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Sustainable & Smart Farming Strategies Using AI

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Abstract

Agriculture is the first source of global population. Now today have billion of the population we have to need to produce maximum amount of food. we cannot live without food Agriculture is play important role of economy and also Indian economy. Smart Farming is more important than traditional farming because its smart farm allows us to produce maximum with less manpower as soon as possible food produce. Smart farming will give us advance Knowledge about the Environment and give to information about the climate change.in smart farming are uses a advance technologies to make farming more efficient, productive and sustainable. Like IOT (Internet of things) using IoT sensor placed in soil and fields collect data like temperature, humidity helps farmers decide when to water, fertilizer, or harvest.AI and ML is also used in Smart farming to artificial intelligence used to analyse data from sensor, drones. Predict crop diseases, weather impact. blockchain technology ensure transparency in food supply chain. GPS (global positioning System) helps to planting and tracking machinery. Drons used to crop monitoring spraying pesticides and mapping fields Amidst the large number of recent research publications related to smart agriculture and intelligent farming practices, a need arises to summarize their findings in a single consolidated review article. This work endeavours to summarize recent key technologies and applications of smart agriculture, delineate the prevalent challenges it faces, highlight its publicly available datasets for adoption, and offer some policy guidelines for stakeholders, assisting them in making informed decisions regarding technology adoption and investment. We conclude that smart agriculture can potentially revolutionize the agricultural sector, provided we overcome the challenges by ensuring effective collaboration among stakeholders, a strong infrastructure, digital literacy, adoption incentives.

Keywords: *Smart Agriculture, Internet of Things (IoT), Artificial Intelligence (AI), Precision Farming, Sustainable Agriculture.*

Introduction

India is an agriculture-based country, and farming plays a vital role in its economy. However, challenges such as population growth, climate change, water scarcity, and the need for higher productivity have made traditional farming methods less effective. Smart farming enables farmers to monitor field conditions in real time, make informed decisions, and use resources such as water and fertilizer efficiently. This leads to increased productivity, reduced costs, and sustainable development.

The integration of the Internet of Things (IoT) and Machine Learning (ML) is significantly improving agricultural practices. Smart agriculture represents a major shift from conventional farming methods by leveraging IoT sensors and ML algorithms to optimize farming operations. IoT sensors, such as soil moisture sensors, temperature sensors, and humidity sensors, provide real-time data on environmental conditions, enabling precise monitoring and control of agricultural processes. ML algorithms, including linear regression, decision trees, and Support Vector Machines (SVM), analyze this data to offer predictive modeling, anomaly detection, and optimization. These technologies improve agricultural efficiency and productivity.

Several major government initiatives support smart agriculture in India, including the Digital Agriculture Mission (2021–2025), PM-KISAN Scheme, Soil Health Card Scheme, and Pradhan Mantri Krishi Sinchai Yojana (PMKSY). Smart agriculture is transforming traditional farming into a modern, efficient, and sustainable system by integrating advanced

technologies. Wireless technologies are also used for data collection and transmission across large agricultural fields. Overall, smart agriculture helps ensure long-term food security and rural development.

Literature review:

Smart agriculture is a Morden way of farming that uses technologies like, AI, big data, and smart sensors to improve productivity and sustainability. Ant studies show that these technologies help farms make better decisions and use resources efficiently T-based system use sensor in fields to collect real-time data such as soil moisture, temperature, humidity, and nutrients .Tise data helps former manage irrigation, fertilizers, and pest control more effectively, which increases crop yield and reduces waste .Smart sensor play an important role by not only collecting data but also helping in automatic actions. For example, soil moisture sensor can automatically start irrigation when needed, saving water and effort. Artificial intelligence and machine learning help in predicting crop yield, detecting diseases early, and suggesting better farming methods. Thise make farming more advanced and reduces risks. Cloude computing and big data allow storage and analysis of large amounts of data. Farmers can access this information through mobilises, making it easier to take decisions even form remota areas. However, there as some challenges such as hight cost, lack of technical knowledge, poor internet connectivity in rural areas, and data security issues. Also, different technologies sometime do not work well together. Smart agriculture has emerged as a transformative approach to modern farming, integrating advanced technologies such as an AL (artificial intelligence), and big data smart sensor to improve agricultural productivity and efficiency.

Several studies emphasize that IoT-based agricultural systems facilitate real time monitoring and soil condition. Sensors deployed in fields collect data parameters such as temperature, humidity. This data is transmitted through wireless networks and analysed to support precision farming practices. As a result, farmers can optimize fertilizing, cropping and reduce time (Gubbi et al., 2013).

Research on smart sensor technologies highlights their critical role in precision agriculture. Smart sensors not only measure environmental parameters but also process and communicate data, enabling automated responses. **(Aqeel-Ur-Rehman et al., 2014**).

In addition, study on AI and machine learning applications in agriculture show that these technologies enhance predictive and prescriptive analytics. By analytics historical data and crop yield detect plant diseases, and recommend optimal farming practices. This shift from traditional reactive farming to predictive agriculture significantly improves productivity and reduces risks (Wolfert et al., 2017).

Big data analytics further support smart agriculture by providing scalable platforms for data storage, processing, and visualization. Farmers can access insights through mobile applications and web dashboards, enabling informed decision-making even in remote areas. These technologies also facilitate integration with other systems such as drones, satellite imaging, and automated machinery.

Despite the advantages, the literature identifies several challenges in the adoption of smart agriculture. Moreover, interoperability between different technologies and standardization of systems are ongoing issues that require attention.

Problem statement:

Challenges in Traditional Farming Traditional agriculture remains the backbone of food production in India, yet it faces systemic inefficiencies that threaten productivity, sustainability, and farmer livelihoods. The key issues are:

1. Low Productivity: Conventional farming relies heavily on experience-based practices and uniform input application across fields. Lack of site-specific nutrient management and delayed pest/disease detection results in sub-optimal yields. According to ICAR, the yield gap for major crops in India is 30-50% compared to global averages. Fragmented landholdings and limited mechanization further restrict output per hectare, especially for smallholder farmers in Maharashtra.
2. Water Wastage Flood irrigation is still dominant, with efficiency as low as 35-40%. Farmers often irrigate based on fixed schedules rather than actual crop water requirements or soil moisture status. This leads to excessive groundwater depletion — Central Ground Water Board reports 256 blocks in Maharashtra as over-exploited. Water wastage also increases soil salinity and reduces long-term fertility.

3. Climate Unpredictability Rising temperature, erratic monsoon patterns, unseasonal rains, and frequent droughts severely impact crop cycles. Traditional farming lacks tools for micro-climate monitoring or early warning systems. A single extreme weather event can destroy an entire season's crop. Farmers have minimal capacity to adapt planting dates or select climate-resilient varieties in real time.
4. Lack of Real-Time Decision-Making Critical decisions on irrigation, fertilization, and pest control are often delayed due to dependence on manual field scouting and local advice. By the time symptoms like wilting or pest infestation are visible, significant damage has already occurred. There is no integration of weather forecasts, soil data, or market prices into day-to-day farm operations, leading to reactive rather than proactive management. Resulting Impact: These interconnected issues cause reduced profitability, increased input costs, environmental degradation, and heightened vulnerability to climate change. This creates an urgent need for data-driven, technology-enabled approaches that provide precise, timely, and localized decision support — the core gap that smart farming with AI and IoT aims to address.

Objective:

Smart farming aims to improve agriculture productivity, sustainability, and profitability digitately technologies like AI and IOT. Resource optimization and cost saving, utilizing IOT sensor and ai to manage input like water, fertilizer. Using ai drones and autonomised machinery to handle repetitive and demanding tasks, shifting the farmer reform Manul Labour to data analysis and strategic management IOT (Internet of Things) sensor are used to monitoring soil, water and wether.AI and Machine Learning used for predict analytics for, identifying crop stress or optimizing spraying Autonomous machinery for instance harvesting, weeding, and drone for surveying. Urbanization rate is gradually rising and it is estimated that by 2050 around 80% the word population. The total population in earth increase by 3 billion. This upward trend can lead to food storage, so we required amount of 80% of available farmland through a smart farming.

Research Methodology: Smart Agriculture (Karim (2025))

A research methodology in smart agriculture is a structured framework used to design, deploy, and evaluate data-driven technologies (like IoT, AI, and robotics) in real-world farming environments to improve productivity and sustainability. It typically follows a multidisciplinary approach bridging agronomy, engineering, and data.to understanding impotence impact of IOT in smart agriculture. The qualitative aspect focuses on literature review and expert opinions, while the quantitative aspect includes data collection from IoT devices and analysis of efficiency improvements in farming practices

1. Research Design

These studies adopted some qualitative and quantitative iot techniques to analysed the role of smart sensors in smart agriculture. The research focuses on evaluating how sensor-based systems improve agricultural productivity, efficiency, and sustainability.

2. Data Collection Methods

a. Primary Data: Field experiments using smart sensors (e.g., soil moisture, temperature sensors), Surveys and interviews with farmers using smart agriculture technologies, Observations of sensor-based irrigation and monitoring systems

b. Secondary Data: Research papers and journals, Government reports such as those by NITI Aayog, Online databases, agricultural websites, and case studies

3. Study Area: The study can be conducted in selected agricultural regions where smart farming practices are being adopted (e.g., parts of Maharashtra, Punjab, or Karnataka). These areas are chosen due to their increasing use of IoT-based agricultural solutions.

4. Tools and Technologies Used: Smart sensors (soil moisture, humidity, temperature), Microcontrollers (e.g., Arduino, Raspberry Pi), IoT platforms (data analysis, data storing)

Components of IoT-Based Smart Agriculture

* Smart Sensors: Smart agriculture (also called precision agriculture) uses advanced technologies like IoT, AI, and smart sensors to improve crop productivity, reduce resource waste, and support sustainable farming. Smart sensors play a key role by collecting real-time data from the field.

What are Smart Sensors?

Smart sensors are devices that not only measure physical parameters but also process and transmit data.

They typically include, Sensing element (detects changes), Microprocessor (processes data), Communication module (Wi-Fi, Bluetooth, LoRa, etc.)

Types of Smart Sensors in Agriculture

a. Soil sensor: Measure moisture, temperature Help optimize irrigation and fertilization
b. Climate Sensors: Monitor temperature, humidity, rainfall, wind speed, Useful for predicting weather conditions
c. Crop health: sensor detect crop health, stress, and crop growth condition, often use imaging and spectral analysis
d. Water Sensors: Monitor water levels and quality, prevent over-irrigation and water wastage, Working, Smart sensors in agriculture operate through a systematic flow of data collection, processing, communication, and decision-making. There are some steps are included

1. Data Acquisition

Sensors are deployed in the field to continuously monitor environmental and soil parameters such as moisture, temperature, humidity, pH, and light intensity. These sensors detect physical changes and convert them into electrical signals.

2. Data Processing

The collected data is processed either: Locally (Edge Computing): Using microcontrollers embedded within the sensor system, remotely (Cloud Computing): Data is sent to cloud platforms for advanced analysis, this step may include filtering, calibration, and initial analysis.

3. Data Transmission

Processed data is transmitted through communication technologies such as: Wi-Fi, Bluetooth, Zigbee, these technologies form part of an IoT (Internet of Things) network, enabling seamless data transfer from the field to central systems.

4. Data Analysis and Interpretation: Advanced algorithms and software tools analysed the data to generate meaningful insights. This may include: Predicting irrigation needs, detecting crop stress or disease, Monitoring environmental trends.

Use of Smart Sensor:

1. 1960–1980: Early Stage (Basic Sensors): Only simple sensors (temperature, pressure, etc.) were used, very limited use in agriculture.
2. 1980–1990: Introduction of Microprocessors Sensors were combined with microprocessors, this allowed data processing, marking the beginning of "smart" sensors.
3. 1990–2000: Start of Precision Agriculture: Use of GPS and basic sensor systems began, Farmers started monitoring soil moisture and crop conditions.
4. 2000–2010: Wireless Technology Growth: Wireless Sensor Networks (WSN) were introduced, Sensors could send data remotely from fields.
5. 2010–Present: IoT-Based Smart Sensors: Rapid growth due to IoT, cloud computing, and AI, Real-time monitoring, automation, and mobile-based control became possible.

Benefits of IOT in Farming (Sachin Gupta2026)

- Enhanced Productivity: o Precision farming increases crop yields through optimized resource use.
- Efficient Water and Energy Use: o Automated irrigation reduces water consumption by 30-50%. o Smart systems lower electricity costs by optimizing pump usage.
- Time reducing through automation machinery: using iot we can save time and manpower like drones and GPS etc. Increases Farmer Income
- Beter decision making: using historical data finding future

Role of information technology in Morden agriculture (Amrita Paragaien 2026)

IOT in agriculture refers to using digital tools like computer, mobile networks, sensor networks, and software to improve farm outcomes. It about delivering he right information to the right farmer at the right time so that can make better decisions about crops, weather, and inputs etc. Mordn agriculture use to technologies like the internet things IoT SENSORS, DRONES, GPS, and data analytics to monitor farm conditions and make data driven decisions this is called precision

agriculture. IOT sensors measure soil moisture, temperature, nutrients, and weathering real time. Data analytics helps farmers know when and how much to water, fertilize, or irrigate. GPS provide aerial imaging and precise field mapping. Can improve yield's and reduce wastage of water and inputs. Cloude platforms collect and store massive farm data for analysis and prediction. Based on these data, tolls can suggest optimal planting times, irrigation schedules, or pest- control measures

Need of IOT in agriculture (Sachin Gupta 2026)

Agriculture is the backbone of many economies, especially in countries like India. However, traditional farming faces challenges such as climate change, water scarcity, low productivity, and inefficient resource use. The internet of things ITO has emerged as a Morden solution that integrates sensor, data analytics, and automatic to transform agriculture into small farming. IOT connects devices like soil sensor, weather stations, and irrigation system to collect real time data and improve decision making. IOT sensors help farmers mentor, soil moisture, temperature, humidity, nutrient levels.

CONCLUSION:

Smart agriculture uses Morden technologies like IOT, sensor, and data to make farming easier and better. It helps farmers save water, reduce hard work, and increase crop production. it also protects crops from diseases and bad weather. Farming more efficient, profitable, and eco- friendly. In the future, it will play an important role in feeding the growing population and improving farmers lives. In addition, smart agriculture reduces the need for manual lobar and makes farming less time consuming. It supports sustainable farming by protecting the informant and conserving natural resources. Overall smart agriculture makes farming smarter, easier, and more profitable. In the coming years, it will play a key role in ensuring food security and improving the standard of living for farmers.

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