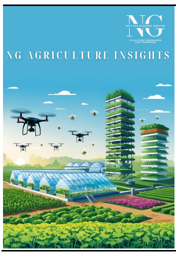

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Artificial Intelligence and Application: Application of Machine Learning, Deep Learning, Internet of Things and Digital Farming

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A B S T R A C T

Currently, agriculture is under pressure from a rising population, decreasing land availability, changes in climate, and increasing costs of inputs. Artificial Intelligence (AI) and other related technologies are becoming more and more useful in helping farmers to make better decisions and to use their resources more efficiently. The article looks at the concepts and the applications of AI, Machine Learning (ML), Deep Learning (DL) and the Internet of Things (IoT). It describes how the combination of these technologies forms the basis of Digital Farming. ML allows for the prediction of yields, the classification of soil, and the recommendation of fertilizer and irrigation schedules. Meanwhile, DL, which makes use of Convolutional Neural Networks, enables precise detection of pests, diseases and weeds based on images. IoT links together field sensors, weather stations and farming machinery to create instant monitoring networks, and Digital Farming integrates these tools with remote sensing, GPS/GIS and mobile applications in order to support data-driven, site-specific crop management. The article also examines the advantages, a practical workflow, the challenges and the future prospects, referring to the agricultural situation in India and to the initiatives carried out by the Indian Council of Agricultural Research (ICAR) and the Government of India.

Keywords: Artificial Intelligence, Climate Resilience, Digital farming, GIS, GPS, IoT

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1. INTRODUCTION

Agriculture has for a long time relied on the farmer's skill in reading the land, the weather, and the crops. In recent decades this traditional knowledge has been increasingly supplemented by digital tools which are able to detect, record and interpret information that is beyond the reach of the human eye. Artificial Intelligence means the ability of computer systems to carry out tasks which normally would have to be done by a human being, for example identifying a leaf that is diseased or predicting the yield of a field. In this wide field, Machine Learning and Deep Learning offer the learning capability, while the Internet of Things provides the real-time data that these systems require (Ahmad et al., 2024; Shaikh et al., 2022). Agriculture is continuously exposed to environmental stresses that can alter crop growth, productivity and biochemical processes. Abiotic stresses may substantially influence physiological and metabolic responses, including secondary-metabolite biosynthesis in medicinal and aromatic plants (Pradhan et al., 2024). Consequently, technologies capable of monitoring environmental conditions and crop responses can contribute to more climate-resilient agricultural management.

The agricultural sector in India provides a means of livelihood for a large part of the rural population. It is in a good position to take advantage of these technologies because of the extent of farming carried out and the variety of agro-climatic regions it has. On the other hand, the fact that landholdings are small and fragmented means that the need to adopt these technologies is greater but so is the difficulty of

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doing so. This article looks at AI, ML, DL and IoT, explains their uses in agriculture in a way that is appropriate for an agricultural student, and demonstrates how they work together in the concept of Digital Farming to help achieve efficient, sustainable and environmentally resilient production. (Husain & Rehmat, 2025; Ahmad *et al*., 2024)

2. ARTIFICIAL INTELLIGENCE IN AGRICULTURE

The application of AI in agriculture involves the use of intelligent systems to analyse data relating to farming and to aid in the making of decisions that have usually been based solely on experience. Rather than having to inspect each field individually, AI-based systems examine images, sensor data and weather records in order to provide timely, location-specific advice. Typical applications are crop monitoring and the prediction of yield, the detection of pests and diseases, the identification of weeds, the management of soil and nutrients, smart irrigation, making decisions based on weather conditions, giving recommendations regarding the use of fertilizers, carrying out remote sensing using satellites and drones, employing agricultural robotics, monitoring livestock, using smart greenhouses, and using machinery guided by GPS and GIS. The benefit of these intelligent systems is that they combine a variety of different types of information together such as the results of soil tests, data on crop greenness obtained from satellites, records of rainfall and the requirements of different crop varieties, all of which can be taken into account when producing a single fertilizer recommendation. In India, this comprehensive approach is encouraged via agricultural advisory services and through government platforms which link farmers with ICA institutes and the State Agricultural Universities, sending the scientific recommendations directly to farmers' mobile phones. (Shaikh *et al*., 2022; Ahmad *et al*., 2024)

3. APPLICATION OF MACHINE LEARNING IN AGRICULTURE

Machine learning in the field of agriculture involves training a programme on historical data so that it can detect patterns and predict outcomes for new data, without being provided with a specific rule for each individual situation. In this area, ML models are trained using past yields, weather conditions, soil requirements and market prices in order to make useful predictions for the next season. By analysing the relationships between soil, farming practices and expected yields, machine learning is able to estimate the expected yield before harvest, thus helping with decisions regarding storage, transport and pricing. Moreover, machine learning can classify the type and fertility of the soil based on data from sensors and tests, which enables fertiliser doses to be tailored to each field rather than applying a general regional rate (Attri *et al*., 2024; Jabed & Murad, 2024). The response of crops to nutrient management may vary with nutrient level and genotype. For instance, differences in growth and yield response to phosphorus application have been observed among cowpea genotypes (Sudharani et al., 2018). Such variability highlights the importance of crop- and site-specific nutrient management. Machine learning can classify the type and fertility of the soil based on data from sensors and tests, enabling fertilizer doses to be tailored to individual fields rather than applying a general regional rate.

Historical weather patterns are used by machine learning models to predict the probability of a pest or disease outbreak, and by studying how soil moisture varies with weather conditions and the stage of crop growth the models can assist with planning water-saving irrigation. Machine learning models that are based on market arrival data and price trends also aid farmers in deciding both when and where to sell their crops. A review that is frequently cited classifies agricultural applications of machine learning into the areas of crop management, livestock management, water management and soil management, illustrating the wide range of farming systems in which the technology has already been applied. (Jabed & Murad, 2024; Shaikh *et al*., 2022)

4. THE USE OF DEEP LEARNING IN AGRICULTURE

Deep Learning is an advanced type of machine learning which makes use of artificial neural networks having many layers, a design loosely based on the human brain. In the case of traditional machine learning it is usually necessary for an expert to initially determine the important features, but deep learning models are able to learn relevant features directly from raw data like images, making them suitable for use in visual recognition. The model most frequently employed for image analysis, a Convolutional Neural Network (CNN), examines a photograph in small sections, first learning simple patterns such as edges and colours before going on to combine these into more complex features like a disease spot or the outline of a weed. (Albahar, 2023; Ahmad *et al*., 2024)

Farmers can take a photograph of an affected leaf and a CNN-based app will then suggest the most probable disease together with the appropriate management steps. Meanwhile, the same type of technique can be used to tell the difference between weeds and crop seedlings so that herbicides can be applied target ally. Deep learning models also count and assess the quality of fruit using images taken with a camera, and when they are applied to images obtained from satellites or drones, they are able to classify land use and identify areas that are under stress over large areas. Self-driving tractors and autonomous sprayers use DL-based computer vision to detect crop rows and targets in real time. A thorough survey showed that deep learning is generally more accurate than earlier image-processing methods when it comes to these tasks. (Albahar, 2023)

5. THE INTERNET OF THINGS (IOT) IN AGRICULTURE

The Internet of Things consists of a network of physical sensors and devices that are connected to the internet, so that they can continuously collect, transmit, and share data. By fitting sensors into a field, a greenhouse or an animal shed, it becomes possible to monitor the conditions at all times without the farmer having to be constantly present. Sensors commonly used measure soil moisture, temperature, humidity, rainfall, and livestock activity, and they send the readings through Wi-Fi, mobile networks or low-power wide-area networks, the latter of which is important in situations where wired connections are not feasible (Shaikh et al., 2022; Dhanaraju *et al*., 2022).

Sensor data is generally transmitted to a cloud platform where it is stored and analysed, enabling farmers to monitor it in real time via a mobile application and triggering automatic alerts in cases such as when soil moisture drops below a certain level. Soil-moisture sensors connected to automated drip valves release water only when it is required; weather stations offer highly localised forecasts; wearable devices attached to livestock identify signs of illness in their early stages; and greenhouse systems based on IoT technology automatically adjust both ventilation and irrigation. These systems support a range of functions including irrigation and environmental monitoring, but their success relies on reliable connectivity and proper data management (Dhal et al., 2024; Dhanaraju *et al*., 2022).

6. DIGITAL FARMING

Digital farming, also known as precision agriculture, is the practical result of bringing together AI, ML, DL, IoT, remote sensing, GPS/GIS, drones, cloud computing and mobile applications in a coordinated manner. Instead of considering the entire field as being the same, it permits the seeding rate, the amount of fertiliser and the irrigation to be varied within the same field – this is referred to as variable-rate technology. Remote sensing gives an aerial view of the condition of the crops; GPS/GIS then maps this information and directs the machinery; cloud computing takes care of the large volumes of data produced; and the mobile applications provide the farmers with direct recommendations, usually in the local language, supporting the work of the ICAR institutes and the State Agricultural Universities (Dhal *et al*., 2024; Ahmad *et al*., 2024).

7. THE INTEGRATION OF ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, DEEP LEARNING AND THE INTERNET OF THINGS INTO DIGITAL FARMING

The greatest value is obtained when these technologies are used in combination: internet-connected sensors provide the continuous raw data; machine learning and deep learning models analyse this data together with imagery and weather records in order to identify patterns; and AI-powered advisory systems then convert the results into straightforward recommendations. The entire process can be described as a workflow featuring a continuous feedback loop (Dhal *et al*., 2024; Khanna *et al*., 2024).

Table 1: Comparison of AI, ML, DL, IoT and Digital Farming

AI	Broad science of building machines that perform tasks needing human-like intelligence.	Umbrella for smart advisories, robots and decision support.
ML	Subset of AI where algorithms learn patterns from data instead of fixed rules.	Yield/soil/disease prediction, fertilizer and irrigation advice.
DL	ML branch using multi-layer neural networks to learn features from complex data like images.	Image-based disease/weed detection, fruit grading, machine vision.
IoT	Network of connected sensors/devices sharing real-time field data.	Soil/weather sensing, smart irrigation, livestock/greenhouse monitoring.
Digital Farming	Integrated, data-driven approach combining AI, ML, DL, IoT, remote sensing and GIS.	End-to-end precision management from sowing to post-harvest.

- Sensors collect field data such as those relating to the soil, weather, crops and livestock, as well as images obtained from drones and satellites. (Dhal *et al*., 2024)

- The collection of data is sent to a central location where it is stored and organised on a cloud platform. (Dhal *et al.*, 2024)
- Analysis using machine learning and deep learning leads to AI-driven recommendations: the models identify patterns, for example those relating to disease symptoms or moisture stress, and then convert the results into clear advice. (Ahmad *et al.*, 2024; Jabed & Murad, 2024)
- Monitoring and Feedback: The farmer takes action on the advice, usually with the help of a mobile app, and the results are then re-measured in order to improve subsequent recommendations. (Dhal *et al.*, 2024; Dara *et al.*, 2022)

8. THE BENEFITS OF USING AI AND DIGITAL TECHNOLOGIES IN AGRICULTURE

Since the advice given takes into account actual, up-to-date data rather than making use of broad assumptions, these technologies increase the accuracy and speed of farm decisions. They allow farmers to use water, fertilizer and pesticide in a more efficient manner. Early detection of pests, diseases and weather risks also helps to reduce crop losses, while yield predictions aid in better planning for storage and marketing. Monitoring of livestock contributes to improved animal health and welfare, and smart greenhouses make it possible to grow high-value crops under closely controlled conditions. More generally, these tools promote climate-smart agriculture and help transfer scientific knowledge from institutes such as ICAR to farmers in remote areas, often providing it in their own language (Khanna *et al.*, 2024; Aijaz *et al.*, 2025). Appropriate agronomic interventions can substantially influence crop productivity and quality. Vegetable grafting, for example, has been reported as a useful approach for improving vegetable production and quality (Dash *et al.*, 2021). Digital decision-support systems can complement such agronomic practices by assisting in the selection, monitoring and optimization of management interventions according to crop and field conditions.

9. OBSTACLES AND CONSTRAINTS

Even though digital agricultural technologies have great potential, they do encounter practical difficulties—especially in countries like India where farm sizes differ greatly. The prices of sensors, drones, and machinery equipped with AI can be high compared to the income of a small farmer, and the poor rural connectivity makes it difficult to use IoT systems which require a continuous internet connection. There is still a lack of computer skills, and since India has mostly small and fragmented farms, certain large-scale precision technologies may not be cost-effective on a per-farmer basis. Other concerns are the quality and the availability of reliable historical data that is needed to train accurate models, doubts regarding data privacy and ownership, a shortage of qualified personnel to install and maintain these systems, and the problem of gaining access to the technology for farmers and people in remote areas. Moreover, AI predictions are not always reliable when applied in widely differing local conditions, and because the technologies depend so heavily on digital infrastructure, a failure of the network or a power failure can temporarily halt operations that rely on it (Dara *et al.*, 2022; Manzoor et al., 2025; Bhattarai *et al.*, 2026).

Table 2: Major Agricultural Applications and Their Benefits

Yield prediction	Satellite/drone imagery with ML/DL	Better harvest and market planning
Pest/disease detection	CNN-based image recognition	Early diagnosis, lower crop loss
Weed identification	Computer vision, DL on field images	Targeted spraying, lower cost
Soil/nutrient management	ML on soil-test and sensor data	Site-specific fertilizer dose
Smart irrigation	IoT moisture sensors with automated valves	Water saving, timely watering
Livestock monitoring	Wearable IoT sensors with ML analysis	Early illness detection, welfare
Farm advisory apps	AI-based mobile/web platforms	Timely, local-language guidance

10.FUTURE PROSPECTS

The prospects for the use of AI and digital technologies in Indian agriculture are promising, thanks to the increasing connectivity in rural areas, the decreasing cost of sensors and smartphones, and the government's growing interest in digital agriculture. Ongoing investment by the ICAR institutes, the State Agricultural Universities and national digital agriculture initiatives will probably lead to AI and IoT solutions that have been tested locally becoming available to farmers regardless of the size of their landholdings. Cheap, solar-powered IoT devices and mobile applications that can function offline could help to tackle the problem of connectivity. Moreover, closer cooperation between researchers, technology developers and farmer producer organizations will ensure that the tools are designed to meet the actual needs and be available in the languages spoken by Indian farmers. When data privacy frameworks and digital agriculture standards have matured, farmers should acquire more confidence and a greater degree of control over how their data is used, since this is essential for the continued and fair development of digital farming. (FAO, 2025; PIB, 2026; Gakhar *et al*., 2026)

11. CONCLUSION

AI, machine learning, deep learning, and the Internet of Things are gradually turning agriculture away from a method primarily reliant on experience towards one that is increasingly backed by real-time data and predictive insights. Machine learning draws on historical patterns in order to predict outcomes such as crop yield and the risk of disease; deep learning goes a step further by enabling the direct analysis of images for the purpose of identifying diseases and weeds; and the Internet of Things supplies the continuous field-level data that these systems rely on. As part of Digital Farming, these technologies make it possible to manage agricultural operations more accurately, in a more resource-efficient way, and in a manner that is adaptive to climate conditions. In India, where the majority of farmers have small and scattered plots of land, fully benefiting from these technologies will need ongoing focus on affordability, rural connectivity, digital skills, and data governance, together with the research and extension assistance that is already being offered by organizations such as ICAR. With careful and inclusive implementation, intelligent digital technologies can make a real difference to productivity, sustainability and the livelihoods of farmers in Indian agriculture.

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