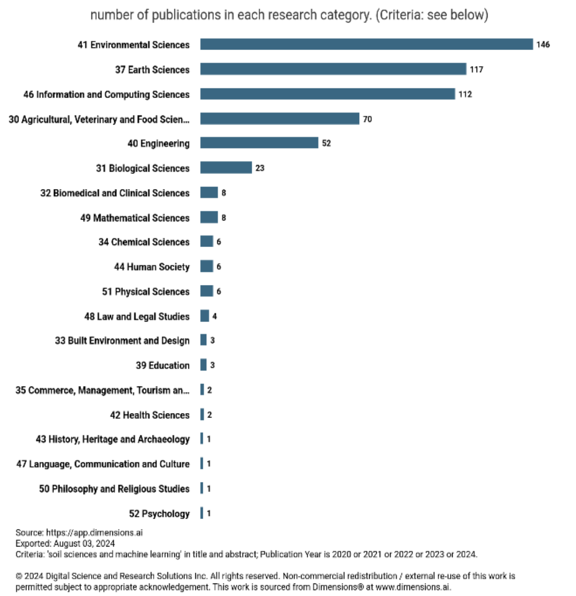

Fig.4: Shows data chart of the journals

Models of Machine Learning

There is a categorization of the different types of models used in Machine learning: Supervised models. Supervised models are the models which learn from the datasets, where the output or the outcome is defined. They are as follows:

1. Classic Neural Networks (Multilayer Perceptrons)
2. Convolutional Neural Networks (CNNs)
3. Recurrent Neural Networks (RNNs)

Unsupervised Learning. Unsupervised models are the ones which do not have an input dataset, but tend to learn from the inputs as they do not have the set of outcomes for the results.

1. Self-Organizing Maps (SOMs)
2. Boltzmann Machines
3. Auto Encoders

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The agricultural landscape in India has witnessed various waves of transformation, from mechanization to the Green Revolution. The Indian agriculture market is poised to reach a staggering value of $580.82 billion by 2028 (Travlos et al., 2017), underscoring the sector's immense potential. Today, it stands on the cusp of a new era of Precision Agriculture, powered by the convergence of digital technologies, including the following:

1. Internet of Things (IoT) and Big Data
2. Artificial Intelligence (AI) and robotics
3. Monitoring with Sensors
4. Aerial Imagery
5. GPS Technology

RESULTS

The map representation of the bibliometric file in dimensions of different authors and their citations. The clusters of the authors showing close relationship among each other and their references of the citations.

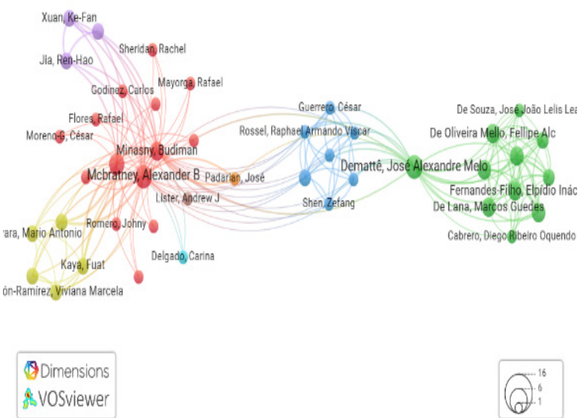

Fig. 5: Network Visualization of clusters of citations.

There are 366 research papers that were found with the keywords as "machine learning technique" and "soil" from the time period from 2015-2024.

DISCUSSIONS

The research objective was to conduct a bibliometric analysis on Systematic Literature Review. The LR study focuses on the different machine learning techniques employed to achieve precision agriculture. Future trends - Crop protection is predicted to experience a vital transformation in the upcoming years as a result of technological improvements and the request for sustainable agricultural techniques. The way crop health is monitored will fundamentally change as a result of new sensors (such as wearable sensors and fungus spore sensors), which offer unparalleled precision and real-time input. When paired with edge computing, these sensors will allow for real-time data processing, resulting in prompt replies and reduced decision-making times.

Challenges or limitations faced by AI in precision agriculture:

- According to a recent government poll, only a small percentage of Indian farmers are literate; as a result, closing the digital divide between farmers and technology will be difficult.
- Farmers are less inclined to step outside of their comfort zone and learn digital skills in order to improve their farming practices.
- The majority of agricultural land is found in rural areas. In rural locations without dependable internet connectivity, implementing IoT architecture and WSN

which depend on cloud services for data storage and analysis is a major problem.

- In different geographical settings, it is challenging for machines to make accurate predictions and categorizations using their cognitive abilities.
- The initial setup of digital farming, which includes hardware and software, requires a huge investment.
- The deployment of smart sensors and other electronic gadgets requires heavy energy consumption.

Civil aviation regulations: Many regions have strict regulatory frameworks governing civil aviation activities because of the potential risks associated with UAV operations. Consequently, only specific applications may be allowed for the usage of UAVs, or users may need to obtain a pilot's license.

Processing power: Gathering, analyzing, storing, sharing, and displaying UAV data can require a significant amount of processing power. Potential users might have to buy more equipment or pick up new abilities in order to manage the massive amounts of data that come along with using UAVs. (Gokool et al, 2023)

There are several potential future applications of vegetation indices in precision agriculture that are not presently utilized. One such application is the use of high-resolution imagery and machine-learning algorithms to map soil properties and variability across a field. By combining soil data with vegetation indices, the present studies can be additionally enriched in the scope of fertilization, irrigation, and planting, leading to improved crop health and yield. (Radocaj et al, 2023)

CONCLUSION

A quick overview of machine learning (ML) algorithms, which are most frequently employed in precision agriculture, is given before exploring the impact of AI and IoT on smart farm management.

Precision agriculture (PA) agricultural applications made possible by UAVs have the power to drastically change smallholder farmers' lives. Using these technologies to inform decisions can increase agricultural productivity and encourage the wise and sustainable use of vital resources (Gokool et al., 2023). The foundation of agricultural yield prediction, weather forecasting, and soil attributes is regression algorithms. In order to identify weeds and diseases in plants, DL algorithms like CNN and ML classification algorithms like SVM, Decision trees, and RF were investigated. Precision agriculture relies heavily on intelligent irrigation systems and harvesting methods since they expedite tasks and minimize the need for human labor.

For this work, robots and drones equipped with digital cameras are used. Globally, farmers are very concerned about livestock management. Livestock management is effectively handled by a knowledge-based agriculture system that uses AI technologies and smart IoT devices. Future research might include developing an NLP-based chatbot for farmers and investigating more ML, DL, and hybrid algorithms in the agriculture sector to ensure the sustainable use of resources. This study produced insightful information about broad trends, significant books, journals, and writers, as well as present issues and potential future directions. It should

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be mentioned, nonetheless, that the subjective standards and procedures utilized to discover and gather the data for our study may have reduced the findings' representation (Zhang et al., 2012).

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