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ITU-T Focus Group Report

(03/2024)

Focus Group on Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture (FG-AI4A)

FGAI4A-WG-AS

Technical Report - Use Cases for AI and IoT for Digital Agriculture

Working Group: Digital Agriculture Use Cases and Solutions

Draft ITU-T FG-AI4A Deliverable

Use Cases for AI and IoT for Digital Agriculture

Summary

This technical report by the ITU-T Focus Group on AI and IoT for Digital Agriculture (FG-AI4A) provides a detailed analysis of how AI and IoT technologies are revolutionizing digital agriculture. It includes numerous use cases demonstrating successful implementations, highlighting their objectives, innovations, data collection methods, and AI/ML algorithms used. The report assesses accuracy, performance, deployment status, and the benefits of these technologies. It also evaluates environmental impacts, offering recommendations for enhancing productivity, sustainability, and efficiency in agriculture. Future research directions and potential advancements are explored to guide further innovation and standardization in this field.

Keywords

Artificial Intelligence (AI), Internet of Things (IoT), Digital Agriculture, Use Cases, Technological Innovations, Data Collection Methods, Machine Learning Algorithms, Agricultural Productivity, Sustainability, Efficiency, Environmental Impact, Scalability, Deployment, Resource Conservation

Note

Acknowledgement

This Technical Report was prepared under the leadership of Mr. Ramy Ahmed Fathy (Giza Systems, Egypt) and Mr Sebastian Bosse ((Fraunhofer HHI, Germany), Chair of FG-AI4A (Fraunhofer HHI, Germany). It is based on the contributions of various authors who participated in the Focus Group activities and submitted use-cases. Mr Raghu Chaliganti (Fraunhofer HHI, Germany), Chair of WG- and Vice-Chairs Ms Vydeki D, (Vellore of Institute of Technology, India) and Mr Ahmed Mohamed AbdelHameed (Giza Systems, Egypt) served as the main Editors of this Technical Report. Ms Mythili Menon (FG-AI4A, Advisor) and Ms Chiara Co (FG-AI4A Assistant) served as the FG-AI4A Secretariat.

Change Log

This document contains Version 1.0 of the ITU-T Technical Report on "Use Cases for AI and IoT for Digital Agriculture that was approved at the ninth FG-AI4A meeting.".

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1 Scope

The scope of this technical report encompasses a comprehensive analysis of the integration of Artificial Intelligence (AI) and Internet of Things (IoT) technologies in digital agriculture. This includes identifying and examining various successful use cases of AI and IoT implementation, highlighting objectives, innovations, data collection methods, AI/ML algorithms, accuracy, performance, deployment states, and key benefits. The report compiles best practices, technological innovations, and trends, offering recommendations to enhance agricultural productivity, sustainability, and efficiency. It evaluates environmental and economic impacts, focusing on resource conservation, reduced chemical usage, cost savings, and improved economic returns for farmers. The scalability and deployment of AI and IoT solutions across different agricultural contexts and regions are examined through case studies of successful deployments. Lastly, the report explores future research directions and potential advancements, identifying areas for further innovation and standardization to guide stakeholders in effectively and sustainably implementing AI and IoT technologies in agriculture.

2 Terms and definitions

Artificial Intelligence (AI) [ITU-T M.3080]: Computerized system that uses cognition to understand information and solve problems.

NOTE 1 – ISO/IEC 2382-28 defines AI as "an interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning".
NOTE 2 – In computer science AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions to achieve its goals.
NOTE 3 – This includes pattern recognition, the application of machine learning and related techniques.
NOTE 4 – Artificial-intelligence is the whole idea and concept of machines being able to carry out tasks in a way that mimics human intelligence and would be considered "smart".

Internet of Things (IoT) [ITU-T Y.2060]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

3 Conventions

None

4 Overview of FGAI4A

In October 2021, the ITU-T SG20 initiated the Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture" (FG-AI4A). This initiative brings together a diverse set of stakeholders to drive the initial stages of standardization in Digital Agriculture. The Focus Group (FG) is structured (see Figure 1) into five working groups (WGs), with the Working Group on Digital Agriculture Use Cases and Solutions (WG-AS) playing a crucial role. WG-AS identifies and analyzes practical applications of AI and IoT technologies in agriculture.

Key Objectives of FG:

- Identify and analyze practical AI and IoT applications.

- Promote sustainability, efficiency, and productivity in agriculture.
- Drive the standardization process for digital agriculture.

5 Use Cases

Following table 1 encompasses selected use cases, illustrating the dynamic integration of digital technologies in agricultural practices. For each use case, the table presents key aspects such as objectives, innovations, data collection methods, impacts, and deployment states, providing a comprehensive overview of how digital transformation is being realized on the ground. These real-world examples not only illustrate the operationalization of AI and IoT technologies across diverse agricultural settings but also highlight their significant contributions to sustainability, efficiency, and productivity enhancements in the sector

Table 1. Use Case Analysis

Base Contribution	Source	Application Area	Objective	Innivations (Technology Used)	Data	AI /ML Algorithm	Accuracy/ Performance	Deployment State	Key Benefits
[FGAI4A-I-020]	Agro Insider, Portugal	Olive yard management	Enhance olive yard performance	Satellite imagery, NDVI analysis, IoT sensor	Smart sampling, Soil and leaf measurements, Tree biometry, Crop water potential, Olive yield and oil yield data	NDVI analysis	Strong correlation ($R^2 = 0.8702$) between NDVI and tree canopy volume	Field-tested*	Optimized resource use, Increased yield, Better economic returns, Reduced environmental impact
FGAI4A-I-021	Agro Insider, Portugal	Rice Cultivation	Improve agronomic practices and enhance yield in rice production	AgroRadar, Spectral Analysis	Smart sampling, Soil and leaf measurements, Crop water potential, Yield data	NDVI analysis	Significant yield increase ($R^2 = 0.678$ between NDVI and yield)	Field-tested*	Significant ROI, enhanced yield and resource efficiency
FG-AI4A-I-062	National Laboratory, Kyoto University	Groundwater Sustainability Assessment	Assess groundwater sustainability using deep learning and InSAR data	Deep learning, InSAR technology	Satellite and ground deformation data	Deep auto-encoder models for ground deformation detection	Improved accuracy in detecting ground subsidence	Ongoing research project	Provides actionable information for groundwater management, supports sustainable food production policies
FG-AI4A-I-089	Electronics and Telecommunications Research Institute (ETRI), Korea	Autonomous Irrigation	Develop an autonomous irrigation system using AI to optimize watering	AI, IoT sensors, Edge Computing, LoRa technology	Soil moisture sensors, weather data, SAP flow information	AI prediction models for irrigation start points	Over 90% accuracy in predicting irrigation needs, improving water use efficiency and crop resilience to climate variability.	Field-tested	Efficient water use, reduced manual intervention, improved crop resilience to climate variability

FG-AI4A-I-094	Microsoft Azure, International Data Spaces Association	Data Collaboration in Data Spaces	Enable secure, sovereign, decentralized data sharing across ecosystems	W3C DCAT/DID/VC/ODRL, IDSA, GAIA-X, CNCF	Data exchange between cloud platforms	EDC, Apache 2.0 license for commercial usage	Facilitates secure, interoperable data exchange	Implemented	Enhances data sovereignty, supports flexible data space design, fosters cloud and data platform integration
FG-AI4A-I-109	Tata Consultancy Services – Digital Food Initiatives, India	Disease Identification in Corn Leaves	Detect and classify corn leaf diseases using CNN and boosting techniques	Convolutional Neural Networks (CNN), Boosting	Images of corn leaves in different health states	NN and Adaptive Boosting	98% accuracy in classifying corn leaf diseases	Pilot-tested	Early disease detection, improved crop management, reduced input costs, higher yield
FG-AI4A-I-110	Fraunhofer Portugal AICOS, GeoDouro—Consultoria e Topografia Lda, Associação para o Desenvolvimento da Viticultura Duriense	Pest Monitoring in Viticulture	Develop an AI-powered mobile solution for automated pest monitoring	AI, IoT, Mobile Computing, SSD ResNet50	Mobile-acquired images of sticky traps	SSD ResNet50 model for insect detection	Class-specific accuracy ranging from 82% to 99%	Field-tested	recommendations, cost-effective and scalable solution
FG-AI4A-I-112	Tata Consultancy Services – Digital Food Initiatives, India	UAV-assisted Detection of Red Spider Mites in Te	Detect Red Spider Mite infestations in tea plantations using UAVs	UAVs with high-resolution cameras, Deep Learning (YOLOv5)	Geo-tagged images of tea crops	YOLOv5, Adam optimizer, cosine LR schedule	Over 95% accuracy in detecting RSM hotspots	Pilot-tested	Early pest detection, reduced chemical use, improved crop health and yield, precise pest management
FG-AI4A-I-138	Ministry of Communications, India	Precision Agriculture	Enhance precision farming using IoD and 5G technology	5G-enabled drones, IoT sensors, AI/ML algorithms, edge computing	UAV-captured images, real-time sensor data	AI/ML models for real-time data analysis and decision making	Over 95% accuracy in crop health monitoring and site-specific interventions	Pilot-tested	Improved crop monitoring, reduced latency in data processing, efficient resource management, enhanced productivity
FG-AI4A-I-142	Ministry of Communications, India	Agriculture (in general)	Monitor and manage soil moisture for efficient irrigation	IoT-enabled soil moisture sensors, Arduino microcontroller, Wi-Fi/GSM module	Real-time data collection, Calibration and validation of sensors	Random Forest, MARS	Sensor accuracy of ±3%, operational range 0% to 100%	Pilot-tested	Enhanced water conservation, Improved crop productivity, Reduced

							moisture content		waterlogging and soil erosion
FG-AI4A-I-143	Ministry of Communications, India	Precision Farming in Banana	Develop IoT-enabled irrigation and AI-based systems for pest, disease, and post-harvest management	IoT moisture sensors, UAVs, AI & ML algorithms	Real-time soil moisture, UAV-captured images	AI/ML models for irrigation, pest, disease management, and post-harvest quality grading	35-40% water savings, 15-20% nitrogen savings, 25-30% yield improvement	Pilot-tested	Optimizes irrigation, improves nutrient use, enhances pest and disease management, improves post-harvest quality
FG-AI4A-I-144	Ministry of Communications, India	Crop Monitoring and Management	Monitor and analyze soil nutrients, physical parameters, and weather for pre-harvest crop management	IoT sensors, AI technology, SAMBHAVTM platform	Real-time data from soil, weather, and leaf sensors	AI-driven data analysis	Achieved a 25% reduction in pesticide usage for pest management	Field-tested	Optimizes irrigation, fertigation, pest, and disease management, improves yield and quality, reduces pesticide use

5.1 Empirical Insights from Digital Agricultural Innovations

5.1.1 Data Science for surface and underground water monitoring

The use case, aims to enhance soil water management using Cosmic-Ray Neutron Sensing (CRNS) technology. This use case submitted by Physikalisches Institut at Heidelberg University in Germany. This approach leverages IoT sensors to gather neutron counts and soil moisture data, providing a non-invasive method for measuring soil moisture over large areas. The data collected is analyzed using machine learning algorithms to improve accuracy and provide real-time insights. Cosmic SWAMP (Smart Water Management Platform) is an IoT-based precision irrigation system designed to optimize water management in agriculture. It integrates Cosmic-Ray Neutron Sensing (CRNS) technology with IoT devices to provide accurate, real-time soil moisture measurements over large areas. The platform aims to enhance irrigation efficiency, conserve water, and improve crop yields through data-driven decision-making.

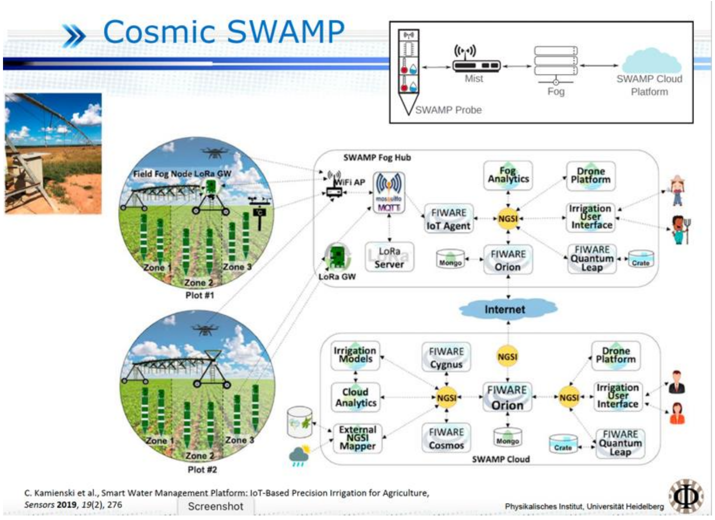

Figure 1. Cosmic SWAMP System Architecture [b-FG-AI4A-I-063]

Aspect	Analytical Insights
AI & IoT-Centric Relevance	The integration of Cosmic-Ray Neutron Sensing (CRNS) with IoT sensors provides a precise and non-invasive method for monitoring soil moisture, crucial for efficient water management in agriculture.
Technological Innovations	CRNS technology bridges the gap between remote sensing and local probes by offering area-averaged soil moisture estimates over large areas (~10 hectares) and significant depths (~50 cm).
Accuracy and Performance	The CRNS system, enhanced with machine learning algorithms, achieves high accuracy in soil moisture measurement, aligning closely with reference data, particularly before and after irrigation events, ensuring reliable data for optimal water management.
Scalability and Deployment	Field-tested[1], its scalability allows adaptation to various agricultural contexts, making it suitable for different crop types and farming scales.
Environmental Impact	By providing accurate soil moisture data, CRNS technology significantly improves soil water management.

[1] Field-tested" means that the technology or method has been tried and evaluated in real-world conditions, outside of a controlled laboratory or experimental setup. It indicates that the implementation has been practically applied in the actual environment where it is intended to be used, and its effectiveness and performance have been assessed under those conditions

Best Practice(s)

Integrate Cosmic-Ray Neutron Sensing (CRNS) with IoT sensors and machine learning algorithms for precise, non-invasive soil moisture monitoring. Conduct extensive field testing to ensure accuracy and scalability, enabling optimized irrigation practices that conserve water, improve crop yields, and enhance sustainability.

Olive Yard Performance Enhancement with AgroRadar Technology

The AGRORADAR project [b-FGAI4A-I-020], as documented in, focuses on improving the performance of olive yards through the utilization of advanced technologies like satellite imagery, NDVI (Normalized Difference Vegetation Index) analysis, and IoT sensors. The project incorporates smart sampling methods to collect extensive data on various parameters including soil and leaf nutrients, tree biometry, crop water potential, and yields of olives and olive oil. NDVI analysis is a key tool in this project, enabling precise monitoring of vegetation health. The high correlation ($R^2 = 0.8702$) between NDVI values and tree canopy volume attests to the accuracy of this approach. This technology has been field-tested, proving its effectiveness in optimizing resource use, boosting yields, and enhancing economic returns. Additionally, it contributes to environmental sustainability by reducing waste, illustrating the transformative impact of AI and IoT in modern agriculture.

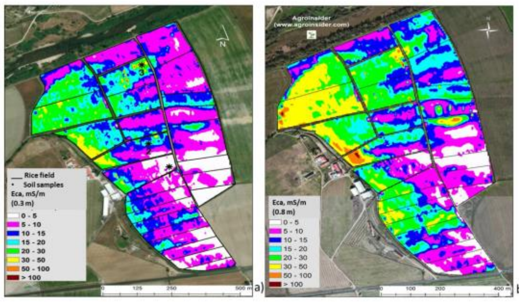

Figure 2a- Soil electro conductivity survey with Varies 3100 with a depth of 0.3 m & 0.8 m depth [b-FGAI4A-I-020]

Rice Performance Enhancement with AgroRadar Technology

As presented [b-FGAI4A-I-021], use case focuses on improving rice crop performance using AgroRadar technology and NDVI analysis. The project integrates smart sampling methods to collect detailed data on soil and leaf measurements, crop water potential, and yield. NDVI analysis plays a critical role in this project, providing significant insights into crop health and potential yield increases, with a correlation ($R^2 = 0.678$) between NDVI values and rice yield. This field-tested approach allows for optimized resource allocation, leading to increased yields and better economic returns. Furthermore, the use of controlled release fertilizers and tailored fertilization strategies based on soil characteristics minimizes nutrient leaching and enhances nitrogen efficiency, reducing environmental impact. This case study highlights the efficacy of AI and IoT in achieving sustainable and profitable agricultural practices, emphasizing the importance of precise, data-driven management.

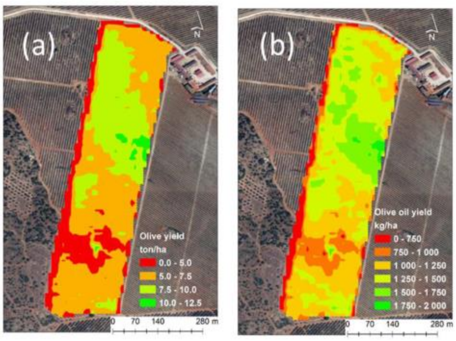

Figure 2b- (a) Olive yield map, (b) Olive oil yield map [b- FGAI4A-I-021]

IoT-Enabled Soil Moisture Sensing System for Efficient Irrigation

As presented in [b- FGAI4A-I-142], this use case describes the development of an IoT-enabled soil moisture sensing system designed to improve irrigation efficiency. The system employs Arduino

Figure 2c. Installation of IoT enabled soil moisture sensor [b- FGAI4A-I-142]

microcontrollers, Wi-Fi/GSM modules for connectivity, and Message Queuing Telemetry Transport (MQTT) protocols for real-time data communication. The sensors, which have been rigorously calibrated and validated, offer precise soil moisture measurements with an accuracy of ±3% across a moisture range of 0% to 100%. This pilot-tested system enhances water conservation by providing accurate, real-time data that enables precise irrigation scheduling. As a result, it improves crop productivity and reduces issues like waterlogging and soil erosion. The use of this technology exemplifies how AI and IoT can optimize irrigation practices, promoting sustainability and efficiency in agriculture.

Analytical Insights Summary of Yield monitoring and Prediction

This table provides a concise summary of the analytical insights for three agricultural use cases, focusing on their AI and IoT-centric relevance, technological innovations, accuracy and performance, scalability and deployment, and environmental impact. It highlights the key benefits and advancements of each use case in a clear and straightforward manner.

Aspect	**Analytical Insights**		
	Olive Yard	Rice	Soil Moisture Sensing
AI & IoT-Centric Relevance	Advanced monitoring using NDVI and IoT sensors for precise data collection and decision-making.	Enhanced crop health monitoring and yield prediction using NDVI and IoT technologies.	Real-time soil moisture monitoring and irrigation management using IoT.
Technological Innovations	Combines satellite imagery, NDVI analysis, and IoT sensors for comprehensive crop management.	Utilizes AgroRadar and NDVI analysis with smart sampling for detailed crop insights.	Integrates Arduino microcontrollers and wireless communication for real-time data collection.
Accuracy and Performance	High accuracy with R^2 = 0.8702 between NDVI and tree canopy volume	Reliable yield prediction with R^2 = 0.678 between NDVI and rice yield.	Sensor accuracy of ±3%, ensuring reliable soil moisture data.
Scalability and Deployment	Field-tested, scalable for various agricultural contexts		Pilot-tested[2], potential for broader implementation across different settings
Environmental Impact	Optimizes resource use, reduces waste and environmental impact.	Reduces nutrient leaching, improves nitrogen efficiency, and minimizes environmental footprint.	Promotes water conservation, reduces waterlogging and soil erosion.

[2] Pilot-tested" refers to a preliminary phase of testing where a system, product, or solution is implemented on a small scale or in a limited scope to evaluate its feasibility, performance, and potential issues before wider deployment. It is an initial trial to gather data, make necessary adjustments, and ensure that the system works effectively under real-world conditions.

Best Practice(s)
Implementing AI and IoT technologies such as NDVI analysis and IoT-enabled soil moisture sensors in precision agriculture enhances the monitoring and management of crop health and resource allocation. These AI & IoT-centric approaches ensure high accuracy in detecting and addressing anomalies, scalable solutions for various agricultural contexts, and significant positive impacts on the environment by optimizing resource use and reducing waste. Continuous monitoring and adaptive management are crucial for achieving long-term sustainability and economic viability in agriculture.

5.1.2 AI-Powered Pest & Disease Monitoring and Management in Agriculture

This comprehensive initiative involves the development of advanced AI-powered solutions to enhance pest monitoring and management in agriculture, focusing on viticulture and tea plantations.

EyesOnTraps AI-Powered Mobile-Based Solution for Pest Monitoring in Viticulture:

Developed by Fraunhofer Portugal AICOS and partners, the EyesOnTraps system uses AI and IoT technologies to improve pest monitoring in vineyards. By automating the detection and counting of key insect species through mobile-acquired images and integrating ambient temperature data, the system provides accurate and timely treatment recommendations. This approach reduces manual labor, increases detection accuracy, and offers a cost-effective, scalable solution for viticulture.

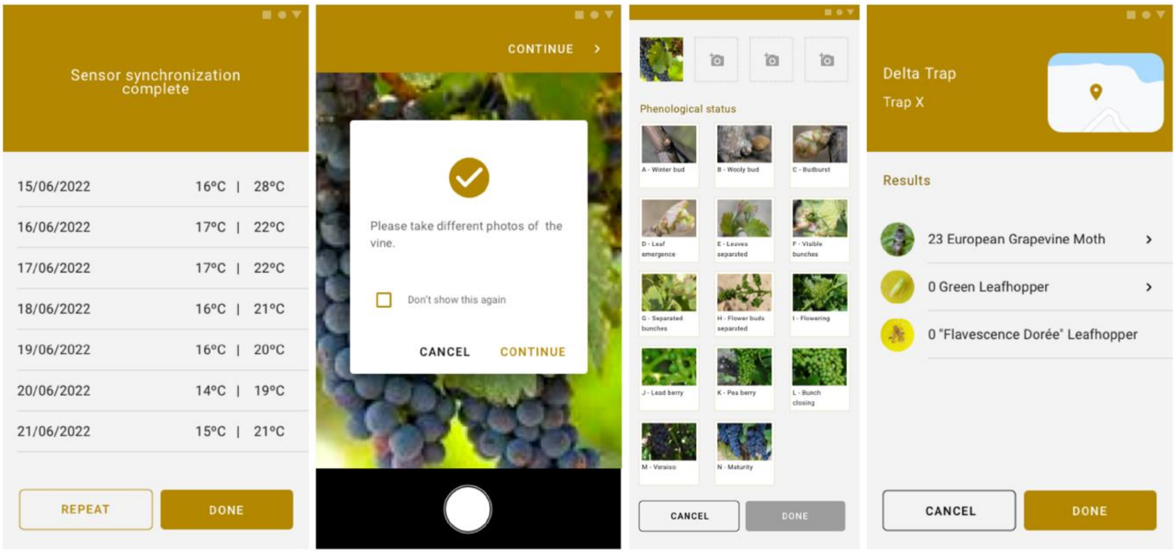

Figure 3 Mobile Application Screens: Temperature Synchronization, Phenological Status Image Acquisition, Selection, and Automated Insect Detection [b- FG-AI4A-I-110]

UAV-assisted Detection of Red Spider Mites in Tea:

Developed by Tata Consultancy Services, this project employs UAVs equipped with high-resolution cameras and deep learning algorithms to detect Red Spider Mites (RSM) in tea plantations. The UAVs capture geo-tagged images, which are analyzed using YOLOv5 to identify RSM hotspots early, enabling timely pest management interventions. This system enhances pest detection precision, reduces chemical use, and improves overall crop health and yield.

Figure 4. Red Spider Mite Hotspot Detection [b- FG-AI4A-I-112]

Aspect	Analytical Insights	
	EyesOnTraps AI-Powered Mobile-Based Solution for Pest Monitoring in Viticultur	UAV-assisted Detection of Red Spider Mites in Tea
AI & IoT-Centric Relevance	Integrates AI-driven image analysis and IoT environmental sensors to provide real-time pest monitoring and data-driven management in vineyards.	Utilizes UAVs equipped with high-resolution cameras and deep learning algorithms to identify and geo-tag Red Spider Mite hotspots in tea plantations.
Technological Innovations	Employs SSD ResNet50 model for automated insect detection on mobile-acquired images, coupled with IoT sensors for ambient temperature monitoring.	Leverages YOLOv5 deep learning models for precise identification and localization of pest infestations, enhancing the accuracy and efficiency of pest monitoring.
Accuracy and Performance	Demonstrates high detection accuracy, with class-specific performance ranging from 82% to 99% accuracy and significant reduction in manual labor.	Achieves 95% accuracy in identifying Red Spider Mite infestations, enabling early intervention and precise pest control measures
Scalability and Deployment	Field-tested, the system is designed for scalability across various vineyard conditions and other agricultural applications.	Field-tested, the solution is scalable for extensive deployment in tea plantations and adaptable to different crop types.
Environmental Impact	Enhances sustainable agriculture by optimizing pesticide use, reducing chemical input, and improving overall vineyard health.	Promotes environmental sustainability by reducing the reliance on chemical treatments, improving crop

		health, and increasing yield through early pest detection.

Best Practice(s)

Integrate AI and IoT technologies for real-time, accurate pest detection and monitoring, utilizing mobile-based solutions and UAVs for data acquisition. Employ advanced deep learning models for precise identification and analysis, ensuring scalability and adaptability across various agricultural contexts. Focus on sustainable practices by optimizing pesticide use, reducing chemical inputs, and enhancing overall crop health and yield.

5.1.3 TG-Irrigation strategy and smart water & climate management

[b-FG-AI4A-I-089] autonomous Irrigation System, developed by the Electronics and Telecommunications Research Institute (ETRI) in Korea, aims to optimize water use in agriculture by leveraging AI and IoT technologies. This system autonomously determines the timing and amount of irrigation needed by crops based on real-time soil moisture levels, weather data, and SAP flow information. By integrating soil moisture sensors and weather data, the system uses AI prediction models to make precise irrigation decisions, reducing manual intervention and ensuring efficient water use. Field tests have demonstrated its effectiveness in improving crop resilience to climate variability and enhancing overall water management efficiency.

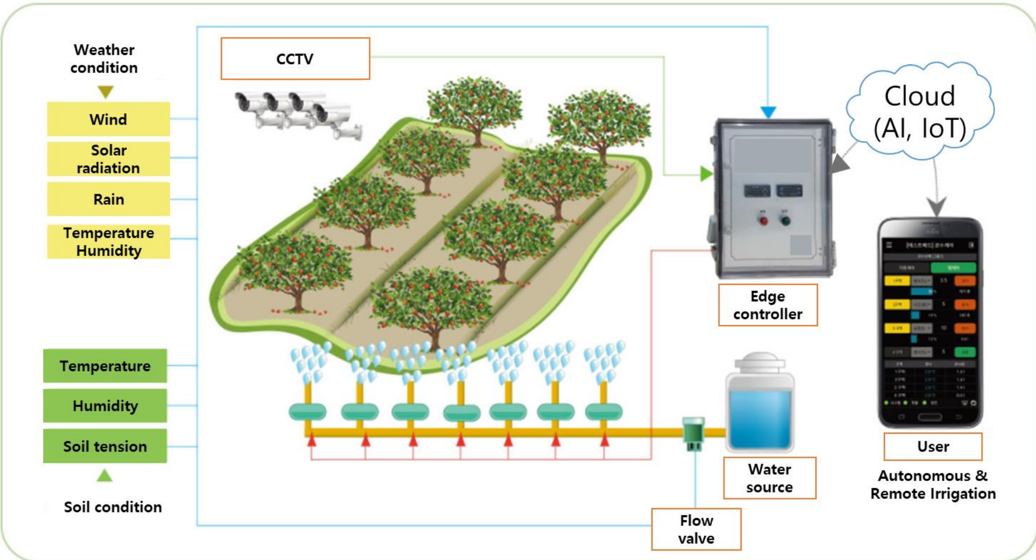

Figure 5 An autonomous irrigation system architecture[b-FG-AI4A-I-089]

[b- FG-AI4A-I-145] use case, submitted by the Ministry of Communications in India, focuses on harnessing sensors and IoT for smart climate and nutrient management in greenhouse cultivation and vertical farming. The system aims to maximize resource utilization, increase crop yields, and reduce environmental impact by deploying interconnected devices and sensors that monitor critical environmental factors such as temperature, humidity, light intensity, and nutrient levels. AI algorithms process this real-time data to dynamically adjust climate conditions and nutrient delivery, ensuring optimal growing conditions for crops. The incorporation of 5G technology facilitates quick communication and remote monitoring, allowing farmers to manage operations more efficiently.

Figure 6. IoT based fertigation system for Greenhouse Capsicum [b-FG-AI4A-I-145]

Aspect	Analytical Insights	
	Autonomous Irrigation System	**Smart Climate and Nutrient Management in Greenhouse and Vertical Farming**
AI & IoT-Centric Relevance	Utilizes AI algorithms and IoT sensors for real-time, autonomous irrigation management based on soil moisture and weather data.	Employs sensors, IoT, AI, and 5G to monitor and optimize climate and nutrient conditions in greenhouses and vertical farming.
Technological Innovations	AI prediction models integrated with IoT sensors automate irrigation, reducing manual intervention and enhancing precision.	Advanced climate and nutrient sensors with AI algorithms dynamically adjust environmental conditions for optimal crop growth
Accuracy and Performance	Over 90% accuracy in predicting irrigation needs, improving water use efficiency and crop resilience to climate variability.	Achieves up to 60% increase in crop yield and 37% higher water use efficiency in hydroponic systems.
Scalability and Deployment	Field-tested, scalable for various crops and environments, promoting broad adoption.	Field-tested, scalable for different greenhouse and vertical farming systems, adaptable to various methods.
Environmental Impact	Optimizes water use, reduces wastage, and enhances sustainability.	Enhances resource efficiency, reduces water and energy consumption, and minimizes environmental impact.

Best Practice(s)

Integrate AI algorithms and IoT sensors for real-time, autonomous management of irrigation, climate, and nutrients, achieving high accuracy and efficiency. Utilize advanced data collection and analysis, combined with 5G connectivity, to dynamically optimize resource use and improve crop yields. Conduct thorough field testing to ensure scalability and adaptability across various agricultural contexts.

5.1.4 Infrastructure

[b- FG-AI4A-I-138] the use case Internet of Drones (IoD) for Precision Agriculture, spearheaded by the Ministry of Communications in India, leverages 5G technology to enhance precision farming. This initiative integrates 5G-enabled drones equipped with high-resolution cameras and various sensors (RGB, multispectral, hyperspectral, thermal) with IoT devices and AI/ML algorithms. The drones collect real-time data on crop health and environmental conditions, which is analyzed using AI and edge computing to provide actionable insights and enable site-specific interventions. Pilot testing has shown high accuracy in crop monitoring, reduced latency in data processing, and improved resource management, leading to enhanced productivity and sustainability in agriculture.

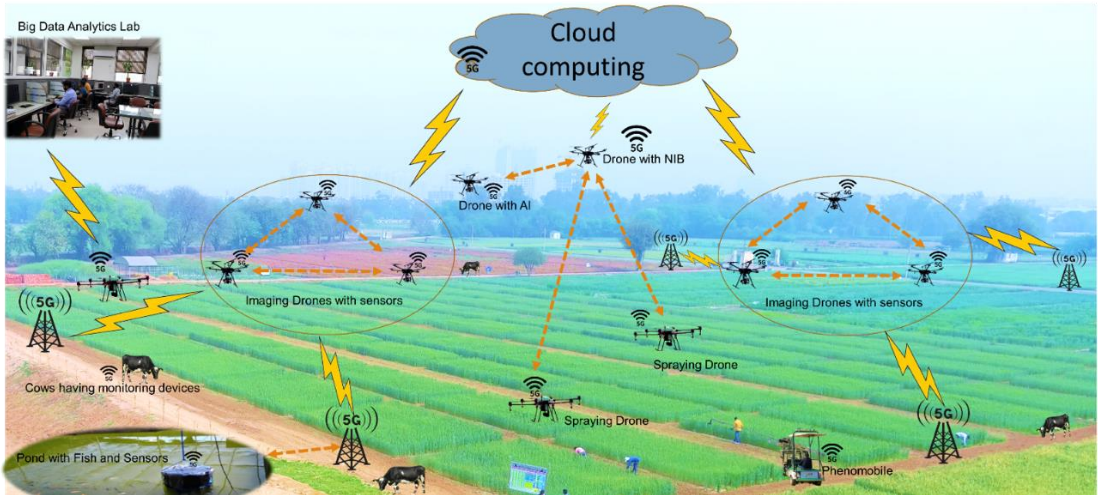

Figure 7. Architecture for implementing Internet of Drones [b- FG-AI4A-I-138]

Aspect	**Analytical Insights**
AI & IoT-Centric Relevance	Integrates 5G-enabled drones with IoT sensors for real-time, high-precision monitoring and data collection in precision agriculture
Technological Innovations	Utilizes AI/ML algorithms and edge computing for on-site data processing and analysis, enhancing decision-making and responsiveness.
Accuracy and Performance	Achieves over 95% accuracy in crop health monitoring and site-specific interventions, ensuring efficient resource management and optimized productivity.
Scalability and Deployment	Pilot-tested[3]
Environmental Impact	By providing accurate soil moisture data, CRNS technology significantly improves soil water management.

[3] Pilot-tested, meaning it has been implemented in a real-world, small-scale environment to evaluate its effectiveness; designed for scalability across different crop types and farming scales, promoting wide adoption.

Best Practice(s)

Leverage 5G-enabled drones and IoT sensors for real-time, high-precision crop monitoring and environmental data collection. Utilize AI/ML algorithms and edge computing for on-site data analysis and decision-making, achieving over 95% accuracy in interventions. Conduct pilot testing to ensure scalability and effectiveness across different crop types and farming scales.

6 Conclusion

The integration of AI and IoT technologies in digital agriculture presents a transformative approach to enhancing productivity, sustainability, and efficiency across various agricultural contexts. This technical report has examined multiple use cases, highlighting their objectives, innovations, data collection methods, AI techniques, accuracy, performance, deployment states, and key benefits. From crop monitoring and pest detection to irrigation management and disease identification, these use cases illustrate the dynamic applications of AI and IoT in modern agriculture.

Key Insights and Best Practices:

1. Advanced Technology Integration:
   - IoT and AI Technologies: The use of IoT sensors and AI algorithms for real-time monitoring and analysis of agricultural parameters has proven effective in optimizing resource use and improving decision-making processes. For instance, the SAMBHAVTM platform integrates IoT sensors and AI to manage soil nutrients and weather conditions, achieving a 25% reduction in pesticide usage.
   - Innovative Platforms: Platforms like SAMBHAVTM and Cosmic SWAMP utilize advanced technologies to provide comprehensive data collection and advisory services, leveraging 5G for fast data communication and real-time decision-making.
2. Effective Data Collection and Analysis:
   - Real-time Monitoring: Sensors and IoT devices provide continuous data on soil moisture, climate conditions, crop health, and more. This data is crucial for making precise and informed decisions, as demonstrated by the IoT-enabled soil moisture sensing system which enhances water conservation and crop productivity.
   - AI/ML Models: Machine learning algorithms analyze collected data to generate actionable insights for irrigation, nutrient management, pest and disease control, and post-harvest quality grading. For example, AI prediction models in autonomous irrigation systems achieve over 90% accuracy in predicting irrigation needs.
3. Scalability and Deployment:
   - Field and Pilot Testing: Thorough field and pilot testing is essential to validate system performance and ensure scalability across different agricultural contexts. Successful pilot tests have demonstrated the feasibility of these technologies in real-world settings, promoting wider adoption.
   - Scalability: The systems are designed to be adaptable to various crop types, farming scales, and environmental conditions, ensuring their broad applicability and effectiveness.
4. Environmental Impact and Sustainability:
   - Resource Efficiency: AI and IoT technologies optimize the use of water, fertilizers, and pesticides through precise interventions, reducing wastage and environmental impact. For example, the precision farming system in banana cultivation achieves significant water and nitrogen savings while improving yield.
   - Sustainable Practices: These technologies enhance sustainable farming practices by minimizing chemical inputs, conserving resources, and improving overall crop health and yield.

5. Continuous Improvement:
- Ongoing Monitoring and Refinement: Continuous monitoring and refinement of AI/ML models based on real-time data and user feedback are crucial for maintaining and improving system performance.
- Adaptation to Local Conditions: Customizing the systems to local agricultural conditions ensures better accuracy and relevance, leading to more effective implementation and outcomes.

In conclusion, the adoption of AI and IoT technologies in digital agriculture has demonstrated significant potential in improving efficiency, sustainability, and productivity. The use cases presented in this report serve as exemplary models for integrating advanced technologies into agricultural practices, highlighting the benefits and best practices for successful implementation. By leveraging these insights, stakeholders can drive further innovations and advancements in the field, contributing to a more sustainable and productive agricultural future.

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