# Technology Innovation Workshop for Environmental Monitoring Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities

APEC Digital Economy Steering Group

May 2026

Asia-Pacific
Economic Cooperation

Asia-Pacific
Economic Cooperation

# Technology Innovation Workshop for Environmental Monitoring Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities

**APEC Digital Economy Steering Group**

**May 2026**

APEC Project: DESG 102 2024A

Produced by
Peruvian Agency for Environmental Assessment and Enforcement (OEFA), attached to the Ministry of the Environment of Peru

Project Management and Technical Coordination:
Odalys Suárez Balcazar
Environmental Specialist

Andrés Campbell Cateriano
Environmental Specialist

Researchers:
Ms. Lisseth Díaz Vargas, MSc.
Project Research Consultant

Ms. Jessica Karen Valverde Alvarado, Mg.
Information Technology Specialist

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org



APEC#226-CT-01.6

Oefa Organismo de Evaluación y Fiscalización Ambiental

# Table of Contents

## 1. GLOSARY

**• Adaptive Governance**
An environmental management approach that integrates flexibility, learning, and cross-sector collaboration to address emerging ecological and technological challenges.

**• Algorithmic Transparency**
A principle stating that AI systems used in public administration must be explainable, auditable, and open to public scrutiny.

**• Big Data (BD)**
Extremely large datasets that can be computationally analyzed to reveal patterns, trends, and associations, particularly those related to human behavior and environmental systems.

**• Blockchain**
A distributed ledger technology that enables secure, traceable, and tamper-resistant databases, frequently used in sustainability certifications and carbon credit systems.

**• Capacity Building**
A process aimed at strengthening institutional, technical, and human resources to enable effective environmental governance and the adoption of technologies.

**• Cloud Computing**
The use of remote servers hosted on the Internet to store, manage, and process environmental data, allowing scalability and real-time analysis.

**• Compliance Automation**
The use of digital systems, AI, and the Internet of Things (IoT) to automatically collect, process, and evaluate compliance data within environmental enforcement processes.

**• Data Governance**
Comprehensive management of the availability, usability, integrity, and security of data within digital monitoring systems, generally regulated through legal and institutional frameworks.

**• Digital Environmental Governance**
A model of environmental management that integrates digital technologies into policy, monitoring, and enforcement systems to enhance efficiency, transparency, and cooperation.

**• Digital Twin**
A virtual model that replicates environmental systems (e.g., ecosystems or industrial processes) using real-time data to simulate, analyze, and predict environmental outcomes.

**• Ethical AI**
The responsible design and use of artificial intelligence, ensuring fairness, non-discrimination, human oversight, and accountability.

**• Explainable AI (XAI)**
A design approach that enables AI systems to be transparent and understandable, clarifying how and why decisions or predictions are produced. It seeks to strengthen trust, accountability, and ethics in AI systems used in contexts with social or environmental impact.

**• Interoperability**
The ability of different information systems, platforms, and organizations to exchange and use data seamlessly through standardized formats and protocols.

**• Machine Learning (ML)**
A subset of AI that enables systems to learn from data and improve performance without explicit programming.

**• Predictive Analysis**
Data analysis techniques that use statistical models and artificial intelligence (AI) to forecast future environmental conditions or identify risks of regulatory non-compliance.

**• Quality Assurance and Quality Control (QA/QC)**
Procedures that ensure accuracy, reliability, and consistency in the collection, processing, and presentation of environmental data.

**• Remote Sensing (RS)**
The collection of information about the Earth's surface through satellites, drones, or aircraft to monitor soil, air, and water quality.

**• Society 5.0**
Japan's strategic vision that integrates digital technologies, including AI and IoT, to balance economic progress with social and environmental well-being.

**• Supervised Learning**
An artificial intelligence method that uses labeled datasets to train models for classification or prediction tasks, commonly applied in environmental triage systems.

**• Traceability**
The ability to verify the origin, transformation, and compliance of products or emissions through digital records, often linked to blockchain systems.

**• Transparency Portals**
Digital platforms that provide public access to verified environmental data, strengthening citizen participation and institutional accountability.

**LIST OF ACRONYMS**

- **AELERT** – Australasian Environmental Law Enforcement and Regulators Network
- **AI** – Artificial Intelligence
- **ALOS-2** – Advanced Land Observing Satellite-2 (Japan)
- **APEC** – Asia-Pacific Economic Cooperation
- **API** – Application Programming Interface
- **APRSAF** – Asia-Pacific Regional Space Agency Forum
- **AWS** – Amazon Web Services
- **BD** – Big Data
- **CEMS** – Continuous Emission Monitoring System
- **CSIRO** – Commonwealth Scientific and Industrial Research Organisation (Australia)
- **DEEN** – Digital Environmental Enforcement Network (proposed APEC mechanism)
- **DESG** – Digital Economy Steering Group (APEC)
- **EO** – Earth Observation
- **EPA** – Environment Protection Authority (Australia)
- **ERP** – Enterprise Resource Planning
- **ESCAP** – United Nations Economic and Social Commission for Asia and the Pacific
- **GEMS** – Geostationary Environmental Monitoring Spectrometer
- **GFW** – Global Forest Watch
- **GIS** – Geographic Information System
- **GLAD** – Global Land Analysis and Discovery
- **IEPS** – Integrated Environmental Permit System (Republic of Korea)
- **INSPIRE** – Infrastructure for Spatial Information in Europe
- **IoT** – Internet of Things
- **IPE** – Institute of Public & Environmental Affairs (China)
- **ISO** – International Organization for Standardization
- **JAXA** – Japan Aerospace Exploration Agency
- **KECO** – Korea Environment Corporation
- **KARI** – Korea Aerospace Research Institute
- **MAFF** – Ministry of Agriculture, Forestry and Fisheries (Japan)
- **MODIS** – Moderate Resolution Imaging Spectroradiometer (NASA)
- **NARO** – National Agriculture and Food Research Organization (Japan)
- **NGII** – National Geographic Information Institute (Republic of Korea)
- **NIER** – National Institute of Environmental Research (Republic of Korea)
- **NISAR** – NASA–ISRO Synthetic Aperture Radar
- **NLP** – Natural Language Processing
- **NWI** – National Water Initiative (Australia)

- **OEFA** – Environmental Assessment and Enforcement Agency (Peru)
- **PCD** – Pollution Control Department (Thailand)
- **POMS** – Pollution Online Monitoring System (Thailand)
- **PPP** – Public-Private Partnership
- **PRISMA** – Palm Oil Remote and Integrated Sustainability Monitoring Application (RSPO, Malaysia)
- **QA/QC** – Quality Assurance / Quality Control
- **RESTEC** – Remote Sensing Technology Center of Japan
- **RS** – Remote Sensing
- **RSPO** – Roundtable on Sustainable Palm Oil (Malaysia)
- **SAR** – Synthetic Aperture Radar
- **SCADA** – Supervisory Control and Data Acquisition
- **SDG** – Sustainable Development Goal
- **SISCrop 2.0** – Sistem Informasi Standing Crop (Indonesia)
- **SMA** – Superintendency of the Environment (Chile)
- **STMS** – Stack Tele-Monitoring System (Republic of Korea)
- **TMS** – Tele-Monitoring System (Republic of Korea)
- **UNEP** – United Nations Environment Programme
- **VNREDSat-1** – Viet Nam Remote Sensing Satellite-1
- **WRI** – World Resources Institute
- **WIN** – Waste Intelligence Network (Australia)

## 2. EXECUTIVE SUMMARY

This document presents the results of the APEC project *“New Technologies for Environmental Enforcement”*, led by the Environmental Assessment and Enforcement Agency (OEFA, Peru), under the supervision of the APEC Secretariat and within the framework of the Digital Economy Steering Group (DESG).

The initiative aligns with the Putrajaya Vision 2040 and the APEC Internet and Digital Economy Roadmap (AIDER), reinforcing APEC economies’ commitment to more efficient, transparent, and inclusive environmental governance.

The study examines how emerging digital technologies—such as artificial intelligence (AI), big data, the Internet of Things (IoT), and remote sensing (RS)—are transforming environmental monitoring and enforcement systems, promoting regulatory efficiency, data traceability, and technical cooperation among economies.

Through a process combining technical analysis, comparative review, and policy dialogue, the project identifies trends, good practices, and shared lessons that guide the transition toward collaborative, evidence-based digital environmental governance.

The research draws on representative experiences from Australia; Canada; Chile; Indonesia; Japan; Republic of Korea; Malaysia and Thailand complemented by the outcomes of the *APEC Technology Innovation Workshop for Environmental Monitoring*, held in Incheon, Republic of Korea (July–August 2025).

These experiences illustrate the rapid shift from reactive enforcement approaches toward predictive, integrated, and data-driven models, where technology becomes a key ally for institutional transparency and environmental compliance.

The results show that APEC economies are incorporating digital technologies to automate processes, anticipate risks, and optimize public resources, shaping a new enforcement architecture based on timely and verifiable information.

Examples such as Thailand’s CEMS/POMS system, Republic of Korea’s CleanSYS telemonitoring system (TMS), Australia’s Waste Intelligence Network (WIN), and the agricultural remote sensing models NARO–MAFF (Japan) and SISCrop 2.0 – National Crop Monitoring System (Indonesia) demonstrate how the integration of sensors, satellite data, and analytical algorithms strengthens operational efficiency and environmental transparency.

In the aquaculture sector, Chile uses a remote monitoring platform that enables risk-based management approaches, prioritizing inspections and improving institutional response capacity.

The integration of geospatial data, satellite observation, and machine learning is laying the foundation for a regional environmental monitoring infrastructure capable of facilitating interoperability, information exchange, and cooperation in the face of transboundary risks. However, this technological transition requires a robust ethical framework: the adoption of AI in environmental management must ensure algorithmic transparency, human oversight, and data protection. Experiences from INECE (United States), AELERT (Australia), and NGII (Republic of Korea) demonstrate that public trust and institutional effectiveness depend on these principles.

The analysis of the case studies and the technical dialogue identifies five critical success factors for advancing toward effective and sustainable digital environmental enforcement:

1. Interoperability and quality assurance/quality control (QA/QC) of environmental data.
2. Clear institutional governance, with defined responsibilities and cross-sector coordination.
3. Technological and financial sustainability, ensuring operational continuity and system maintenance.
4. Multi-stakeholder participation, integrating government, academia, the private sector, and civil society.
5. Regional scalability and replicability, supported by modular infrastructures and open standards.

Despite these advances, structural challenges continue to shape the pace of technological adoption. These include connectivity gaps, the absence of common interoperability and metadata standards, cybersecurity risks, and limited technical training for the use of digital platforms. Overcoming these limitations requires a comprehensive approach that combines technological innovation, technical cooperation, sustained investment, and shared ethical principles.

Likewise, the document proposes a series of non-binding guidelines that APEC economies may consider to strengthen their systems of digital environmental governance:

- Promote common principles of data ethics and governance, adapted to local regulatory contexts and institutional capacities.
- Advance mechanisms for interoperability and quality certification of environmental information, based on voluntary standards and regional best practices.
- Strengthen training programs, technology transfer, and knowledge exchange for environmental agencies and enforcement authorities.
- Foster cooperation networks and applied research initiatives, leveraging existing dialogue spaces and technical platforms within APEC.

These actions consolidate a culture of collaborative innovation that balances technological progress with the values of equity, inclusion, and sustainability that characterize the APEC community.

In summary, the digitalization of environmental enforcement represents a strategic opportunity to modernize public management, enhance transparency, and strengthen citizen trust in environmental institutions.

The evidence gathered demonstrates that the convergence between technology and governance enables a transition from a reactive control model to a predictive, transparent, and preventive one, in which real-time information supports more just, sustainable, and evidence-based decision-making.

The project’s findings reinforce the leadership of participating economies in advancing digital, collaborative, and ethical environmental enforcement, consolidating APEC’s role as a platform for dialogue, innovation, and collective action in support of inclusive and sustainable digital environmental governance.

## 3. INTRODUCTION

Environmental monitoring in the 21st century is undergoing a profound transformation driven by the convergence of digital technologies, advanced data systems, and innovative models of environmental governance. Across APEC economies, this shift is redefining how environmental performance is measured, verified, and enforced. The integration of Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Remote Sensing (RS) has generated new capabilities for real-time observation, predictive modeling, and evidence- based decision-making, strengthening transparency, accountability, and institutional responsiveness throughout the region.

In this context, the project *"New Technologies for Environmental Enforcement"* was designed to identify, document, and analyze successful models of digital environmental monitoring implemented in APEC economies, with emphasis on their technological architectures, regulatory frameworks, institutional enablers, and potential for regional replication. The initiative was coordinated by the Environmental Assessment and Enforcement Agency (OEFA, Peru) and executed with the technical collaboration of institutions and agencies from Japan, Republic of Korea, Thailand, Indonesia, Malaysia, and other APEC member economies.

The project directly responds to APEC's strategic priorities in digital economy, innovation, and sustainable growth, and aligns with the Putrajaya Vision 2040, which promotes the construction of an open, dynamic, resilient, and peaceful Asia-Pacific community. Its objective is to strengthen regional capacities in environmental digitalization, fostering interoperability, data ethics, and institutional cooperation as pillars of sustainable governance.

The methodological approach combined literature review, regulatory mapping, and comparative case analysis, along with the APEC Workshop on Technological Innovation for Environmental Monitoring held in Incheon, Republic of Korea, in July–August 2025. This event gathered more than seventy experts, policymakers, and technical specialists from twelve economies, offering a comprehensive platform for dialogue, experience- sharing, and the formulation of public policy recommendations. The cases presented— such as The Republic of Korea's Smart Telemonitoring System (STMS), Japan's NARO– MAFF platform, Malaysia's blockchain-based PRISMA model, and Chile's AI-assisted enforcement framework—illustrate the diversity of technological trajectories and evolving institutional arrangements across the region.

In this analytical framework, the document conceptualizes digital environmental enforcement as a multidimensional process that requires:

- Technological transformation, through the adoption of systems based on AI, IoT, cloud computing, and blockchain for continuous environmental monitoring and data integration.
- Institutional adaptation, ensuring that environmental agencies possess the organizational and technical capacities needed to manage complex datasets, validate information, and translate it into effective decision-making.

- Ethical and regulatory oversight, establishing transparency, data integrity, and the protection of citizen rights in the design and operation of digital monitoring systems.
- Regional cooperation, fostering harmonized standards, interoperability mechanisms, and sustained capacity development across APEC economies.

The introduction thus establishes the conceptual foundation of the document:

- It positions environmental digitalization within APEC's broader policy framework for sustainable and inclusive growth.
- It articulates the methodological basis for the comparative analysis of case studies, integrating technological, institutional, and regulatory dimensions.
- It defines the scope of the study, emphasizing ethics, interoperability, and cross- border cooperation as critical enablers of a shared regional framework.

Ultimately, this document positions digital environmental governance not merely as a technological innovation, but as a transformative paradigm for sustainability. By converting environmental data into operational intelligence, APEC economies can move from reactive control to predictive, data-driven governance, strengthening regulatory effectiveness, enhancing fiscal transparency, and ensuring that technological progress translates into tangible benefits for environmental quality, institutional legitimacy, and public trust.

**Alignment with APEC Strategic Frameworks**

The Final Policy Report is framed within APEC's long-term strategic vision toward 2040, established in the Putrajaya Vision 2040, which aspires to build an open, dynamic, resilient, and peaceful Asia-Pacific community. The project directly contributes to the second economic driver—Innovation and Digitalization—by promoting the application of emerging technologies such as Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Remote Sensing (RS) in environmental monitoring. Through these technologies, the initiative strengthens digital governance, fosters interoperability, and promotes greater data transparency among APEC economies.

Likewise, the initiative contributes to the implementation of the APEC Internet and Digital Economy Roadmap (AIDER), endorsed by APEC Senior Officials in Da Nang (2017). Specifically, it operationalizes its main areas of action:

a) development of digital infrastructure;
b) interoperability of environmental data platforms;
c) promotion of innovation and enabling technologies; and
d) strengthening trust, security, and ethics in digital systems.

As a project implemented under the Digital Economy Steering Group (DESG) of the Committee on Trade and Investment (CTI), it aligns with the Digital Innovation Sub-Fund and supports APEC's collective efforts to strengthen digital capacities and cooperation among member economies. The document also responds to the principles established in the Aotearoa Plan of Action (2021), which operationalizes the Putrajaya Vision by promoting the integration of innovation, inclusion, and sustainability into domestic and regional policies.

Taken together, these frameworks provide a coherent foundation for the present project, positioning it as a tangible contribution to APEC's goal of fostering quality growth based on innovation, data-driven governance, and regional cooperation.

## 4. PROJECT FRAMEWORK AND CONTEXT: OVERVIEW OF AI AND BIG DATA TECHNOLOGIES IN ENVIRONMENTAL ENFORCEMENT IN APEC

The incorporation of Artificial Intelligence (AI) and Big Data technologies into environmental enforcement represents a paradigm shift in the management of natural resources and sustainability across APEC economies. These tools have redefined how environmental authorities collect, process, and analyze information, enabling predictive, evidence-based, and cost-efficient monitoring systems (OEFA, 2025). Through advanced data analytics, real-time processing, and cloud-based interoperability, AI and Big Data drive a new model of governance centered on transparency, accountability, and technological cooperation.

### 4.1. Digital Transformation in Environmental Monitoring

The convergence of AI and the Internet of Things (IoT) has transformed the collection and analysis of environmental data. Intelligent monitoring systems integrating IoT sensors, satellite data, and AI algorithms enable continuous environmental observation, predictive modeling, and automated decision-making, significantly improving accuracy and operational efficiency (Miller et al., 2025).

This digital transformation supports proactive management, anticipates risks, and enables preventive action in the face of environmental threats—critical components for strengthening regional resilience and sustainability.

In APEC economies, this technological evolution has accelerated the modernization of enforcement systems. Data platforms equipped with machine learning (ML) models can now detect anomalies, correlate emission patterns, and forecast critical thresholds in air, water, and soil quality. These innovations reduce inspection costs and improve compliance rates, in alignment with APEC's agenda for green growth and digital inclusion.

### 4.2. Sectoral Applications

In water resource management, artificial intelligence (AI) and Big Data have optimized quality assessment, resource allocation, and demand forecasting, overcoming the limitations of traditional manual sampling. Predictive models integrate hydrological data from distributed sensors to manage consumption and prevent contamination events, thereby contributing to long-term water security (Kamyab et al., 2023).

In the industrial sector, the implementation of smart sensors, continuous monitoring systems, and cloud-based platforms—such as the CEMS and POMS frameworks in Thailand or the Waste Intelligence Network (WIN) in Australia—has significantly reduced pollution incidents and improved emissions traceability by automating environmental control and ensuring data quality.

These innovations demonstrate the dual benefits of digital technologies for sustainability and industrial competitiveness, in line with APEC's objectives of efficiency and transparency. In the agricultural sector, integrated AI–IoT systems and remote sensing have transformed production and environmental enforcement by enabling remote crop monitoring, irrigation optimization, and early anomaly detection. Models such as SISCrop 2.0 in Indonesia, NARO–MAFF in Japan, and RDA/NASC in Republic of Korea integrate satellite imagery (Sentinel, ALOS-2, CAS500-4) with meteorological data and field sensors, achieving accuracies above 90% in yield estimation and agricultural productivity analysis (Al Mashhadany et al., 2024).

In the fisheries and aquaculture sector, digitalization has also enabled substantial progress: Chile's Environmental Monitoring Intelligence (EMI) platform, operated by the Superintendence of the Environment (SMA), uses satellite imagery, IoT sensors, and AI algorithms to detect unauthorized expansions, changes in water coloration, or environmental non-compliance in salmon farming centers, reducing institutional response times and strengthening risk-based enforcement.

Finally, the use of remote sensing and image analysis through artificial intelligence has achieved classification accuracies above 95% for monitoring land-use change and forest cover (Himeur et al., 2022; Zhang et al., 2020), transforming territorial planning, biodiversity protection, and climate risk assessment across the APEC region.

Taken together, these experiences demonstrate how the convergence of AI, Big Data, IoT, and remote sensing is redefining environmental and production management, consolidating a more efficient, transparent, and sustainable model of digital governance that integrates technological innovation, institutional cooperation, and public ethics as pillars of regional development.

### 4.3. Methodological Advances and Persistent Challenges

The integration of artificial intelligence (AI) with remote sensing data and multisectoral environmental indicators has significantly improved analytical accuracy. Deep learning models and data fusion approaches combine satellite, sensor, and socioeconomic information within coherent decision-support frameworks (Xu et al., 2024).

However, several systemic challenges persist:

a) Interoperability: the fragmentation of databases across institutions limits the integration of information flows and the harmonization of metadata.
b) Data quality and security: inconsistent calibration and limited cybersecurity create risks for the reliability of public environmental systems.
c) Algorithmic transparency: explainable AI (XAI) remains necessary to ensure accountability, public trust, and reproducibility of decisions.

Addressing these challenges requires both technical and institutional innovation, with an emphasis on open standards, regional collaboration, and data-sharing protocols among APEC economies (Alotaibi & Nassif, 2024).

### 4.4. Relevance for APEC and Developing Economies

The adoption of Artificial Intelligence (AI) and Big Data in environmental enforcement strengthens regional cooperation, enhances regulatory capacity, and reduces asymmetries among member economies. Digital platforms facilitate information sharing, the harmonization of best practices, and the training of environmental officials, particularly in developing economies (Popescu et al., 2024; Hajjaji et al., 2021).

For developing and industrializing economies, scalable and open-source infrastructures enable efficient and affordable integration of digital systems, allowing preventive and adaptive monitoring even in resource-limited contexts. This technological democratization fosters more inclusive and resilient growth, consistent with APEC's collective objectives on sustainability and innovation.

### 4.5 Strategic coherence with APEC Frameworks

The findings and recommendations of this document reaffirm APEC's collective commitment to the Putrajaya Vision 2040, which aspires to build an open, dynamic, resilient, and peaceful Asia-Pacific community for the prosperity of all.

By integrating Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Remote Sensing (RS) into environmental enforcement and governance, this project operationalizes the Vision's second economic driver—Innovation and Digitalization—and contributes to the implementation of the Aotearoa Plan of Action (2021).

The initiative also reinforces the objectives of the APEC Internet and Digital Economy Roadmap (AIDER, 2017), particularly with regard to digital infrastructure development, interoperability, and the promotion of trust and security in data-driven systems.

As a project developed under the Digital Economy Steering Group (DESG) of the Committee on Trade and Investment (CTI), it demonstrates APEC's capacity to integrate emerging technologies into sustainable policy frameworks, establishing a regional benchmark for digital environmental governance.

### 4.6. Ethical and Governance Considerations

The implementation of Artificial Intelligence (AI) in environmental enforcement must be accompanied by robust ethical, regulatory, and institutional frameworks. Effective data governance—encompassing privacy, interoperability, and equitable access—is essential to ensure that technological progress does not exacerbate inequalities or information asymmetries (Olawade et al., 2024; Adnan et al., 2024).

The promotion of explainable AI models and multi-stakeholder participation strengthens transparency and public trust, while reinforcing the values of cooperation and accountability promoted by APEC. Consequently, digital governance strategies must integrate innovation with rigorous ethical oversight, ensuring that environmental data remain reliable and are used responsibly.

### 4.7. Strategic Significance and Transition

The integration of Artificial Intelligence (AI) and Big Data into environmental monitoring marks a fundamental transition from traditional, reactive policy frameworks toward intelligent, preventive, and data-driven governance. This transformation aligns with APEC's broader digital agenda, which links sustainability, innovation, and institutional resilience.

By converting environmental data into actionable information, APEC economies are advancing toward interoperable monitoring ecosystems in which technology strengthens both regulatory compliance and sustainability outcomes. Digital tools cease to be peripheral instruments and instead become essential components of governance, enabling transparency, reinforcing accountability, and consolidating cross-border cooperation.

This conceptual framework served as the basis for the APEC Workshop on Technological Innovation for Environmental Monitoring (Incheon, 2025), which examined the practical application of these technologies across member economies. The subsequent analysis synthesizes these experiences, highlighting collaborative contributions, operational models, and shared lessons that illustrate APEC's collective progress toward more digital, transparent, and sustainable environmental enforcement.

.

# 5. WORKSHOP SUMMARY

## 5.1. Purpose and significance of the Workshop

The APEC Workshop on Technological Innovation for Environmental Monitoring – Use of Artificial Intelligence and Big Data in Productive Activities was held at Songdo Convensia, Incheon, Republic of Korea, on 31 July and 1 August 2025, under the sponsorship of APEC and organized by OEFA (Peru), in coordination with the Digital Economy Steering Group (DESG).

The workshop was a key milestone of APEC Project DESG_102_2024A, serving as a platform to validate and expand the findings of Product 1 (Preliminary Research Report) and to exchange experiences on the integration of AI, Big Data, IoT, and Remote Sensing in environmental enforcement.

The event also featured the participation of invited experts from outside the APEC region, particularly from Europe and Latin America, who contributed comparative perspectives on digital governance, data certification, and ethical international cooperation, reinforcing the global and collaborative nature of the initiative.

## 5.2. Workshop Agenda and Thematic Structure

The following presents the agenda of the Technology Innovation *Workshop for Environmental Monitoring, Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities.*

**WORKSHOP AGENDA**
**Technology Innovation Workshop for Environmental Monitoring, Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities**

July 31st and August 1st | Songdo Convensia, Incheon, Republic of Korea

---

**DAY 1:**

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| 08:30 – 09:00 | Participant Registration and ex ante evaluation | | | |
| 09:00 – 09:05 | *Welcome – Opening Remarks* | H.E. Paul Duclos, Ambassador of Peru to the Republic of Korea | Peru | In person |
| 09:05 – 09:15 | *General Overview of the Event* | Peruvian Agency for Environmental Assessment and Enforcement (OEFA) | Peru | In person |

**SESSION 1: INDUSTRIAL SECTOR – REAL-TIME DATA COLLECTION AND USE**
**Moderator: Mr. Gregory Abood, CEO, AELERT Australasian Environmental Law Enforcement and Regulators network (AELERT)**

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| 09:15 – 09:40 | *Bluemap: Public Environmental Data Platforms and Civil Society Participation* | Mr. Jun Ma, Director | Institute of Public & Environmental Affairs – China | In person |
| 09:40 – 10:05 | *Environmental monitoring-innovation delivering more for less* | Dr. Marian Scott, Professor Environmental Statistics | University of Glasgow – United Kingdom | Virtual |
| 10:05 – 10:30 | *Waste Intelligence Network – EPA's journey to share Data and Intelligence* | Mr. John Antony E, Chief Data and Insights Officer | EPA Victoria – Australia | In person |
| 10:30 – 10:45 | *COFEE BREAK* | | | |
| 10:45 – 11:10 | *Pollution Online Monitoring System (POMS)* | Ms. Pantita Buachan Scientist | Department of Industrial Works – Ministry of Industry, Thailand | In person |
| 11:10 – 11:35 | *GEMS Satellite for Real-Time Monitoring of Air Pollution in Asia - The world`s first Geostationary Environmental Monitoring Spectrometer -* | Dr. Won-Jin Lee, Senior Researcher | NIER – Korea | In person |
| 11:35 – 12:00 | *Stack Tele Monitoring System* | Mr. Won-Geun Shin, Division Manager | KECO – Korea | In person |
| 12:00 – 13:00 | Discussion panel y Q&A | Moderate by Mr. Gregory Abood | AELERT – Australia | In-person |
| 13:00 – 14:00 | LUNCH | | | |

WORKSHOP AGENDA

**Technology Innovation Workshop for Environmental Monitoring, Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities**

July 31st and August 1st | Songdo Convensia, Incheon, Republic of Korea

---

**DAY 1:**

**SESSION 2: LEGAL, ETHICAL, AND GOVERNANCE CONSIDERATION**
Moderator: Ms. Alexandria Nelson, Program Director, Digital Economy & Environment, Environmental Law Institute (ELI) and International Network for Environmental Compliance and Enforcement (INECE)

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| **14:10 – 14:15** | *Environmental Law Institute and INECE (International Network for Environmental Compliance and Enforcement) Overview* | **Ms. Alexandria Nelson** Program Director, Digital Economy & Environment | ELI and INECE - USA | In person |
| **14:15 – 14:40** | *AI-assisted triaging system for environmental complaints* | **Mr. Pablo Aguirre,** Head of the Environmental Intelligence Unit | Chile's Environmental Enforcement and Compliance Agency – Chile | Virtual |
| **14:40 – 15:05** | *From Satellite Data to Decisions: Structuring Geospatial Infrastructure for Environmental Oversight and Land Governance* | **Dr. Suyoung Park,** Senior Researcher Officer | National Geographic Information Institute (NGII) – Korea | In person |
| **15:05 – 15:30** | *Prisma by RSPO: A Case Study on Digitalisation, Upgrading Technology and Managing Change* | **Mr. Yen Hun Sung,** Director, Standards & Sustainability | Roundtable of Sustainable Palm Oil (RSPO) – Malaysia | In person |
| **15:30 – 15:55** | *Blueprint for AI Integration in Environmental Agencies: A Strategic Systems Approach* | **Mr. Anthony Rennex** Strategic Systems and Investment Advisor | Department of Natural Resources and Mines, Manufacturing and Regional and Rural Development - Australia | In person |
| **15:55 – 16:20** | *Building regulatory integrity maturity and strategy to deliver material outcomes when using AI and technology* | **Mr. Gregory Abood,** CEO | AELERT – Australia | In person |
| **16:20 – 17:00** | **Discussion Panel and Q&A** | Moderate by **Ms. Alexandria Nelson** | Environmental Law Institute (ELI) / INECE | In person |

**WORKSHOP AGENDA**
**Technology Innovation Workshop for Environmental Monitoring, Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities**

July 31st and August 1st | Songdo Convensia, Incheon, Republic of Korea

**DAY 2:**

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| **08:30 – 09:00** | Participant Registration | | | |
| **09:00 – 09:10** | Welcome Remarks | **Peruvian Agency for Environmental Assessment and Enforcement (OEFA)** | Peru | In person |

**PART I - Satellite and Geospatial Technologies for Agricultural Monitoring**

**Moderator:** Ms. Chochoe Devaporihartakula, Program Manager, Asian Environmental Compliance and Enforcement Network (AECEN)

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| **09:10 – 09:40** | *Forest Foresight: Early detection. Early prediction. Early Intervention* | **Mr. Jorn Dallinga** (In person) Program manager, **Mr. Jonas Van Duijvenbode** (Virtual), Product owner | World Wildlife Fund (WWF) – Netherlands | Hybrid |
| **09:40 – 10:10** | *Utilization SISCrop for Monitoring Standing Crop and Estimation of Rice Production* | **Dr. Haris Syahbuddin**, DEA, Executive Secretary | Ministry of Agriculture – Indonesia | In person |
| **10:10 – 10:40** | *NASA–ISRO NISAR Ecosystems Program* | **Dr. Paul Siqueira** Professor of Electrical and Computer Engineering | University of Massachusetts – USA | Virtual |
| **10:40 – 11:00** | COFFEE BREAK | | | |
| **11:00 – 11:30** | *Korea's Agro-Forestry Satellite: Applications in Forest Disaster, Ecology and Resource Monitoring* | **Dr. Byung-Oh Yoo**, Senior Research Scientist | National Institute of Forest Science (NIFoS) – Korea | In person |
| **11:30 – 12:00** | *Drone-Based and Satellite Monitoring for Agricultural Research and Environmental Management* | **Dr. SukYoung Hong**, Director | Rural Development Administration (RDA) – Korea | In person |
| **12:00 – 13:00** | **Panel Discussion and Q&A** | Moderated by **Ms. Chochoe Devaporihartakula** | AECEN - Asia | In person |
| **13:00 – 14:00** | LUNCH | | | |

WORKSHOP AGENDA

**Technology Innovation Workshop for Environmental Monitoring, Using Technologies Such as Artificial Intelligence and Big Data in Productive Activities**

July 31st and August 1st | Songdo Convensia, Incheon, Republic of Korea

---

**DAY2 :**

**SESSION 3 – PART II:: Digitalization for Sustainability, Traceability, and Environmental Compliance**

**Moderator**: Ms. Chochoe Devaporihartakula, Program Manager, Asian Environmental Compliance and Enforcement Network (AECEN)

| TIME | ACTIVITY | SPEAKER | INSTITUTION / ECONOMY | FORMAT |
|---|---|---|---|---|
| **14:10 – 14:35** | *Case studies on the utilization of Satellite Imagery in agricultural Administration in Japan* | **Mr. Naoki Ishitsuka**, Group Leader | National Agriculture and Food Research Organization (NARO) – Japan | In person |
| **14:35 – 15:00** | *Global Forest Watch* | **Ms. Anne Rosenbarger**, Researcher | World Resources Institute (WRI) – United States | In person |
| **15:00 – 15:25** | *Remote environmental monitoring to strengthen compliance with salmon farming* | **Dr. Julian Cabezas**, Data Scientist and Team Lead | Chile's Environmental Enforcement and Compliance Agency (SMA)– Chile | In person |
| **15:25 – 15:45** | **COFFEE BREAK** | | | |
| **15:45 – 16:10** | *Eyes in the Sky and Eyes on the Data – Embedding Remote Monitoring in Water Compliance Regulation* | **Ms. Margaret Sexton**, Director Innovation, Systems and Intelligence | Natural Resources Access Regulator (NRAR) – Australia | In person |
| **16:10 – 16:35** | *20 Years of Implementing a Voluntary Sustainability Scheme: Evolution of RSPO Standards and Incorporation of Remote Sensing and Technology* | **Mr. Yen Hun Sung**, Director, Standards & Sustainability | Roundtable of Sustainable Palm Oil – Malaysia | In person |
| **16:35 – 17:30** | **Panel Discussion and Q&A** | Moderated by **Ms. Chochoe Devaporihartakula** | AECEN - Asia | In person |
| **17:30 – 17:45** | Closing Remarks + Key reflections, conclusions | Moderators + OEFA Team | Peru | In person |

The workshop combined technical presentations and public policy discussions, bringing together more than seventy participants from twelve APEC economies and associated international organizations.

The agenda was organized progressively, covering topics ranging from technological innovation and digital infrastructures to ethical aspects and institutional governance. See Table 1.

**Table 1. Structure of the Workshop Sessions**

| Day / Session | Theme | Technologies and Approach | Representative Cases |
|---|---|---|---|
| **Day 1 – Session I** | Industrial sector: real-time data collection and use | IoT, AI, Big Data | Blue Map (China), Waste Intelligence Network (Australia), POMS and CEMS (Thailand), GEMS and STMS (Republic of Korea) |
| **Day 1 – Session II** | Legal, Ethical, and Governance Dimensions | Data governance, institutional maturity | SMA (Chile), ELI/INECE (USA), NGII (Republic of Korea), RSPO (Malaysia), AELERT (Australia) |
| **Day 2 – Session III** | Satellite and geospatial technologies for agricultural monitoring | RS, GIS, AI-based analysis | SISCrop 2.0 (Indonesia), NIFoS and RDA (Republic of Korea), WWF (Netherlands) |
| **Day 2 – Session IV** | Digitalization for sustainability, traceability, and environmental compliance | Blockchain, IoT, open data | NARO (Japan), RSPO (Malaysia), WRI (USA), NRAR (Australia), REM (Chile) |

***Source****: Own elaboration*

Each session addressed a specific dimension of digital environmental governance, collectively demonstrating how APEC economies are evolving from reactive monitoring systems toward predictive, data-driven environmental management frameworks.

### 5.3. Analytical Narrative of the Discussions

The analytical narrative of the workshop was organized into four thematic sessions, each focused on a specific yet complementary dimension of digital environmental governance. Taken together, the presentations demonstrated how APEC economies are evolving from reactive enforcement models toward predictive, interoperable, and evidence-based systems supported by the use of Artificial Intelligence (AI), Big Data, and the Internet of Things (IoT).

The sessions also highlighted a growing convergence between technological innovation, institutional strengthening, and ethical governance, emphasizing that digital transformation is not only a technical process but also an organizational evolution aimed at transparency, accountability, and inclusion.

This narrative synthesizes the main discussions and technical insights from the workshop, underscoring the public policy lessons and the strategic outcomes for APEC's regional agenda on digital environmental governance.

## SESSION 1: INDUSTRIAL SECTOR – REAL-TIME DATA COLLECTION AND USE

The first session established the technological foundations of digital environmental monitoring in APEC, focusing on how digital tools and real-time data are transforming environmental enforcement in the industrial sector.

Under the technical moderation of Mr. Gregory Abood, CEO of the Australasian Environmental Law Enforcement and Regulators Network (AELERT), experts from Australia, China, Thailand, Republic of Korea and the United Kingdom participated, along with partner institutions from other regions, enriching the international comparison. The interventions highlighted the transition from a reactive model to a predictive, data-driven one with high standards of transparency, in line with the Putrajaya Vision 2040 and the AIDER Roadmap.

The session unfolded as an integrated technical block in which six presentations demonstrated the evolution of digital monitoring systems across various institutional contexts. From citizen-participation platforms to satellite networks and telemonitoring systems, the block showed a common trajectory toward the institutionalization of real-time environmental monitoring in APEC.

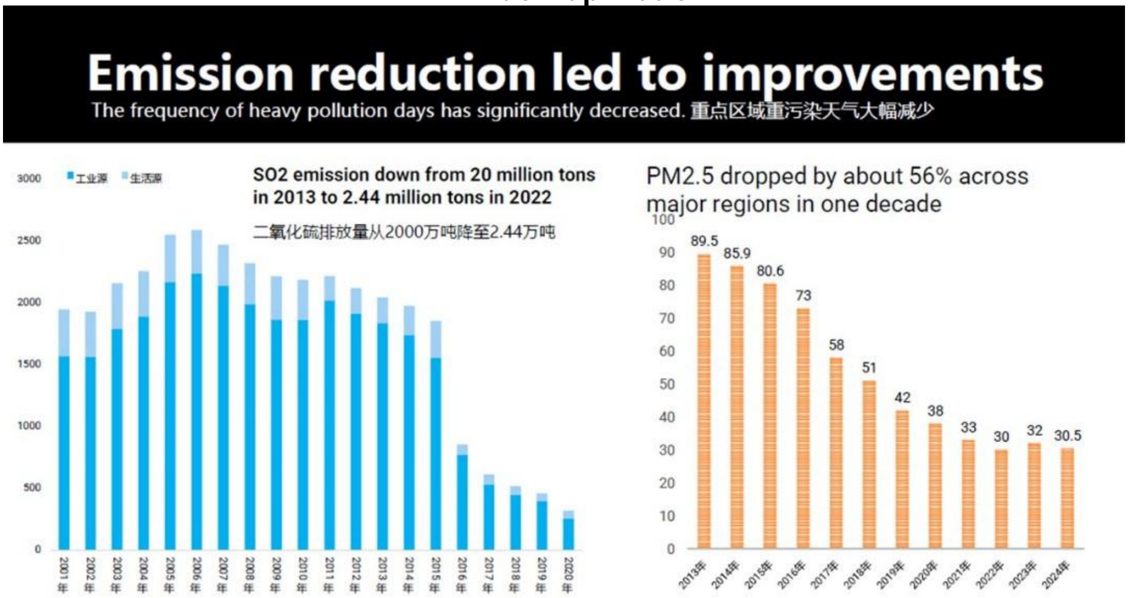
Each case contributed a complementary perspective: data transparency (China and the United Kingdom), predictive analytics (Australia), automated compliance (Thailand), satellite-based modelling (Republic of Korea–NIER), and institutional telemonitoring (KECO).

- **Mr. Jun Ma – Director, Institute of Public and Environmental Affairs (IPE), China**
  **Topic:** Blue Map for the Green Transition

Mr. Jun Ma presented Blue Map, China's flagship environmental transparency platform, which integrates real-time emissions and compliance data from government sources. The application enables citizens and civil society organizations to submit "micro-reports" on potential violations, linking public oversight with enforcement actions.

The model contributed to reducing $SO_2$ emissions from 20 to 2.4 million tons over ten years, demonstrating the impact of transparency and social participation.

**Figure 01. Reduction of $SO_2$ Emissions in China (2013–2022): Impact of the Blue Map Platform**

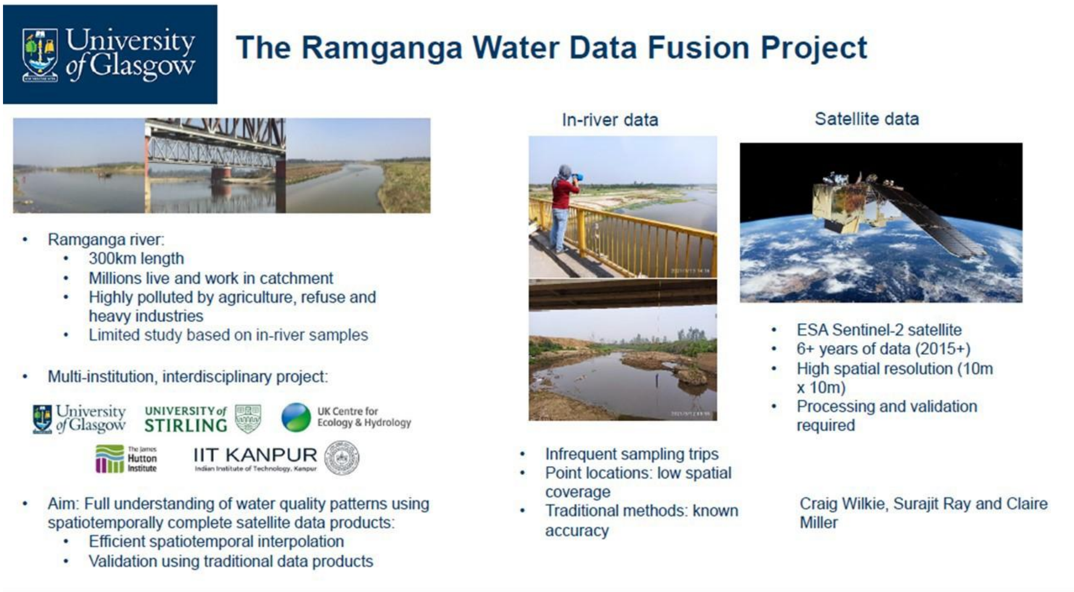



***Source:*** *Mr. Ma Jun (2025). The Blue Map for Green Transition. Institute of Public & Environmental Affairs (IPE), Incheon, Republic of Korea. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Dr. Marian Scott – University of Glasgow (United Kingdom)**
  **Topic:** Environmental monitoring – innovation delivering more for less

Dr. Marian Scott presented the Digital IEM framework, which integrates IoT sensors, satellite observation, quantum sensors, and digital twins to establish adaptive monitoring systems. Her approach, based on data fusion and interoperability, supports evidence- based environmental governance consistent with the Putrajaya Vision 2040.

**Figure 02. Ramganga River Data Fusion Project: Integration of Satellite and In-Situ Data for Adaptive Monitoring**

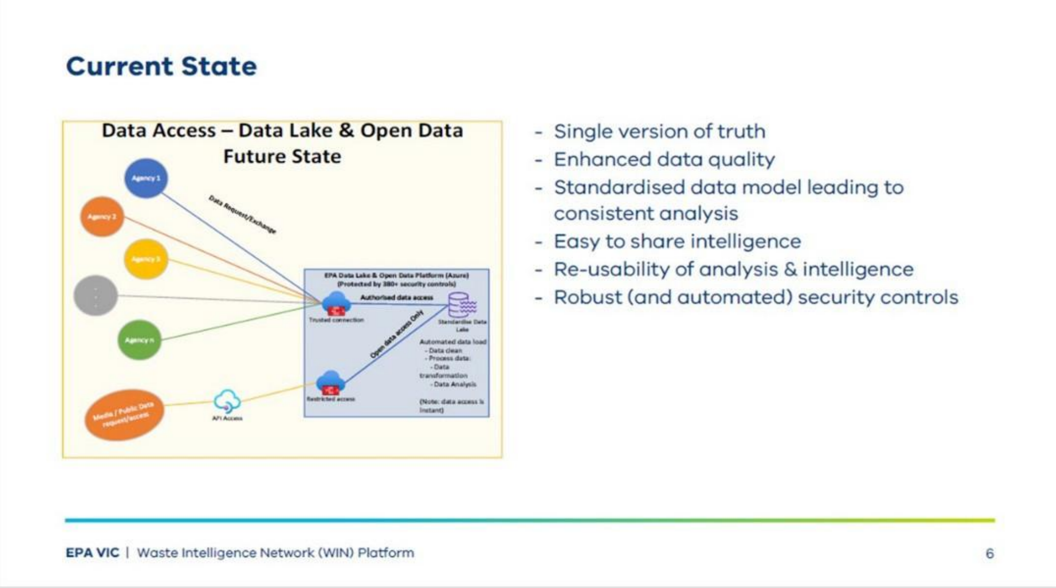



***Source:*** *Dr. Scott Marian (2025). Environmental Digital Monitoring: Innovation Delivering More for Less. School of Mathematics and Statistics, University of Glasgow, United Kingdom. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Mr. John Antony – Director of Data and Information, EPA Victoria (Australia) Topic:** Waste Intelligence Network (WIN): Big Data for Environmental Enforcement

Mr. John Antony presented WIN, an inter-agency platform that integrates 33,000 inspections and 15,000 operators within a secure cloud environment supported by AI-based analytics. The system reduces processing times and detects illegal dumping, strengthening cooperation among environmental, prosecutorial, and police authorities.

**Figure 03. Current Status of the Waste Intelligence Network (WIN): EPA Victoria's Open Data Platform and Data Lake (Azure)**

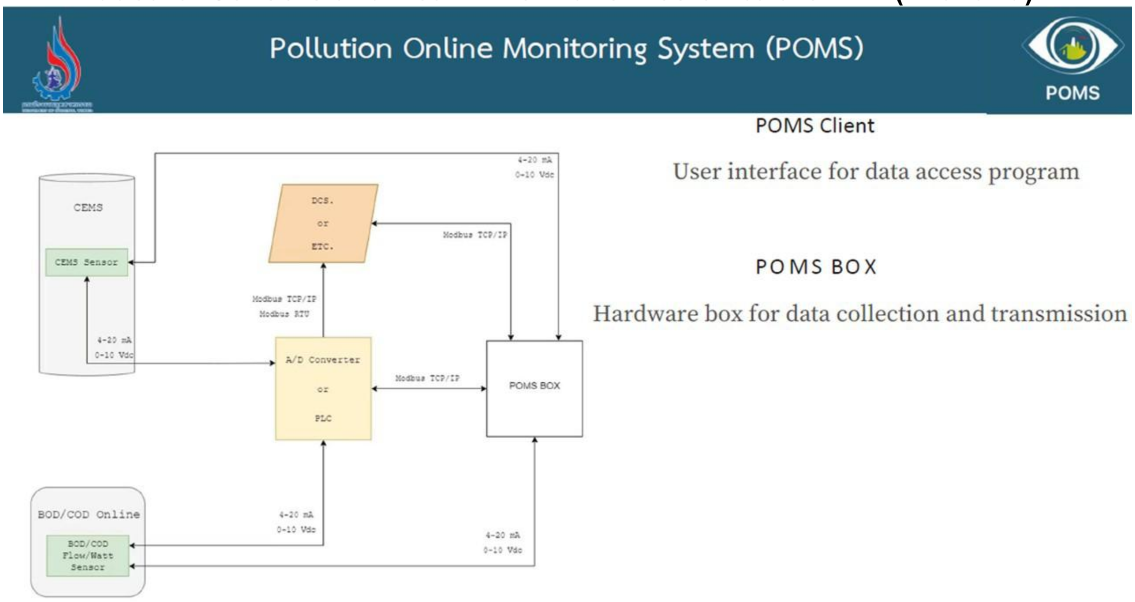



***Source:*** *Mr. Antony John. (2025). Digital Platform of the Waste Intelligence Network (WIN)*
*– Current Achievements. Environment Protection Authority Victoria (EPA VIC), Australia. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Ms. Pantita Buachan – Department of Industrial Works (DIW), Ministry of Industry, Thailand**
  **Topic:** Improving Transparency and Regulatory Compliance through CEMS and POMS in Thailand's Industrial Sector

Ms. Pantita Buachan explained the dual CEMS/POMS framework, which requires industrial facilities to implement black-box devices for the real-time transmission of emissions and effluent data. The system ensures the integrity and non-tampering of information, and its expansion toward water-quality monitoring reflects a high level of institutional maturity.

**Figure 04. Data Connectivity Architecture of the POMS System: Integration of Industrial Sensors and Real-Time Transmission to the DIW (Thailand)**

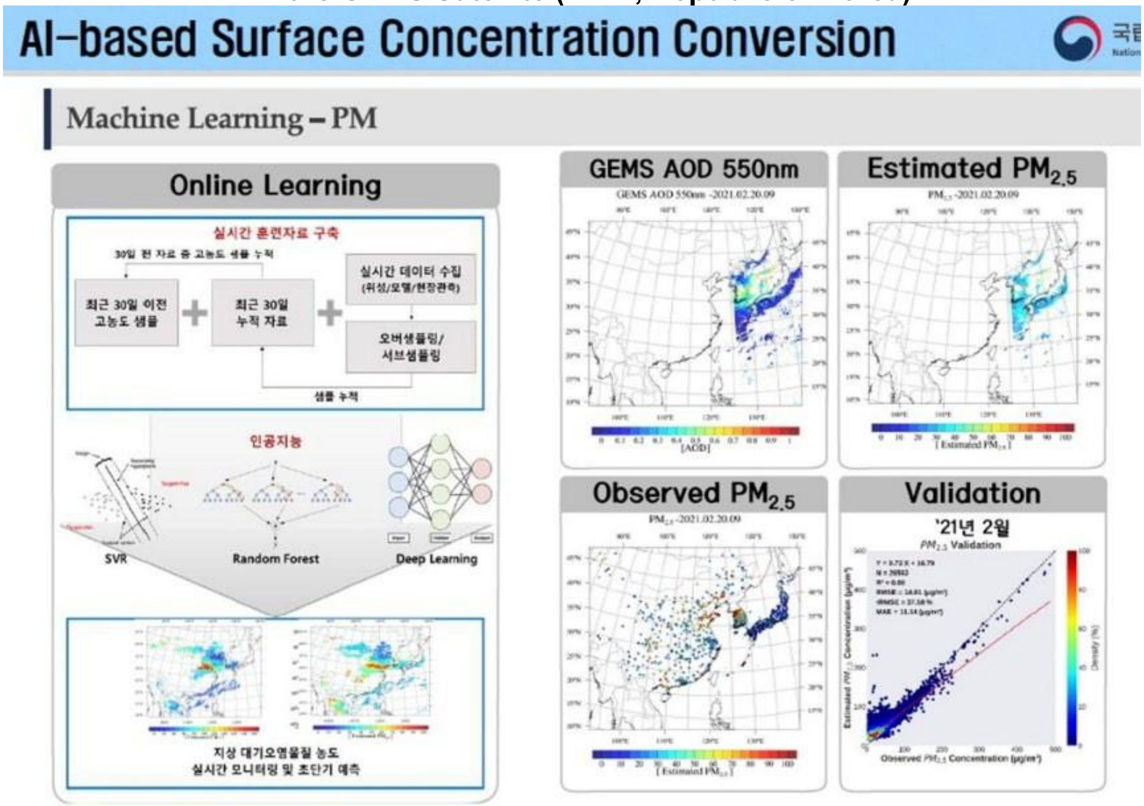



***Source:*** *Ms. Buachan, Pantita. (2025). Enhancing Transparency and Regulatory Compliance Through CEMS and POMS in Thailand's Industrial Sector. Department of Industrial Works, Ministry of Industry, Thailand.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, July 31, 2025.*

- **Mr. Won-Jin Lee – Principal Researcher, National Institute of Environmental Research (NIER), Republic of Korea**
  **Topic:** GEMS Satellite for Real-Time Air Pollution Monitoring in Asia – AI and Big Data for Air Quality Management

Mr. Lee presented the GEMS satellite (GEO-KOMPSAT-2B), which provides hourly data on air pollutants across East Asia. Through the use of AI and Big Data, the system correlates pollution levels with economic and health variables. The satellite is part of the Geostationary Air Quality Constellation (GEMS–TEMPO–Sentinel-4), strengthening regional interoperability in atmospheric monitoring.

**Figure 05. Machine Learning Workflow for Estimating $PM_{2.5}$ Using Data from the GEMS Satellite (NIER, Republic of Korea)**

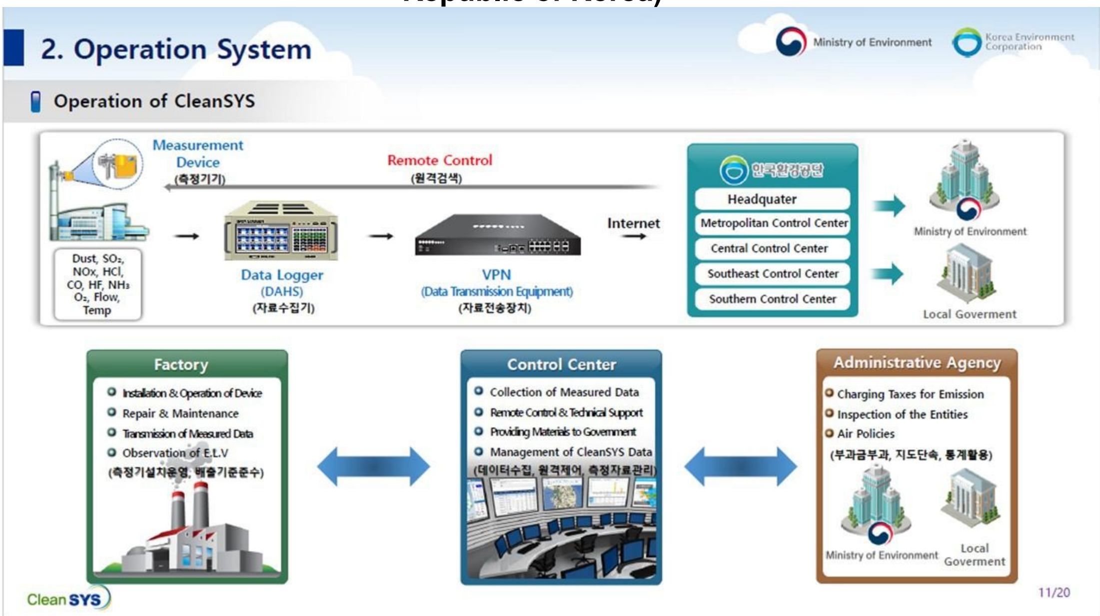



***Source**: Mr. Lee Won-Jin. (2025). GEMS Satellite for Real-Time Monitoring of Air Pollution in Asia: Applications of AI and Big Data for Air Quality Management. National Institute of Environmental Research (NIER), Republic of Korea.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Mr. Won-Geun Shin – Division Manager, Korea Environment Corporation (KECO), Republic of Korea**
  **Topic:** CleanSYS Telemonitoring System (TMS)

Mr. Shin presented CleanSYS, the local industrial emissions telemonitoring system, in operation since 1997. This system monitors, in real time, more than 3,000 industrial stacks, applies QA/QC protocols (RATA ≤ 20%), and is integrated with the fiscal system associated with emissions.

**Figure 06. Operation of the CleanSYS System: Integration of Industrial Monitoring, Control Centers, and Environmental Fiscal Management (KECO, Republic of Korea)**




***Source:** Mr. Shin Won-Geun. (2025). Telemonitoring System for Emissions (CleanSYS): Republic of Korea's Digital System for the Continuous Management of Air Emissions. Korea Environment Corporation (KECO), Republic of Korea. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

The six presentations demonstrated the transition from reactive environmental enforcement toward a predictive, digital, and ethical governance model. Together, they highlighted the role of technological innovation, institutional integration, and inter-agency cooperation as central drivers of intelligent and collaborative environmental enforcement across APEC economies.

## DISCUSSION PANEL – SESSION 1: INDUSTRIAL SECTOR – REAL-TIME DATA COLLECTION AND USE

Below is the synthesis of the first panel and the Q&A session from Session 1, moderated by Gregory Abood, CEO of AELERT.

The panel emphasized that transparency and access to information constitute the foundation for transforming environmental monitoring into public accountability, behavioral change, and verifiable outcomes. It also highlighted that inter-institutional and international collaboration substantially accelerates this process.

### Key Contributions

- **Mr. Jun Ma (China)**
  He demonstrated how citizen pressure regarding high $PM_{2.5}$ levels and independent research contributed to the inclusion of $PM_{2.5}$ and ozone in air quality

standards, as well as the real-time disclosure of emissions data (CEMS). Transparency generated reputational and financial incentives: brands and financial institutions use this information to exclude violators and reinforce accountability.

- **Dr. Marian Scott (United Kingdom)**
  She reaffirmed the importance of public access to information and the value of citizen science integrated into environmental monitoring. Regarding the precautionary principle, she highlighted the need for decisions based on weight of evidence, collaboration, and traceable reasoning. She noted that digital twins and agent-based modelling are complementary tools to integrate social and environmental dynamics, for example in water management.

- **Mr. Won-Jin Lee (**Republic of **Korea)**
  He explained that through the GEMS satellite, Republic of Korea openly publishes all collected data to foster scientific analysis and air quality management. Among the challenges, he underscored the need to interoperate large volumes of environmental data with low-frequency health datasets. GEMS also detects $SO_2$ as a precursor of eruptive events—information especially useful for volcanic economies such as Indonesia—and provides accessible public visualizations.

- **Mr. Won-Geun Shin (**Republic of **Korea)**
  Regarding the CleanSYS system (continuous emissions monitoring), he emphasized that quality assurance is ensured from installation through remote verification and audits. Within maximum emission limits, priority monitoring is conducted for sensitive facilities. The cost (approx. USD 100,000) is covered by the government for SMEs, while major emitters finance it directly.

- **Ms. Pantita Buachan (Thailand)**
  She explained that, to safeguard data integrity, the government provides a tamper- proof “black box” that receives each plant’s CEMS signals. Daily calibration with standard gases and cross-verification through accredited laboratories are mandatory. Random inspections and third-party certification further strengthen system reliability.

- **Mr. John Antony (Australia – EPA/Waste Intelligence Network)**
  He described the transition from a reactive approach toward a preventive one based on two strategic pillars: (1) institutional partnerships to reduce the economic incentives for environmental crime, and (2) pedagogical public communication to avoid alarmism, including community programs such as Garden Safe, designed to educate and generate participatory mapping.

**Closing Remarks and Recommendations from Panel 1**

- Effective collaboration: grounded in trust, continuous communication, shared data use, technologies, and coordination mechanisms.
- Smart policy: incorporate all stakeholders before regulating, combining incentives and recognition with control mechanisms.
- Data governance: standardization, interoperability, and explainability as requirements to sustain legitimacy and public trust.

## SESSION 2: LEGAL, ETHICAL, AND GOVERNANCE DIMENSIONS

This second session examined the institutional, legal, and ethical dimensions associated with the integration of artificial intelligence (AI), big data, and geospatial technologies into environmental management systems.

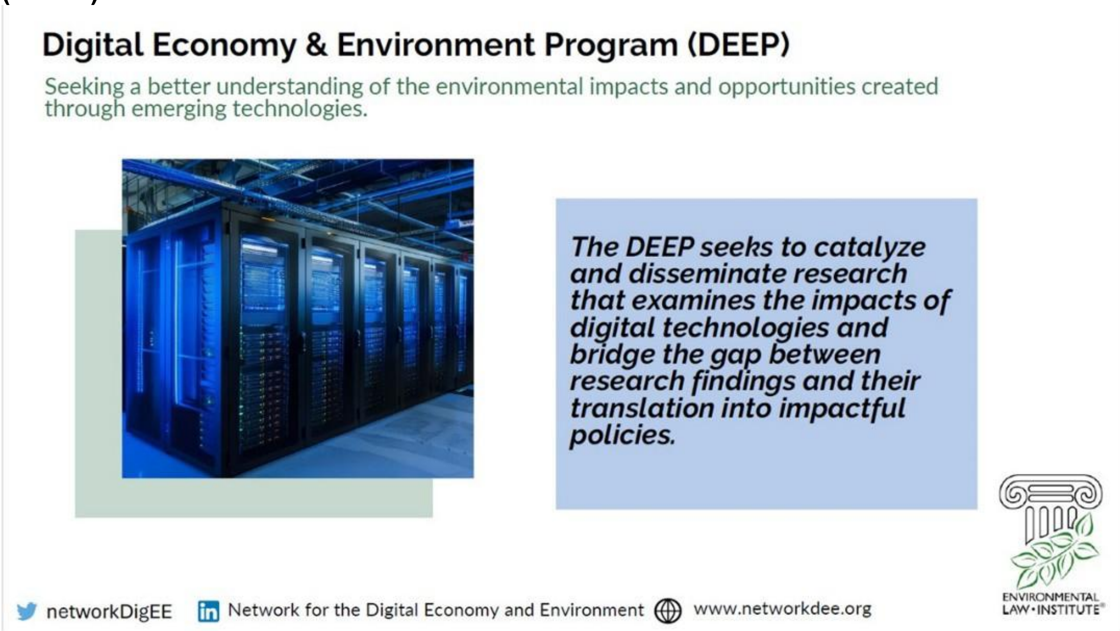
Moderated by Ms. Alexandra Nelson, senior representative of the Environmental Law Institute (ELI) and the International Network for Environmental Compliance and Enforcement (INECE) of the United States, the debate fostered a high-level reflection on how technology, governance, and human oversight must evolve simultaneously to ensure legitimacy, transparency, and public trust in environmental digitalization processes.

- **Ms. Alexandra Nelson – Environmental Law Institute (ELI) / International Network for Environmental Compliance and Enforcement (INECE), United States**

  **Topic:** Ethical and Institutional Dimensions of the Digital Environmental Transition

Ms. Nelson presented INECE, a global network founded in 1989 aimed at strengthening compliance with environmental laws through cooperation and capacity-building, as well as ELI, a research center with more than five decades of experience integrating science, law, and policy. She explained that the Digital Economy and Environment Program (DEEP) analyzes how emerging technologies, such as AI, Big Data, and quantum computing, are transforming environmental law and governance frameworks. She emphasized that technological innovation must be accompanied by safeguards for equity, transparency, and accountability, underscoring that technology alone will not resolve structural challenges such as climate change without robust legal frameworks, adequate institutional capacities, and public trust.

**Figure 07. Conceptual Map – Digital Economy and Environment Program (DEEP)**

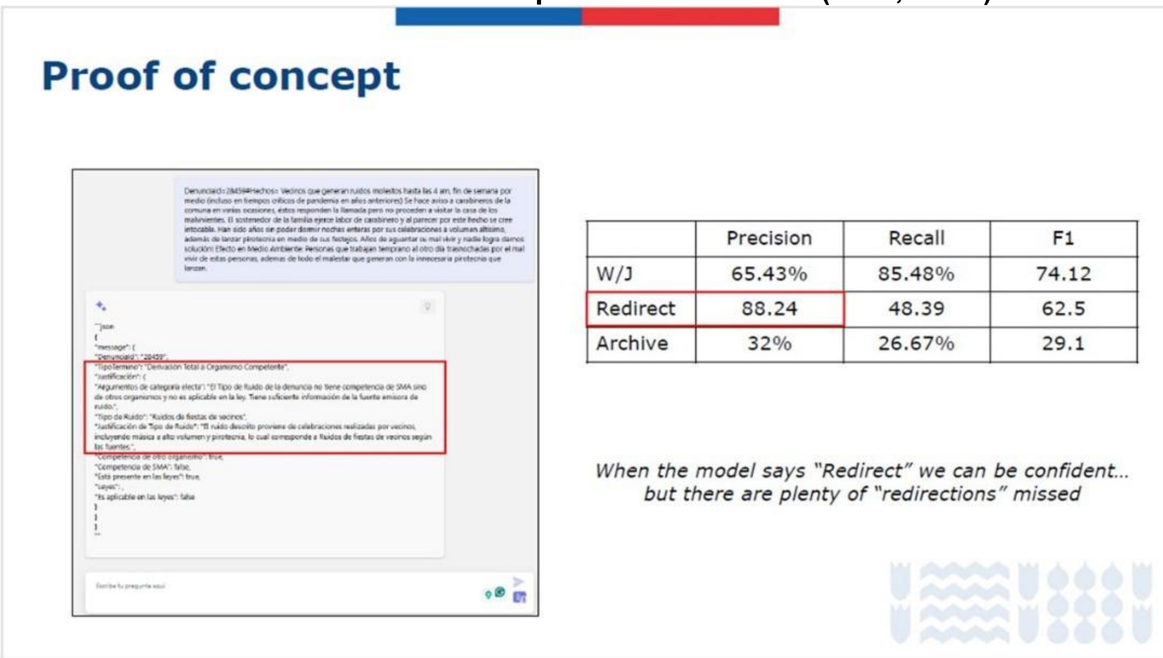



***Source:*** *Ms. Nelson, Alexandria. (2025). Overview of the International Network for Environmental Compliance and Enforcement (INECE) and the Digital Economy and Environment Program (DEEP). Environmental Law Institute (ELI), United States. Presentation at the APEC Workshop on the Digital Economy and Environment Program (DEEP), Seoul, 31 July 2025.*

- **Mr. Pablo Aguirre – Superintendency of the Environment (SMA), Chile**
  **Topic:** Use of Artificial Intelligence for the Management of Environmental Complaints

Mr. Aguirre presented the SMA of Chile’s pilot project that applies artificial intelligence to the management of citizen complaints. The system analyzes complaint texts and classifies them into three categories: “archive,” “redirect,” or “investigate,” achieving high levels of accuracy, particularly in cases involving noise pollution. The tool has reduced processing times and optimized the use of human resources, without replacing the technical judgment of officials. Nonetheless, ethical and transparency challenges persist, including the control of algorithmic bias and effective communication with the public.

**Figure 08. Proof of Concept – Performance Metrics of the AI Model for Environmental Complaint Classification (SMA, Chile)**




***Source:*** *Mr. Aguirre, Pablo. (2025). AI-Assisted Classification System for Environmental Complaints. Superintendence of the Environment (SMA), Chile. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, July 31, 2025.*

- **Dr. Suyoung Park – National Geographic Information Institute (NGII), Republic of Korea**
  **Topic:** Geospatial Infrastructure for Environmental Supervision and Territorial Governance

Dr. Park explained how NGII integrates artificial intelligence and high-resolution satellite data to develop a digital twin of the Korean territory. The system uses super-resolution imagery, automatic land-use change detection, and object-extraction techniques to strengthen urban management and disaster response. Automation and standardization are essential to handle the growing volume of geospatial data required for adaptive territorial governance.

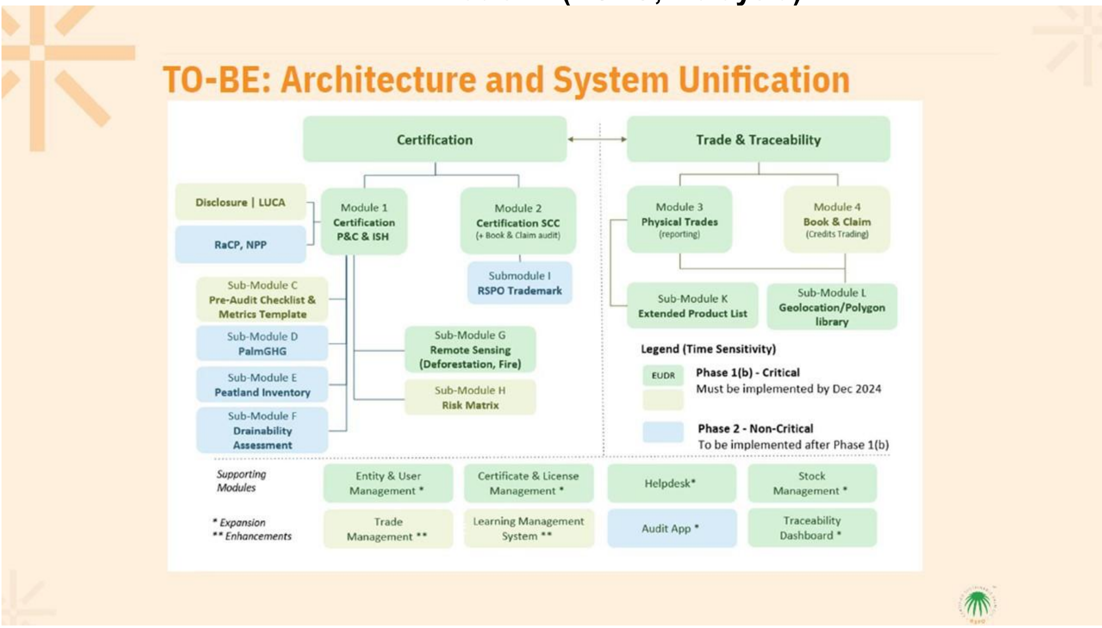
**Figure 09. Effect of Super-Resolution on Vehicle Recognition – Example of AI Application in High-Resolution Satellite Imagery (NGII, Republic of Korea)**


***Source:*** *Dr. Park, Suyoung. (2025). From Satellite Data to Decisions: Structuring Geospatial Infrastructure for Environmental Supervision and Territorial Governance. National Geographic Information Institute (NGII), Republic of Korea. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Mr. Yen Hun Sung – Roundtable on Sustainable Palm Oil (RSPO), Malaysia Topic:** Digital Transformation of RSPO through the PRISMA Platform

Mr. Hun presented the unification of RSPO’s previously fragmented systems into a centralized platform known as PRISMA, designed to enhance traceability, transparency, and accountability across the global palm oil value chain. The platform establishes a shared data architecture and an equitable governance model among members, auditors, and administrators. Stakeholder commitment, clear communication, and technical training were key factors enabling its successful implementation.

**Figure 10. "TO-BE" System Architecture and Unification – PRISMA Digital Platform (RSPO, Malaysia)**




***Source:*** *Mr. Sung, Yen Hun. (2025). PRISMA Digital Transformation of RSPO: Technological Modernization and Change Management. Roundtable on Sustainable Palm Oil (RSPO), Malaysia. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

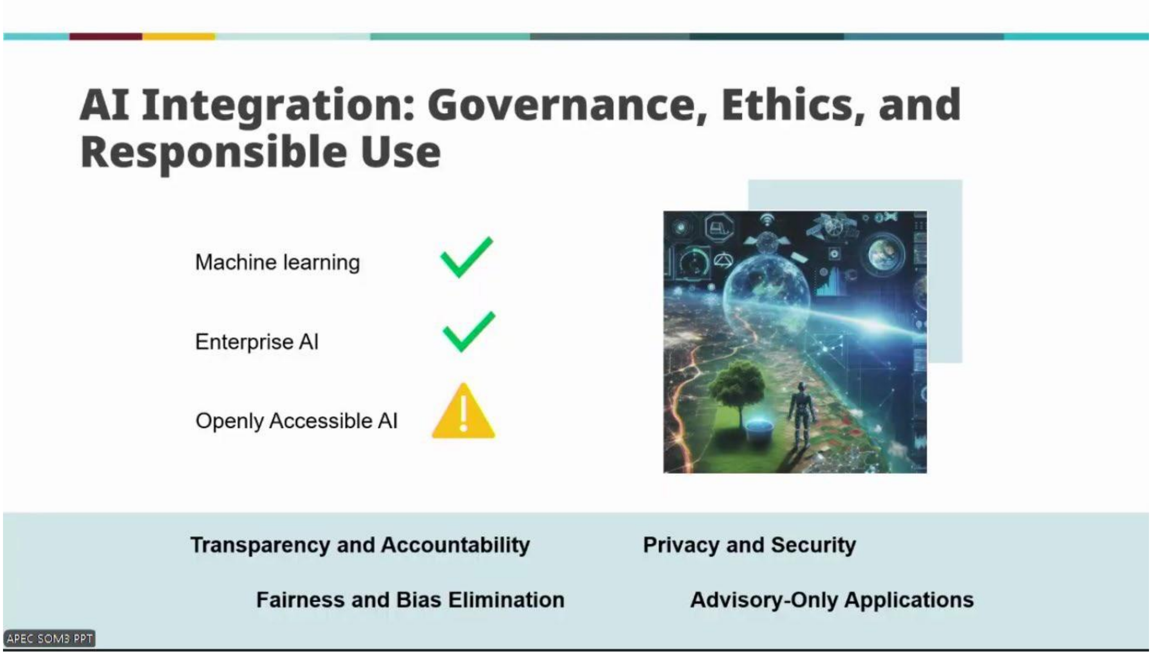
- **Mr. Anthony Rennex – Department of Natural Resources and Mines, Industry and Regional and Rural Development (Government of Queensland), Australia Topic:** Strategic Plan for Integrating Artificial Intelligence into Environmental Management

Mr. Rennex, Investment and Strategic Systems Advisor at the Queensland Department of Natural Resources, presented the institutional roadmap for incorporating AI into the management of the state's extensive natural resources. His presentation highlighted the main challenges faced by environmental agencies in contexts characterized by legacy systems, siloed databases, and large-scale territories, all of which hinder interoperability and integrated analysis.

The modernization plan is structured around three pillars: (i) modern data governance, based on open standards and interoperability protocols; (ii) real-time editable spatial services, enabling continuous tracking of territorial and environmental changes; and (iii) progressive integration of AI as a support tool designed to complement—rather than replace—human decision-making.

Rennex emphasized that the strategy seeks to build a future-ready data infrastructure capable of incorporating predictive algorithms into environmental planning. Pilot projects have shown promising results in the early detection of illegal deforestation, administrative optimization, and the development of a digital technical information library for regulatory staff. He concluded that the success of environmental digitalization depends as much on institutional maturity as on public trust in the responsible use of AI.

**Figure 11. Strategic Roadmap for Integrating AI into Queensland's Environmental Governance – Data Modernization Framework**

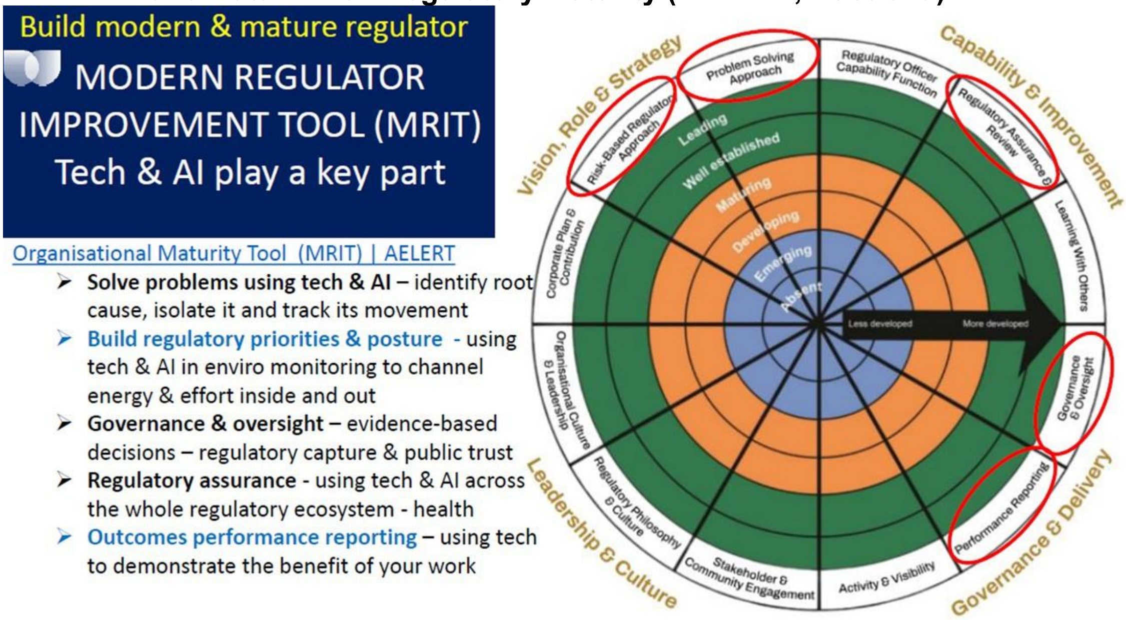



***Source:*** *Mr. Rennex, Anthony. (2025). Integrating Artificial Intelligence in Environmental Management Systems: A Strategic Roadmap for Queensland. Department of Natural Resources and Mines, Queensland, Australia.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Mr. Gregory Abood – Australasian Environmental Law Enforcement and Regulators Network (AELERT), Australia**
  **Topic:** Technology in Environmental Monitoring – Legal, Ethical and Governance Dimensions (LEG)

Mr. Gregory Abood, Executive Director of the Australasian Environmental Law Enforcement and Regulators Network (AELERT), emphasized the importance of integrity and ethics in regulatory systems through the metaphor of the Moreton Bay Fig tree, which symbolizes the ethical and legal roots that support resilient institutions. He presented the SELF test (Scrutiny, Ethical, Legal, and Fair) as a benchmark for regulatory credibility, as well as the Modern Regulator Improvement Tool (MRIT), designed to assess and strengthen institutional maturity, promote inter-agency collaboration, and integrate artificial intelligence and data-driven decision-making within an ethical governance framework. He stressed that technological innovation must always serve the public interest and that its purpose is to reinforce, not replace, human judgment and institutional accountability.

**Figure 12. Modern Regulator Improvement Tool (MRIT) – Framework for Ethical and Data-Driven Regulatory Maturity (AELERT, Australia)**




***Source:*** *Mr. Abood Gregory (2025). Preserving Regulatory Integrity and Credibility: Technology, Ethics and Governance in Environmental Regulation. Australasian Environmental Law Enforcement and Regulators Network (AELERT), Australia. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

Taken together, the six presentations demonstrated that the digital transformation of environmental governance requires not only technological innovation, but also ethical safeguards, legal coherence, and institutional maturity. These dimensions are essential for APEC to advance toward a responsible and trustworthy model of digital environmental enforcement.

## DISCUSSION PANEL – SESSION 2: ADOPTION OF AI IN ENVIRONMENTAL GOVERNANCE

The session, moderated by Ms. Alexandra Nelson, brought together international panelists who discussed the challenges and strategies for adopting AI and digitalization within public and private institutions dedicated to environmental governance.

- Cultural challenges and institutional transparency:

Mr. Aguirre emphasized that the primary challenge is not technological but cultural. He explained that the development of digital tools must be co-created with internal teams—in his case, the complaints management unit—to ensure ownership, transparency, and understanding of both risks and benefits. He also highlighted the importance of clearly communicating the capabilities and limitations of AI in order to build public trust.

- Collaboration and trust among regulators:

Mr. Abood stressed that cooperation among regulatory and enforcement agencies is essential to reducing risks. He noted that institutional isolation increases vulnerability, and that collaborative platforms such as AELERT and APEC are fundamental for sharing experiences, avoiding common mistakes, and strengthening trust among regulators.

- Credibility and accuracy of data:

Ms. Park addressed the issue from a technical perspective, underscoring the need to ensure the precision, stability, and credibility of the data used in AI systems, as well as to establish guidelines and control measures to prevent misuse. She noted that public and regulatory consensus is essential for the successful adoption of environmental digitalization.

- Institutional preparedness and strategic purpose:

Mr. Sung pointed out that AI, like any technology, is not a solution in itself but a tool that requires institutional maturity. He recommended that organizations ask themselves: “Should we use it?” and “Are we prepared to do so?”. He stressed the importance of evaluating the true purpose and expected returns before adopting a technology, citing the experience with blockchain and the initial resistance generated by a lack of understanding.

- Digital maturity and AI governance:

Mr. Rennex presented the experience of the Government of Queensland, which began using machine learning a decade ago. He noted that after an initial period of restrictions, the economy moved toward a regulated model for institutional AI use, implementing training, technical guidelines, policies, and clear regulatory frameworks, which has enabled a more responsible and mature deployment of these technologies.

**International Exchange and Cooperation**

During the final round, the panelists agreed on the need to strengthen cross-border cooperation and the exchange of data and innovations:

- Mr. Rennex proposed connecting technical teams from Australia and Republic of Korea to share algorithms and geospatial methodologies.
- Mr. Sung emphasized the importance of establishing a common data language (interoperability) to facilitate international collaboration.
- Ms. Park announced the Republic of Korea’s initiative to host a UN Virtual Data Center for the Asia-Pacific region, aimed at democratizing access to satellite information.
- Mr. Abood underscored the relevance of joint strategic planning to address transboundary challenges such as climate change or the management of shared watersheds.

The panel concluded by highlighting three central messages:

1. Trust and transparency are the foundation for adopting AI in the public sector.
2. Cooperation and co-creation among institutions, economies, and scientific communities are essential for effective implementation.
3. Institutional and regulatory maturity—supported by capacity-building, ethical principles, and clear policy frameworks—is indispensable for the responsible use of AI.

The moderator closed by emphasizing that international collaboration and the open exchange of data are essential to accelerating innovation and strengthening digital environmental governance within the APEC framework.

## DAY 2: SESSION 3 – SATELLITE AND GEOSPATIAL TECHNOLOGIES FOR AGRICULTURAL MONITORING

The third session examined how satellite observation, geospatial analysis, and artificial intelligence–based models are transforming environmental monitoring and agricultural management across APEC economies. It represented a conceptual transition from the digitalization of the industrial sector (Sessions I and II) toward approaches grounded in sustainable land management and predictive ecosystem governance.

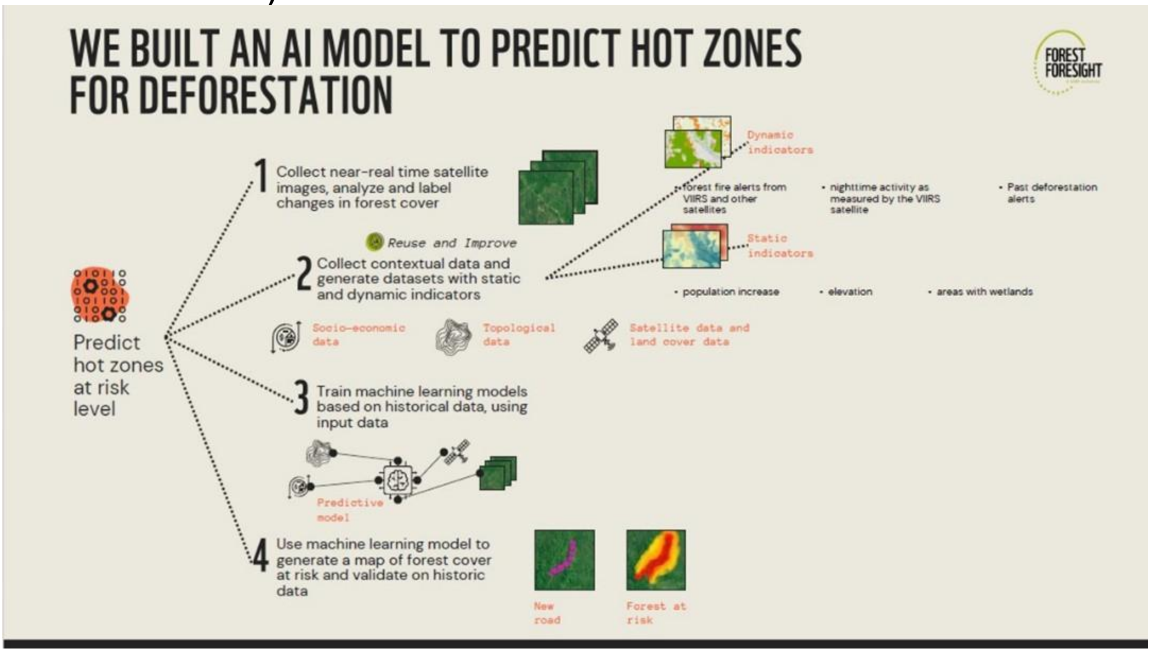
Under the moderation of Ms. Chochoe Devaporihartakula, Program Manager of the Asian Environmental Compliance and Enforcement Network (AECEN), the session fostered a policy-oriented dialogue linking space-based technologies with agricultural innovation and environmental enforcement. The moderator emphasized the critical importance of interoperability and trust within regional data ecosystems, framing the discussion within the digital sustainability and resilience commitments established under the Putrajaya Vision 2040.

Presentations from the Netherlands, Indonesia, and Republic of Korea demonstrated how the integration of remote sensing (RS), geographic information systems (GIS), and artificial intelligence (AI) enables early detection of deforestation, precision agriculture, and climate- resilient management of natural resources.

- **Mr. Jorn Dallinga – Wageningen University & Research (Netherlands)**
  **Topic:** Forest Foresight: Predictive Monitoring of Forest Loss Using Satellite Data and AI

Mr. Jorn Dallinga, from Wageningen University & Research, presented *Forest Foresight*, an open-source predictive platform that integrates Sentinel-1 (radar) and Sentinel-2 (optical) satellite imagery with machine-learning algorithms to anticipate short-term forest- cover loss. The system identifies deforestation “hotspots” by correlating environmental and socioeconomic variables such as proximity to roads, rainfall, and population density. With an approximate accuracy of 75%, Forest Foresight optimizes field inspections and enables the prioritization of enforcement actions based on evidence, demonstrating the potential of AI-driven geospatial analysis to shift from reactive enforcement to preventive approaches.

**Figure 13. Predictive Workflow of Forest Foresight – Integration of AI and Satellite Data for Deforestation-Risk Prediction (Jorn Dallinga, Netherlands)**




***Source:*** *Mr. Dallinga Jorn. (2025). Forest Foresight: Predictive Modeling and Early Warning System for Deforestation Risk. Satelligence, Netherlands*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, August 1, 2025*

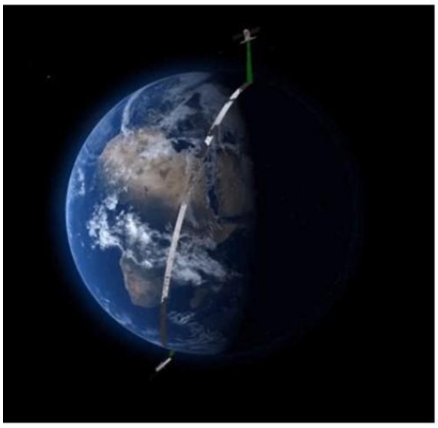
- **Dr. Haris Syahbuddin – Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture**
  **Topic:** Use of SISCrop 2.0 for Monitoring Standing Crops and Estimating Rice Production

Dr. Haris Syahbuddin, from the Agricultural Research and Development Agency of Indonesia's Ministry of Agriculture, presented SISCrop 2.0, the domestic satellite-based crop monitoring system. The platform uses Sentinel-1 Synthetic Aperture Radar (SAR) imagery, with a spatial resolution of 10 m, unaffected by cloud cover, and acquired every 10–15 days, to map rice fields and classify the phenological stages of the crop, including planting, growth, maturation, and harvest.

Through the integration of remote sensing and field validation at more than 3,000 sampling points, the system achieves an accuracy above 90%, enabling early yield estimation, fertilization planning, and precision agriculture practices. SISCrop 2.0 constitutes a technological pillar of Indonesia's local food self-sufficiency policy for 2024–2029, linking satellite observation with strategic decision-making on food security.

**Figure 14. Sentinel-1 Radar Data as the Basis of SISCrop 2.0 – Indonesia's Local Crop Monitoring System**

Satellite SENTINEL-1 as the based of SISCROP 2.0



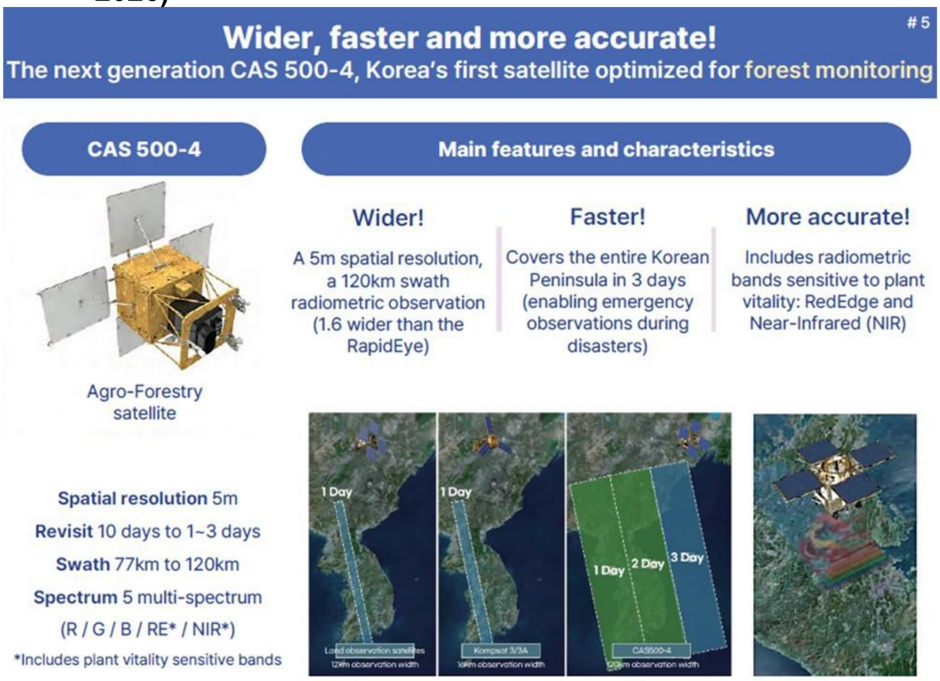
| No. | Parameter | Sentinel 1 |
|---|---|---|
| 1. | Sensor | *Synthetic Apperture Radar* (SAR), free from cloud cover, no issue with time (day and night) * |
| 3. | Temporal resolution | 10-15 days |
| 4. | Spatial Resolution | 10 m |
| 5. | Monitor Standing Crop | Fase pengairan; Fase vegetatif 1 (<41 HST); Fase vegetatif 2 (41-64 HST); Fase generatif 1 (65-95 HST); Fase generatif 2 (96-112/120 HST); Fase bera |
| 6. | Productivity | Analysis the Biomass to predict the productivity and production |
| 7. | Accuracy | *Overall Accuracy* varied: up to 90,32% (Province) & 90,91% (Regency) |

***Source:*** *Dr. Syahbuddin Haris****. (2025). Use of the SISCROP 2.0 System for Standing Crop Monitorin****g and Rice Production Estimation. Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture, Indonesia. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

- **Mr. Byung-Oh Yoo – National Institute of Forest Science (NIFoS), Republic of Korea**
  **Topic:** Republic of Korea's Agro-Forestry Satellite: Applications for Monitoring Forest Disasters, Ecology, and Resources

Mr. Yoo presented the upcoming CAS500-4 mission, a Korean agro-forestry satellite with a spatial resolution of 5 meters and a swath width of 120 kilometers, scheduled for launch in 2026. The mission will generate four levels of derived products—ranging from basic geometric corrections to forest productivity maps—and will support regional cooperation in detecting forest fires and landslides. The CAS500-4 system is integrated into the Republic of Korea's geospatial innovation agenda, incorporating cloud-based data management, automated object extraction, and compatibility with the future APEC Digital Environmental Observatory.

**Figure 15. Key Features of CAS500-4 – Republic of Korea's Next-Generation Satellite for Forest Monitoring (NIFoS, Launch 2026)**




***Source:*** *Mr. Yoo Byung-Oh. (2025). Agroforestry Satellite and CAS500-4: Advances in Digital Forest and Agricultural Monitoring in Republic of Korea. National Institute of Forest Science (NIFoS), Republic of Korea. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

- **Mr. Suk-Young Hong – Rural Development Administration (RDA), Republic of Korea**
  **Topic:** Drone- and Satellite-Based Monitoring for Agricultural Research and Environmental Management

Mr. Suk-Young Hong presented the local agricultural observation framework developed by Republic of Korea's Rural Development Administration (RDA), which integrates imagery collected through drones, agricultural satellites (CAS500-4 and complementary missions), meteorological observations, and artificial intelligence–based analytics. Its purpose is to strengthen data-driven agricultural management and support the formulation of sustainable and adaptive policies.

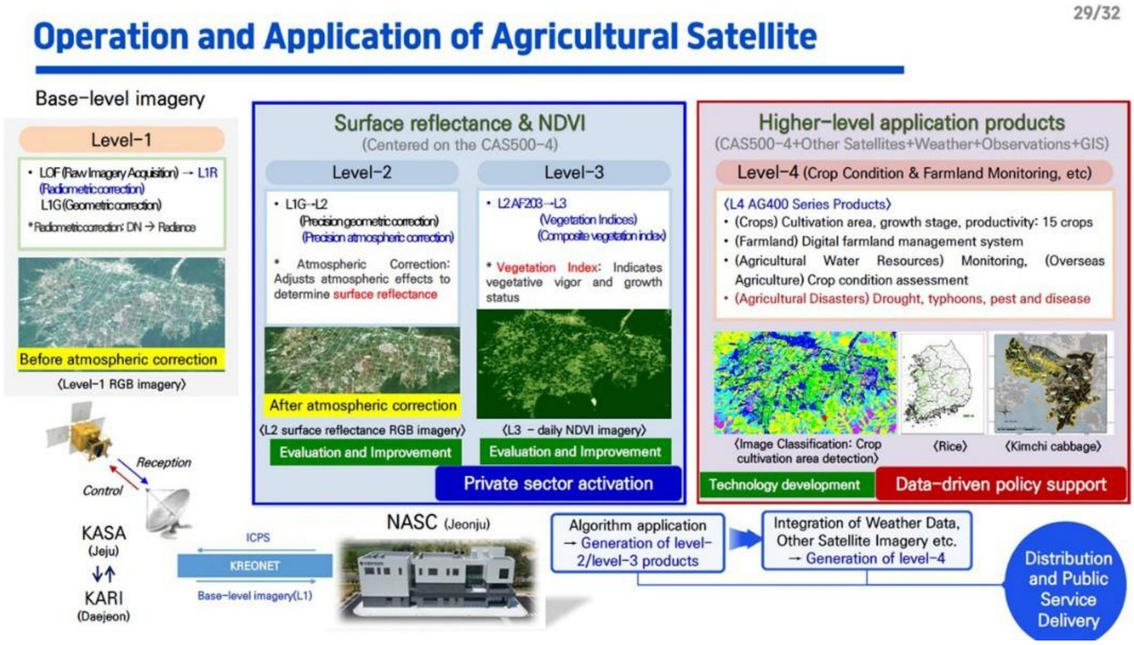
The system, managed by the National Agricultural Satellite Center (NASC), generates information through a structured workflow composed of several levels:

- Level 1: image acquisition and application of geometric and radiometric corrections.
- Level 2: generation of surface reflectance imagery with atmospheric correction.
- Level 3: development of composite vegetation indices (NDVI) to assess crop vigor and growth.
- Level 4: applied products integrating meteorological, field, and GIS data to monitor cultivated areas, phenological stages, productivity, and conditions associated with agricultural disasters (droughts, typhoons, pests, and diseases).

The presentation highlighted the value chain that connects satellite-generated data with public policy formulation, demonstrating how this integration strengthens precision agriculture, digital agricultural land-management systems, and institutional capacity to respond to environmental variability.

The model promoted by RDA and NASC exemplifies the consolidation of an interconnected agricultural ecosystem, where technological innovation supports decision- making at all levels of governance.

**Figure 16. Operation and Application of the Agricultural Satellite – Multilevel Data Flow for Agricultural Management (RDA, 2025)**




***Source:*** *Mr. Hong Suk Young. (2025). Drone- and Satellite-Based Monitoring for Agricultural Research and Environmental Management: Experiences from the RDA. Rural Development Administration (RDA), National Institute of Agricultural Sciences (NIAS), Republic of Korea.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

Together, these four presentations demonstrated how APEC economies are building an integrated geospatial infrastructure to support predictive, transparent, and cooperative governance of agricultural and forest resources.

## DISCUSSION PANEL – SESSION 3: SATELLITE AND GEOSPATIAL TECHNOLOGIES FOR AGRICULTURAL MONITORING

The Session 3 panel examined how predictive artificial intelligence, remote sensing (via satellites and drones), and local information systems can be translated into timely field- level actions for forest and agricultural management. A clear core message emerged: technology is only effective when it solves a real problem, is validated on the ground, and is sustained through an institutional framework, adequate financing, and cross-sector cooperation.

- Deforestation prediction

Mr. Dallinga emphasized that public trust is built by being transparent about model limitations and by demonstrating operational value, particularly for patrol planning. He explained that positional accuracy is prioritized over recall depending on user needs (for instance, a 70–80% rate is acceptable if it improves field effectiveness). From an ethical perspective, he noted that predictions do not constitute evidence and that community engagement and proportional intervention protocols are essential.

- Agroforestry

Mr. Yoo presented the development of algorithms and maps for species distribution (wood, bamboo, and rattan), as well as for the detection and potential prediction of forest fires. He indicated that while the Korean agroforestry satellite is pending launch, current models rely on Sentinel-2 data. He emphasized that future integration of terrestrial, atmospheric, and spatial information will support domestic and regional decision-making in progressive stages.

- Agriculture

Mr. Hong described the “CAS” satellite roadmap: CAS-1 and CAS-2, focused on land use and urban areas (high resolution, Ministry of Land); CAS-4, dedicated to vegetation for agriculture and forestry (with RDA and KFS as main users); and CAS-5, aimed at monitoring water resources through C-band SAR (post-2027). For agricultural operations, he noted that drones are more useful at plot scale for imagery-based diagnostics and variable-rate fertilization through task maps. He explained the typical crop rotation—wheat and barley in winter, rice in summer—and highlighted the local soil analysis program that provides differentiated fertilization recommendations.

- Agricultural monitoring and operational continuity

Mr. Syahbuddin detailed a biweekly monitoring system operating from the economy-wideto the sub-district level, supported by an active agricultural extension service and close inter- ministerial coordination (irrigation, climate, statistics). He emphasized that public policy and financing are decisive factors: subsidies (seeds and fertilizers) and investments in irrigation have increased production; without institutional support, he warned, systems “go dormant” and lose operational continuity.

**Cross-cutting Messages:**

- Trust in predictive models: Metrics must be adjusted to user needs, and results must be continuously validated in the field.
- Forest resource mapping: Algorithms remain in testing stages and require international cooperation, including with Indonesia.
- Forest fires: Early detection is currently available; full prediction capabilities will depend on the new agroforestry satellite.
- Use of data for decision-making: Participants emphasized the importance of fusing satellite and ground data and establishing governance frameworks that enable timely responses.

- Challenges: Gaps persist between the speed of technological development and local operational capacity; aligning policies, financing, and regional capabilities remains essential.

The panel concluded that innovation, including AI, satellites, and drones, must be accompanied by ethical protocols, quality standards, community participation, and interinstitutional coordination. Only under these conditions can monitoring and prediction systems translate into effective territorial management aimed at protecting forests, strengthening food security, and improving decision-making.

## SESSION 4: DIGITALIZATION FOR SUSTAINABILITY, TRACEABILITY, AND ENVIRONMENTAL COMPLIANCE

The fourth session examined how digital transformation strengthens sustainability, transparency, and environmental compliance across sectors such as agriculture, forestry, industry, and water resources. Moderated by Ms. Chochoe Devaporihartakula from the Asian Environmental Compliance and Enforcement Network (AECEN), the dialogue brought together policymakers, enforcement authorities, and data specialists to analyze the integration of digital tools into institutional governance and market mechanisms.

The moderator emphasized that APEC economies are entering a phase of institutional digitalization in which artificial intelligence (AI), blockchain, and open-data ecosystems are becoming foundational pillars for traceability and accountability. She also underscored the need to establish ethical data governance and to reinforce cross-border cooperation, aligning the discussion with the principles of the Putrajaya Vision 2040 on innovation, inclusion, and sustainable growth.

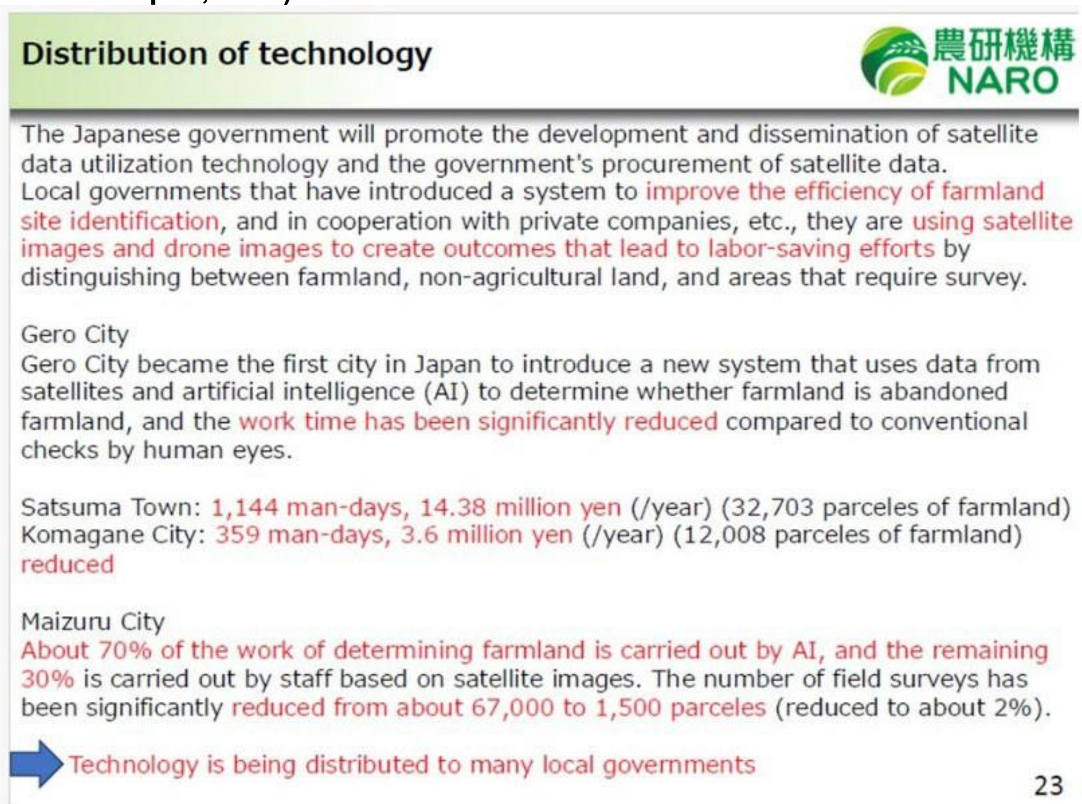
The presentations from Australia; Chile; Japan; Malaysia and the United States illustrated how digital infrastructures and AI-based analytics support regulatory automation, supply- chain traceability, and multisector transparency.

- **Mr. Naoki Ishitsuka – National Agriculture and Food Research Organization (NARO), Japan**
  **Topic:** Case Studies on the Use of Satellite Imagery in Agricultural Administration in Japan

Mr. Naoki Ishitsuka presented Japan's digital agricultural monitoring initiative, coordinated by the Ministry of Agriculture, Forestry and Fisheries (MAFF) and implemented by the National Agriculture and Food Research Organization (NARO). The program integrates satellite imagery—primarily from ALOS-2 (SAR) and Sentinel-2—together with data from drones and IoT sensors into a cloud-based administrative platform. Through this framework, Japan has automated the verification of cultivated land, crop classification, and several environmental assessments, including sediment runoff and methane emissions in rice paddies.

A central element of the initiative is its progressive decentralization: MAFF has transferred these digital tools to local governments, enabling a significant reduction in inspection costs and workload while improving data transparency and reliability. Municipalities such as Gero, Satsuma, and Maizuru have demonstrated substantial efficiency gains, with reductions of more than 70% in fieldwork requirements. By linking satellite analysis with public administration, the Japanese model illustrates how digital agriculture can strengthen regulatory compliance and contribute to the local vision of a carbon-neutral agricultural sector.

**Figure 17. Distribution of Technology – Use of Satellite Data for Farmland Verification by Local Governments (MAFF/NARO, Japan, 2025)**




***Source:*** *Mr. Ishitsuka Naoki. (2025). Case Studies on the Use of Satellite Imagery in Agricultural Administration in Japan. Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization (NARO), Japan.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

Finally, the speaker highlighted the integration of these technologies into the local carbon credit scheme (J-Credit), which allows for the certification of verifiable greenhouse gas reductions in the agricultural sector. In particular, a new method (2023) was approved for reducing methane emissions in rice paddies by extending the drying period of the fields, which can be verified by satellite. Radar images (SAR) make it possible to verify the absence of surface water and serve as objective evidence for the generation and trading of carbon credits.

MAFF expects these technologies to support the continuous monitoring of sustainable agricultural practices and their expansion to other Asian economies. In addition, a new foundation model based on satellite data from the Japan Aerospace Exploration Agency (JAXA) is being developed to improve automated detection of land use changes and strengthen digital governance of agricultural carbon under the J-Credit framework.

- **Ms. Anne Rosenbarger – World Resources Institute (WRI), United States**
  **Topic:** Global Forest Watch (GFW) and Digital Transparency for Corporate Accountability

Ms. Rosenbarger presented Global Forest Watch (GFW), the WRI open-data platform that issues near-real-time deforestation alerts using satellite imagery and AI-based algorithms (GLAD and RADD). GFW integrates multisource remote sensing information to identify tree-cover loss and land-use change in tropical regions, linking these data to corporate supply-chain monitoring systems.

She highlighted the GFW Pro module, which enables companies, governments, and civil society organizations to assess deforestation risks, verify environmental commitments, and strengthen accountability through shared data dashboards. The tool allows users to upload sourcing areas, analyze deforestation alerts, collaborate with partners, and act based on evidence, contributing to the achievement of deforestation-free supply chains.

Rosenbarger underscored that GFW functions as a global transparency infrastructure that supports compliance with policies such as the European Union Deforestation Regulation (EUDR) and the Accountability Framework Initiative (AFI). By mobilizing open environmental data and cloud-based analytics, GFW reinforces public–private cooperation and improves corporate environmental disclosure practices at global scale.

**Figure 18. Transform Your Supply Chain in 4 Steps – Business Application of GFW Pro (WRI, 2025)**


***Source:** Ms. Rosenbarger Anne. (2025). Mobilizing Data for Impact at Agricultural Frontiers: Lessons from Global Forest Watch. World Resources Institute (WRI), United States. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

- **Mr. Julián Cabezas Peña – Superintendence of the Environment (SMA), Chile**
  **Topic:** Remote Environmental Monitoring to Strengthen Compliance in Salmon Aquaculture

Mr. Julian Cabezas, representing the Superintendence of the Environment (SMA) of Chile, presented the economy's pioneering experience in the use of remote environmental monitoring and artificial intelligence (AI) to strengthen compliance oversight in the salmon aquaculture sector. Through the *Environmental Monitoring Intelligence (EMI)* platform, the SMA integrates satellite imagery, drone surveillance, and IoT sensors within a centralized data architecture that enables real-time detection of anomalies such as unauthorized expansion of cages, changes in water coloration, and deviations from the Environmental Qualification Resolutions (RCA).

The AI-generated alerts are linked to the SMA Observatory, allowing the agency to prioritize inspection actions, reduce response times, and optimize institutional resources. Cabezas emphasized that the system is designed to support, rather than replace, human judgment, thereby strengthening transparency and efficiency in environmental governance. Moreover, cooperation with SERNAPESCA, the Ministry of the Environment, and research centers ensures data validation and technical robustness, positioning Chile's EMI model as a regional benchmark for predictive and preventive digital environmental governance aligned with APEC's vision.

**Figure 19. Enhancements in Digital Enforcement in the Salmon Farming Sector – Results of SMA's Remote Monitoring (Chile)**


***Source:*** *Mr. Cabezas, Julián. (2025). Remote Environmental Monitoring to Strengthen Compliance in Salmon Aquaculture. Superintendence of the Environment (SMA), Chile. Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 31 July 2025.*

- **Ms. Margaret Sexton – Natural Resources Access Regulator (NRAR), Australia Topic:** Eyes in the Sky and Eyes on the Data: Integrating Remote Monitoring into Water-Compliance Regulation

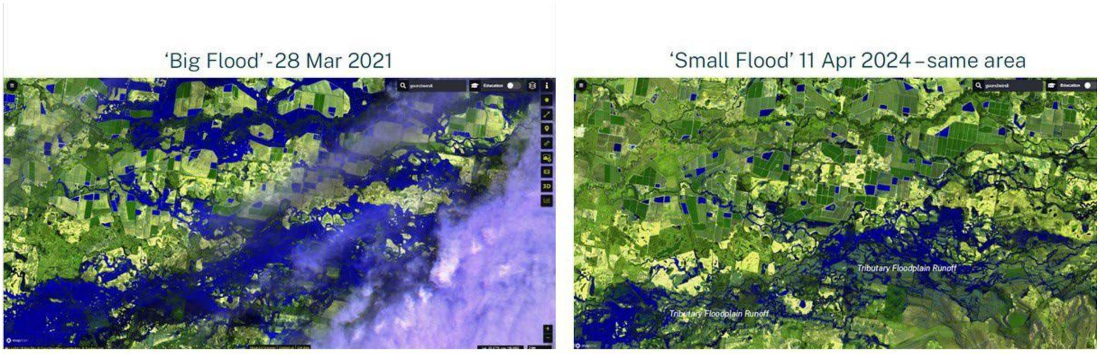
Ms. Margaret Sexton presented NRAR's digital compliance initiative, *"Eyes in the Sky, Eyes on the Data"*, which applies remote sensing, aerial drones, and GIS dashboards to monitor water use across 800,000 km² and more than 38,000 licensed works in New South Wales.

Through continuous satellite observation and spatial analysis, NRAR identifies irregular extraction patterns, prioritizes field inspections, and ensures evidence-based enforcement. Cases related to permanent plantings and floodplain harvesting demonstrate how geospatial intelligence strengthens targeted compliance and enhances public confidence in transparent water governance.

NRAR's monitoring program integrates multitemporal imagery from Landsat, Sentinel, and commercial sensors such as Nearmap to detect unauthorized deviations and record seasonal changes in irrigation practices.

By incorporating remote monitoring into routine compliance procedures, NRAR promotes transparency, fairness, and efficiency in the protection of Australia's water resources, benefiting communities, industries, and ecosystems.

**Figure 20. Floodplain Harvesting Monitoring Using Satellite Imagery – Comparison of the 2021 and 2024 Events (NRAR, Australia)**



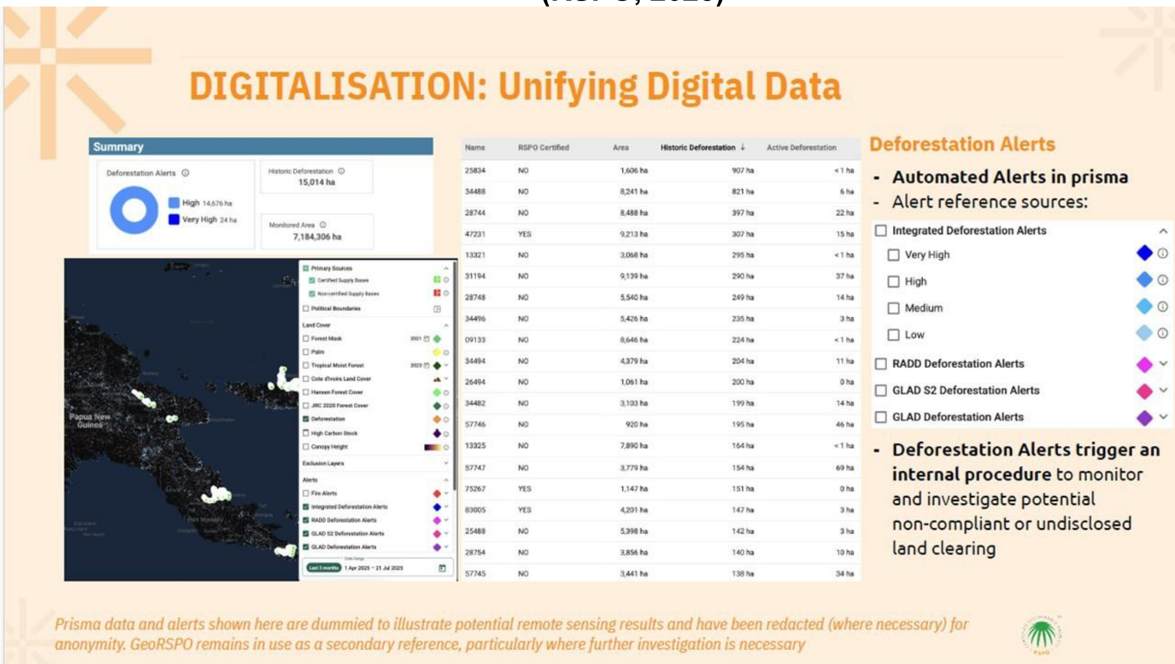

***Source:*** *Ms. Sexton, Margaret. (2025). Eyes in the Sky and Eyes on the Data: Integrating Remote Monitoring into Water-Compliance Regulation. Natural Resources Access Regulator (NRAR), New South Wales, Australia.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

- **Mr. Yen Hun Sung – Roundtable on Sustainable Palm Oil (RSPO), Malaysia Topic:** 20 Years of Implementing a Voluntary Sustainability Program: Evolution of RSPO Standards and the Integration of Remote Sensing and Technology

Mr. Sung presented PRISMA, the core digital-transformation platform of RSPO, which centralizes geospatial information and environmental compliance data from certified entities.

PRISMA integrates GeoRSPO maps with remote-sensing modules and automated deforestation alerts (RADD and GLAD), strengthening transparency and remote verification under the NDPE principles (No Deforestation, No Peat, No Exploitation).

**Figure 21. Automated Deforestation Alert System of the PRISMA Platform (RSPO, 2025)**




***Source:*** *Mr. Sung, Yen Hun. (2025). 20 Years of Implementing a Voluntary Sustainability Program: Evolution of RSPO Standards and the Integration of Remote Sensing and Technology. Roundtable on Sustainable Palm Oil (RSPO), Malaysia.*
*Presentation at the APEC Workshop on Digital Environmental Monitoring, Seoul, 1 August 2025.*

These presentations illustrate how APEC economies are institutionalizing digital sustainability by articulating technological innovation, ethical governance, and market accountability.

**DISCUSSION PANEL – SESSION 4: DIGITALIZATION FOR SUSTAINABILITY, TRACEABILITY, AND ENVIRONMENTAL COMPLIANCE**

The fourth panel examined how to build trust and translate complex data into concrete actions by combining digital innovation (AI, satellite monitoring, and open platforms) with stakeholder participation, clear communication, and collaboration across institutions and economies.

Ms. Anne Rosenbarger noted that the Global Forest Watch approach has evolved from the original mindset of “if you build it, they will come” toward a user co-creation model. Today, tool development begins with the joint identification of real-world problems, early definition of use cases, and information needs. The process incorporates pilots and validation at each stage, ensuring that the products are useful and applicable. New platforms enable large-scale forest-restoration monitoring, close information gaps, and support both regulators and companies with environmental commitments. However, she stressed that environmental and restorative justice requires going beyond technology, calling for community participation to ensure legitimacy and sustainable results.

Mr. Julián Cabezas emphasized that trust is built when regulators act in areas of highest public demand (for example, enforcement in the salmon aquaculture sector) and when solutions accurately address correctly identified problems. He underscored the importance of acknowledging challenges while maintaining a focus on tangible outcomes.

Mr. Naoki Ishitsuka explained that digitalization made it possible to replace labor-intensive tasks, such as hours of field inspection, thereby reducing the environmental footprint associated with travel and discouraging practices such as excessive herbicide use when better maintenance criteria (e.g., mechanical vegetation cutting) exist.

Ms. Margaret Sexton highlighted that translating complex data for diverse audiences requires disaggregation at the local scale (catchments or valleys), simple visualizations, and single key indicators that help explain complex regulatory frameworks. She also emphasized the importance of communicating a balanced message that recognizes the majority of compliant users while strengthening capacities where gaps persist.

Mr. Yen Hun Sung indicated that citizens and clients increasingly demand verifiable transparency: certifications alone are no longer sufficient; there must be direct access to data. Digitalization therefore raises accountability standards across supply chains.

**Cross-cutting Themes:**

- Water allocation and territorial conflicts: Although water regulators do not define allocation quotas, they help mitigate tensions through localized information, education, and dialogue processes that support equitable and sustainable resource use.
- Restoration monitoring: The use of annual time series is increasing to verify compliance and close cases; however, at the social scale, this process requires incorporating participatory components in addition to remote sensing.
- Protected timber (CITES): WRI is developing specific traceability projects for species, including the use of genetic markers, independent of Global Forest Watch.
- Fire prediction: Although proofs of concept exist, operational application requires extremely high precision and clearly defined protocols, given the sensitivity of acting on anticipatory predictions.
- International collaboration: Panelists expressed openness to cooperate and share good practices; OEFA could help facilitate these technical and coordination links.

The panel concluded by emphasizing the importance of co-creation with users—from design through tool validation; the availability of open, disaggregated, and community-accessible data to inform decision-making; the real efficiencies that allow resource reallocation (reduced field hours and lower environmental footprint); and the need for protocols and ethical principles for acting on predictive analytics. Finally, it highlighted that partnerships and capacity transfer are essential conditions for scaling these digital monitoring and enforcement systems.

### 5.4. Shared priorities for digital environmental governance

Throughout the workshop, participants reaffirmed that the transition toward digital environmental governance depends not only on technological innovation but also on institutional collaboration, shared learning, and ethical alignment across APEC economies.

The sessions revealed a clear convergence of priorities, emphasizing that digital transformation in environmental enforcement must be grounded in human-capital development, transparent data management, and coordinated regional action. Rather than isolated domestic strategies, the discussions reflected a shared understanding that progress relies on three complementary dimensions.

First, capacity building was identified as a strategic enabler. Economies agreed that sustained investment in training, regional mentorships, and professional networks is essential for environmental authorities and inspectors to adopt emerging technologies such as artificial intelligence, remote sensing, and big-data analytics. Human-capital development was considered the strongest and most durable foundation for digital transition.

Second, participants highlighted the importance of interoperability and ethical data governance. They noted that progress must occur gradually, through compatible metadata systems, open-data frameworks, and safeguards that ensure privacy, transparency, and data integrity. This standards-based, progressive approach was regarded as fundamental to strengthening cross-border cooperation without compromising data sovereignty.

Finally, there was consensus on the need for sustained policy dialogue and ongoing regional alignment. Harmonizing approaches to AI ethics, digital evidence, and data-sharing mechanisms was identified as a long-term objective aimed at strengthening mutual trust and facilitating joint environmental-monitoring initiatives among APEC economies. Rather than uniform regulation, participants advocated for an adaptive governance framework that enables interoperability and mutual recognition of digital environmental tools.

In summary, the workshop reaffirmed that regional cooperation—rather than technological uniformity—is the foundation of a sustainable digital transformation. Its success will depend on strengthened capacities, trust-based data exchange, and the gradual convergence of policies—areas in which APEC can play a strategic role as a platform for dialogue, experimentation, and collective learning.

### 5.5. Emerging conclusions and ways forward

The discussions held during the workshop revealed that APEC economies are converging toward a shared vision of anticipatory, transparent, and data-driven environmental governance. The integration of artificial intelligence, the Internet of Things, remote sensing, and big data is no longer understood as a mere technical enhancement, but as a systemic transformation that is redefining how environmental institutions operate and cooperate.

Four central ideas emerged from the sessions:

- From monitoring to governance: The use of AI and big data is driving a shift from environmental observation toward predictive, evidence-based decision-making.
- Institutional maturity as a key enabler: The effectiveness of digital technologies depends on robust regulatory frameworks, coherent data governance, and strengthened institutional ethics.
- Open and interoperable data ecosystems: Experiences such as Blue Map and Global Forest Watch demonstrate that transparency and open data foster accountability and enhance citizen participation.
- Integration and results orientation: The most advanced systems link digital monitoring with enforcement, policy instruments, and market mechanisms that promote environmental compliance and sustainability.

Taken together, these findings outline a progressive trajectory within APEC in which digitalization strengthens cooperation, stimulates innovation, and contributes to achieving the region's goals for inclusive and sustainable growth.

Looking ahead, APEC can consolidate this momentum through:

- continued capacity building for inspectors and technical specialists;
- the development of regional frameworks on digital ethics and interoperability;
- pilot projects that link environmental data with fiscal and market instruments;
- peer-learning mechanisms and shared metrics on environmental digitalization.

In sum, the workshop reaffirmed that technology acquires real value when it is embedded within ethical, inclusive, and evidence-based governance. APEC's leadership lies in transforming digital innovation into a public good that advances sustainability and collective environmental management.

# 6. CASE STUDIES – ENVIRONMENTAL GOOD PRACTICES WITH TECHNOLOGICAL COMPONENTS

## 6.1. Purpose and Scope of the Technical Synthesis

Building on the discussions held during the workshop and the analytical work conducted in earlier stages of the project, this synthesis consolidates the main technological, institutional, and governance-related findings derived from the APEC initiative on new technologies for environmental enforcement. The analysis integrates case studies and practical experiences presented by participating economies, offering an integrated view of how Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Remote Sensing (RS) are transforming environmental monitoring, verification, and compliance practices.

The purpose of this synthesis is to identify convergent trends and technical lessons that demonstrate how digital tools are being applied to strengthen environmental governance. The evidence collected shows that successful digitalization models depend not only on technological innovation but also on institutional maturity and the ethical frameworks that guide their implementation.

The objective of this chapter is to compile, systematize, and disseminate a set of technological solutions presented during the workshop. It seeks to provide information that enables an understanding of the scope and characteristics of each initiative, as well as offer practical guidance on the technical requirements, digital architectures, and interoperability conditions necessary to replicate these solutions across different productive sectors in APEC economies.

Throughout the chapter, the dossier presents case studies validated through technical questionnaires and supporting material provided by the representatives of each initiative. All cases are described using a common framework, allowing for comparison, identification of technological best practices, and recognition of enabling conditions for effective implementation.

This dossier is intended for:

- Government entities interested in strengthening environmental enforcement through modern technological tools.
- Research centers, technical organizations, and academia seeking to apply methodologies based on remote sensing, drones, artificial intelligence, and big data in new contexts, as well as contribute to applied research, specialist training, and scientific validation.
- Private sector stakeholders and producers requiring effective and scalable solutions to meet environmental standards and improve the sustainability of their operations.
- International cooperation agencies and multilateral forums promoting interoperability and the exchange of data and knowledge among economies.

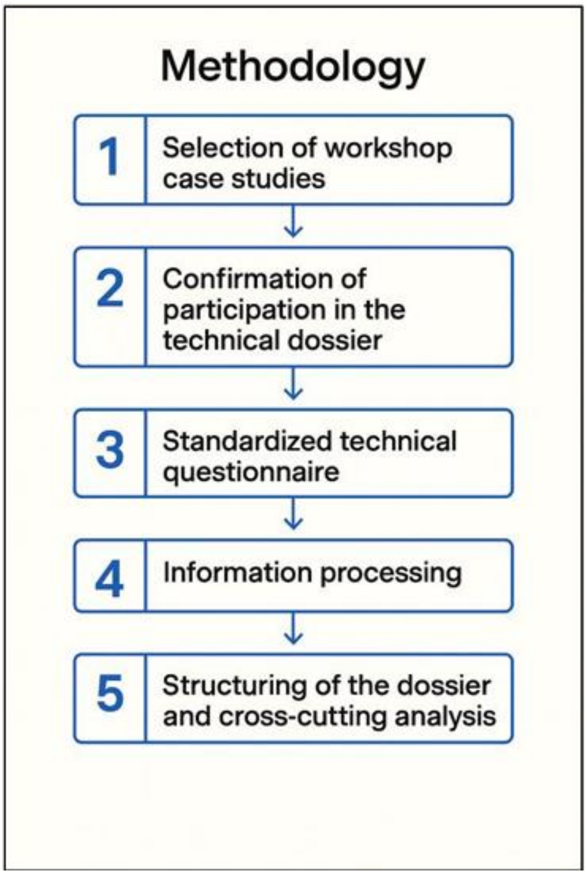
In line with the above, the dossier aims to serve as a technical reference instrument to promote the adoption, adaptation, and scaling of technological solutions applied to environmental and productive monitoring. The experiences shared and discussed during the workshop are presented with a focus on their potential replicability in other APEC economies.

### 6.2. Work Methodology

The process of developing the technical dossier was carried out using a methodology structured in successive stages, designed to ensure the quality, comparability, and consistency of the information collected. This approach made it possible to systematize the case studies in a uniform manner, validate the technical information with the responsible entities, and ensure coherence with the project's objectives.

The stages of the process are presented below:

**Figure 22. Methodological framework for the development of the technical dossier.**




***Source:*** *Prepared by the technical team of the dossier (OEFA, 2025).*

### 6.2.1. Selection of Workshop Cases

Based on the presentations delivered during the Technology Innovation Workshop for Environmental Monitoring, a set of representative cases was selected according to four main criteria: degree of innovation, technical validation, sectoral relevance, and potential replicability across APEC economies. This process made it possible to prioritize diverse technological solutions with demonstrable impacts.

### 6.1.2. Confirmation of Participation in the Technical Dossier

Subsequently, the presenters whose cases were selected were contacted to confirm their formal participation in the dossier. At this stage, they were informed about the official nature of the publication within the APEC framework and were asked to provide consent for the inclusion of their experience, in accordance with the forum's standards of transparency and collaboration.

### 6.1.3. Standardized Technical Questionnaire

Contributors who confirmed participation received a standardized technical questionnaire designed to gather homogeneous and comparable information. The questionnaire included questions related to the objectives of the solution, technological architecture, infrastructure requirements, regulatory framework, implementation, operation and maintenance costs, sustainability, and conditions for replicability.

### 6.1.4. Information Processing

The responses obtained were reviewed, systematized, and transformed into a common narrative format. This process aimed to ensure clarity, internal consistency, and cross- case comparability. Complementary materials—such as links, annexes, diagrams, and supporting documents—were also integrated, either provided directly by contributors or developed from the information received.

### 6.1.5. Structuring of the Dossier and Cross-cutting Analysis

Once the technical records were processed, the information was organized into three main components:

- Chapters on selected cases, which provide a detailed description of each technological solution presented during the workshop. Each chapter follows a uniform reference framework that includes: context, technological architecture, infrastructure requirements, regulatory framework, operation and maintenance, costs, sustainability, and potential replicability in other APEC economies.
- Cross-cutting comparative analysis, which synthesizes common trends, recurring challenges, and lessons learned related to the implementation of these technological solutions.
- Strategic conclusions and recommendations, aimed at facilitating the adoption, adaptation, and scaling of the technologies described in other institutional contexts within APEC.

This methodological approach ensured the technical coherence of the dossier and strengthened the validity of the synthesis presented, resulting from a collaborative and systematically reviewed process within the APEC framework.

## 6.3 Technical Sheets of Selected Cases

This section presents the technical sheets of the solutions selected after the workshop, organized under a common framework that enables comparative analysis. Each sheet
describes the context, technological architecture, infrastructure requirements, regulatory framework, operation, costs, and sustainability, while also emphasizing the conditions necessary for adoption, adaptation, and scaling of the solution in other APEC economies.

The technologies included in this section are:

1. Japan: Use of satellite imagery for agricultural administration (NARO/MAFF).
2. Thailand: Pollution Online Monitoring System (POMS) and Continuous Emission Monitoring Systems (CEMS).
3. Republic of Korea: Drone and satellite-based monitoring for agricultural research and environmental management (RDA).
4. Indonesia: SISCrop 2.0 – Agricultural traceability and monitoring platform.
5. Malaysia: RSPO – Evolution of standards and the integration of remote sensing and technology.

### 6.3.1. Japan: Use of Satellite Imagery for Agricultural Administration (NARO/MAFF)

This section is based on the information provided by Mr. Naoki Ishitsuka, Group Leader at the National Agriculture and Food Research Organization (NARO), Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, complemented by his presentation during the workshop. The content has been processed under the analytical framework of the dossier to facilitate understanding of the technological architecture, applied methodologies, and conditions that enable its potential replicability in other APEC economies.

#### A) Context and Scope

Japan has developed an integrated agricultural administration system based on satellite imagery, led by NARO and MAFF. The core of the initiative is the *Fude* polygons, which represent approximately 30 million agricultural plots across the economy and have been available as open data under a Creative Commons Attribution[1] (CC-BY) license since 2019. This geospatial input serves as the basis for remotely validating whether agricultural land is cultivated, fallow, or abandoned, significantly reducing the need for extensive on- site inspections.

The system is designed to optimize field inspections, reduce administrative costs, identify unused land, verify agricultural subsidies, and estimate environmental

[1] This license allows the use, distribution, and adaptation of the data as long as proper credit is given to the original source, thereby promoting responsible reuse and transparency in the management of geospatial information.

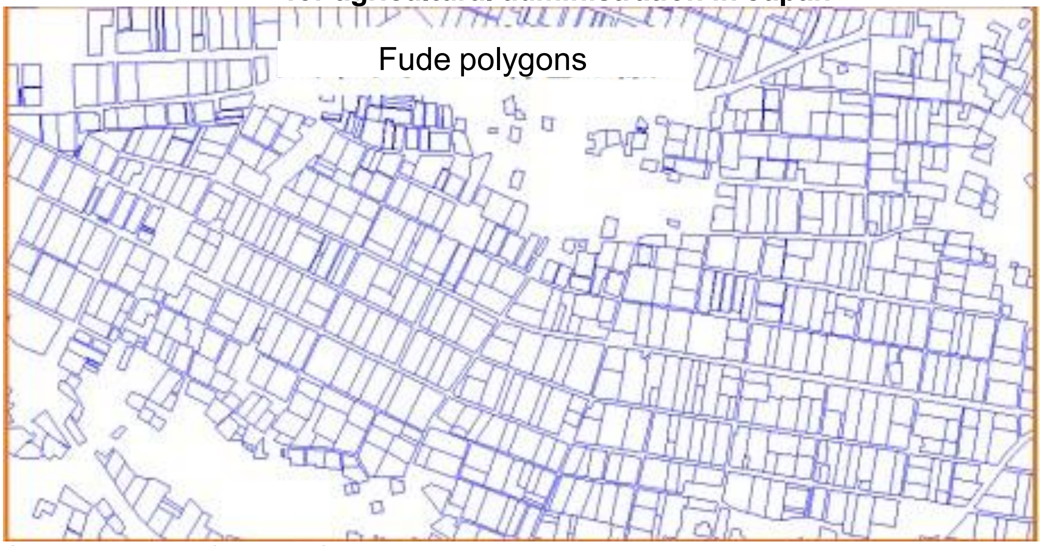
impacts derived from agricultural practices.

**B) Main Technical Components**

The system developed by NARO integrates geospatial information from agricultural polygons with optical and SAR satellite imagery, enabling the automated verification of land use. Its main technical components are as follows:

a) **Fude Polygons:**
These constitute the central geospatial input of the solution. They are generated manually through the superimposition of aerial and satellite imagery within a GIS environment, allowing for precise delineation of every agricultural plot in the economy.

**Figure 23. Model for the use of satellite imagery and Fude polygons for agricultural administration in Japan**




***Source:*** *Extracted from NARO/MAFF presentation at the Workshop (2025).*

b) **Satellite Data:**
These constitute a fundamental input to the solution and are downloaded and preprocessed from Google Earth Engine (GEE) or other authorized providers. In addition to optical imagery, the system incorporates data from synthetic aperture radar (SAR) satellites, primarily PALSAR-2 and Sentinel-1, which allow reliable information to be obtained even under cloudy conditions.

c) **eMAFF Application:**
This is a specialized mobile application used internally by the Japanese government, designed to optimize the management and oversight of agricultural land. The tool enables local governments and field teams to perform on-site validation of the results generated through satellite analysis, facilitating land-use verification and the confirmation of agricultural activities in the field.

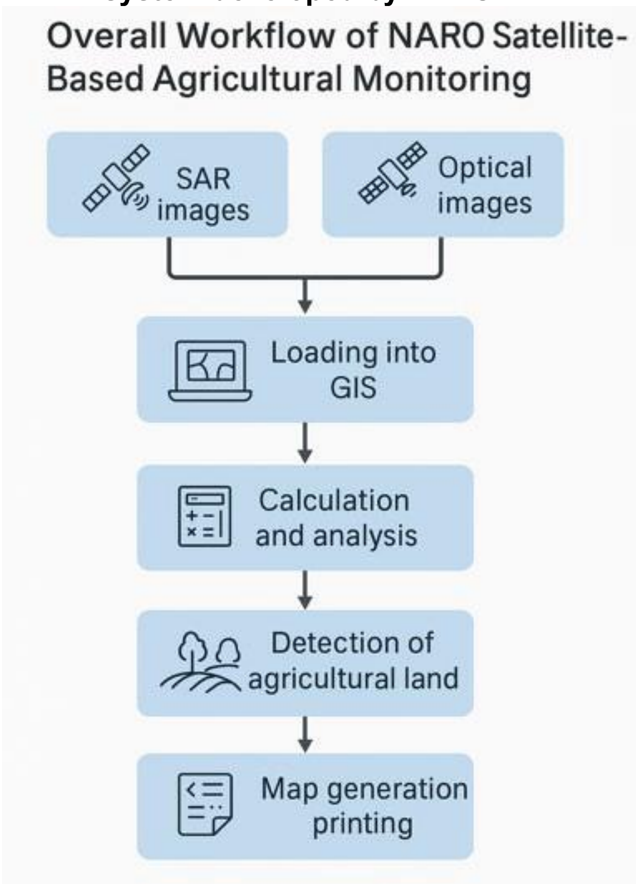
d) **QGIS Application**
This is the primary environment for visualizing, analyzing, and validating geospatial information. In this platform, Fude polygons are integrated with optical and SAR satellite imagery, on which the analysis methods defined by

NARO are applied:

- Backscatter Intensity Threshold Method: Used to determine whether an agricultural plot is in active cultivation or not.
- Differential Minimum Value Method: Used to verify whether grasslands or agricultural areas in mountainous regions have been effectively cultivated or managed, based on the comparison of satellite imagery time series.

All the components described interact as follows:

**Figure 24. General workflow of the satellite-based agricultural monitoring system developed by NARO**




***Source:*** *Prepared based on the NARO/MAFF presentation at the Workshop (2025).*

## C) Required Infrastructure

The implementation of the system described does not require complex or high-cost technological infrastructure, as the model is designed to leverage existing resources and freely accessible tools, facilitating its replicability in other APEC economies.

In general, the infrastructure requirements are focused on the following:

a) **Connectivity:**
Stable internet access for downloading imagery and synchronizing data with cloud- based analysis platforms (e.g., Google Earth Engine), as well as for integrating layers into QGIS when online services are used.

b) **Processing and storage:**
A standard desktop or laptop computer with sufficient capacity to operate QGIS and manage geospatial files (GeoTIFF, GeoJSON, among others).

c) **Field devices:**
For on-site verification, only a mobile device with GPS and internet connectivity is required, compatible with the eMAFF application.

### D) Regulatory Framework and Standards

The system is supported by a regulatory framework that allows the use of satellite imagery as valid evidence within agricultural verification processes in Japan. The official provisions that support this application are summarized in the following table:

**Table 2. Regulatory frameworks and official guidelines supporting the use of satellite imagery in agricultural verification processes in Japan**

| Title | Description |
|---|---|
| **Agricultural Land Act (2022)** | Recognizes the use of satellite information and remote-sensing tools as complementary means for the supervision and classification of agricultural land. |
| **Implementation Guidelines for Direct Payment Subsidies in Mountainous and Hilly Regions** | Partially revised in 2020, these guidelines introduce the possibility of using aerial photographs and satellite imagery as methods for verifying land-management conditions. |
| **Field Survey Implementation Manual Using Satellite Imagery (2023)**<br>https://www.maff.go.jp/j/zyukyu/attach/pdf/eisei-18.pdf<br>(Language: Japanese only) | Establishes the official technical guidelines for applying the backscatter threshold method in QGIS, using SAR imagery (Sentinel-1, PALSAR-2) as valid evidence in the verification processes for direct payment schemes in mountainous regions. |

***Source:*** *Prepared based on information from NARO/MAFF (APEC Workshop, 2025).*

### E) Use Cases and Field Experiences

The system developed by NARO/MAFF has been progressively adopted by local governments in Japan, demonstrating its effectiveness in reducing fieldwork and administrative costs through the use of satellite imagery, drones, and artificial intelligence analysis. Below are some representative cases:

a) City of Gero (Gifu):
The first locality to implement a system integrating satellite data and artificial intelligence models to identify abandoned agricultural land. The labor workload decreased significantly compared to traditional on-site inspections.

b) City of Maizuru (Kyoto):
Approximately 70% of verifications are conducted through artificial intelligence and satellite analysis, reducing on-site inspections from 67,000 to approximately 1,500 plots (a reduction of nearly 98%).

These experiences demonstrate the progressive expansion of the technology across different local governments, strengthening institutional efficiency and showcasing the scalability of the model in varied territorial contexts. They also confirm its usefulness as a pre-verification tool, reserving physical inspections only for cases requiring additional validation.

### F) Technological Sustainability and Future Perspectives

To ensure the continuity and potential replicability of the solution, the following key conditions have been identified:

a) Periodic maintenance and updating of the FUDE polygons, as well as the continuous incorporation of new satellite imagery into the system, ensuring that both resources remain available in open formats and compatible with freely accessible platforms such as QGIS and Google Earth Engine.
b) Strengthening the technical capacities of local governments in geospatial analysis, satellite data management, and process automation using open-source software tools—a fundamental condition for sustaining the model and facilitating its adaptation in other APEC economies.

### G) Transferability to Other APEC Economies

The model developed by Japan for satellite-based agricultural administration presents high potential for transfer and adaptation to other APEC economies due to its modular design, use of open platforms, and minimal reliance on specialized infrastructure.

**Conditions for Adoption:**

a) Availability of baseline geospatial data or digitized agricultural cadasters that can serve as analytical units, functioning similarly to the Fude polygons.
b) Access to free or low-cost satellite imagery—such as Sentinel-1, Sentinel-2, or Landsat—and sufficient connectivity to process these datasets in cloud-based environments (e.g., Google Earth Engine).
c) Local technical capacities in geospatial analysis, quality control, and the use of open-source GIS tools (such as QGIS).
d) Existence of an institutional or regulatory framework that recognizes satellite information as a valid means of administrative or environmental verification.

**Factors for Replication:**

a) The use of open-source software and open data reduces entry barriers and facilitates the training of technical personnel.
b) The system's architecture enables interoperability between local platforms and cloud services, adapting to different levels of connectivity and computational capacity.
c) The analytical methods can be adjusted to local conditions using time series of satellite imagery from local or regional programs, which strengthens the relevance of the analysis.
d) Its application can be expanded to other productive sectors, including forest monitoring, water-resource management, or land-use oversight in environmental programs.

### 6.3.2 Thailand: Pollution Online Monitoring System (POMS)

This section is based on the information provided by Ms. Pantita Buachan, Scientist Professional Level at the Department of Industrial Works (DIW), Ministry of Industry of Thailand, complemented by the presentation *"Enhancing Transparency and Compliance through CEMS and POMS in Thailand's Industrial Sector"* delivered during the workshop. The content has been processed and organized to describe the system's architecture, real- time data transmission mechanisms, regulatory compliance standards, and the conditions that enable its replicability in other APEC economies.

#### A) Context and Scope

Thailand has developed and implemented a domestic online pollution monitoring system with the objective of ensuring more transparent, reliable, and real-time control of industrial pollution. This effort, led by the Department of Industrial Works (DIW), responds to the need to strengthen environmental enforcement amid the economy's industrial growth, particularly in the control of air emissions and wastewater discharges.

The system has economy-wide coverage and is mandatory for industries with wastewater discharges exceeding 500 $m^3$ per day, biochemical oxygen demand (BOD) loads over 4,000 kg/day, or facilities with significant air-emission outputs.

The system has been designed to meet the following objectives:

- Transparency: Online and real-time reporting of emissions and discharge data, accessible to regulatory agencies and relevant stakeholders.
- Emission control: Continuous detection of exceedances and automatic alert generation to facilitate timely corrective actions.
- Regulatory compliance: Enforcement of ministerial orders requiring the mandatory installation of online monitoring systems for specific types of industrial facilities.
- Public trust: Provision of verifiable data that reduces potential conflicts with local communities and reinforces institutional credibility.

#### B) Main Technical Components

Thailand's industrial environmental monitoring system combines field hardware, digital infrastructure, and analytical software to ensure a reliable flow of real-time information on emissions and discharges. Its architecture includes the following technical components:

**a) Sensors and Monitoring Equipment:**

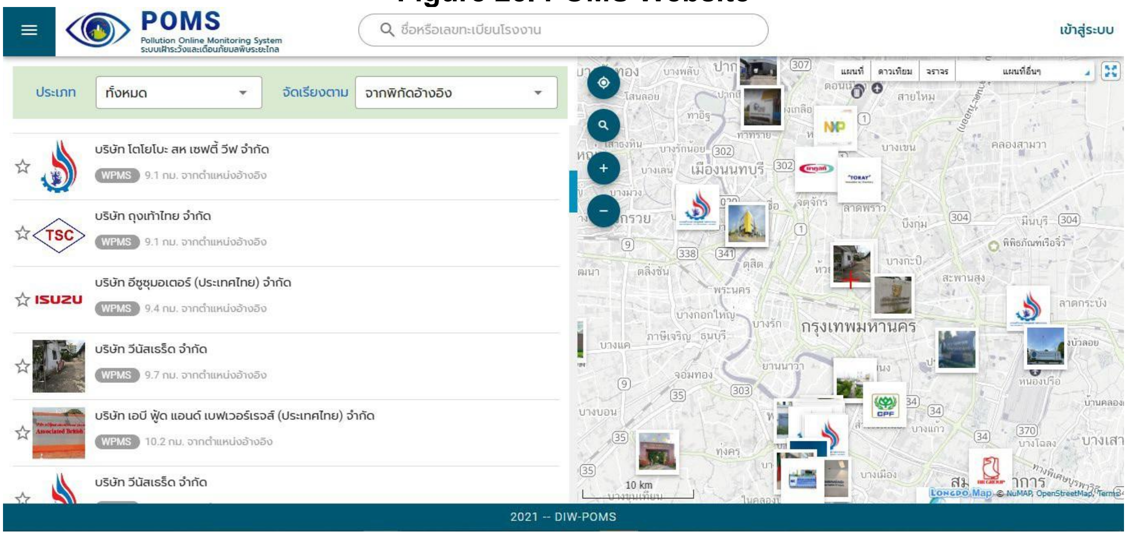
This includes Continuous Emission Monitoring Systems (CEMS), installed on industrial stacks and gas-outlet ducts, which continuously and automatically measure parameters such as $SO_2$, NOx, CO, $CO_2$, $O_2$, particulate matter (PM), temperature, and gas flow.

For water monitoring, online BOD/COD systems are used, recording parameters such as biological and chemical oxygen demand, pH, conductivity, temperature, and discharge flow.

**b) Pollution Online Monitoring System (POMS) Platform:**
This component consists of:

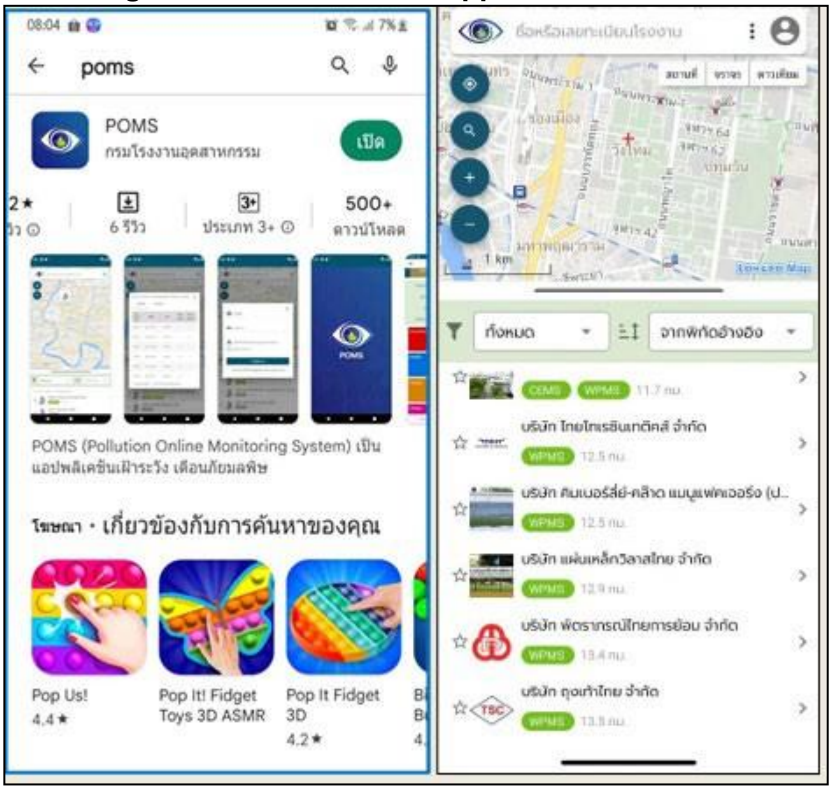
- **POMS Box:** A device that receives signals from CEMS or BOD/COD equipment (raw data) and transmits them via secure internet protocols to DIW's central servers.
- **POMS Client:** A web platform and mobile application that enables real-time dashboard visualization, geospatial monitoring of facilities, automated alert generation, reporting tools, and direct data access for regulatory authorities.

**Figure 25. POMS Website**




***Source:** Extracted from https://poms.diw.go.th/*

**Figure 26. POMS Mobile Application Interface**



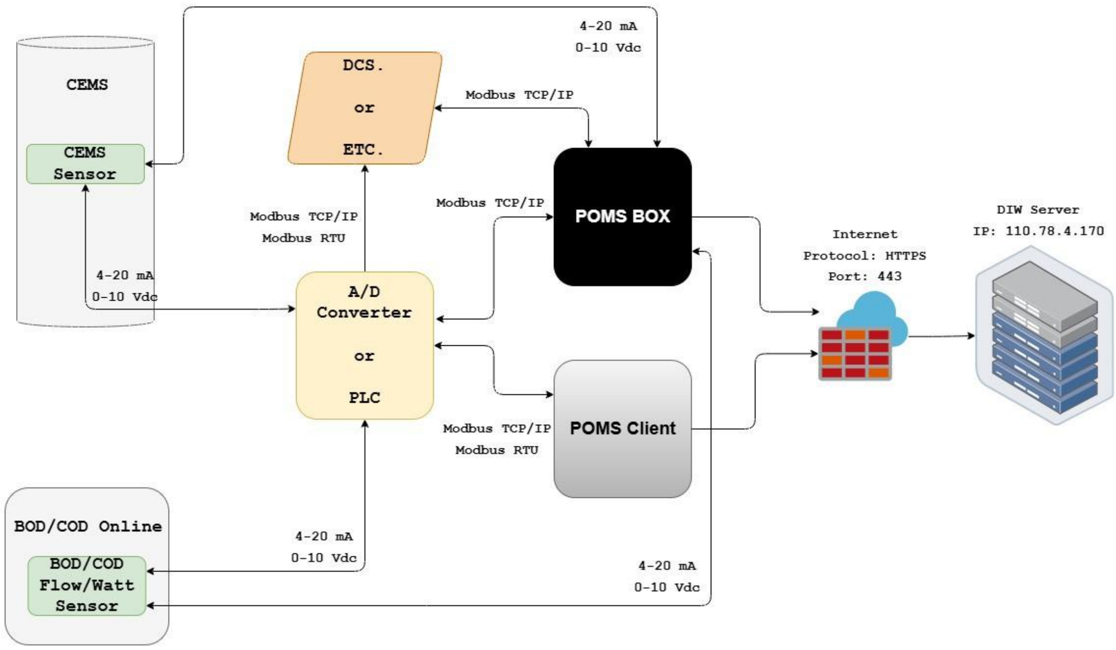

***Source:*** *Extracted from DIW presentation at the Workshop (2025).*

The POMS system is designed to integrate with other environmental monitoring systems and data sources, including:

- The Wastewater Pollution Monitoring System (WPMS), which manages data from online BOD/COD analyzers.
- Fixed and mobile environmental monitoring stations, operated by the Pollution Control Department (PCD) and local governments.
- Public-access portals, currently under development, aimed at strengthening transparency and facilitating citizen access to emissions and effluent data.
- Inter-institutional data-sharing mechanisms, through interoperability with the Pollution Control Department (PCD), the Industrial Estate Authority of Thailand (IEAT), and other government agencies.

The components described interact as follows:

**Figure 27. Architecture of the POMS Monitoring System in Thailand**




***Source:*** *Prepared based on the questionnaire completed by Ms. Buachan Pantita.*

## C) Required Infrastructure

The implementation of Thailand's environmental monitoring system requires a robust and hybrid technological infrastructure composed of field equipment, secure communication networks, and central servers that support the operation of the Pollution Online Monitoring System (POMS). In general, the requirements are focused on the following:

- **Connectivity:**
  Broadband internet and 4G/5G mobile networks for continuous data transmission. POMS Boxes include temporary buffer storage, allowing automatic retransmission when connectivity is restored.

- **Servers and Storage:**
  A hybrid central data system (on-premises + cloud) with backup and disaster-recovery mechanisms. Currently, the system operates at the Industrial Environmental Monitoring Center (IEMC) of the Department of Industrial Works (DIW).

- **Power Supply and Environmental Conditions:**
  CEMS equipment and POMS Boxes require uninterruptible power supply (UPS) systems to prevent data loss during power outages. DIW data centers are equipped with HVAC systems (temperature and humidity control), surge protection, and fire- suppression systems, ensuring stable conditions for server and analyzer operation.

- **Physical Requirements at the Facility:**
  Plant-level installation must ensure adequate conditions for the integrated operation of CEMS and POMS Boxes, meeting the following criteria:
  - Access to sampling points that comply with the technical guidelines of the
    U.S. Environmental Protection Agency (U.S. EPA) and DIW.
  - Physical security measures to prevent tampering or unauthorized access to analyzers, probes, and POMS Boxes.
  - Sufficient space and structural integrity to mount probes, analyzers, and data-acquisition systems.
  - Outdoor protection against vibrations, humidity, dust, and other factors that may affect operational stability.

Taken together, this infrastructure enables secure and continuous transmission of environmental data from industrial plants to DIW's central server, ensuring full traceability throughout the process.

## D) Regulatory Framework and Standards

The regulatory framework supporting CEMS and POMS is based on the Thailand Factory Act (1992) and a series of subsequent ministerial notifications:

**Table 3.** Regulatory framework applicable to the POMS system in Thailand

| Title | Description |
|---|---|
| Ministerial Regulation B.E. 2544 (2001) | Issued by the Ministry of Industry, it establishes the obligation to install CEMS in industries classified as high environmental risk. It defines the parameters to be monitored, data transmission frequency, and calibration and maintenance requirements. |
| DIW Notifications (2007, 2010, 2015) | Require wastewater treatment plants with discharges ≥500 $m^3$/day or organic loads ≥4,000 kg/day BOD to install online BOD/COD monitoring systems. |
| Ministerial Order B.E. 2565 (2022) | Expands regulatory coverage and incorporates the use of POMS as the official platform for the collection and validation of emissions and discharge data. |
| DIW Technical Guidelines | Establish the audit, calibration, and quality-control procedures applicable to equipment and technical providers. |

***Source:*** *Prepared based on the questionnaire completed by Ms. Buachan Pantita.*

Additionally, the Thai system adopts U.S. EPA guidelines, particularly:

- 40 CFR Part 60 (Standards of Performance for New Stationary Sources): Regulates atmospheric pollutant monitoring in new industrial facilities.
- 40 CFR Part 75 (Continuous Emission Monitoring): Defines methodologies and technical requirements for automated systems measuring gaseous emissions and particulate matter.

These standards support international technical harmonization and ensure the comparability of environmental data generated by Thai industries with those from other APEC economies.

**E) Licensing and Intellectual Property**

The Department of Industrial Works (DIW) retains ownership of the rights over the Pollution Online Monitoring System (POMS), including its database architecture, communication protocols, and the web platform used for environmental data management. The equipment and firmware used in the system are licensed by authorized manufacturers, but their operation remains under state supervision.

Additionally, DIW maintains exclusive authority over the use, dissemination, and redistribution of data generated by the CEMS and POMS systems.

The specific conditions are as follows:

- International collaboration:
  The use or incorporation of regulatory compliance data in projects or databases led by international organizations (e.g., APEC or UNEP) requires formal authorization from DIW, ensuring proper source attribution and alignment with domestic policies on environmental data protection.

- Academic and research reuse:
  Reuse of information for scientific or academic purposes is permitted, provided that cooperation agreements are established to ensure the authenticity, confidentiality, and traceability of the data, preserving its integrity as regulatory evidence.

**F) Data Governance and System Operation**

Thailand's system incorporates a comprehensive data-governance model designed to ensure the quality, traceability, and appropriate use of information generated by industrial facilities. This model combines automated quality-assurance processes (QA/QC) with specialized operational functions, ensuring both technical reliability and institutional management of the system.

**a) Data Quality Assurance and Control (QA/QC)**

POMS applies both automated and manual quality-control mechanisms to validate the integrity of data transmitted by industrial sensors:

- **Automated validation (QA):**
  - The data-capture process follows DIW and U.S. EPA guidelines, which require a minimum of 80% valid daily data for a plant's operation to be considered compliant.
  - Each incoming data point passes through filters that detect transmission errors, signal interruptions, and outliers.

- **Quality control (QC):**
    - The system classifies data as valid, suspicious, or invalid according to DIW's technical criteria.
    - Equipment providers submit calibration and reference-test reports, which are audited by certified inspectors.

- **Standardized formats and versioning:**
    - Data transmitted by industries are stored in structured formats (CSV/JSON/XML) defined by DIW to ensure interoperability across different providers.
    - The system includes an automated versioning scheme that records the history of modifications, updates, and validations.

- **Performance metrics:**
    - The system maintains operational availability of 90% or higher, with an average latency of less than five minutes between data capture and transmission.

- **Information security:**
    - Digital signatures, audit logs, data encryption, and chain-of-custody traceability mechanisms are applied.

This quality-assurance approach ensures that the information is auditable, traceable, and suitable for automated enforcement processes.

**b) Operational Roles and Management Structure**

The operation of the system requires a multidisciplinary organizational structure combining expertise in environmental engineering, information technologies, and data analytics. The main roles in daily system operation include:

**Table 4.** Operational roles and responsibilities in Thailand's POMS system

| Role | Description |
| --- | --- |
| **Plant Operators** | Responsible for routine operation of analyzers, ensuring continuous sampling and performing initial incident resolution. |
| **CEMS Maintenance Personnel** | Conduct preventive and corrective maintenance, including sensor cleaning, probe calibration, and replacement of consumables (e.g., filters and reagents). |
| **Data QA/QC Personnel (Regulators)** | Validate incoming data, identify anomalies, and perform correlation checks with reference laboratory results. |
| **IT and Cybersecurity Personnel** | Maintain server availability, ensure secure data transmission, prevent cyber threats, and guarantee system redundancy at DIW's central monitoring center. |

***Source:*** *Prepared based on the questionnaire completed by Ms. Buachan Pantita.*

### c) Implementation Costs

The deployment of Thailand's environmental monitoring system is based on a mixed implementation model between the public sector and regulated industries. The Department of Industrial Works (DIW) establishes the technical standards, central infrastructure, and data platform, while each industrial facility is responsible for installing and maintaining its own monitoring equipment and transmission modules connected to the local system.

The cost structure combines capital expenditure (CAPEX) for initial installation and operational expenditure (OPEX) associated with maintenance, connectivity, and specialized services.

**Table 5. Summary of cost components and financial responsibilities.**

| Component | Description | Funding Responsibility |
|---|---|---|
| **CEMS and Online BOD/COD Equipment** | Analyzers, auxiliary sensors, sampling units, and POMS Box. | Industrial facility (user) |
| **Network and Communications Infrastructure** | VPN / 4G/5G connectivity, secure modems, industrial routers. | Industrial facility (user) |
| **Central Servers and Storage** | Infrastructure hosted at DIW/IEMC with redundancy and automatic backup. | DIW – public funding |
| **POMS Management Software** | Development, maintenance, and system licenses. | DIW |
| **Technical Support and QA/QC** | Calibration, data validation, and annual audits. | Shared (industry + DIW) |
| **Training and Technical Assistance** | Training for operators, inspectors, and IT personnel. | DIW, with international support (e.g., UNEP/APEC) |

***Source:*** *Prepared based on the questionnaire completed by Ms. Pantita Buachan.*

### d) Use Cases and Field Experiences

CEMS and POMS systems have been widely implemented across industrial economies, power plants, petrochemical complexes, and large manufacturing facilities in Thailand. By 2021, the system had achieved economy-wide coverage, with hundreds of factories connected to the online monitoring framework.

The main lessons identified during deployment are as follows:

- Technical: The initial reliance on modem-based and satellite communication links generated latency issues and data loss. The progressive migration toward broadband networks and mobile communications significantly reduced these problems and improved the system's operational stability.

- Operational: Continuous calibration and the strict application of quality assurance and quality control (QA/QC) procedures have been essential to maintaining data reliability, particularly for BOD/COD analyzers, which require periodic correlation with reference laboratory results.

- Institutional: The existence of a proactive regulatory framework, along with adequate budget allocations—for example, THB 17.2 million allocated to POMS and THB 15 million for the modernization of the IEMC—were decisive factors for successful implementation.

- Limiting factors: Initial technical experience in handling advanced analyzers was limited, which delayed system commissioning. Capacity building for operators, vendors, and regulators was key to overcoming this gap.

**e) Technological Sustainability and System Outlook**

DIW has established a roadmap aimed at expanding the functional scope of the system and strengthening its analytical and interoperability capabilities. The prioritized evolution lines include:

- **Integration of artificial intelligence and machine learning**, with the purpose of automatically identifying non-compliance patterns, data anomalies, and irregular emission behaviors.
- **Implementation of environmental big-data modules**, capable of processing large volumes of information originating from multiple sources (CEMS, POMS, monitoring stations, and IoT sensors).
- **Progressive migration toward hybrid cloud environments**, increasing storage capacity, scalability, and security against operational incidents or cyberattacks.
- **Standardization of APIs and data protocols**, aimed at improving interoperability among local agencies and facilitating connection with international monitoring systems.

**f) Implementation and Deployment**

The deployment of CEMS and POMS in Thailand was carried out through a phased implementation plan:

1. Diagnostic phase: Identification of sampling points, gap analysis of existing systems, and assessment of regulatory requirements applicable to the target categories of industrial facilities.

2. Pilot projects (2018–2020): Initial integration of online BOD/COD analyzers and CEMS in a limited set of industrial installations, with the purpose of validating connectivity, data transmission, and QA/QC frameworks.

3. Scaling phase (2021): Economy-wide rollout supported by a budget allocation of THB 17.2 million for POMS development and THB 15 million for the modernization of the IEMC.

4. Key milestones achieved:
    - August 2021: Full operational launch of POMS.
    - 2022: Expansion of the regulatory scope in accordance with Ministerial Orders B.E. 2565.

5. Dependencies: The success of the deployment depended on inter-agency coordination, technical assistance from analyzer vendors, and the stability of the ICT infrastructure used.

Additionally, the following definitions for acceptance tests, KPIs, and success criteria were applied:

- **Factory Acceptance Tests (FAT):** Conducted at vendor facilities to validate the specifications of analyzers and communication modules.

- **Site Acceptance Tests (SAT):** Performed after installation to verify performance under real operating conditions.

- **Commissioning KPIs:**
    - Hourly availability ≥ 90%.
    - Accuracy within ±15% for CEMS parameters and within regulatory thresholds for online BOD/COD.
    - Data latency < 5 minutes for real-time transmission.
    o ≥ 80% availability of valid data per day.

- **Success criteria:** Compliance with ministerial regulations, uninterrupted integration with DIW central servers, and sustained reliability during a six-month verification period.

### g) Transferability to Other APEC Economies

Thailand's experience with CEMS and POMS is transferable to other APEC economies provided that minimum enabling conditions are established and that adoption follows a phased approach, beginning with targeted pilots and progressively expanding coverage at the sectoral or economy-wide level.

**Key prerequisites:**

- A legal framework that mandates online emission monitoring.
- Government commitment to the centralized integration of environmental data.
- Secure and reliable ICT infrastructure with redundancy and standardized transmission protocols.

**Identified barriers:**

- High initial capital costs (CAPEX) associated with analyzers and CEMS equipment, requiring adequate budget planning.
- Limited availability of trained technical personnel for maintenance, calibration, and data QA/QC.

- Connectivity constraints in remote areas, which may affect continuous data transmission.

**h) Recommendations for replication:**

- Adopt a gradual approach, starting with pilots in priority sectors and advancing toward economy-wide expansion.
- Strengthen institutional capacity in data QA/QC and environmental analytics, including regional training programs.
- Develop inter-agency data exchange mechanisms to maximize regulatory and public policy value.
- Leverage cloud-based platforms and mobile networks to overcome geographic and infrastructure barriers, ensuring operational continuity and reliable data transmission.

### 6.3.3 Republic of Korea: Drone and Satellite-Based Monitoring for Agricultural Research and Environmental Management

The information presented in this section was provided by Dr. SukYoung Hong, researcher at the Rural Development Administration (RDA) of the Republic of Korea, and complemented with his presentation during the *Technology Innovation Workshop for Environmental Monitoring*. The content has been processed and analyzed to describe the system architecture, real-time data transmission mechanisms, compliance standards, and the conditions that enable its potential replicability across other APEC economies.

**A) Context and Scope**

Republic of Korea, through the Rural Development Administration (RDA) and its National Agricultural Satellite Center (NASC), is developing an integrated agricultural and environmental monitoring system based on satellite observation and the use of drones, which provide complementary spatial coverage and resolutions.

The environmental and public policy objectives of this initiative focus on the multidimensional use of satellite platforms to strengthen food security, climate resilience, disaster management, and international cooperation. Among its main applications are the monitoring of crop areas and yields, the detection of anomalies, the tracking of land-use changes, agricultural monitoring in grain-importing economies, as well as the provision of agricultural information for international technical assistance initiatives.

The limitations identified correspond mainly to operational and environmental factors, such as persistent cloud cover affecting optical observation, the need for continuous funding for infrastructure maintenance and systematic field data collection, and the estimated lifespan of the satellite mission, which is approximately five years.

Currently, the system is already generating satellite-based estimates of rice-cultivated areas and is preparing for the operational launch of the CAS500-4[2] (Agricultural & Forestry Satellite) in 2026. This advancement will allow the gradual expansion of satellite monitoring to 15 major crops by 2030.

**B) Main Technical Components**

The agricultural and environmental monitoring system developed by RDA is based on a multiscale observation architecture that combines instruments operating at different altitude levels, remote acquisition systems, geospatial data networks, and analytical tools powered by artificial intelligence.

This system integrates the following components for precision observation:

**Table 6. Platforms and Sensors**

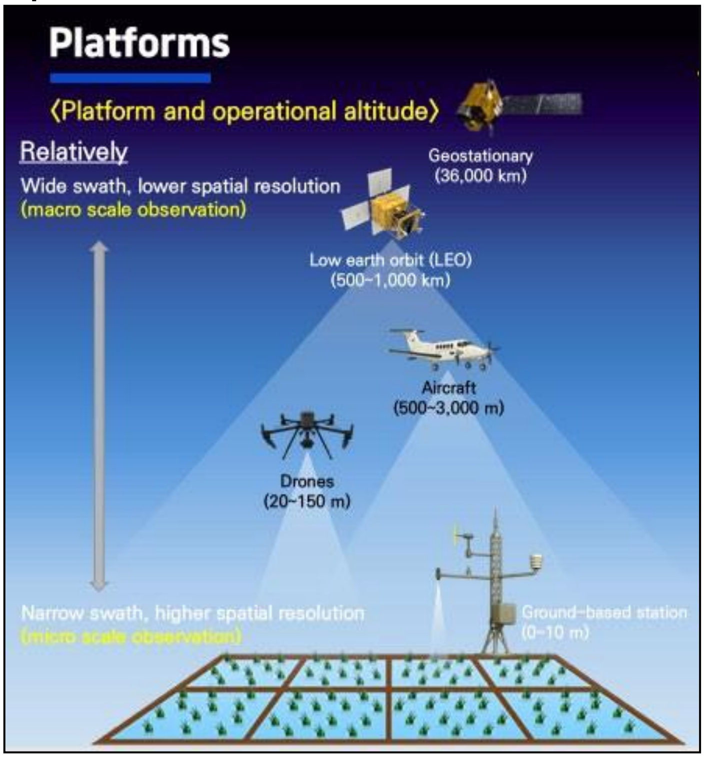
| Platform / Sensor | Operating range |
|---|---|
| Ground instruments | 0–10 m |
| Drones | 20–150 m |
| Aircraft | 500–3000 m |
| LEO satellites (low Earth orbit) | 500–1000 km |
| Geostationary satellites[3] | ~36,000 km |

By integrating imagery from CAS500-4 with drones (centimeter-level resolution), aircraft (decimeter-level resolution), and other satellites (such as Sentinel-2 and Landsat-9), a multisensor monitoring system is established that complements high-resolution, low- altitude observation with wide-coverage, high-orbit observation.

2 Earth observation satellite belonging to the Compact Advanced Satellite 500 (CAS500) program (KARI, Republic of Korea), designed to provide high-resolution optical imagery (≈ 0.5 m) and support applications in agriculture, forestry, disaster management, and land-use planning. Its launch is planned as part of the series of satellites dedicated to agro-forestry monitoring.
Source: https://database.eohandbook.com/database/missionsummary.aspx?missionID=1014

3 This set includes the core of the Korean system: the CAS500-4 Agricultural and Forestry Satellite, through which it is possible to cover 86.7% of the Korean Peninsula within a 3-day period and monitor crop growth conditions throughout the entire year.

**Figure 28. Components of the drone- and satellite-based monitoring system.**




***Source*****:** E*xtracted from the RDA presentation at the Workshop (2025).*

The data obtained from the listed components enter a standardized processing workflow structured into four levels (L1 to L4), which is currently under implementation. Each level is responsible for a specific set of actions in the data processing chain:

- Level 1 (L1): Includes radiometric calibration and geometric correction of images captured by satellites and drones.
- Level 2 (L2): Applies atmospheric and surface reflectance correction algorithms, generating baseline products ready for thematic analysis.
- Level 3 (L3): Combines optical data, radar data, and field observations to produce agricultural indicators.
- Level 4 (L4): Uses machine learning (ML) algorithms for crop classification, yield estimation, and agricultural disaster detection.

<u>Reference Data</u>:

a) **Farm Map**:

- Belonging to the Ministry of Agriculture, Food and Rural Affairs (MAFRA), it is used as the fundamental parcel-level reference layer to link satellite- and drone-derived results with actual agricultural land. It is updated annually to ensure accuracy.
- It is constructed from high-resolution aerial imagery and reflects current cultivation conditions more precisely than cadastral maps, including detailed

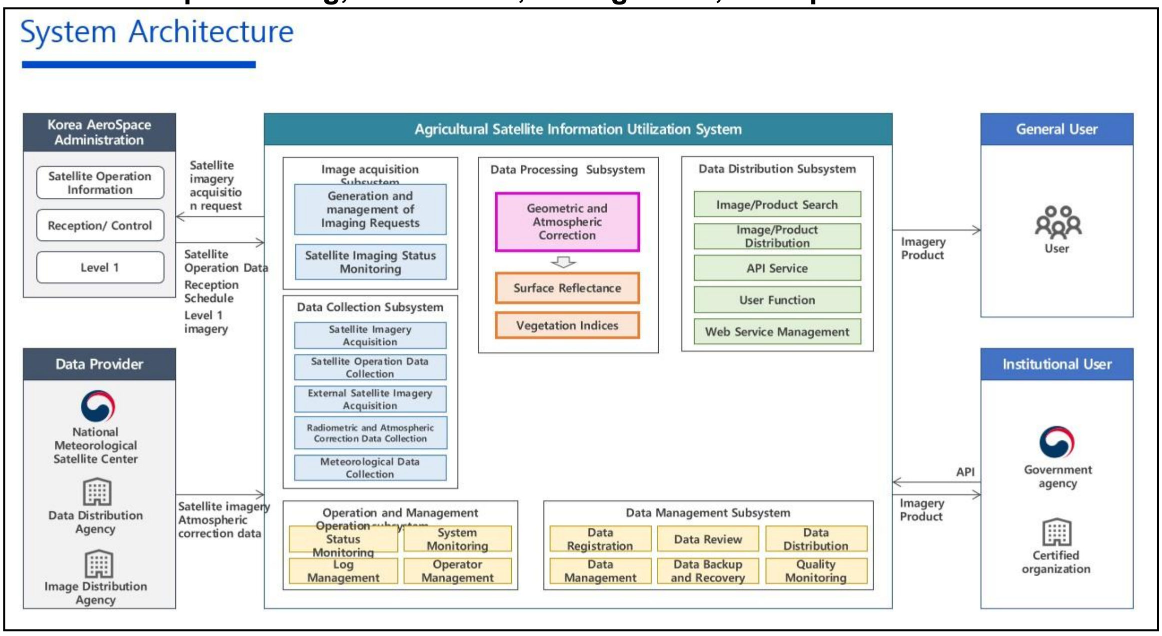
orchards, and facilities).

- Its availability in GIS-compatible formats (e.g., SHP, CSV) makes it highly suitable for system integration and automation.

The Korean system integrates the components described within an architecture composed of interconnected subsystems that manage image acquisition, processing, distribution, administration, and operational supervision. Each module performs a specific role within the satellite data value chain: from tasking and monitoring image captures, through geometric and atmospheric corrections, to the generation of analytical products and their dissemination through web services.

Figure 29 illustrates how the system coordinates the acquisition of satellite imagery (through the Korea Aerospace Research Institute – KARI and the National Meteorological Satellite Center – NMSC), its processing via geometric and atmospheric corrections, the generation of derived products such as vegetation indices, and their distribution to institutional and general users through API services and web platforms.

**Figure 29. Architecture of the Agricultural Satellite Information Utilization System of the Republic of Korea, showing the subsystems for acquisition, processing, distribution, management, and operation.**




***Source:*** *Provided by Dr. Hong, SukYoung*

### C) Required Infrastructure

The Korean system requires an integrated digital and physical infrastructure that combines observation capabilities with large-scale data processing and storage. Overall, the infrastructure requirements are concentrated in the following areas:

- **Connectivity:** Satellite imagery received by KASA[4] (Korea Aerospace Administration) and KARI (Korea Aerospace Research Institute) is transmitted through KREONET (Korea Research Environment Open Network), a domestic high-speed research network. This infrastructure ensures reliable transfer of large volumes of L1 data at 10 Gbps with low latency, enabling near-real-time delivery and stable operations.

- **Servers and storage:** The computing and storage infrastructure has been established as an integrated framework to ensure reliable processing and long- term archiving of large volumes of satellite imagery.
  The full system is organized into operational and service networks.
  - The operational network manages image acquisition and processing.
  - The service network distributes information products and provides public access.

  This integrated structure provides a secure and sustainable basis for managing the data generated during the satellite's five-year operational lifespan, ensuring archiving, analysis, and availability of derived products.

- **Field equipment:** Includes the platforms and sensors described in the previous section.
  Drones are used for field validation and verification, providing high-resolution imagery that complements satellite observations.
  Ground stations receive and process satellite data, enabling real-time delivery to end users.

- **Power supply:** Key facilities are equipped with uninterruptible power systems (UPS) to ensure stable supply and prevent data loss.

- **Technical monitoring:** Includes a real-time monitoring framework to supervise the status of satellite imagery after launch, as well as a unified dashboard that tracks the availability of processing streams, computing and storage utilization, and network connectivity. Queue management allows users to visualize pending, ongoing, completed, and failed jobs across the different product levels.

### D) Regulations and Standards

The development of the agricultural and environmental monitoring system using drones and satellites, led by the Rural Development Administration (RDA) and its National Agricultural Satellite Center (NASC), is grounded in the adoption and development of regulations across the different associated components:

[4] The Korea AeroSpace Administration (KASA) was established in May 2024 as South Korea's new domestic space agency. With its creation, the Korea Aerospace Research Institute (KARI) was incorporated under its coordination, operating as a specialized research center within KASA's organizational structure.

**Table 7. Regulatory framework related to the Korean monitoring system**

| Activity | Associated Phase / Law | Responsible Entities |
|---|---|---|
| Collection and distribution of imagery from the Agricultural and Forestry Satellite (CAS500-4) | In progress (in accordance with relevant domestic laws and regulations, such as the Framework Act on National Spatial Data Infrastructure, the Space Development Promotion Act, and the Satellite Information Security Management Regulations) | Rural Development Administration (RDA) and Korea Forest Service (KFS) |
| Operation of unmanned aerial vehicles (UAVs or drones) and processing of derived data | Aviation Safety Act and drone-related regulations | — |

***Source****: Prepared based on the questionnaire completed by Dr. Hong, SukYoung*

Additionally, the Korean system adopts the **UTM-K coordinate system** as its local geodetic reference, ensuring interoperability and positional consistency with international standards.

### E) Licensing and Intellectual Property

Imagery from the CAS500-4 satellite will be made available under a public-access scheme, promoting its adoption by public and private entities. The licensing framework and attribution requirements are currently under development, with the objective of aligning with international open-data policies and global interoperability standards.

### F) Data Governance and System Operation

The development program for the Agricultural and Forestry Satellite has established an integrated data management and analysis framework designed to ensure the reliability and applicability of derived products.

#### a) Data Quality Assurance and Quality Control (QA/QC)

- **Automatic validation (QA):**
  The system incorporates Unusable Data Masks (UDM) to identify pixels affected by clouds, shadows, snow, or other factors that reduce image usability. This feature strengthens the QA/QC process by ensuring that subsequent analyses use only valid pixels.
  Additionally, a precise set of Ground Control Points (GCPs) has been established for the entire Korean peninsula, and simulation images have been used to evaluate automated GCP extraction and matching algorithms.

- **Quality control (QC):**
  Building on advances achieved with WorkflowVcation technology for geometric accuracy and orthorectification, the system integrates standardized formats, automated QA/QC procedures, and field verification within a unified workflow. Periodic performance validations, plausibility checks, and calibration and verification campaigns are planned to reinforce the reproducibility and reliability of the data services.

- **Format standardization and versioning:**
  Once actual satellite imagery becomes available, derived products will be generated and distributed in standardized formats (GeoTIFF, SHP, CSV), accompanied by their respective UDM layers, supported by metadata and version-control mechanisms.

This unified QA/QC framework aims to strengthen the credibility of agricultural and environmental monitoring, providing a solid technical basis for policy formulation and evidence-based decision-making.

**b) Operational Roles and Management Structure**

NASC has a team of 27 specialists, composed of experts in satellite operations, image analysis, agriculture, and IT/security, organized into two main units:

- Satellite Planning & Operations Team: Responsible for system acquisition and operation, initial data processing, security management, and the production of basic imagery products (L2/L3).

- Satellite Analysis & Application Team: Focused on the automated use of data, development of analytical methods, generation of application-level products (L4), and provision of agricultural information services.

Additionally, the Agricultural and Forestry Satellite (CAS500-4) will be operated and managed through close collaboration between the Korea Aerospace Administration (KASA), the Korea Forest Service (KFS), and the Rural Development Administration (RDA).

During the pre-launch preparation phase, technical and operational support from specialized private companies with experience in satellite operations has also been incorporated to ensure stable and efficient system management.

**G) Implementation Costs**

This project is fully funded through the local R&D budget, covering the following components:

- CAPEX: satellites, payloads, ground stations, computing and storage infrastructure.
- OPEX: connectivity, cloud services, calibration and validation campaigns, and UAV operations.

The model is entirely government-led, with no dependence on private financing, ensuring long-term sustainability.

**H) Use Cases and Field Experiences**

The Korean system is conducting pilot studies on major crops such as rice, wheat, barley, kimchi cabbage, onions, and garlic, using satellite imagery, drone-based data, field surveys, and AI-based models.

**Table 8. Applications of Satellite Imagery in Agriculture (CAS500-4)**

| Category | Current applications (demonstrated in pilots) | Potential applications (after CAS500-4 launch) |
|---|---|---|
| **Major crops** | – Estimation of rice-cultivated areas.<br>– Monitoring rice growth consistent with official statistics.<br>– Yield prediction models integrating NDVI and climate data. | – Economy-wide estimation of rice areas and yields with higher accuracy.<br>– Food security assessments under climate change scenarios. |
| **Dryland crops (wheat, barley)** | – Parcel-level identification.<br>– Estimation of growth trajectories using UAV + satellite data. | – Integration into economy-wide-scale strategic crop management models. |
| **Highland crops (kimchi cabbage, onion, garlic)** | – Seasonal crop classification.<br>– Anomaly detection.<br>– Harvest prediction. | – Assessment of disaster impacts (pests, diseases, droughts, floods). |
| **North Korea (special case)** | – Identification of rice cultivation areas.<br>– Detection of anomalies under extreme climate conditions. | – Expansion to regional monitoring for food security. |
| **Rice Planting Area Adjustment System** | – Led by the Ministry of Agriculture, Food and Rural Affairs | – Key tool to improve transparency and reliability of monitoring policies. |

***Source:*** *Prepared based on the questionnaire completed by Dr. Hong, SukYoung*

These case studies lay the groundwork for the application of satellite information in crop classification, yield estimation, growth monitoring, and disaster impact assessment in agriculture.

Likewise, building on these positive results, ongoing research is expanding the use of satellite imagery for disaster monitoring, including the detection of pests and disease outbreaks, as well as climate-related risks, with the aim of strengthening agricultural risk management and resilience.

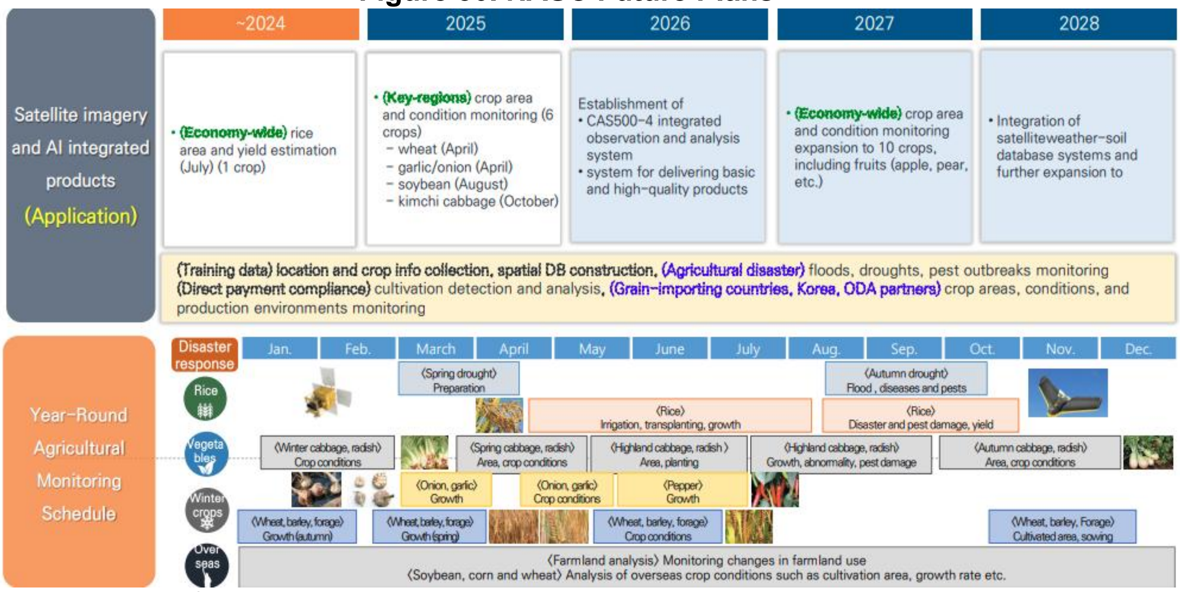
## I) Technological Sustainability and System Outlook

The roadmap for the Agricultural and Forestry Satellite (CAS500-4) begins with monitoring rice cultivation areas, yield estimation, and disaster detection. In the medium term, its scope is expected to expand through an integrated observation system combining satellites, drones, and Geographic Information System (GIS) applications. By 2028, the program aims to extend monitoring to a total of 15 major crops.

- **Expected impacts:**
  - Advancement of digital agriculture through the integration of satellite data, drones, agricultural machinery, and artificial intelligence algorithms.
  - Independent operation of Republic of Korea's first dedicated agricultural satellite (CAS500-4), strengthening local capabilities for satellite-based monitoring.

- **Risk management:**
  Collaboration with KARI, KFS, private companies, and international partners (e.g., NASA and USDA) enhances the reliability of CAS500-4 operations. Continuity of operations will also be ensured through the development and deployment of follow-on satellites, guaranteeing long-term service stability.

**Figure 30. NASC Future Plans**




***Source:*** *Extracted from the RDA presentation at the Workshop (2025).*

## J) Implementation and Deployment

The implementation of the system will be carried out gradually and oriented toward technological validation.

1. Before the satellite launch, the baseline operational infrastructure will be established, including processing environments, control interfaces, and analytical frameworks required for data integration and product generation.

2. Following the launch of CAS500-4, the project will enter a pilot phase, during which the system will be applied to limited areas in order to verify operational performance, adjust algorithms, and validate interoperability among satellite platforms, drones, and GIS systems.
   During deployment, technical acceptance tests will be conducted, including Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT), which will verify latency, accuracy, availability, and compliance with inspection criteria. Key Performance Indicators (KPIs) will also be used to confirm system stability and effectiveness during the commissioning phase.

3. The capacity-building component includes specialized training in drone operation, GIS/RS processing, quality assurance and quality control (QA/QC), and IT security, as well as the implementation of inter-institutional governance mechanisms to ensure effective coordination and structured change management during the transition to full operation.

**K) Transferability to Other APEC Economies**

The Korean solution presents a modular approach based on the integration of satellite data, drones, and ground sensors, allowing its structure to be replicated as long as minimum conditions for infrastructure, technical capacity, and institutional coordination are met.

**Key prerequisites:**

- Servers or cloud services with sufficient storage and geospatial processing capacity, as well as stable connectivity for data transmission.
- Use of interoperable tools (QGIS, GEE, GeoTIFF) that enable integration with existing local systems.
- Imagery from international programs such as Sentinel (ESA) or Landsat (USGS), while domestic capabilities are being developed.
- Availability of analysts specialized in remote sensing, agricultural modeling, QA/QC, and geospatial data management.
- Effective collaboration among agricultural, meteorological, and environmental agencies to ensure information sharing.

**Aspects to consider:**

- Need for initial investment in infrastructure to ensure system sustainability.
- Expansion of connectivity and access to high-speed networks in rural areas to guarantee continuous data transmission.
- Consolidation of local data sources and strengthening of satellite cooperation agreements to reduce external dependency.
- Strengthening of technical capacities in remote sensing and advanced analytics to fully leverage the potential of the data.
- Development of data governance policies that facilitate inter-agency data exchange and open access to information.

**Recommendations for replication:**

- Start with pilot projects in representative agricultural areas and with a limited number of strategic crops.
- Leverage open-access satellite imagery (Sentinel, Landsat) while local observation systems are consolidated.
- Promote the use of open standards (OGC, ISO) and API services that facilitate interoperability and information exchange.
- Develop institutional capacities through training programs in QA/QC, remote sensing, and data science applied to agriculture.

### 6.3.4. Indonesia: SISCrop 2.0 - Agricultural Traceability and Monitoring Platform

The information presented in this section was provided by Dr. Haris Syahbuddin, Executive Secretary of the Ministry of Agriculture of the Republic of Indonesia, and complemented with the presentation delivered during the *Technology Innovation Workshop for Environmental Monitoring*.

The content has been processed and analyzed with the purpose of describing the architecture of the SISCrop 2.0 system, the mechanisms for data processing and updating, the technical and quality assurance standards applied, and the conditions that enable its transferability and adaptation in other APEC economies.

#### A) Context and Scope

Indonesia, through its Ministry of Agriculture, has developed a standing crop information system (SISCrop 2.0), whose purpose is to generate essential agricultural information, including the growth phases of rice crops, productivity estimates, fertilization recommendations, and other associated data. This system functions as a strategic tool to strengthen sustainable agricultural development at both domestic and regional levels.

A key advantage of SISCrop 2.0 is its ability to provide near–real-time information through 15-day update cycles. It also contributes directly to food security by supporting production stability in the context of climate change and land constraints, thanks to the continuous monitoring of agricultural areas.

SISCrop 2.0 plays a central role in meeting the agricultural performance indicators established in the RPJMN (Domestic Medium-Term Development Plan), RPJMD (regional development plans), and the Renstra (Institutional Strategic Plan), particularly with respect to increasing domestic rice productivity.

Currently, the information generated by SISCrop 2.0 is available at the subdistrict (kecamatan) administrative level across all regions of Indonesia. In addition, the system offers open access, allowing the general public to consult its information.

#### B) Main Technical Components

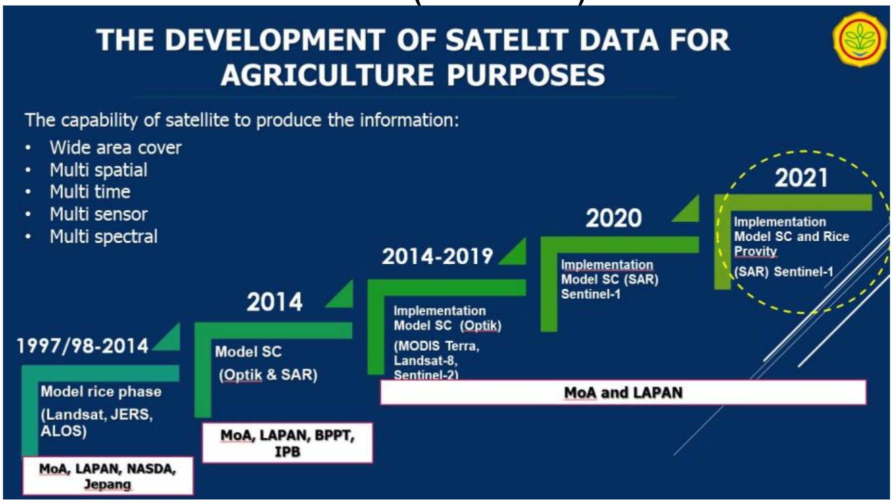
The technological components of SISCrop 2.0—including the satellite platforms used, the data processing and validation chain, quality assurance strategies, and access and dissemination mechanisms—are described below:

a) **Satellite imagery**

This component includes Synthetic Aperture Radar (SAR) imagery obtained from the Sentinel-1 satellite. These images have a spatial resolution of 10 meters and a revisit frequency of 10 to 15 days, ensuring systematic economy-wide information updates.

These data represent the result of Indonesia's progressive evolution in the use and processing of satellite imagery for agricultural purposes, as shown in Figure 31.

**Figure 31. Evolution of the use of satellite data in Indonesia for agriculture (1997– 2021).**




***Source:*** *Extracted from the questionnaire completed by Dr. Syahbuddin, Haris*

b) **SISCrop 2.0 System**

This is the central platform for processing, analyzing, and managing the program's monitoring data, achieving an accuracy level of 80–85% for irrigated and rainfed rice fields. The platform generates detailed information on rice crop development, identifying six main phenological phases that describe the crop's progression throughout its production cycle:

1. Flooding or irrigation
2. Vegetative 1
3. Vegetative 2
4. Generative 1
5. Generative 2
6. Harvest

The platform can be accessed through the following link: https://scs1.brmpkementan.id

**C) Required Infrastructure**
Operation of Indonesia's information system requires a hybrid technological infrastructure that combines local capabilities with cloud services to ensure continuous processing of satellite data, management of large volumes of geospatial information, and permanent system availability.

In general, the infrastructure requirements focus on the following aspects:

- **Connectivity:**
  Access to the platform can be made from any location using smartphones, tablets, or personal computers with an Internet connection, completely free of charge.

- **Servers and storage:**
  All data and information generated from the analysis are stored on internal servers and cloud infrastructure. This architecture has enabled the systematic and complete recording of information since 2020.

**D) Regulations and Standards**

The SISCrop 2.0 system operates under the regulatory framework defined by the Ministry of Agriculture of the Republic of Indonesia, in alignment with local policies on agricultural planning and statistical modernization.

The data and products generated by the platform have official recognition and are used as a reference for public policy formulation in the agricultural sector, including the allocation and distribution of machinery, seeds, fertilizers, and other strategic inputs. This institutional endorsement consolidates the system as an authoritative source of technical information for governmental decision-making.

**E) Licensing and Intellectual Property**

The SISCrop 2.0 system is governed by the provisions of the Indonesian Ministry of Agriculture regarding the rights of use, attribution, and reuse of public information.

To access raw or high-resolution data, users must coordinate and submit a formal request specifying the required datasets, their intended use, and the locations of interest. In certain cases, information exchange is formalized through cooperation agreements or institutional Memoranda of Understanding (MoUs), in order to ensure traceability, confidentiality, and compliance with domestic interoperability standards.

In line with this, the use of derived products (thematic maps, indicators, or reports) requires explicit citation of the source: "SISCrop 2.0 – Ministry of Agriculture of Indonesia", in accordance with institutional attribution and recognition practices.

**F) Data Governance and System Operation**

Data governance within the system is based on principles of traceability, interoperability, and quality assurance, enabling structured management of the full information cycle—from satellite acquisition to the publication of analytical products. In parallel, system operation relies on an organizational model that integrates technical teams, field personnel, and IT support units, ensuring the continuity and reliability of the service at the economy level.

### a) Data Quality Assurance and Quality Control (QA/QC)

The system applies a comprehensive quality assurance (QA) and quality control (QC) approach to maintain the accuracy, consistency, and traceability of the information generated:

- **Quality Assurance (QA):**
  The system uses Sentinel-1 SAR imagery with a spatial resolution of 10 meters and 15-day updates for all regions of Indonesia.
  In addition, the sampling design and sample size of the **Crop Cutting Experiment (CCE)** follow the methodology established by the Central Statistics Agency.
  The CCE serves as a fundamental field verification mechanism, providing reliable data for calibrating and validating satellite-based models.

- **Quality Control (QC):**
  Statistical checks (plausibility rules), SAR noise-handling techniques (speckle filtering), and cross-validation with the CCE are applied. Reference overall accuracy (OA) ranges between 80% and 85%, with phase-specific precision/recall metrics detailed in the annexes.
  Confusion matrices are documented by region and by temporal window.

- **Format standardization:**
  The SISCrop 2.0 system provides its spatial data in the standardized **GeoTIFF** format.

These guidelines ensure the accuracy and credibility of the estimates, strengthening the role of the system in agricultural monitoring and in evidence-based policymaking.

### b) Operational Roles and Management Structure

The operation of the system is overseen by the Ministry of Agriculture of Indonesia through a structure composed of multiple units, including:

**Table 9. Teams Involved in the Operation of the SISCrop 2.0 System**

| Unit / Team | Main Responsibilities |
|---|---|
| Remote Sensing Team | Responsible for data processing, analysis, and model development. |
| Field Study Team | Responsible for data collection and verification. |
| Information Technology and System Administration Team | Responsible for managing the system’s web platform. |

***Source:*** *Prepared based on the questionnaire completed by Dr. Syahbuddin, Haris*

### G) Use Cases and Field Experiences

The SISCrop 2.0 system is operational at the local level and constitutes one of Indonesia's primary agricultural monitoring platforms. Its implementation has made it possible to obtain updated information every 15 days with a spatial resolution of 10 meters. This periodic update capability and comprehensive coverage ensure continuous monitoring of crop conditions and productive status in near-real-time.

The data and information generated by SISCrop 2.0 are currently used as an official reference for public policy formulation in the agricultural sector, including the distribution of machinery, seeds, fertilizers, and other strategic inputs. The integration of these data into planning processes enables the Ministry of Agriculture to optimize resource allocation, reduce error margins in demand estimation, and support decisions regarding investment and producer assistance.

In its current configuration, SISCrop 2.0 generates two main types of information:

- Crop growth phases.
- Productivity indicators.

These experiences demonstrate that SISCrop 2.0 has consolidated itself as a local agricultural observation infrastructure, combining satellite monitoring, empirical verification, and advanced analytics to strengthen food security, agricultural productivity, and evidence-based decision-making within Indonesia's agricultural modernization framework.

### H) Technological Sustainability and System Outlook

The system's design ensures scalability and operational continuity through a hybrid architecture that combines cloud infrastructure with institutional servers. This model enables the processing of large volumes of SAR data (Sentinel-1) with biweekly update cycles, while maintaining service stability and traceability of the generated products.

Furthermore, the adoption of cloud-based analysis platforms such as Google Earth Engine reduces dependency on local hardware and facilitates the implementation of algorithmic improvements remotely and collaboratively. These features strengthen the system's technological resilience against failures, increases in demand, and requirements for expanded coverage.

The operation of the system faces several challenges, including:

- Variations in regional agricultural calendars, which may affect phenological classification.
- Extreme weather events, such as floods or droughts, which alter production cycles.
- Noise or interference in SAR data, which may reduce model accuracy.

To mitigate these risks, SISCrop 2.0 applies adaptive algorithms calibrated with local information, combines radar and optical data when available, and maintains a redundant cloud-based backup system.

The current development of SISCrop 2.0 focuses primarily on improving advanced algorithms, with special emphasis on swampy rice-field typologies, which pose specific challenges regarding data interpretation and modeling accuracy.

At the same time, exploratory initiatives are underway to establish image-analysis techniques and algorithmic frameworks that can be adapted and scaled for application to other priority agricultural commodities. These efforts seek to broaden the applicability of the system, enhance model robustness, and support evidence-based decision-making in the agricultural sector.

**I) Transferability to Other APEC Economies**

Indonesia's experience with the SISCrop 2.0 system demonstrates the ability to scale technological solutions based on satellite processing, cloud infrastructure, and geospatial data management at a domestic level. Its modular architecture, quality-assurance protocols, and technological governance model make it a replicable reference for other APEC economies seeking to strengthen the digitalization of agricultural monitoring through interoperable and sustainable platforms.

**Key prerequisites:**

- A hybrid technological infrastructure (cloud + local servers) ensuring availability, security, and scalability for satellite data processing.
- Access to open data sources such as Sentinel-1 SAR, along with sufficient connectivity for the acquisition, preprocessing, and transmission of large-volume geospatial information.
- Local technical capacities in automated processing, remote sensing, geospatial data analysis, and cloud platform administration, supported by specialized personnel in QA/QC, metadata management, and cybersecurity.

**Aspects to consider:**

- Strengthening digital infrastructure and connectivity, particularly in rural or hard-to- reach areas, to enable the exchange and synchronization of large data volumes.
- Developing capacities in information technology (IT) for managing satellite-analysis platforms and cloud-computing environments.
- Expanding specialized human capital in SAR processing and cloud-based programming to ensure long-term system sustainability.
- Budget planning and technological licensing strategies that support operational continuity and infrastructure upgrades.

**Recommendations for replication:**

- Adopt a modular and scalable architecture that allows the gradual integration of new processing, analysis, and visualization modules according to each economy's technological maturity.
- Implement capacity-building strategies in IT, prioritizing the training of local teams in cloud processing, geospatial data management, and cybersecurity.
- Establish technical cooperation agreements among APEC economies for sharing algorithms, QA/QC methodologies, and best practices in cloud infrastructure management.

- Incorporate technological-sustainability mechanisms that ensure funding for maintenance, licensing, storage, and the evolution of the system architecture in the medium and long term.

### 6.3.5. Malaysia: RSPO – Evolution of Standards and the Integration of Remote Sensing and Technology

The information presented in this section was provided by Mr. Yen Hun Sung, representative of the Roundtable on Sustainable Palm Oil (RSPO), and complemented by the presentation *“RSPO – Evolution of Standards and Integration of Remote Sensing and Technology”* delivered during the Technology Innovation Workshop for Environmental Monitoring.

The content has been analyzed and systematized for the purpose of describing the normative and technological evolution of RSPO standards, the digital architecture of the PRISMA system, the mechanisms for remote monitoring and environmental risk analysis, as well as the institutional and technical conditions that support its replicability in other APEC economies.

#### A) Context and Scope

Malaysia hosts the headquarters of the Roundtable on Sustainable Palm Oil (RSPO). This global organization was established in 2004 as a voluntary sustainability scheme aimed at promoting responsible palm oil production through a multi-stakeholder consensus-driven approach.

RSPO encompasses the entire palm oil supply chain and value chain, with the objective of transforming markets through the integration of sustainable and responsible practices supported by all stakeholders involved across these chains.

The collective sustainability intent expressed in RSPO standards, systems, and procedures is as robust as the multisectoral consensus reached in each cycle, given that the standards are reviewed and updated every five years, and the systems and procedures are adjusted accordingly.

RSPO has progressively incorporated new technologies as they have evolved. The decision to modernize its infrastructure by integrating previously fragmented standards, systems, and procedures under a common architecture —known as PRISMA (Palm Resource Information & Sustainability Management)— has created a strategic opportunity to optimize the use of current and future technologies and innovations, strengthening its role as a global alliance committed to sustainable palm oil.

In this way, RSPO has evolved into a global certification platform that seeks to balance the environmental, social, and economic impacts associated with oil palm cultivation.

#### B) Main Technical Components

RSPO’s technical architecture integrates both the normative and procedural mechanisms and the digital systems designed to operationalize and monitor real-time compliance with the standards. This section describes some of the digital systems that form part of the catalog of tools promoted by the organization:

a) **GeoRSPO**: A public-access geospatial platform that consolidates the digital boundaries of concessions registered by RSPO members, promoting territorial transparency and enabling free download of cartographic data for audits, analysis, and environmental oversight.

b) **Fire Monitoring System**: A specialized module that detects and manages fire alerts by integrating satellite information from VIIRS and MODIS. It includes an automated verification workflow that spans from initial detection to field validation and the issuance of alerts.

c) **Risk and Remote Sensing Module**: A central component of RSPO's digital system that integrates deforestation alerts and geospatial analysis through the overlay of High Conservation Value (HCV) and High Carbon Stock (HCS) layers. It enables the identification of intersections between planted areas and environmentally sensitive zones, standardizing terminology, data structures, and risk assessment procedures.

Other internal and external systems not detailed here are described in RSPO's Impact Reports and Updates (https://rspo.org/resources/?category=impact-reports), some of which have already been integrated into the PRISMA platform as applicable.

**C) Required Infrastructure**

The PRISMA system operates on cloud-based infrastructure with dynamic scalability capable of supporting up to 1,000 simultaneous users. It includes redundancy, backup, and retention mechanisms aligned with the security standards of the selected cloud platform. Access is managed through accounts assigned to RSPO members (currently more than 14,000 users), with authentication administered by institutional superusers.

**D) Normative Framework and Standards**

RSPO's regulatory framework is grounded in its Principles and Criteria (P&C), complemented by the New Planting Procedure (NPP) and the Remediation and Compensation Procedure (RaCP), which guide sustainable expansion and the correction of environmental impacts.

Since 2005, successive versions of the P&C (2007, 2013, 2018, and 2024) have strengthened provisions related to deforestation, peatland management, ecosystem conservation, and fire prevention, consolidating a comprehensive framework for environmental sustainability.

The 2024 version of the P&C reinforces the convergence between regulation and technology, aligning compliance mechanisms with international standards such as those of the ISEAL Alliance and the European Union Deforestation Regulation (EUDR).

**E) Licensing and Intellectual Property**

The use and management of data within the RSPO digital ecosystem are governed by the principles established in its institutional charter and in the consent agreements signed by member organizations. The PRISMA system manages geospatial information, reports, and alerts on behalf of members, respecting ownership of the original data and operating under a dual-consent model:

- Primary permission from the member to share or process the information.
- Secondary authorization, which regulates the specific use of the data for each event or transaction.

Geographical concessions and digital maps approved by the RSPO General Assembly are publicly accessible through GeoRSPO, where they can be viewed and downloaded in digital formats. However, internal datasets remain restricted and may only be shared through Non-Disclosure Agreements (NDA) or with explicit authorization from the data owners.

RSPO applies open licenses to information published on its public portal, whereas undisclosed data are considered sensitive or confidential and are protected through access-control mechanisms, encryption, and user segregation within PRISMA.

Taken together, RSPO's licensing model balances transparency with data governance, ensuring that digital information flows remain within the ethical, legal, and technological frameworks that regulate intellectual property protection and data sovereignty.

**F) Data Governance and System Operation**

Data governance within RSPO is grounded in the principles of transparency, integrity, and traceability, ensuring that geospatial information, documentation, and environmental alerts are managed under strict digital control, security, and audit protocols.

The PRISMA system applies a hierarchical access model, in which only accredited RSPO members may operate the platform, and designated superusers are responsible for authorizing and overseeing internal permissions.

Although PRISMA currently operates as a closed and proprietary platform, its modular architecture anticipates future interoperability through secure APIs, once the required licensing and governance frameworks have been defined to enable external connections under controlled conditions.

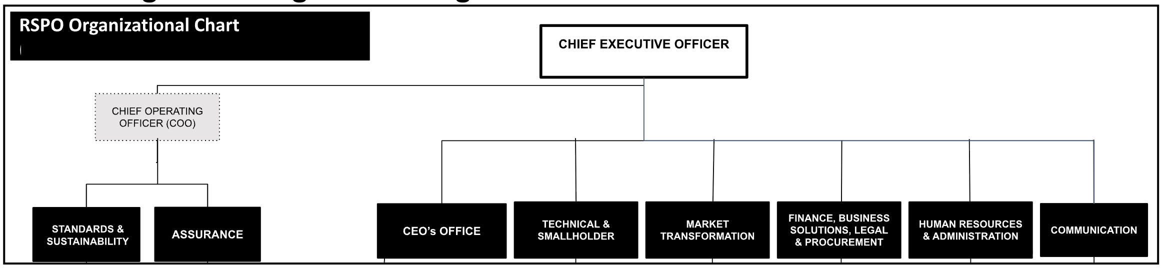
From an operational standpoint, system administration is led by the RSPO Secretariat, headquartered in Kuala Lumpur.

For operations specifically related to the PRISMA system, responsibilities are distributed as follows:

- System Development and Operation: Led by the Office of the Chief Executive Officer, with support from the relevant technical divisions.
- Remote Sensing and Risk Analysis: Managed by the Assurance function within the Integrity division, in coordination with other support units.

- Compliance and Certification: Supervised by the Assurance function under Certification, supported by specialized divisions.
- Member Support: Decentralized and adapted according to the type of assistance required by users or associated members.
- Information Technology and Cybersecurity: Administered by the Enterprise Solutions division, in coordination with the Office of the Chief Executive Officer.

**Figure 32. High-Level Organizational Chart of the RSPO Secretariat**




***Source:*** *Extracted from questionnaire completed by Mr. Sung, Yen Hun*

### G) Implementation Costs

Detailed information on the development, implementation, and operational costs of the PRISMA system is internal and not publicly disclosed, in accordance with RSPO's confidentiality policies. Nevertheless, it is relevant to note that the development of PRISMA—officially launched in February 2025—was carried out between 2022 and 2025, driven by the regulatory requirements of the European Union Deforestation Regulation (EUDR), and represents the largest CAPEX and OPEX investment in the organization's history.

### H) Experiences and Use Cases

The results presented in the RSPO Impact Reports 2024–2025 demonstrate significant progress in the application of standards and in the effectiveness of digital monitoring systems:

- Conservation: Protection of approximately 470,000 hectares of forests with High Conservation Value (HCV) and High Carbon Stock (HCS), in addition to 650,000 hectares of conserved natural ecosystems worldwide.
- Peatlands: Inventory and responsible management of more than 376,000 hectares of peatlands, including active rehabilitation programs in over 3,000 hectares of degraded areas.
- Fire prevention: Significant reduction of fire risk in RSPO concessions, where the likelihood of hotspot detection is up to 60 times lower than in non-certified areas.

From an operational perspective, the implementation of the PRISMA system enabled the unification of deforestation, fire, and peatland management data within a single cloud- based architecture. However, the global rollout faced connectivity challenges in economies with restrictions on the selected cloud platform, which required the establishment of alternative access mechanisms through virtual private networks (VPNs) and mirrored portals linked to the main system.

This experience highlighted a key lesson learned: it is essential to plan secondary access routes and contingency pathways that address known availability gaps, ensuring operational continuity and enabling full participation of all users in the global monitoring network.

### I) Technological Sustainability and System Outlook

The technological sustainability of the PRISMA system is supported by a modular and scalable architecture designed to progressively integrate new data sources, algorithms, and environmental monitoring functions. This approach enables RSPO to maintain an adaptable digital ecosystem capable of evolving in response to technological advancements, international regulatory changes (such as the EUDR), and the needs of its members in terms of traceability, risk, and compliance.

- In terms of maintenance, the PRISMA cloud infrastructure incorporates continuous monitoring, telemetry, and version-control procedures, ensuring system availability, security, and operational resilience.
- Centralized user administration, together with backup, encryption, and auditing protocols, strengthens data integrity and ensures the long-term sustainability of the digital environment.

From a technological and innovation perspective, RSPO envisions the incorporation of predictive and thematic modules in the next development phases of the system, including:

- Monitoring methane emissions and industrial effluents (POME) through hyperspectral imagery.
- Tracking peatland and wetland ecosystem health using environmental degradation indicators.
- Predictive models for fires and deforestation, integrating climatic, historical, and spatial data.
- Expansion of monitoring to new sensitive ecosystems such as mangroves, grasslands, and shrublands.

These projections align with the RSPO Theory of Change (https://rspo.org/our-impact/roadmap-towards-change/), which seeks to consolidate a global technological infrastructure capable of strengthening sustainability in the sector and accelerating the transition toward deforestation-free agriculture.

Overall, PRISMA represents not only a monitoring tool but also a replicable model of digital governance in which technology, data, and standards operate in an integrated manner to drive transparency, innovation, and long-term environmental sustainability.

### J) Implementation and Deployment

The implementation of the PRISMA system represented one of the most extensive digital transformation processes in RSPO's history, aimed at unifying fragmented systems into a comprehensive platform for certification, traceability, and environmental monitoring.

The project was conceived as a strategic response to the European Union Deforestation Regulation (EUDR), which established strict timelines to ensure traceability across agricultural supply chains.

The development plan was executed between 2022 and 2025 under an agile, phased approach, beginning with the preparation of the digital blueprint, an assessment of technological gaps, and the selection of the provider consortium.

The main stages included:

- Phase 1 – Analysis and Design (2022–2023):
  Development of the To-Be model and documentation of As-Is processes, with particular emphasis on interoperability with pre-existing systems.
- Phase 2 – Development (2023–2024):
  Construction of priority modules for certification, trade, and traceability, followed by User Acceptance Testing (UAT).
- Phase 3 – Launch (2025):
  Official roll-out of PRISMA, including a set of modules considered critical for system operation.

The process faced substantial challenges stemming from compressed timelines, diverse functional requirements, and the coexistence of manual and digital procedures. Differences in the interpretation of operational rules and certification requirements were identified, prompting intensive efforts in documentation alignment, change management, and functional standardization.

Despite these challenges, the system achieved its official launch in February 2025, meeting critical objectives related to operational continuity and data migration.

**K) Transferability to Other APEC Economies**

RSPO's experience implementing the PRISMA digital system highlights two levels of technological application for other APEC economies:

a) Integration into the existing RSPO digital ecosystem, and
b) Implementation of an equivalent environmental monitoring platform inspired by PRISMA's architecture and technological principles.

**a) Integration into the RSPO Digital Ecosystem**

From a technological perspective, the participation of new actors in RSPO's digital systems requires meeting a set of minimum interoperability, security, and data-management requirements.

**Key technical requirements:**

- **Stable and secure connectivity:** Access to RSPO cloud environments through encrypted tunnels (VPN) or certified gateways, including support for HTTPS protocols where applicable.
- **Data format compatibility:** Ability to handle geospatial layers in standard formats and encode them under common spatial reference systems.
- **Digital identity management:** Integration with PRISMA's federated authentication scheme, administered by superusers within each member organization.

- **Compliance with data-protection policies:** Treatment of sensitive information according to RSPO guidelines and applicable privacy frameworks in each economy.
- **User technical training:** Capacity-building on the correct use of system modules to ensure traceability and proper interpretation of indicators.

#### b) Deployment of a Platform Analogous to PRISMA

For economies seeking to develop their own environmental monitoring system inspired by PRISMA's architecture, the technological requirements are grouped into five main dimensions:

**1. Architecture and Technological Environment**

- Adoption of a hybrid or multi-cloud infrastructure with dynamic scalability and regional redundancy.
- Modular design based on microservices and RESTful APIs, enabling the integration of new modules (e.g., deforestation, fires, peatlands, emissions).
- Implementation of STAC catalogs and OGC-compliant services to ensure geospatial interoperability.

**2. Data and Analytics**

- Integration of satellite sources and local vector datasets.
- Automated QA/QC modules for detecting errors, duplicates, or inconsistencies.

**3. Security and Digital Governance**

- Encryption policies for data in transit and at rest, role-based access control (RBAC), and continuous event auditing.
- Identity management using centralized directories and multi-factor authentication.
- Disaster Recovery Plan (DRP) protocols, with defined recovery time windows.

**4. Technical Capacities and Human Resources**

- Multidisciplinary teams combining expertise in remote sensing, backend development, cybersecurity, and geospatial database administration.
- Regional support centers or helpdesks with 24/7 monitoring and incident management.

**5. Maintenance and Scalability**

- Incorporation of telemetry and observability tools to measure availability and latency.
- Continuous update strategies and version-management processes to ensure improvements without service interruptions.

### 6.4. Comparative Analysis and Replicability Factors in APEC Economies

This section consolidates the cross-cutting analysis of the technological solutions described in the previous chapters, with the aim of identifying common factors that support their replicability and adaptation across other APEC economies. The focus is placed on the technological components that determine the feasibility of scaling these innovations in diverse institutional and environmental contexts.

### 6.4.1. Common Technical Requirements

The comparative analysis of the five solutions presented reveals a set of cross-cutting technical requirements that constitute the foundation for their successful implementation in any APEC economy. These requirements reflect a convergence toward interoperable digital architectures, built on open standards and supported by secure, scalable and sustainable infrastructures.

The following common elements are highlighted:

**a) Digital infrastructure:**
All solutions require platforms with distributed processing capacity and scalable storage, preferably deployed in cloud-based or hybrid environments.

**b) Standardization of geospatial data:**
Interoperability depends on the use of shared geodetic references, standardized metadata and open formats (e.g., GeoTIFF, GeoJSON, CSV), which enable integration across systems and economies.

**c) Quality assurance and quality control (QA/QC) protocols**
All implementations include mechanisms for data assurance and quality control (QA/QC), regression testing and version traceability, ensuring the reliability of information used for decision-making processes.

**d) Connectivity and data transmisión**
The solutions require stable network coverage (Internet, 4G/5G or satellite) both in the field and in data centers, combined with redundant systems and automatic backups that ensure service continuity in the event of disruptions or disasters.

**e) Compatibility with advanced analytics and artificial intelligence**
The architectures must support the integration of machine learning and deep learning models (ML/DL), using specialized analytical libraries or environments (e.g., Python, R or TensorFlow), enabling dynamic index adjustment and continuous improvement of algorithms and derived products.

**f) Technical and institutional capacities**
The sustainability of the solutions depends on multidisciplinary teams with competencies in remote sensing, artificial intelligence, data science, geographic information systems (GIS), database management and cybersecurity.

Taken together, these requirements constitute the technological foundation needed to ensure regional interoperability, functional scalability and operational sustainability of the digital environmental monitoring solutions promoted within APEC.

### 6.4.2. Considerations for Replicability

Despite the progress made in the adoption of digital technologies, the replicability of the solutions analyzed faces a set of structural and operational barriers that constrain their regional scaling. These barriers can be grouped into five main areas:

- Insufficient digital infrastructure: Rural connectivity must be strengthened, and the availability of cloud services or domestic data centers must be improved to support the transmission of large volumes of geospatial information and the continuous operation of real-time platforms.
- Human capacity gaps: Technical teams require enhanced competencies in remote sensing, artificial intelligence, data management and cybersecurity to ensure system maintenance and long-term evolution.
- Regulatory and legal gaps: It is essential to establish regulatory frameworks that formally recognize digital data as valid evidence for environmental compliance or agricultural verification processes, preventing limitations in their operational use or integration into compliance systems.
- Access and licensing restrictions: Confidentiality conditions for certain datasets or intellectual property limitations (as in RSPO or POMS) restrict reuse and hinder interoperability with public or regional platforms.
- Institutional and system fragmentation: The coexistence of multiple isolated platforms across ministries and levels of government creates redundancies, technical incompatibilities and gaps in digital governance. This underscores the need for common interoperability frameworks and data-sharing agreements.

These constraints highlight the importance of adopting a comprehensive approach that combines investment in technological infrastructure, strengthened digital capabilities and modernization of regulatory and institutional frameworks to enable the effective adoption of monitoring solutions based on information technologies across the APEC region.

### 6.4.3. Minimum Conditions for Adoption

To ensure successful implementation in other APEC economies, a minimum set of technological conditions must be in place. These include:

- Availability of updated and structured geospatial and environmental baseline datasets.
- Technological infrastructure compatible with cloud services and secure APIs.
- Technical personnel with competencies in geographic information systems (GIS), applied AI and data quality assurance/quality control (QA/QC).

### 6.4.4. Scaling Potential within APEC

The comparative analysis of the technological solutions evaluates, in this section, their replicability based on the information technology (IT) components that underpin them: digital architecture, data-processing capacity, platform integration and institutional maturity to operate interoperable ecosystems.

The order of presentation is organized from lower to higher technological complexity, considering the level of infrastructure, digitalization and data-governance requirements needed for implementation.

**A) Indonesia: SISCrop 2.0**

SISCrop 2.0 integrates automated satellite processing, SAR data management and classification algorithms, supported by cloud infrastructure for the storage, analysis and periodic publication of geospatial products. From a technological standpoint, it requires orchestrated processing pipelines, version-control mechanisms and geospatial APIs for the delivery of thematic layers and dashboards. Its replication is well-suited for economies seeking to modernize agricultural planning and strengthen local information systems through cloud-based technologies and interoperable platforms that integrate field data with remote sensing. It offers a modular architecture that can be adopted rapidly, making it a low-complexity solution with high regional applicability.

Two potential pathways exist for its adoption in other APEC economies:

**A.1) Replication through a licensing agreement or bilateral cooperation with Indonesia**

- Conditions: Requires an institutional agreement enabling the transfer of software, technical documentation and calibration models.
- IT requirements: Access to the original system architecture, compatible cloud-infrastructure support, continuous update services and capacity-building mechanisms for operation and maintenance.
- Advantage: Accelerates implementation by adopting a solution already tested domestically.
- Limitation: Its applicability depends on Indonesia's technological-exchange policies and cooperation frameworks; there is no public information indicating that SISCrop
  2.0 is available under open-license terms.

**A.2) Development of an analogous solution based on its architecture and methodologies**

- Conditions: Does not require direct licensing, but it does require the adoption of the system's conceptual model and technical workflow.
- IT requirements: Teams with experience in Python, GEE, QGIS or equivalent platforms; interoperable cloud infrastructure; open-data repositories (Sentinel, Landsat); and documented QA/QC processes.
- Advantage: Greater technological independence and flexibility to adapt the system to local crops, production dynamics and contextual conditions.
- Limitation: Requires upfront investment in development, calibration and technical training to achieve performance levels equivalent to the original system.

**B) Malaysia: RSPO – PRISMA**

The RSPO *PRISMA* platform was developed as a digital system for traceability and environmental monitoring in the sustainable palm oil sector, enabling the registration, verification, and reporting of compliance with the criteria established by the Roundtable on Sustainable Palm Oil (RSPO). Its technological architecture is based on a centralized web platform, relational databases, and secure APIs that facilitate the connection between producers, auditors, and certification bodies. The system manages geospatial information, compliance documents, and transactional records within an authenticated environment, ensuring traceability and version control.

From an information technology perspective, it is a lightweight and highly interoperable solution with moderate requirements: secure server access, stable connectivity, role- based administration, and a normalized data structure that supports integration with other systems. Its modular design allows for adaptations or extensions to production sectors that require environmental impact monitoring, certification management, or digitalization of compliance processes.

As in the case of SISCrop 2.0, there are two potential pathways for its adoption or adaptation in APEC economies:

**B.1) Replication through a cooperation agreement with the RSPO or with the developing technology entity**

- Conditions: Requires an institutional agreement regulating the use of the software, access to functional modules, technical specifications, and maintenance guidelines.
- IT requirements: Secure web infrastructure, support for relational databases, and compliance with security and confidentiality protocols.
- Advantage: Enables the use of a mature solution validated in complex production contexts.
- Limitation: Its use is oriented to the palm oil sector and RSPO members; external adoption requires specific authorizations or agreements defining access terms and adaptation parameters.

**B.2) Development of an analogue platform based on its technological model**

- Conditions: Does not require access to the original software but does require the adoption of its conceptual traceability model and digital architecture: producer management, georeferenced integration, audit workflows, and online reporting mechanisms.
- IT requirements: Development of a secure-authenticated web application; structured database with geospatial components; interoperable APIs; and modules for document and geographic validation.
- Advantage: High adaptability to other productive sectors or sustainability schemes, with the ability to interoperate with governmental or private platforms.
- Limitation: Requires significant initial investment in design, development, and testing, as well as a regulatory framework for the exchange and protection of sensitive data.

**C) Japan – NARO/MAFF**

The system developed by the National Agriculture and Food Research Organization (NARO) and Japan’s Ministry of Agriculture, Forestry, and Fisheries (MAFF) constitutes an advanced digital infrastructure for agricultural administration based on satellite imagery. Its primary objective is to partially replace field inspections by integrating SAR and optical data, parcel-level information (Fude), and a mobile application (eMAFF) that enables on- site verification. From a technological standpoint, it combines geospatial processing, crop classification through supervised learning algorithms, and standardized QA/QC procedures, all integrated within a highly regulated institutional environment.

Unlike the cases of Indonesia and Malaysia, the Japanese system is not a licensable or commercial solution but a public-sector infrastructure component embedded within local agricultural administration. Therefore, its replicability is not oriented toward direct software transfer, but rather toward the adoption of its technical methodologies and digital governance model.

**C.1) Methodological Replicability**

This modality focuses on the transfer of practices, algorithms, and technical standards developed by NARO/MAFF. APEC economies may adopt its methodological approach for the combined use of SAR and optical imagery in crop detection, the identification of idle or abandoned lands, and field verification through mobile applications.

- Transferable elements: QA/QC protocols, supervised classification methodologies (e.g., Random Forest), sampling design for field validation, and integration structures with agricultural cadastres.
- IT requirements: Interoperable geospatial infrastructure, cloud-based processing capacity, geospatial APIs, and structured storage with metadata traceability.
- Advantages: Enables the transfer of technically proven knowledge and its adaptation to different productive contexts.
- Limitations: Does not include access to the original software; requires local technical capacities in remote sensing, GIS, and data analytics.

**C.2) Institutional or Governance Replicability**

This level of replicability focuses on adopting the Japanese model of inter-institutional governance, which integrates ministries, local governments, and technical agencies within a unified digital ecosystem. The approach centers on ensuring interoperability among administrative systems, the recognition of satellite data as valid regulatory evidence, and full traceability of administrative processes related to agricultural management.

**D) Republic of Korea: Integrated Environmental Monitoring System – NASC**

The solution developed by the NASC of the Republic of Korea stands as a regional benchmark for the integration of advanced geospatial technologies, artificial intelligence (AI), and cloud services for territorial and environmental management. The system combines multi-source satellite imagery (optical, SAR, thermal, and aerial) within an interoperable geospatial infrastructure that supports applications in environmental supervision, land governance, and disaster response.

From an IT perspective, it employs distributed architectures based on cloud computing, data-flow orchestration, RESTful APIs, and high-performance computing resources for automated processing and analysis.

Unlike sector-specific or institutional platforms, the NGII model functions as a domestic spatial data infrastructure designed for interoperability among public agencies, academic institutions, and private actors. Therefore, its replicability focuses on transferring its technological architecture and governance model rather than directly adopting the software or platforms developed in Republic of Korea.

### D.1) Technological Replicability

The technological architecture can be reproduced using other sources of open satellite data; however, the use of CAS500-4—when available through cooperation agreements— would allow replication of Republic of Korea's level of detail and analytical precision.

- **If replication seeks to use CAS500-4 data (direct cooperation with Republic of Korea):**
  - Requirements: Requires satellite-data sharing agreements or technical cooperation with KARI or NGII. Access to CAS500-4 would entail specific licensing, as these data are not openly accessible like Sentinel or Landsat.
  - IT requirements: Infrastructure to receive, store, and process high-resolution imagery (broadband connectivity, centralized storage, GPUs for super-resolution processing).
  - Advantage: Enables reproduction of the accuracy and analytical quality of the Korean model.
  - Limitation: Subject to data availability, acquisition costs, and bilateral cooperation agreements.

- **If replication uses alternative datasets (e.g., Sentinel-2, Landsat-8/9, Planet):**
  - Feasibility: The technological architecture and NGII processing workflows can be replicated without relying on CAS500-4.
  - IT requirements: Lower requirements, as open data have coarser resolutions and do not demand the same computational capacity.
  - Advantage: Enables conceptual and methodological transfer without licensing constraints.
  - Limitation: Reduces spatial resolution and the ability to monitor fine-scale objects (roads, buildings, parcel boundaries).

### D.2) Strategic or Institutional Replicability

This level of replicability focuses on adopting Republic of Korea's domestic geospatial governance model, which promotes inter-institutional interoperability and the integration of environmental, urban, and cadastral data within a unified framework.

## E) Thailand: POMS/CEMS

The Pollution Online Monitoring System (POMS), integrated with the Continuous Emission Monitoring Systems (CEMS), constitutes Thailand's local infrastructure for real-time industrial environmental monitoring. Its primary objective is to collect, validate, and transmit emission data from industrial sources directly to the local environmental authorities, ensuring transparency, traceability, and regulatory compliance.

From an information technology perspective, the POMS/CEMS integrates smart industrial sensors, data acquisition and transmission systems, and network-based supervisory platforms (POMS Box / POMS Client + central server).

The system employs secure communication protocols, authentication and access-control mechanisms, and centralized databases to enable real-time data storage, auditing, and visualization.

**E.1) Technological Replicability**

Technological replicability involves designing or adopting an equivalent infrastructure that integrates monitoring hardware, data-transmission software, and a centralized environment for data acquisition and analysis. This is not a system that can be transferred directly through licensing, but rather a reference architecture that can be adapted by other APEC economies in accordance with their regulatory frameworks and industrial development levels.

**Transferable elements:**
- End-to-end data-flow architecture: source → CEMS → POMS Box → secure network → central server → authority.
- Communication and data-storage protocols.
- Automated QA/QC modules, time-series validation, and deviation-based alert mechanisms.
- Regulatory dashboards and web-based supervisory panels.

**Industrial and IT requirements:**
- Certified and calibrated sensors for gases, particulates, flow, and temperature.
- Reliable network infrastructure (4G/5G or satellite) and electrical redundancy.
- Secure processing and storage servers (on-premises or private cloud).
- Capacity for predictive maintenance and remote monitoring of equipment.

**Advantages:**
- Enables continuous and automated environmental monitoring.
- Facilitates remote enforcement and industrial transparency.
- Generates real-time, auditable, and fully traceable data.

**Limitations:**
- High dependence on physical infrastructure and telecommunications.
- Requires specialized technical personnel in instrumentation, networking, and cybersecurity.
- Significant upfront costs for acquisition, calibration, and maintenance.

**E.2) Institutional or Regulatory Replicability**

Institutional replicability focuses on the adoption of Thailand's regulatory and data-governance model, under which industries continuously report their emissions to the environmental authority following uniform technical standards and automated control mechanisms. This approach is particularly relevant for economies seeking to modernize their environmental enforcement systems or fulfill commitments related to industrial transparency and compliance.

## 6.5. Conclusions and Recommendations

The analysis of the five technological solutions presented in this chapter demonstrates a clear convergence toward a common model of environmental monitoring based on information technology (IT). The replicability of these solutions depends on the development of scalable, standardized digital infrastructures; robust data-governance frameworks; and regulatory mechanisms that enable the use of digital information in enforcement processes and decision-making.

Based on the comparative assessment conducted, a set of technological best practices emerges that APEC economies may consider when designing, modernizing, or scaling their environmental, agricultural, and industrial monitoring platforms:

- Solutions should be designed under modular, service-oriented architectures (SOA or microservices), which facilitate component exchange, interoperability, and integration of analytical modules across economies.
- The use of international standards for geospatial metadata and data exchange is essential.
- Systems must be conceived as cloud-ready, leveraging hybrid environments (public/private cloud) and distributed processing workflows.
- Access controls based on roles, federated authentication or SSO, and data-encryption policies (in transit and at rest) are indispensable.
- Quality assurance must be embedded within the automated processing pipeline through technical validations, cross-verification of information, and version control.
- The success of these solutions relies not only on technology, but equally on human capital.
- Each solution should be documented under a homogeneous structure that includes technical specifications, data flows, APIs, and operational procedures.

The solutions analyzed confirm that technological convergence within APEC is sustained by three core pillars: interoperable digital infrastructure; human and institutional capabilities; and the standardization of data coupled with regional cooperation. Progressively meeting these best practices will enable economies not only to implement standalone solutions, but also to interconnect them, share information in real time, and build an APEC-wide network for intelligent environmental monitoring, grounded in secure, open, and sustainable information technologies.

# 7. PUBLIC POLICY RECOMMENDATIONS

The evidence and discussions presented throughout this document demonstrate that the digital transformation of environmental monitoring in APEC economies requires not only technological innovation, but also institutional coordination, ethical governance, and a shared framework for data interoperability and transparency. Building on the analytical results and lessons derived from the representative case studies, this section formulates strategic recommendations aimed at economy's actions and regional cooperation, with the purpose of consolidating ethical, interoperable, and collaborative digital environmental governance across the Asia–Pacific region.

These recommendations seek to support the transition from experimental or pilot-level technology use toward long-term institutional adoption, linking artificial intelligence, big data, and remote sensing with ethical governance practices and technical cooperation among member economies.

## 7.1. Technological Governance and Institutional Strengthening

The transition toward digital environmental enforcement requires a solid, transparent, and coherent governance framework. In this regard, APEC economies could consider developing domestic guidelines for digital management of environmental monitoring and information systems, inspired by good practices from economies such as Republic of Korea (NASC) and Japan (NARO–MAFF). These guidelines should promote ethical data use, system interoperability, and transparency in environmental information management.

Additionally, economies may strengthen institutional capacities through training programs in applied artificial intelligence, QA/QC, cybersecurity, and data analytics, fostering collaboration among environmental agencies, universities, and technology centers. APEC—through platforms such as the Digital Economy Steering Group (DESG)—provides an ideal venue to promote technical exchange, harmonize standards, and share experiences.

**Table 10. Governance and Institutional Capacity Measures**

| Policy Element | Strategic Approach | Expected Outcome |
|---|---|---|
| **Domestic Digital Governance Framework** | Ethical and interoperability principles | Institutional transparency and coherence |
| **Capacity Strengthening** | Training programs in AI, QA/QC, and cybersecurity | Competent and adaptive regulators |
| **Open Data and APIs** | Standardized protocols and cloud-based systems | Secure and traceable environmental data exchange |

## 7.2. Digital Infrastructure and Data Management

Strengthening environmental enforcement depends on interoperable and reliable digital infrastructures. APEC economies could explore modular, service-oriented architectures (SOA or microservices) that integrate local platforms through hybrid cloud environments, enabling progressive and secure sharing of environmental data.

Likewise, economies could develop economy-wide frameworks for environmental data certification—understood as a formal set of standards, procedures, and technical criteria intended to ensure that environmental data generated by public, private, or community entities are verifiable, traceable, accurate, and mutually compatible. Such frameworks should adopt common QA/QC standards, harmonized metadata, and interoperable formats (GeoTIFF, CSV, JSON), aligned with international norms such as ISO 19115.

These measures would strengthen institutional reliability and the cross-border legitimacy of environmental data.

**Table 11. Data Infrastructure and Certification**

| Action Area | Key Mechanism | Outcome |
|---|---|---|
| **Interoperable Platforms** | Modular cloud-based architecture | Real-time and scalable environmental monitoring |
| **QA/QC and Metadata** | Certification system | Verified and comparable datasets |
| **Data Integrity** | Secure cloud repositories | Auditable and traceable environmental information |

### 7.3. Integration of Fiscal Policy, Market Instruments, and Sustainability

APEC economies may consider linking their digital environmental monitoring systems with fiscal and market-based instruments that incentivize regulatory compliance and sustainable resource management. Experiences such as Republic of Korea's STMS demonstrate how real-time data can support the implementation of transparent, evidence- based environmental fees, incentives, or taxes.

It is also relevant to explore digital traceability platforms or carbon-market mechanisms, drawing on initiatives such as J-Credit (Japan)[5] or PRISMA (Malaysia)[6], always within domestic or subregional frameworks and supported—on a voluntary basis—through APEC cooperation forums.

---

[5] Japan - Case Studies on the Utilization of Satellite Imagery in Agricultural Administration in Japan.

[6] The RSPO experience shows that sustainable value chains require robust standards, verifiable traceability, and multi-stakeholder governance supported by reliable data. Its PRISMA platform represents an advanced example of how digitalization can unify certification, auditing, and monitoring processes, addressing data fragmentation and enabling the identification of risks, gaps, and improvement opportunities in real time. By standardizing information, ensuring the integrity of records, and facilitating the participation of smallholders, PRISMA strengthens market integrity and demonstrates how digital infrastructure becomes a critical enabler for more transparent, inclusive, and sustainability-aligned value chains within APEC.

**Table 12. Fiscal and Market Integration for Environmental Digitalization**

| Policy Approach | Example / Mechanism | Expected Impact |
|---|---|---|
| **Fiscal Integration** | STMS – Republic of Korea | Real-time linkage between emission data and environmental taxes |
| **Carbon Markets** | J-Credit – Japan | Verified and tradable emission reductions |
| **Sustainable Value Chains** | PRISMA – Malaysia | Digital traceability across agricultural and forestry sectors |

### 7.4. Ethics, Transparency, and Artificial Intelligence Governance

The growing use of AI in environmental management underscores the need to establish ethical principles and mechanisms for algorithmic transparency. In this regard, APEC economies could develop economy codes or ethical guidelines for environmental AI that promote fairness, explainability (XAI), and human oversight in automated monitoring and analysis processes.

APEC could also facilitate the exchange of good practices and technical guidance on responsible AI through its specialized working groups. Initiatives such as Blue Map (China) and Global Forest Watch (United States) demonstrate that open-data models and operational transparency strengthen public trust and accountability, principles that can be adapted to the institutional contexts of different member economies.

### 7.5. Regional Cooperation and Institutional Convergence

Cooperation and mutual learning are essential to sustaining technological innovation. In this sense, APEC could consider creating and/or strengthening spaces for technical collaboration—such as thematic groups within **DESG** or **PPSTI**—that support the exchange of experiences on interoperability, QA/QC, and digital ethics.

These spaces would not be regulatory in nature; rather, they would operate as voluntary mechanisms for learning and coordination designed to support local policies.

**Table 13. Regional Cooperation and Evaluation Mechanisms**

| Level | Instrument | Strategic Objective |
|---|---|---|
| **Regional** | Working groups and forums (DESG, PPSTI) | Technical exchange and voluntary cooperation |
| **Domestic** | Integration into green growth plans | Policy coherence and institutional alignment |
| **Monitoring** | Voluntary reports or reviews | Continuous assessment of digital enforcement effectiveness |

### 7.6. Dialogue Platforms in APEC for Digital Environmental Cooperation

APEC forums such as the Digital Economy Steering Group (DESG) and the Policy Partnership on Science, Technology and Innovation (PPSTI) constitute strategic platforms for promoting technical and policy exchange on data ethics, interoperability, and digital governance.

Through specialized workshops, pilot projects, and mechanisms for academic cooperation, these spaces facilitate the alignment of efforts and the strengthening of regional capacities, enabling economies to share tools, methodologies, and experiences without establishing binding obligations.

### 7.7. Towards Predictive, Transparent, and Ethical Environmental Governance

The lessons derived from this project confirm that the future of environmental enforcement is moving toward anticipatory, transparent, and ethically grounded digital governance.

By integrating technological innovation, accountability mechanisms, and transparency in data use, APEC economies can consolidate evidence-based and results-oriented environmental management models aligned with public expectations for trust and integrity.

This integrated approach, combining technology, ethics, and regional cooperation. represents a substantial contribution to global efforts to strengthen fair, sustainable, and information-driven environmental governance.

## 8. CONCLUSIONS

The transition toward digital environmental enforcement represents a transformative process across APEC economies. The experiences analyzed and the technical discussions held during the regional workshop have made it possible to identify common patterns and shared challenges that outline a new horizon of environmental governance— one based on data, cooperation, and ethics.

This chapter synthesizes the project’s strategic findings, highlighting the cross-cutting lessons, institutional impact, and future opportunities for strengthening digital environmental governance in the region. The focus is placed on how APEC economies may consider adopting local policies, technological platforms, and collaborative frameworks that promote environmental management that is more transparent, efficient, and predictive, with the enabling support of the APEC forum.

### 8.1. Digital Transformation and Strategic Lessons Learned

The evidence gathered in this study confirms that the digitalization of environmental enforcement is not limited to the incorporation of new technological tools; rather, it requires a broad institutional and cultural reconfiguration. Based on the representative cases reviewed, five fundamental strategic lessons emerge to guide this transition process:

a) **Interoperability as a central pillar:** The standardization of formats, metadata, and QA/QC protocols forms the foundation for establishing a common technical language in the exchange of environmental information, enhancing operational coherence and strengthening institutional trust.
b) **Institutional strengthening and continuous training:** The sustainability of the digital transformation process depends on teams trained in artificial intelligence, data analytics, remote sensing, GIS, and cybersecurity. Continuous skills development is essential to ensure the operability and evolution of digital systems.
c) **Ethics and transparency of algorithms:** The deployment of AI-based technologies must be grounded in principles of fairness, explainability (XAI), and human oversight. Algorithmic transparency and accountability are essential components to prevent bias and ensure the legitimacy of decision-making processes.
d) **Innovation within flexible frameworks:** Economies can incorporate emerging technologies as long as the integrity, security, and traceability of environmental data are preserved. Adaptive regulatory frameworks support innovation without compromising system reliability.
e) **Cooperation facilitated by APEC:** Regional forums, such as the DESG and PPSTI, play a strategic role in technical coordination, experience sharing, and peer learning, contributing to the strengthening of digital environmental governance across the region.

### 8.2. Institutional and Regional Impact

The initiative's main achievement has been demonstrating that technology can generate public value when integrated into regulatory systems under principles of transparency and accountability. When applied rigorously and ethically, digitalization enhances enforcement efficiency, reduces information asymmetries, and strengthens public trust in environmental oversight processes.

At the regional level, APEC can continue to play a facilitating role through specialized workshops, repositories of best practices, and voluntary pilot projects aimed at strengthening interoperability and technical convergence among economies. These mechanisms do not impose regulatory obligations, but they promote cooperation, mutual learning, and the progressive adoption of common standards. In doing so, the forum contributes to aligning efforts toward a shared vision of sustainable development and high- quality growth across the Asia–Pacific region.

### 8.3. Future Perspectives for Digital Governance

The future of digital environmental governance in the APEC region will depend on the ability of economies to integrate technological innovation, institutional ethics, and voluntary cooperation. Emerging trends—such as digital twins, intelligent automation, and predictive early-warning systems—offer increasingly powerful tools to anticipate risks, assess impacts, and formulate evidence-based environmental policies.

APEC can play a key role by promoting applied research, capacity-building initiatives, and voluntary standards that guide data interoperability and the ethical use of artificial intelligence. In the long term, these efforts can help consolidate a regional ecosystem of environmental governance grounded in transparency, trust, and shared responsibility.

### 8.4. Toward Ethical and Predictive Governance

The digitalization of environmental enforcement represents a decisive opportunity to consolidate an ethical, transparent, and forward-looking model of environmental governance. APEC economies have demonstrated that cooperation, trust, and innovation can converge into an enforcement framework that combines technical rigor with public legitimacy.

By strengthening their domestic frameworks and sharing experiences through APEC's dialogue platforms, economies are laying the groundwork for a new regional paradigm of digital environmental governance—one that not only incorporates technological advances, but also directs them toward sustainability, inclusion, and environmental justice.

## 9. REFERENCES


- Adnan, M., Xiao, B., Ali, M. U., Bibi, S., Yu, H., Xiao, P., et al. (2024). *Human inventions and their environmental challenges, especially artificial intelligence: New challenges require new thinking. Environmental Challenges, 17*, 100345.

- Ahaneku, C. V., Obiamalu, C. C., Aseh, P., Amasiani, E. J., & Muogbo, D. C. (2025). *Mining in the age of artificial intelligence (AI): Harnessing big data for environmental stewardship. Archives of Current Research International, 25*(8), 1–20.

- Al Mashhadany, Y., Alsanad, H. R., Al-Askari, M. A., Algburi, S., & Taha, B. (2024). *Irrigation intelligence—Enabling a cloud-based Internet of Things approach for enhanced water management in agriculture. Environmental Monitoring and Assessment, 196*(4), 1–15.

- Alotaibi, E., & Nassif, N. (2024). *Artificial intelligence in environmental monitoring: In- depth analysis. Discover Artificial Intelligence, 4*, 1–25.
  Hajjaji, Y., Boulila, W., Farah, I., Romdhani, I., & Hussain, A. (2021). *Big data and IoT-based applications in smart environments: A systematic review. Computer Science Review, 39*, 100345.

- Himeur, Y., Rimal, B., Tiwary, A., & Amira, A. (2022). *Using artificial intelligence and data fusion for environmental monitoring: A review and future perspectives. Information Fusion, 81*, 1–21.

- Kamyab, H., Khademi, T., Chelliapan, S., Saberi Kamarposhti, M., Rezania, S., Yusuf, M., Farajnezhad, M., Abbas, M., Jeon, B. H., & Ahn, Y. (2023). *The latest innovative avenues for the utilization of artificial intelligence and big data analytics in water resource management. Results in Engineering, 20*, 101123.

- Miller, T., Durlik, I., Kostecka, E., Kozlovska, P., Łobodzińska, A., & Sokołowska, S. (2025). *Integrating artificial intelligence agents with the Internet of Things for enhanced environmental monitoring: Applications in water quality and climate data. Electronics, 14*(3), 1–25.

- Olawade, D., Wada, O. Z., Ige, A. O., Egbewole, B. I., Olojo, A. S., & Oladapo, B. I. (2024). *Artificial intelligence in environmental monitoring: Advancements, challenges, and future directions. Hygiene and Environmental Health Advances, 4*, 100123.

- Environmental Assessment and Enforcement Agency [OEFA]. (2025). *Technology Innovation Workshop for Environmental Monitoring Using Technologies such as Artificial Intelligence and Big Data in Productive Activities.* Lima: APEC–OEFA.

- Popescu, S. M., Mansoor, S., Wani, O. A., Kumar, S. S., Sharma, V., & Sharma, A. (2024). *Artificial intelligence and IoT-driven technologies for environmental pollution monitoring and management. Frontiers in Environmental Science, 12*, 1–18.

- Xu, H., Yang, X., Hu, Y., Wang, D., Liang, Z., & Mu, H. (2024). *Trusted artificial intelligence for environmental assessments: An explainable high-precision model with multi-source big data. Environmental Science and Ecotechnology, 20*, 100345.

- Zhang, X., Shu, K., Rajkumar, S., & Sivakumar, V. (2020). *Research on deep integration of the application of artificial intelligence in environmental monitoring systems and the real economy. Environmental Impact Assessment Review, 85*, 106464.

- Government of Japan, Ministry of Agriculture, Forestry and Fisheries (MAFF). (2023). *Field Survey Implementation Manual Using Satellite Imagery.* Tokyo, Japan. Available at: https://www.maff.go.jp/j/zyukyu/attach/pdf/eisei-18.pdf *(Manual for Implementing Field Surveys Using Satellite Imagery. Tokyo, Japan.)*

- Government of Japan, MAFF. (2024). *Fude Polygons Open Data Portal.* Retrieved from: https://www.maff.go.jp/j/tokei/porigon/index.html *(Portal de datos abiertos de polígonos Fude.)*

- National Agriculture and Food Research Organization (NARO) & MAFF. (2025). *Presentation: Satellite Imagery for Agricultural Administration.* Presented at the *APEC Technology Innovation Workshop for Environmental Monitoring, Incheon, Republic of Korea (July - August 2025).*

- Department of Industrial Works (DIW), Ministry of Industry of Thailand. (2022). Ministerial Order B.E. 2565 (2022) on Continuous Emission and Pollution Online Monitoring Systems (CEMS/POMS). Bangkok, Thailand.

- DIW. (2020). Industrial Environmental Monitoring Center (IEMC) – Technical Guidelines for Continuous Monitoring and Data QA/QC. Bangkok, Thailand.

- Pantita Buachan. (2025). Enhancing Transparency and Compliance through CEMS and POMS in Thailand’s Industrial Sector. Presentation at the APEC Technology Innovation Workshop for Environmental Monitoring, Incheon, Republic of Korea.

- United States Environmental Protection Agency (U.S. EPA). (2020). 40 CFR Part 60
  - Standards of Performance for New Stationary Sources. Washington, D.C., USA.
  U.S. EPA. (2020). 40 CFR Part 75 – Continuous Emission Monitoring. Washington, D.C., USA.

- Rural Development Administration (RDA), Republic of Korea. (2024). National Agricultural Satellite Center (NASC) Overview Report. Jeonju, Republic of Korea.

- SukYoung Hong. (2025). Agricultural and Environmental Monitoring using Drones and Satellites (RDA). Presentation at the APEC Technology Innovation Workshop for Environmental Monitoring, Incheon, Republic of Korea.

- Korea Aerospace Research Institute (KARI). (2023). CAS500-4 Mission Overview. Daejeon, Republic of Korea.

- Statistics Korea (KOSTAT). (2024). Agricultural Production Statistics and Remote Sensing Integration Pilot. Seoul, Republic of Korea.

- Ministry of Agriculture, Food and Rural Affairs (MAFRA). (2024). Farm Map Dataset, Open Access Geospatial Reference for Agricultural Land Management. Seoul, Republic of Korea.

- European Space Agency (ESA). (2024). *Sentinel-1 Technical Guide.* Copernicus Open Access Hub / ESA EO Portal. Disponible en: https://sentinels.copernicus.eu

- Google LLC. (2024). *Google Earth Engine – Platform Documentation.* Disponible en: https://developers.google.com/earth-engine

- QGIS Development Team. (2024). *QGIS User Guide, Version 3.34.* Open Source Geospatial Foundation. Disponible en: https://qgis.org

- Roundtable on Sustainable Palm Oil (RSPO). (2024). *RSPO Principles and Criteria for the Production of Sustainable Palm Oil (P&C 2018 – Revised 2024).* Kuala Lumpur, Malaysia.

- Rural Development Administration (RDA). (2024). *Agricultural and Forestry Satellite CAS500-4 – Overview and Applications.* Republic of Korea.

**9.1. Technical Questionnaires:**

**Dr. Haris Syahbuddin, D.E.A.** (2025). *Technical Questionnaire: SISCROP 2.0 – Standing Crop & Rice Production (Indonesia).* Ministry of Agriculture, República de Indonesia.

**Ms. Naoki Ishitsuka.** (2025). *Technical Questionnaire: Satellite Imagery for Agricultural Administration (NARO/MAFF – Japan).* National Agriculture and Food Research Organization (NARO) / Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan.

**Dr. SukYoung Hong.** (2025). *Technical Questionnaire: Drone- and Satellite-Based Monitoring for Agricultural Research & Environmental Management (Republic of Korea).* Rural Development Administration (RDA), Republic of Korea.

.**Dr. Suyoung Park.** (2025). *Technical Questionnaire: From Satellite Data to Decisions – Geospatial Infrastructure for Environmental Oversight and Land Governance (Republic of Korea).* National Geographic Information Institute (NGII), Republic of Korea.

**Mr. Yen Hun Sung.** (2025). *Technical Questionnaire: RSPO – Standards Evolution and the Integration of Remote Sensing and Technology (Malaysia).* Roundtable on Sustainable Palm Oil (RSPO), Malaysia.

**9.2 Credits**

**Contributors**

**Mr. Naoki Ishitsuka** – Group Leader, *National Agriculture and Food Research Organization (NARO/MAFF, Japan)*.

**Ms. Pantita Buachan** – Scientist Professional Level, *Department of Industrial Works (DIW, Ministry of Industry, Thailand)*

**Dr. SukYoung Hong** – Senior Researcher, *Rural Development Administration (RDA, Republic of Korea)*.

**Dr. Haris Syahbuddin** – Director, *Indonesian Center for Agricultural Land Resources Research and Development (ICALRD, Indonesia)*.

**Mr. Yen Hun Sung** – Environmental Manager, *Roundtable on Sustainable Palm Oil (RSPO, Malaysia)*.

These collaborators contributed substantive technical inputs that informed the characterization, comparative analysis, and policy recommendations presented throughout this report.