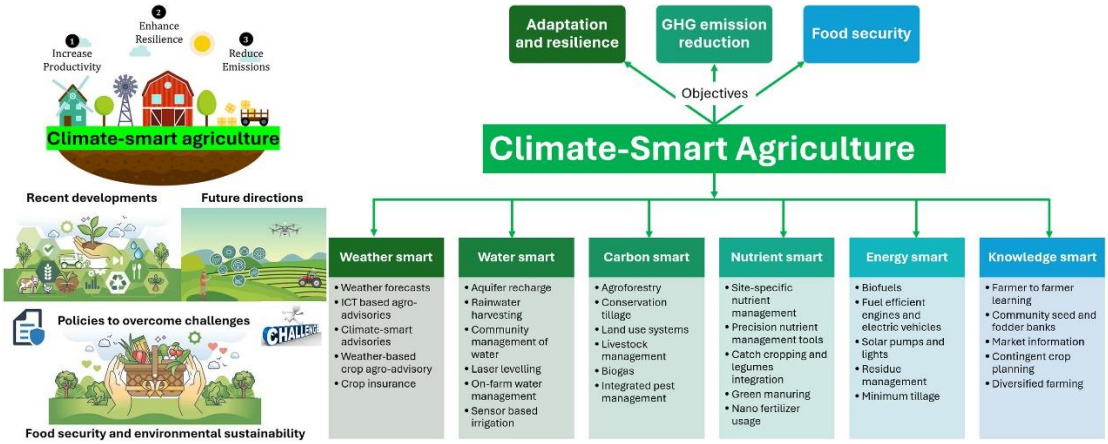
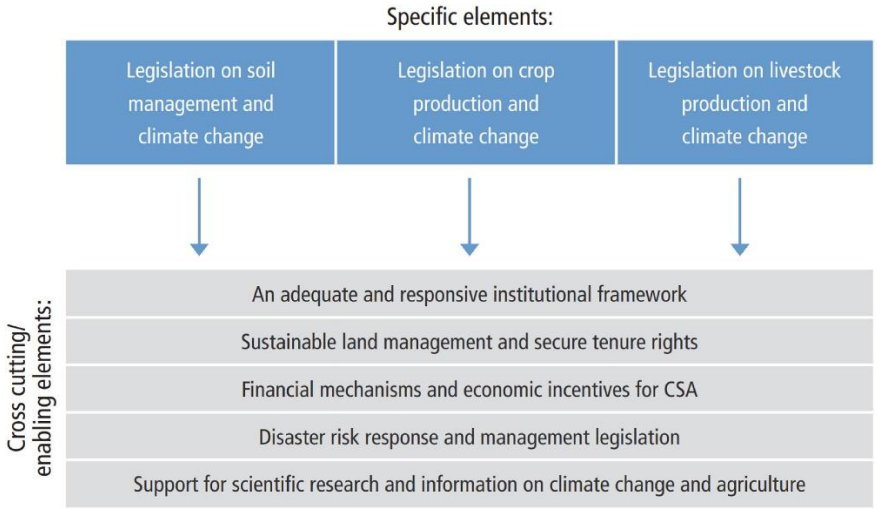
Smart Agriculture or "Climate Smart Agriculture"



https://www.sciencedirect.com/science/article/pii/S2950409024000200#undfig1



Highlights

- Major climate-smart agriculture innovations in developed and emerging nations are outlined.
- Climate-smart agriculture goals, strategies, and legislation are discussed.
- Different climate-smart agriculture solutions for different climate change impacts are compared.
- The challenges and future directions of climate-smart agriculture are examined and categorized.
- Policies for climate-smart agriculture to ensure food security and environmental sustainability are suggested.

Smart agriculture (or smart farming) is the application of advanced technologies—IoT sensors, AI, drones, and robotics—to improve farming efficiency, sustainability, and crop yields. By leveraging data-driven insights, it enables precise, automated management of crops and livestock, reducing waste and resource consumption (e.g., water, pesticides).

Key Components and Technologies

- IoT Sensors: Real-time monitoring of soil moisture, temperature, nutrients, and weather conditions.

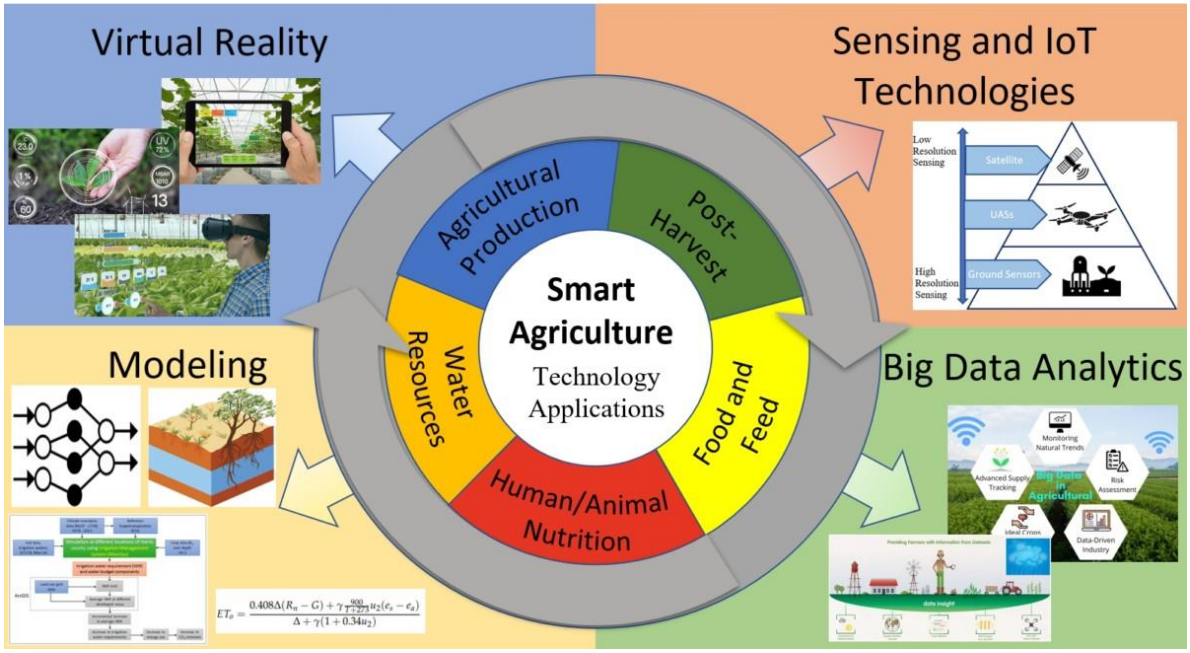
- Drones/UAVs: Used for aerial surveying, crop monitoring, spraying, and evaluating health.
- AI and Machine Learning: Analyzes data from sensors and cameras to predict trends, diagnose pests, and optimize decisions.
- Robotics/Automation: Autonomous machinery for harvesting, planting, and weeding.
- Smart Greenhouses: Automated climate control for optimized growth environments

Usage Examples

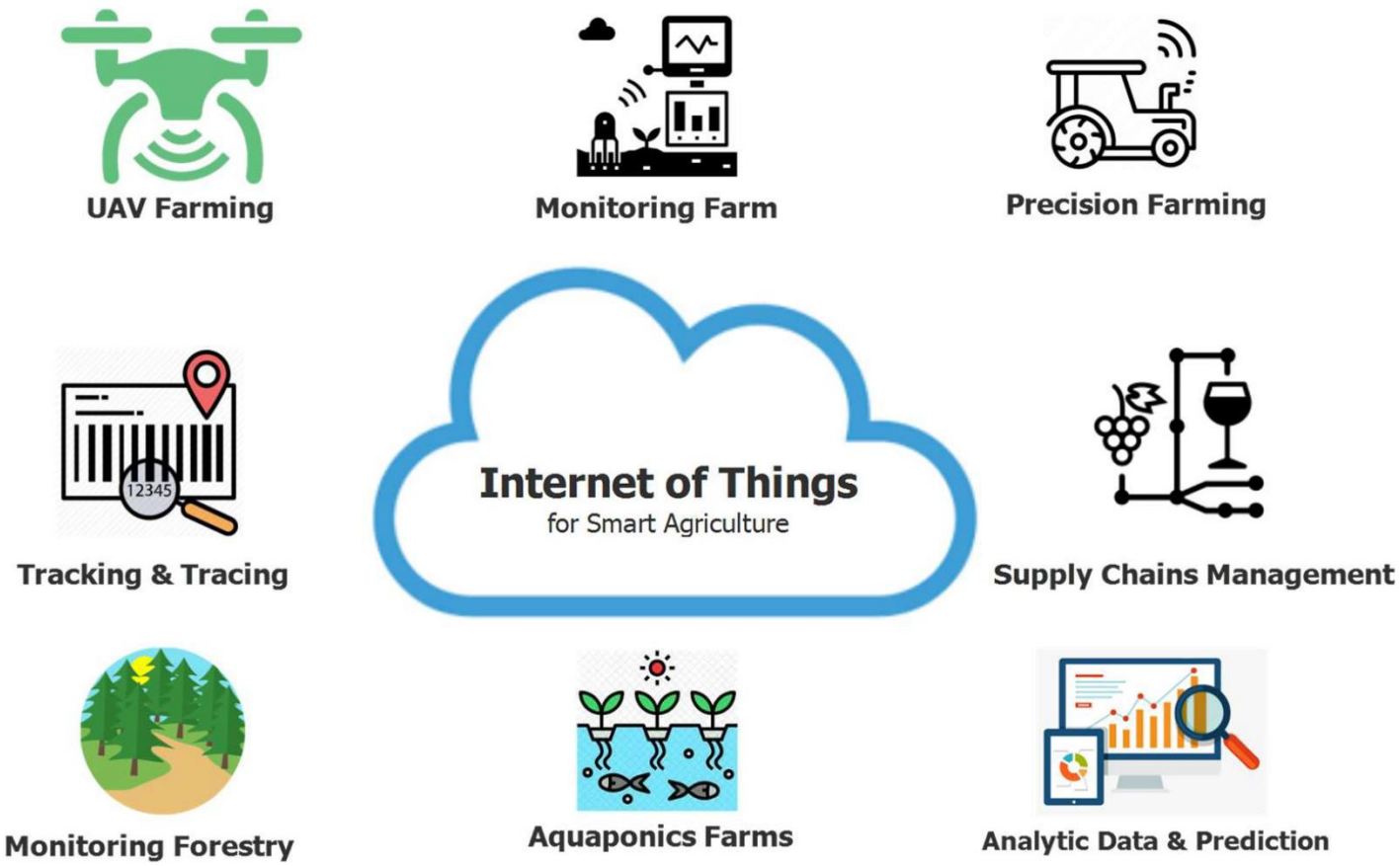
- Precision Irrigation: Sensors detect low soil moisture and automatically trigger irrigation, saving water.
- Targeted Spraying: Drones or robots identify weeds or pests, applying pesticides only to affected areas rather than the whole field.
- Livestock Management: Wearable sensors track cattle health, location, and temperature, directly updating a management dashboard.
- Crop Monitoring: Drones use cameras to scan crops for nutritional deficiencies or diseases.

Synonyms and Related Terms

- Digital farming
- Precision agriculture
- Smart farming
- Climate-smart agriculture (focuses on sustainability)
- AgTech (Agricultural Technology)



https://www.pvamu.edu/cafnr/homepage-2/research/natural-resources/climate-smart-agriculture/



https://encyclopedia.pub/entry/21106

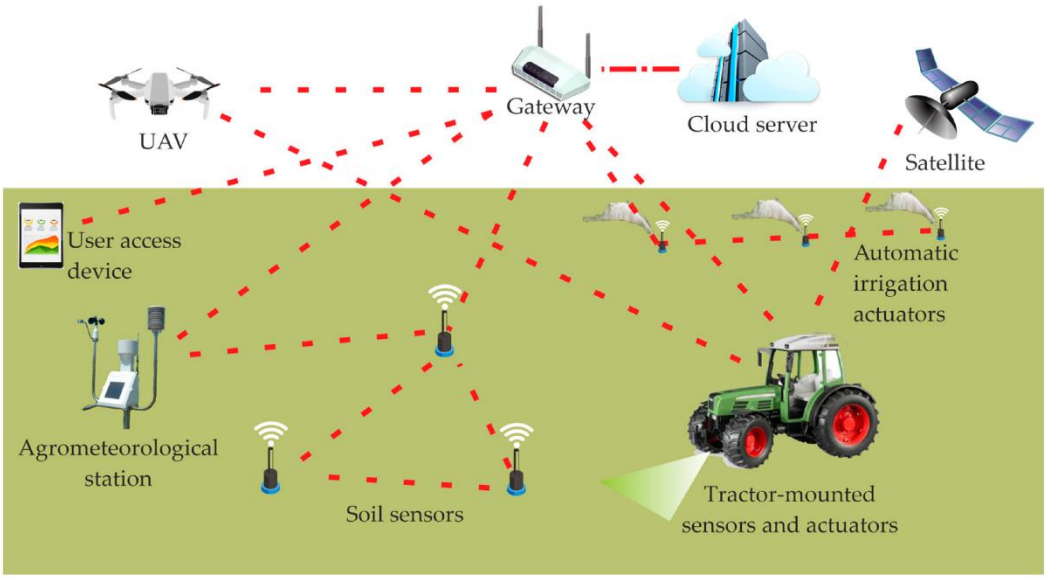
IoT-Enabled Smart Agriculture

This entry is adapted from the peer-reviewed paper 10.3390/app12073396

The growth of the global population coupled with a decline in natural resources, farmland, and the increase in unpredictable environmental conditions leads to food security is becoming a major concern for all nations worldwide. These problems are motivators that are driving the agricultural industry to transition to smart agriculture with the application of the Internet of Things (IoT) and big data solutions to improve operational efficiency and productivity. The IoT integrates a series of existing state-of-the-art solutions and technologies, such as wireless sensor networks, cognitive radio ad hoc networks, cloud computing, big data, and end-user applications. IoT is defined as the network of all objects that are embedded within devices, sensors, machines, software and people through the Internet environment to communicate, exchange information and interact in order to provide a comprehensive solution between the real world and the virtual world.

In order to meet the current global needs of humanity, new solutions and technologies are constantly being proposed and implemented. This has led to the advent of the Internet of Things (IoT) [1][2]. IoT is defined as the network of all objects that are embedded within devices, sensors, machines, software and people through the Internet environment to communicate, exchange information and interact in order to provide a comprehensive solution between the real world and the virtual world [3]. In recent years, IoT has been applied in a series of domains, such as smart homes [4][5], smart cities [6][7], smart energy [8][9], autonomous vehicles [10][11], smart agriculture [12][13][14][15], campus management [16][17], healthcare [18][19], and logistics [20][21]. Series of other IoT applications have been described by Shafique et al. [22]. An illustration of rich and diverse IoT applications for smart agriculture is provided in Figure 1.

According to the United Nations' (UN 2019) statistics, the world population is estimated to grow to 10 billion by 2050 [23]. As a consequence, the requirements of agricultural products are continually increasing. However, farmlands are declining, natural resources are increasingly depleted, and the rise of unpredictable nature challenges, such as global warming, salinization, and flooding, make food security the most concerning problem for all nations worldwide.



https://www.mdpi.com/2078-2489/15/8/466

The Implementation of "Smart" Technologies in the Agricultural Sector: A Review

Abstract

The growing global population demands an increase in agricultural production and the promotion of sustainable practices. Smart agriculture, driven by advanced technologies, is crucial to achieving these goals. These technologies provide real-time information for crop monitoring, yield prediction, and essential farming functions. However, adopting intelligent farming systems poses challenges, including learning new systems and dealing with installation costs. Robust support is crucial for integrating smart farming into practices. Understanding the current state of agriculture, technology trends, and the challenges in technology acceptance is essential for a smooth transition to Agriculture 4.0. This work reports on the pivotal synergy of IoT technology with other research trends, such as weather forecasting and robotics. It also presents the applications of smart agriculture worldwide, with an emphasis on government initiatives to support farmers and promote global adoption. The aim of this work is to provide a comprehensive review of smart technologies for precision agriculture and especially of their adoption level and results on the global scale; to this end, this review examines three important areas of smart agriculture, namely field, greenhouse, and livestock monitoring.

Keywords:

IoT; precision agriculture; smart farming; Agriculture 4.0



https://news.mit.edu/2016/nanobionic-spinach-plants-detect-explosives-1031

Spinach is no longer just a superfood: **By embedding leaves with carbon nanotubes**, MIT engineers have transformed spinach plants into sensors that can detect explosives and wirelessly relay that information to a handheld device similar to a smartphone.

This is one of the first demonstrations of engineering electronic systems into plants, an approach that the researchers call "**plant nanobionics.**"

"The goal of plant nanobionics is to introduce nanoparticles into the plant to give it non-native functions," says Michael Strano, the Carbon P. Dubbs Professor of Chemical Engineering at MIT and the leader of the research team.

Recommendations - Agriculture NIST IoT

NIST IoT Advisory Board recommendations for smart agriculture focus on accelerating adoption through federal funding for broadband, subsidizing IoT sensors, establishing test-farm networks, and strengthening cybersecurity. Key goals include improving yield prediction and pest management using AI, promoting data standards for interoperability, and bridging the rural digital divide to increase sustainability and efficiency.

https://www.sciencedirect.com/science/article/pii/S2772375524002211

Cybersecurity threats and mitigation measures in agriculture 4.0 and 5.0

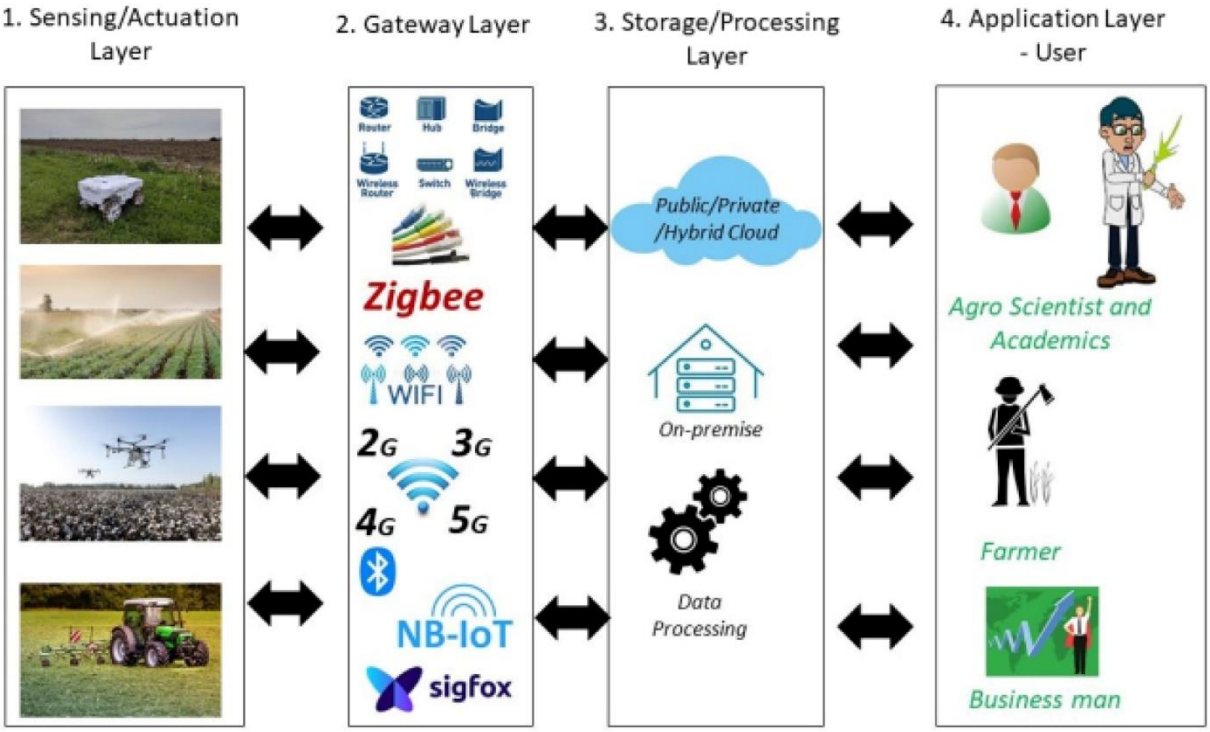
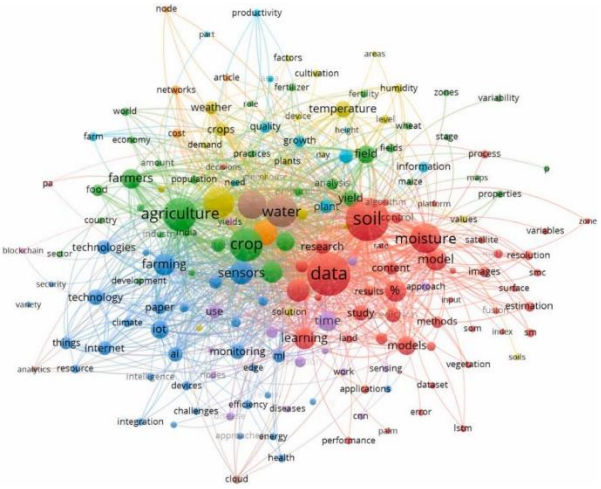


Fig. 5. Layers targeted during attacks on smart agricultural systems [16].

Concerning the risks of smart technologies in agriculture, Demestichas et al. [15] pointed out that the rapid evolution of modern agriculture to incorporate smart communication strategies presented serious security issues from potential cyberattacks. The view was supported by Gupta et al. [47], who also pointed out that the use of smart communication technologies and IoT increased the vulnerability of farming environments to cybersecurity threats. A similar observation was made by Barreto and Amaral [7] regarding the inherent security risks of smart farming. In that respect, the findings imply that cybersecurity risks in agriculture increase with the massive use of communication technologies. Besides communication technologies, studies further attribute cybersecurity risks in agriculture to the wide use of big data. The proposition was presented by Amiri-Zarandi et al. [48], who noted that a large volume of agriculture data presented privacy challenges and attracted potential hacking activities by cyber criminals. According to Benmalek [49], ransomware attacks are the most common cyber threat directed at farm databases. The implication is that the availability of data is regarded as a rich asset by cyberattackers, leading to an increase in cybersecurity issues in smart farming solutions.



https://www.nist.gov/system/files/documents/2023/02/28/IoT%20AB%20Member%20-%20Chandra%20Statement%202023-01-18.pdf



https://www.sciencedirect.com/science/article/pii/S294991192500053X#fig2

Soil moisture monitoring technologies in smart agriculture: A comprehensive review

Fig. 2. Keywords co-occurrence network using VOS viewer.

The keyword network reveals three distinct research clusters: sensor-focused (IoT, WSN, monitoring), analytics-focused (machine learning, prediction, optimization), and application-focused (irrigation, crop yield, sustainability). The central positioning of "soil moisture" indicates its role as the primary bridge between technological development and agricultural applications, suggesting that future research should prioritize soil moisture as the key integration point for multidisciplinary approaches.

Soil moisture monitoring is a critical component of modern agriculture, directly impacting crop productivity and resource management. With increasing pressures from climate change, water scarcity, and global food demand, there is a growing need for innovative and data-driven approaches to optimize agricultural practices. This systematic and conceptual review explores the role of advanced technologies in transforming soil moisture monitoring and smart agriculture. It aims to address major global challenges, including food security, water scarcity, and climate variability. By synthesizing advancements in Internet of Things (IoT), machine learning (ML), remote sensing, and related technologies, this review aims to elucidate their contributions to precision farming, resource optimization, and sustainable agricultural practices. The review provides a comprehensive analysis of current trends, methodologies, and technological integrations, identifying key innovations that enhance crop productivity and environmental resilience. It seeks to guide researchers, policymakers, and agritech stakeholders toward scalable, inclusive solutions by highlighting research gaps and proposing future directions for equitable and sustainable agricultural transformation.

https://pmc.ncbi.nlm.nih.gov/articles/PMC12116683/

Frontiers Plant Science

2025 May 14;16:1587869. doi: 10.3389/fpls.2025.1587869

Integration of smart sensors and IOT in precision agriculture: trends, challenges and future prospectives

Traditional farming methods, effective for generations, struggle to meet rising global food demands due to limitations in productivity, efficiency, and sustainability amid climate change and resource scarcity. Precision agriculture presents a viable solution by optimizing resource use, enhancing efficiency, and fostering sustainable practices through data-driven decision-making supported by advanced sensors and Internet of Things (IoT) technologies. This review examines various smart sensors used in precision agriculture, including soil sensors for moisture, pH, and plant stress sensors etc. These sensors deliver real-time data that enables informed decision-making, facilitating targeted interventions like optimized irrigation, fertilization, and pest management. Additionally, the review highlights the transformative role of IoT in precision agriculture. The integration of sensor networks with IoT platforms allows for remote monitoring, data analysis via artificial intelligence (AI) and machine learning (ML), and automated control systems, enabling predictive analytics to address challenges such as disease outbreaks and yield forecasting. However, while precision agriculture offers significant benefits, it faces challenges including high initial investment costs, complexities in data management, needs for technical expertise, data security and privacy concerns, and issues with connectivity in remote agricultural areas. Addressing these technological and economic challenges is essential for maximizing the potential of precision agriculture in enhancing global food security and sustainability. Therefore, in this review we explore the latest trends, challenges, and opportunities associated with IoT enabled smart sensors in precision agriculture.

Keywords: precision agriculture, smart sensors, IoT, big data, automation, challenges

https://pages.nist.gov/GCTC/uploads/blueprints/2019-Ag-Rura-Blueprint.pdf

Agriculture/Rural Supercluster Blueprint Global City Teams Challenge Washington, DC July 10, 2019 Rural America, Rural Economies and Rural Connectivity

https://ieeexplore.ieee.org/abstract/document/10371307

Internet of Things and Wireless Sensor Networks for Smart Agriculture Applications: A Survey

The increasing food scarcity necessitates sustainable agriculture achieved through automation to meet the growing demand. Integrating the Internet of Things (IoT) and Wireless Sensor Networks (WSNs) is crucial in enhancing food production across various agricultural domains, encompassing irrigation, soil moisture monitoring, fertilizer optimization and control, early-stage pest and crop disease management, and energy conservation. Wireless application protocols such as ZigBee, WiFi, SigFox, and LoRaWAN are commonly employed to collect real-time data for monitoring purposes. Embracing advanced technology is imperative to ensure efficient annual production. Therefore, this study emphasizes a comprehensive, future-oriented approach, delving into IoT-WSNs, wireless network protocols, and their applications in agriculture since 2019. It thoroughly discusses the overview of IoT and WSNs, encompassing their architectures and summarization of network protocols. Furthermore, the study addresses recent issues and challenges related to IoT-WSNs and proposes mitigation strategies. It provides clear recommendations for the future, emphasizing the integration of advanced technology aiming to contribute to the future development of smart agriculture systems.



NATIONAL NANOTECHNOLOGY INITIATIVE SUPPLEMENT TO THE PRESIDENT'S 2026 BUDGET

https://www.nano.gov/sites/default/files/NNI-FY26-Budget-Supplement.pdf

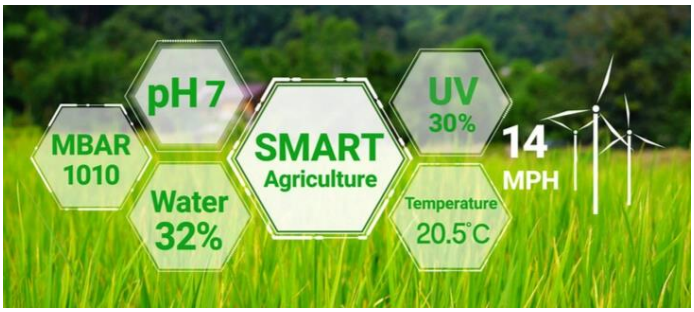
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What is nanotechnology? Nanotechnology is the understanding and control of matter at the nanoscale—at dimensions between approximately 1 and 100 nanometers—where unique phenomena enable novel applications. A nanometer is one-billionth of a meter. For reference, a sheet of paper is about 100,000 nanometers thick. Matter can exhibit unusual physical, chemical, and biological properties at the nanoscale, differing in important ways from the properties of bulk materials, single atoms, and molecules. Some nanostructured materials are stronger or have different magnetic properties compared to other forms or sizes of the same material. Others are better at conducting heat or electricity. Nanomaterials may become more chemically reactive, reflect light better, or change color as their size or structure is altered. Nanotechnology serves as the foundation for key industries of the future such as artificial intelligence, quantum information science, and advanced manufacturing. Nanotechnology innovations are ensuring continued U.S. leadership in the semiconductor and strategic computing industries, and are advancing many other national priorities, including space exploration, energy, advanced communications (5G/6G), healthcare, **agriculture,** aviation, and national security. Examples of nanotechnology innovations are illustrated below: (a) flexible electronics for smart bandages, real-time health monitoring, and therapeutics; (b) specialized and energyefficient hardware for artificial intelligence; (c) nanowire photon detectors for high-speed quantum communication; (d) nanomaterials for enhanced oil production and more efficient refining; (e) materials and devices for water testing and purification; (f) radiation-resistant materials for nuclear fission and fusion power reactors; (g) multifunctional, lightweight, and heat-resistant materials for aerospace applications; (h) smart windows enabled by nanoscale coatings for more energy-efficient and comfortable buildings.

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Enabling advances in fundamental understanding of nanomaterials with unique instrumentation and light sources. Scientists have been using light sources and innovative instruments available only at DOE National Laboratories to develop fundamental knowledge about nanomaterials at the molecular level, which can be used to develop novel applications.

Probing atomic vibrations at the quantum interface with surface-sensitive spintronic terahertz spectroscopy The ability to probe and understand quantum dynamics of surfaces—such as surface phonon modes in quantum paraelectrics for facilitating interfacial superconductivity—is highly challenging, especially below 1 THz. The main challenges are that the interface of interest is very small (only a few nanometers thick) and that high resolution, THz-range quantum effects are difficult to capture. Researchers from Argonne National Laboratory and a university have created a surface-sensitive spintronic terahertz spectroscopy (SSTS) instrument capable of sensing the collective phonon modes only a few nanometers deep, probing surface soft transverse optical (TO1) phonon dynamics in KTaO3 and SrTiO3. SSTS relies on a thin magnetic film being deposited onto the oxide crystal, granting researchers the ability to probe the interface when the magnetic layer is struck with radiation. The SSTS technique opens the door for sensing other quantum behaviors that are difficult to measure, especially at interfaces, such as magnetism and superconductivity. The combination of advanced instrumentation and techniques such as SSTS is important for retaining U.S. global leadership in nanotechnology and quantum technologies.

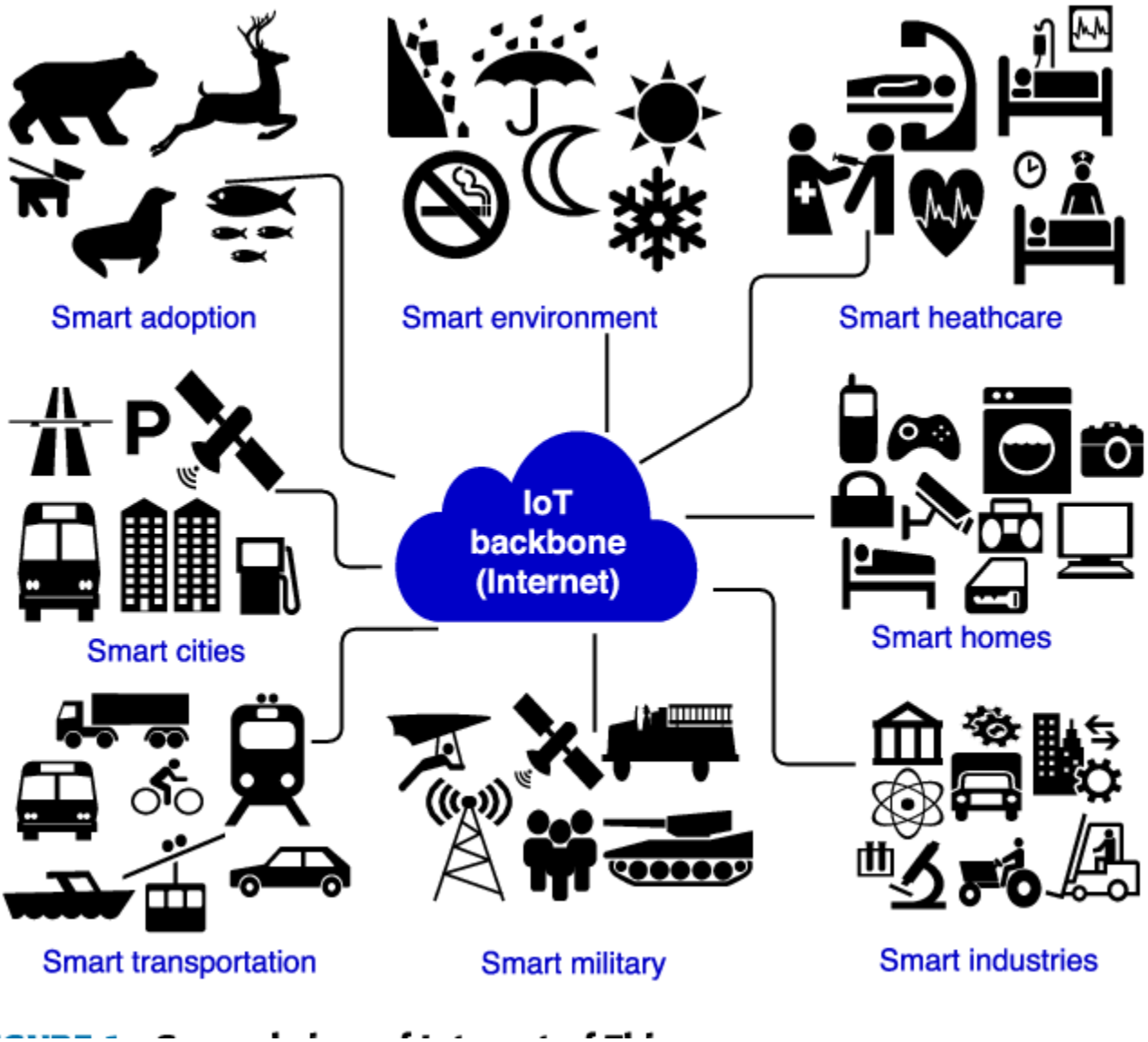


https://eos.com/blog/smart-farming/

Smart Farming: Technologies & Benefits For Agriculture

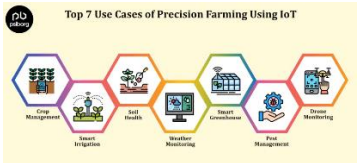
The development of modern technologies impacts all spheres of human activity, including the agricultural sector. Smart farming is a relatively new concept of advanced farm management. Smart farming in agriculture involves using various software and equipment to optimize and automate routine processes. With the spread of the Internet and mobile devices, such technologies have become available not only for large companies but also for small private farms. It helps growers

optimize production and compete with larger agro companies. Since smart agriculture practices have undeniable advantages for businesses over conventional methods, it is worth exploring the features of this approach in more depth.



THIS PDF IS PROVIDED BY THE PSINERGY CHANNEL … the internet of everything includes everything – which means everything in the biosphere we live in which includes us. Your "aura" is anatomical; take back your knowledge of neurology, electrophysiology and biophysics to understand the changes in smart agriculture, smart healthcare and of course, drone warfare with network centric warfare.

Thank you for your consideration to understand these economic and logistics based shifts in our supply chains globally. May we restore human integrity and problem solve in good faith rather than consistent conflict.



https://psiborg.in/precision-farming-using-iot/

Precision Agriculture Using IoT: Explained

The IoT-based precision agriculture solution uses smart devices and sensors to improve the traditional farming system. Smart agricultural solutions can involve machines and even farm operations. Precision farming can easily be understood as a site-specific crop management and monitoring solution.

The basic role of precision agriculture using IoT is to generate large amounts of data, give real-time information based on the data, and automate tasks. All of this is done to improve productivity and increase profitability.

Types of Precision Farming Technology

Some notable precision farming technologies that are utilized by agritech businesses are:

Remote Sensing

The remote sensing technology uses sensors to collect data like soil moisture, crop health, and other factors remotely.

This remote-sensing technology helps farmers make better decisions and develop crop-specific strategies to increase agriculture yields and decrease waste.

GPS

The Global Positioning System, GPS provides instant and accurate data regarding the location and condition of the farm, all in near real-time.

This technology is very helpful in tracking the location of where the fertilizer or pesticides have been sprinkled on the farm.

Soil Sensors

The soil sensors are actively used in soil health monitoring and give farmers detailed insights on soil moisture levels, nitrogen levels, and several other parameters to promote active growth in crops.

The soil sensors can be placed all around the farm and in the regions where farmers want to keep an eye to improve soil fertility in that specific area.

Crop Sensors

The crop sensors are used to monitor several aspects of plant health, such as chlorophyll level, pest intrusion, precipitation, and temperature. By getting real-time information on these factors, farmers can monitor and pinpoint the areas of the field under stress and adjust their strategies accordingly.

Drones

Who doesn't know about drones, these days? Drones are now so popular that they are literally used everywhere, from deliveries to clicking wedding photos. However, very little of the population is aware of the use of drones in agriculture. The drones used in agriculture are equipped with cameras, sensors, and GPS. They collect information regarding crop health, create detailed maps, and identify areas that require care.

What are the Advantages of Precision Farming?

As we said, IoT has many use cases in the agriculture industry. However, before tapping into that topic, let's first understand how the IoT benefits precision agriculture.

Sensing and Monitoring

IoT technology uses several agricultural sensors. These sensors are considered electrotechnical devices that can measure the physical quantities of the environment and convert these measurements into a signal that can be interpreted by an instrument. So, these sensors record various agricultural parameters like temperature, humidity, CO2/O2 level, moisture content, NPK value, and more to help farmers better manage their farms.

Insightful Farming

Once you get the data about the soil, crop, livestock, and farm territory, you can work according to that data. Smart IoT solutions make you make knowledgeable decisions to increase profitability. This means farmers can make precise decisions about the amount of seed or fertilizer to be put in the soil.

Automation

In addition to the manufacturing industry, the agritech industry is another sector that can benefit greatly from automation. Until now, most agricultural work has been carried out manually. However, this can be very tiring for workers and farmers. IoT automation for various agricultural processes can make agricultural work easier.

Also Read: IoT in Manufacturing Industry

Reduced Costs

The practices of precision farming using IoT make use of strategies that can significantly minimize the overall farming cost by minimizing the use of fertilizers, pesticides, and water. With site-specific management strategies, farmers can use their resources more efficiently, ultimately reducing input costs and improving profitability.

Better Turnaround

When you get accurate and good insight into the soil and the crop, you can make better decisions. Plus, automated agriculture and smart supply chain management make precision farming easier and more profitable for the users.