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MINISTRY OF
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INDIAai

INDIA AI IMPACT SUMMIT 2026

COMPENDIUM

Real-World Impact of AI in Agriculture

AIAIC
AI and AgriTech Innovation Center
— AI for Every Acre —

WORLD BANK GROUP

WADHWANI AI

Disclaimer

The case studies included in this compendium have been evaluated based on information submitted by the respective authors and participating organizations. Responsibility for the accuracy of data, metrics, and representations rests solely with the submitting authors. The evaluation committee and partner institutions shall not be held liable for any discrepancies, omissions, or subsequent changes in the information provided.

Partners: IndiaAI Mission, Ministry of Electronics and Information Technology (MeitY), Artificial Intelligence & AgriTech Innovation Centre (AIAIC), Government of Maharashtra, Wadhwani AI, The World Bank

We thank the Ministry of Agriculture and Farmers Welfare (MoAFW) and the Indian Council of Agricultural Research (ICAR) for facilitating this compendium.

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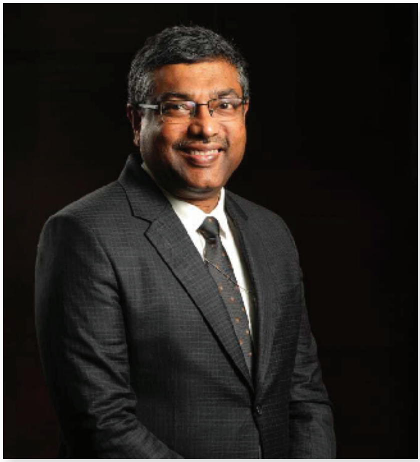
Foreword



The India-AI Impact Summit 2026 represents an important milestone for the developing world. As the first global AI Summit to be hosted in the Global South, the Summit is dedicated to contextualising the global AI agenda to the realities of emerging economies. Our focus is not merely on the technology, but on its utility in solving fundamental development challenges.

The Summit charts a path towards a future where the transformative power of AI serves humanity, drives inclusive growth, fosters social development, and promotes people-centric innovations that protect our planet. It also seeks to amplify the voice of the Global South, ensuring that technological advancements and opportunities are shared broadly, not concentrated in a few regions.

The agricultural sector is central to this vision given it is the lifeblood of the Indian economy and guarantor of food security for over 1.4 billion people. Consequently, India advocates for a model of AI democratisation where advanced predictive capabilities are accessible not just to industrial conglomerates, but to the smallholder farmers who sustain the global food system.

Through the IndiaAI Mission, we are operationalising this vision. We are fostering an innovation ecosystem that facilitates the development and deployment of AI applications in critical sectors such as agriculture, through solutions focused on AI-driven multilingual advisory assistants and chemical-free soil testing, to automated crop quality assessment and smart fisheries management. We are also fostering the availability of indigenous datasets across sectors that can enable the refinement of AI solutions rooted in our socio-economic and agricultural context.

The Casebook on the Real-World Impact of Artificial Intelligence in Agriculture, developed in partnership with the Government of Maharashtra's AI and Agritech Innovation Center (AIAIC), supported by The World Bank and Wadhwani AI, serves as a blueprint for this transformation. It offers policymakers and researchers a comprehensive reference for replicating scalable, ethical AI solutions that strengthen food security across the Global South, and support the digital transformation of agricultural systems. It stands as an example of how international collaboration can deliver practical and scalable outcomes for developing economies, particularly in strengthening food security and farmer livelihoods.

We acknowledge with appreciation the leadership of the Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India, and the partnership of the AIAIC, supported by The World Bank and Wadhwani AI.

Together, these efforts demonstrate that Artificial Intelligence, when grounded in the needs of the Global South, can be a powerful instrument for equitable development and farmer prosperity.

Shri S. Krishnan
Secretary

Ministry of Electronics and Information Technology
Government of India

Foreword

At the India AI Impact Summit 2026, India's vision is to move beyond high-level principles to demonstrable, on-the-ground impact. The Summit's holistic vision of People, Planet, and Progress requires that we deploy technology to secure the most basic of human needs. In agriculture, this means transitioning to proactive, data-driven decision-making for enhanced agricultural yield and farmer livelihoods.

India's democratisation of AI-enabled agricultural solutions has delivered transformative outcomes. The IndiaAI Mission is committed to democratising these capabilities and ensuring that they reach farmers in the remotest corners of our country. We have prioritised the creation of indigenous solutions that function in low-bandwidth, multilingual environments and ensure that every farmer has access to the same resources as a global agri-business.

The Casebook on the Real-World Impact of Artificial Intelligence in Agriculture, developed in partnership with the Government of Maharashtra's AI and Agritech Innovation Center (AIAIC), supported by The World Bank, and Wadhwani AI, highlights the real-world impact of AI in agriculture.

This Casebook invited contributions from researchers, innovators, agricultural institutions, and technology providers worldwide, resulting in an enthusiastic response of over 263 abstracts from diverse geographies. Submissions underwent rigorous multi-stage technical evaluation, assessing relevance, scalability, farmer-centric design, and alignment with Sustainable Development Goals. Selected contributors provided comprehensive case studies detailing solution architecture, deployment models, impact assessments, ethical considerations, and lessons learned. Each submission was reviewed by an expert Evaluation Committee with representatives from the Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India, AIAIC supported by The World Bank, and Wadhwani AI.

The resulting Casebook presents a curated set of 26 use cases utilising AI for resource management, multilingual advisory platforms, and digital carbon verification systems, enabling climate resilience, financial inclusion, and transparent market linkages for smallholder farmers.

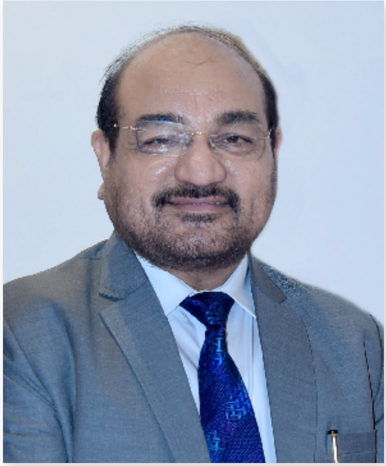
We extend our sincere appreciation to the leadership provided by the Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India, and the partnership of AIAIC supported by The World Bank, and Wadhwani AI in advancing responsible AI in agriculture. Together, these collective efforts reaffirm that AI, when developed and deployed responsibly, ethically, and inclusively, can serve as a powerful tool for a resilient and food-secure future.

We acknowledge with appreciation the leadership of the Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India, and the partnership of the AIAIC, supported by the World Bank and Wadhwani AI.

Shri Abhishek Singh
CEO, IndiaAI Mission

Additional Secretary, Ministry of Electronics and Information Technology
Government of India

Foreword



Agriculture today stands at the intersection of growing climate uncertainty, resource constraints, and the imperative to ensure food, nutrition and livelihood security for millions of smallholder farmers and consumers. In this context, Artificial Intelligence offers new tools to strengthen agricultural decision-making, enhance resilience, and improve productivity provided these technologies are grounded in sound science, local agronomic realities, and farmer-centric design. For the Indian Council of Agricultural Research (ICAR), the application of AI in agriculture must be guided by a clear objective: translating data and computational advances into actionable insights that are reliable, scalable, and usable at the field level.

AI has the potential to complement traditional agricultural research by enabling more precise crop monitoring, early detection of pests and diseases, improved soil and water management, and more accurate weather and yield forecasting. When integrated responsibly, these capabilities can significantly strengthen extension systems and support timely interventions across diverse agro-climatic zones. India's agricultural landscape is characterized by heterogeneity of crops, soils, climates, and farming practices. This diversity presents both a challenge and an opportunity for AI. Models trained on narrow datasets or designed without domain expertise risk producing unreliable outcomes. Conversely, AI systems developed in close collaboration with agricultural scientists, extension workers, and farmers can enhance the relevance and credibility of digital advisories.

Indian Council of Agricultural Research, therefore, emphasises the importance of robust datasets, scientific validation, and continuous feedback from the field as foundational elements of AI-enabled agricultural solutions. The Casebook on the Real-World Impact of Artificial Intelligence in Agriculture, developed by IndiaAI in partnership with the Government of Maharashtra's AI and Agritech Innovation Center (AIAIC), captures this convergence of technology and agricultural science. The casebook presents a curated set of AI applications that address key challenges across the agricultural value chain from resource optimisation and crop health management to multilingual advisory platforms, market linkages, and climate resilience. Each case reflects practical deployment experiences, impact outcomes, and lessons for scaling solutions across regions.

The strong response to the global call for submissions underscores growing interest in applying AI to agriculture in ways that are evidence-based and farmerfocused. A rigorous multi-stage evaluation process, involving experts from ICAR, Ministry of Agriculture and Farmers Welfare, and partner institutions, ensured that the selected cases demonstrate scientific credibility, scalability, and alignment with sustainable development objectives. This approach reinforces the importance of institutional oversight and interdisciplinary collaboration in translating innovation into impact. As India hosts the India AI Impact Summit 2026, ICAR reaffirms its commitment to advancing digital and AI-driven innovations that strengthen agricultural systems while safeguarding scientific integrity and farmer trust. We value the leadership of the Ministry of Electronics and Information Technology and the IndiaAI Mission in partnership with AIAIC, in fostering responsible AI adoption in agriculture.

This casebook reflects a shared understanding that AI is not a substitute for agricultural science, but a powerful enabler when applied judiciously. When grounded in research, validated through field experience, and designed around farmers' needs, Artificial Intelligence can contribute meaningfully to resilient agriculture, improved livelihoods, and a food-secure future.

Shri Dr. M. L. Jat
Director General, Indian Council of Agricultural Research

Secretary, Department of Agricultural Research and Education
Ministry of Agriculture and Farmers Welfare
Government of India

Note From Knowledge Partners

This Casebook on AI and Agriculture brings together practical examples of how AI is being used on the ground to solve everyday challenges in agriculture. Each case study reflects real deployments that support farmers, institutions, and markets in making better, more informed decisions. The following section outlines how these cases were identified and selected.

AI in agriculture is no longer optional; it is essential in a sector facing climate volatility, resource pressure, and widening information gaps. This Casebook captures how real-world deployments are translating technology into everyday farming decisions, strengthening resilience, productivity, and access to opportunity.

The evaluation and selection of entries for the Casebook on the Real-World Impact of Artificial Intelligence in Agriculture followed a structured, multi-stage screening and review process aimed at ensuring quality, credibility, and a strong focus on field-tested AI solutions.

The process was overseen by an expert evaluation committee chaired by **Dr. Rabi Narayan Sahoo**, Principal Scientist, ICAR-Indian Agricultural Research Institute & Program Leader, ICAR-Network Programme on Precision Agriculture (NePPA). Committee members included -

- **Shri Anindya Banerjee, Advisor, Digital Agriculture**
- **Shri Sudir Natla Reddy, Scientist C, Ministry of Electronics and Information Technology**
- **Mr. Shrikant Andge, Managing Director, AI & AgriTech Innovation Center, Government of Maharashtra**
- **Ms. Arshia Gupta, Rural Development Specialist, The World Bank**
- **Mr. Vikas Kanungo, Senior Consultant, AI & Digital Transformation, The World Bank**
- **Mr. J. P. Tripathi, Director, Agriculture, Wadhwani AI**

Together, the committee brought experience spanning government, research institutions, and international development organisations.

The evaluation process followed clearly defined timelines built around phased screening and review. Submissions first underwent an eligibility check to identify incomplete or inaccurate applications. After this screening stage, 257 out of 264 entries qualified for evaluation.

The committee applied clear selection guidelines centered on demonstrated, field-tested AI solutions. Only entries that had been deployed, piloted, or tested in real-world environments were considered. Submissions at the ideation stage were excluded, along with solutions heavily dependent on the Internet of Things (IoT) or automation where AI functioned only as a superficial layer. Entries that had been tested but did not present measurable outcome-level results were also filtered out. These screening steps formed the backbone of the evaluation timeline and ensured consistency across all submissions.

The final evaluation pool reflected both domestic and international participation. Of the qualified entries, 233 came from India and 24 from 13 other participating countries. Within India, submissions were spread across regions, including 77 use cases from southern states, 99 from western states (88 of them from Maharashtra), 10 from eastern states, and 47 from northern and central states. From this pool, a curated shortlist was presented to the committee for final consideration, including 20 Indian entries and eight international submissions.

The cases in this volume trace the many ways AI is entering the everyday life of farmers — from the soil beneath his feet to the markets where crops are sold. Some solutions work deep in the field. Systems like Chemistry-Aware Crop Yield Prediction read the hidden chemistry of soil and combine it with satellite intelligence to guide smarter farming decisions. Others operate at landscape scale. Platforms such as Geo-AI Digital MRV for Climate-Smart Rice verify sustainable practices across thousands of farms, turning climate action into measurable reality.

At the farmer interface, advisory systems like MahaVISTAAR and FarmerChat show how AI can act as a daily companion, answering questions, flagging risks, and supporting decisions in real time. Post-harvest innovations, including AI-Driven Grain Quality Assessment and horticulture grading systems, bring fairness and transparency to agricultural markets. Financial intelligence tools (Agri FinTech) like SatSource Agricultural Credit Intelligence are helping banks finally see the farm clearly, opening doors to faster and more inclusive credit. Readers will find a glimpse into these innovations — short windows into how each system works, what problems it addresses, and what impact it has achieved on the ground.

We thank the IndiaAI Mission, the Indian Council of Agricultural Research (ICAR), and the Ministry of Agriculture and Farmers Welfare (MoAFW) for their leadership and support. Their commitment, along with contributions from partners and innovators, demonstrates how public-purpose technology can drive inclusive agricultural transformation.

Glossary

Term	Definition
AI (Artificial Intelligence)	Computational systems that learn patterns from data and generate decisions or predictions without explicit rule programming.
AI Advisory System	A digital platform that uses AI models to generate context-aware agricultural recommendations tailored to farmer conditions.
AgriLLM (Agricultural Large Language Model)	A domain-trained language model specialised in agronomy, capable of generating scientifically grounded advisory responses.
Alternate Wetting and Drying (AWD)	A rice cultivation practice that reduces methane emissions and water use by allowing controlled irrigation cycles.
API (Application Programming Interface)	A standardised protocol enabling software systems to exchange data and services automatically.
Biophysical Modeling	Mathematical simulation of plant growth and crop behaviour based on radiation, canopy, and environmental physics.
Carbon MRV (Monitoring, Reporting, Verification)	Digital systems that quantify and validate carbon sequestration or emission reductions for certification.
Climate-Smart Agriculture	Farming approaches that increase productivity while improving resilience and reducing environmental impact.
Computer Vision	AI technology that enables automated interpretation of images and visual data.
Consent-Based Data Governance	A framework where farmers control how their data is collected, used, and shared.
Digital Public Infrastructure (DPI)	Shared, interoperable digital systems that act as foundational rails for public services.
Digital Twin (Agriculture)	A virtual model of a farm built from real-time data for simulation and predictive decision-making.
Discriminative AI	Models designed to classify, detect, or predict outcomes from structured inputs (e.g., crop stress classification).
Earth Observation (EO)	Monitoring of land and environmental conditions using satellite or remote sensing systems.
Edge AI	AI processing performed directly on devices rather than centralised servers.
Explainable AI (XAI)	AI systems that provide transparent reasoning behind their decisions.

Farmer Producer Organisation (FPO)	A farmer-owned enterprise for aggregation, production, and market access.
Generative AI	AI systems capable of generating new content such as text, advisory messages, or compliance documents.
Geospatial Intelligence	Insights derived from satellite imagery, GPS data, and spatial analytics.
Hyperspectral Imaging	Spectral analysis capturing hundreds of wavelength bands to infer soil or crop properties.
Hyperlocal Forecasting	Weather or crop predictions at highly localised geographic scales.
IoT (Internet of Things)	Networks of sensors that transmit real-time field telemetry.
Machine Learning (ML)	AI methods that learn patterns from historical data.
Mass Spectrometry Soil Profiling	High-precision chemical analysis of soil elemental composition used in predictive modeling.
Multispectral Imaging	Satellite imaging across selected wavelength bands for crop analysis.
NDVI (Normalised Difference Vegetation Index)	A vegetation health indicator derived from satellite reflectance.
Near-Infrared Spectroscopy (NIRS)	Non-destructive soil testing using light absorption patterns.
OCR (Optical Character Recognition)	AI extraction of text from images.
Phygital Model	A hybrid system combining physical extension work with digital advisory.
Physics-Guided Machine Learning	AI models constrained by scientific crop growth simulations.
Precision Agriculture	Data-driven farming optimising inputs at field level.
Radiative Transfer Modeling	Simulation of light interaction with crop canopies.
Remote Sensing	Data collection without physical contact using satellites or drones.
SAR (Synthetic Aperture Radar)	Radar satellite imaging capable of penetrating clouds.
Self-Supervised Learning	Model training using unlabeled data.
Soil Health Card	A diagnostic soil fertility report.
Spectroscopy	Measurement of material properties using light spectra.
Super-Resolution Imaging	AI methods that enhance image resolution beyond sensor limits.

Telemetry	Continuous automated transmission of sensor data.
Time-Series Data	Sequential measurements tracked over time.
Traceability System	Digital tracking of agricultural products across supply chains.
Transformer Model	Deep learning architecture used in modern language and pattern recognition AI.
Unsupervised Learning	AI that identifies patterns without labeled outputs.
Yield Prediction Model	AI estimating expected crop output.
Zero-Literacy Interface	Systems designed for users without reading ability, often voice-first.

Case Study 1

MahaVISTAAR: Responsible AI–Enabled Agricultural and Livestock Advisory at Population Scale

Author: Parimal Singh, Project Director, Project on Climate Resilient Agriculture
Organisation: Department of Agriculture, Government of Maharashtra

Agriculture and allied livelihoods form the backbone of Maharashtra's rural economy. Despite the growing availability of digital tools, farmers and livestock rearers continue to face fragmented access to knowledge, markets, schemes, and services. Information related to crops, animal husbandry, weather, prices, inputs, and benefits is spread across multiple systems and often presented in technical formats that are difficult to interpret. These challenges increase decision risk, delay access to benefits, and weaken extension reach — particularly for small and marginal farmers, women farmers, and livestock-dependent households. MahaVISTAAR was conceived to translate Maharashtra's AI policy vision into a practical, farmer-facing system that delivers trusted guidance at scale.

MahaVISTAAR is a flagship AI-enabled agricultural advisory initiative of the Department of Agriculture, Government of Maharashtra, aligned with the MahaAgri-AI Policy 2025–2029 and implemented under the national BharatVISTAAR framework. The platform is designed as digital public infrastructure for agriculture and livestock. It provides farmers with a single conversational interface — accessible via voice or text — to seek guidance in their local language. AI functions strictly as an orchestration and decision-support layer. It captures farmer intent, retrieves relevant information from verified institutional sources, combines multiple data inputs, and presents simplified, contextual guidance. Institutional bodies such as the Department of Agriculture, State Agricultural Universities, research institutions, APMCs, and allied departments remain the authoritative source of truth.

The platform supports both crops and livestock, including cattle, buffaloes, poultry, fisheries, and other animals, enabling holistic farm household decision-making.

MahaVISTAAR is accessible through mobile applications, web platforms, and voice-based services, ensuring inclusion across smartphones, feature phones, and low-connectivity environments. It integrates with existing state agricultural initiatives to avoid duplication and ensure consistency. Primary users include small and marginal farmers, livestock rearers, women farmers, and mixed-farming households across Maharashtra. Secondary users include extension workers and frontline staff, for whom MahaVISTAAR acts as a digital reference for verified, up-to-date advisory.

2.2 million+

farmer downloads enabling population-scale conversational advisory

The platform has demonstrated strong adoption with sustained and repeat usage across diverse geographies, reflecting both relevance and trust among farmers. As of the latest reporting period, over 2.2 million farmer app downloads have been recorded, more than 0.4 million unique farmers are actively using the platform, and over 1.5 million farmer questions have been asked and answered through conversational AI.

Case Study 1

Farmers actively use the platform for crop advisory, livestock management, scheme information, market intelligence, and weather-based decisions, indicating trust and relevance in real farming contexts.

The platform has reduced farmers' dependence on fragmented and informal information sources, improved access to timely guidance, and increased confidence in decision-making. Aggregated insights from farmer interactions help institutions identify emerging risks, scheme awareness gaps, and regional stress patterns, supporting more responsive and evidence-driven governance.

MahaVISTAAR follows privacy-by-design and trust-by-design principles aligned with the Digital Personal Data Protection Act, 2023. Data processing is consent-based and purpose-limited, with minimal personal data collection. Individual data remains with respective data fiduciaries, while only aggregated and anonymised signals are used for system improvement. Personalised data is not shared with private systems. AI safety measures include source-grounded responses, language validation using vetted Indic models, confidence thresholds, and feedback pathways to prevent speculative or unsafe outputs. Transparency is reinforced through clear source attribution.

Inclusion is a core design principle. MahaVISTAAR is multilingual, voice-first, and accessible across literacy and connectivity constraints. It supports both crop and livestock livelihoods and is being extended to include local and tribal languages to reach underserved communities.

A key success has been demonstrating that responsible AI can be embedded within public institutions to deliver value at population scale. A major lesson has been the importance of keeping AI subordinate to institutional authority to build trust. Ongoing challenges such as data curation and language adaptation are addressed through strong institutional partnerships.

MahaVISTAAR shows how Maharashtra's AI policy vision can be translated into a real, farmer-facing system that improves decision-making, strengthens extension systems, and supports inclusive agricultural growth. By combining responsible AI with institutional knowledge, it offers a scalable and replicable model for AI-enabled agriculture grounded in public purpose.

Chemistry-Aware Crop Yield Prediction: Mass Spectrometry x AI for Precision Agriculture

Authors: Abhishek, Shrey Agarwal
Organisation: Alt Carbon

Location: Karnataka, India

India's smallholder-dominated agriculture runs on thin margins and high uncertainty. A farmer's income is often determined by forces they cannot see or predict—rainfall variability, pest pressure, and, crucially, field-to-field differences in soil chemistry that determine how crops respond to inputs. Most yield prediction tools in India operate at coarse resolution or rely heavily on satellite imagery and generic soil maps (typically ~250 m–1 km), smoothing over the micro-variability that drives 40–60% of yield variation. The result is forecasts that are difficult to trust at the plot level and recommendations that cannot reliably answer a farmer's central question: how much should be applied, where, and what return can be expected.

India's smallholder farmers, who constitute 86% of the country's farming community, lack access to precise soil health intelligence and predictive tools that can optimise their limited resources. They need accurate yield models to inform nutrient management, irrigation decisions, harvest planning, crop insurance, credit access, and climate-resilient practices. What is missing is a scalable way to make yield prediction chemistry-aware without requiring expensive, repeated ground-truth campaigns.

Alt Carbon addresses this gap by integrating mass spectrometry–enabled soil elemental profiles, built through on-ground work across thousands of acres digitised and mapped using its in-house MRV system FELUDA and state-of-the-art earth sciences laboratory infrastructure, including the Darjeeling Climate Action Lab (DCAL) and Shonku Labs. By combining high-precision soil chemistry with AI, the system introduces a new layer of agricultural intelligence that has historically been unavailable at scale in India.

The core innovation is an unsupervised yield prediction system that treats soil chemistry as the foundational layer and combines it with multi-temporal satellite observations and weather intelligence through a physics-guided deep learning architecture. The geochemistry layer captures 25 macro- and micronutrients, heavy metals, rare earth elements, organic carbon and nitrogen stoichiometry, ion balances, mineral oxides, isotopic signatures, and three-dimensional nutrient availability mapping. Satellite integration draws from Sentinel-2, Sentinel-1 SAR, and Landsat-8/9 to monitor vegetation, biomass, and evapotranspiration. Weather intelligence incorporates ERA5, NASA POWER, and CHIRPS datasets to model temperature, precipitation, radiation, and monsoon behaviour.

Physics-guided machine learning uses DSSAT crop models to generate synthetic yield labels from soil chemistry and weather inputs. Transformer-based deep learning models learn from these outputs alongside sparse ground-truth data, requiring 10–15× less labeled data than conventional supervised systems. Self-supervised pre-training on more than 50,000 unlabeled satellite time series allows the model to learn universal crop growth patterns before fine-tuning on chemistry-rich datasets.

This geochemistry-first approach identifies nutrient imbalances, soil health constraints, and hidden toxicities that satellite-only systems cannot detect.

Case Study 2

20–32%

yield increase for 2,847 farmers in one season

The platform is currently deployed across 15,000 hectares in West Bengal, including Darjeeling tea estates and paddy rice farms, reaching approximately 27,000 smallholder farmers with an average holding of 2.1 hectares. It operates through a cloud-based API and mobile interface for extension workers and progressive farmers, supported by SMS alerts during critical growth stages. Implementation follows a phased sampling strategy, beginning with high-density chemical profiling and transitioning towards automated predictions guided by active learning.

Cost optimisation is achieved through geostatistical interpolation, reducing effective per-hectare costs while maintaining precision. The automated pipeline processes 25,000 fields in approximately six hours, from ingestion to prediction and farmer alerts, enabling rapid scaling across agroclimatic zones.

Measured outcomes from 2,847 farmers during the 2023–24 season show yield increases of 20–32%, fertiliser cost reductions of 25–40%, and additional income of INR 14,200–18,600 per hectare. Participating paddy farmers achieved yields of 4.2–4.8 tonnes per hectare compared to India's national average of 2.9 tonnes.

Model performance reached 88–94% field-level accuracy (R^2), with 75-day pre-harvest forecasting and full field coverage compared to the 3–5% sampling typical of traditional systems. Environmental gains include a 28% reduction in nitrogen use and measurable increases in soil organic carbon.

Technical challenges around sparse data were addressed through physics-guided modeling, SAR integration to mitigate cloud cover, and interpretability tools that build farmer trust.

Operational lessons emphasised the importance of transparent uncertainty communication, vernacular interfaces, and advisory integration to accelerate adoption. Strategic sampling and physics-based modeling proved essential in data-constrained environments.

The roadmap targets expansion to 45,000 hectares and 80,000 farmers across six states by 2026, with long-term plans to reach 500,000 hectares by 2028 through integration with India's soil testing network. The goal is to establish a national geochemistry-to-yield infrastructure that democratises chemistry-aware farming and positions India at the forefront of element-aware agricultural AI.

MapMyCrop: AI-Powered Precision Sugarcane Intelligence; Satellite-Based Crop Monitoring, Sucrose Prediction, and Harvest Optimisation for Sugarcane Farmers and Sugar Mills

Authors: Ramya Badami, Bhushan Gosavi
Organisation: Map My Crop
Location: Maharashtra, India

India, the world's second-largest sugarcane producer with 5.2 million hectares under cultivation, faces a productivity paradox. Average yields remain at 98–148 tonnes per hectare, below the achievable 221–358 tonnes. Farmers lack access to timely intelligence on soil health, irrigation, nutrient management, and optimal harvest timing. The consequences cascade through the value chain: premature harvesting reduces sucrose by 1–3%, impacting farmer Fair and Remunerative Price (FRP) payments, while mills experience 0.5–1.0% recovery losses. Climate variability demands data-driven interventions that traditional extension services cannot deliver at scale.

MapMyCrop's sugarcane intelligence platform converts satellite and field data into farm-level recommendations through an integrated workflow. The system ingests imagery from multiple satellite constellations with 10-day to daily revisits, ensuring continuous monitoring even during cloud-prone monsoons. Proprietary super-resolution models enhance imagery to 1m resolution while integrating hyperlocal weather and soil parameters to create a digital twin of each farm. Proprietary algorithms process more than 30 remote sensing layers to compute vegetation indices such as NDVI, EVI, NDWI, and chlorophyll content. The crop stress differentiation model distinguishes pest damage, nutrient deficiency, and water stress, enabling targeted interventions.

Four AI advisory engines generate actionable insights: an AI fertigation engine adjusts NPK dosage based on vegetation-rainfall correlations; an AI germination model predicts emergence from soil moisture and temperature; a pest forecast model triggers seven-day advance alerts for shoot borer, top borer, and whitefly; and an AI ripening model optimises nutrient schedules for maximum sucrose accumulation. A sucrose prediction model trained on more than 50,000 ground-truth samples predicts sugar concentration at multiple stalk positions with up to 95% accuracy. The maturity ratio algorithm determines optimal harvest timing, generating 15-day forward harvest windows for peak Brix levels. API integrations allow mills to coordinate harvest schedules, improving recovery rates.

Advisories are delivered via mobile app and WhatsApp in Hindi, Marathi, Kannada, and Tamil, supported by FPO partnerships that provide field implementation assistance. Continuous validation through mill laboratory readings and farmer feedback improved model accuracy from 85% to 95%.

57%+

yield improvement through AI-driven crop optimisation

Case Study 3

The platform currently monitors more than 3,000 sugarcane farms across Maharashtra, Karnataka, Madhya Pradesh, and Tamil Nadu, spanning over 15 districts and partnerships with 25+ sugar cooperatives and FPOs. Farmers and enterprises use the system differently: smallholders access crop intelligence through mobile interfaces, while mills leverage bulk analytics dashboards and harvest coordination tools.

Documented outcomes show measurable impact. Farmers achieved yields of 221–358 tonnes per hectare compared to traditional 98–148 tonnes, representing improvements exceeding 57%. AI fertigation reduced fertiliser use by 20–25% while improving nutrient efficiency. Harvest optimisation enabled farmers to consistently operate within optimal Brix windows. Early pest alerts reduced crop loss by 10–15%.

Data governance follows consent-based collection, with farmers retaining ownership and deletion rights. Infrastructure is secured through ISO 27001-certified systems with role-based access controls. Algorithmic fairness is monitored across regions and farm sizes, and privacy-by-design principles guide development. Inclusion is addressed through vernacular interfaces, visual-first design for low-literacy users, and freemium access ensuring cost is not a barrier.

Rapid adoption has been driven by visible yield improvements and strong mill partnerships. Challenges include cloud cover during monsoons, farmer digital literacy gaps, and model recalibration across agro-climatic zones. Lessons learned confirm that mill and FPO partnerships are essential for scale and accuracy. The platform demonstrates a replicable model for satellite-driven precision agriculture across diverse cropping systems.

Case Study 4

Advisory – Chatbot

farmbetter: Digital AI-Driven Climate Resilience for Smallholder Farmers

Authors: Evalyne Waithira Njuguna, Benjamin Graub
Organisation: farmbetter

Location: Nairobi, Kenya

Smallholder farmers across Africa and India face increasing climate uncertainty, productivity pressures, and income instability, often without access to timely, localised agronomic advice. Traditional extension systems struggle to reach dispersed rural populations, especially in low-bandwidth and low-literacy environments. farmbetter was designed to bridge this gap by delivering AI-powered, real-time farming intelligence directly to farmers in accessible formats.

farmbetter leverages AI to empower smallholder farmers with personalised farming advice that improves productivity, climate resilience, and income. The platform operates through an integrated three-in-one ecosystem comprising a WhatsApp chatbot for farmers, a mobile app for advisors, and a dashboard for partner organisations. By integrating soil health data, weather intelligence, and market information, the system generates predictive insights, pest and disease forecasts, and tailored crop management recommendations. The architecture enables advisors and institutions to coordinate interventions while maintaining farmer-centered delivery.

In Africa, the platform has reached more than 50,000 farmers across eight countries. Documented outcomes include 20–30% yield increases and a 15% reduction in post-harvest losses. In India, through the AgriPath project, farmbetter collaborated with local partners to deploy AI-driven decision tools and climate-smart agricultural practices, demonstrating adaptability across diverse farming systems.

20–30%

yield increase among participating farmers

The solution connects farmers, advisors, and institutions within a shared digital ecosystem that supports evidence-based decision-making and efficient resource allocation. The interface is designed for accessibility, functioning in low-bandwidth environments and supporting users with limited digital literacy. Local partnerships ensure culturally appropriate guidance and trust-building at the community level.

By combining predictive analytics, personalised advisory, and accessible delivery channels, farmbetter demonstrates how AI can strengthen climate resilience and improve livelihoods for smallholder farmers in the Global South. The platform presents a replicable model for scaling inclusive agricultural intelligence across regions.

Case Study 5

Advisory – Seed Production

SeedWorks: AI Copilot for Intelligent Seed Production & Farmer Support

Author: Srinagesh Palagummi
Organisation: Prsti Technologies Pvt Ltd

Location: Telangana, India

Seed production is a living supply chain fundamentally different from industrial manufacturing. The factory floor is an open field, the machinery is a living plant, and the production clock is governed by thermal accumulation and genotype expression rather than calendar days. India's seed sector, a global leader in hybrid seed production, operates under a persistent triangle of risk shaped by climate volatility, operational opacity, and governance challenges. Unpredictable monsoon patterns and vapour pressure deficit shocks during flowering cause sudden pollen sterility and seed set failure even when crop canopies appear visually healthy. Production depends on geographically dispersed contract growers, yet field observations, input records, and crop loss reporting remain largely manual, creating disputes, delayed corrective action, and lack of spatial benchmarking. Counterfeit infiltration and paper-based traceability further weaken regulatory auditability. The sector requires a transition from post-season diagnostics to pre-season intelligence and in-season correction.

SeedWorks Copilot functions as a national digital twin of seed production built on two intelligence pillars. The enterprise planning brain draws on more than five years of internal master data including hybrid genetics, sowing dates, yield performance, and rejection trends, capturing approximately 200 attributes per field. AI modeling combines non-linear time-series learning, ensemble ranking models, and probabilistic simulation to capture biological variability and climate uncertainty.

Artificial neural networks and LSTM models support yield prediction, XGBoost ranks cluster performance, greedy optimisation stabilises acreage allocation, and Monte Carlo simulations stress-test flowering outcomes under climate scenarios. The second pillar is a farmer-wise yield predictor that integrates satellite biomass, SAR data, and sub-hourly climate stacks to estimate intake volumes weeks before harvest at parcel resolution, triggering early anomaly alerts and enterprise planning escalations.

Deployment began with internal contract grower networks focused on enterprise planning, yield prediction, in-season anomaly detection, and forensic root-cause analysis. Future phases include AgriStack integration, soil and climate data exchange, government DPI alignment, parcel identity binding, and multilingual voice-first farmer support. The current validated deployment spans 7,000 hectares of hybrid rice seed production across four states, engaging approximately 8,000 contract farmers and forming a multi-year genetic-by-environment learning backbone for India's seed clusters. The national scale target is 100,000–500,000 farmers across 500,000–1,000,000 hectares in eight to ten states, enabling India's first SKU-wise, district-wise, and stage-wise seed intelligence dashboard with audit-grade production evidence.

>90%

forecasting accuracy for final seed intake volumes

Case Study 5

Measured and targeted outcomes include 10–20% yield improvement through optimised site selection, 25–35% water savings via moisture-aware irrigation planning, and forecasting precision exceeding 90% for final seed intake volumes. Loss adjudication accuracy above 90% is achieved through multi-gate forensic root-cause analysis and neighbour benchmarking. The system enables full QR-linked hybrid and parcel traceability while supporting fair compensation and dispute reduction for growers.

Consent-based data governance, explainable AI, and benchmarked attribution models ensure fairness and transparency. Inclusive design prioritises voice-first interfaces for low-literacy farmers and low-resource environments.

Early success demonstrates that AI planning can stabiliase acreage through heat-clock alignment, predict intake volumes before harvest, and classify loss causes objectively. Challenges include calibration across hybrid varieties and districts and expanding reliable government data exchange. Lessons confirm that biological supply chains require thermal intelligence rather than calendar logic, multi-source evidence is essential for fairness, and voice-first systems accelerate adoption compared to text-only tools.

SeedWorks Copilot presents a national model for AI-enabled biological supply chain stabilisation, combining SKU-level planning, parcel-level yield prediction, and forensic loss adjudication to strengthen seed production resilience.

Case Study 6

Advisory – Chatbot

FarmerChat: AI-Powered Agricultural Advisory at Scale

Author: Nidhi Bhasin
Organisation: Digital Green Trust

Location: Delhi, India

India's 150 million smallholder farmers are vital to rural livelihoods and national food security, yet face persistent information gaps due to climate volatility, emerging pests and diseases, fragmented markets, and limited access to extension services. Nearly 58% of farm households lack formal support, and productivity per unit of land lags behind other major producers. Digital Green's theory of change holds that timely, localised, and trusted agricultural advisory strengthens farmers' self-efficacy, improving decision-making, adoption of good practices, and ultimately productivity, resilience, and incomes. Over 17 years, its community video–based extension model achieved adoption rates up to 24% higher than traditional systems while reducing cost per adoption tenfold. Building on this evidence, Digital Green is scaling a digital-first, AI-enabled advisory model that retains contextual relevance.

FarmerChat is an AI-powered agricultural advisory platform designed for smallholder farmers and frontline extension workers. It uses Generative AI, including large language models, to provide real-time conversational guidance through text, voice, and images. Farmers can ask questions in local languages, share photos of crops or livestock, and receive actionable recommendations adapted to their context. Because agriculture is high-stakes, FarmerChat does not rely on generic AI outputs. Responses are grounded in curated, expert-verified agricultural knowledge using a retrieval-augmented.generation architecture. Domain-specific enhancements — including fine-tuned speech-to-text for local accents and strengthened image diagnostics — ensure accuracy even with noisy inputs such as low-quality images or field-recorded voice notes. Continuous reinforcement learning from human feedback, led by agricultural experts, improves relevance and safety over time.

Beyond individual queries, FarmerChat functions as a learning knowledge system. Aggregated interaction data surfaces emerging trends such as pest outbreaks or misinformation, informing iterative model updates and advisory refinement.

More than **0.4 million** users onboarded across India

Deployment follows a dual strategy. Institutional partnerships integrate the platform into public extension systems through state agriculture departments, rural livelihoods missions, animal husbandry departments, FPOs, SHGs, and community organisations that support onboarding and trust-building. Digital acquisition expands direct farmer reach through social platforms, localised SEO strategies, and telecom partnerships that improve access in low-connectivity areas. Field orientation sessions and peer demonstrations reinforce sustained use.

FarmerChat is active across India, Kenya, Nigeria, Ethiopia, and Brazil. In India alone, more than 0.4 million users have joined the platform. The goal is to reach 1 million users by April 2026 and 5.5 million by April 2028 while maintaining free access and reducing delivery costs below USD 1 per user.

Independent evaluations demonstrate strong impact. A 60 Decibels survey found 74% of farmers rated guidance as highly relevant, 83% reported easier access to information, and 80% considered it comprehensive. The platform achieved a Net Promoter Score of 72. IDinsight's evaluation showed 60% of users acted on advice, primarily in pest management, fertiliser use, and livestock care. In-app surveys revealed 70% of active users applied recommendations within 30 days.

Case Study 6

Delivery costs fell from USD 35 per farmer in traditional extension to under USD 1, with adoption rates up to 10 times higher.

FarmerChat incorporates multi-layer AI safety systems including grounded knowledge bases, escalation of high-risk queries, bias monitoring, and strong privacy protections such as anonymisation and farmer data ownership. Inclusion is central: the platform is designed for low literacy, supports multilingual voice interfaces, and works on low-end smartphones.

Evidence shows improved efficiency and confidence among extension workers — especially women — using the system.

The platform demonstrates that AI advisory is most effective when embedded in trusted local institutions, continuously expert-validated, and designed around real farmer communication practices. FarmerChat offers a replicable model for climate-resilient, farmer-centered digital extension.

MetsaQ: Rewiring Agri-Food Markets through AI-Enabled Climate and Advisory Intelligence

Authors: Ruchika Murmu, Krishna Mishra, Aakash Gupta
Organisation: Metsa
Location: Delhi, India

For India's 120 million smallholder farming households, climate uncertainty and market volatility are not abstract concerns — they determine whether families eat, whether children attend school, and whether farmers fall into debt cycles. Climate variability increasingly disrupts traditional farming knowledge, while fragmented markets leave farmers as price-takers rather than price-makers. Women farmers, comprising 65% of agricultural labour, face additional barriers in accessing advisory services and credit. Existing digital solutions often bypass these marginalised farmers, designed instead for literate, connected, male users. MetsaQ was conceived to reverse this pattern by placing inclusion at the center of AI deployment in agriculture.

MetsaQ is an AI-enabled agrifood information exchange built on a hybrid intelligence architecture that combines multiple AI paradigms for agricultural decision support. Small language models deployed locally enable multilingual conversational interfaces that allow farmers to interact in regional languages. These models generate contextual, personalised advisory by interpreting farmer queries against plot-specific data profiles. Complementing the SLMs, rule-based expert systems incorporate agronomist-validated decision rules that ensure recommendation explainability. Each advisory includes reasoning chains that farmers and extension workers can verify, building trust through transparency. The platform also employs discriminative AI models, including gradient-boosted decision trees for yield prediction, risk classification algorithms, and soil health assessment models integrating soil test data, satellite imagery, and historical yield patterns.

A robust data pipeline integrates weather data from IMD, Sentinel-2 satellite imagery, soil health cards, mandi price data, and farmer-captured field observations through validated APIs.

MetsaQ has been deployed through pilots across three states. In Odisha, the platform engages approximately 50 Farmer Producer Organisations and 25,000 farmers across multiple blocks in Puri, Ganjam, and Nayagarh districts in collaboration with Odisha University of Agriculture and Technology. In Himachal Pradesh and Jammu & Kashmir, deployment in partnership with FIL Industries spans the apple value chain, covering approximately 250,000 acres and engaging 200,000 farmers with tools for farmer digitisation, marketplace linkage, and climate-smart advisory tailored to apple cultivation.

Primary beneficiaries are smallholder farmers historically excluded from digital services, including women farmers, marginal landholders with less than one hectare, and farmers in remote areas. FPOs and SHGs serve as institutional anchors, while secondary beneficiaries include financial institutions seeking responsible lending pathways and policymakers requiring ground-level evidence for program design.

Rs 8,500

average income increase per acre for participating farmers

Case Study 7

Measured impacts focus on farmer-level outcomes. Participating farmers report average income improvements of Rs 8,500 per acre through better crop planning and price realisation, alongside input cost reductions of 12% from optimised fertiliser and seed recommendations. FPOs using MetsaQ report 15% better price realisation compared to non-participating groups. For financial inclusion, 34% of participating farmers accessed formal credit assessment processes through verifiable activity records, compared to an 11% baseline in comparable communities. Advisory adherence of 68% has enabled proactive response to weather alerts, with farmers reporting reduced crop losses during unseasonal rainfall events.

Inclusion is built into the system design. Forty-two per cent of Odisha users are women farmers engaged through women's SHGs. Interfaces support Odia, Hindi, Kashmiri, and English, with voice interaction for low-literacy users.

Offline functionality enables access in low-connectivity areas, and the platform operates on basic smartphones requiring less than 2GB RAM. Economic accessibility is maintained through a no-farmer-fee model sustained through institutional partnerships.

Farmer data sovereignty is treated as non-negotiable. Consent is obtained at collection, farmers can view and delete their data, and commercial use requires explicit permission. AI recommendations remain explainable, and regular bias audits ensure equitable performance across user groups. The project demonstrates that intentional inclusion design builds trust and adoption. Women's groups have emerged as powerful channels for sustainable technology diffusion, confirming that linking AI benefits to tangible economic outcomes accelerates adoption. MetsaQ presents a model for responsible AI deployment that advances both productivity and equity in agricultural transformation.

FarmAdvice: Closing the 1:50,000 Extension Gap via Voice-First AI Advisory

Authors: Olorunniisola Alagbe, Jemima Ajisafe
Organisation: Crop2Cash Ltd.

Location: Oyo, Nigeria

Sub-Saharan Africa's agricultural sector faces a severe shortage of human extension agents. While global standards recommend one agent per 500 farmers, ratios in Nigeria and surrounding regions are often reported as high as 1:50,000. This disparity leaves millions of smallholders without the guidance needed to adapt to erratic weather or manage pest outbreaks. Despite high mobile phone penetration, 93% of Nigerian smallholders struggle to access reliable agricultural information due to literacy barriers and the high cost of data.

FarmAdvice is a generative AI model in Africa that uses an IVR-based interface to bridge the digital divide. The system listens to farmer queries in local dialects, transcribes audio with 88–95% accuracy, and generates context-specific advice. Responses are grounded in a tokenised knowledge base of verified agronomic data, ensuring 99% source fidelity and eliminating AI hallucinations.

Deployment follows a "phygital" adoption strategy combining physical and digital engagement. Awareness is raised through field agents, community workshops, and cooperatives. To improve retention, FarmAdvice is bundled with physical services such as input sales and credit, embedding advisory support into the farmer's financial lifecycle.

The platform has scaled to 26,000 farmers in Nigeria within 12 months after pilot deployment and is currently being localised for the Kenyan market to support East African dialects.

Infrastructure is hosted on Windows Azure to ensure enterprise-grade security and the ability to process millions of calls. Primary users are rural smallholder farmers, while agro-processors, development finance institutions, and NGOs use anonymised insights for monitoring and planning.

Scaled to **26,000** farmers in one year via voice-first AI advisory

Measured impact shows a 96.8% contextual relevance score reported by users, with AI helping farmers navigate low-rain periods through regenerative practices. The broader Crop2Cash ecosystem reports up to a 70% increase in farmer income among active users. Safety classifiers filter all non-agricultural or harmful queries, independent agronomists conduct weekly quality audits, and all audio is anonymised with informed consent prompts at call initiation. Inclusion safeguards require a 30% participation quota for women and youth in participating cooperatives.

A major technical success was improving accented speech recognition from 35% to over 90% accuracy within one year. Ongoing challenges include telecom infrastructure instability, with carrier downtime reaching up to 60% in some regions. Lessons learned confirm that voice is the most inclusive interface for rural Africa, enabling AI to translate complex data into actionable advice for farmers with limited literacy.

Case Study 8

FarmAdvice demonstrates that the extension gap can be addressed through strategic generative AI deployment. By removing literacy and hardware barriers, the platform democratises access to precision advisory.

Localisation of AI models to linguistic diversity shows that inclusive design can drive climate resilience and economic empowerment for vulnerable farming communities.

Case Study 9

Pathogen Detection – AI Imaging

SporeCam: Real-Time Airborne Pathogen Detection Intelligence

Authors: Jaydeep Prakash Rane, Anvay Shrikant Bhole
Organisation: Scanit Technologies, Inc.
Location: California, United States

Current crop disease management remains largely reactive, relying on manual scouting and weather models that often detect infections too late, leading to irreversible yield loss. Scanit introduces a proactive, data-driven alternative through real-time pathogen pressure measurement. Early warnings and dynamic digital threat maps allow growers to act before visible symptoms appear, significantly reducing risk and improving intervention timing.

Scanit's flagship IoT device, SporeCam™, functions as an autonomous, field-based laboratory for fungal disease detection. The system analyses up to one million airborne particles per day using dual-spectrum imaging with white and UV light to detect pathogen signatures on an hourly basis. Hidden biological markers captured in these images are processed by a cloud-based AI engine referencing a digital pathogen spore library. The AI enhances optical signature libraries so proprietary algorithms can differentiate between visually similar diseases. A single SporeCam™ can detect multiple pathogens across crops simultaneously and cover more acreage than traditional field IoT devices, enabling multiple small farms to benefit from a shared monitoring node.

The device operates continuously with minimal farmer input, converting raw biological data into localised insights delivered through dashboards, mobile alerts, or API integrations. This supports a "Labs to Land" model where laboratory-grade detection is accessible directly at field level. The system benefits farmers and FPOs through precise disease intelligence, improves forecast accuracy for disease detection applications, provides policymakers with reliable planning data, supports insurance companies with district-level risk profiling, assists agri-input firms with demand forecasting, and generates datasets for research institutions.

Scanit demonstrated large-scale deployment through a partnership with Evergreen FS Inc. in Illinois. The monitoring network expanded from 20 million acres in 2022 to more than 40 million acres in 2023–24, tracking four major fungal diseases in corn. In 2024, Evergreen integrated Scanit's ground-truth pacthogen data into its Agtrinsic disease detection platform, combining biological signals with agronomic and weather models. This enabled daily risk scoring, hotspot mapping, and actionable prompts such as "scout now," "hold," or "treat." The system distinguished between weather-favorable conditions and confirmed pathogen presence.

40+

million acres monitored through real-time airborne pathogen detection

Two seasons of deployment delivered measurable impact. Approximately 1,430 farmers benefited directly, with 1,085 farms onboarded and 275 active advisors. Around 1.27 million disease-risk alerts were issued, improving agronomist productivity by 18–28%.
Risk-prioritised scouting triggered more than 110,000 targeted actions.

Case Study 9

Roughly 79,000 fungicide applications were avoided or deferred, generating an estimated 9.9 million USD in grower benefit. Yield protection in high-pressure environments reached approximately 2–6 bushels per acre. Early-warning layers supported around 260 counties or districts, providing 7–12 days of lead time compared to symptom-based detection.

Global validation strengthens the technology's credibility. Multi-year Bayer studies confirmed autonomous, accurate pathogen detection correlated with in-field disease occurrence. Syngenta agronomists validated projected yield gains of 20–30 bushels per acre through early detection in Project Bin Buster.

In India, deployments in Maharashtra's grape regions through ABM Knowledgeware Ltd and expanded partnerships with DeHaat demonstrate adaptation beyond row crops and across international markets.

Scanit maintains a privacy-centric governance model. Environmental and pathogen data are anonymised, transmitted through encrypted APIs, and accessible only to authorised institutions. Beyond agriculture, the SporeCam™ platform supports bio-surveillance applications relevant to agro-security and public health.

Case Study 10

Chatbot – Paddy Advisory

Living Agricultural Intelligence: Dynamic AI Advisory for Rice Landscapes

Authors: Shalini Gakhar, Anton Urfels
Organisation: International Rice Research Institute
Location: Delhi, India

Rice production systems are increasingly shaped by climate variability, fragmented extension capacity, and uneven access to high-quality agronomic intelligence. Traditional advisory models rely on static recommendations that cannot respond to real-time field variation or evolving management conditions. Farmers require advisory systems that learn continuously from landscape data and farmer interaction, converting passive datasets into active, context-aware intelligence. This initiative introduces a living advisory architecture designed to bridge scientific rigour, digital scale, and equitable farmer access.

The solution is a co-developed dynamic advisory system that converts passive data into active landscape intelligence. Its foundation is a dynamic data stack integrating Rice Crop Manager (RCM), Landscape Crop Assessment Survey (LCAS/LCAS+), and earth observation datasets. Historical agronomic and spatial datasets are combined with fresh, increasingly high-resolution geospatial data streams. Advanced AI/ML models analyse this combined dataset to generate spatial and context-specific inputs. Rather than producing generic summaries, the system infers how plot-level and management conditions shape the most appropriate recommendations. These inputs are fed into domain-specific AgriLLMs that ingest evolving data, including lean data submitted by farmers through chat interfaces, and continuously refine outputs over time. The system operates under the DynAg framework co-developed by IRRI to ensure scientific validity, social inclusion, and prioritisation of marginalised farmers and local languages.

Deployment follows a multi-modal delivery strategy that converts complex analytics into actionable advice. Intelligence is to be delivered through channels including WhatsApp chatbots such as PaddyMitra and FarmerChatbot and the government's Kisan Sarathi platform. A human-assisted AI model is used for quality assurance: AgriLLMs generate advisory content while human experts validate complex or high-stakes queries. A feedback loop captures lean data from farmer interactions and feeds it back into the intelligence stack, allowing the system to adapt continuously to changing field conditions.

Scale is supposed to be achieved by embedding the system within existing national digital infrastructure and extension networks. AI/ML analytics-based advisories have already reached more than one million farmers through Jeevika and related extension platforms. Integration with Kisan Sarathi and other platforms leverages established user bases across millions of farmers. LCAS+ further expands scale by mobilising agricultural students from state universities in partnership with ICAR and local institutions, creating a sustainable pipeline of ground-truth data collection validated through multiple state pilots.

36%

reduction in nitrogen pollution through AI-targeted nutrient advice

Case Study 10

Primary users are smallholder farmers, with explicit design safeguards for women and marginalised communities under the DynAg framework. Institutional users include government extension officers, NGO field workers, and researchers accessing anonymised datasets for evaluation and planning. Inclusion is embedded through voice-enabled interfaces, vernacular support, and public platform integration that ensures advisory access regardless of ability to pay.

Measured impact shows that existing systems such as PaddyMitra already have a potential to reach more than one million farmers. Targeted nutrient management advice derived from the platform demonstrates a 36% reduction in nitrogen pollution. Regional modeling indicates potential increases of 2.22 million tonnes in sustainable rice production through AI-guided irrigation strategies. Field trials report yield gains of up to 1 tonne per hectare from targeted productivity interventions.

Ethics and governance follow the DynAg framework. Advisory outputs are vetted for local relevance to prevent harmful recommendations. Data collection and model training incorporate gender and socio-economic safeguards, and farmer data is treated as a sovereign asset used only to improve services. Multi-modal delivery ensures accessibility for low-literacy users, and integration with public infrastructure supports equitable access.

The system demonstrates that a living agricultural intelligence framework can connect static databases, real-time needs, and tailored delivery. Challenges include integrating dynamic AI with legacy infrastructure and maintaining human validation workflows at national scale. Lessons confirm that AI advisory systems require continuous ground-truth data and strong scientific anchoring to build trust and sustain adoption.

The initiative provides a scalable blueprint for national digital extension. By transforming passive repositories into self-learning advisory ecosystems delivered through human-assisted AI, it moves agricultural advisory beyond generic broadcasts toward context-sensitive precision intelligence.

Case Study 11

Advisory - Digital Public Infrastructure

fieldWISE: Transforming Indian Agriculture Through Digital Public Infrastructure

Author: Nikhilesh Kumar Organisation: fieldWISE Location: Telangana, India

Indian agriculture faces interconnected structural challenges: fragmented farm data scattered across multiple systems, climate volatility increasing weather-related crop losses, pest and disease outbreaks spreading unchecked due to delayed information, market access barriers isolating farmers from buyers, and persistent gaps in government scheme utilisation. While state governments possess valuable agricultural information — soil health, weather patterns, irrigation data, and crop performance — this intelligence remains siloed and disconnected from real-time field conditions. Smallholder farmers, representing over 86% of India's agricultural population, lack timely, actionable intelligence to optimise crop selection, sowing timing, and input allocation. Government agencies struggle to monitor agricultural performance across diverse landscapes, implement schemes with precision, or respond to agricultural crises with adequate warning.

fieldWISE functions as digital public infrastructure that integrates diverse data sources, including satellite imagery, weather stations, soil testing laboratories, IoT field sensors, and government registries, and distills aggregated intelligence into field-level, user-specific recommendations. Advanced modules support climate-smart crop planning and input optimisation, real-time field monitoring and validation, AI-powered advisory services, crop health and water stress alerts, pest and disease forecasting, soil nutrition mapping, yield prediction, and seamless market linkage. The architecture operates on open standards with RESTful APIs, enabling integration with central government systems such as PM-KISAN, Farmer ID registry, and e-KYC, as well as state platforms including e-Panta, d-Krishi, and InSight. This openness ensures the platform acts as scalable infrastructure upon which future innovation can be built.

In Andhra Pradesh, fieldWISE powers APAIMS 2.0, one of India's most comprehensive agricultural digitisation initiatives. Designed to eliminate offline agricultural operations beginning Kharif 2025, APAIMS consolidates seed distribution, pest alerts, agro-advisories, input supply chain management, e-marketplace access, and direct benefit transfer workflows into a unified system. The deployment emphasises modularity, allowing officials to extend features without custom development while ensuring zero-discretionary operations and consistent governance across mandals and districts.

In Kerala, fieldWISE underpins the Kerala Agriculture Technology Hub and Information Repository (KATHIR), operated with the Department of Agriculture and Farmers Welfare. Accessibility is prioritised through multi-language support in more than 11 languages, voice-based navigation, and image-based crop mapping that eliminates literacy requirements. WhatsApp-based advisory delivery extends reach through widely used communication channels.

12 million

farmers served through state-scale agricultural digital infrastructure

Case Study 11

The platform demonstrates large-scale operational impact: 12 million farmers across six states, 3 million farms digitised with geo-tagged boundaries, 12,000 villages integrated into agroclimatic crop planning, and 35 major irrigation projects monitored in real time. APAIMS deployments (2017–2019) covered 800,000 hectares with targeted pest advisories, optimised crop planning for 10 million farms, enabled early drought declarations across 274 mandals, and reduced fertiliser consumption by 7.5% across 18,000 villages without yield loss. KATHIR implementation includes 1.1 million registered farmers, 0.15 million application downloads, 0.16 million digitised farm boundaries, 1.1 million hectares classified, 0.7 million plots monitored daily, and 35 operational soil testing laboratories.

The ecosystem serves multiple stakeholders. Farmers receive scheme enrolment guidance, weather alerts, real-time water stress notifications, pest forecasts, crop-specific sowing advisories based on 11 years of weather analysis, soil health card-based fertiliser recommendations, crop loss reporting, insurance services, mechanisation access, and market linkage. Government officials monitor statewide crop coverage, track scheme implementation with audit transparency, and coordinate disaster responses.

Financial institutions and insurers use verified crop intelligence for underwriting and claims assessment. Agricultural businesses access field-level demand signals for targeted service delivery.

fieldWISE applies privacy-by-design governance. Farmers provide explicit digital consent through a Consent Manager framework with transparent revocation mechanisms. All personal and agricultural data is hosted within state data centers to preserve sovereignty and regulatory compliance. Open API architecture enables independent audits and third-party verification of algorithmic fairness. Accessibility safeguards include voice-enabled advisories, vernacular language support, WhatsApp delivery, and zero-literacy mobile design, ensuring inclusion of women and smallholder farmers. Precision input recommendations promote economically sustainable agriculture, while water stress monitoring and drought forecasting strengthen climate resilience.

Case Study 12

AI-Powered Cow Necklace Sensors Deployment in Kashmir Valley

Author: Chandrasekar Vuppalapat
Organisation: Hanumayamma Innovations and Technologies, Inc.
Location: California, USA

Agriculture and livestock systems worldwide are under increasing strain due to climate change, environmental volatility, rising input costs, and growing food demand. Dairy farming, which sustains the livelihoods of millions of small and marginal farmers, is especially vulnerable to delayed disease detection, heat and cold stress, and productivity losses. This deployment documents the use of AI-powered Cow Necklace Sensors in the Kashmir Valley, demonstrating how artificial intelligence and IoT can transform livestock health monitoring, climate resilience, and food security outcomes.

Kashmir Valley occupies a unique position in India's agricultural future. With fertile land, abundant water resources, and the presence of all four seasons, the region is increasingly viewed as a future food basket capable of supporting India's population of over 1.4 billion. At the same time, the valley experiences extreme environmental variability, including high altitude, harsh winters, sudden temperature changes, and sharp humidity fluctuations. These conditions place continuous physiological stress on cattle and make traditional manual monitoring insufficient. The deployment was intentionally designed as both a regional solution and a global reference model. Climatic patterns observed in Kashmir resemble stress scenarios emerging in temperate and semi-cold regions across Europe, North America, and Central Asia, making the insights globally transferable.

Hanumayamma deployed veterinary-grade wearable Cow Necklace Sensors capable of continuous, non-invasive monitoring. Each device captures high-frequency telemetry, including body contact temperature, activity levels, rumination behaviour, and environmental exposure such as humidity. Sensors are ruggedised to operate reliably in difficult terrain and extreme weather, with long battery life to support uninterrupted data collection. Telemetry streams into an AI-enabled analytics platform where machine learning models process the signals in near real time. The system converts raw biological data into actionable intelligence, delivering alerts and insights to farmers, veterinarians, and institutions without overwhelming users with raw data.

Early AI alerts detect livestock stress before visible symptoms

A primary objective was early health and stress detection. In conventional dairy systems, illness is often recognised only after visible symptoms appear, by which point productivity losses are already significant. The AI models establish individualised baselines for each animal and detect subtle deviations from normal behaviour. Sudden increases in contact temperature or abnormal drops in rumination can indicate infection or digestive stress days before visible symptoms.

Case Study 12

By combining physiological data with environmental indicators, the system calculates heat index–based stress models. Moderate to severe heat stress windows were detected even in a traditionally cold region, highlighting hidden climate impacts on livestock. Early warnings enabled proactive feed adjustments, hydration management, shelter modification, and timely veterinary care, reducing suffering and preventing productivity losses.

One of the most significant outcomes is validation of AI livestock monitoring in extreme Himalayan conditions. Sensors maintained stable performance through sub-zero winters, humidity fluctuations, and rugged field environments. This operational resilience is critical for scaling AI in agriculture, where systems must function far from controlled environments. Reliable performance in Kashmir demonstrates that similar technologies can operate effectively in other climate-stressed regions worldwide.

The project was conducted in collaboration with regional agricultural and veterinary institutions, supporting structured research integration. Continuous sensor data enabled veterinary research, teaching, and climate adaptation studies. Moving from anecdotal observations to longitudinal datasets strengthened institutional capacity to understand seasonal stress, disease patterns, and climate impacts on livestock. AI thus functions not only as a farm tool but as a strategic research asset.

At the farm level, early health alerts reduced avoidable veterinary costs, minimised mortality risk, and stabilised milk productivity. For smallholders dependent on daily milk income, this translates directly into improved financial resilience. At the ecosystem level, healthier livestock improves loan repayment capacity and reduces credit risk for cooperatives and rural banks. Stabilising livestock productivity strengthens supply chains and rural economies.

Continuous livestock monitoring also creates the foundation for methane-aware livestock analytics. By correlating health, behaviour, and feed efficiency data, AI systems can support more sustainable livestock management practices aligned with climate goals.

Case Study 13

AI-Driven Regional Crop Intelligence for Intelligent Crop Planning and Precision Advisory

Author: Nikhil Toshniwal Organisation: DeHaat Location: Rajasthan, India

Indian agriculture operates under high spatial and temporal variability in climate, soils, and pest pressure. While digital advisory tools have expanded rapidly, most remain limited by generic crop calendars, reactive messaging, and poor integration with real-world conditions. Farmers often receive advice that is not crop-stage specific, not aligned with imminent weather risks, and difficult to operationalise. At the same time, frontline actors — retailers, field officers, and calling teams — lack real-time visibility into regional crop conditions, limiting timely and coordinated interventions. This use case addresses these gaps by institutionalising advisory as a continuous, regionally intelligent service rather than a standalone message or seasonal campaign.

At the core of the system is a guardrailed agronomic intelligence layer that combines artificial intelligence with validated agricultural rule sets to deliver safe, explainable, and context-aware recommendations. Regional intelligence inputs include satellite-derived crop health and stress indicators, hyperlocal and short-term weather forecasts linked to agronomic actions, Soil Health Card data and region-wise nutrient deficiency patterns, and large-scale farmer-sourced pest and disease diagnostics tagged to crop, geography, and time. These inputs are processed by an AI-assisted advisory engine that prioritises risks, detects emerging patterns, and recommends the next best agronomic action at crop-stage and regional levels. AI is deliberately constrained: it does not generate speculative advice but operates within scientifically validated templates and thresholds. This ensures AI functions as an enabler of scale and consistency rather than an autonomous decision-maker.

Advisory intelligence is operationalised through a multichannel delivery model that meets farmers and frontline actors where they already operate. Farmers receive timely advisories via mobile applications such as AgriCentral, messaging platforms, and assisted interactions tailored to crop stage, local weather risk, and regional pest pressure. Retail stores access contextual advisory views to guide input recommendations aligned with prevailing crop conditions. Field teams use mobile tools to view crop health signals and risk alerts before on-ground visits, while calling teams are supported by AI-assisted crop- and stage-aware talking points that improve relevance and trust. Each interaction is logged back into the system, enabling continuous learning and refinement.

The platform operates at national scale. It is deployed across major agricultural regions of India, with more than 10.6 million registered farmers, including over 6.4 million geo-mapped farmers actively interacting with advisory services. The system generates more than 26 million advisory sessions monthly across Crop Care, Crop Plan, Weather/Khetedge View, and mandi price modules. Between 200,000 and 300,000 crop diagnostics are conducted each month. Over the past year, approximately 1.42 million pest and disease detections have been recorded, creating a high-density regional diagnostic layer that supports outbreak and severity analysis.

Case Study 13

Primary users include smallholder farmers across cereals, oilseeds, and horticultural crops, as well as frontline extension workers and agri-retail operators. Programme and operations teams use aggregated regional intelligence for planning and coordination.

Measured impact includes earlier detection of pest and disease outbreaks through aggregated diagnostics, improved timing of irrigation and crop protection actions using weather-linked advisories, and reduced inappropriate or mistimed input application by aligning recommendations with crop stage and regional soil conditions. The system shifts advisory from reactive problem-solving to proactive, preventive decision support. While outcomes vary by crop and region, advisory relevance and timeliness consistently improve.

26 million

advisory sessions generated monthly at national scale

Beyond regional intelligence, the system incorporates a central Farm Maps layer that enables deeper personalisation. Farm Maps serves as DeHaat's unified Farmer 360° digital profile, consolidating advisory, input transactions, output sales, field activities, and livestock services into a longitudinal, consent-based identity. This profile includes landholding and plot-level information, season-wise crop histories, input purchase and usage patterns, transaction and repayment behaviour, and allied activity records. Ethics and governance safeguards include farmer consent frameworks, role-based data access, explainable and auditable AI outputs, and multilingual delivery to ensure accessibility for smallholders and first-time digital users.

The deployment demonstrates that AI advisory delivers public value only when tightly coupled with agronomic science, strong governance, and trusted delivery channels. By shifting from generic messaging to regionally intelligent, crop-stage-aware decision support — and selectively enabling farm-level intelligence — the system provides a scalable blueprint for responsible smart farming in emerging economies.

Parakh: Transforming Post-Harvest Value Chains with AI-Based Grain Quality Assessment and Digital Trade Platforms

Author: Nirja Mehta
Organisation: Upjao Agrotech Private Limited

Location: Gujarat, India

Agricultural trade and procurement systems in India continue to face structural challenges that limit farmer income and reduce trust in formal markets. Farmers often operate within closed trading environments with restricted buyer access, limited competition, and inadequate transparency in price discovery. Farmers are often required to travel long distances to mandis to sell their produce, resulting in significant transportation and opportunity costs. These additional expenses reduce their net earnings and, in many cases, place farmers at a disadvantage against trader cartels that dominate local markets. Quality assessment of grains is largely manual and subjective, leading to inconsistent grading, disputes, and suppressed prices. In government procurement systems, these inefficiencies further impact operational efficiency, traceability, and farmer confidence. There is a pressing need for scalable, technology-driven solutions that bring transparency, objectivity, and fairness to agricultural markets while aligning with public-sector procurement frameworks.

Parakh is an AgriTech platform designed to modernise agricultural trade and procurement by integrating two core innovations. The digital open-market trading platform enables farmers to sell produce to any registered trader at any time through competitive digital bidding. This expands market access, improves price discovery, and reduces dependency on local intermediaries. Upjao's AI-based grain analysers objectively evaluate grain quality using machine-based systems, eliminating manual bias and directly linking quality grades with price outcomes. This incentivises farmers to improve produce quality while ensuring transparency in procurement. Together, these solutions create a farmer-centric, data-driven ecosystem that benefits farmers, traders, and public-sector agencies.

The first pilot focused on enabling open digital trade for commodities such as bajra and paddy through the Parakh platform. Approximately 300–400 farmers were connected, facilitating 300–400 bids and enabling a total trade value of approximately 50 million INR. Competitive digital bidding increased trader participation and improved price transparency. Farmers experienced an average 7% increase in profit realisation, driven by healthy competition and wider buyer access. The platform enabled farmers to trade at their convenience, reduced reliance on local intermediaries, and demonstrated how digital marketplaces can directly enhance farmer incomes at scale.

5–7%

average price improvement for participating farmers

A second pilot deployed AI-powered grain quality assessment machines for paddy procurement in partnership with GUJCOMASOL within a cooperative public-sector framework. Approximately 500 farmers were directly connected, with 32,517 gunny bags procured, totaling 22,76,917 kilograms (2,277 metric tonnes, approximately) and procurement value of approximately 100 million INR. Objective, machine-based grading enabled A-grade paddy farmers to receive a 5% price premium. The system removed subjectivity from quality assessment, improved transparency, and strengthened trust between farmers and procurement agencies.

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For the public sector, the pilot demonstrated a reliable and auditable method for quality-linked procurement, reducing disputes and improving operational efficiency.

Beyond pilot deployments, Parakh supported government paddy procurement under State Civil Supplies operations, benefiting approximately 3,300 additional farmers.

Objective quality assessment improved acceptance confidence, reduced grading-related grievances, and enabled faster, more transparent procurement processes at scale. This deployment highlighted the platform's ability to operate within government procurement environments while maintaining transparency, fairness, and scalability.

Across all pilots and procurement-linked deployments, approximately 4,100–4,200 farmers benefited, with total trade and procurement value of approximately 150 million INR and average farmer price improvements of 5–7%. Commodities covered include paddy and bajra, with 100% machine-based quality evaluation in deployed use cases. The platform demonstrates a modular, commodity-agnostic model that can scale across APMCs, PACS, FPOs, cooperatives, and state procurement agencies, while aligning with national priorities around digital agriculture and transparent procurement.

Adaptive AI-Based Grading and Sorting for Quality Assessment in Horticulture Crops

Authors: Nitin Gupta, Vinay Kumar Reddy Vadde
Organisation: Sickle Innovations Private Limited
Location: Punjab, India

India produces over 100 million tonnes of fruits annually and ranks among the world's top producers. Despite this, nearly 40% of fruit — valued at approximately 26 billion INR — is lost each year due to inefficiencies in harvesting, sorting, grading, and post-harvest handling. Losses during sorting and grading alone account for thousands of crores annually. These challenges are most severe in fruit crops where market prices are highly sensitive to visual quality. Manual grading dominates most packhouses and mandis, making quality assessment subjective, slow, and dependent on skilled labour. Even a single defective fruit during auction can reduce prices for entire consignments, disproportionately affecting farmers. Orchard labour requirements are nearly nine times higher than cereal crops, creating a strong need for a scalable, adaptive, and transparent AI-driven solution.

The solution is an AI-powered computer vision system embedded within indigenous optical grading and sorting machines for high-value fruits including kinnow, orange, apple, and pomegranate. High-speed cameras, controlled illumination, and deep learning models analyse fruits in real time for color, size, shape, and surface defects such as blemishes, pest damage, cracks, and fungal marks. Unlike rule-based methods, the system continuously learns from diverse datasets collected across geographies, seasons, and fruit varieties, enabling accurate detection of region-specific defects and consistent performance under variable conditions.

In addition to grading, the system generates quantitative defect profiles at the lot level, transforming grading from subjective judgment into data-backed quality assessment.

Deployment spans packhouses operated by farmers, FPOs, traders, and procurement companies across multiple Indian states. Implementation focuses on seamless integration into existing workflows, supported by installation, calibration, and operator training. A human-in-the-loop framework allows supervisors to validate outputs and improve model performance through feedback

95% grading accuracy with AI-enabled defect detection

More than 90 AI-powered grading installations are active across India, processing thousands of tonnes annually and handling up to 200,000 kilograms per hour during peak harvest. The organisation has served over 0.3 million farmers through its broader mechanisation portfolio and a 200+ dealer network.

Field results show clear impact. Manual grading typically achieves 60–80% accuracy; AI improves this to over 95%. Processing speed has nearly tripled, labour costs have fallen by 40%, and post-harvest losses have declined up to 20%. Consistent grading reduces auction disputes and improves price realisation. At a system level, the technology reduces food waste and increases transparency across horticulture value chains.

Case Study 15

Ethical governance includes auditable AI decisions, human oversight, bias monitoring, and compliance with data protection norms. The system processes no personal data. Designed for smallholder contexts, the technology lowers adoption barriers and extends advanced grading infrastructure closer to the farmgate.

The deployment shows that AI delivers real value when embedded in practical hardware aligned with farmer economics. Early challenges around trust and dataset diversity were addressed through transparency, visible financial gains, and continuous user engagement.

Case Study 16

Traceability

AI-Enabled Traceability and Climate Governance for Deforestation-Free Agriculture and Carbon Markets in the Global South

Author: Lin Kennard
Organisation: TRST01 Global Ventures Pte Ltd
Location: Singapore

Across Southeast Asia, fragmented smallholder supply chains face growing pressure from global buyers and regulatory frameworks that demand traceability, deforestation monitoring, and verified sustainability compliance. Traditional paper-based documentation systems cannot reliably track origin, land use, or environmental risk at scale, creating barriers to market access for farmers and exporters. As international regulations tighten and environmental scrutiny increases, agricultural supply chains require digital infrastructure capable of integrating geospatial intelligence, farmer registries, and automated compliance workflows.

TRST01 deployed an adaptable AI-powered traceability platform across Indonesia, Malaysia, Thailand, Vietnam, and Laos for rubber and coffee supply chains. Discriminative AI models screen for deforestation, analyse land use, and validate yield plausibility using satellite imagery and geospatial data. Integrated cross-border compliance tools align local production data with evolving EU regulations and global buyer requirements. Generative AI automates compliance documentation, buyer disclosures, and localised farmer communications, reducing manual reporting workloads and improving data reliability.

Deployment followed country-specific strategies, integrating government datasets where available and working directly with exporters, processors, and cooperatives. Farmer onboarding combined mobile self-registration with assisted mapping and GPS boundary capture to enable accurate land digitisation. Adoption accelerated in response to export compliance timelines, buyer mandates, and measurable reductions in audit and verification costs.

250,000+

hectares digitally mapped across global supply chains

The platform currently covers more than 250,000 hectares and engages over 150,000 farmers across Southeast Asia. Large cooperatives, exporter networks, and farmer groups actively use the system, demonstrating scalability across diverse production environments. The TRST01Chain ecosystem establishes digital farmer registries and AI-driven land mapping across fragmented smallholder systems and estate operations, creating supply chain visibility and regulatory readiness.

In Côte d'Ivoire, TRST01 implemented a customised AI-driven platform for rubber traceability and deforestation risk management. Satellite-based AI differentiates forest and plantation land, identifies encroachment risks, and establishes deforestation baselines aligned with EUDR requirements. AI-based aggregation maintains a lot of integrity through informal procurement channels, while generative AI automates exporter reporting. The system operates across 84,000 hectares in partnership with more than 35 cooperatives, benefiting over 60,000 smallholder rubber farmers and strengthening compliance across the sector.

Case Study 16

TRST01 is also deploying sovereign digital climate infrastructure in Africa. In the Democratic Republic of the Congo, an AI-powered national registry is being established for forest governance and carbon market transparency. Discriminative AI enables forest classification and deforestation detection, while blockchain-based registries track carbon assets in alignment with Article 6 of the Paris Agreement. In Malawi, the Paris Agreement Integrated Platform is under active deployment to digitise national emissions data, apply AI-based validation, and support automated climate reporting aligned with UNFCCC standards. These national systems are designed to enable regulatory oversight, carbon finance readiness, and sovereign data governance.

Together, these deployments demonstrate how AI-driven traceability, geospatial intelligence, and automated compliance systems can operate across smallholder agriculture, estate production, and national climate governance. The platform unites farmers, cooperatives, exporters, regulators, and buyers in interoperable digital ecosystems that support responsible sourcing, ESG alignment, and future integration with carbon markets.

AI-SafeMarketMap: AI-Powered Farm-to-Fork Traceability and Food Safety Mapping System for Informal Markets in Africa

Authors: Kyanda Charles, Irene Gimbo
Organisation: AI-SafeMarketMap Initiative

Location: Uganda, Africa

Informal food markets supply more than 80% of fresh produce consumed in sub-Saharan Africa, yet they operate with minimal food safety monitoring, traceability, or consumer awareness mechanisms. In Uganda and across Africa, fruits and vegetables rejected from export markets due to excessive pesticide residues or poor post-harvest handling are frequently diverted into informal domestic markets instead of being destroyed. This exposes millions of consumers to chronic chemical ingestion, contributing to rising foodborne illnesses and long-term non-communicable diseases. Regulatory agencies face capacity constraints and limited real-time visibility across fragmented value chains. Farmers and cooperatives investing in good agricultural practices lack tools to differentiate their produce and receive fair price premiums.
AI-SafeMarketMap addresses this gap by introducing AI-driven traceability, risk intelligence, and market transparency that closes knowledge gaps in informal food systems.

AI-SafeMarketMap is an AI-powered digital application that maps market centers, traces produce from monitored farmer groups and cooperatives, and certifies market points using a Health-Conscious Food Index (HCFI). The platform applies geospatial AI and computer vision to identify market stalls, machine learning models to assess food safety risk, and QR-based batch traceability linked to cooperative aggregation points and cold storage systems.

Models are trained on field-verified hygiene inspections, handling records, cold-room logs, and laboratory-validated Maximum Residue Limit data aligned with Codex Alimentarius standards. Natural language processing analyses consumer and vendor feedback to detect emerging risks, generating real-time AI risk maps for regulators and consumers.

Deployment follows a phased, low-resource strategy that leverages existing farmer cooperatives and youth-led block farming structures. Trained youth market safety agents conduct participatory mapping and hygiene data collection using offline-first mobile tools. Safe market points are onboarded through incentives such as digital safety badges, increased visibility, and consumer trust rather than punitive enforcement. Adoption is reinforced through radio programs, television campaigns, SMS alerts, and social media outreach that encourage demand for safe food and promote application use for market verification.

30%

reduction in circulation of high-risk produce

Case Study 17

The solution has been piloted in Eastern Uganda, engaging more than 600 smallholder farmers organised in cooperatives and youth groups, covering over 120 informal markets and serving approximately 15,000 consumers weekly across three urban and peri-urban districts. National recognition through the Coop360 Innovation Award validates scalability within Uganda's cooperative ecosystem.

Primary users include organised smallholder farmers, youth groups, cooperatives, informal market vendors, and trained market safety agents. Secondary beneficiaries include consumers, local governments, food safety regulators, exporters, and development partners seeking data-driven oversight of informal food systems.

Early pilots indicate measurable outcomes: a projected 30% reduction in circulation of high-risk produce, a 20% increase in vendor income through improved consumer trust, a 15–25% reduction in post-harvest losses through cold-chain utilisation, and creation of digital employment opportunities for youth as market mappers and safety agents.

Ethical governance emphasises informed consent, anonymised data handling, role-based access control, and human-in-the-loop validation. Models are audited quarterly for bias and drift, with regional variance capped below 5%. Inclusion safeguards ensure multilingual interfaces, offline functionality, and onboarding strategies that prioritise women and youth.

The initiative demonstrates that AI can transform informal agricultural markets into safer and more transparent systems. By combining traceability, geospatial intelligence, and public awareness, the platform protects consumer health, rewards responsible farmers, and strengthens cooperative food systems at scale.

Case Study 18

Ag FinTech

SatSource: Farm-Level Intelligence Powering Scalable Agricultural Credit in India

Authors: Rahul Dhayal, Prateep Basu
Organisation: SatSure Analytics India Private Limited
Location: Delhi, India

Agricultural finance in India faces a persistent structural challenge. While agriculture supports a large share of livelihoods and national food security, formal credit systems struggle to serve small and marginal farmers consistently. This is not due to lack of demand or policy support, but to information asymmetry. Banks are required to make lending decisions with limited, fragmented inputs: self-declared crop information, inconsistent land records, and manual field verification. These methods are slow, costly, and increasingly unreliable in a climate-volatile environment. As a result, lenders face long turnaround times for Kisan Credit Card loans, low approval rates for new-to-credit farmers, and portfolio stress during adverse seasons. The system is reactive by design. The core problem is simple: banks cannot see the farm at scale.

SatSource was built to make farms visible, measurable, and comparable at population scale. At its core, SatSource converts satellite imagery, climate signals, and agronomic patterns into a standardised Farm Score and Farm Report that can be directly used in lending decisions. Each farm is assessed consistently across geographies using the same logic, enabling lenders to scale without scaling manual operations. A typical SatSource Farm Report includes verified farm boundaries and land use, cropping history across the last six seasons, crop identification and performance assessment, cropping intensity and irrigation condition, rainfall and groundwater stress indicators, regional agricultural potential benchmarking, and a consolidated, interpretable risk view for lending. Importantly, the output is not a black-box score.

Each Farm Score is accompanied by a transparent breakdown of contributing factors, allowing credit officers, risk teams, and regulators to understand why a farm is scored the way it is.

SatSource is deployed as an execution-first intelligence layer rather than a standalone analytics tool. Banks integrate SatSource via APIs into their existing lending workflows. During loan origination or renewal, the Farm Score and Farm Report are automatically pulled into the credit assessment process. Credit officers no longer rely solely on declarations or field visits; they make decisions with a verified view of farm behaviour over time. This design enables three critical shifts: from collateral-driven to productivity-driven lending, from manual verification to automated assessment, and from reactive risk management to proactive monitoring. As a result, lending decisions become faster, more consistent, and more defensible.

Loan processing time reduced from weeks to less than one day

SatSource is currently operational across more than eight states, covering over 230 districts and 0.228 million villages. To date, 0.63 million farm plots have been analysed, 0.42 million hectares assessed, and more than 60,000 farmer accounts evaluated, with the majority of coverage among small and marginal farmers cultivating less than two hectares. Across partner banks and financial institutions, SatSource has delivered measurable outcomes.

Case Study 18

Loan processing time has reduced from weeks to less than one day. Approval rates increased by up to 50%, particularly for new-to-credit farmers. Field verification costs dropped by up to 80%, and portfolio quality improved through early identification of stress before default events. These gains allow banks to expand outreach without increasing operational risk.

Climate risk is embedded directly into credit decisions through continuous monitoring of crop health, rainfall deviation, and water stress. Lenders can detect early signs of climate-induced stress, adjust exposure strategies proactively, design climate-aligned lending products, and reduce shock-driven defaults during adverse seasons. By integrating climate intelligence at the farm level, SatSource shifts agricultural finance from a reactive model to one that is climate-responsive by design.

SatSource is built as a Digital Public Infrastructure-aligned service. Its integration with the Unified Lending Interface allows farm intelligence to be accessed through a standardised national rail, reducing onboarding friction and enabling interoperability across institutions. The platform functions as a shared intelligence layer for agricultural finance, similar to how digital payment and identity systems transformed financial inclusion in India. Strategic collaborations with development finance and agri-finance partners further support the transition toward affordable, cash-flow-based lending for underserved farmer segments.

SatSource demonstrates how planet-scale intelligence, when embedded into national systems with execution discipline and citizen-first principles, can unlock economic growth while strengthening climate resilience. By turning farms into transparent, auditable data assets, the system enables credit decisions based on capability, resilience, and performance rather than paperwork or proximity. This establishes a foundation for inclusive, climate-smart agricultural finance at scale.

Case Study 19

Ag FinTech – Alternate Credit Scoring

KhetScore: AI-Driven Analytical Tool Unlocking Inclusive Financial Services for Smallholder Farmers

Authors: Tarun Katoch, Pankaj Gaur
Organisation: Dvara E-Registry

Location: Telangana, India

Eighty-six percent of India's 140 million farmers are small and marginal farmers facing rising climate risks, including erratic rainfall, floods, droughts, and temperature stress. Climate vulnerability is compounded by deep financial exclusion: nearly 70% of smallholders lack access to formal credit and insurance because they do not possess conventional credit scores or documentation. National Innovations on Climate Resilient Agriculture (NICRA) has identified 310 climate-vulnerable districts, and recent FEED–DIU findings show that extreme weather events over the past five years affected more than 60% of marginal farmers through crop losses. Despite this, only about 30% of farmers are covered by crop insurance and roughly 25% receive timely institutional credit. The majority depend on informal moneylenders charging 30–120% annual interest, trapping households in low-investment, low-productivity cycles. Women and tenant farmers face even greater exclusion: women contribute over 60% of agricultural labor but receive only 6% of formal credit, while tenant farmers are excluded due to informal land tenure. NABARD reports that 85% of farmers face unclear land title issues, making ownership-based lending ineffective.

Conventional agricultural finance relies on credit histories and land ownership, systematically excluding climate-vulnerable farmers. Insurance systems face similar constraints, offering blanket products at Gram Panchayat level that fail to reflect individual risk profiles and depend on slow, manual claim processes.

This combination of climate exposure, financial exclusion, and low insurance penetration prevents farmers from investing in climate-resilient practices. Breaking this cycle requires data-driven, farmer-centric financial infrastructure where artificial intelligence plays a central role.

KhetScore, developed by Dvara E-Registry (DER), is an AI-driven alternate credit scoring system designed to redefine creditworthiness by shifting the focus from ownership to land use, productivity, cash-flow potential, and climate risk. The system functions as a three-year historical land analytics index built on geospatial intelligence and AI/ML models. It integrates multi-source satellite imagery, weather data, and agronomic patterns to evaluate approximately 200 data points across 11 parameters, including cropping intensity, cultivated area, crop health, soil and crop moisture, vegetation vigor, nutrient status, mechanical damage, and climate factors such as droughts, floods, rainfall, and temperature. The platform uses established remote sensing indices such as NDVI, GNDVI, NDMI, NMDI, and radar-based indicators derived from multispectral and microwave satellite datasets. AI models assign dynamic weightages to generate a farmer-specific KhetScore. While KhetScore captures three years of performance history, KhetScoreNow assesses current season crop health to support real-time risk monitoring.

Case Study 19

1,750 million INR in institutional credit unlocked for **40,000+** smallholder farmers

The system enables multiple financial use cases. As an alternate credit score, it allows banks and NBFCs to lend to farmers lacking conventional credit histories through objective, explainable risk assessments. For insurance, KhetScore supports individual farmer-level risk profiling rather than Gram Panchayat-level generalisation, enabling customised premiums. Combined with picture-based loss assessment, it enables faster and more transparent claim settlement. DER piloted this approach with IFPRI and HDFC ERGO in Odisha and Maharashtra. Through a Business Correspondent model, DER partners with banks and NBFCs including DCB Bank, Shivalik Small Finance Bank, Samunnati, PAHAL, and Agriwise to deliver doorstep digital credit via trained Farmer Solution Officers. This includes onboarding, eKYC, application processing, and loan disbursement, removing systemic barriers.

DER's FPO-anchored and women-centric implementation model supports scale and inclusion. Through partnerships with more than 300 FPOs, over 120,000 farmers have been onboarded onto the Doordrishti digital platform.

To date, DER has disbursed over 1,750 million INR in institutional credit to more than 40,000 smallholder farmers, with 100% of loans including women as primary or co-borrowers. Forty percent of beneficiaries were first-time borrowers, and 35% of loans listed women as primary borrowers. Eighty-two of 200 insured farmers using KhetScore and picture-based assessment received 3.5 million INR in crop loss coverage, mitigating climate risk. Credit access enabled investment in climate-smart practices, while DER facilitated affordable inputs through FPO networks.

An IFPRI impact study in Odisha covering 1,700 farmers found that KhetScore significantly expanded access to credit by removing paperwork and ownership barriers. Farmers recorded an average 110 USD increase in income per acre, a 120 USD increase in profitability per acre, and a 30% increase in women's participation in household financial decisions. KhetScore demonstrates how AI grounded in agronomic science can unlock climate finance at scale. By converting land and climate data into actionable financial intelligence, the platform enables inclusive credit, insurance, and climate-resilient agriculture, offering a replicable model for transforming smallholder financial systems.

GEO AI-Based dMRV for Verifying AWD Practice in Rice Farms in Carbon Offset Projects

Authors: Jagriti Dabas, Sidharrth Kumar Singh
Organisation: ARMS 4 AI
Location: Delhi, India

Agriculture contributes significantly to global greenhouse gas (GHG) emissions, with flooded rice cultivation being a major source of methane emissions. Climate mitigation programmes increasingly promote sustainable practices such as Alternate Wetting and Drying (AWD) to reduce water use and methane emissions while maintaining crop productivity. However, large-scale adoption of AWD-based carbon projects is constrained by the lack of reliable, timely, and scalable monitoring, reporting, and verification (MRV) mechanisms. Conventional MRV approaches rely heavily on field surveys, manual reporting, and infrequent measurements, resulting in high costs, long verification timelines, limited spatial coverage, and challenges in transparency and trust. These limitations restrict participation by smallholders, slow carbon credit issuance, and reduce confidence among project developers, auditors, and buyers. There is a critical need for a digital, off-field MRV system that can generate accurate, daily, farm-level evidence of sustainable practices at scale.

ARMS 4 AI has developed a Geo-AI–enabled Digital MRV (dMRV) platform that automates monitoring and verification of carbon initiatives using satellite-based Earth Observation (EO) data and artificial intelligence. The solution leverages multi-sensor satellite datasets, including Sentinel-2 (optical), Sentinel-3 SLSTR and OLCI (thermal and optical), Landsat-8, and weather model data, toderive daily farm-level indicators at 10m resolution. Proprietary smart downscaling and multi-sensor fusion techniques are applied to overcome the coarse spatial resolution of daily thermal data, while machine learning models validate and enhance accuracy.

The platform generates pixel-level insights on soil moisture, flooding patterns, AWD compliance, crop yield, sowing and harvest dates, and pixel-wise methane estimation. These outputs directly support carbon credit auditing, reporting, and verification without requiring physical field inspections.

The platform is deployed as a cloud-based Software-as-a-Service (SaaS) solution. Onboarding involves digitisation of farm boundaries, integration of satellite data pipelines, and configuration of project-specific parameters. Project partners do not require specialised hardware or field sensors. Field-level adoption is supported through partnerships with agribusinesses, project developers, and institutional stakeholders who act as intermediaries for farmer engagement. Automated reporting outputs, including farm-wise and project-level dashboards and downloadable reports, are delivered to stakeholders for decision-making, compliance, and verification.

The solution has been operationally scaled from pilot deployments covering approximately 200 hectares to large-scale implementations exceeding 40,000 hectares of rice farms. It supports daily monitoring across thousands of individual plots, including farms as small as one acre. The platform processes more than 36 satellite-derived layers and over 25 agro-ecosystem parameters per monitoring cycle, demonstrating readiness for large, multi-district deployments.

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Measured impacts include a reduction in MRV timelines from several months or years to minutes, enabling faster verification and credit issuance. The system provides daily, plot-level evidence of AWD adoption and soil moisture dynamics, improving trust and compliance. Proven accuracy ($R^2 > 0.9$) has been validated against ground observations. By enabling precise verification of sustainable practices, the platform supports methane reduction, water conservation, and improved eligibility for carbon incentives, contributing to farmer income stabilisation and climate mitigation goals.

The platform follows a satellite-only, off-field data approach, minimising intrusion and eliminating bias from selective field sampling. Data privacy is ensured through secure cloud infrastructure and controlled access. AI models are validated using ground truth data and continuously monitored for performance consistency. The system emphasises transparency by providing traceable, auditable outputs suitable for third-party verification.

The use case is highly relevant for smallholder farmers and low-resource settings, as it requires no on-field sensors or digital literacy at the farm level.

The approach reduces entry barriers for participation in carbon markets. Aggregation through cooperatives, FPOs, and project developers supports inclusion of marginal farmers and enables gender-neutral participation through institutional interfaces.

MRV timelines reduced from months to minutes

The primary success of the project lies in demonstrating that fully digital, satellite-based MRV can achieve both high accuracy and large-scale deployment. The ability to deliver daily, 10m insights from multi-scale data represents a significant technical advancement. Challenges include dependency on satellite data availability under persistent cloud cover and the need for continuous stakeholder capacity building to interpret digital MRV outputs.

Key lessons include the importance of multi-sensor fusion for operational reliability, the value of automation in reducing MRV costs, and the necessity of institutional partnerships for farmer onboarding and trust-building. Validation with ground data remains critical for acceptance by auditors and buyers.

Case Study 21

Carbon MRV – Soil & Biomass

Varaha: Scaling High-Integrity Nature-Based Carbon Removals through AI-Driven Verification

Author: Vishal Kuchanur Organisation: Varaha Location: Maharashtra, India

Agriculture is both a major source of global emissions and one of the most effective pathways for carbon sequestration. Smallholder farmers in the Global South often lack the technical capacity to prove their environmental impact to international registries such as Verra or Puro.earth. Traditional verification systems are manual, slow, expensive, and vulnerable to fraud. Varaha addresses this gap by building a scalable digital infrastructure that converts soil health and biomass improvements into verified carbon assets.

The platform operates through a three-pillar framework: data collection, data validation, and carbon quantification. Artificial intelligence is embedded across the entire lifecycle. During pre-feasibility screening, remote sensing models scan thousands of hectares to identify disqualifying conditions such as recent deforestation or protected land status before onboarding begins. In the field, surveyors use the Varaha mobile app to submit geo-tagged photos and videos of agricultural activities. AI models immediately verify image integrity through blur detection and tamper checks while computer vision systems validate content, such as counting saplings or estimating biochar pile volume. Long-term monitoring uses time-series satellite imagery to track crop phenology and tree growth, ensuring permanence — a critical requirement for carbon credit certification.

Deployment follows a structured "Golden Path" workflow. Varaha partners with local organisations that manage trained surveyors responsible for mapping precise GPS polygons of each participating farm. These field boundaries are cross-verified by remote sensing teams to prevent encroachment into restricted zones and to maintain registry-grade spatial accuracy. The workflow ensures standardised onboarding, consistent data capture, and audit-ready evidence trails.

The system has demonstrated strong validation performance across multiple geospatial tasks. Varaha's models achieve approximately 95% accuracy in building detection, 90% accuracy in waterbody detection, and 86% accuracy in tree detection across heterogeneous landscapes. These high-integrity validations enable the creation of science-backed carbon credits that command higher market value. Verified asset counts are directly linked to farmer payouts, ensuring financial returns are based on measurable environmental performance.

95%

AI accuracy in geospatial carbon asset verification

By digitising carbon verification at farm scale, Varaha enables smallholders to participate in global carbon markets without bearing the cost or complexity of manual certification. The infrastructure transforms environmental stewardship into a verifiable economic asset, aligning climate goals with farmer income. The platform demonstrates how AI-driven monitoring, validation, and quantification can unlock climate finance for underserved agricultural communities while maintaining global registry standards.

Case Study 22

AI Pest Intelligence

AI Smart Pheromone Trap for Area-Wide Pink Bollworm Management

Authors: K Rameash, V N Wagmare, A H Prakash, Y G Prasad, R Raja, Rishi Kumar, J P Singh, Rabi N. Sahoo, Anil Rai, A. Bandyopadhyay

Organisations:	Location
ICAR–Central Institute for Cotton Research	Nagpur, India
Directorate of Plant Protection, Quarantine & Storage	New Delhi, India
ICAR–Indian Agricultural Research Institute	New Delhi, India
Indian Council of Agricultural Research	New Delhi, India

Pink bollworm (PBW), *Pectinophora gossypiella*, has emerged as a pest of national significance in India, severely threatening cotton production due to resistance development against Bt cotton hybrids. National cotton output declined from 36 million bales in 2019–20 to 29.7 million bales in 2024–25, destabilising farm incomes and the cotton value chain. The pest's cryptic lifecycle makes early detection difficult, and conventional pheromone trap monitoring relies on manual observation, which is labour-intensive, delayed, and prone to error. These limitations reduce the ability to respond within the narrow control window required for effective PBW management.

The AI Smart Pheromone Trap, developed under the ICAR-Network Program on Precision Agriculture (NePPA), replaces manual pest scouting with automated, real-time monitoring using computer vision, IoT sensors, and cloud-based analytics. The system captures trapped images and environmental parameters and transmits them hourly through GSM networks, and processes them using machine learning to detect and count PBW moths. When trap catches exceed the economic threshold level, automated voice advisories are issued in local languages, enabling immediate farmer response.

The trap hardware consists of a solar-powered single-board computer, camera module, weather sensor, GSM transmitter, and rechargeable battery. Images and weather data are uploaded to a remote server where a YOLO v8 machine learning model identifies PBW adults with 96.2% detection accuracy.

A dedicated web portal provides real-time trap images, insect counts, and weather parameters across multiple locations. Mobile voice alerts deliver localised pest warnings and management recommendations directly to farmers, ensuring accessibility even for low-literacy users.

38.6% reduction in pesticide use and 18.5% yield increase during Punjab pilot deployment

The system operates in three integrated stages: field monitoring, AI detection in the cloud, and instant information delivery. Pheromone lures attract PBW moths onto sticky liners, cameras capture high-resolution images, and weather sensors record temperature, humidity, pressure, and altitude. AI algorithms analyse images, generate counts, and synchronise area-wide pest intelligence. Processed data is distributed through Android, Windows, and web dashboards, enabling coordinated pest surveillance across districts.

Pilot deployment in Punjab during 2024–25 across Mansa, Bathinda, and Sri Muktsar Sahib districts demonstrated strong impact. Over 0.4 million Punjabi voice alerts were sent to 28,190 cotton growers. Compared to conventional pest management, farms using AI Smart Traps achieved a 38.6% reduction in pesticide use, 34.2% lower spray costs, and an 18.5% yield increase while maintaining effective PBW control. Daily alerts and weekly advisories enabled synchronised, area-wide pest management. The programme expanded in 2025–26 to additional districts across Punjab, Rajasthan, and Haryana.

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The system is adaptable to other crops and pests by changing pheromone lures and retraining AI models. It supports multiple communication infrastructures including LTE GSM, LoRaWAN, Wi-Fi, and satellite networks, allowing deployment in remote areas. Solar-powered operation enables off-grid use. The centralised AI architecture supports regional or national scaling, processing data from multiple traps simultaneously without increasing labor requirements.

Proposed stakeholders include cotton farmers, extension agencies, Krishi Vigyan Kendras, ICAR research institutes, and State Agricultural Universities. Researchers can use longitudinal pest data for resistance monitoring and predictive modeling. Extension networks can deliver synchronised advisories based on real-time intelligence.

Commercially, the technology supports subscription-based pest surveillance services, agri-tech platform integration, and public–private partnership models. Its compatibility with digital advisory ecosystems enables scalable commercialisation across crops and geographies. The system reduces chemical dependency while improving operational efficiency and sustainability.

The AI Smart Pheromone Trap demonstrates how IoT-enabled computer vision can transform pest management from reactive spraying to data-driven early warning. By combining automated surveillance, real-time advisory delivery, and area-wide analytics, the system strengthens integrated pest management, improves farmer profitability, and reduces environmental impact.

VASUDHA: Visualise and Assess Soil Using Digital Hyperspectral Analytics

Authors: Rabi N. Sahoo, Rajeev Ranjan, Rejith R.G, Amrita Bhandari, Tarun Kondraju, Somnath Bairiganjan, Mahesh C. Meena, Nayan Ahmad, Nirmal Kumar, G. P. Obi Reddy, Hrittick Biswas, Nishant K Sinha, M. Mohanty, Anil Rai, A. Bandyopadhyay

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ICAR-National Bureau of Soil Survey & Land use Planning	Nagpur
ICAR-Indian Institute of Soil Science	Bhopal
Indian Council of Agricultural Research	New Delhi

Traditional laboratory-based soil testing is time-consuming, costly, and often unable to meet the pace required under the national Soil Health Card Scheme. It also cannot support real-time decision-making for precision nutrient management. VASUDHA (Visualise and Assess Soil Using Digital Hyperspectral Analytics) was developed under ICAR-Network Program on Precision Agriculture (NePPA) to complement conventional wet laboratory analysis through a low-cost, real-time, and sustainable digital alternative.

VASUDHA is an Artificial Intelligence–based soil diagnostics platform that predicts key soil fertility parameters directly from hyperspectral signatures. The system estimates soil pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus, and available potassium using VNIR/SWIR and MIR spectral domains. It supports both real-time acquisition from spectrometers and offline analysis of previously recorded spectral files, enabling flexible laboratory and field-portable workflows.

The predictive AI models were developed using one of the largest hyperspectral soil datasets in India, consisting of more than 17,000 laboratory-analysed soil samples collected across diverse agro-ecological regions. For each sample, laboratory fertility measurements were paired with reflectance and absorbance spectra, enabling the training of machine learning models that establish robust relationships between spectral signatures and soil nutrient properties.

The system incorporates both generic national models and soil-type-specific models tailored to major soil classes such as alluvial, black, red, and mountain soils. This dual modeling framework improves prediction accuracy across heterogeneous landscapes.

VASUDHA operates through a multi-stage spectroscopy and machine learning pipeline. All spectra undergo standardised pre-processing, including calibration, smoothing, noise reduction, normalisation, outlier handling, and resampling to model-specific wavelength grids. Feature extraction transforms processed spectra into latent variables representing information-rich spectral patterns. Machine learning models trained on more than 17,000-sample dataset to generate predictions for soil fertility parameters.

The software provides real-time visualisation of raw and processed spectra, tabular prediction outputs, comparative multi-sample analysis, and exportable results in CSV, PNG, and spectral formats. Predictions are categorised into agronomically relevant nutrient classes (Low, Medium and High), enabling immediate interpretation for fertiliser recommendations without laboratory delay.

Case Study 23

AI and hyperspectral-based soil prediction trained on 17,000+ laboratory soil samples

VASUDHA represents the first indigenous platform integrating hyperspectral VNIR/SWIR and MIR spectral analytics into a unified soil fertility prediction system. It enables in-situ nutrient mapping without chemical reagents, reduces labor and laboratory costs, and provides portable real-time soil diagnostics. The system is fully Python-based, customisable, and compatible with open-source scientific and cost-effective ecosystems. It supports applications in precision agriculture, soil health monitoring, digital soil mapping, and rapid decision support.

Proposed stakeholders include state and national soil testing laboratories, research institutions, Krishi Vigyan Kendras, universities, fertiliser companies, agri-startups, Farmer Producer Organisations, and farmers. As a green digital technology, VASUDHA reduces chemical dependence and operational costs while expanding soil testing capacity.

VASUDHA demonstrates strong commercial potential as a scalable digital soil diagnostics platform. Its architecture supports spectroscopy-based soil testing centers capable of high-throughput processing without chemical reagents.

The system can be integrated into handheld hyperspectral sensors, portable MIR devices, IoT soil monitoring systems, and precision agriculture platforms. Licensing models enable adoption by government and private laboratories. Enterprise deployment supports district-scale soil assessment, long-term monitoring, and spatial nutrient mapping. Educational institutions can use the platform for spectroscopy and soil science training programs. Its digital-first architecture aligns with global growth in precision agriculture, regenerative farming, and carbon monitoring.

VASUDHA provides a fast, scalable, and cost-efficient digital soil diagnostic platform alternative to conventional soil testing. By combining hyperspectral analytics and machine learning within an operational platform, it enables real-time soil fertility diagnostics and supports sustainable nutrient management at scale.

VASUDHA was officially released by the Hon'ble Union Minister of Agriculture & Farmers Welfare and the Director General of ICAR on July 16, 2025.

Case Study 24

The Farm Guardian Rover – Revolutionising Precision Agriculture with AI and Robotics

Author: Bhushan Darekar
Organisation: Agmove Robotics India Pvt. Ltd.
Location: Maharashtra, India

The Farm Guardian Rover is deployed in vineyards and horticulture farms to automate spraying, intercultural operations, and crop management. Using centimeter-level RTK navigation and AI-based perception, the Rover navigates narrow rows autonomously, performs uniform electrostatic spraying, reduces pesticide wastage, and supports multi-utility field tasks. It enables small and mid-scale farmers to increase productivity, reduce costs, improve yield quality, and transition toward sustainable precision agriculture.

The system addresses a persistent operational challenge in horticulture: labour-intensive, inconsistent, and inefficient crop protection practices. Manual spraying often leads to uneven chemical distribution, excess pesticide usage, and exposure risks for farm workers. The Rover replaces repetitive manual operations with consistent, programmable execution. Electrostatic spraying technology ensures uniform droplet coverage and better adhesion to plant surfaces, reducing chemical drift and improving input efficiency.

AI-based perception allows the Rover to operate safely within tight row spacing common in vineyards and high-value horticulture farms. The autonomous navigation stack combines RTK correction with obstacle awareness to maintain stable performance across varied terrain conditions. Multi-utility attachments enable the Rover to perform additional intercultural tasks beyond spraying, increasing equipment utilisation and return on investment for farmers.

Uniform AI-driven spraying reduces pesticide waste and labour dependency

Field deployments demonstrate measurable operational benefits. Farmers report reduced pesticide consumption, improved spray consistency, and lower labour dependency during peak seasons. Uniform application improves crop health and quality, directly contributing to yield stability. Automation also reduces operator exposure to agrochemicals, strengthening occupational safety on farms.

The platform is designed for small and mid-scale farms rather than only large mechanised operations. Compact dimensions, modular attachments, and intuitive control interfaces allow integration into existing horticulture workflows. Training requirements are minimal, and local service support enables reliable adoption in rural environments.

The Farm Guardian Rover demonstrates how robotics and AI can modernise horticulture practices while remaining accessible to non-industrial farmers.

Challenges include initial capital investment barriers and adaptation across diverse crop geometries. Lessons learned highlight the importance of modular design, farmer training, and service ecosystems in ensuring sustainable technology adoption.

Case Study 25

Anti-Counterfeiting

Patented Anti-Counterfeit UID Seal for Secure Agricultural Supply Chains

Author: Prashant Uday Yadav
Organisation: SUN SOLUTION
Location: Maharashtra, India

India's agricultural supply chains face a persistent challenge of counterfeiting, duplication, and identity dilution affecting both high-value produce and critical agricultural inputs. Counterfeit products lead to financial losses for farmers, reduced crop yields, soil degradation, failed insurance claims, and erosion of consumer trust. Despite policy efforts promoting QR-based traceability, most existing systems rely on static identifiers that can be copied or digitally cloned. For GI-tagged produce such as premium fruits, counterfeit labeling deprives genuine farmers of price premiums and damages export credibility. In agricultural inputs, fake products can result in crop failure and long-term agrarian distress. There is a critical need for a system that combines physical tamper prevention with AI-driven intelligence so authentication is enforceable, not merely digital.

The solution introduces an AI-enabled tamper-preventive UID seal that secures agricultural supply chains from farm gate to end consumer. The patented seal is physically split into visible and hidden components. The hidden identifier is revealed only when the seal is broken, making reuse impossible. Authentication is performed using standard mobile phones via image capture or messaging interfaces, ensuring accessibility without specialised hardware. AI models verify image authenticity, detect reuse attempts, flag abnormal scan patterns, and identify geographic inconsistencies. This bridges physical product integrity with digital intelligence.

The system integrates multiple layers of protection. OCR verification confirms seal geometry and printed identifiers before and after opening. Anomaly detection algorithms analyse scan frequency, time, location, and user behaviour to detect suspicious activity. Pattern recognition models generate dynamic risk scores for products and batches, enabling proactive enforcement. Decision dashboards visualise aggregated data for cooperatives and regulators, highlighting counterfeiting hotspots and supply-chain leakages.

Non-replicable UID seals prevent reuse and enable real-time counterfeit detection

Deployment has been piloted with farmer producer organisations and cooperatives in Maharashtra, especially for GI-tagged fruits and controlled pilots for agricultural inputs. UID seals are applied at farm or packhouse level and tracked through distribution channels. Farmers gain protection against identity theft and improved price realisation. Consumers gain simple authenticity verification. Regulators receive data-driven oversight tools that support subsidy validation, insurance verification, and compliance monitoring.

Case Study 25

Early deployments show reduced counterfeit circulation risk, improved traceability compliance, and strengthened trust between farmers and buyers. The system generates early alerts that allow intervention before large-scale damage occurs. The architecture is scalable across crops, agricultural inputs, and domestic and export supply chains. Because authentication relies on low-cost seals and mobile interactions, it remains viable for smallholder farmers. AI models improve continuously as data volume increases.

The solution aligns with national agri-AI objectives by combining physical security with artificial intelligence, protecting farmer livelihoods, enabling data-driven governance, and strengthening transparency across supply chains. By addressing counterfeiting at its root rather than digitising labels alone, the system demonstrates a pragmatic model for AI-enabled agricultural integrity at scale.

Case Study 26

Soil Intelligence – NIR + AI

Neoperk: Portable AI-Driven Soil Testing for National-Scale Fertility Management

Authors: Satyendra Gupta, Obaid Sayed
Organisation: Neoperk Technologies

Location: Maharashtra, India

India requires soil testing at an unprecedented scale, with more than 100 million samples needed annually to support balanced fertilisation and sustainable crop production. The current soil testing ecosystem is constrained by centralised laboratories, wet-chemistry methods, high operational costs, and long turnaround times. With only one soil testing laboratory available for approximately 88,000 farmers, results are often delayed, inconsistent, or inaccessible, leading to low adoption and inefficient fertiliser use.

Neoperk addresses this structural challenge by replacing conventional chemical-based soil testing with a Near-Infrared Spectroscopy (NIRS) and AI/ML-based soil analysis platform that is portable, scalable, and field-deployable. The technology leverages diffuse reflectance spectroscopy in the NIR range, where soil constituents such as organic carbon, minerals, moisture, and nutrient-associated bonds exhibit characteristic absorption features. These spectral signatures encode information about soil chemical properties without requiring chemical reagents or destructive testing.

>90%

classification accuracy for field-scale soil nutrient decisions

In a collaborative validation study with ICAR–NBSS&LUP, Nagpur, Neoperk developed and tested spectral models using 564 soil samples collected across six districts of Maharashtra, representing wide variability in geology, mineralogy, texture, and soil-forming processes. Spectral data were acquired using both an industry-grade Vis–NIR spectroradiometer (ASD FieldSpec Pro FR) and Neoperk's portable NIR device, followed by laboratory wet-chemistry analysis to generate reference values.

Machine learning regression models were developed using a 70:30 calibration–validation split. Model performance was evaluated on independent test samples using standard statistical metrics (R^2 and RMSE) against laboratory measurements. Results demonstrated that Neoperk's device achieves laboratory-comparable accuracy for several key soil parameters. Neoperk's NIR spectra performed at par with the ASD system for available nitrogen, phosphorus, and potassium, and outperformed it for soil organic carbon in both calibration and validation datasets. The validated models confirm that portable NIR spectroscopy, when combined with robust AI/ML pipelines, can reliably estimate soil chemical properties at field scale.

The platform is optimised not only for numerical prediction but also for decision-grade classification critical for agronomic advisory. Soil test values are translated into agronomically relevant nutrient categories (Low, Medium, High) under established fertiliser recommendation frameworks. Across parameters, the system achieves greater than 90% classification accuracy, ensuring fertiliser and crop recommendations remain consistent with laboratory-based advisories even when minor numerical deviations exist.

Case Study 26

This distinction is essential: laboratory tests prioritise precise chemical quantification, while farmers require correct nutrient decisions. Neoperk's AI-driven classification and advisory engine ensures high reliability in fertiliser guidance, reducing over-application, minimising input costs, and preventing long-term soil degradation. The platform integrates soil diagnostics with crop-specific nutrient models, agro-climatic data, and historical soil trends to deliver personalised, location-specific recommendations. Farmers using Neoperk's advisories report 15–20% income improvement driven by optimised fertiliser use, improved yield quality, and reduced wastage.

From a sustainability and scalability perspective, the chemical-free NIRS + AI/ML approach reduces cost per test, eliminates hazardous reagents, and enables continuous soil monitoring at national scale.

The system aligns with India's Soil Health Card objectives while providing a future-ready pathway towards precision agriculture, climate-resilient farming, and data-driven soil health management.

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