

Supplement

ITU-T Y Suppl. 83 (07/2024)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Supplements to the Y-series Recommendations

Optimizing digital agriculture with best practices for integrating artificial intelligence and Internet of things

Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

GLOBAL INFORMATION INFRASTRUCTURE	Y.100-Y.999
General	Y.100-Y.199
Services, applications and middleware	Y.200-Y.299
Network aspects	Y.300-Y.399
Interfaces and protocols	Y.400-Y.499
Numbering, addressing and naming	Y.500-Y.599
Operation, administration and maintenance	Y.600-Y.699
Security	Y.700-Y.799
Performances	Y.800-Y.899
INTERNET PROTOCOL ASPECTS	Y.1000-Y.1999
General	Y.1000-Y.1099
Services and applications	Y.1100-Y.1199
Architecture, access, network capabilities and resource management	Y.1200-Y.1299
Transport	Y.1300-Y.1399
Interworking	Y.1400-Y.1499
Quality of service and network performance	Y.1500-Y.1599
Signalling	Y.1600-Y.1699
Operation, administration and maintenance	Y.1700-Y.1799
Charging	Y.1800-Y.1899
IPTV over NGN	Y.1900-Y.1999
NEXT GENERATION NETWORKS	Y.2000-Y.2999
Frameworks and functional architecture models	Y.2000-Y.2099
Quality of Service and performance	Y.2100-Y.2199
Service aspects: Service capabilities and service architecture	Y.2200-Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250-Y.2299
Enhancements to NGN	Y.2300-Y.2399
Network management	Y.2400-Y.2499
Computing power networks	Y.2500-Y.2599
Packet-based Networks	Y.2600-Y.2699
Security	Y.2700-Y.2799
Generalized mobility	Y.2800-Y.2899
Carrier grade open environment	Y.2900-Y.2999
FUTURE NETWORKS	Y.3000-Y.3499
CLOUD COMPUTING	Y.3500-Y.3599
BIG DATA	Y.3600-Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800-Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	Y.4000-Y.4999
General	Y.4000-Y.4049
Definitions and terminologies	Y.4050-Y.4099
Requirements and use cases	Y.4100-Y.4249
Infrastructure, connectivity and networks	Y.4250-Y.4399
Frameworks, architectures and protocols	Y.4400-Y.4549
Services, applications, computation and data processing	Y.4550-Y.4699
Management, control and performance	Y.4700-Y.4799
Identification and security	Y.4800-Y.4899
Evaluation and assessment	Y.4900-Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Supplement 83 to ITU-T Y-series Recommendations

Optimizing digital agriculture with best practices for integrating artificial intelligence and Internet of things

Summary

Supplement 83 to ITU-T Y-series Recommendations provides a detailed analysis of how artificial intelligence (AI) and Internet of things (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.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y Suppl. 83	2024-07-12	20	11.1002/1000/16122

Keywords

Agricultural productivity, artificial intelligence (AI), data collection methods, deployment, digital agriculture, efficiency, environmental impact, Internet of things (IoT), machine learning algorithms, resource conservation, scalability, sustainability, technological innovations, use cases.

* To access the Recommendation, type the URL <https://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, and information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this publication may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the standards development process.

As of the date of approval of this publication, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this publication. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2024

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

	Page
1 Scope	1
2 References.....	1
3 Definitions	1
3.1 Terms defined elsewhere	1
3.2 Terms defined in this Supplement	1
4 Conventions	2
5 Abbreviations and acronyms	2
6 Overview of FGAI4A	2
7 Unveiling transformative FGAI4A use cases	4
7.1 Use cases	4
7.2 Empirical insights from digital agricultural innovations	9
8 Conclusions	24
Appendix I – Use case template.....	26
Appendix II – Actor/Business role.....	28
Appendix III – Actor role.....	29
Appendix IV – Communication technologies.....	30
Bibliography.....	31

Supplement 83 to ITU-T Y-series Recommendations

Optimizing digital agriculture with best practices for integrating artificial intelligence and Internet of things

1 Scope

The scope of this Supplement 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 Supplement 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 Supplement 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 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 artificial intelligence (AI) [b-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".

3.1.2 Internet of Things (IoT) [b-ITU-T Y.4000]: 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.

3.2 Terms defined in this Supplement

This Supplement defines the following terms:

3.2.1 field-tested: That a technology or method has been tried and evaluated in real-world conditions, outside a controlled laboratory or experimental set-up. 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.

3.2.2 pilot-test: 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.

3.2.3 ongoing research: Continuous efforts to advance and improve technology, methodologies and understanding in a particular field.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AI	Artificial Intelligence
CNN	Convolutional Neural Network
CRNS	Cosmic-Ray Neutron Sensing
DFI	Digital Food Initiatives
FG-AI4A	Focus Group on AI and IoT for Digital Agriculture
GHG	Greenhouse Gas
ICAR	Indian Council for Agriculture Research
InSAR	Interferometric Synthetic Aperture Radar
IoD	Internet of Drones
IoT	Internet of Things
KPI	Key Performance Indicator
LTE	Long-Term Evolution (4G)
NDVI	Normalized Difference Vegetation Index
RGB	Red, Green and Blue
RSM	Red Spider Mite
SSM	Spatial Soil Moisture
UAV	Uncrewed Aerial Vehicle
UGV	Uncrewed Ground Vehicle
5G	Fifth Generation mobile network

5 Conventions

None.

6 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 application of AI and IoT in agriculture aligns with the United Nations Sustainable Development Goals (SDGs),¹ specifically Goal 2 (Zero Hunger), Goal 13 (Climate Action) and Goal 15 (Life on

¹ <https://www.itu.int/en/action/environment-and-climate-change/Pages/ITU-in-the-UN-Environmental-Agenda.aspx#gsc.tab=0>

Land). Adopting AI and IoT in agriculture not only supports global SDGs but also drives significant advancements in agricultural efficiency, sustainability and productivity. Through real-time data collection and analysis, these technologies enable precise resource management and proactive decision-making, ultimately contributing to a more sustainable and equitable future for global agriculture.

Key objectives of the Focus Group:

- Identify and analyse practical AI and IoT applications.
- Promote sustainability, efficiency and productivity in agriculture.
- Drive the standardization process for digital agriculture.

Figure 1 illustrates the structure and workflow of the Focus Group on Artificial Intelligence & Internet of Things for Digital Agriculture (FG-AI4A). It features several working groups (WGs) focused on different aspects, including glossary (WG-Gloss), data acquisition and modelling (WG-AMD), use cases and solutions (WG-AS), standards-related activities (WG-Roadmap), and ethical, legal, and regulatory considerations (WG-ELR).

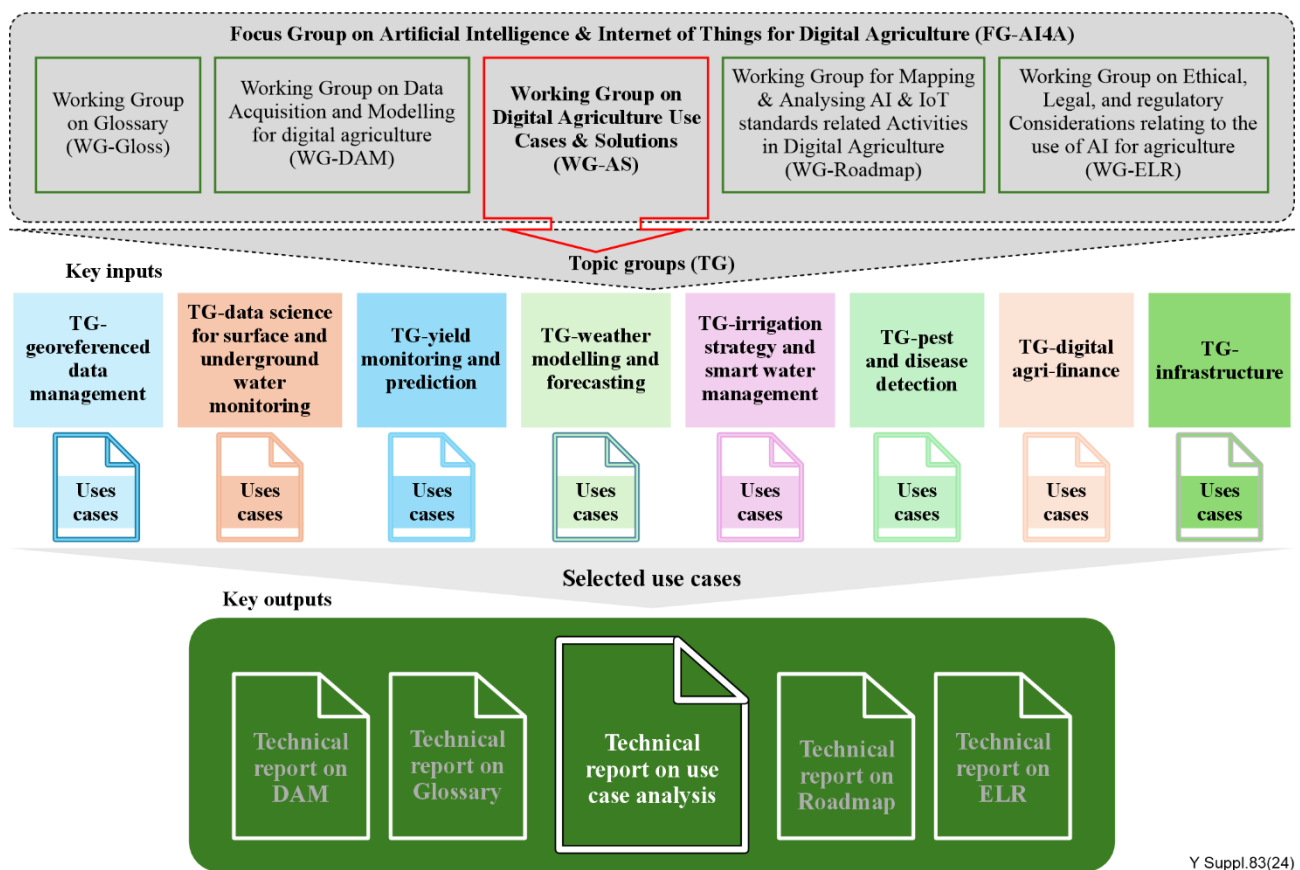


Figure 1 – FGAIA4A structure

Working Group on Digital Agriculture Use Cases and Solutions (WG-AS) plays a crucial role. WG-AS identifies and analyses practical applications of AI and IoT technologies in agriculture. WG-AS designed a template (see Appendix I) in line with ITU guidelines to submit use cases. Key use cases (inputs) are collected by topic groups (TGs) covering areas such as georeferenced data management and data science. These inputs are analysed through practical use cases, leading to the production of comprehensive technical reports on Data Acquisition and Modelling, Glossary, Use Case Analysis, Road Map and Ethical, Legal and Regulatory Considerations. The diagram highlights the systematic approach to leveraging AI and IoT in agriculture, from gathering data to generating detailed technical guidelines and standards.

7 Unveiling transformative FGAI4A use cases

7.1 Use cases

Table 1 categorizes approved use cases into various topics. Table 2 provides a detailed analysis of these use cases, outlining their objectives, technological innovations, data collection methods, AI/ML algorithms, accuracy, deployment states and key benefits. It highlights real-world applications of AI and IoT technologies in agriculture, showcasing their impact on enhancing resource efficiency, sustainability and productivity through improved data-driven decision-making and operational efficiencies.

Table 1 – List of selected use cases

Topic group (TG)	List of use cases
TG-Data Science for surface and underground water monitoring	Data Science for surface and underground water monitoring
	Assessment of the Sustainability of Groundwater Use from Deep Learning and InSAR
	Use of CRNS for soil water management
TG-Georeferenced Data Management	Anonymized Geographical Entity Registration System
	Crop Health and Sustainability Assessment of Farms Using Digital Twins
TG-Yield monitoring and Prediction	Olive Yard Performance Enhancement with AgroRadar Technology
	Rice Performance Enhancement with AgroRadar Technology
	Developing a deep-learning standard for smallholder farm crop yield prediction
TG-Irrigation strategy and smart water management	An autonomous irrigation system
	Use case on Harnessing Sensors and IoT for Smart Climate and Nutrient Management in Greenhouse Cultivation and Vertical Farming
	Use case on Design and development of an IoT-enabled soil moisture sensing system
TG-Pest & Disease Detection	Applications of AI and IoT in Cashewnut farming
	IoT-based Farmland Surveillance System with Disease Detection in Paddy Crops
	Artificial-Intelligence-based Disease Identification in Wheat Crops
	EyesOnTraps: AI-Powered Mobile-Based Solution for Pest Monitoring in Viticulture
	Diseases Identification in Corn Leaves using Convolutional Neural Networks (CNN) and Boosting
	Uncrewed-aerial-vehicle-assisted Detection of Red Spider Mites in Tea
	Use case on IoT-based Intelligent platform for End-to-End Crop Monitoring and Management during Pre-harvest Stages
TG-Infrastructure	Internet of Drones (IoD): Exploring 5G Sky for Agriculture 4.0
TG-Digital Agri-Finance	Supply Chain Finance Linking with Carbon Accounting Data for Agriculture Business and Products (Oxford Roadmapping, National Eco-Industrial Design Institute (China), Hubei University of Technology (China))
	An agriculture impact co-investment platform

Table 2 – Use case analysis

Document ID	Source	Application area	Objective	Innovations (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 return on investment, enhanced yield and resource efficiency
FG-AI4A-I-56	Leibniz Centre for Agricultural Landscape Research (ZALF)	Smallholder farms	Predict crop yields and monitor crop health using deep learning	Convolutional neural networks (CNN), drone-mounted multispectral cameras	CNN, drone-mounted multispectral cameras	CNN	Mean squared error of 0.05, R^2 of 0.85 for yield prediction, 92% accuracy in object detection tasks.	Ongoing research	Provides reliable yield predictions, early disease detection, supports informed decision-making.
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), Republic of 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	AI prediction models for irrigation start points	Over 90% accuracy in predicting irrigation needs	Field-tested	Efficient water use, reduced manual intervention

Table 2 – Use case analysis

Document ID	Source	Application area	Objective	Innovations (technology used)	Data	AI/ML algorithm	Accuracy/performance	Deployment state	Key benefits
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/OD RL, IDSA, GAIA-X, CNCF	Data exchange between cloud platforms	EDC, Apache 2.0 licence 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	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	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	Uncrewed-aerial-vehicle-(UAV)-assisted detection of Red Spider Mites in tea	Detect red spider mite (RSM) infestations in tea plantations using UAVs	UAVs with high-resolution cameras, deep learning (YOLOv5)	Geo-tagged images of tea crops	YOLOv5, Adam optimizer, cosine learning rate 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-137	Krifin	Agricultural investment	Facilitate investments in sustainable agricultural projects through a smart digital platform	AI-driven analytics, IoT-based data collection, real-time monitoring	Environmental, social and economic impact data from agricultural activities	AI-driven analytics, IoT	High accuracy in impact assessment, reliable investment decision support	Ongoing research	Connects investors with sustainable projects, enhances resource management, promotes environmental sustainability
FG-AI4A-I-138	Indian Council of Agricultural Research (ICAR),	Precision agriculture	Enhance precision farming using IoD and 5G technology	5G-enabled drones, IoT sensors, AI/ML algorithms, edge	UAV-captured images, real-time sensor	AI/ML models for real-time	Over 95% accuracy in crop health	Pilot-tested	Improved crop monitoring, reduced latency in