Research Advances on

Artificial Intelligence, IoT and Robotics in Indian Agriculture

भाकृअनुप
ICAR

Indian Council of Agricultural Research
New Delhi 110 001

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2026

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शिवराज सिंह चौहान
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सत्यमेव जयते

कृषि एवं किसान कल्याण और ग्रामीण विकास मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
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संदेश

भारत की कृषि आज ऐसे दौर में है जहाँ बढ़ती जनसंख्या की खाद्य-सुरक्षा, जलवायु परिवर्तन, प्राकृतिक संसाधनों की घटती उपलब्धता तथा श्रम की कमी जैसी चुनौतियाँ एक साथ सामने हैं। कृत्रिम बुद्धिमत्ता, मशीन लर्निंग, रोबोटिक्स और इंटरनेट ऑफ थिंग्स जैसे अत्याधुनिक डिजिटल साधन इन चुनौतियों का समाधान प्रदान करते हुए खेती को अधिक उत्पादक, लाभकारी और टिकाऊ बनाने की क्षमता रखते हैं।

मुझे यह जानकर प्रसन्नता हुई कि भारतीय कृषि अनुसंधान परिषद (ICAR) ने "Research Advances on Artificial Intelligence, IoT and Robotics in Indian Agriculture" शीर्षक से यह महत्वपूर्ण प्रकाशन तैयार किया है, जिसमें देश भर के ICAR संस्थानों और सहयोगी संगठनों द्वारा विकसित एआई एवं रोबोटिक्स आधारित नवाचारों को एक साथ प्रस्तुत किया गया है। यह संकलन न केवल शोध-परिणामों का दस्तावेज है, बल्कि तकनीक के व्यावहारिक उपयोग, उद्यमिता विकास और स्टार्ट-अप पारितंत्र के लिए भी मार्गदर्शन प्रदान करता है।

एआई-समर्थित निर्णय-सहायता प्रणालियाँ, स्मार्ट सेंसर, ड्रोन, रोबोटिक यंत्र और डेटा-एनालिटिक्स अब फसल नियोजन से लेकर कटाई-पश्चात प्रबंधन तथा बाजार से जुड़ाव तक, कृषि मूल्य-श्रृंखला के हर चरण को सशक्त बना रहे हैं। इन तकनीकों से छोटे और सीमांत किसानों को उनकी भू-स्थिति, मौसम और बाजार की जानकारी के आधार पर समय पर, स्थान-विशिष्ट सलाह मिल सकेगी, जिससे जोखिम घटेगा और आय में स्थिरता आएगी।

मुझे विश्वास है कि यह प्रकाशन वैज्ञानिकों, शिक्षाविदों, नीति-निर्माताओं, कृषि-उद्यमियों और जागरूक किसानों के लिए एक महत्त्वपूर्ण पथ प्रदर्शक सिद्ध हो सकता है तथा अनुसंधान-सहयोग, निजी-सार्वजनिक साझेदारी और तकनीक के तीव्र प्रसार को नया आयाम देगा। मैं इस संकलन से जुड़े सभी संपादकों, सहभागियों और ICAR परिवार के वैज्ञानिकों को हार्दिक बधाई देता हूँ और आशा करता हूँ कि यहाँ प्रस्तुत प्रौद्योगिकियाँ विकसित भारत @2047 के हमारे राष्ट्रीय संकल्प को साकार करने में महत्वपूर्ण भूमिका निभाएँगी।

(शिवराज सिंह चौहान)

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Minister of State For
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Government of India

संदेश

भारतीय किसान परंपरागत ज्ञान, परिश्रम और प्रकृति के साथ सामंजस्य पर आधारित खेती करते आए हैं। अब इसी खेती को वैज्ञानिक अनुसंधान और डिजिटल तकनीक के साथ जोड़कर नई ऊँचाइयों पर ले जाने का समय आ गया है। कृत्रिम बुद्धिमत्ता, रोबोटिक्स, ड्रोन, सेंसर व नेटवर्क आधारित प्रणालियाँ खेती को अधिक सटीक, श्रम बचत और पर्यावरण अनुकूल बना रही है, जिससे उत्पादकता बढ़ाने के साथ साथ किसानों की आय में स्थायी वृद्धि संभव हो रही है।

"Research Advances on Artificial Intelligence, IoT and Robotics in Indian Agriculture" में संकलित प्रौद्योगिकियाँ इस परिवर्तन यात्रा की स्पष्ट दिशा दिखाती हैं। इन नवाचारों के माध्यम से फसल स्वास्थ्य की वास्तविक समय में निगरानी, जल पोषक प्रबंधन का अनुकूलन, कीटरोग की पूर्व चेतावनी, पशुधन एवं मत्स्य पालन का स्मार्ट प्रबंधन तथा आपूर्ति श्रृंखला की पारदर्शिता जाने अनेक लक्ष्य साधे जा सकते हैं। यह भी उल्लेखनीय है कि इन प्रयासों के साथ साथ सरकार कृषि टेक स्टार्ट अप्श और नवाचार परक उद्यमिता को प्रोत्साहित कर रही है। जिससे ग्रामीण युवाओं के लिए रोज़गार और स्वरोज़गार के नए अवसर निर्मित हो रहे हैं।

मैं आशा करता हूँ कि यह प्रकाशन ICAR के वैज्ञानिक समुदाय, राज्य कृषि विश्वविद्यालयों, निजी क्षेत्र, स्टार्ट अप्श और किसानों के बीच सार्थक संवाद को और गति देगा तथा खेत स्तर पर उपयुक्त, सस्ती और सरल तकनीक अपनाने में सहायक सिद्ध होगा। मैं इस कार्य से जुड़े सभी वज्ञानिकों, संपादकों और सहयोगियों को हार्दिक बधाई देता हूँ और विश्वास व्यक्त करता हूँ कि यह संकलन विज्ञान संचालित, किसान केन्द्रित और तकनीक समर्थ कृषि के हमारे संकल्प को मज़बूती प्रदान करेगा।

(भागीरथ चौधरी)

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FOREWORD

Manifestation of innovations in the area of artificial intelligence (AI), machine learning (ML) and robotics for the growth of Indian agriculture and overall prosperity of farming community is a monumental challenge that needs to be overhauled in immediate future on a war-footing. This will strengthen Indian agriculture and readying it to confront the intertwined challenges of climate variability, natural resource degradation, labour scarcity, and the need to sustainably feed a population projected to exceed 1.6 billion by 2047. Integration of intelligent and autonomous technologies with existing practices and protocols has become indispensable for scaling the productivity, profitability, and environmental sustainability goals.

Indian Council of Agricultural Research (ICAR) through its strategic foresight, coordinated planning, and collaborative innovation is committed to make Indian agricultural practices globally relevant and its produce internationally acceptable. ICAR has accelerated the adoption of data-driven, precision-based, and automation-enabled solutions across the agricultural value chain ranging from, farm mechanization, crop protection, genomic research, natural resource management, crop improvement, aquatic health and veterinary research. These interventions directly support the vast agricultural landscape of nearly 1.6 million km², benefiting over 146 million farm households, which form the backbone of rural livelihoods and national food security.

As India marches ahead towards the attainment of **Viksit Bharat@2047** goals, it is worthwhile to mention that Indian AI in agriculture market is projected to grow at a CAGR of 19.5% and touch US$ 350 million in the coming decade. It is high time for the policy makers and the lawmakers to realise the importance of greater investment in quality digital infrastructure in the rural landscape, ensuring data security, quality, transparency; thus, skilling the people to overcome barriers in the adoption of agrarian digital innovations and its equitable access.

This compendium **"Research Advances on Artificial Intelligence, IoT and Robotics in Indian Agriculture",** documents exhaustively the innovations achieved under ICAR's national research programmes and demonstrates how AI, deep learning robotics, drones, and Internet of Things (IoT) technologies are collectively introducing a of paradigm shift agricultural research towards science-led and data-intensive approaches to mentor the future of Indian agriculture to make is future ready and sturdy enough to realize the goals of **Viksit Bharat @2047.**

I express my sincere appreciation to the Deputy Director Generals of the subject matter divisions, – Agricultural Engineering, Crop Science, Natural Resource Management, Education, Extension, Horticultural Science, Fisheries Science, and Animal Science for their leadership in coordinating, compiling, and validating the contributions presented in this volume. Their guidance in fostering innovation, strengthening inter-institutional collaboration, and aligning research priorities with national development goals has been instrumental in creating this comprehensive document.

I also acknowledge the dedicated efforts of scientists, research scholars, and technical experts across ICAR institutes (listed under all sections) who have tirelessly designed, developed, and validated AI and robotics-based solutions tailored to India's diverse agro-ecological regions. Their work exemplifies ICAR's commitment to leveraging frontier technologies for farmer welfare, rural prosperity, and the strengthening of India's agricultural economy.

(ML Jat)

Secretary, Department of Agricultural Research and Education (DARE),
Ministry of Agriculture & Farmers Welfare,
Government of India &
Director General,
Indian Council of Agricultural Research (ICAR), New Delhi

Dated: 22 April 2026
New Delhi

PREFACE

Indian agriculture is at the cross roads, while on one hand it has to ensure food security for 1.4 billion people, on the other hand 86% of Indian farmers are living of less than a hectare of land. Size challenges are limiting comprehensive mechanization initiatives resulting in consistently lower returns and diminishing productivity. Unpredictable climate, depleted soil quality and water level only add to the woes of Indian farmer. Artificial intelligence (AI) technologies, such as machine learning, computer vision and robotics, offer innovative solution to enhance productivity, predict environmental risks and optimize resource allocations.

Despite all the promise and virtues, the adoption of digital solutions by Indian farmers remains critically low, at a dismal 11%, although it is better than the Asian average of 9%. Some critical issues that plague adoption are, - low perceived usefulness, poor compatibility, low digital literacy, weak peer penetration, unclear return of investment, data and ethics concern. In this context, the Indian Council of Agricultural Research (ICAR) with its network of research Institutes across the eight subject matter divisions has created a repository of more than 100 AI and robotics-oriented technologies suitable for Indian conditions and at par with the needs of Indian farmers.

Research Advances on Artificial Intelligence and Robotics in Indian Agriculture, is a portfolio of technologies across that are a true blend of frontier digital technologies focussed at making Indian agriculture future-proof aligned with the national priorities of Digital India, Atmanirbhar Bharat, and Viksit Bharat @2047. Embodied in this compendium are innovative applications of AI/ML technologies and robotics for, shouldering pre and post-production farm mechanization from conventional machinery toward intelligent, autonomous and data-driven systems that are efficient, safe, and cost effective; relaying conventional crop protection and pest management to a more data driven approach; inculcating adaptive use of bioinformatics softwares and computation techniques for effective genomic research; solutions for spatial and temporal complexity of soil – water - crop interactions; carrying out data-driven crop improvement and agroclimatic assessment for devising strategies to create support network for informed decision-making of farm level; rapid transformation of aquatic health management with the integration of smart technologies; shifting animal health management and veterinary research to intelligent, non-invasive, and data-driven solutions for long-standing challenges of livestock production and management. The basket of technologies reported in this document highlights how intelligent automation, data analytics, and digital decision-support systems are enabling a transition from conventional farming to smart, predictive, and resilient agricultural systems—central to achieving food security, farmer prosperity, and environmental sustainability under the vision of **Viksit Bharat @2047.**

Collectively, these initiatives represent one of the most comprehensive institutional efforts in adopting AI and robotics within the National Agricultural Research System (NARS). Beyond generating scientific knowledge, the outcome of these technological breakthroughs have laid a strong foundation for technology commercialization, public–private partnerships, start-up engagement, and capacity building, thereby contributing to the growth of India's agri-tech innovation ecosystem.

The editors believe that this publication will serve as a valuable reference for scientists, academicians, policymakers, industry stakeholders, and young innovators who wish to pick up the challenge of delivering path breaking digital solution to Indian agriculture. It is envisaged that the scalable, field-validated technologies tailored to India's diverse agro-ecological conditions showcased over here shall inspire further research collaborations and innovations. The initiatives documented herein stand as a testament to commitment of ICAR for advancing science-led, technology-driven agriculture, ensuring that India's farmers are empowered, competitive, and resilient as the nation progresses towards **Viksit Bharat @2047**.

K. P. Singh
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Narendra Singh Chandel
Rabi Narayan Sahoo
Jyoti Choudhary
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Editors

CONTENTS

Chapter 1

Intelligent Systems for Smart Farm Mechanization

Farm mechanization is evolving at a rapid rate from conventional machinery toward intelligent, autonomous, and data-driven systems that are customised efficient, safe, and cost effective. Intelligent systems are an integration of sensors, electronics, artificial intelligence (AI), machine learning (ML), robotics, computer vision, Internet-of-Things (IoT), and unmanned platforms for field operations aimed to reduce labour dependency, and enable precision agriculture across diverse cropping systems and farm sizes.

Precision input application is the core focus of smart mechanization. Image-based and GPS-enabled variable-rate nitrogen and granular fertilizer applicators, sensor-based deep fertilizer placement systems, and high-clearance robots for grid-based nutrient application ensure accurate delivery of inputs based on crop requirement. Advanced planting and transplanting solutions, including robotic precision planters for bold seeds, electronic multi-crop seed metering modules, robotic grippers, plug-type vegetable transplanters, and unmanned four-wheel paddy transplanters, all strive for efficient and uniform planting. Vision-based inter- and intra-row weeders, remote-operated weeders, and variable-swath herbicide applicator robots support site-specific weed management, particularly for small and high-value vegetable farms.

AI-based emergency braking systems, unmanned multi-purpose track-type vehicles, and smart tractors which incorporate safety and efficient features such as automatic draft and slip control. Drone-assisted sprayers and UAV-based multispectral imagery enable rapid crop health assessment and yield prediction, complementing large-scale forecasting models such as FASAL. Controlled environment agriculture can benefit from plant nitrogen monitoring systems, automatic spraying in polyhouses, and AI-enabled abiotic stress detection devices.

Robotics and automation are finding extended use in harvesting and post-harvest operations. There are technologies for robotic harvesters for grape bunches, multi-class detection and path-tracking algorithms for precision apple harvesting and computer vision enabled fruit graders. AI-based grain analyzer software, biosensors for real-time quality monitoring, rapid aflatoxin detection devices, and electronic nose systems for quality traits only exemplify artificial intelligence applications for post-harvest decision-making.

Human-centric AI innovations include smartphone-based fatigue detection systems with EMG and IMU sensors, and IoT-based custom hiring monitoring meters aimed to improve operational safety and machinery utilization. Together, these intelligent mechanization systems across various pre and post production operations represent a transformative pathway toward resilient, efficient, and future-ready agriculture.

1.1 Robotic precision planter for bold seeds

The robotic precision planter is an advanced mechanized system designed for accurate and uniform sowing of bold seeds. It ensures precise seed placement, optimal depth control, and uniform spacing, thereby, improving planting efficiency, crop establishment, and reducing labour dependency in modern agriculture. The robotic precision planter performs optimally at a medium operating speed of 0.8 km/h. The planting speed was recorded as 5.5s per hill, indicating consistent and precise seed placement. The developed planter had a total weight of 460 kg and an approximate manufacturing cost of Rs. 6,00,000/-. Field evaluation of the robotic precision planter was conducted for sowing pea, a bold-seeded crop, under field conditions. The results demonstrated the efficiency, accuracy, and suitability of the robotic precision planter for bold seed sowing operations.

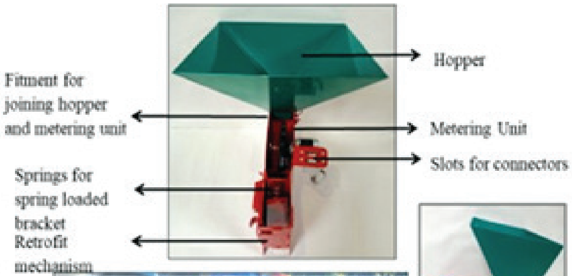
USP : Robotic precision planter delivers bold-seed sowing with accurate placement, depth and spacing, boosting establishment, efficiency and consistency, reducing labour, proven in pea fields at different speed

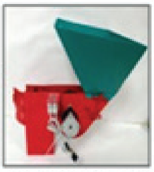
Name of the Inventors: Dr HL Kushwaha, Dr Sudip Misra, Dr JP Sinha, Dr Tapan Kumar Khura, and Dr SC Misra

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.2 Smart multi crop seed metering module

The Pusa - ESMM (Electronic Seed Metering Module) developed at ICAR-Indian Agriculture Research Institute (ICAR-IARI) is designed for precise and uniform seed delivery across a wide range of crops for smart sowing. It uses electronically controlled actuators and sensors to regulate seed rate and spacing, enabling accurate seed placement, reduced seed wastage, and improved planting efficiency under varying field conditions. This module can be retrofitted on cultivators. The cost of one module is approximately Rs. 2,000/-. The system is lightweight, easy to transport, and suitable for multi-crop precision seeding. This technology ensures precise seed placement and seed savings, thereby enhancing farmers' income at an affordable cost.




Joined view of retrofit unit


Split view of the retrofit unit


Assembled ESMM retrofit units on the spring tyne type cultivator


Easy transportation

USP : Pusa-ESMM is a low cost, retrofit electronic seed metering module enabling precise, uniform multi crop sowing with reduced seed wastage, smart control, and improved planting efficiency under variable field conditions

Name of the Inventors: Dr HL Kushwaha, and Dr Adarsh Kumar

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.3 End-effector for plug-type vegetable seedlings

Vegetable seedling transplanting is a time-consuming and laborious process. An end-effector featuring a single jaw-type gripping mechanism has been developed and tested for the extraction of seedlings from nursery pro-trays. This system employs computer-based PLC programming to execute the seedling extraction using a gripper-type end-effector. The gripper removes each seedling separately from the first row of the nursery tray and releases them to the delivery pipe. Then the designed robot propels itself forward using DC motors and a PLC-based directional control unit. The developed system was tested with vegetable seedlings including chili and tomato resulting in a seedling extraction rate of 3 seedlings/min. The results showed that for nursery-grown seedlings, the success rate, leakage rate as well as successful transplanting ranged from 91 to 95 %, 7.6 to 13.9%, and 66.6 to 90.3%, respectively.

USP	:	PLC controlled robotic end effector enables automated extraction and delivery of vegetable seedlings, achieving 3 seedlings/min with 91–95 % success rate, reducing labour cost
Name of the Inventors	:	Dr Abhijit Khadatkar, and Dr AP Pandirwar
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.4 Unmanned four-wheel intelligent paddy transplanter

A multi-functional remote-controlled system has been developed for a four-wheel rice transplanter with affordable electronic control systems to reduce human drudgery, gender-friendliness and easy to use with unskilled person to perform the rice transplanting operation in puddled paddy field. The developed system consists of remote-controlled system to remotely-control the mobility, braking, transplanting function (transplanting tray raising/lowering and planting arm engage/disengage) and emergency stop of the machine with the help of programmed electronic control unit (ECU). An electronic control unit consists of ten channel remote-controller with transmitter module to transmit the signal from the remote to the receiver. The remote-controlled system was easily attachable / detachable to a commercially available ride-on-type rice transplanter it was evaluated in puddled paddy field. The developed system was remotely operated by operator standing out of field at a distance of 200 m. The field capacity, field efficiency and fuel consumption of developed remote-controlled system attachment to ride-on-rice transplanter found as 0.24 ha/h, 71 % and 3.1 L/ha, respectively; at forward speed of 1.61 km/h and slip rate of 12 %.

USP : Remote-controlled attachment for ride-on rice transplanters reduces human drudgery, enables gender friendly operation by unskilled users, and achieves 0.24 ha/h field capacity with 71 % efficiency

Name of the Inventors: Dr Syed Imran S, and Dr T Senthilkumar

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.5 Unmanned multi-purpose track-type vehicle for farm operations

A remote-controlled self-propelled track-type vehicle reports an enhanced efficiency and safety in small-scale farming operations. The system is powered by a 6.9 kW petrol engine and features a hydraulic transmission system, a track-type mechanism, a remote-control interface real time monitoring system and anti-collision system. The signal from remote control unit transmitted to electronic control unit in vehicle for their multiple functions including direction, speed, braking, and equipment operation can be remotely controlled from a safe distance of up to 500 meters. It allows operators to control it from a safe location, features a real-time vision-based monitoring system for long-distance operation and includes an anti-collision unit to prevent accidents. The developed system also features a pivot turning mechanism, allowing it to operate efficiently in minimal headland area requirements. This enhances maneuverability and makes it well-suited for small farms with limited space for turning operations. The multi-row planter achieved a field capacity of 0.16 ha/h with a field efficiency of 74.6%. For the weeding operation, the system demonstrated a field capacity of 0.15 ha/h, a field efficiency of 76.6%, and a weeding efficiency of 90.23%. The unit is gender-friendly and helps reduce human drudgery.

USP : Remote-controlled, track-type vehicle enhances small farm efficiency and safety with 0.15–0.16 ha/h field capacity, real time vision monitoring, anti-collision system, pivot turning, and reduced human drudgery

Name of the Inventors: Dr Syed Imran S, and Dr T Senthilkumar

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.6 Vision based inter and intra-row weeder for small land holdings

The design and development of a vision-based inter and intra-row weeder suitable for small land holdings was undertaken to improve precision weeding and reduce labour dependency. The machine has a field capacity of 0.12 ha/h, making farm friendly operations. It operates with an effective cutting width of 600 mm, ensuring efficient weed removal between and within crop rows. The tentative cost of the developed weeder is approximately Rs. 1.5 lakhs. The operational cost is about Rs. 1,000 per day, making it an economical solution for small and marginal farmers.

USP : Vision based inter and intra-row weeder for small farms enables precise, labor saving weed management with 0.12 ha/h field capacity, 600 mm cutting width, and cost effective operation

Name of the Inventors: Dr Chethan CR

More Information : Director, ICAR-Directorate of Weed Research, Jabalpur - 482010

1.7 Remote operated weeder for wide spaced field crops

Weeding in row crops is one of the most labour-intensive and time-consuming operation mostly done manually in developing nations. The remote-controlled robotic weeder comprises an electronic control unit, a four-wheel drive vehicle, and a weeding unit, other components of the weeder includes DC motors, motor drivers, GPS module, flight controller, receiver, and sweep tynes. It is powered by 24 V, 42 Ah power supply to drive 4 dc motors and also to power the electronic components. Two sweep tynes of 160 mm size was used for weeding and the overall width of cut was 350 mm. The weight of machine is 115 kg and it can withstand a slope of 22 degrees. The field capacity of the machine in raised bed and flatbed is 0.07 ha/h and 0.04 ha/h, respectively. The developed weeder was tested in raised beds and in flatbed field conditions with maize crops having 450 mm of row spacing. The weeding efficiency and plant damage are about 61.6% and 4.2% in raised beds, whereas, the same was 74.9% and 14.6% in flatbed field conditions. The field capacity of the machine in raised bed and flatbed is 0.07 ha/h and 0.04 ha/h, respectively.

USP : Remote-operated robotic weeder efficiently manages wide spaced row crops, achieving up to 75% weeding efficiency with minimal crop damage, reducing labor in maize cultivation

Name of the Inventors: Dr Abhijit Khadatkar, and Dr PB Sujith

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

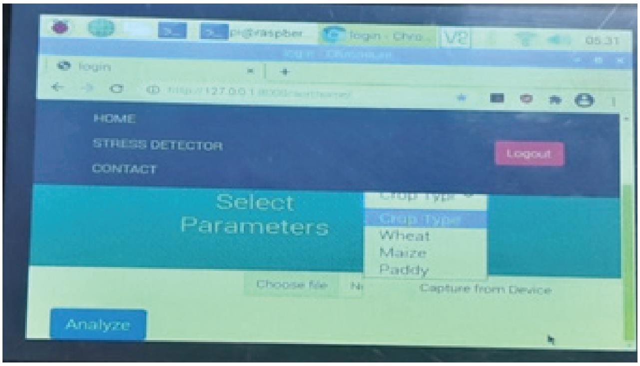
1.8 Variable swath herbicide applicator robot for high-value vegetable crop

The agricultural robot was developed to perform precise weed management by navigating efficiently through inter-row spaces of variable widths while adapting to different crop growth stages. It is capable of adjusting its height to suit crops at various developmental stages, ensuring safe movement without causing mechanical damage. A key feature of the robot is its adjustable frame width, which can be varied from about 1.4 m to 2.6 m. This flexibility allows it to operate in fields with different row spacings and cropping patterns. The robot is equipped with special robotic arms fitted with cameras and spray nozzles. The vision system identifies weeds based on colour, and the targeted spraying mechanism applies herbicides precisely only on detected weeds. This selective spraying significantly reduces chemical usage and minimizes environmental impact. The robot employs a precise spraying control system to ensure accurate and efficient herbicide application. Structurally, the robot has a length of 3.0 m, a height of 2.5 m, and a total weight of 450 kg. It maintains a ground clearance of approximately 1.0 m between its two wheels, enabling it to pass over vegetable crops of varying heights without crop damage. The robot operates using a combination of solar energy and stored battery power, making it energy efficient. It can be remotely operated within a radius of 1.0 km, allowing farmers to control operations from a single location.

USP	:	Solar and battery-powered agricultural robot navigates variable row widths, detects weeds via vision, and applies precise herbicide only on weeds, reducing chemical use and crop damage efficiently
Name of the Inventors	:	Dr Dilip Kumar Kushwaha, Dr Pramod Kumar Sahoo, and Dr GA Rajanna
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.9 AI enabled device for detection of abiotic stress in field crops

The device assembles a Raspberry Pi single board computer and a digital RGB camera. A validated, state-of-the-art, transfer-learning based deep learning model GoogLeNet was deployed on-board to process the captured images and classify them on the basis of stress in real time. The captured images and results are displayed on a custom graphic user interface. The device is also capable of predicting stress in-house from historically collected images fed as inputs to the device. The results are produced in 200 ms post-capture/feeding of the images. The device was field-tested in wheat and maize crops, stress identification accuracies were 92.9 and 97.9%, respectively. The developed device offers a user-friendly mode to identify water stress in real time for the growers for timely decision making on plant health and crop yield improvement. The estimated cost of the developed device is Rs. 16000.



USP : AI enabled device using Raspberry Pi and RGB camera detects abiotic stress in wheat and maize with 93–98% accuracy in 200 ms, supporting real time crop health management

Name of the Inventors: Dr Narendra Singh Chandel, Dr Subir Kumar Chakraborty, Dr YA Rajwade, and Dr Dilip Jat

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.10 Sensor based applicator for deep fertilizer placement

The sensor based deep placement fertilizer applicator can be used as an attachment to four-wheel paddy transplanter. It consists of electronic metering mechanism system, which involves microcontroller, proximity sensor, 10A relay, 12V 2A wiper motors, 12V 1A motor and metering plate with orifice hole. The proximity sensor attached near to the planting unit detects the movement of rotary arm. The power to the electronic control system is provided through the rice transplanters battery. A blower was attached with the fertilizer unit to ensure easy flow of fertilizer at required amount and depth. The performance parameters of rice transplanter with deep placement fertilizer applicator such as fertilizer application efficiency, field capacity and field efficiency are found to be 71%, 0.24 ha/h and 62%, respectively. The tool enables simultaneous fertilizer application during transplanting, ensuring deep placement of urea.

USP	:	Sensor-based deep placement fertilizer applicator attaches to paddy transplanters, enabling simultaneous urea application during transplanting with 71% efficiency, 0.24 ha/h field capacity, and 62% field efficiency
Name of the Inventors	:	Dr Syed Imran S, and Dr Satya Prakash Kumar
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.11 Automatic dispensing system for smart poultry feeding

Poultry rearing in a deep litter system is one of the most drudgery-prone, labour intensive and time-consuming operation. The smart feed dispensing system for poultry can reduce the drudgery associated with feeding systems and feed wastage due manual mishandling and excessive feeding. The system consists of a hopper, augur-type feed dispenser, stepper motor, and programmable logic controller. The developed system is able to dispense the feed at an accuracy of 100% as per the recommended dose. Feed dispensing quantities ranged from 246.9 g in the first week (1-7 days) to 2536.4 g in the ninth week (57-63 days). The weight of machine is about 70 kg and the cost of machine is Rs. 50,000/-.

USP	:	Smart poultry feed dispenser automates deep litter feeding with 100% dosing accuracy, reduces labour and feed wastage, handles 246–2536 g/week, weighs 70 kg
Name of the Inventors	:	Dr Abhijit Khadatkar, and Dr UC Dubey
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.12 Image based variable-rate nitrogen applicator

A Variable Rate fertilizer Application (VRA) system assisted by Deep Learning (DL) model deployed embedded system to enable rapid RGB image-based detection of nitrogen stress in wheat crop and subsequent application of N fertilizer. The developed VRA could operate in sync with embedded system at an operating speed of 0.4 m/s with a field capacity of 0.32 ha/h in a 26 DAS wheat crop. The average percentage N fertilizer saving under VRA as compared to traditional technique was 37.53 % with an insignificant ($p < 0.05$) difference in yield. This system ensures a real-time effective technique for precise classification of N stress and its real-time mechanized management in wheat crop. Cost of the technology is Rs. 95000/-.

USP	:	Deep learning assisted variable rate fertilizer applicator detects nitrogen stress in wheat via RGB images, enabling real time, precise N application, saving 37.5% fertilizer with unchanged yield
Name of the Inventors	:	Dr Narendra Singh Chandel, and Dr Dilip Jat
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.13 High clearance robot for grid based variable rate fertilizer application

A high-clearance, battery-operated robotic fertilizer applicator can be used for crops such as maize, pigeon pea, and bajra. The system operates on a 24V, 200Ah battery and provides up to 6.5 hours of continuous operation per charge. With a ground clearance of 1.6 m, it safely operates in tall and wide-spaced crops while following a tractor wheel tread to prevent crop damage. The robot features adjustable row spacing from 10 to 50 cm and a GPS-based variable rate fertilizer application system using a microcontroller-controlled fluted roller metering mechanism. A 60 kg fertilizer box reduces the need for frequent refilling. Additional features include easy manoeuvrability, crop-protective dividers, obstacle detection sensors, and camera support. The unit can be transported by tractor towing and performs efficiently under varied soil conditions. This technology improves fertilizer use efficiency, reduces labour and operational costs, supports sustainable farming practices, and aligns with India's green energy initiatives while offering potential for multiple precision farming applications.

USP : High clearance, battery operated robotic fertilizer applicator enables GPS-based variable rate application in tall crops, improving nutrient use efficiency, reducing labour, and supporting sustainable, precision farming

Name of the Inventors: Dr Dilip K Kushwaha

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.14 GPS based variable rate granular fertilizer applicator

This research is focused on techniques for variable rate application of granular fertilizer as a basal dose. An Electronic Control Unit (ECU) in open source micro-controller and digital nutrient map integrated Variable Rate applicator was developed for Fertilizer Application (VRFA). Grid identification algorithm was developed to decode "$GPRMC" string of valid NMEA for coordinate, direction and speed. The control software and VRFA graphical user interface (GUI) interfaced GPS location, application rate, speed and grid identification code. A 9-row tractor operated VRFA was developed and evaluated for precise application of urea, SSP and MOP fertilizers. The effective field capacity of VRFA was observed to be 0.21 ha/h at forward speed of 2.0 km/h. The VRFA could yield a N, P, K fertilizer savings of 24.5, 16.6, and 9.0 kg/ha over uniform rate application in the field, respectively.

USP : GPS integrated variable rate fertilizer applicator enables precise basal application of N, P, K, improving nutrient use efficiency and saving 9–24.5 kg/ha compared to uniform application

Name of the Inventors: Dr Narendra Singh Chandel, and Dr CR Mehta

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.15 Plant nitrogen monitoring and management system for polyhouse

This unique system enables precise and efficient nitrogen management in protected cultivation. The system operates with a field capacity of about 0.015–0.020 ha/h and can cover a 500 m^2 polyhouse area within approximately 3.0 to 3.25 hours. Nitrogen estimation models were trained using a dataset of 2,500 tomato leaf images collected over three growing seasons. Leaf detection is performed with more than 95% accuracy using the YOLO-based vision model. The complete process of nitrogen estimation and foliar spraying for a single plant takes around 12 to 15 seconds, ensuring timely and targeted nutrient application. The system has a tentative cost of Rs. 1.5 lakh and weighs about 100 kg, with an overall dimensions of 2.5 × 0.5 × 1.0 m. The operational cost is approximately Rs. 100 per hour, making it an economical solution for precision nutrient management in polyhouse cultivation.

USP : AI-powered system for precise nitrogen monitoring and targeted foliar application inside polyhouse, achieving >95% leaf detection accuracy, efficient nutrient management, and reduced labor and operational costs

Name of the Inventors: Dr Dilip Jat, Dr NS Chandel, Dr Yogesh Rajwade, and Dr Abhijit Sarkar

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.16 Mobile robotic spraying system for polyhouse

This mobile robotic sprayer has an improved efficiency, uniformity, and safety of plant protection and nutrient application under protected cultivation. The system mainly comprises embedded sensors (ultrasonic, proximity, XBee) and controllers (Arduino, PLC). The controller manoeuvres the system intelligently on a piping track between the rows as well as on the head space achieving end-to-end automation for spraying operations. The system has a field capacity of 0.10–0.12 ha/h and can cover a 500 m^2 polyhouse area within approximately 25 to 30 minutes. It is suitable for spraying insecticides, pesticides, and for foliar application of nutrients, ensuring uniform coverage across crops. The optimum operating parameters were identified as a forward speed of 0.79 km/h, a spray distance of 250 mm, and a working pressure of 0.4 MPa, which provide better spray coverage with optimized droplet size at the desired application rate. The machine has a tentative cost of about Rs. 1.5 lakh and weighs nearly 100 kg, with compact dimensions of 2.5 × 0.5 × 1.0 m, making it suitable for movement inside polyhouses. The operational cost ranges from Rs. 60 to 100 per hour. Compared to a conventional knapsack sprayer, the automatic spraying system saves about 65.5% time and 67.5% labour.

USP : Mobile robotic sprayer for polyhouses provides automated, uniform, and efficient pesticide and nutrient application, saving 65% time, 68% labor, and ensuring safe, precise crop protection

Name of the Inventors: Dr Dilip Jat, Dr Satya Prakash Kumar, and Dr Yogesh Rajwade

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.17 Drone assisted sprayer

The hexacopter drone is designed with a payload and tank capacity of 4 L, programmed for small and medium-scale spraying operations over a predefined path for chemical application. It operates at an average forward speed of 5 m/s with a flight endurance of approximately 9 minutes per sortie. The total weight of the drone is about 6 kg, ensuring stable flight and easy manoeuvrability. The UAV is equipped with a 1.5 m wide boom for mounting spray nozzles, which enables uniform swath coverage. A diaphragm pump with a discharge rate of 1.3 L/min is used to deliver the spray liquid. The spraying system consists of two hydraulic flat-fan polymer nozzles with a spray angle of 60°, fitted with anti-drip heads to prevent chemical wastage. The droplet size ranges between 150 and 200 μm at an operating pressure of 3 bar, ensuring effective pesticide deposition and reduced drift. The tentative cost of the developed drone is approximately Rs150000/-. This UAV-based spraying system reduces labour requirements, improves timeliness of application, and supports precision agriculture practices.

USP	:	UAV (Hexacopter) with 4 L payload and precision nozzles enables small-to-medium scale spraying, reducing labor, improving chemical efficiency, and supporting timely, precision agriculture practices
Name of the Inventors	:	Dr HL Kushwaha, Dr Indra Mani, Dr JP Sinha, Dr Sudip Mishra, Dr Tapan Kumar Khura, and Dr Dilip Kumar Kushwaha
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.18 Robotic harvester for grape bunches

The unmanned vehicle is a battery-powered unit designed to operate efficiently in vineyard conditions. The vehicle comprises a chassis, main frame with chassis, transmission system, electronic control unit, remote control system, tray holding system, robotic arm platform. Four lugged rubber wheels of diameter 600 mm driven by 24 V DC motors ensure traction and manoeuvrability on vineyard soil. The ECU manages critical operations, including speed, direction, and braking. Commands are received via a remote controller operational within a 1 km range. The ECU interprets signals from the controller and executes the different control assigned to the channel. An inbuilt battery system ensures prolonged operation during harvesting activities. Optimized vision system is attached to the vehicle for detection of ripen and unripen grape bunch. Its battery-powered platform provides scope for different farm operation and crop monitoring.

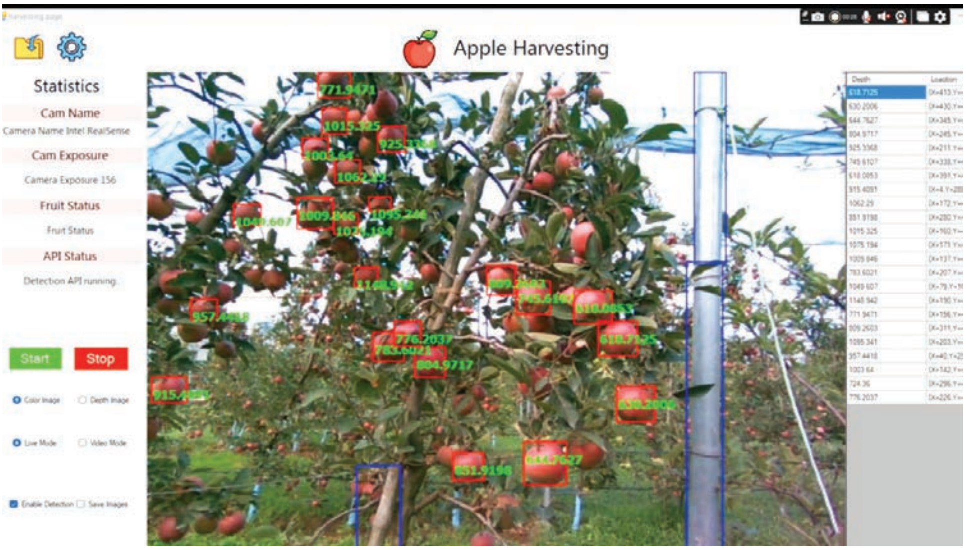
USP : Battery powered unmanned vineyard vehicle integrates robotic arm and vision system to detect ripe/unripe grape bunches, offering versatile crop monitoring and efficient harvesting with remote control

Name of the Inventors: Dr Syed Imran S, Dr T Senthilkumar, Dr NA Deshmukh, and Dr AK Sharma

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.19 Algorithm for multi-class detection and path tracking for apple harvesting

An advanced algorithm for multi-class detection and path tracking has been developed to support autonomous apple harvesting in orchard environments. The system employs a hybrid DL model that integrates the fast object detection capability of with the precise instance segmentation features. This combined framework enables accurate detection and classification of multiple classes, including apples and various obstacles such as tree trunks, branches, and support structures. The hybrid model was optimized to handle challenges common in orchards, such as occlusion, varying illumination, and complex backgrounds. The ensemble framework achieved a high precision rate of 98% for obstacle detection and 97% for apple detection, ensuring reliable identification with minimal false alarms. In addition, the algorithm performs on-tree detection and precise localization of apples using segmentation masks, which helps determine their spatial position for harvesting.



USP : Hybrid DL algorithm enables autonomous apple harvesting by accurately detecting apples and obstacles with over 97% precision, ensuring reliable on tree localization and safe path tracking

Name of the Inventors: Dr Shaghaf Kaukab

More Information : Director, ICAR-Central Institute of Post-Harvest Engineering and Technology, Ludhiana - 141001

1.20 Automatic system draft and slip control in tractors

The system act as a closed loop feedback control configuration of sensors, a microcontroller-based central processing unit, a control unit, and an electro-hydraulic lift link mechanism for continuously monitoring wheel slip and draft during field operations and communicates with the tractor's hydraulic system to adjust implement depth, whenever, these parameters deviate from the desired range. The developed system achieved a measuring efficiency of 99% for both wheel slip and draft detection. Field evaluations demonstrated that this system can reduce fuel consumption by up to 14% and increase field capacity by up to 36% in Vertisol soils. With a technology cost of approximately Rs. 2.0 lakh, the system provides a cost-effective solution for optimizing tillage performance, improving operational efficiency, conserving fuel, and enhancing overall productivity in agricultural field operations.

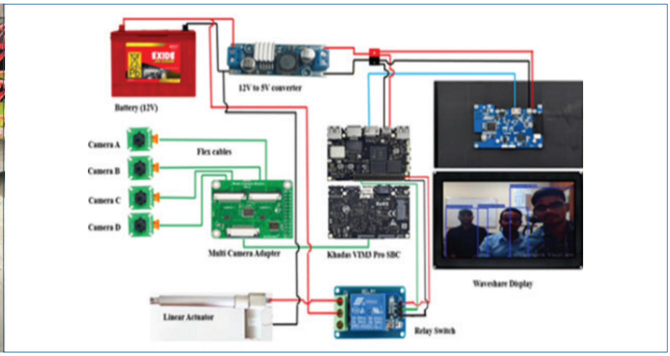
USP : AI enabled tractor feedback system continuously monitors wheel slip and draft, automatically adjusts implement depth, improves fuel efficiency by 14%, and increases field capacity by 36%

Name of the Inventors: Dr AK Roul, and Dr HS Pandey

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.21 AI-based emergency braking system for tractors

An AI-based emergency braking system for tractors ensures to enhance operator safety during agricultural operations by addressing critical blind-spot issues. Tractors often have limited visibility at the front, sides, and rear, which significantly increases the risk of accidents involving humans or animals. The proposed system uses artificial intelligence to detect obstacles in real time within a range of 1 to 15 m and automatically activates braking to prevent collisions. The system is designed to be compatible with standard agricultural tractors and can be integrated without major structural modifications. The sensing and processing unit continuously monitors the surroundings and analyzes visual data to identify potential hazards within the blind spots. Once a threat is detected, the braking mechanism is triggered instantly, reducing reaction time and improving operational safety. The tentative cost of the system is approximately Rs. 1,50,000. It has a compact and lightweight design, weighing about 6–10 kg, including electronics, actuators, and mounting components, and fits within the tractor cabin or pedal area. The operational cost is minimal, as it runs solely on the tractor's 12 V battery without any additional fuel consumption, making it a practical and energy-efficient safety solution.



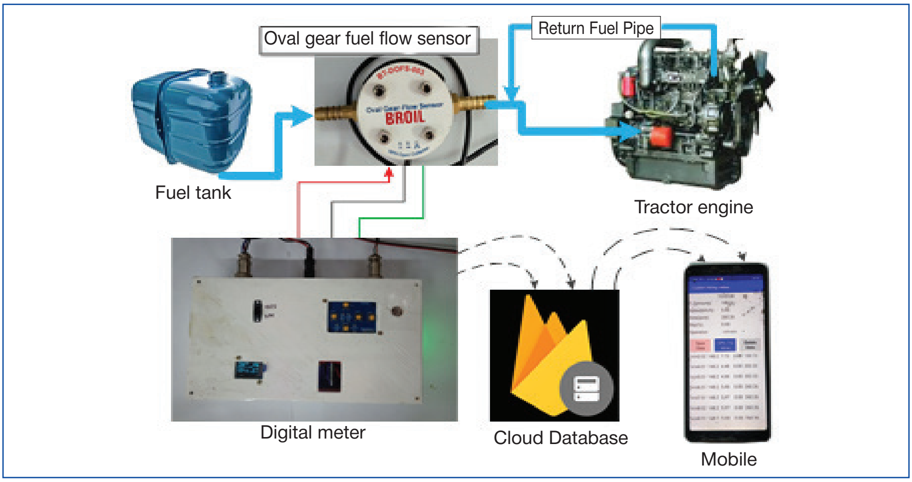
USP : AI based tractor emergency braking system detects obstacles in blind spots (1–15 m) and automatically stops the tractor, enhancing operator safety with minimal cost and easy integration

Name of the Inventors: Dr P Pradhan, and Dr S Sahoo

More Information : Director, Indian Institute of Technology, Kharagpur - 721302

1.22 IoT based custom hiring monitoring meter of agricultural machines

An IoT-based custom hiring monitoring meter enables real-time recording and monitoring of tractor fuel consumption and operational parameters. The system integrates a mechanical fuel flow unit with sensors, an electronics controller board, dual Wi-Fi microcontroller modules, a data logger, an OLED display, a customized keypad, and a GPS module for live location tracking. The controller is programmed in C++ using the Arduino IDE, while secure cloud data storage and transfer are managed through Google Firebase. A user-friendly mobile application, developed using the MIT App Inventor platform, allows remote visualization of tractor performance and usage data. The unit is compact, powered directly by the tractor battery, and developed at an approximate cost of Rs. 25,000. This monitoring meter is highly useful for ensuring transparency, accountability, and efficiency in custom hiring services. It can be adopted by Custom Hiring Centers, agricultural cooperatives, and service providers to track fuel use, operating hours, and machine location. The system supports large-scale farm management, research, and policy planning, and can be extended to other farm machinery and rural transport systems, promoting digital and sustainable agriculture.



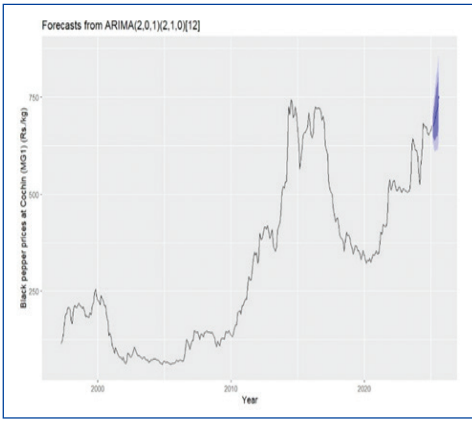
USP : IoT-based tractor monitoring meter records fuel use, operational data, and GPS location in real time, enabling efficient, transparent, and scalable management of custom hiring services

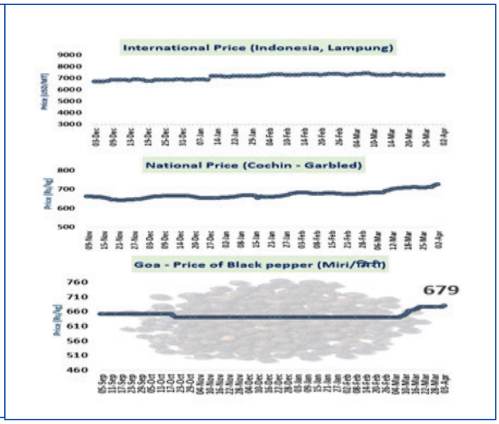
Name of the Inventors: Dr Rajeev Kumar

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.23 ML based price forecasting system for plantation crops

Empowering farmers with machine learning-based price forecasts for plantation crops has the capacity of forecasting the prices of plantation crops (Black pepper, cashew, arecanut and coconut) on the west coast of India. The market intelligence advisories are shared with 1700 farmers regularly. Tentative cost of the development has a financial outlay of 6.60 lakh. The model is implemented in the coastal districts of the west coast region of India. It is purely a software- and modelling-based solution and does not involve the development or deployment of any hardware/device. Hence, weight and size are not applicable. The system only involves computation, model development, and deployment of machine learning algorithms, and therefore does not incur operational costs.

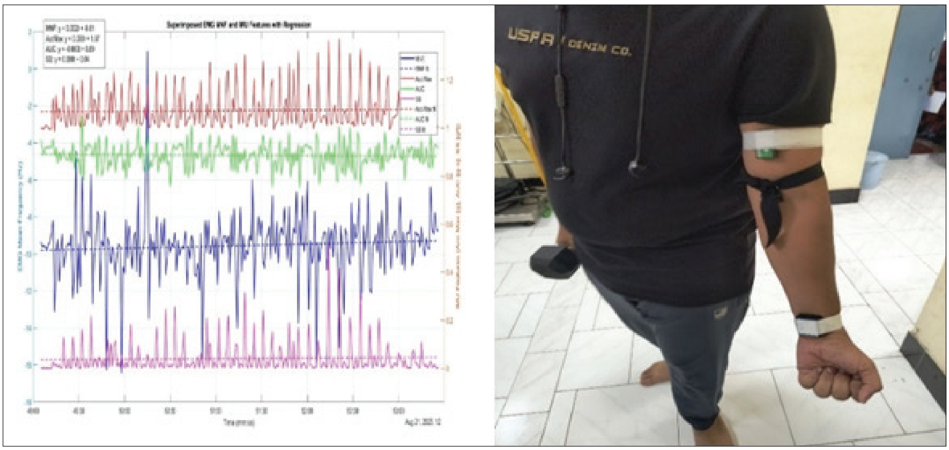




USP	:	Machine learning based software forecasts prices of plantation crops like black pepper, cashew, arecanut, and coconut farmers, enabling timely market decisions without hardware or operational costs
Name of the Inventors	:	Dr Shripad Bhat
More Information	:	Director, ICAR-Central Coastal Agricultural Research Institute, Goa - 403402

1.24 Smartphone-based EMG and IMU integrated fatigue detection system

Human fatigue during repetitive agricultural operations can lead to reduced performance and increased risk of errors or accidents. Taking this issue under consideration a smartphone-based EMG and IMU integrated fatigue detection system has been developed to assess muscle fatigue in real time. The system uses motion sensors and smartphone-based processing to monitor operator movements and quantify fatigue levels during tractor operations. Designed for standard agricultural tractors, it enables timely intervention to reduce operator strain and improve work efficiency. The system is compact and lightweight, weighing approximately 6–10 kg, including electronics, actuators, and mounting frame, and can be easily installed within the tractor cabin or pedal area. It operates using the tractor's 12 V battery, keeping operational costs very low with no additional fuel consumption. The tentative cost of the system is around Rs. 1,50,000. By providing real-time fatigue monitoring, this technology supports safer, more efficient, and ergonomically sustainable agricultural operations.



USP	:	A smartphone based EMG–IMU system monitors tractor operator fatigue in real time, enhancing safety, reducing strain, and improving efficiency through compact, low cost, ergonomically sustainable technology
Name of the Inventors	:	Dr P Pradhan, and Dr S Sahoo
More Information	:	Director, Indian Institute of Technology, Kharagpur - 721302

1.25 FASAL: Yield forecasting model using space, agro-meteorology and land-based observations for maize, wheat and mustard

Weather based model was developed for wheat yield prediction using long term weather data during wheat crop growing period and yield data. Model was developed using SMLR, PCA-SMLR, ANN, PCA-ANN, LASSO and Elastic net techniques for Hisar, Ludhiana, Amritsar, Patiala and ICAR-IARI, New Delhi. On the basis of accuracy parameters LASSO and elastic net performed best having lowest value of RMSE and nRMSE for all the study area. Machine learning techniques were used for estimating the wheat yield for different districts of Punjab using long term weather data. Models for mustard yield prediction was developed using long-term weather data during the crop growing period along with mustard yield data. On the basis of model accuracy parameters PCA-SVM model performed best among all the six models developed for mustard yield prediction of study areas.

USP	:	Weather based ML models, including LASSO, Elastic Net, and PCA-SVM, accurately predict wheat and mustard yields using long term climatic data for site specific agricultural planning
Name of the Inventors	:	Dr Ananta Vashisth
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

1.26 UAV-based multispectral imagery for yield prediction

A UAV-based multispectral imaging system monitors crops for precision agriculture, using a hexacopter (Agriboat, Iotech World Aviation, Gurgaon) equipped with an RTK GNSS receiver for high-accuracy positioning. The UAV carries a RedEdge-P multispectral sensor (MicaSense, USA) that captures five spectral bands—blue (475 nm), green (560 nm), red (666 nm), red edge (717 nm), and Near-Infrared (NIR, 842 nm)—along with a high-resolution panchromatic band. The sensor's global shutter, radiometric calibration, and integrated Downwelling Light Sensor (DLS 2) ensure precise, repeatable data for advanced vegetation analysis, including NDVI and GNDVI calculations. The multispectral system enables early detection of crop stress, assessment of plant vigour, chlorophyll content, biomass estimation, and canopy structure analysis. The RedEdge-P weighs 0.5 kg, while the small-category drone weighs 14.5 kg, totalling 15 kg. The system costs approximately Rs. 15 lakh. The system predicts crop yield by analyzing spectral indices, canopy reflectance, and growth dynamics over time. Its lightweight, UAV-compatible design allows repeated surveys, providing high-resolution data for precise crop health monitoring, yield forecasting, and sustainable farm management.

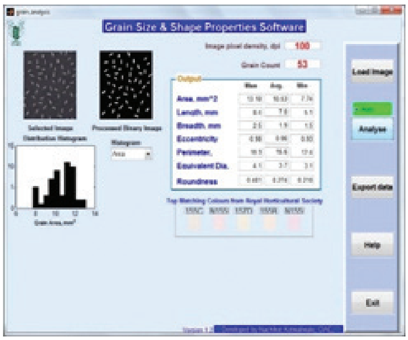
USP : UAV based multispectral imaging system enables high-resolution crop monitoring, early stress detection, and yield forecasting using spectral indices and RTK-GNSS positioning for precision agriculture

Name of the Inventors: Dr Satya Prakash Kumar, Dr RK Sahni, and Er R Sanodiya

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.27 Use of machine vision for distinguishing among crop varieties

Three software namely, "Size & Shape Measurement Software" and "Rice Panicle Analysis Software", "Software for analysis of okra plant parts". This software can read images taken using document scanner/ camera and give output as various size/shape properties to an accuracy of 0.1 mm. The software are suitable for analysis of fruit, leaf, stem, seed images and measure up to 30 features based on morphology, chromatic and texture of the image. It is a helpful tool for distinguishing among varieties/ germplasm of rice, Indian mustard, chickpea and okra using visible imaging; and optimizes imaging and image processing under visible spectral domain. A comprehensive web-based image database has been developed for rice, mustard, chickpea, and okra, currently containing over 30,000 images, with 17,000 uploaded online images. The database captures various plant parts - seed, leaf, flower, and fruit - using digital cameras, flatbed scanners, microscopes, and hyperspectral imaging (400–1050 nm, 97 bands, 6 µm pixel size). New measurable traits, including morphological (kernel area, eccentricity, perimeter), textural (energy, entropy, contrast), and color features (RGB, hue), were identified. The system enables high-throughput trait analysis that is not possible manually, supporting precision phenotyping, variety discrimination, and advanced crop research through standardized image management and processing.



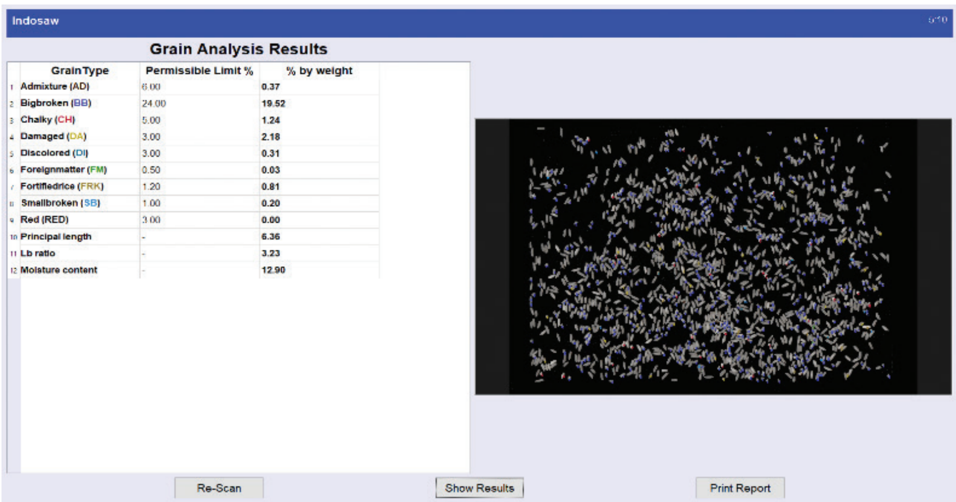
USP : Three software tools enable high throughput image based analysis of plant traits, measuring morphology, color, and texture to 0.1 mm accuracy, supporting precision phenotyping and variety discrimination

Name of the Inventors: Dr Nachiket Kotwaliwale, Dr Karan Singh, Dr Monika A Joshi, Dr Abhijit Kar, Dr KK Gangopadhyay, Dr Anjula Pandey, Dr Nabarun Bhattacharya, and Dr Amitava Akuli

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.28 AI-based grain analyzer software

The software is a standalone digital solution for rapid and objective grain quality assessment. Built on advanced computer vision techniques and deep learning models, the software can segment complex touching kernels, and classify grains into refractions such as broken, chalky, discoloured, damaged etc. and other refractions with high accuracy. It can be integrated into flatbed scanners, industrial cameras. Optimized for GPU-enabled systems, it can process 20 grams of grain samples within 2 minutes against the manual classification of 20 minutes. The software has been successfully implemented in a dual-scanner imaging system developed by INDOSAW, Ambala, Haryana. The tentative cost of the software is 4.0 lakhs. This software has direct applications in procurement centers, mandis, Food Corporation of India (FCI) depots, rice mills, wheat processing units, grain export agencies, and regulatory authorities. It ensures compliance with BIS/FCI norms, reduces subjectivity in grading, enhances transparency in trade, and minimizes disputes.



USP : Standalone software uses deep learning and computer vision for rapid, accurate grain quality assessment, segmenting complex kernels, reducing manual grading time, and ensuring transparency in trade

Name of the Inventors: Dr Dhritiman Saha

More Information : ICAR-Central Institute of Post-Harvest Engineering and Technology, Ludhiana - 141001

1.29 Computer vision based adaptive DL model enabled automatic fruit grader

This machine is an ergonomically designed single operator machine of 6.4 m length, 1 m in width and 1.6 m in height made in SS-304; and produces noise far less than 80 db. The machine runs on a three-phase electric power. The capacity of the machine is about 1700 fruits/h. The machine performs postharvest operations, like—washing, vision-based sorting and weight-based grading of citrus fruits with much reduced human effort while achieving excellent performance for the designated tasks. The machine is equipped with an effective custom lightweight CNN model ''SortNet''. Weight grading and colour sorting efficiency is more than 90%. This machine offers an overall reduction of drudgery by about 83%. Overall operating B: C ratio of the machine is 1.5. The cleaning/washing of spherical horticultural fruits by pressurized water followed by singulation of each and every washed fruit in a continuous action without causing any damage to the handled material.

USP : Ergonomically, single-operator citrus postharvest machine integrates washing, vision based sorting, and weight grading using CNN 'SortNet', achieving over 90% efficiency and reducing labor drudgery by 83%

Name of the Inventors: Dr Subir Kumar Chakraborty, and Er Subeesh A

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

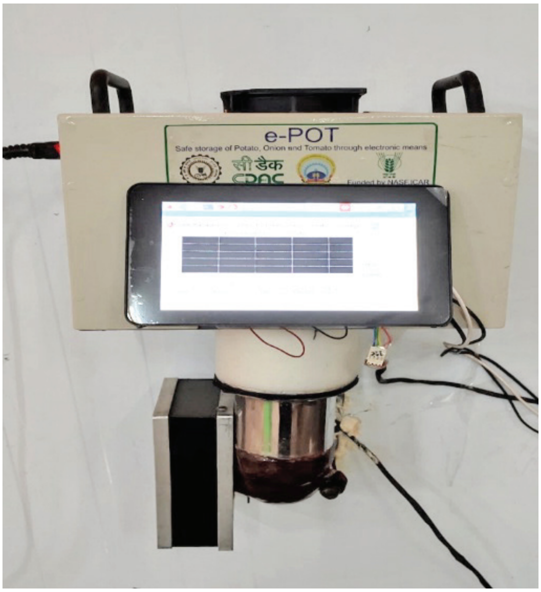
1.30 Multi spectral sensor based device for rapid detection of Aflatoxin B1

Exposure of maize to aspergillus flavus while on and off the fields leads to aflatoxin contamination. This is a very serious food safety concern in food and feed supply. Rapid detection of contamination in the grain on-site, preferably with a hand-held instrument, before it comes into the food chain is necessary and imperative. Hyperspectral Imaging (HSI) is a popular non-invasive technique for detection of fungal contamination in maize kernels. HSI data secures its acceptance for development of tools and gadgets that can be used for rapid detection of fungal contamination. HSI spectral data was obtained using maize samples, (i) inoculated with six different concentrations (25, 40, 70, 200, 300 and 500 ppb) of aflatoxin-B1, and (ii) under natural contamination with aspergillus flavus. Based on this result a hand-held hardware was developed that comprised a multispectral sensor having 18-channels in the UV, visible and IR ranging from 410 to 940 nm with a built in aperture, 16-bit ADC and operating at 2.7 to 3.6 V, LEDs (white, UV and IR) that could illuminate the target with the largest swath, a micro controller (Arduino Mega 2560), a power bank (5V, 2A, 5000 mAh) and a 2.4″ touch TFT display. All the components were fitted in 3D printed (0.2 mm, asbestos) cuboidal housing with an opening right beneath the spectral sensor which can be closed with half turn self-locking cap/sample holder. The instrument demonstrated a working accuracy of more than 80% in classifying infected aflatoxin containing grains into low (< 30 ppb), medium (> 30 ppb and 100 ppb) categories.

USP	:	A hand held hyperspectral imaging device rapidly detects aflatoxin contamination in maize, classifying grains on-site with over 80% accuracy for improved food safety and prevention
Name of the Inventors	:	Dr Subir Kumar Chakraborty, and Dr M K Tripathi
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.31 e-POT (e-sensing system for disease detection in potato, onion and tomato)

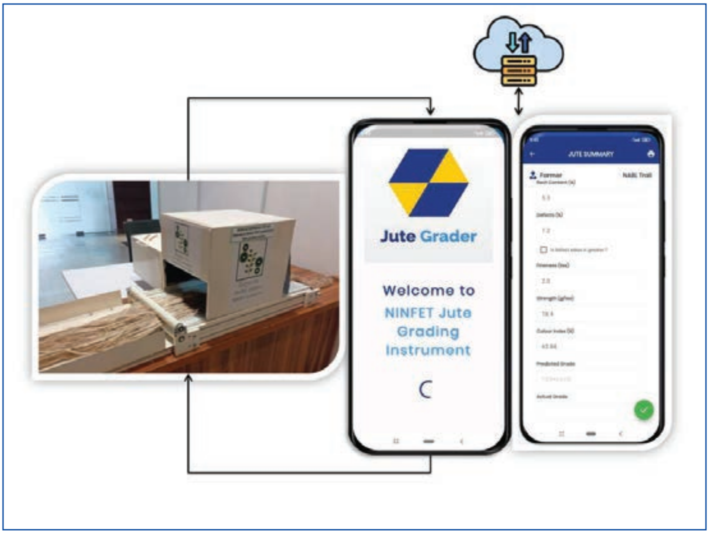
An electronic nose built with an array of 8 metal oxide semiconductor gas sensors, assisted with machine learning models deployed embedded system to enable rapid volatile organic compounds detection owing to bacterial and fungal infection in potato, onion and tomato during storage. Algorithm developed can collect data at every 30 minutes. The system can sniff and indicate the health of the stored commodity through the developed spoilage index within 2 mins of operation. This e-nose delivers a real-time effective technique for precise classification of bacterial and fungal infection in stored potato and onions. The dimension of this device is 30 ×25×18 cm, weighing about 2 kg, which can be installed on the cold storage room (190000L). Tentative cost of the technology is Rs. 100000/-.



USP	:	AI enabled electronic nose rapidly detects bacterial and fungal infections in stored potatoes, onions, and tomatoes, providing real-time spoilage assessment for large cold storage facilities
Name of the Inventors	:	Dr Debabandya Mohapatra, Dr Alokesh Ghosh, Dr Bharat Kumar Modhera, Dr Amitav Akuli, Dr Hena Roy, Dr Adinath Kate, and Dr MK Tripathi
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

1.32 AI-IoT enabled jute fibre grading system

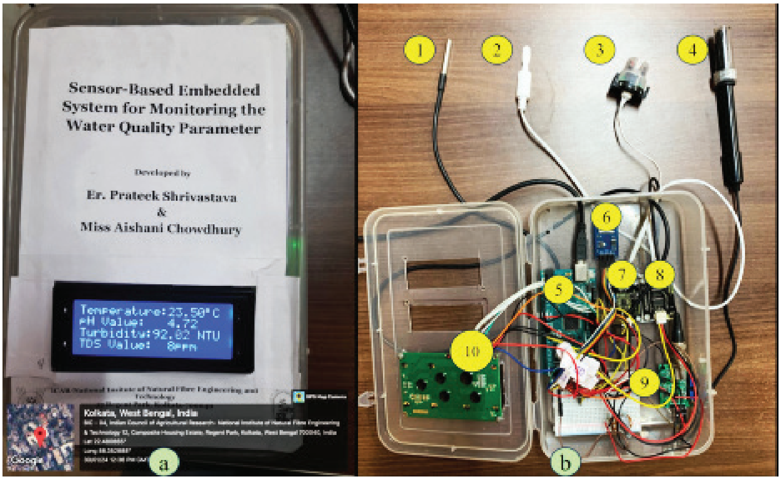
The developed AI-IoT enabled jute fibre grading instrument consists of a sample tray, feed roller, conveyor, image capturing unit, color measurement unit, and bundle strength unit. The conveyor moves the fibre at a fixed distance under the image capturing unit, the bundle strength measurement unit features a fibre breaking unit with a limit switch, motors, an S-type load cell with an amplifier, and microcontroller. After measuring all parameters, the mobile app "Jute Grader" displays the test results. Once confirmed, the results are sent to and stored on the cloud server. A distinguishing feature of this jute grading instrument is its ability to measure all parameters of the jute within five minutes, providing both individual values and the final grade of the jute fibre. Approximately 100 samples can be tested in a day. The total cost required for operating the instrument was Rs. 754 per hour. AI IoT-enabled jute grading system has wide scope in improving fairness, and standardization across the jute sector. It ensures transparent and accurate grading, eliminating human bias and helping farmers receive fair prices for their produce.



USP	:	The AI-IoT jute grading instrument measures fibre quality and strength within five minutes provides cloud based results, ensures unbiased grading, and promotes transparency and fairness in the jute sector
Name of the Inventors	:	Dr Nageshkumar T
More Information	:	Director, ICAR-National Institute of Natural Fibre Engineering and Technology, Kolkata - 700040

1.33 Jute retting water quality assessment device

The developed system is fitted with a temperature sensor, pH sensor, turbidity sensor, TDS sensor, microcontroller, storage module, and a display screen. Field validation established a nonsignificant difference between actual and measured water quality values in terms of temperature, turbidity, and TDS at 95% level of significance. Developed embedded system is easy-to-build, easy-to-use, and cost-effective (Rs. 15,000/-) for the determination of water quality parameters as well as the endpoint of retting, which may be helpful for research and academic purposes



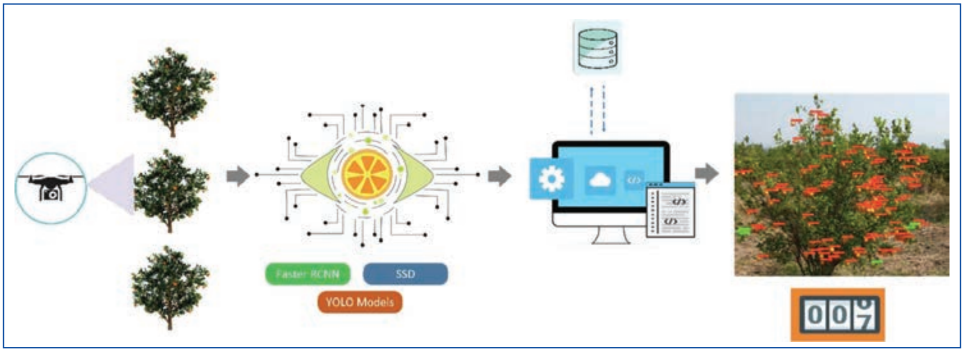
USP : The embedded system measures water quality and retting endpoints accurately using sensors and microcontroller, offering an easy-to-build, user friendly, and cost effective solution for research and academic use

Name of the Inventors: Dr Prateek Shrivastava

More Information : Director, ICAR-National Institute of Natural Fibre Engineering and Technology, Kolkata - 700040

1.34 Web-based application for yield estimation in citrus orchard

Orchard yield estimation enables a farmer to make informed decisions. The limitations of visual inspection-based yield estimation approaches can be effectively addressed by the intervention of Unmanned Aerial Vehicles (UAVs) and advanced image processing tools using deep learning algorithms. This innovation combines deep learning-driven UAV imagery and an in-house web-based application, "DeepYield"; to measure yield in a citrus fruit orchard. The state-of-the-art deep learning object detection models were evaluated for detecting "harvest-ready" and "unripe" citrus fruits from the tree images. Fruit size estimation was carried out using traditional as well as deep learning-based image segmentation models. The developed solution was integrated into a web-based application as 'DeepYield' to enhance users' convenience and equip them with an automated yield estimation solution.



USP : DeepYield combines UAV imagery and deep learning to accurately estimate citrus orchard yield, distinguishing ripe and unripe fruits, enabling automated, timely, and data driven farming decisions

Name of the Inventors: Er Subeesh A, and Dr Satya Prakash Kumar

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

Chapter 2

AI-Powered Pest Management and Crop Protection

Protecting the crop from abiotic and biotic stresses pose a major challenge for enhancing agricultural productivity and ensuring food security. Conventional pest management approaches are chemical-intensive, increasingly constrained by resistance development, pose serious environmental concerns, and introduce high operational costs. The listed technologies demonstrate that Artificial Intelligence (AI), Internet-of-Things (IoT), machine vision, and drone technologies are redefining crop protection by enabling early detection, precision intervention, and data-driven decision support. AI-powered pest management systems are shifting crop protection from blanket treatments to intelligent, need-based solutions.

AI diagnostic kits for real-time monitoring of nematodes, AI-enabled web applications for disease detection, AI systems for detecting leaf blight complexes in wheat and ML based early detection of fungal foliar and bacterial wilt diseases in potato enhance preventive crop protection. These digital support systems for disease surveillance facilitate timely identification and management of complex stresses evolving out of biotic and abiotic vectors alike. For rice, a comprehensive digital ecosystem has emerged, including AAVISHKAR for pest diagnosis, SRDSS for spatial decision support, AI-based pest pheno-forecasting portals and prediction models using ML for real-time advisories. AI-based systems for pest surveillance and management in maize, brinjal, okra, and tomato—including IoT-based advisory platforms and Pest Identification Management Systems (PIMS)—strengthen crop-specific protection strategies. Mobile applications promoting non-chemical insect pest management further support Integrated Pest Management (IPM) principles.

With a renewed thrust in oilseeds and pulses production, there are many AI driven innovations which are capable of bolstering the production goals for these items. "SoyAI" integrates AI modelling to optimize soybean cultivation, while handheld image-based devices and tools such as "Tilhantec – Oilseeds Doctor" support rapid disease and insect identification.

There are established AI based diagnostics that complement precision application technologies as demonstrated by, – smart traps for real-time monitoring of pink bollworm in cotton, drone-based chemical topping for canopy management, machine-vision-based site-specific sprayers, tele-robotic selective pesticide applicators, and drone-enabled crop health monitoring systems such as “Drone Agri” to reduce input use and associated environmental impact. National-scale initiatives like the AI-enabled National Pest Surveillance System (NPSS) and platforms such as PUSAeCMS, Pusa Phenomobile, and PUSA N-Manager integrate monitoring, phenotyping, and nutrient management. In a nutshell, the enumerated AI-powered discoveries and innovations represent a paradigm shift toward sustainable, precise, and resilient crop protection systems.

2.1 AI diagnostic kit for real-time monitoring of nematodes in sugarcane

An artificial intelligence-powered diagnostic kit has been developed for real-time monitoring of nematode pests in sugarcane, providing rapid, accurate, and automated identification of plant-parasitic nematodes. The system assists farmers and agronomists in diagnosing nematode infestations and recommending appropriate control measures, reducing crop losses and improving productivity. Nematode images are captured from varied resolutions and angles and then normalized using advanced image enhancement techniques to ensure consistent and high-quality input for the AI model. The diagnostic kit leverages a deep learning and computer vision framework capable of distinguishing different nematode species with high precision. The deep learning architecture is continuously optimized to improve discrimination between nematode species, ensuring reliable identification even under challenging imaging conditions. The kit has achieved a testing accuracy of 0.95 at the species level, demonstrating its effectiveness for practical field applications. The tentative cost of the system is approximately Rs. 16.30 lakhs, making it a high-precision tool for sugarcane nematode management and precision agriculture initiatives.

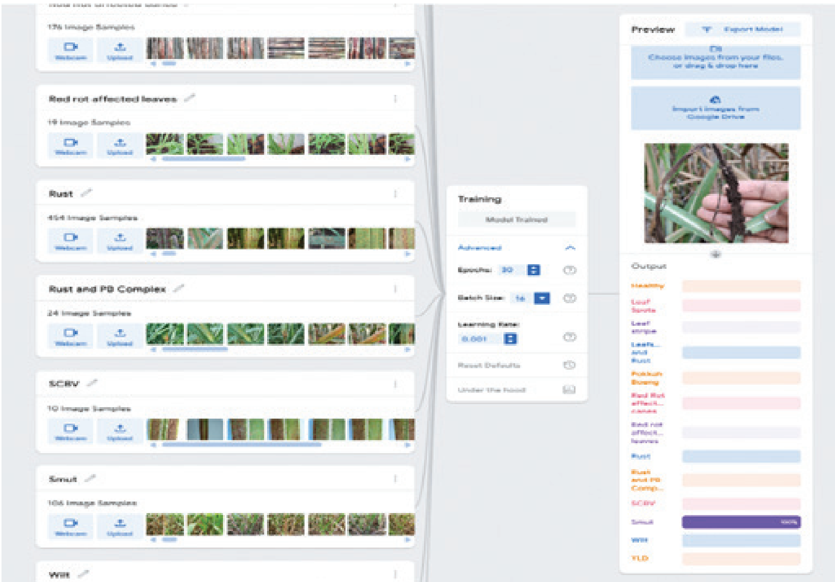
USP : AI powered diagnostic kit enables rapid, accurate identification of sugarcane nematodes, supporting real time pest management, reducing crop losses, and enhancing productivity in precision agriculture

Name of the Inventors: Dr C Sankaranarayanan, Dr D Suryaprabha, and Dr N Seenivasan

More Information : Director, ICAR-Sugarcane Breeding Institute, Coimbatore - 641007

2.2 AI enabled web app for sugarcane disease detection

An AI-enabled web application has been developed for real-time detection of sugarcane diseases. Initially, a comprehensive dataset of images representing all major sugarcane diseases was compiled to train and validate deep learning models for accurate disease identification and classification. The prediction model is validated against these datasets to ensure high accuracy and reliability. Users can access the system through a cloud-based web interface, allowing easy and remote disease monitoring. Additionally, the model is designed for versatility and can be readily converted into an Android application by software enabling mobile-based sugarcane disease detection and supporting timely management decisions for farmers.



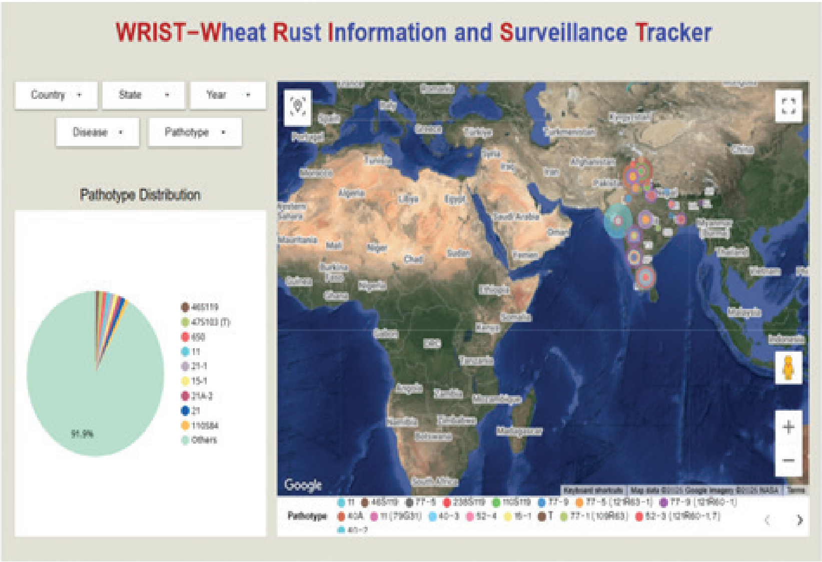
USP : AI powered web application enables real time sugarcane disease detection with high accuracy, accessible via cloud or mobile, supporting timely interventions and informed crop management decisions for farmers

Name of the Inventors: Dr R Selvakumar, and Dr A Ramesh Sundar

More Information : Director, ICAR-Sugarcane Breeding Institute, Coimbatore - 641007

2.3 AI enabled biotic and abiotic stress detection and advisory mobile application for crops

WRIST – Wheat Rust Information and Surveillance Tracker is a tool designed to monitor the distribution and dynamics of wheat rust races across India. This was developed using 15 years of historical data, it tracks yellow rust, black rust, and brown rust, providing insights into their spread in major wheat-growing zones. The system also incorporates rust dynamics from neighbouring countries, including Nepal, Bhutan, and Bangladesh, for a comprehensive regional perspective. The underlying dataset comprises over 10,000 samples collected from diverse locations, enabling accurate mapping and surveillance. WRIST supports timely decision-making for disease management, helping farmers and researchers mitigate wheat rust impacts effectively.



USP	:	WRIST monitors wheat rust distribution across India using 15 years of data, enabling timely, accurate surveillance, informed management decisions, and mitigation of yellow, black, and brown rust impacts
Name of the Inventors	:	Dr Prem Lal Kashyap, Dr OP Gangwar, Dr Pramod Prasad, and Dr YP Lakshmi Sonkusale
More Information	:	Director, ICAR-Indian Institute of Wheat and Barley Research, Karnal - 132001

2.4 AI based detection of disease and pests in sugarcane

The Artificial Intelligence based sugarcane insect pest and disease symptom classifier is a software tool designed for rapid, accurate, and autonomous monitoring of sugarcane pests and diseases under field conditions. The system can classify 11 categories, including 10 major sugarcane pests and healthy plants, using a dataset of 4,315 real-time and controlled images. It effectively identifies major diseases across different sugarcane varieties, growth stages, and climatic zones, handling overlapping symptoms and complex backgrounds with high robustness. The AI classifier is developed using open-source deep learning frameworks on a standard GPU-enabled workstation. It is deployable as a low-cost, farmer-friendly mobile application and can be potentially free for farmers. Being software-based, it has no physical size or weight and can be used via smartphones, drones, or cloud servers. Operational costs are minimal, requiring only image capture from a smartphone or drone. Performance metrics demonstrate high reliability, with accuracy of 99.36%, precision of 96.09%, recall of 94.61%, and specificity of 99.65%. By enabling early detection of pest infestations, it helps farmers, extension workers, and sugar mills reduce sugarcane yield losses, which in India can range from 20–46%.

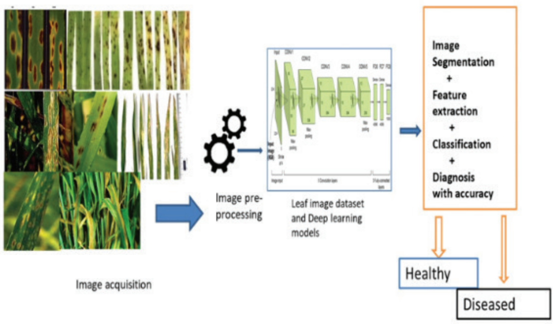
USP : AI based sugarcane pest and disease classifier enables rapid, accurate field monitoring via mobile or drones, supporting early detection, reducing yield losses, and enhancing sustainable sugarcane management

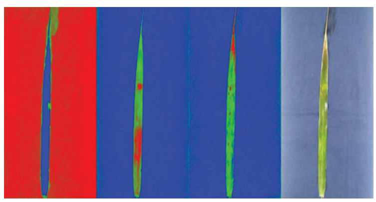
Name of the Inventors: Dr Chandramani Raj, Dr DN Borase, Dr Arun Baitha, Dr S Hasan, Dr Shweta Singh, and Dr RU Modi

More Information : ICAR–Indian Sugarcane Research Institute, Lucknow - 226002

2.5 AI system for detection of leaf blight complex in wheat

An artificial intelligence-based system is being developed for rapid and accurate detection of wheat leaf blight under field conditions. The system is designed to process 500–1000 leaf images per day per device, delivering real-time detection within 5–10 seconds per image. The technology integrates a field-deployable AI camera with cloud-based data processing and mobile application support, with an estimated cost of Rs. 1.5–3.0 lakh. Operational costs are projected at Rs. 5,000–10,000 per year, covering software licensing, cloud storage, mobile data usage, and routine maintenance. The system enables early, rapid, and non-invasive diagnosis of wheat leaf blight, supporting timely management decisions and reducing yield losses. It is suitable for mobile-based applications and can be integrated into precision agriculture decision-support systems This AI-based detection system promises to enhance wheat disease monitoring, improve field-level decision-making, and support sustainable crop management practices.





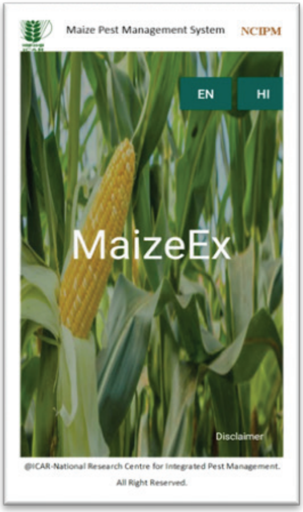
USP : AI based wheat leaf blight detection system provides rapid, non-invasive, real time diagnosis, supporting early management, reducing yield losses, and enabling precise, sustainable wheat crop protection

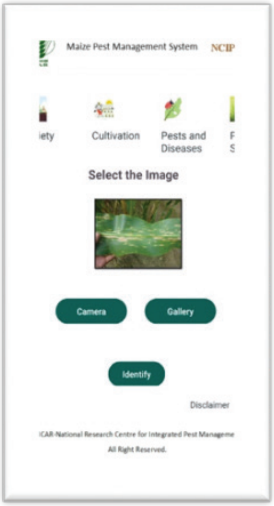
Name of the Inventors: Dr Abhijeet Shankar Kashyap, Dr Nazia Manzar, Dr Bikram Jyoti

More Information : Director, ICAR-National Bureau of Agriculturally Important Microorganisms, Mau - 275103

2.6 AI-based identification, surveillance and management of key pests of maize

A mobile application has been developed for AI-based identification, surveillance, and management of key pests in maize crops. The app enables farmers, extension workers, and agronomists to quickly identify major maize pests and access recommended management practices for effective control. It integrates AI-based pest detection to support real-time monitoring and decision-making, enhancing pest management efficiency in the field. The AI model underlying the app is currently being refined to improve accuracy and reliability for diverse field conditions. The system provides a comprehensive platform for both pest identification and management guidance, helping reduce crop losses and supporting sustainable maize production. Once fully optimized, it aims to serve as a practical, user-friendly tool for precision pest monitoring, timely interventions, and enhanced crop protection, contributing to improved maize yield and farm productivity.

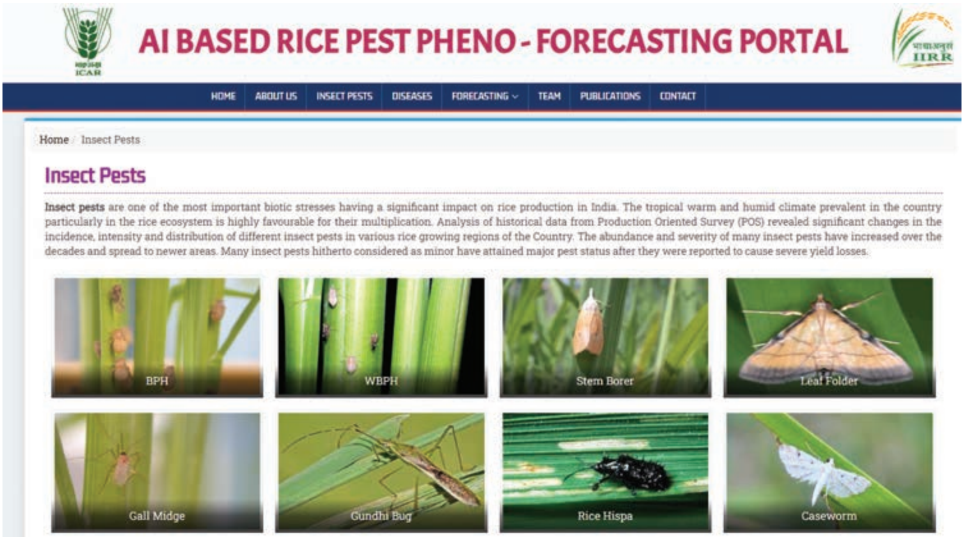




USP	:	AI powered mobile app for maize enables real time pest identification, surveillance, and management, supporting timely interventions, reducing crop losses, and promoting sustainable, precision maize cultivation
Name of the Inventors	:	Dr Niranjan Singh, Dr Anoop Kumar, and Dr MK Khokhar
More Information	:	Director, ICAR-National Research Institute for Integrated Pest Management, New Delhi - 110012

2.7 AI based rice pest pheno-forecasting portal

The AI-based Rice Pest Pheno-Forecasting Portal integrates real-time and historical weather data with pest phenology and crop growth models to simulate the life cycles and population dynamics of major rice pests, such as brown planthopper and leaf folders. Using geospatial mapping and predictive analytics, it generates localized forecasts, risk alerts, and management advisories, accessible via an interactive web interface for researchers, extension agents, and farmers. Unlike traditional reactive pest control methods, this portal combines climate data, pest biology, and crop modelling to provide predictive insights. It produces region-specific risk maps and timely alerts, enabling informed decisions to reduce unnecessary pesticide use and minimize crop losses. Overall, the Rice Pest Pheno-Forecasting Portal enhances sustainable rice production by delivering science-driven pest monitoring, early warnings, and actionable intelligence for effective pest management.



USP : The Rice Pest Pheno-Forecasting Portal predicts rice pest outbreaks using AI, climate data, and crop models, delivering localized risk alerts and actionable management advisories for sustainable pest control

Name of the Inventors: Dr CH Padmavathi, Dr B Sailaja, Dr Santosha Rathod, Dr M Srinivas Prasad, and Dr R Meenakshi Sundaram

More Information : Director, ICAR-Indian Institute of Rice Research, Hyderabad - 500030

2.8 AI based rice expert system

The AI rule-based Rice Expert System (http://www.ricexpert.in) is a comprehensive digital tool for rice pest and disease management, developed using Microsoft SQL as the back end and ASP.Net as the front end. It integrates three main components: a knowledge base, an inference engine, and a user interface. The knowledge base contains 90 rules for insect pest identification and 105 rules for disease diagnosis, providing extensive diagnostic coverage. The inference engine employs forward and backward chaining methods, supported by 16 stored procedures and 23 ASP pages, forming the system's core logic. The user interface uses a structured, image-assisted questionnaire, starting with location and weather details, followed by crop variety, growth stage, and observed symptoms. Each subsequent question is filtered based on previous responses, ensuring accurate diagnosis. The system evaluates economic threshold levels and generates tailored, location-specific management recommendations when thresholds are exceeded. The platform also maintains a dynamic, updatable database of emerging pest and disease trends, supporting monitoring and analysis of location-specific outbreaks. It has a 2 GB spatial database and low operational costs, requiring server space and technical personnel for updates. Future mobile integration will extend its reach, providing nationwide accessibility to farmers, researchers, and extension workers.

USP : Rice Expert System is an AI based digital tool providing accurate, location specific rice pest and disease diagnosis with tailored management recommendations, supporting cost effective, sustainable crop protection

Name of the Inventors: Dr B Sailaja, Dr AP Padma Kumari, Dr D Krishnaveni, and Dr R Meenakshi Sundaram

More Information : Director, ICAR-Indian Institute of Rice Research, Hyderabad - 500030

2.9 Image based hand held device for disease identification in soybean

A real-time detector for soybean leaf diseases based on deep convolutional neural networks was developed to identify the anthracnose, frogeye leaf spot (FLS), rhizoctonia aerial blight (RAB), soybean mosaic virus (SMV), and yellow mosaic virus (YMV). More than 3000 RGB images of disease-free leaves, anthracnose, FLS, RAB, SMV, and YMV-affected leaves of soybean were collected from the agriculture fields. The results indicate that maximum detection accuracy i.e. greater than 65% at 0.90 level of minimum detection confidence. Thus, proving that the real-time detector based on deep learning provides a feasible solution for diagnosing soybean leaf diseases. The cost of the device Rs. 15000/-.

USP	:	Deep Learning based real time detector identifies major soybean leaf diseases with over 65% accuracy, providing affordable, rapid, and practical disease diagnosis
Name of the Inventors	:	Dr Manoj Kumar, Dr Narendra Singh Chandel and Dr LS Rajput
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

2.10 SoyAI: Transforming soybean cultivation through AI modelling

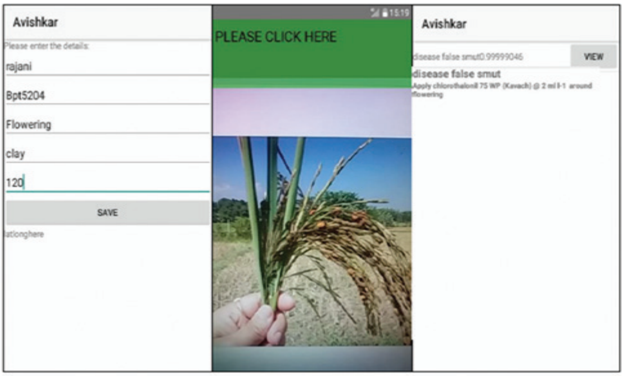
Soybean Gyan – AI Powered Mobile App is an advanced digital support to the soybean farming community. With an app size of 6.12 MB, it is easily downloadable and accessible on Android devices. Built using Flutter Framework and Dart Programming Language, compiled on Android Studio, the app offers a user-friendly, interactive interface delivering comprehensive information on soybean farming, production, and protection technologies. The app incorporates intelligent tools such as AI-based disease and pest diagnosis, AI-driven weather-based pest and disease prediction, and an AI-enabled chatbot for instant personalized assistance. It supports multiple languages, ensuring accessibility to diverse farmer groups. Additional features include farmer advisory services, guidance on good agricultural practices, weekly advisories, mandi price updates, and direct access to the ICAR-NSRI YouTube channel for practical learning through videos. With unlimited capacity and low operational costs, Soybean Gyan serves as a valuable resource for soybean cultivators and stakeholders. It bridges knowledge gaps, promotes scientific and sustainable cultivation practices, and supports profitable soybean farming by providing timely, accurate, and actionable information to farmers.

USP : Soybean Gyan is an AI-powered mobile app delivering disease diagnosis, weather based pest predictions, advisory services, and market insights, enabling sustainable, profitable, and informed soybean farming

Name of the Inventors: Dr Savita Kolhe

More Information : Director, ICAR-National Soybean Research Institute, Indore - 452001

2.11 AAVISHKAR- An AI based mobile application for diagnosing rice pests



Powered by a Convolutional Neural Network (CNN), AAVISHKAR diagnoses major biotic stresses in rice, including five insect pests, five diseases, and five weeds. Farmers input basic details such as name, location, variety, age, and soil type, and capture crop symptoms via camera. The app instantly identifies the stress, provides the class label with nearly 90% accuracy, and suggests control measures in both text and voice modes. It is simple to install on Android devices and has been demonstrated and adopted by farmers through ICAR-IIRR training programs. The app contains a database of more than 3000 images and is being further refined to include additional biotic and abiotic stresses, more images, and automated training and labelling APIs under the new title RAISE – Rice AI Stress Evaluator. The basic app size is 45 MB, with a tentative development cost of approximately Rs. 40 lakhs, covering image capture, AI model development, and integration. Operational costs include server/cloud space and technical support. RAISE enhances sustainable rice agriculture by providing real-time advisories, improving adaptive management, and generating actionable research insights. It supports farmers in timely stress management, strengthens resilience to climate variability, and contributes to food security and rural economic revitalization.

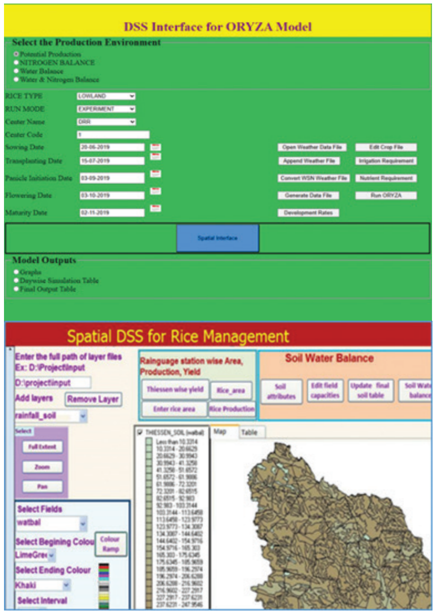
USP : AAVISHKAR uses CNN based AI to diagnose rice biotic stresses with ~90% accuracy, providing real time identification, control recommendations, and actionable advisories for sustainable, resilient rice farming

Name of the Inventors: Dr B Sailaja, Dr CH Padmavathi, Dr D Krishnaveni, Dr B Sreedevi, Dr GS Laha, Dr APK Padma Kumari, Dr MS Prasad, Dr Santosha Rathod, Dr Brajendra, Dr V Manasa, Dr R Mahender Kumar, and Dr N Somasekhar

More Information : Director, ICAR-Indian Institute of Rice Research, Hyderabad - 500030

2.12 SRDSS – Spatial rice decision support system

SRDSS – Spatial Rice Decision Support System is an advanced tool developed for site-specific rice crop management by integrating climate data, crop models, and GIS layers. It estimates rice yield and soil-water balance at polygon or pixel levels, offering multiple management options to simplify complex crop simulation models for common users. The system facilitates precision yield estimation, soil-water monitoring, and adaptive management decisions under varying climatic and soil conditions, making it useful for researchers, extension workers, farmers, and policymakers. The platform supports multi-source data integration, combining AI-based future climate projections, crop models, and spatial layers like soil and weather to generate reliable, actionable insights. It provides guidance on optimum sowing windows, irrigation scheduling, and other management practices. Using SRDSS, district-level climate potential yield gaps have been computed for major rice varieties across Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, and Kerala. The system has user-friendly interfaces, accessible on desktops, laptops, and Android devices, ensuring interoperability and wider adoption. SRDSS reduces operational complexity, supports policy planning, and advances digital agriculture. Operational costs include server space and technical personnel for updates, and the system is scalable to other crops and agro-climatic zones.



USP	:	SRDSS integrates climate data, crop models, and GIS to provide site specific rice management, enabling yield prediction, irrigation scheduling, and adaptive decisions for farmers, researchers, and policymakers
Name of the Inventors	:	Dr B Sailaja, Dr Santosh Rathod, Dr SR Voleti, Dr D Subrahmanyam, R Meenakshi Sundaram, Dr K Surekha, Dr P Raghuveer Rao, and Dr R Mahender Kumar
More Information	:	Director, ICAR-Indian Institute of Rice Research, Hyderabad - 500030

2.13 IoT based crop advisory system for tomato insect pests

The IoT-based crop advisory system for tomato provides timely forewarnings of pest occurrences by analyzing weather parameters and crop growth stages. By predicting potential pest outbreaks in advance, the system enables farmers to implement precautionary measures, reducing crop losses effectively. The portal also tracks the occurrence of pests and natural enemies, including invasive species, across India over time, helping monitor pest migration patterns from one region to another. When farmers input pest occurrence data, the system automatically captures weather data based on spatial coordinates, ensuring accurate and location-specific advisories. This integrated IoT-based approach combines real-time environmental monitoring with crop phenology to deliver actionable insights, supporting proactive pest management. Overall, the system enhances tomato crop protection, improves yield, and contributes to sustainable and efficient farming practices by enabling informed, data-driven decisions.

USP : IoT-based tomato advisory system predicts pest outbreaks using weather and crop data, enabling proactive management, reducing losses, and data driven farming

Name of the Inventors: Dr M Pratheepa, Dr K Sreedevi, Dr Gundappa, and Dr K Selvaraj

More Information : Director, ICAR-National Bureau of Agricultural Insect Resources, Bangalore - 560024

2.14 PIMS: Pest identification management system for brinjal and okra

PIMS okra and brinjal is an AI-based mobile application designed for the identification and management of key pests in the crops. The app enables farmers, extension workers, and agronomists to quickly detect pest infestations and provides recommended control measures for effective crop protection. It integrates artificial intelligence to ensure accurate, real-time pest identification, simplifying decision making for pest management. The app is currently available in two languages, making it accessible to a wider range of users. By offering a user-friendly interface and actionable guidance, PIMS supports sustainable farming, reduces crop losses, and enhances productivity in okra and brinjal cultivation.

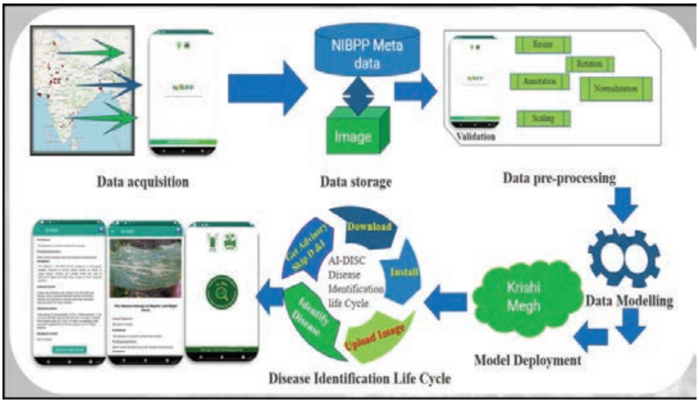
USP : PIMS Okra and Brinjal app uses AI for real time pest identification and management, providing actionable guidance to enhance crop protection, productivity, and sustainable farming practices

Name of the Inventors: Dr Niranjan Singh, Dr PN Meena, and Dr Raghavendra D

More Information : Director, ICAR-National Research Institute for Integrated Pest Management, New Delhi - 110012

2.15 AI-DISC: Multi crop disease identification mobile application

The mobile app enables capturing and managing images of crop and livestock diseases for online databases. It is useful for disease identification in multiple crops, including field and horticultural crops. Using deep learning models, the app can diagnose over 50 diseases across 19 major crops, including 10 horticultural crops. The platform allows farmers and allied communities to access real-time diagnostic support, improving pest and disease management. The developed app, AI-DISC, is available on Google Play, facilitating practical demonstrations and adoption among end users.



USP : AI-DISC delivers instant, expert level crop disease and pest diagnosis through AI powered image analysis, bringing real time scientific advisory directly to farmers smartphones

Name of the Inventors: Dr Sudeep Marwaha, Dr RC Agrawal, Dr Rajender Parsad, Dr Ramasubramanian V, Dr Alka Arora, Dr Anshu Bharadwaj, Dr Ajit, Dr Shashi Dahiya, Dr SN Islam, Dr Chandan Kumar Deb, Dr Md Ashraful Haque, Dr Sapna Nigam, Dr Mrinmoy Ray, Dr Achal Lama, Dr Soumen Pal, Dr Rajni Jain, Dr Sujay Rakshit, Dr P Lakshmi Soujanya, Dr Sumit Kumar Aggarwal, Dr KS Hooda, Dr Brejesh Lall, Dr Lokesh Gupta, Dr Kalpit Dipakkumar Shah, Dr Prasannakumar MK, Dr VS Acharya, Dr Abhishek Shukla, Dr Ladhu Ram Choudhary, Dr Palash Deb Nath, Dr Shubha Trivedi, Dr Mehraj Ul Din Shah, Dr Ravinder Singh Rana, Dr Subrata Dutta, and Dr Vaibhav Kumar Singh

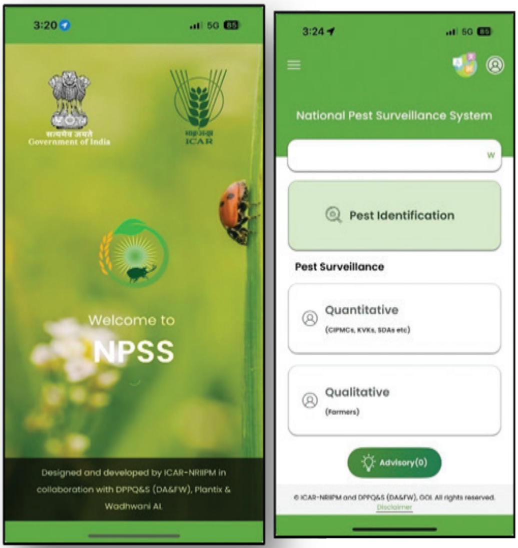
More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi-110012

2.16 PUSAeCMS: Internet-based crop monitoring system

It is a cloud based platform enabling near-real-time monitoring of crop health over large areas and multiple temporal scales without delays. It significantly reduces the labour, energy, and time required in traditional crop monitoring methods and can scale from small fields to village, district, state, and country levels, with some limitations on processing time, spatial resolution, and temporal scale. The system allows rapid big data analytics for efficient retrieval of crop condition information and supports additional functionalities such as differentiating moist and dry soil, identifying paddy versus non-paddy fields, and detecting waterlogged areas for flood damage assessment. The tool features a custom GUI-driven codebase for satellite image analysis and can process multi-resolution satellite data across months or years. It integrates 120+ spectral indices, composite crop health indices, and machine learning or physical model-based generation of biophysical products such as LAI, chlorophyll, nitrogen, water content, and soil moisture. PUSAeCMS is linked with Google Earth Engine (GEE), digital soil fertility maps, and supports drone-image analytics. It provides easy visualization and exports results in generic formats (.csv, .geotiff) and has been validated for crops like rice, wheat, cotton, and banana. The platform is free of cost with no operational charges.

USP	:	PUSAeCMS is a cloud-based platform for near-real-time, large-scale crop monitoring, integrating multi resolution satellite data, AI analytics, and biophysical indices to support efficient, scalable, and free crop management
Name of the Inventors	:	Dr RN Sahoo, Dr Tarun Kondraju, Dr Rajeev Ranjan, Dr Rejith RG, Dr Amrita Bhandari, Dr Shalini Gakhar, Dr Viswanathan C, Dr Anil Rai, and Mr Sanjeev Kumar
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.17 National pest surveillance system (NPSS) leveraging AI



National Pest Surveillance System (NPSS) is a digital platform that utilizes artificial intelligence (AI) and modern ICT tools, including smartphones and web-based applications, to support pest identification and deliver pest surveillance-based advisories to farmers. The system provides AI-based identification of pests across 65 crops and enables the surveillance of key pests in 31 major crops, generating actionable management recommendations for farmers. NPSS integrates pest monitoring with advisory services, allowing farmers to receive timely and accurate guidance for effective pest management. The platform is designed to simplify pest diagnosis, reduce crop losses, and promote sustainable farming practices. By combining advanced technology with localized information delivery, NPSS helps farmers make informed decisions, enhances the efficiency of pest management strategies, and contributes to increased productivity and resilience in Indian agriculture. It is currently available in six Indian regional languages, ensuring accessibility to a diverse farming community.

USP	:	NPSS is an AI powered platform providing real time pest identification and localized management advisories across 65 crops, enabling informed, sustainable, and efficient pest management for Indian farmers
Name of the Inventors	:	Dr Niranjan Singh, Dr Anoop Kumar, Dr MK Khokhar, Dr PN Meena, Dr M Malik, Dr M Chaudhary, Dr Raghvendra D, Dr Ajanta Birah, and Dr SK Singh
More Information	:	Director, ICAR- National Research Institute for Integrated Pest Management, New Delhi - 110068

2.18 Tilhantec – Oilseeds Doctor: An AI tool for identification and advisory for managing diseases and insects in oilseed crops

Tilhantec is an AI-powered mobile web application developed for the identification and management of diseases and insect pests in oilseed crops such as sesame, castor, safflower, and sunflower. The tool employs advanced deep learning models, including MobileNet, DenseNet, and Inception, to ensure accurate detection and classification of pests and diseases. Supporting unlimited users, it provides actionable advisories to farmers, extension officials, and other stakeholders. Integrated with offline functionality, the application enables users in remote and connectivity-limited areas to access reliable diagnostics without internet access. The technology facilitates better decision-making and crop management, ensuring accessibility for users without technical expertise while supporting sustainable oilseed cultivation and improving livelihoods.

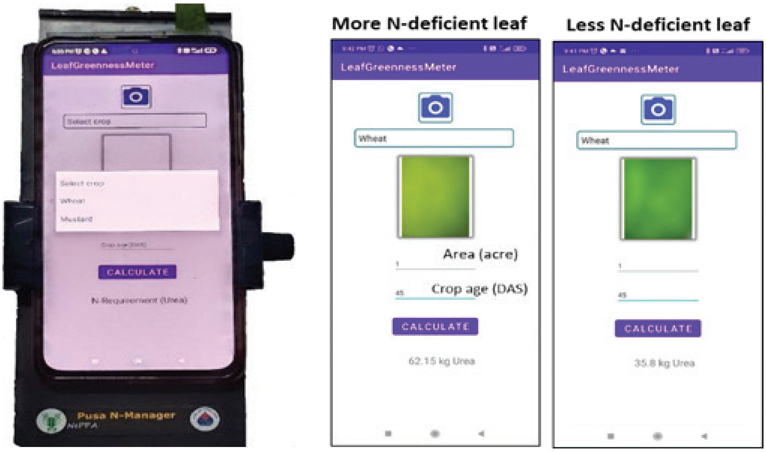
USP : Tilhantec AI app enables accurate, offline identification and management of pests and diseases in oilseed crops, supporting sustainable cultivation and informed decision making for all users

Name of the Inventors: Dr CH Sarada, Dr M Santha Lakshmi Prasad, Dr RD Prasad, Dr K Sakthivel, Dr PS Srinivas, Dr P Duraimurugan, Dr T Boopathi, and Dr M Suresh

More Information : Director, ICAR-Indian Institute of Oilseeds Research, Hyderabad - 500030

2.19 PUSA N-Manager: Mobile application for nitrogen management

A smartphone-based device has been developed to estimate the in-season top-dress nitrogen (urea) requirement for wheat using RGB images of leaves. It is primarily used during critical growth stages such as crown root initiation and booting. The system calculates the precise nitrogen requirement in the background and presents the results in terms of urea, considering that urea contains 46% nitrogen, making it easier for farmers to interpret. The device weighs 500 grams and measures 15 × 5 cm. Tentative cost per unit is Rs. 500, and it requires a smartphone. The second leaf from the top is placed in the sample holder beneath the camera lens, and the built-in light source ensures controlled illumination. Ten measurements are recommended for accuracy. The device's advantages include contact sensing for precise leaf positioning and controlled lighting, allowing reliable image capture anytime. Using the RGB images, a spectral index called Greenness Fraction (GF) is calculated. A regression model estimates actual leaf nitrogen (Na), compared with critical nitrogen concentration (Nc) from InfoCrop simulations. The nitrogen deficit is divided by nitrogen use efficiency (50%) to compute the required urea for the specified area, enabling precise and timely fertilization.



USP	:	Smartphone based device uses RGB leaf images and AI to estimate in-season wheat nitrogen requirements, enabling precise, timely urea application and improving fertilizer use efficiency
Name of the Inventors	:	Dr Rajkumar Dhakar
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

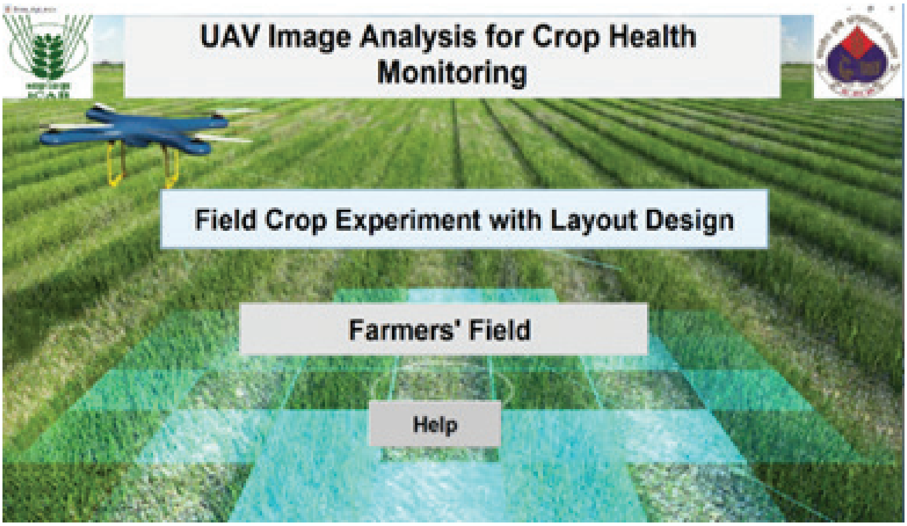
2.20 Pusa phenomobile: GPS guided autonomous mobile platform for crop phenotyping

Pusa Phenomobile is a GPS-guided, autonomous mobile platform designed to overcome the limitations of traditional labour intensive crop monitoring methods. Built on a robust platform measuring 1.2 × 3.5 m and costing approximately Rs.15 lakhs, it can navigate difficult field paths with ease. Equipped with a self-stabilizing boom adjustable for different heights and angles, the Phenomobile enables precise observation of crop health using imaging and non-imaging sensors with the help of AI. This stable, versatile system allows efficient, large-area crop monitoring without additional operational costs, enhancing data collection for research, precision agriculture, and decision-making in field management.

USP	:	Pusa Phenomobile is a GPS guided autonomous platform that uses AI enabled sensors for precise, large area crop monitoring, reducing labour while enhancing research and precision agriculture decisions
Name of the Inventors	:	Dr RN Sahoo, Dr Sudhir Kumar, Dr Raju Dandapani, Dr Rajeev Ranjan, Rahul Tiwari, and Dr C Viswanathan
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.21 Drone Agri: Software for real time monitoring of crop health

Drone Agri is a small (30 MB) software tool developed for fast processing of drone-based RGB and multispectral images to enable near-real-time crop health monitoring. With a tentative cost of Rs. 1 lakh and no operational costs, the software efficiently calculates multiple vegetation indices for individual plots or entire fields, reducing the labor, energy, and time required by traditional monitoring methods. It provides ready-to-analyze outputs in CSV format, allowing researchers and farmers to quickly assess crop conditions with the help of AI. By streamlining drone imagery analysis, Drone Agri supports precise, timely, and scalable decision-making for effective crop management and improved agricultural productivity.



USP	:	Drone Agri: Software rapidly processes drone RGB and multispectral images to provide AI driven, near-real-time crop health monitoring, enabling precise, scalable, and time efficient decision making
Name of the Inventors	:	Dr RN Sahoo, Dr Swati Goel, Dr Amrita Bhandari, Dr Rajeev Ranjan, Dr Sudhir Kumar, Dr Dhandapani R, Dr Viswanathan C, Dr Tarun Kondraju, Dr Rejith RG, and Dr Shalini Gakhar
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.22 Mobile application for non-chemical methods in insect pest management

BIPM for tomato pests is an AI-based mobile application developed to support sustainable and biologically driven pest management in tomato cultivation. The app focuses on accurate detection and classification of major tomato insect pests and their natural enemies, helping farmers distinguish harmful insects from beneficial predators and parasitoids. Using artificial intelligence and machine learning techniques, the app enables users to upload field images through smartphones for instant diagnosis and advisory support. It identifies key pests such as Phthorimaea absoluta, Helicoverpa armigera, Liriomyza trifolii, Bemisia tabaci, and Spodoptera litura, along with natural enemies including Trichogramma spp., Chrysoperla spp., coccinellids, spiders, and braconid parasitoids. The system is trained on a comprehensive image dataset of approximately 12,000 labelled images, ensuring reliable prediction and classification. By promoting awareness of beneficial insects, the app encourages adoption of biological control practices and reduces unnecessary pesticide use. The platform can be integrated with tomato crop advisory systems and accessed in hybrid mode across mobile phones, tablets, desktops, and web interfaces. Overall, BIPM for tomato pests empowers farmers with timely, eco-friendly pest management decisions and improved productivity.

USP	:	BIPM app uses AI to accurately identify tomato pests and beneficial insects, enabling eco-friendly, biologically driven pest management and reducing unnecessary pesticide use
Name of the Inventors	:	Dr M Pratheepa, Dr K Subaharan, and Dr Richa Varshney
More Information	:	ICAR-National Bureau of Agricultural Insect Resources, Bangalore - 560024

2.23 Smart trap for real-time monitoring pink bollworm in cotton

The AI Smart Trap for monitoring pink bollworm in cotton is an automated pheromone trap that captures insect images, counts trapped insects using an inbuilt machine learning algorithm, and transmits data along with weather parameters to a remote server for real-time pest monitoring. This enables timely pest management advisories and informed decisions for farmers and government agencies. Each trap covers a village, costs Rs. 42,000, weighs 20 kg, measures 210 × 45 cm, and incurs an operational cost of Rs. 4,000 per year for 5G data and consumables. Deployed in Bathinda, Mansa, and Muktsar districts of Punjab, the AI Trap integrates pest data with environmental parameters to support site-specific, data-driven interventions. Its use has helped maintain pink bollworm populations below the Economic Threshold Level (ETL), resulting in a 36.61% reduction in pesticide use, 34.2% reduction in pesticide costs, and a 16.54% increase in yield compared to conventional pest management methods. This technology provides a cost-effective solution for cotton pest management.Top of Form

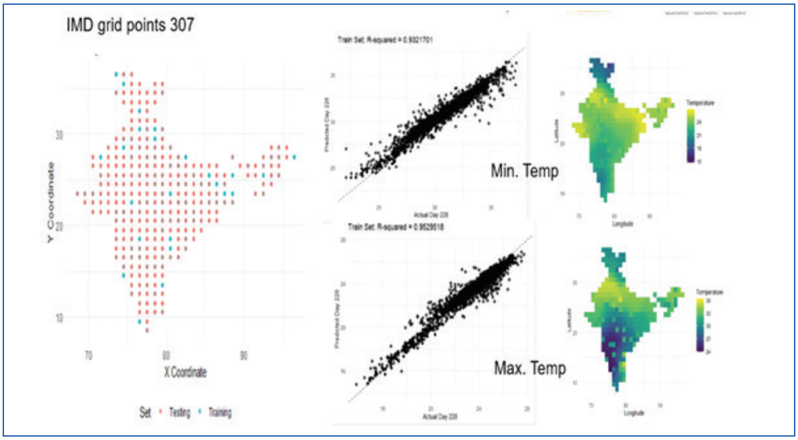
USP : AI Smart Trap automates pink bollworm monitoring in cotton, integrating pest counts and environmental data to enable real time, site specific management, reducing pesticide use and increasing yields

Name of the Inventors: Dr K Rameash

More Information : Director, ICAR-Central Institute for Cotton Research, Nagpur - 441108

2.24 Spatial temperature predication using GRF model for real time advisory

The Spatial Temperature Prediction system employs a Geographic Random Forest (GRF) machine learning model to estimate daily temperatures across India using historical IMD gridded data. The GRF model achieves high accuracy with R^2 values up to 0.9 and low MSE, capturing spatial variability for fine-scale, location-specific temperature predictions. These predictions are used to model rice phenology through Growing Degree Days (GDD), enabling identification of optimum sowing and transplanting windows, forecasting pest development stages, and recommending heat-tolerant rice varieties. The system is scalable, cost-effective, and updatable using freely available data. Performance evaluation using the D-Index yielded values between 0.91–0.95, indicating high reliability in predicting rice growth stages. Integration with spatial decision support systems allows climate-resilient agricultural planning, optimizing crop management under temperature variability. By providing targeted recommendations for sowing, variety selection, and pest forecasting, the model improves crop establishment, reduces heat stress risks, minimizes yield variability, and enhances productivity.



USP : Geographic Random Forest–based temperature prediction enables fine scale rice phenology modeling, optimizing sowing windows, pest forecasting, and heat resilient variety selection for climate smart crop management

Name of the Inventors: Dr B Sailaja, Dr Santosh Rathod, Dr CH Padmavathi, Dr R Mahender Kumar, and Dr R Meenakshi Sundaram

More Information : Director, ICAR-Indian Institute of Rice Research, Hyderabad - 500030

2.25 Drone based grassland development for degraded land restoration

Drone-based grassland development offers an innovative solution for restoring degraded lands and addressing fodder deficits in India. Lightweight native grass seeds, combined into pellets, are efficiently sown using drones, overcoming the challenges of tough and inaccessible terrains. The system includes a small-size drone and a seed pelleting machine, with a tentative cost of Rs. 30 lakhs and operational expenses around Rs. 10 lakhs. This technology supports rehabilitation of degraded lands, management of permanent pastures, silvipastoral systems, village common lands, *gaushalas*, forest fringe areas, and other hard-to-reach regions. Additionally, it enables economic valuation of ecosystem services, including carbon credit generation from restored grasslands and Payment for Ecosystem Services (PES) to dependent communities. By combining advanced drone technology with ecological restoration, this approach provides a cost-effective, and everlasting strategy for enhancing pasturelands, improving fodder availability, and promoting environmental and socio-economic benefits.





USP : Drone based grassland development enables efficient sowing of native seed pellets in inaccessible terrains, restoring degraded lands, improving fodder availability, and generating ecosystem services and carbon credits

Name of the Inventors: Dr Amit K Singh, Dr Avijit Ghosh, and Dr Sunil R Swami

More Information : Director, ICAR-Indian Grassland and Fodder Research Institute, Jhansi - 284003

2.26 Machine vision based site specific sprayer for vegetable crops

A machine vision–based site-specific target sprayer was developed for vegetable crops to enable real-time disease detection and precise pesticide application. The system uses a YOLOv10n object detection model, which demonstrated high performance with precision, recall, and mAP50 values of 0.953, 0.945, and 0.979, respectively. Mounted on a remotely operated platform powered by a quad-core ARM Cortex-A57 processor, the sprayer performs targeted spraying only on diseased crop regions. The machine has a field capacity of 0.021 ha h^{-1}, field efficiency of 60.77%, and detection–actuation accuracy of 76.11%. During field evaluation in tomato crops, it achieved a 76.30% reduction in pesticide use compared to conventional knapsack spraying while maintaining effective disease control. The sprayer weighs approximately 60 kg, operates at a cost of Rs.170 per hour, and requires 61 Wh power. With a total development cost of about Rs. 1.56 lakh, the system offers an economically viable solution with a payback period of 3.69 years, promoting sustainable and efficient crop protection.

USP : Machine vision guided target sprayer uses real time AI disease detection to cut pesticide use by over 76% while ensuring precise, economical, and sustainable vegetable crop protection

Name of the Inventors: Dr Roaf Ahmad Parray, Dr Tapan Kumar Khura, and Dr Bishnu Maya

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.27 ML based early detection of fungal foliar disease and bacterial wilt disease in potato crop

The application of machine learning with hyperspectral imaging and remote sensing was focussed for the early detection of fungal foliar diseases and bacterial wilt in potato crops. The proposed system captures hyperspectral data in the 400–1000 nm range with 200–250 contiguous bands, enabling detection of subtle physiological changes before visible symptoms appear. Operating at a scanning rate of 1–1.5 ha per hour with 2–5 cm spatial resolution, the system generates high-resolution, field-scale disease-risk maps. Machine learning models analyze spectral signatures to classify disease presence, assess severity, and identify geotagged hotspots using a robust database of over 1,200 potato leaf scans covering early to late disease stages, supporting precision disease management. The platform provides real-time alerts and visual dashboards and can be integrated with existing GIS and farm-management systems for automated decision support. Overall, the technology enables timely, site-specific interventions, reduces unnecessary chemical use, and promotes potato production through early and accurate disease diagnosis.

USP : ML driven hyperspectral imaging enables early, field scale detection and mapping of potato diseases before visible symptoms, supporting timely, site specific interventions and reduced chemical use

Name of the Inventors: Dr V Shanmugam

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.28 A tele-robotic target-specific selective pesticide applicator for greenhouse and open-field

A tele-robotic target-specific selective pesticide applicator was developed for use in both greenhouse and open-field conditions to improve spray efficiency and operator safety. The system uses foliage-sensing sensors to detect crop presence and activate spraying only when required, thereby minimizing chemical wastage. The total development cost of the robot is Rs. 1,20,000, while the operational cost for pesticide application is Rs. 99.60 per hour. Field trials demonstrated a 24.95% reduction in pesticide use when sensor-based spraying was activated compared to continuous spraying. The applicator also enhances worker safety by preventing direct chemical exposure and includes safety features such as low-tank alarms. Optimal spray performance was achieved using a flat-fan nozzle at 1 km/h, producing adequate spray coverage, suitable droplet size, and uniform droplet distribution for effective pest control.

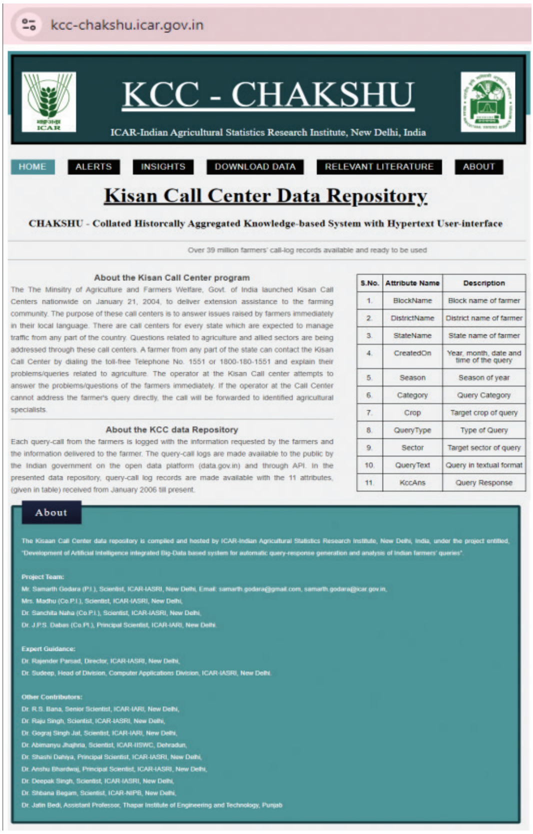
USP : Tele-robotic, sensor based pesticide applicator enables target-specific spraying, reducing chemical use by ~25%, improving operator safety, and enhancing spray efficiency in greenhouse and field crops

Name of the Inventors: Dr Mude Arjun Naik, Dr Adarsh Kumar, Dr Dilip Kumar Kushwaha, and Dr HL Kushwaha

More Information : Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

2.29 KCC-CHAKSHU: Collated historically aggregated knowledge based system with hypertext user interface

The KCC-CHAKSHU portal is a data driven initiative to strengthen India's Kisan Call Center (KCC) system through the integration of AI and Big Data analytics. The portal analyzes over 40 million pre-processed farmer queries to generate real time insights, enabling faster, more accurate, and evidence based agricultural advisories. Multiple AI driven frameworks have been developed under this initiative. AgriResponse provides text based plant protection solutions, while AgriMine extracts national level spatial and temporal patterns from helpline data, with temporal convolution networks proving effective in forecasting seasonal crop needs. AgrIntel focuses on food production challenges and disease outbreak prediction using advanced deep learning models. Together, these frameworks enhance agricultural extension services, support policy formulation, enable targeted interventions, and promote sustainable, data informed decision making for farmers, researchers, and policymakers.



USP : KCC-CHAKSHU transforms millions of farmer queries into real time, AI driven insights, enabling faster advisories, disease forecasting, and data backed agricultural decision making at a national scale

Name of the Inventors: Dr Samarath Godara

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

Chapter 3
Soft Tools in Genomic Research

Genomic research has long made adaptive use of bioinformatics software and computation techniques leveraging machine learning and statistical modelling enabled efficient analysis, interpretation, and application of complex biological data. Machine learning interventions have enabled the integration of algorithms, predictive models, and spectral analytics to play a pivotal role in translating large-scale genomic and phenotypic datasets into actionable insights for crop improvement, and sustainable nutrient management.

Bioinformatics software for genome sequence coverage inspection ensures the quality and completeness of sequencing data, forming a critical foundation for accurate genome assembly and its variant detection. Machine learning–based servers for the identification of anti-nutritional proteins in plants accelerate screening processes, aiding the development of nutritionally enhanced crop varieties. Similarly, prediction servers for aluminium toxicity tolerance genes enable rapid identification of stress-resilient genotypes, supporting breeding programs for acid-soil environments. Local ancestry analysis in cross breeds provides deeper understanding of genetic inheritance and trait expression, strengthening selective breeding strategies. In parallel, near-infrared spectroscopy (NIRS)–based prediction models offer rapid, non-destructive assessment of nutritionally relevant biochemical traits, linking genomics with phenomics.

These soft tools will enhance the speed, accuracy, and impact of genomic research, enable data-driven innovation and support wholesomely to achieve sustainable agriculture and livestock improvement targets.

3.1 Bioinformatics software for genome sequence coverage inspection

Genome Sequence Coverage Inspection Tool (GSCIT) is a novel GUI-based bioinformatics desktop software developed to assess genome sequence coverage of Next-Generation Sequencing (NGS) data at the raw level. Sequence coverage is a critical indicator of data sufficiency for accurate gene discovery; however, no dedicated tool previously existed to evaluate coverage quality prior to downstream analysis. GSCIT addresses this gap by enabling comprehensive coverage profiling using a novel AI-integrated hash table mapping algorithm, ensuring precise and efficient read mapping across organisms from any biological kingdom. The software is platform-independent, compatible with Linux, macOS, and Windows, and operates fully offline, offering enhanced data security without reliance on external tools or libraries. GSCIT can handle genomic datasets ranging from small viral genomes (e.g., SARS-CoV-2) to large and complex genomes such as wheat. Its intuitive graphical interface makes it accessible to both researchers and professionals, reducing analysis time, effort, and cost. Developed at an approximate cost of Rs. 7 lakh, GSCIT is the first Indian GUI-based bioinformatics desktop software for coverage inspection and is publicly available free of cost. The tool provides a robust, secure, and versatile solution for accurate genomic research and quality assessment using AI.

USP : GSCIT is a free, offline, platform independent GUI tool using AI integrated algorithms to accurately inspect NGS genome coverage, ensuring reliable data quality before downstream genomic analysis

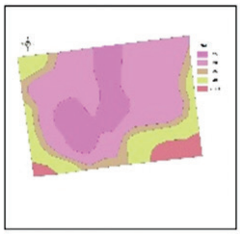
Name of the Inventors: Dr Shbana Begam, Dr Samarth Godara, Dr Ramcharan Bhattacharya, Dr Anil Kumar Singh, Dr Sudeep Marwaha, and Dr Rajender Parsad

More Information : Director, ICAR-National Institute for Plant Biotechnology, New Delhi - 110012

3.2 Nitrogen application dose estimation algorithm for cotton

An in-season nitrogen (N) application dose estimation algorithm for cotton was developed using drone-based multispectral imaging to enable precise and site-specific nutrient management. The approach is based on the relationship between cotton canopy reflectance at specific wavelength bands and leaf tissue nitrogen concentration. Multispectral images acquired using a drone-mounted sensor were processed to derive vegetation indices, particularly the normalized difference red-edge (NDRE), which showed a statistically significant relationship with leaf N content at flowering and boll formation stages, this enabled generation of spatial Nitrogen Adequacy Index (NAI) maps to assess in-field N sufficiency. The AI based algorithm supports preparation of management zone maps for variable-rate nitrogen application, enhancing fertilizer-use efficiency and yield optimization. The drone-based multispectral imaging and processing system costs approximately Rs. 20 lakh, offering a scalable solution for precision cotton nutrition management.





USP	: Drone based multispectral imaging with AI algorithm enables in season, site specific nitrogen dose estimation in cotton, improving fertilizer use efficiency and yield through variable rate application
Name of the Inventors	: Dr R Raja, Dr D Kanjana, Dr AH Prakash, Dr P Nalayini, Dr K Rameash, Dr D Blaise, and Dr VN Waghmare
More Information	: Director, ICAR-Central Institute for Cotton Research, Nagpur - 441108

3.3 ML based server for identification of anti-nutritional proteins in plants

Anti-nutritional factors are inherently present in major crop plants and negatively affect the bioavailability of essential vitamins and minerals when consumed by humans. There is currently no dedicated computational platform available for the systematic identification of plant proteins encoding anti-nutritional factors. To address this gap, an online server named ANPS (Anti-Nutritional Protein Server) has been developed. ANPS is the first machine learning–based server specifically designed for the identification of anti-nutritional proteins in crop plants. The server employs multiple supervised learning algorithms, including Support Vector Machine (SVM), Random Forest (RF), AdaBoost, Extreme Gradient Boosting (XGBoost), and Naïve Bayes (NB), to ensure robust and accurate prediction performance. The backend of ANPS is developed using Python, while the user-friendly web interface is implemented using HTML. ANPS provides a reliable and efficient computational tool to support plant biologists and breeders in identifying anti-nutritional proteins, thereby facilitating the development of nutritionally improved crop varieties.

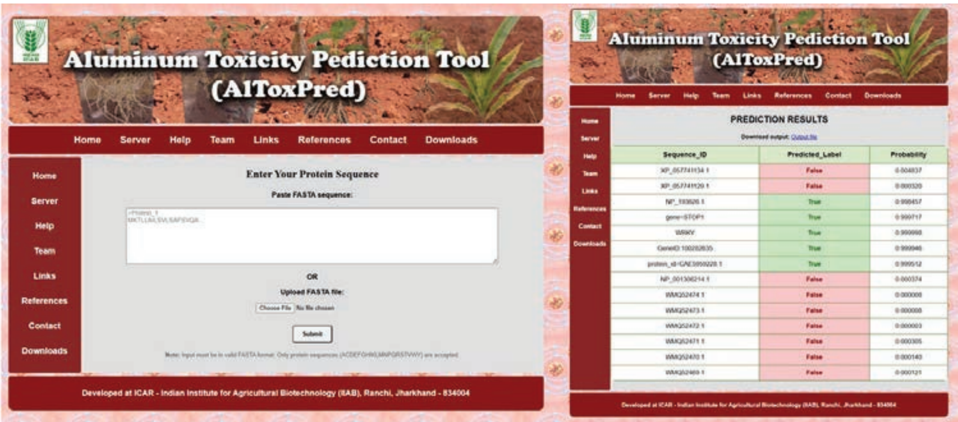
USP : ANPS is the first ML based online server for accurate identification of anti-nutritional proteins in crops, supporting development of nutritionally improved plant varieties

Name of the Inventors: Dr Yuvaraj I

More Information : Director, ICAR-National Institute for Plant Biotechnology, Pusa, New Delhi - 110012

3.4 Prediction server for aluminium toxicity tolerance genes

Aluminium toxicity is a major constraint to crop productivity in acidic soils, severely affecting root growth and nutrient uptake. Identification of aluminium toxicity tolerance genes is therefore crucial for developing stress-resilient crop varieties. This computational tool enables accurate prediction of aluminium toxicity tolerance genes from newly sequenced genomes of any crop species. By integrating advanced machine learning–based prediction models, the server provides a rapid and cost-effective approach for large-scale genome analysis with an accuracy of 93.5%. Genes identified through the tool can be further validated using experimental and molecular techniques and subsequently utilized in crop improvement programs. The application of this tool supports marker-assisted selection and genetic engineering approaches aimed at enhancing aluminium stress tolerance. Overall, the server offers a valuable resource for plant scientists and breeders seeking to accelerate the development of aluminium toxicity–tolerant crop varieties, contributing to sustainable agriculture and improved crop performance under acidic soil conditions.



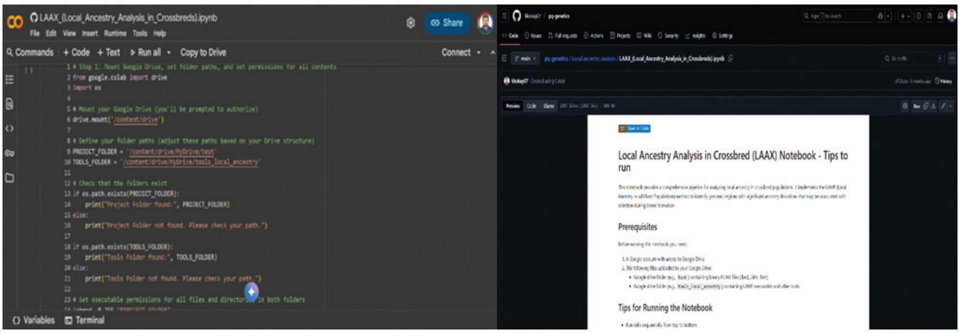
USP : Machine learning based genomic server rapidly predicts aluminium toxicity tolerance genes across crops, enabling cost effective genome analysis and accelerating development of stress resilient varieties

Name of the Inventors: Dr Tanmaya Kumar Sahu, Divya Ranjan Pradhan, Piyush Kumar, KR Soren, Sandip Garai, and Kishor U Tribhuvan

More Information : ICAR-Indian Institute of Agricultural Biotechnology, Ranchi - 834003

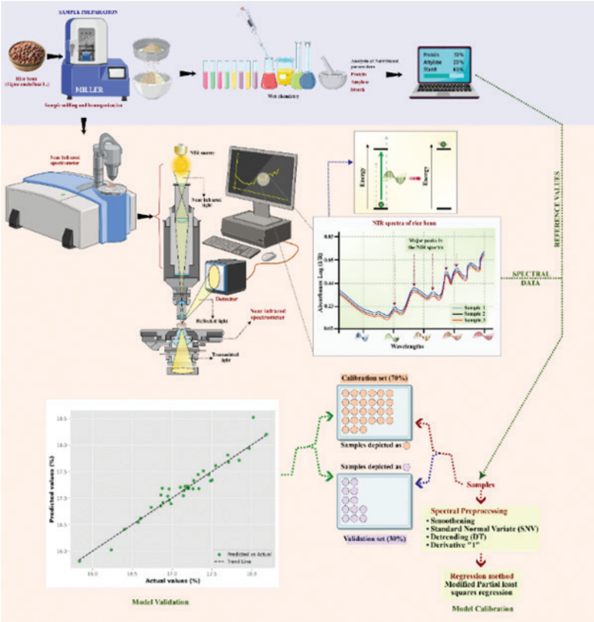
3.5 Local ancestry analysis in cross breeds

Genomic exploration of lesser-known chicken populations of Jharkhand is essential for understanding their genetic diversity, ancestry composition, and adaptive potential. We developed LAAX (Local Ancestry Analyses in Crossbreds), a computational framework for analyzing local ancestry patterns in crossbred populations using machine learning–based approaches. LAAX enables identification of genomic regions exhibiting post-admixture signatures of selection, including selective sweeps and adaptive introgression events that occurred during breed formation. The tool employs Hidden Markov Models and statistical clustering algorithms to detect significant ancestry deviations across the genome. LAAX supports input data up to 100 MB, requires minimal disk space (132 KB), and operates with 16 GB RAM. Developed entirely using open-source tools such as Python and Google Collaboratory, the platform incurs no developmental or operational costs. LAAX provides a valuable resource for population genetics research, breeding decision-making, and conservation strategies in crossbred livestock populations.



USP	:	LAAX is a zero-cost, ML based genomic framework enabling precise local ancestry analysis to detect selection and adaptive introgression in crossbred chicken populations for breeding and conservation
Name of the Inventors:		Dr Kanaka KK, Dr Sandip Garai, and Dr Tanmaya K Sahu
More Information	:	Director, ICAR-Indian Institute of Agricultural Biotechnology, Ranchi - 834003

3.6 NIRS-based prediction models for analysing nutritionally relevant biochemical traits



Rapid and accurate assessment of nutritional quality is critical for the improvement and utilization of underutilized crop species. The proposed approach enables rapid, non-destructive, and high-throughput prediction of nutritionally relevant biochemical traits, offering an efficient alternative to conventional laboratory-based methods. It facilitates large-scale screening of extensive germplasm collections to identify nutrient-rich genotypes with superior nutritional profiles using AI. The system provides strong support to crop improvement programs by enabling trait-specific core set selection and targeted breeding for enhanced nutritional traits. In addition, the platform benefits industrial stakeholders by accelerating the development of value-added food, feed, and nutraceutical products derived from underutilized crops. By significantly reducing dependence on time-consuming and costly wet-lab assays, the approach lowers the overall cost per analysis while improving throughput and decision-making efficiency. Overall, this technology contributes to sustainable nutrition-focused breeding and enhanced utilization of crop genetic resources.

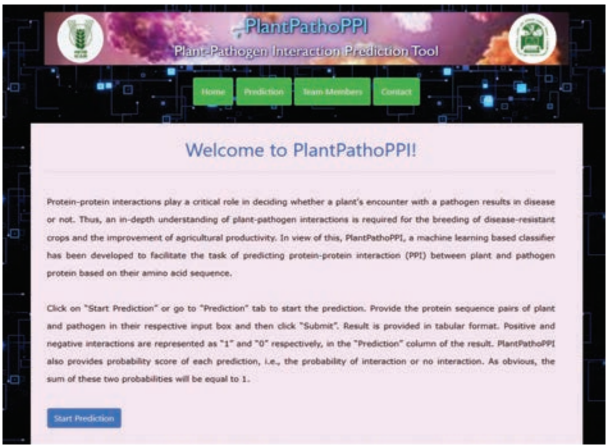
USP : AI enabled, non-destructive high-throughput platform rapidly predicts nutritional traits in underutilized crops, and reducing lab costs while accelerating nutrition focused breeding and value added product development

Name of the Inventors: Dr Simardeep Kaur

More Information : Director, ICAR Research Complex for NEH Region Umiam - 793103

3.7 PM_ProInteract: A web application predict protein-ligand interaction in plants and microbes

PM_ProInteract is a comprehensive web based platform designed to predict protein ligand interactions in plants and microbes, which are fundamental to plant growth, immunity, and microbial pathogenicity. Experimental methods for studying these interactions are time consuming, while traditional computational approaches often oversimplify binding dynamics. PM_ProInteract addresses these challenges using machine learning driven, data centric models capable of capturing diverse interaction patterns. The platform integrates two core components: PhytoMicroBioPred, a classification model that predicts small molecule interactions with plant and microbial proteins with accuracies of 86% and over 90%, respectively; and PlantPathoPPI, an ensemble based model for plant pathogen protein protein interactions achieving approximately 97% accuracy. By combining protein ligand and protein-protein interaction predictions, PM_ProInteract enables efficient screening of bioactive compounds, identification of virulence factors, and discovery of host defense regulators, supporting sustainable crop protection and disease resistant crop development.



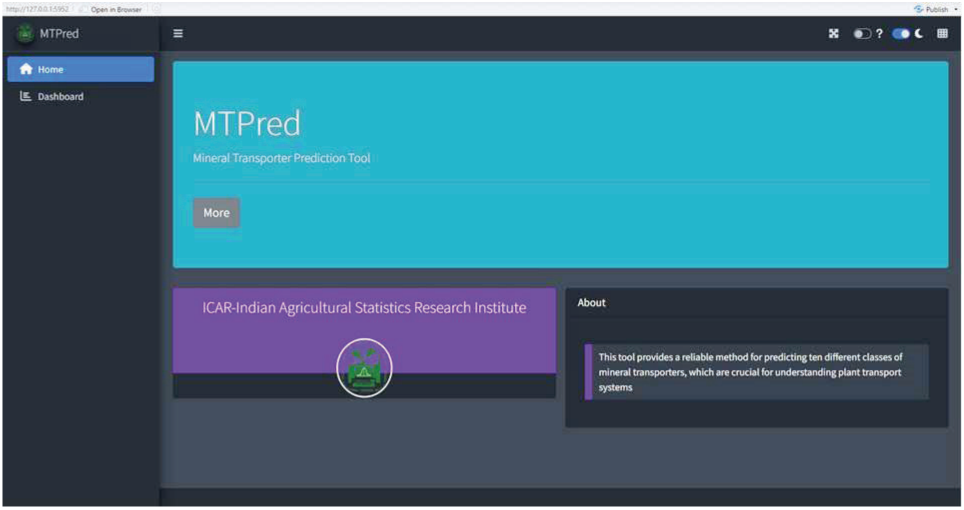
USP : A unified, high accuracy ML platform that integrates protein ligand and protein-protein interaction prediction to accelerate sustainable crop protection and antimicrobial discovery

Name of the Inventors: Dr Sneha Murmu, Dr Himanshu Shekhar Chaurasia, Dr Soumya Sharma, Dr Ritwika Das, Dr Md Samir Farooqi, and Dr Girish Kumar Jha

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

3.8 Machine learning–based model of mineral nutrition related genes in higher plants

A comprehensive ML framework was developed for the prediction and functional annotation of mineral transporter and homeostasis genes in higher plants. A curated dataset of 32,533 transporter protein sequences representing ten essential mineral classes N, P, K, Ca, Mg, Mn, Fe, Zn, Cu, and Na was compiled from UniProt. Eight ML algorithms were trained and evaluated, with Random Forest (81.08%) and LightGBM (81.07%) achieving the highest classification accuracy. The framework enables robust and accurate identification of mineral transporter proteins across diverse mineral categories, providing a reliable computational pipeline for mineral nutrition research. This work represents a significant step toward developing a prediction server for genome wide mining of mineral related genes. The framework supports molecular breeding by accelerating the discovery of candidate genes for improved mineral use efficiency, nutrient uptake, and development of climate resilient, nutrient efficient crop varieties.



USP : A scalable, cost effective ML platform that rapidly annotates nutrient related genes to accelerate breeding of nutrient efficient, climate resilient crops while reducing dependence on expensive experimental validation

Name of the Inventors: Dr Soumya Sharma, Dr Sneha Murmu, Dr Ritwika Das, and Dr Girish Kumar Jha

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

3.9 Prediction server for IRES

Translation initiation in eukaryotes primarily occurs through a 5′ cap-dependent mechanism; however, cap independent initiation is also possible through internal ribosome entry sites (IRES). IRES elements enable ribosomes to initiate translation internally without scanning the 5′ untranslated region, mediated by specific RNA secondary and tertiary structures that interact with the translational machinery. A prediction server for IRES was developed using state-of-art machine learning approaches, including deep learning, support vector machines (SVM), and random forest (RF). These models classify transcripts as IRES or non-IRES and are systematically compared using performance metrics such as sensitivity, specificity, accuracy, ROC curve, AUC, precision, recall, and F-score. The framework also attempts to identify open reading frame length, amino acid sequences, and homologous genes, supporting functional genomics and translational regulation studies.

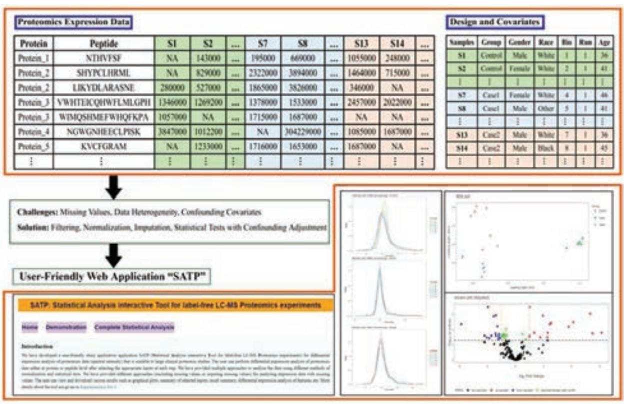
USP : An advanced ML powered prediction server that accurately identifies IRES elements in eukaryotic transcripts while integrating structural features and functional annotations to support translational regulation and functional genomics research

Name of the Inventors: Dr Sarika Sahu, Dr Soumya Sharma, and Dr DC Mishra

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

3.10 SATP (Statistical analysis interactive tool for label free LC-MS proteomics experiments)

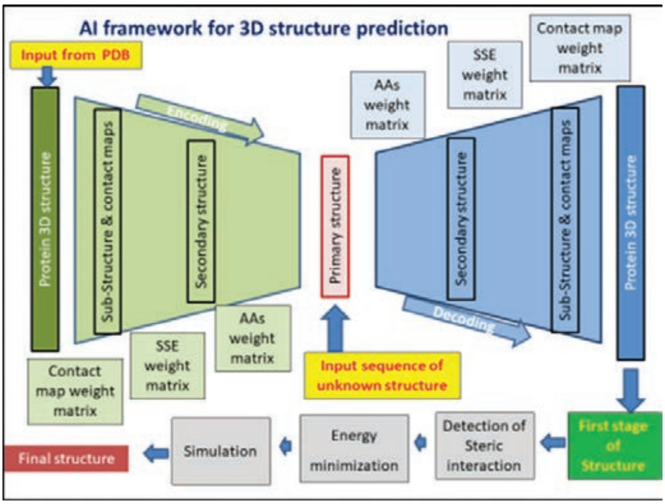
Proteomics studies using LC-MS often face challenges such as missing values (due to random errors, poor-quality samples, or detection limits) and heterogeneity (arising from technical or biological variability). These issues can confound important findings. Additionally, clinical and pre-clinical metadata (e.g., sex, exposure) and field experiments data offer valuable covariates that are often underutilized. To address this, the SATP web application (URL: https://ulbbf.shinyapps.io/satp/) was developed as a user-friendly and scalable platform for differential expression analysis in label-free LC-MS proteomics. The SATP tool has significant scientific and technical impact by addressing key challenges in LC-MS proteomics data analysis, including missing values, heterogeneity, and the need for multi-factor statistical models. Its integration of normalization, imputation, and advanced analysis methods makes it a comprehensive platform for differential expression studies. The tool has broad applications across biomedicine, agriculture, and animal sciences. In biomedicine, it aids in identifying disease-associated proteins, thereby advancing diagnostics and therapeutics. In agriculture, it enables the discovery of proteins linked to stress tolerance, growth, and yield, supporting crop productivity. In animal sciences, it helps to identify protein markers for disease resistance, reproduction, and growth traits, contributing to livestock improvement.



USP	:	This will aid to discovery of novel proteins and genes responsible for various economically important traits in plants and animals
Name of the Inventors	:	Dr Sudhir Srivastava, Dr ML Merchant, Dr CJ McClain, Dr Anil Rai, Dr KK Chaturvedi, Dr UB Angadi, Dr DC Mishra, and Dr SN Rai
More Information	:	Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

3.11 AI based framework for prediction of protein 3D structure

An AI framework for protein 3D structure prediction was developed using Long Short Term Memory (LSTM) deep learning models trained on Protein Data Bank datasets. The framework enables accurate prediction of protein backbone topology, followed by side chain packing using FASPR and structural refinement through ModRefiner to generate reliable protein models. The developed framework has significant policy relevance for agriculture and allied sectors. In crops, it supports the identification of proteins governing stress tolerance, disease resistance, and nutrient use efficiency, facilitating the development of climate resilient varieties and sustainable crop management strategies. In livestock, it aids vaccine design, disease control, feed optimization, and reduction of anti-nutritional factors. The framework strengthens data driven decision making, reduces dependence on costly experimental trials, and accelerates translational research. Overall, it aligns with national priorities on food security, sustainable agriculture, and innovation driven growth, contributing to enhanced productivity, resilience, and long term agricultural sustainability.



USP : A cost effective, end to end AI framework that delivers accurate protein 3D structures from sequence data, enabling faster, data driven crop and livestock innovation aligned with sustainable agriculture and food security goals

Name of the Inventors: Dr UB Angadi, and Dr Sudhir Srivastava

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

3.12 Model assisted estimators using survey weighted artificial neural network (SWANN) in complex surveys

Survey Weighted Regression (SWR) is commonly used for modeling survey data, but it depends on restrictive assumptions such as linearity and known population distributions, which are often unrealistic in complex agricultural surveys. To overcome these limitations, a Survey Weighted Artificial Neural Network (SWANN) model was developed by integrating survey weights into Artificial Neural Networks. SWANN is a non-parametric, data driven approach capable of capturing complex, nonlinear relationships without assuming any specific population distribution. A model assisted SWANN estimator for population mean and total was formulated, along with its variance and variance estimator under finite population sampling. The proposed estimator is particularly suitable for agricultural surveys, where crop yield is influenced by interacting factors such as climate, soil conditions, and management practices. By accounting for unequal selection probabilities and nonlinear dependencies, SWANN provides more accurate, precise, and reliable estimates. The methodology is valuable for government agencies, research institutions, policymakers, and data scientists, supporting improved decision-making, resource allocation, and evidence based agricultural planning.

USP : A novel survey weighted neural network based estimator that captures complex nonlinear relationships in agricultural survey data, delivering more accurate, unbiased, and efficient crop yield estimates without restrictive distributional assumptions

Name of the Inventors: Dr Deepak Singh, Dr Raju Kumar, Dr Samarth Godara, and Dr Bharti

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

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Chapter 4

Intelligent Approaches for Soil and Water Management

Sustainable soil and water management practices manifests itself to enhance agricultural productivity, conserve natural resources, and make agriculture resilient to climate variability. With increasing pressure on land and freshwater resources, traditional management practices are no longer sufficient to address the spatial and temporal complexity of soil–water–crop interactions. Intelligent approaches that integrate advanced sensing technologies with artificial intelligence (AI), machine learning (ML), the Internet-of-Things (IoT) are transforming soil and water management from rule-based operations to data-driven, adaptive systems.

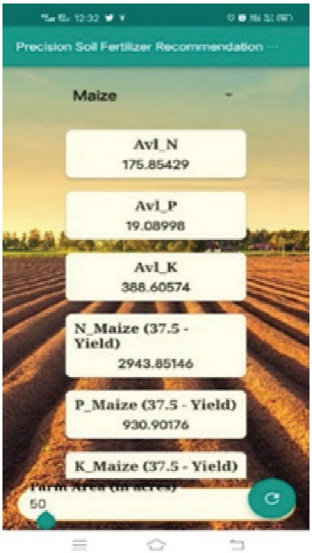
At the field scale, digital lysimeters provide precise measurements of crop water use, enabling accurate irrigation scheduling based on real-time evapotranspiration and soil moisture dynamics. Complementing this, ML and deep learning (DL) techniques for the estimation of daily reference evapotranspiration (ET_{ref}) improve irrigation planning, especially in data-scarce regions. AI-driven solutions for quantifying runoff-induced losses further enhance resource efficiency by predicting soil, nutrient, water losses under varying rainfall and land-use scenarios. When extended to larger landscapes, AI/ML models for watershed-scale modelling support integrated water resource planning, flood mitigation, and soil conservation strategies.

Precision nutrient and water management is strengthened through field-scale fertilizer recommendation systems that combine Soil Test Crop Response (STCR) equations with digital soil maps. Advanced analytical platforms such as "VASUDHA - Visualisation and Assessment Software Using Digital Hyperspectral Analytics" add a powerful dimension by enabling high-resolution assessment of soil and crop conditions. These systems generate spatially explicit input recommendations, reducing overuse of fertilizers while maintaining soil health. Advanced tools for managing irrigation systems, including smart check gate control systems based on wireless water-level and soil-moisture sensing, allow automated regulation of water flows in canals and fields, improving conveyance efficiency and equity in water distribution. Innovations such as solar-powered, IoT-enabled floating axial flow pumps further support energy-efficient water lifting in remote and off-grid agricultural landscapes.

Enhanced water productivity and crop yields are reported by technologies like, - AI and IoT-based intelligent irrigation systems integrate sensor data, weather forecasts, and crop models to deliver precise irrigation for field crops, ML-based decision support systems (DSS) for micro-irrigation management optimize scheduling and fertigation. Beyond open-field agriculture, controlled environment systems are gaining prominence. IoT-based vertical farming hydroponics management systems and sensor-enabled greenhouse vertical farming technologies enable continuous monitoring and control of nutrient solutions, temperature, humidity, and light, ensuring efficient water use and year-round production.

Collectively, the aforesaid intelligent approaches represent a tectonic shift toward smart, efficient, and sustainable soil and water management systems that align productivity goals with environmental stewardship.

4.1 Field-scale fertilizer recommendation systems using STCR equations and digital soil maps



Soil Test Crop Response (STCR) equations are integrated with high-resolution digital soil maps to generate precise, field-scale fertilizer recommendations system. The system is designed for multi-user, role-based access and can process district to state level soil datasets while delivering target yield fertilizer advisories at individual field parcel level. Deployed on a Linux-based virtual machine with PostgreSQL/PostGIS, this platform efficiently handles spatial analysis and nutrient calculations. A configuration of 4 vCPUs, 16 GB RAM, and 200–300 GB SSD supports approximately 75–150 concurrent users and can generate 3,000–6,000 fertilizer recommendations per day.

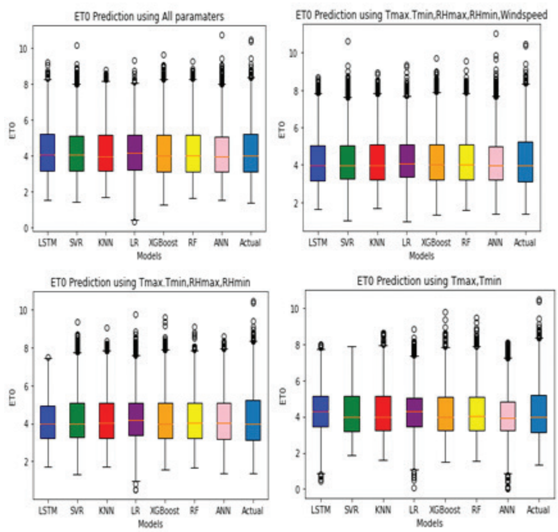
USP : STCR-based digital platform integrates high resolution soil maps to deliver field scale, target yield fertilizer recommendations at large scale, supporting multi user access and high throughput nutrient advisory generation

Name of the Inventors: Dr Nishant Sinha, Dr M Mohanty, Dr RN Sahoo, Dr Pradip Dey, Dr Nirmal Kumar, Dr J Somasundaram, Dr. Jitendra Kumar, Dr Dhiraj Kumar, Dr Rahul Mishra, Dr Rajeev Ranjan, Dr KM Hati, Dr RS Chaudhary, Dr SP Datta, Dr Anil Rai, and Dr SK Chaudhari

More Information : Director, ICAR-Indian Institute of Soil Science, Bhopal - 462038

4.2 ML/DL techniques for estimation of daily ET_{ref}

Accurate estimation of daily reference evapotranspiration (ET_{ref}) is essential for irrigation planning and water resource management. Conventional empirical and FAO-56 Penman–Monteith methods require complete meteorological datasets, which are often unavailable in many regions. Appropriate ML/DL techniques were evaluated for estimation of ET_0 using sparse meteorological data for the Phulnakhara canal command area, Odisha, India. Five ML models—linear regression, random forest, support vector regression (SVR), XGBoost, and KNN regression—along with feedforward neural networks and long short-term memory (LSTM) models were assessed using different input combinations. Model outputs were compared with Penman–Monteith ET_0. Results showed strong positive correlations of ET_0 with sunshine hours and maximum temperature. The findings demonstrate that ML and DL models can accurately estimate ET_0 under data-scarce conditions, supporting efficient irrigation scheduling, reduced dependence on costly weather stations, and improved water use efficiency in canal command areas.



USP : ML and DL models accurately estimate reference evapotranspiration using limited weather data, enabling reliable irrigation scheduling and improved water use efficiency in data scarce canal command areas

Name of the Inventors: Dr Ajit Kumar Nayak, Dr A Sarangi, Dr S Pradhan, Dr RK Panda, Dr NM Jeepsa, Dr BS Satpathy, and Dr Mithlesh Kumar

More Information : Director, ICAR-Indian Institute of Water Management, Bhubaneswar - 751023

4.3 IoT Enabled digital lysimeter

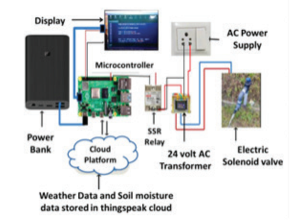
An IoT-enabled digital weighing-type field lysimeter can be used for precise measurement of soil water balance components and irrigation scheduling. The lysimeter has a surface area of 1.36 m² and is mounted on a 1.5-ton single-point load cell, ensuring high accuracy. A solar-powered system comprising 20 W panel and 7 Ah battery provides uninterrupted operation. The cylindrical HDPE inner tank contains a gravel drainage layer and 60 cm soil profile, with drainage collected in a PVC tank and monitored using an ultrasonic sensor. Automatic drainage is controlled through a mini pump and float switches. Soil moisture and temperature sensors are installed at multiple depths. The system demonstrated excellent calibration performance with high linearity and minimal hysteresis. Data are logged every six minutes using an ESP32 controller and stored locally and on the IoT cloud. The lysimeter supports ET_a estimation, crop coefficient determination, soil water balance studies, irrigation scheduling, and climate-responsive crop research at a total cost of approximately Rs. 57000/- with negligible operational expenses.

USP : Low-cost, solar powered IoT weighing lysimeter enables high precision soil water balance and evapotranspiration measurement for accurate irrigation scheduling and climate responsive crop research

Name of the Inventors: Dr Ajita Gupta, and Dr RK Singh

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

4.4 AI & IoT based intelligent irrigation system for field crops



Agriculture is seeing rapid adoption of Artificial Intelligence (AI) and Machine Learning (ML) both in terms of agricultural products and in-field farming techniques. An AI/IOT based intelligent irrigation system for field crops was developed using the ESP microcontroller as AI/IoT hardware, and the NOOBs (Raspbian) operating system. A microcontroller fetches real-time weather data from "weather website" (https://weather.com) and stored on cloud platform server along with soil moisture data from sensor. The system was evaluated in maize and wheat crops under different micro irrigation systems (drip and sprinkler). The average water saving of 12-22% was recorded with the developed system with yield increase of up to 15% across different crops.

USP	:	AI–IoT intelligent irrigation system uses real time weather and soil data to save 12–22% water and increase crop yields up to 15%
Name of the Inventors	:	Dr CD Singh, Dr Mukesh Kumar, and Dr YA Rajwade
More Information	:	Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

4.5 ML based DSS for micro-irrigation management

An ML based Decision Support System (DSS) has been developed to optimize micro-irrigation scheduling for crops. The DSS comprises three modules,- Module 1: includes a web application for predicting reference evapotranspiration (ET_{ref}) using Python and HTML. Real-time forecasted weather data are integrated via Flask API to provide five-day lead-time ET_o predictions. Module 2: estimates crop water demand using weather, soil, and crop databases. Module 3: functions as an irrigation scheduler, guiding system for farmers on the timing and amount of irrigation required. This cost-effective ML based DSS enhances irrigation efficiency, ensures optimal water use, and supports precision management of crops grown under micro-irrigation systems.

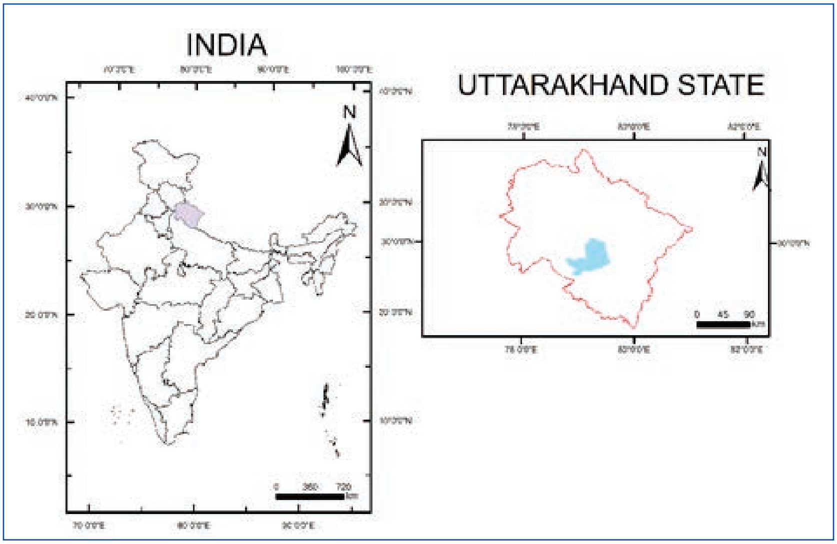
USP : ML based irrigation DSS predicts ET, estimates crop water demand, and schedules precise micro-irrigation, improving water use efficiency and enabling cost effective precision crop management

Name of the Inventors: Dr AM Waghaye, and Dr Karan Singh

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

4.6 AI/ML models for watershed scale modelling

An AI/ML-based platform has been developed for watershed-scale modeling using multi-year data from the Ramganga watershed catchment. The software supports large-scale datasets and can execute multiple machine learning models simultaneously, enabling accurate prediction and analysis of hydrological and environmental parameters. The platform was using Python, R, and JavaScript, the web-based application employs Django/Flask for backend and React.js for frontend development. Key AI/ML libraries include Scikit-learn, TensorFlow, and PyTorch, while Pandas and NumPy are used for data handling. PostgreSQL/MySQL databases manage data storage, and visualization is achieved using Plotly and Matplotlib. The platform is deployed via Docker containers on AWS or in-house servers, with secure role-based access and HTTPS encryption. Tentative development and maintenance costs range from Rs. 6–10 lakhs, with annual operational costs of Rs. 1–3 lakhs. The system provides a scalable, efficient solution for large-scale watershed modeling and management.



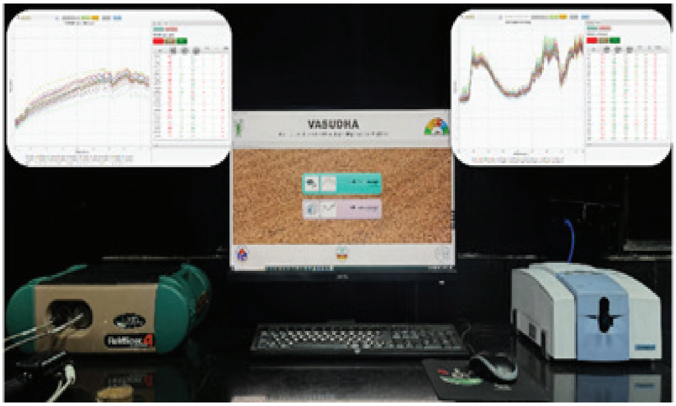
USP : AI based watershed modelling platform enables large scale, multi-year hydrological analysis using multiple models, delivering accurate predictions, secure deployment, and scalable decision support for watershed management

Name of the Inventors: Dr Sadikul Islam, Dr SS Shrimali, and Dr PR Ojasvi

More Information : Director, ICAR-Indian Institute of Soil and Water Conservation, Dehradun - 248195

4.7 VASUDHA: Visualisation and assessment software using digital hyperspectral analytics

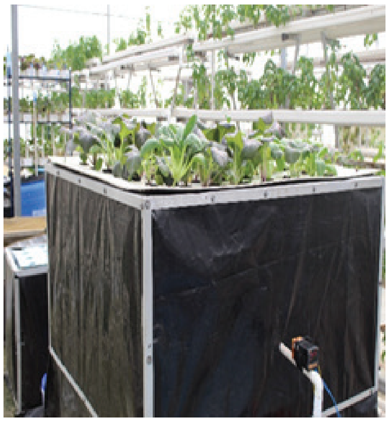
VASUDHA is an advanced software platform designed for real-time visualization and assessment of soil health using digital hyperspectral analytics. It processes VNIR-SWIR reflectance spectra and MIR absorbance spectra with machine learning algorithms to provide accurate soil fertility evaluations. The software, with a compact size (145 MB), can be integrated with portable VNIR-SWIR and MIR sensors to form a field-deployable soil health assessment device, reducing labour, laboratory, and chemical costs. VASUDHA provides instant, real-time soil fertility readings and categorizes them into low, medium, or high, enabling users to make immediate decisions regarding nutrient management. It assesses up to six critical soil parameters, including available nitrogen, phosphorus, potassium, pH, soil organic carbon, and electrical conductivity. VASUDHA offers a scalable, portable, and efficient solution for precise soil health monitoring, supporting sustainable agriculture and improved soil management practices globally. The tentative cost of this analytical tool is Rs. 5 lakh.



USP	: VASUDHA uses hyperspectral analytics and machine learning for instant, field deployable soil fertility assessment, reducing laboratory costs while enabling precise, real time nutrient management decisions
Name of the Inventors	: Dr RN Sahoo, Dr Rajeev Ranjan, Dr Amrita Bhandari, Dr Tarun Teja Kondraju, Dr Somnath, Dr Rejith RG, Dr Nishant Sinha, Dr M Mohanty, Dr Nirmal Kumar, and Dr Anil Rai
More Information	: Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

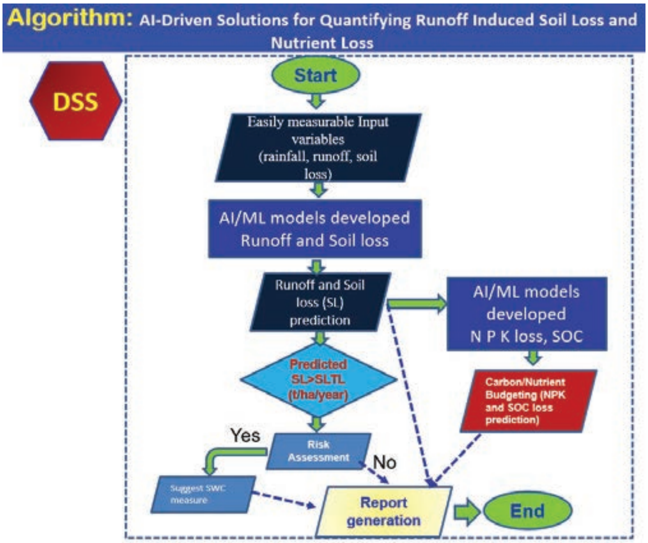
4.8 IoT enabled smart hydroponics

The Sensvert system is an IoT-enabled automated nutrition decision support platform developed for multi-tier hydroponic and greenhouse vertical farms. Designed for precision fertigation, it enables real-time monitoring of key nutrients, improving resource-use efficiency and supporting sustainable urban and peri-urban agriculture. The system integrates ion-selective electrodes (ISEs) for NO_3^-, K^+, and Ca^{2+} with ±5% accuracy alongside EC, pH, and temperature sensors, all connected to a central fertigation controller. A hybrid LoRa + NB-IoT communication network ensures reliable, continuous data transfer. Trials on lettuce and bok choy demonstrated stable nutrient control, enhanced nutrient use efficiency, and reduced fertilizer application compared to conventional EC-based methods. High-value horticultural crops were standardized for optimal growth and marketable yield. Demonstrated on a 1000 m^2 scale, Sensvert has a tentative cost of Rs. 1.67 crore and annual operational cost of Rs. 24 lakh.



USP	:	Sensvert is an IoT enabled precision fertigation decision support system using real time ion-selective nutrient sensing to optimize fertilizer use, improve yields, and enhance sustainability in vertical and greenhouse farming
Name of the Inventors	:	Dr Murtaza Hasan
More Information	:	Director, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

4.9 AI-Driven solutions for quantifying runoff induced losses



An AI-driven platform has been developed to quantify runoff-induced soil erosion and nutrient losses, supporting multi-year and large-scale datasets (>10,000 records). The system can execute multiple machine learning models simultaneously for accurate prediction and analysis. Built using Python, R, and JavaScript, the web-based application employs Django/Flask for backend and React.js for frontend development. Key AI/ML libraries include Scikit-learn, TensorFlow, and PyTorch, while data management relies on Pandas, NumPy, and PostgreSQL/MySQL. Visualization is enabled through Plotly and Matplotlib. The platform is deployed via Docker containers on AWS or in-house servers, with secure role-based access and HTTPS encryption. Tentative development and maintenance costs range from Rs.16–22 lakhs, with annual operational costs of Rs.1–3 lakhs covering server upkeep, data storage, updates, and support. Its scalable, cloud-compatible design ensures efficient analysis for soil and nutrient loss assessment in large agricultural landscapes.

USP : AI powered, cloud ready platform predicts runoff driven soil erosion and nutrient losses at scale, enabling accurate, secure, and efficient analysis for large agricultural landscapes

Name of the Inventors: Dr Sadikul Islam, Dr SS Shrimalli, Dr Rajesh Kaushal, Dr M Sankar, Dr Rama Pal, and Dr M Muruganandam

More Information : Director, ICAR-Indian Institute of Soil and Water Conservation, Dehradun - 248195

4.10 Smart check-gate control system

This is an IoT-based solution designed for precise water management in rice cultivation using wireless water-level and soil-moisture sensing. The system comprises wireless water-level sensors, multipoint soil-moisture sensors, a LoRa–GSM gateway, a motorized check gate with controller, and a mobile-based application platform. In transplanted rice, real-time ponded water depth is monitored and automatically regulated through check-gate actuation to maintain stage-specific water requirements, reducing labor and preventing over-flooding or water stress. For direct-seeded rice, multipoint soil-moisture sensors placed within the root zone enable threshold-based irrigation by controlling gate operations to maintain optimal soil moisture conditions. LoRa communication allows a single gateway to cover up to a 5 km radius, with one water-level sensor per plot. The system has a tentative cost of Rs. 3 lakh and an annual operational cost of approximately Rs. 5,000. This integrated approach significantly enhances surface irrigation efficiency and water productivity in rice-based systems.

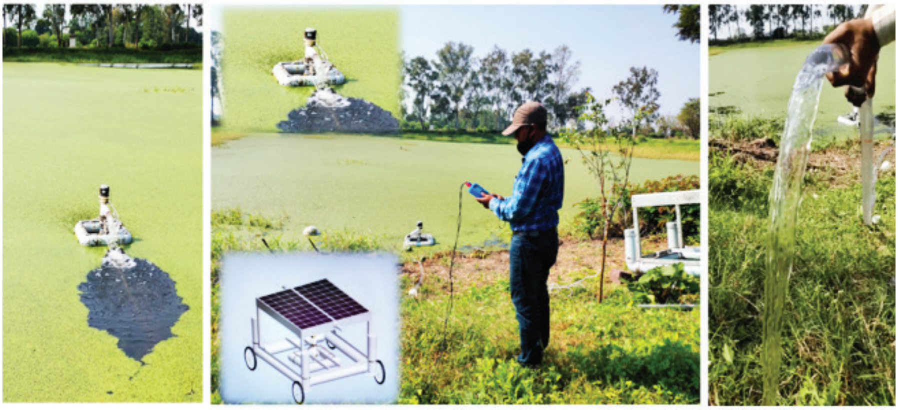
USP : IoT enabled rice water management system automates stage specific irrigation using wireless sensors and motorized gates, reducing labour, preventing water stress, and significantly improving irrigation efficiency and productivity

Name of the Inventors: Dr Monalisha Pramanik, Dr Manoj Khanna, Dr PS Brahmanand Dr Rajeev Ranjan, Dr RN Sahoo, Dr Susama Sudhisri, Dr Vijay Prajapati, and Mr Anand Gupta

More Information : Project Director, Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

4.11 Solar powered IoT enabled floating axial flow pump

A portable solar-powered floating axial flow pump was developed for efficient surface water lifting in irrigation. The system is IoT-enabled for basic monitoring and performance tracking. It is equipped with a 250 W motor pump assembly and a 340 W solar panel, delivering a discharge capacity of about 20,000 litres per day. The floating pump unit has an approximate weight of 75 kg and dimensions of 1.5 × 1.33 m, enabling easy deployment in ponds, canals, and reservoirs. The cost of the developed unit is around Rs. 50,000.



USP : Portable solar powered floating axial flow pump delivers efficient, IoT monitored surface water lifting for irrigation, enabling easy deployment and low cost, sustainable water management

Name of the Inventors: Dr Mukesh Kumar, and Dr CD Singh

More Information : Director, ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038

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Chapter 5

Data-Driven Crop Improvement and Agroclimatic Assessment

Safeguarding agriculture in India from the impending crisis posed by climate variability is monumental task to address in the context of emerging pest and disease pressures. The current scenario underscores the importance of data-driven crop improvement and agroclimatic assessment for devising strategies to create support network for informed decision-making of farm level, regional, and national scales. By integrating geospatial technologies, climate modelling, artificial intelligence (AI), and digital advisory platforms, modern agricultural systems are transcending from reactive management to predictive and precision-based interventions.

Spatial risk mapping tools for management of crop diseases across India play a crucial role in anticipating disease outbreaks and minimizing yield losses. These tools combine historical disease incidence, weather parameters, and crop phenology to generate region-specific risk maps, enabling timely preventive measures. Agroclimatic assessments further support long-term planning, as demonstrated by climate vulnerability analyses for coconut cultivation and future climate suitability projections for arecanut across India. Thus, helping in identifying agronomical high-risk zones, guide varietal selection, and informing adaptive strategies to mitigate the impact of temperature rise, altered rainfall patterns, and extreme weather events.

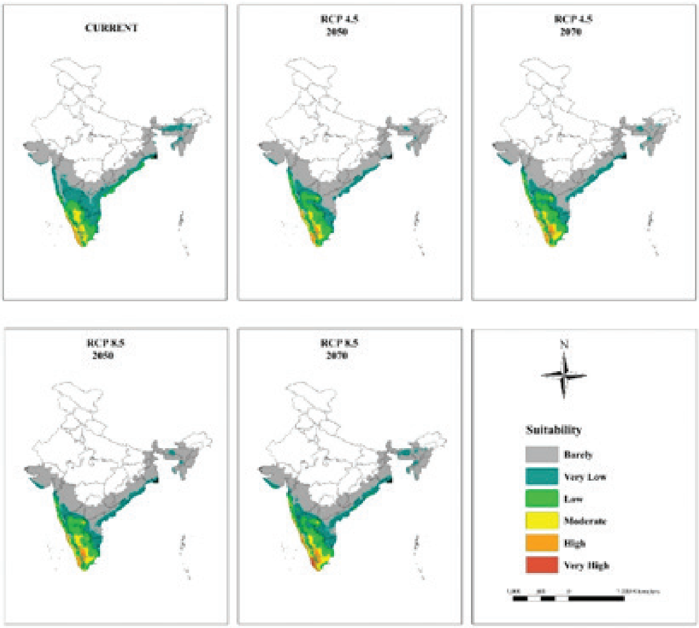
Digital innovations are also transforming orchard-level management. The digital orchard health card for mango provides a comprehensive data-based profile of tree health by integrating soil, nutrient status, pest incidence, and management history. This equips the orchard owners to adopt the right site-specific practices that promises to improve fruit quality and productivity. Similarly, "Cashew Protect", an AI-based mobile application, empowers farmers to rapidly identify pests, diseases, and nutrient deficiencies using image-based diagnostics, reducing dependence on delayed or inaccurate field assessments.

The last-mile delivery of knowledge is strengthened by AI-integrated chatbots offer real-time, personalized advisory services to cashew growers in local languages. These platforms bridge the gap between research and farmers by delivering actionable recommendations on crop management, weather risks, and input use. Fusing digital advisories, standardized operating procedures (SOPs) for the application of pesticides and micronutrients by drones extend adoption of precision agriculture principles, while ensuring uniform coverage, reduced chemical usage, and enhanced operator safety.

All the innovative data-driven agroclimatic assessment tools represent a holistic framework for resilient crop improvement by combining predictive analytics, digital diagnostics, and precision agriculture interventions.

5.1 Climate vulnerability for coconut cultivation

Climate vulnerability assessment for coconut cultivation involves the use of weather, climatic datasets, and region-specific environmental characteristics integrated into the MaxEnt model. Computational equipment is utilized to analyze and model coconut's sensitivity to climate change across India, considering climate projections for the 2050s and 2070s under two Representative Concentration Pathways (RCPs). The AI model estimates potential shifts in suitable cultivation areas and predicts future coconut production based on prevailing and projected climatic factors in specific regions. These insights support long-term developmental planning, policy formulation, and implementation of adaptive strategies for coconut cultivation. The analysis enables identification of vulnerable regions, guides climate-resilient cultivation practices, and informs interventions to sustain productivity, ensuring effective adaptation of the coconut sector to future climate variability and enhancing food and livelihood security.



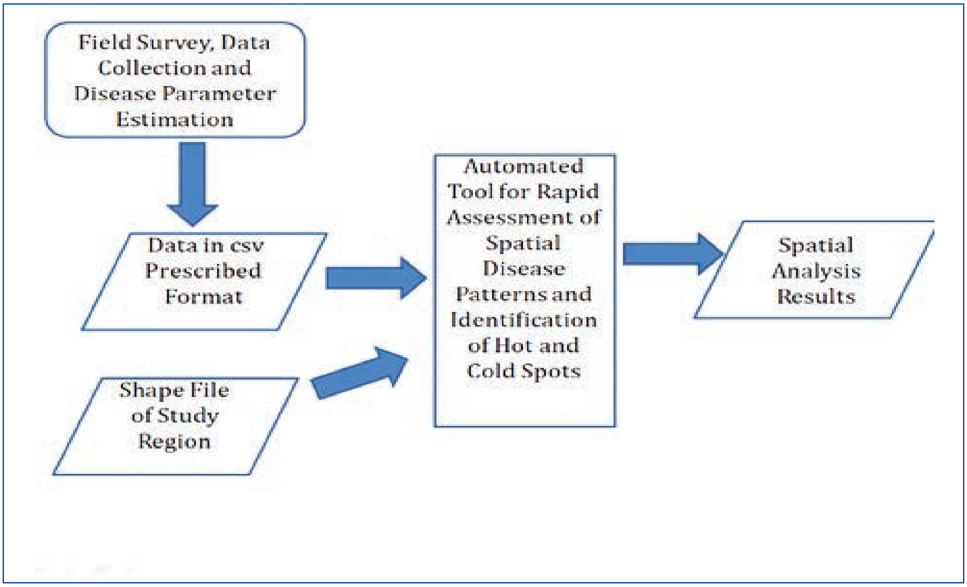
USP : AI driven MaxEnt climate vulnerability assessment predicts future coconut suitability and production under climate scenarios, guiding adaptive planning and climate resilient cultivation strategies

Name of the Inventors: Dr K Balachandra Hebbar

More Information : Director, Central Plantation Crops Research Institute Kasaragod - 671124

5.2 Spatial risk mapping tool for management of crop diseases across India

The spatial risk mapping tool can be used for early detection and management of crop diseases across Indian agricultural regions. Using geo-spatial and statistical techniques, the software estimates the spatial distribution and extent of pest and disease spread, identifying high-risk areas in targeted regions. The tool operates on standard computational equipment, keeping operational costs minimal. It provides actionable insights for extension officers, researchers, and local government policymakers, enabling timely interventions to mitigate crop losses. By visualizing disease risk levels, the platform supports informed decision-making, efficient resource allocation, and proactive disease management, contributing to enhanced crop protection and agricultural productivity across diverse farming systems.

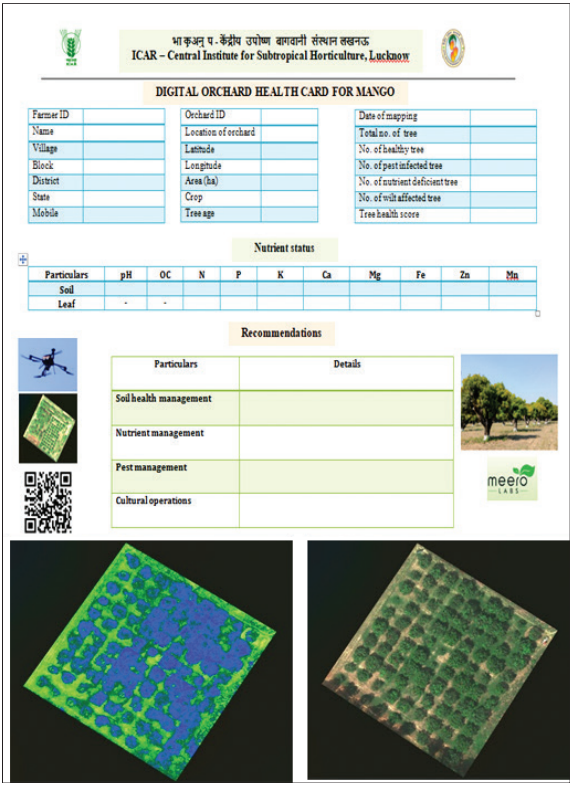


USP : Geospatial risk mapping software enables early detection of crop disease hotspots, supporting timely interventions, efficient resource allocation, and proactive crop protection across Indian agriculture

Name of the Inventors: Dr Sandip Shil

More Information : Director, ICAR-Central Plantation Crops Research Institute, Kasaragod - 671124

5.3 Digital orchard health card for mango



The Digital Orchard Health Card for Mango is a technology-driven tool developed by ICAR-CISH, Lucknow, in collaboration with Meero Labs, Mumbai, to assess and monitor the health status of mango orchards. Using multispectral imaging, the system provides detailed information on tree health, canopy condition, soil and leaf nutrient status, and pest or disease incidence. Recommendations for orchard management are delivered through a mobile-enabled integrated digital platform, making it accessible and user-friendly for growers. The tool is designed for individual mango farmers and can connect over 2,000 growers. Each Digital Orchard Health Card has a tentative cost of Rs. 500, with operational costs of Rs. 650 per hectare. It supports farmers in adopting better management practices, ensuring certification, traceability, and compliance of orchard produce while enhancing productivity and sustainability in mango cultivation.

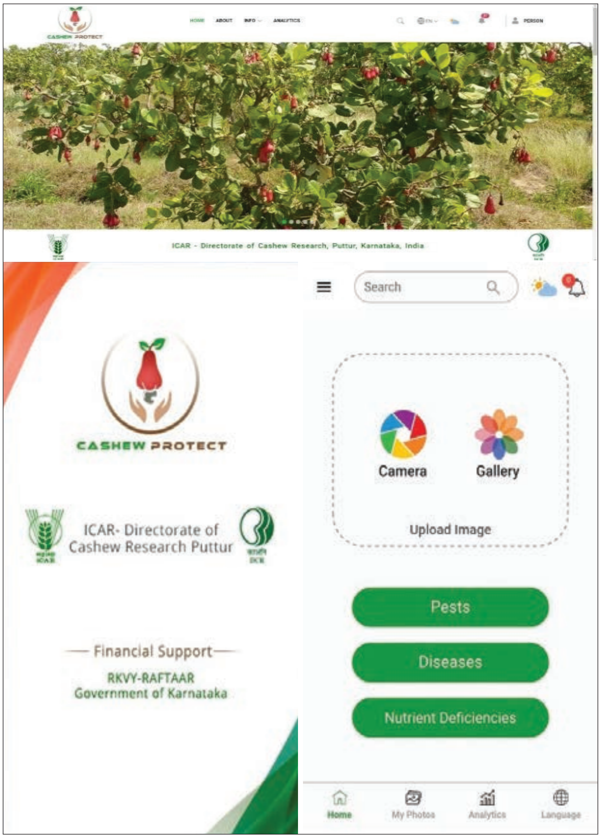
USP : Digital Orchard Health Card uses multispectral imaging and mobile advisory to deliver affordable, per tree mango health assessment, management recommendations, traceability, and sustainable productivity improvement

Name of the Inventors: Dr T Damodaran

More Information : Director, ICAR-Central Institute for Subtropical Horticulture, Lucknow - 226101

5.4 Cashew Protect: An AI-based app for identification of pests, diseases, and nutrient deficiencies

Cashew Protect is the world's first AI-based app and website for cashew. The app identifies nine major pests, two diseases, and one nutrient deficiency, helping farmers manage orchard health effectively. Available in 11 languages, it caters to all cashew-growing states in India and is available in Google Play Store and Apple Store, with a 4.9 rating. The app is also used in countries including Nigeria, USA, UAE, Ghana, Philippines, and Brazil. Developed with a budget of Rs. 16 lakhs, Cashew Protect provides an innovative, accessible, and scalable solution for pest, disease, and nutrient management in cashew cultivation.



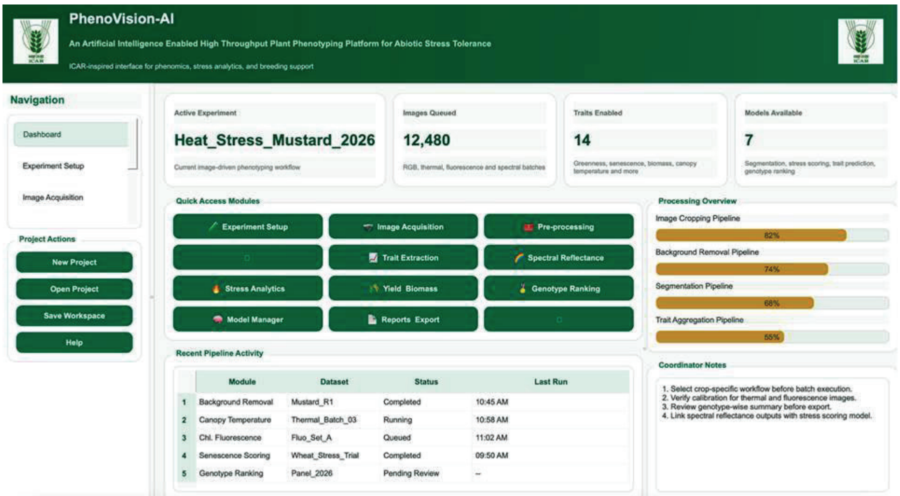
USP : Cashew Protect is the world's first AI based cashew advisory app, enabling multilingual pest, disease, and nutrient diagnosis with global adoption and farmer friendly accessibility

Name of the Inventors: Dr Mohan GS

More Information : Director, ICAR-Directorate of Cashew Research, Puttur - 574202

5.5 Pheno Vision-AI: An AI enabled high through put plant pheno typing platform for abiotic stress tolerance

This technology presents an AI enabled high throughput plant phenotyping (HTP) platform that integrates computer vision, DL, and automated pipelines to overcome phenotyping bottlenecks and accelerate crop improvement. It delivers end-to-end, non-destructive solutions for trait characterization, stress assessment, growth stage identification, and yield prediction in wheat, mustard, rice, and other crops. Several specialized modules have been developed, including MuSiC for siliqua counting in mustard, WheatSpikeSense for real time wheat ear detection, SpikeSegNet and Web-SpikeSegNet for spike identification, m-Senescencica for senescence staging, SlypNet for spikelet detection, and PanicleDet for automated paddy stage detection. Future efforts aim to unify these tools into an Integrated Analysis Platform incorporating sensor data and scalable web applications. The unified system will support breeder friendly workflows, enable precision agriculture, enhance genetic gain, and contribute to the development of climate resilient, high yielding crop varieties.



USP	:	AI driven high throughput phenotyping platform enabling real time, non-destructive trait analysis and yield prediction to accelerate breeder led crop improvement
Name of the Inventors	:	Dr Chandan Kumar Deb, Dr Madhurima Das, Dr Md. Ashraful Haque, Dr Alka Arora, Dr Sudeep Marwaha, Dr Sudhir Kumar, and Dr Viswanathan C
More Information	:	Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

5.6 Survey weighted machine learning models in complex surveys for crop yield estimation

Crop yield estimation is inherently complex due to its multifactorial nature. Traditionally, yield estimation in India relies on crop cutting experiments (CCEs) under the general crop estimation surveys (GCES). The implementation of pradhan mantri fasal bima yojana (PMFBY) has significantly increased the demand for CCEs, highlighting the need for efficient alternatives. To address this, survey weighted support vector regression (SWSVR) and survey weighted random forest (SWRF) models were developed for yield prediction in both sampled and non-sampled areas. Using these models, efficient estimators for population mean and total yield were formulated, with potential to substantially reduce the number of required CCEs. Additionally, to overcome data incompleteness caused by non-sampling errors, a novel ML based imputation methodology was introduced, improving model accuracy. The proposed approaches offer a viable alternative to GCES and support PMFBY stakeholders and policymakers in faster and more reliable settlement of farmers' insurance claims.

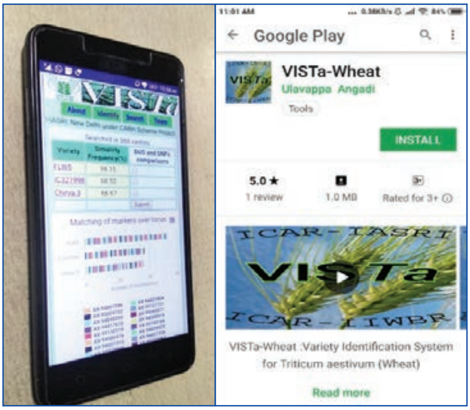
USP : An efficient, survey weighted machine learning framework that improves crop yield estimation accuracy, handles missing data, and significantly reduces dependence on costly CCEs under PMFBY

Name of the Inventors: Dr Pankaj Das, Dr Ankur Biswas, Dr Tauqueer Ahmad, and Dr Prachi Misra Sahoo

More Information : Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

5.7 VISTa: Variety identification system for Triticum aestivum

VISTa is a DNA based platform developed to accurately identify wheat varieties, offering a faster and more reliable alternative to traditional field based testing methods. Conventional identification methods rely on visible plant traits, which are time consuming, influenced by environmental conditions, and often inadequate for legal or commercial use. VISTa overcomes these challenges by using DNA profiles from 386 wheat varieties, ensuring precise and environment independent identification. The platform supports the protection of breeders' rights, seed authenticity, and resolution of ownership or benefit sharing disputes under the PPV&FR Act. It also helps meet national and international intellectual property requirements related to plant varieties. Available as a user friendly web server, VISTa has been widely used globally. The approach can be extended to other crops, strengthening varietal protection, reducing adulteration, and promoting innovation and trust in agricultural systems.



USP	:	A fast, DNA based and legally robust varietal identification platform that ensures seed authenticity, protects breeders and farmers rights, and strengthens IPR compliance and agricultural sustainability
Name of the Inventors	:	Dr MA Iquebal, Dr Rajender Parsad, Dr CN Mishra, Dr Sarika, Dr Deepender Kumar, Dr Nishu Raghav, Dr Surinder Paul, Dr Sonia Sheoran, Dr Pradeep Sharma, Dr Arun Gupta, Dr Vinod Tiwari, Dr Ulavappa B Angadi, Dr Neeraj Kumar, Dr Anil Rai, Dr GP Singh, Dr Dinesh Kumar, and Dr Ratan Tiwari
More Information	:	Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 110012

Chapter 6

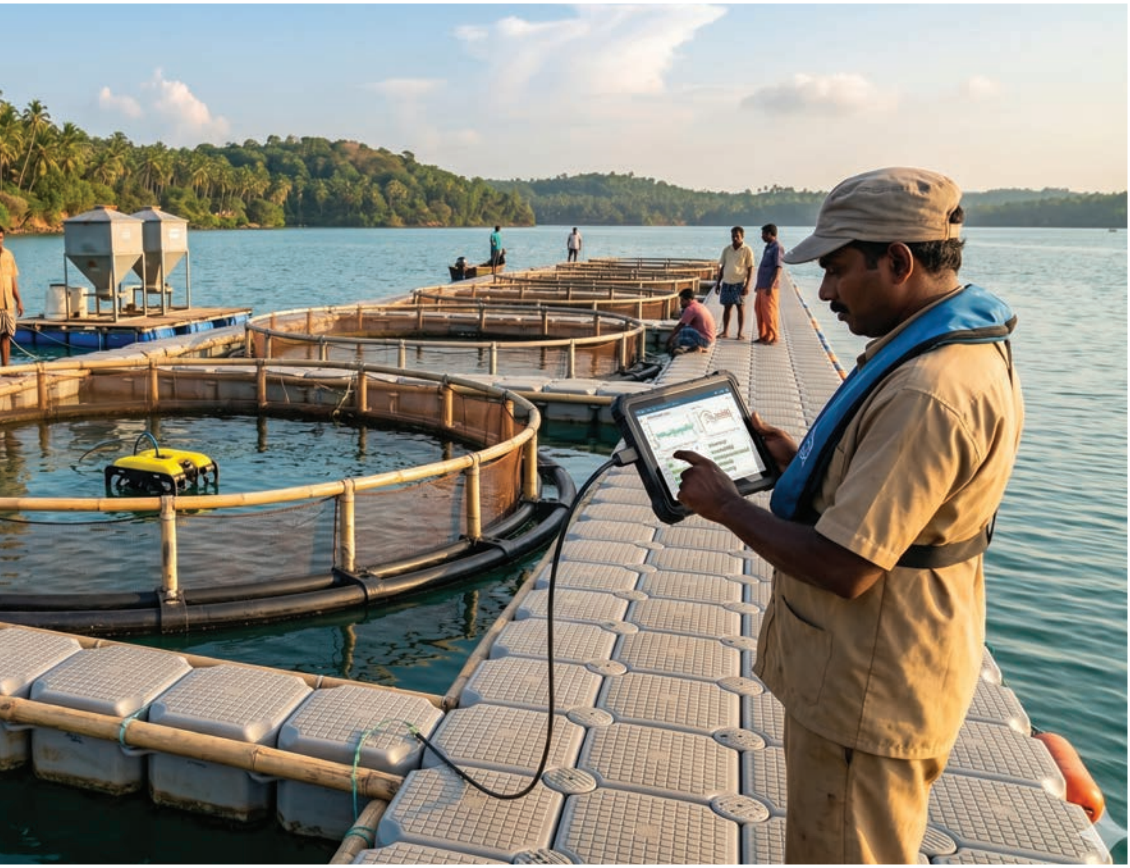
Smart Technologies in Aquatic Health Management

Aquatic health management is undergoing a rapid transformation with the integration of smart technologies, driven by the need for sustainable fish production, efficient resource utilization, and improved animal welfare. Amalgamation of Internet-of-Things (IoT), artificial intelligence (AI), sensor technologies, automation, and drone systems have enabled real-time monitoring, precision control, and data-driven decision-making across the whole aquaculture and fisheries sector. These innovations are critical in the context of climate variability, water quality degradation, disease outbreaks, and rising demand for safe and high-quality aquatic products.

Smart feeding systems form the backbone of modern aquaculture operations. Smart fish pond feeders, smart aquarium feeders, and smart recirculatory aquaculture system (RAS) feeders are customised with optimized feed delivery system based on fish behaviour vis-à-vis environmental conditions, thereby reducing feed wastage and improving feed conversion ratios. In specie specific systems such as catfish RAS, automated feeding integrated with water quality sensors enhances growth performance while maintaining optimal dissolved oxygen, ammonia, and temperature levels. Decision-support platforms such as "AquaNIRNAY" further strengthen farm management by packaging multi-source data to guide feeding, health, and water management practices.

IoT-based precision technologies extend beyond feeding to holistic ecosystem monitoring. IoT-enabled enclosure culture and inland open-water fisheries management systems facilitate continuous assessment of water quality parameters, stock health, and carrying capacity. Real-time turbidity monitoring systems with messaging services provide early warnings of pollution or sediment disturbances, enabling timely corrective actions. Advanced filtration solutions, such as sensor-based mechanical-cum-biological drum filters, enhance biosecurity and water reuse efficiency in intensive aquaculture systems.

Emerging technologies such as drones and AI-powered sensors are expanding the scope of aquatic health management. Drone-based water sampling and live fish transport systems, stock assessment and habitat surveillance reduce human intervention in fish husbandry practices. Smart portable fish freshness assessment sensors ensure post-harvest quality and food safety. These smart technologies add up to represent a paradigm shift toward resilient, intelligent, and sustainable aquatic health management systems.



6.1 Smart fish pond feeder

The feeder is an IoT-enabled automated feeding system designed to optimize aquaculture operations. It dispenses feed according to a programmable schedule, with real-time adjustments based on fish behaviour monitored via an IP camera. All feeding data and behavioural analytics are stored and processed in a centralized data management console. The system is powered by a solar energy setup, reducing operational costs and enabling energy-efficient functioning. A 5G router ensures seamless data transfer and remote monitoring. The developed system having feed capacity of 100 kg, the feeder achieves over 95% dispensing accuracy, significantly minimizing feed wastage. Solar-powered operation can save up to 60% on energy costs, while automation reduces manual labour requirements by approximately 50%. The compact unit integrates solar panels, IoT controllers, IP cameras, and a 5G router, with an estimated cost of Rs. 50,000–60,000 per unit. The technology enhances feed efficiency, fish growth, and overall aquaculture productivity.

USP : Solar powered IoT feeder with camera based behaviour analytics delivers over 95% accurate feeding, reducing feed waste, labour, and energy costs in aquaculture

Name of the Inventors: Dr SK Swain, Dr PC Das, Dr CK Misra, Dr S Ferose Khan, Dr Himanshu Shekhar Swain, Dr RN Sahoo, Dr I Sivaraman, Dr Nirmal Kumar

More Information : Director, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751002

6.2 Smart aquarium feeder

The smart aquarium feeder is an automated feeding solution designed to simplify aquarium management while ensuring optimal fish health. The feeder delivers feed on a programmable schedule, preventing overfeeding and reducing feed wastage, which helps maintain cleaner water and a healthier aquatic environment. Its compact design makes it suitable for both home and commercial aquariums. Equipped with a rechargeable battery and IoT integration, the system operates efficiently with low operational costs. The feeder supports a feed capacity of 100 kg, allowing for consistent and precise feeding routines. With an estimated cost of Rs. 5,000 to Rs 7,000 per unit, this technology offers an affordable and practical option for aquarium enthusiasts and commercial fish keepers. By automating feeding, it ensures the well-being of fish while reducing labour and maintenance efforts.

USP : Smart IoT aquarium feeder automates precise feeding schedules, reducing wastage, improving water quality and fish health, with affordable, low maintenance operation

Name of the Inventors: Dr SK Swain, Dr PC Das, Dr CK Misra, Dr S Ferose Khan, Dr Himanshu Shekhar Swain, Dr RN Sahoo, Dr I Sivaraman, and Dr Nirmal Kumar

More Information : Director, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751002

6.3 Smart recirculatory aquaculture system (RAS) feeder

The recirculatory aquaculture system (RAS) feeder is an automated feeding solution designed for intensive aquaculture systems, including RAS, biofloc, and aquaponics. It stores feed in a 5 kg container and dispenses it at pre-set intervals using an auger-based mechanism. A NodeMCU microcontroller governs feeder operations, while a mobile app allows users to remotely adjust feeding schedules, monitor dispensing, and track feed data. The RTC module ensures precise, time-accurate feed delivery, and a rechargeable battery provides uninterrupted operation. The feeder is compact, user-friendly, and optimized for controlled environments, minimizing feed wastage and labour requirements. With low operational costs and cloud-based monitoring, it enhances feed efficiency and promotes better fish growth. The estimated cost per unit ranges from Rs. 12,000 to 15,000, offering an affordable, technologically advanced solution for automated feeding in modern aquaculture systems.

USP : Smart IoT enabled RAS feeder automates precise, app controlled feed dispensing, reducing wastage and labour while improving feed efficiency and fish growth in intensive aquaculture systems

Name of the Inventors: Dr SK Swain, Dr PC Das, Dr CK Misra, Dr S Ferose Khan, Dr Himanshu Shekhar Swain, Dr RN Sahoo, Dr I Sivaraman, and Dr Nirmal Kumar

More Information : Director, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751002

6.4 Catfish recirculatory aquaculture system (RAS)

The system is designed for efficient and intensive catfish production by maintaining optimal water quality and fish health. The system recirculates water through advanced filtration and aeration units, removing solid and dissolved waste while ensuring sufficient oxygenation. Key components include a sediment tank filter, drum filter for solid waste removal, sand filter for fine particles, biological filter for ammonia and nitrite conversion, UV filter for disinfection, and a robust aeration system. Automation reduces manual labour and enhances energy efficiency. The system supports 15 tanks, each with a 500 L capacity, consuming approximately 25 units of electricity per 10 tonnes of water per day. The estimated cost of complete setup was range from Rs. 6–10 lakhs. This RAS offers a sustainable, high-efficiency solution for intensive catfish cultivation with improved growth and productivity.Top of Form

USP : Automated recirculating aquaculture system integrates multi stage filtration and aeration to maintain optimal water quality, enabling energy efficient, intensive catfish production with improved growth and productivity

Name of the Inventors: Dr SK Swain, Dr PC Das, Dr CK Misra, Dr S Ferose Khan, Dr Himanshu Shekhar Swain, Dr RN Sahoo, Dr I Sivaraman, and Dr Nirmal Kumar

More Information : Director, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751002

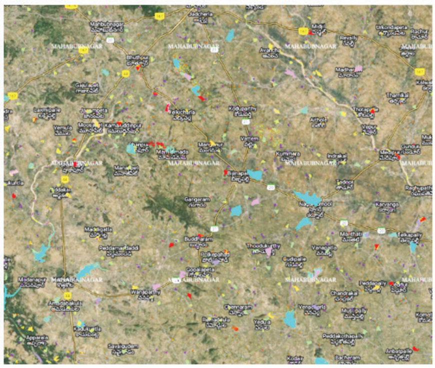
6.5 Sensor base mechanical-cum-biological drum filter in aquaculture

This is an advanced water treatment system designed to maintain high water quality in aquaculture, including RAS, hatcheries, ornamental units, as well as in industrial wastewater and recreational water facilities. The filter combines mechanical filtration (70–100 µm mesh drum) to remove suspended solids with biological filtration using bioballs and nitrifying bacteria to convert toxic ammonia into nitrate. Automated cleaning is achieved through float-sensor activation and a 0.5 hp backwash pump, ensuring low maintenance and continuous operation. The system operates at 40,000 LPH, with scalable capacities based on requirements. It saves 40–50% freshwater during backwash, reduces electricity consumption, and lowers recurring operational costs. Lightweight and energy-efficient, the filter is cost-effective, with a tentative price of Rs. 1.5 – 2.5 lakhs. The drum filter enhances water quality, fish health, and environmental sustainability while providing reliable solutions for small- and large-scale aquaculture operations.

USP	:	Automated drum biofilter combines fine mechanical and biological filtration to deliver high quality water with low energy, 40–50% water savings, and minimal maintenance for sustainable aquaculture systems
Name of the Inventors	:	Dr AK Verma, Dr Chandrakant MH, Dr BB Nayak, and Dr Ashutosh D Deo
More Information	:	Director, ICAR-Central Institute of Fisheries Education, Mumbai - 400061

6.6 AquaNIRNAY

AquaNIRNAY is an advanced geospatial Decision Support System (DSS) designed to enhance aquaculture planning across India. Utilizing satellite imagery and machine learning algorithms, the system delivers accurate, real-time insights into water body dynamics, supporting informed decision-making for aquaculture development. It provides precise mapping of water bodies, seasonal analysis, and identification of suitable sites, helping reduce reliance on trial-and-error methods for site selection. The platform promotes environmentally sustainable aquaculture practices by guiding the selection of ecologically appropriate locations and optimizing resource use. Operational costs are primarily dependent on satellite data processing requirements. AquaNIRNAY enables policymakers, researchers, and aquaculture entrepreneurs to plan, monitor, and manage water bodies efficiently, ensuring sustainable growth, improved productivity, and reduced environmental impact in aquaculture operations across diverse regions of India.



USP : AquaNIRNAY leverages satellite imagery and machine learning to deliver real time geospatial decision support for sustainable, efficient aquaculture site selection and water body management across India

Name of the Inventors: Dr SK Swain, Dr PC Das, Dr CK Misra, Dr S Ferose Khan, Dr Himanshu Sekhar Swain, Dr RN Sahoo, Dr I Sivaraman, and Dr Nirmal Kumar

More Information : Director, ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar - 751002

6.7 Smart portable fish freshness assessment sensor

A smart, handheld device for rapid on-site assessment of fish freshness, integrating a microcontroller, camera, LCD screen, portable power unit, and a 3D-printed outer casing. The device runs an image processing and deep learning model to evaluate the freshness of three fish species: Indian mackerel, tilapia, and sardine, with the potential to include additional species in the future. Weighing approximately 250 g and measuring 0.16 × 0.11 × 0.03 m, the device is highly portable and easy to use. With a tentative cost of Rs. 20,000 per unit and no operational costs, it provides a fast, reliable, and user-friendly solution. The device will find use with food safety officers, government enterprises, fish consumers, entrepreneurs, and start-ups, ensuring quality control and enhancing food safety in the fisheries sector.

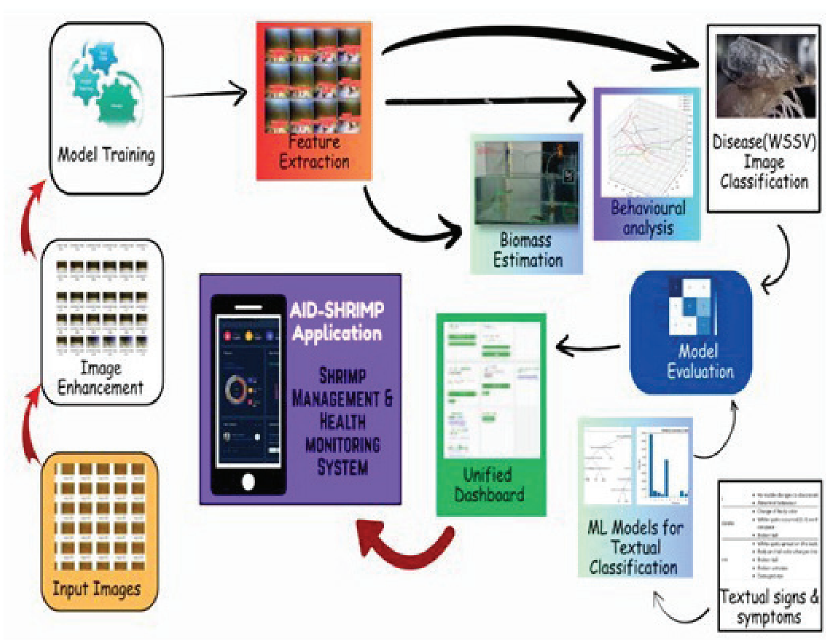
USP : A low cost, handheld AI powered device enables rapid on site fish freshness assessment using image processing, ensuring reliable quality control and enhanced food safety for fisheries stakeholders

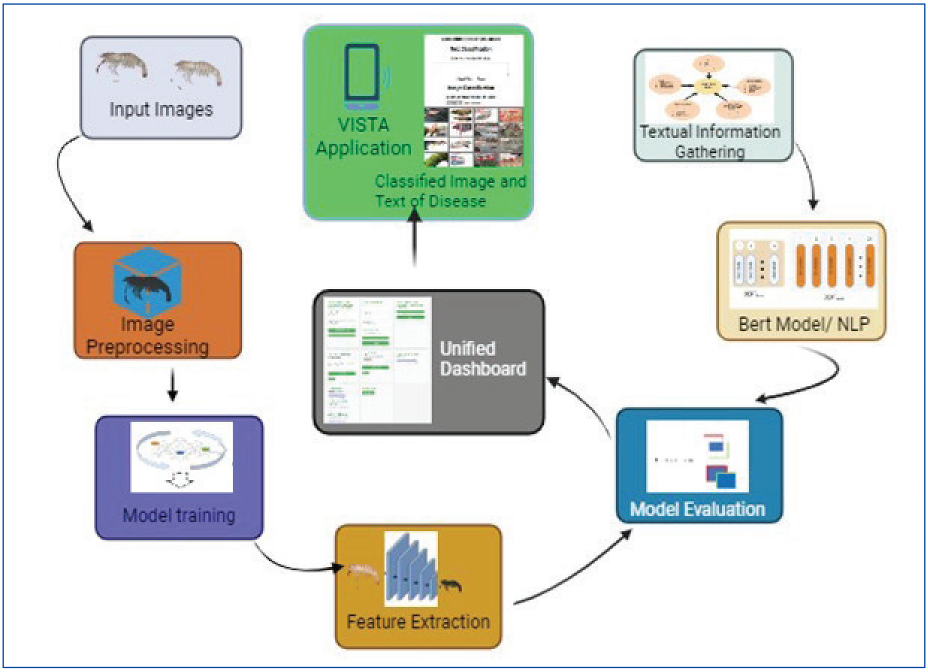
Name of the Inventors: Dr Murali S, Dr Aniesrani Delfiya DS, Dr Murugadas V, Dr Binsi PK, and Dr George Ninan

More Information : Director, ICAR-Central Institute of Fisheries Technology, Kochi - 682029

6.8 AI-IoT based system for ornamental fish behaviour analysis

Ornamental fish detection and behavior analysis (OFDABA) is an innovative platform for the detection, behavioural analysis, and health monitoring of ornamental fish and shrimp. Using IoT and machine learning, the system predicts changes in fish behaviour in response to water quality parameters monitored via IoT sensors, enabling early detection of stress or disease. For shrimp health management, the VISTA framework provides a unified dashboard for disease detection and classification. It integrates object detection model for disease symptoms in shrimp images and BERT NLP for categorizing diseases based on textual symptom descriptions. Users can upload images and provide written observations, ensuring a comprehensive and accurate diagnosis. Additionally, the AID-SHRIMP (AI-Driven Shrimp Health and Reflex Integrated Monitoring) platform combines real-time monitoring, behavioral analysis, and health assessment to enhance aquaculture productivity and sustainability. OFDABA offers a cutting-edge solution for ornamental fish and shrimp farming, enabling proactive management, disease prevention, and improved overall stock health in both research and commercial aquaculture operations.





USP : OFDABA integrates IoT and AI to predict behaviour, detect disease, and monitor health of ornamental fish and shrimp, enabling proactive management, early diagnosis, and sustainable aquaculture productivity

Name of the Inventors: Dr Vinod Kumar Yadav, Dr Ashutosh Deo, Dr Vidya Shree Bharti, Dr Arun Sharma, and Dr Arpita Sharma

More Information : Director, ICAR Central Institute of Fisheries Education, Mumbai - 400061

6.9 IoT based precision enclosure culture and fisheries management in inland open waters

An IoT-based precision enclosure culture system has been developed to enhance fisheries management in inland open waters, particularly for intensive farming with high stocking densities. The system monitors real-time dissolved oxygen (DO) levels and automatically controls aerators to maintain optimal water quality, reducing stress and mortality in fish. The technology integrates a microcontroller-based aerator control system, IoT sensors, and a user-friendly mobile app that sends automatic alert messages/SMS to notify farm owners of DO stress conditions, enabling timely interventions. The system operates on solar power, minimizing electricity consumption and manpower requirements. The IoT unit weighs approximately 5 kg, the solar panel 1.5 kg, with dimensions of 40 × 30 cm (IoT system) and 65 × 50 cm (solar panel). The cost of the system is Rs. 1.5 lakh and it promotes sustainable aquaculture, improving productivity, reducing fish health risks, and ensuring efficient water quality management in enclosure culture systems.

USP	:	Solar powered IoT precision enclosure culture system enables real time dissolved oxygen monitoring and automatic aerator control with mobile alerts, reducing fish stress, mortality, and manpower while improving productivity
Name of the Inventors	:	Dr Basanta Kumar Das, Dr Srikanta Samanta, Dr Chayna Jana, Dr DK Meena, Dr BK Behera, Dr Pranaya Parida, Dr Abul Hassan, Dr Himanshu Sekhar Swain, Dr RN Sahoo, and Dr JK Jena
More Information	:	Director, ICAR-Central Inland Fisheries Research Institute, Barrackpore - 700120

6.10 IoT based turbidity monitoring system with real-time messaging service in water bodies

The IoT-based turbidity monitoring system is designed for continuous, real-time monitoring of water turbidity in aquaculture systems, ensuring optimal water quality for sensitive fish species. Traditional monitoring relies on periodic sampling, which cannot capture rapid changes in turbidity. This system integrates IoT sensors with a microcontroller and a solar-powered unit (weight ~7 kg; IoT system 5 kg, solar panel 1.5 kg; dimensions: IoT 40 cm × 30 cm, solar panel 65 cm × 50 cm) to provide 24/7 monitoring without human intervention. The system sends automatic alert messages/SMS to farm owners when high turbidity is detected, enabling timely interventions that reduce stress, prevent health deterioration, and minimize fish mortality. Operational cost is low, limited to mobile SIM recharge (~Rs. 300/month). Priced at approximately Rs. 1.0 lakh, this technology overcomes the limitations of traditional monitoring, promotes sustainable aquaculture management, and ensures effective, real-time response to turbidity fluctuations for improved fish health and productivity.

USP : Solar powered IoT turbidity monitoring system provides 24/7 real time water quality alerts via SMS, enabling timely interventions, reducing fish stress and mortality, at low operational cost

Name of the Inventors: Dr Basanta Kumar Das, Dr Srikanta Samanta, Dr Chayna Jana, Dr RN Sahoo, and Dr JK Jena

More Information : Director, ICAR-Central Inland Fisheries Research Institute, Barrackpore - 700120

6.11 Drone based water sampling system

The remote controlled drone-based water sampling system is designed to collect 1 litre of water from inland open water bodies, including rivers, lakes, reservoirs, wetlands, and oxbow lakes. The system weighs approximately 15 kg (including payload). The tentative cost is Rs. 13.0 lakh, with operational expenses limited to battery replacement (two batteries at Rs. 24,000 after ~2 years) and periodic maintenance. This technology provides a safe and efficient alternative to traditional water sampling methods, which often require boats or shoreline collection and pose risks in inaccessible, polluted, or difficult terrains. The drone's vertical water sampler minimizes manpower requirements, reduces labour and boat costs, and saves time. Equipped with emergency safety features, it can land and take off from the water surface if needed. The system is ideal for government agencies, research organizations, and NGOs conducting inland aquatic ecosystem health monitoring, providing rapid, reliable, and safe water sample collection from challenging locations.

USP : Remote controlled drone water sampler safely collects one litre samples from inaccessible inland waters, reducing manpower, risk, time, and boat costs while enabling rapid, reliable ecosystem monitoring.

Name of the Inventors: Dr Basanta Kumar Das, Dr BK Behera, Dr Pranaya Parida, Dr Himanshu Sekhar Swain, Dr RN Sahoo, Dr Anil Rai, Dr JK Jena, and Dr Trilochan Mahapatra

More Information : Director, ICAR-Central Inland Fisheries Research Institute, Barrackpore - 700120

6.12 Drone applications for managing fish husbandry practices

Drones offer significant potential for improving efficiency and precision in fisheries and aquaculture management. A purpose-designed drone system with a payload capacity of 10 kg and an operational range of up to 1 km (within visual line of sight) has been developed for applications such as feed broadcasting, therapeutic chemical spraying, and general husbandry operations. The drone has an approximate payload carrying capacity of 24.5 kg. The use of drones enables rapid and uniform application of fish feed, medicines, and disinfectants over large water bodies, significantly reducing labor, time, and human exposure to polluted or inaccessible areas. Controlled and targeted delivery improves resource utilization and farm productivity while enhancing safety and convenience for farmers. Operational costs primarily include battery replacement (two batteries costing about Rs. 24,000 each after approximately two years) and periodic maintenance. Demonstration and awareness programs have been conducted to showcase these benefits to fish farmers.

USP : Purpose built aquaculture drone enables rapid, uniform feed and chemical application with high payload, reducing labour, time, and human exposure while improving resource efficiency and farm productivity

Name of the Inventors: Dr Basanta Kumar Das, Dr Chayna Jana, and Dr Pranaya Parida

More Information : Director, ICAR-Central Inland Fisheries Research Institute, Barrackpore - 700120

6.13 Comprehensive media share base for marine fishery machine learning routines of Indian EEZ

MARLIN@CMFRI is a mobile-based digital platform developed to support marine fisheries research through large-scale, participatory data collection within India's Exclusive Economic Zone (EEZ). The Android application enables users to upload geo-tagged photographs of marine fish species along with relevant metadata, creating an extensive visual repository of marine fishery resources. The platform is designed to handle large volumes of citizen-contributed data and serves as a foundation for developing artificial intelligence–based systems for automated marine species identification. MARLIN@CMFRI is freely available to researchers and end users, promoting wide adoption and collaborative research. Being entirely software-based, the application has a compact size of approximately 6.7 MB, making it easy to install and use on standard smartphones. The app has demonstrated effectiveness in collecting reliable geo-referenced information on marine fish landings and species diversity. The generated database provides valuable inputs for fisheries research, stock assessment, conservation planning, and evidence-based policy formulation within the Indian EEZ.Top of Form

USP	:	MARLIN@CMFRI is a free mobile platform enabling participatory, geo tagged marine fisheries data collection, building AI ready databases for research, conservation, and policy within India's EEZ
Name of the Inventors	:	Dr Eldho Varghese, Dr J Jayasankar, Dr Somy Kuriakose, Dr KG Mini, Dr Vinaykumar Vase, Dr Rekha J Nair, Dr Muktha M, and Dr Biplab Banerjee
More Information	:	Director, ICAR-Central Marine Fisheries Research Institute, Kochi - 682018

Chapter 7

Digital Tools for Animal Health and Veterinary Research

Digital tools are shifting animal health management and veterinary research to intelligent, non-invasive, and data-driven solutions for long-standing challenges of livestock production and management. The integration of Machine Learning (ML), Artificial Intelligence (AI), deep learning (DL), computer vision, and sensor-based technologies has opened newer avenues for precision livestock farming and advanced veterinary diagnostics.

Innovations such as gender determination of chicks using digital imaging and AI contribute significantly to ethical poultry management, complementing this, is the Smart Environment Monitoring System (GEMS) that leverages sensor networks and real-time data analytics to continuously monitor environmental parameters such as temperature, humidity, and air quality in all types of animal housing.

In the domain of infectious disease surveillance, MolEpidPred, an ML/AI-based solution for the molecular epidemiology of the Foot-and-Mouth Disease (FMD) virus, represents a major advancement. Advanced imaging technologies further strengthen early disease detection. Infrared (IR) thermography–based systems allow for the early identification of mastitis in Murrah buffaloes by detecting subtle temperature variations, enabling timely intervention and reducing economic losses. By analyzing genetic and epidemiological data, such platforms support rapid outbreak prediction, strain tracking, and informed decision-making for disease control strategies. Similarly, ML frameworks for identification of porcine cells enhance cellular-level research by automating classification tasks, accelerating experimental workflows, and improving accuracy in veterinary biomedical research.

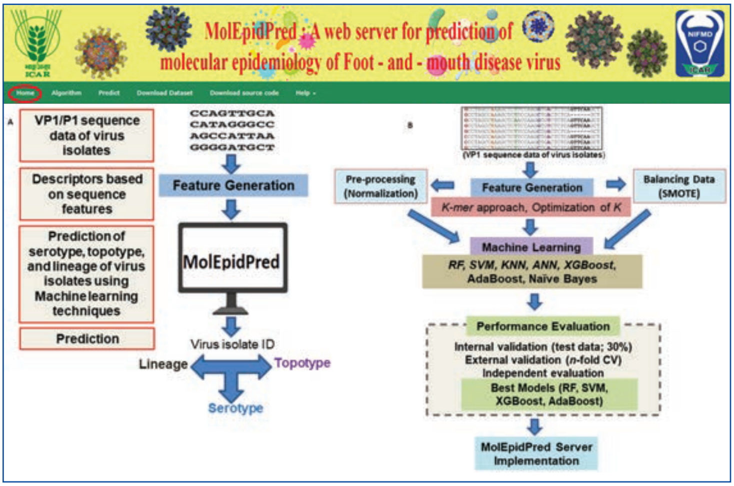
Computer vision–based approaches are also gaining prominence. Facial image-based biometric recognition systems provide a reliable, non-invasive method for unique animal identification, supporting traceability, health record management, and theft prevention. In parallel, deep learning–based identification and classification of similar-looking indigenous cattle breeds address challenges in breed conservation, genetic improvement, and policy planning by enabling accurate breed differentiation.

Behavioural monitoring solutions, such as AI-enabled software for detecting estrus and parturient behaviour in Mithun (*Bos frontalis*), improve reproductive management by providing precise alerts, reducing reliance on manual observation, and enhancing reproductive efficiency.

The above-mentioned digital tools demonstrate the transformative potential of AI- and sensor-driven technologies in animal health and veterinary research. Their adoption by the various stakeholders will ensure precision, sustainability, and resilience in livestock management systems while advancing animal welfare research capabilities.

7.1 MolEpidPred: ML/AI solution for molecular epidemiology of FMD virus

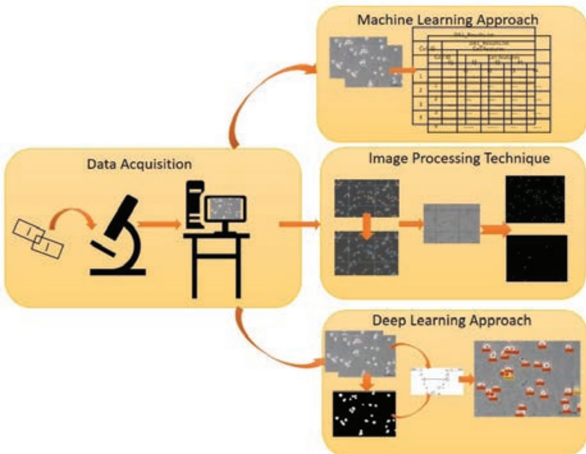
Foot-and-Mouth Disease (FMD) virus is a highly contagious livestock pathogen causing severe economic losses worldwide due to reduced productivity and persistent infections. MolEpidPred is a machine learning and artificial intelligence–based web platform designed for fast, accurate, and high-throughput molecular epidemiology of FMD virus using VP1 nucleotide sequence data. The tool provides a user-friendly, single-click interface to predict serotype, topotype, and lineage of FMD virus isolates within seconds, reporting results in the World Reference Laboratory for FMD–recommended format. MolEpidPred employs a three-step hierarchical prediction framework and integrates multiple ML models, including Support Vector Machine, Random Forest, AdaBoost, and Extreme Gradient Boosting, with an option for consensus-based prediction to enhance confidence. The web interface is developed using modern web technologies with an ASP.NET backend and R as the statistical engine. Capable of handling large datasets, MolEpidPred has attracted significant global usage, demonstrating its utility as the first AI/ML solution for large-scale molecular epidemiology of FMD virus.



USP	:	MolEpidPred is the first AI/ML-driven web platform enabling rapid, high-throughput, and highly accurate serotype, topotype, and lineage prediction of FMD virus from VP1 sequences in a single-click
Name of the Inventors	:	Dr Samarendra Das, Dr Soumen Pal, and Dr Saravanan Subramaniam
More Information	:	Director, ICAR-National Institute of Foot and Mouth Disease, Bhubaneswar - 752050

7.2 ML framework for identification of porcine cells

Machine learning based algorithms are being developed for automated identification of porcine cells from microscopic image datasets. The proposed framework enables high-throughput processing and analysis of large volumes of cellular images for accurate segmentation, detection, classification, and counting of porcine cells. Advanced deep learning models are trained to extract discriminative morphological features, significantly reducing analysis time while minimizing operator dependent variability and manual errors. Development costs are primarily associated with computational infrastructure, including GPU or cloud-based platforms, along with experimental validation using annotated datasets. The trained models are designed to be deployable on standard desktop computers or integrated into user friendly desktop applications, ensuring broad accessibility for researchers and diagnostic laboratories. Operational costs mainly involve computational expenses for periodic model retraining, software updates, and secure data storage. Overall, this technology provides a robust and automated solution for porcine cell analysis, enhancing accuracy, reproducibility, and efficiency, and offering substantial support for biomedical research, veterinary diagnostics, and translational studies.



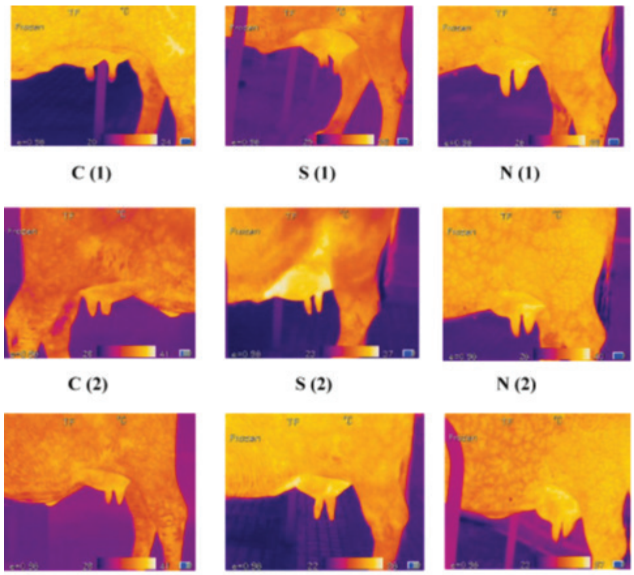
USP : Machine learning based automated porcine cell identification enables high throughput, accurate segmentation, classification, and counting from microscopic images, reducing manual effort and variability while supporting efficient biomedical and veterinary diagnostics

Name of the Inventors: Dr Salam Jayachitra Devi, and Jaya Bharati

More Information : Director, ICAR-National Research Centre on Pig, Guwahati - 781131

7.3 IR thermography based early identification of mastitis in Murrah buffaloes

Mastitis poses a major economic challenge to the dairy sector, with estimated losses of approximately Rs. 7000 crores in India. Infrared thermographic (IRT) image processing combined with artificial intelligence offers a promising non-invasive approach for early detection of mastitis in Murrah buffaloes. A deep learning model was developed using IRT images to diagnose sub-clinical mastitis under controlled conditions. The model was trained using AI on a comprehensive dataset comprising 2,493 thermograms of clinical mastitis–affected quarters, 2,749 sub-clinical mastitis–affected quarters, and 2,373 healthy quarters captured using an IRT camera. Testing accuracy of the sequential model reached 97% for healthy versus clinical mastitis and 94% for healthy versus sub-clinical mastitis. The tentative cost involves procurement of an IRT camera (Rs. 0.90–5.00 lakh).



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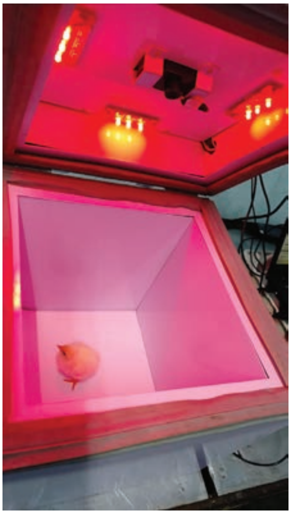
USP	:	AI driven infrared thermography enables non-invasive, early and highly accurate detection of clinical and sub-clinical mastitis in Murrah buffaloes, reducing dairy losses and improving herd health
Name of the Inventors	:	Dr Mukesh Bhakat, Dr TK Mohanty, and Dr Gayathri S Lal
More Information	:	Director, ICAR-National Dairy Research Institute Karnal - 132001

7.4 Gender determination of chick and smart Environment Monitoring System (GEMS)

Gender determination of chick and smart Environment Monitoring System (GEMS) is an integrated technology developed for improving efficiency and sustainability in poultry farming and hatchery operations. The system comprises two major components: an IoT sensor–based framework for real-time environmental monitoring in poultry farms and an AI/ML based chick gender identification system, termed *Chirpalyzer*, using vocalization data of day-old chicks. The IoT framework enables continuous monitoring of temperature, humidity, dust, and harmful gases such as CO_2 and ammonia, with automatic alarm generation when threshold limits are exceeded. Chirpalyzer allows rapid, non-invasive sexing of 2–5 chicks per minute with over 90% accuracy in white leghorn chicks. The system has been successfully tested in research and commercial poultry farms.



Sensor Node for Broiler farm

USP : Integrated IoT and AI system enables real time poultry environment monitoring and non-invasive chick gender identification with over 90% accuracy, improving hatchery efficiency, sustainability, and welfare

Name of the Inventors: Dr A Kannan, Dr RN Chatterjee, Dr SV Rama Rao, Dr TR Kannaki, and Dr SK Bhanja

More Information : Director, ICAR-Directorate of Poultry Research, Hyderabad - 500030

7.5 AI enabled software for detecting estrus and parturient behaviour in Mithun (Bos frontalis)

An advanced artificial intelligence based software has been developed for automated detection of estrus and parturient behaviour in Mithun (*Bos frontalis*) using deep learning techniques. The system is built on a convolutional neural network (CNN) architecture and employs an object detection model for real-time analysis of continuous video surveillance data. The software automatically identifies and classifies key behavioural patterns such as feeding, standing, mounting, and lying, which are critical indicators of reproductive status and animal well-being. By analyzing recorded video streams, the system enables accurate identification of estrus and parturient behaviours without the need for constant manual observation. This technology supports farmers, veterinarians, and researchers by facilitating timely estrus detection, effective calving observation, and behaviour-based health assessment. It also offers significant potential for livestock behaviour research, reproductive management, and animal welfare monitoring, contributing to precision livestock farming and improved productivity of Mithun under field conditions.

USP	:	AI-powered CNN software enables real time video based detection of estrus and parturient behaviours in Mithun, improving reproductive management, welfare monitoring, and productivity
Name of the Inventors	:	Dr L Sunitibala Devi, Dr Harshit Kumar, Dr SS Hanah, Dr YM Somagond, Dr Kobu Khate, and Dr Girish PS
More Information	:	Director, ICAR-National Research Centre on Mithun, Medziphema - 797106

7.6 DL based identification and classification of similar-looking indigenous cattle breeds

Accurate identification of phenotypically similar indigenous cattle breeds is crucial for effective herd management, genetic improvement, and conservation. This work utilises deep learning for differentiating two visually similar Indian cattle breeds, Sahiwal and Red Sindhi, using images captured with mobile cameras under field conditions. An EfficientNet-based convolutional neural network model was developed and evaluated using images collected from 120 animals, achieving an initial classification accuracy of 66%. The results demonstrate the feasibility of automated breed identification using low-cost, easily accessible mobile imaging, eliminating the need for specialized cameras and improving practicality for farmers. The study highlights key challenges such as high visual similarity between breeds and limited training datasets. Future research will focus on expanding and diversifying image datasets and adopting more advanced deep learning architectures to enhance classification performance. Overall, the proposed AI-based approach shows strong potential to reduce dependence on expert judgment, support accurate breed identification in field conditions, and promote sustainable livestock management and genetic purity.

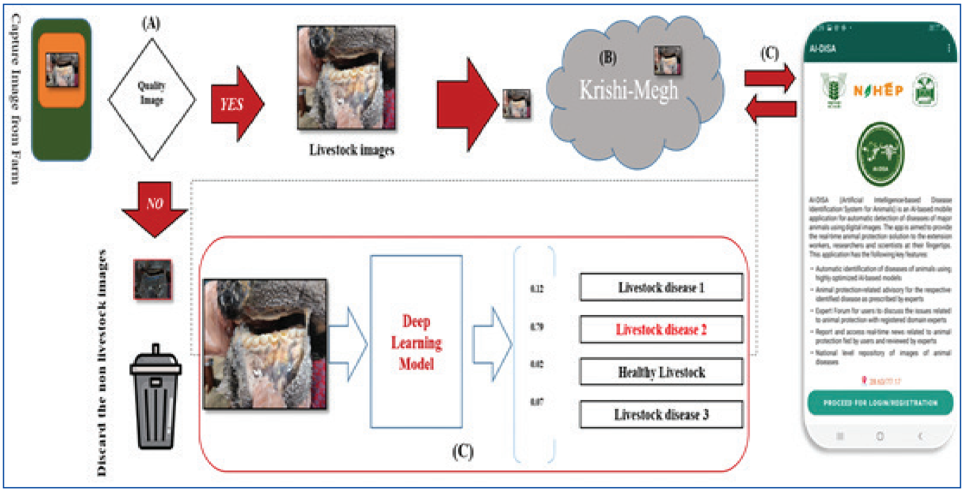
USP : Low cost mobile image based deep learning enables automated identification of visually similar indigenous cattle breeds, reducing expert dependence and supporting practical herd management and genetic conservation under field conditions

Name of the Inventors: Dr Indu Devi, Dr Warhade Radhika, and Dr TK Mohanty

More Information : Director, ICAR-National Dairy Research Institute, Karnal - 132001

7.7 AI-DISA: AI based disease identification system for animals

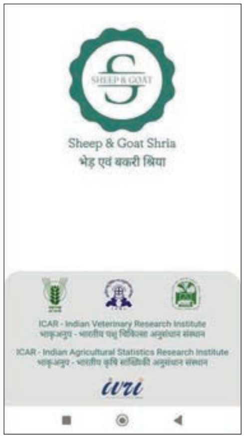
AI-DISA (AI based Disease Identification System for Animals) is an AI powered mobile platform designed for rapid detection and advisory of animal diseases. The system integrates DL based image analysis with knowledge driven modules to identify visible symptoms in bovine and canine species. Currently, AI-DISA detects three major bovine diseases i.e. foot and mouth disease, mastitis, and lumpy skin disease and five canine diseases, covering a total of nine diseases across two animal groups. It delivers real time, evidence based advisories to farmers, veterinarians, and livestock owners, enabling timely disease management at the field level. AI-DISA also supports participatory disease surveillance through crowdsourced, geo tagged data, generating valuable spatio temporal insights. By reducing diagnostic delays, strengthening veterinary extension services, and enabling early warning and targeted control strategies, AI-DISA contributes significantly to improved animal health, productivity, and informed policy decision making.



USP	:	AI-DISA enables instant, AI driven detection and advisory of livestock and canine diseases through image based diagnosis and geo tagged surveillance, supporting rapid field level and policy decisions
Name of the Inventors	:	Dr Sudeep Marwaha, Dr Alka Arora, Dr Anshu Bharadwaj, Dr Ajit, Dr Shashi Dahiya, Dr SN Islam, Dr Chandan Kumar Deb, Dr Md Ashraful Haque, Dr Madhu
More Information	:	Director, ICAR-Indian Agricultural Statistics Research Institute, New Delhi - 10012

7.8 Chatbots for improving livestock, pet and poultry health and production

SHRIA (Smart Heuristic Response based Intelligent Assistant) is an advanced, AI driven educational platform designed to deliver instant, personalized, and scalable support to stakeholders in the livestock sector. Powered by natural language processing (NLP) and AI, SHRIA provides real time, context specific, and scientifically validated information through multilingual, voice enabled interaction in 10 Indian languages. Three dedicated Chatbots Dairy SHRIA, Sheep and Goat SHRIA, and Swine SHRIA offer comprehensive guidance on breeding, feeding, healthcare, management, calf rearing, and organic practices. Designed for accessibility across literacy levels, SHRIA bridges critical knowledge gaps in rural farming communities. Field tested by ICAR-IVRI students, the platform demonstrates high efficiency with an average response time of 2.37 seconds and thousands of real world queries successfully resolved. By reducing misinformation and ensuring timely advisory, SHRIA improves animal health, productivity, and profitability while supporting veterinarians, policymakers, and extension systems with consistent, scalable knowledge dissemination.



USP : SHRIA delivers instant, voice enabled, multilingual (10 Indian languages) AI advisory for livestock management, providing scientifically accurate guidance at scale to farmers and veterinarians

Name of the Inventors: Dr Rupasi Tiwari, Dr Triveni Dutt, Dr Sanchita Naha, Dr Chandan Kumar Deb, Dr Sudeep Marwaha, Dr Brejesh Lall, Dr Anuj Chauhan, Dr UK De, Dr K Mahendran, Dr Amit Kumar, Dr Sameer Srivastava, Dr Ashok Kumar M, Dr Mahesh Chander, Dr Ajit Singh Yadav, and Dr AK Tiwari

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7.9 BufAMPpred: DL based AMP prediction server

An improved buffalo specific antimicrobial peptide (AMP) prediction web server was developed using a deep neural network based on a hybrid CNN–LSTM architecture. The model outperformed existing AMP prediction tools, achieving an accuracy of 98.72% and an AUC of 99.14% in distinguishing AMP from non AMP sequences. The server features a user friendly interface that allows users to submit protein sequences in FASTA format either by direct input or file upload. Prediction outputs are displayed in a downloadable tabular format for easy analysis. A key advantage of the server is its capability to process up to 500 sequences in a single submission, overcoming the limitations of most existing tools that support only single sequence analysis. The outcomes of this study can strengthen disease resistance in buffalo and support global dairy and meat industries, while computationally identified AMPs offer promising alternatives to antibiotics for managing antimicrobial resistance in livestock farming.

USP	:	A high accuracy, buffalo specific AMP prediction server with CNN–LSTM intelligence developed and bulk sequence processing for combating disease and antimicrobial resistance in livestock
Name of the Inventors	:	Dr MA Iquebal, Dr Aamir Khan, Dr Kalpana Singh, Dr Ajay Verma, Dr Sarika, Dr Varij Nayan, Dr UB Angadi, Dr TK Datta, Dr Anil Rai, and Dr Dinesh Kumar
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Chapter 8
Synthesis of Development and Way Forward

There is a global strive across all the innovations to align the outcomes as per the proclaimed SDG's of the United Nations adopted in 2015. Agriculture is no exception, given that in the present times it is facing a never before witnessed magnitude to multifaceted challenges of climate change urbanization, resource scarcity and population.

The world is witnessing a rapid spread of innovations in the field of artificial intelligence (AI) in almost all the domains of human endeavours. Amalgamation of AI, remote sensing, satellite imagery, and IoT devices is a key enabler of data driven decision making to realize real-time monitoring of agriculture. Harnessing the applicability of AI tools for agriculture can lead to an improves precision agriculture practices, resource allocation, crop improvement, crop protection, germ plasm characterization, and whether forecasting; everything contributing to enhance agricultural productivity, food security and livelihood diversification. The integration of Artificial Intelligence (AI), Machine Learning (ML), and Robotics into agricultural systems represents one of the most transformative technological evolutions of the 21st century. Globally, AI-driven agriculture is projected to reach a market value of USD 4.7 billion by 2028, growing at a CAGR of nearly 23%, driven by advancements in computer vision, autonomous equipment, and precision decision-support systems. Within this context, AI-based crop disease detection has emerged as a key enabler for ensuring food security, particularly in the face of climate variability, shrinking arable land, and rising pest and pathogen threats. According to FAO estimates, up to 40% of global crop production is lost annually to pests and diseases, translating to economic losses exceeding USD 220 billion. The World Bank further highlights that effective digital surveillance systems could reduce these losses by 15–25%, underscoring the strategic importance of AI-powered early warning and diagnostic tools in safeguarding global food systems.

8.1 Precipitation of AI technologies in agriculture

Leveraging the revolutionary transformative capabilities of AI, work carried out in India during the past decade has led to evolution of a pattern of research work in the ICAR capabilities eco-system. A quick glance across the pattern reveals an optimized application of computer systems and algorithms to perform tasks such as reasoning, sensing, and decision making across the entire agricultural value chain of the country. All the innovations and interventions, directly or indirectly is contributing to advancements of efforts towards reducing the environmental effect of agriculture and enhancing food security by minimizing the detrimental effect of pests, diseases, and climate variability.

Reaping benefits of these technologies is in need of proactive policy formulation, robust cyber security protocols, a digitally literate clientele and a fool-proof cloud infrastructure. A comparative mapping of AI based technologies in Indian perspective as compared to that of the world can be presented as:

AI applications	Developed countries	Developing countries
Precision agriculture	• AI-powered tractors, drones, and IoT sensors to optimize input use. • Machine learning models to predict optimal planting and harvesting times.	• Mobile-based AI advisory platforms offer low-cost recommendations for input applications. • Smart irrigation solutions like solar-powered drip systems reduce water wastage.
Disease prediction and crop monitoring	• AI-driven image recognition and machine learning models diagnose plant diseases using satellite imagery. • AI-assisted drones survey fields and detect pest infestations.	• Low-cost AI-powered mobile apps help farmers detect diseases through smartphone images.
Climate-resilient agriculture	• AI-powered weather prediction models provide real-time climate forecasts. • AI-driven soil health sensors optimize fertilization.	• SMS-based weather advisory services provide smallholder farmers with real-time climate alerts. • AI-integrated mobile solutions suggest drought resistant crops. • Localised, real time agricultural guidance that enhances production, resilience, and development.

AI applications	Developed countries	Developing countries
Livestock management	• AI-powered facial recognition for cattle identification and health monitoring, optimizing animal feed supply chain and production. • Precision feeding systems that optimize nutrition, reduce waste and efficient feeding systems in livestock.	• AI-enabled mobile applications allow farmers to diagnose livestock diseases via smartphone photos. • AI-based automated milking systems help dairy farmers improve milk yields to enhance productivity in dairy farming.
Supply chain optimization	• AI-integrated blockchain systems ensure transparency in food supply chains. • AI-driven inventory management reduces food waste and optimizes logistics that helps reduce postharvest losses.	• Mobile-based AI platforms connect farmers directly with buyers, reducing middlemen. Thus, helping the transformation of agrifood system. • AI-driven price forecasting apps help farmers optimize sales which connects smallholder producers in the food value chain to a broader online market and offers access to fair prices, and bulk sales information

8.2 Gaps in the adoption of AI technologies

Acceptability of technology by individuals and organizations is guided by two key factors, - Perceived Usefulness (PU) expresses the performance enhancement capability of the technology, and Perceived Ease of Use (PEOU) which entails the extent of user-friendliness of the technology. These two factors are the components of Technology Acceptance Model (TAM) that explains the adoption of newer technologies by a population. Adoption of AI, IoT and technologies related to robotics depend of PU and PEOU. There has to be a mechanism laid out by which the farmers, business houses and policy makers have to be convinced about the benefits of these technologies for increasing productivity, improving efficiency, and reducing risks. The key challenges that influence the application of TAM in adoption of AI/IoT/ Robotics technologies in agriculture is digital divide due to the digital illiteracy of the end users and the poor infrastructure to support such technologies. Also, the digital technologies come with substantial financial investment, again an impediment to adoption of these technologies by small farmers.

A reason of failure of TAM can be attributed to the PU components with respect to the digital technologies, where in the farmers' expresses reluctance in shifting traditional farming methods to AI-based decision-making. This is particularly true for cases where the farmers have successfully operated their farms without AI in the past. Trust, or the lack of it, maligns the AI technologies far before they reach the end users. Here, it is important to mention that exhaustive trainings and on-field demonstrations of AI technologies are the only way out for their adoption.

The developing countries have adopted AI driven farm management systems in addressing labour shortages and increasing efficiency. Real-time analytics on soil conditions and whether parameters are already helping farmers in making informed decisions; robotic rice planters and harvesters, fully robot-controlled animal farms are reducing the dependencies on human labour. In India, automation is gradually being introduced in the form of AI-powered drones for pesticide spraying and crop monitoring.

Admittedly, AI technologies are the future of agriculture across the world. The developing countries have to overcome the financial and infrastructural barriers quickly to ensure sustainable and inclusive agricultural development. Absence of sufficient technical support in terms of technology maintenance, availability of spares, and unorganized training for the stakeholders further exacerbates the adoption of digital technologies.

8.3 Ethical aspects of data driven agriculture

Ethical and societal considerations are key dimension in AI adoption in agriculture, highlighting risks such as data privacy violations, job displacement, and algorithmic bias as barriers to socially acceptable AI adoption. These ethical concerns are closely linked with the policy and governance landscape, where supportive institutions and regulatory frameworks play a mediating role in guiding technological adoption. Ethical deployment of AI calls for transparency, participatory design, and the democratization of technology to prevent the marginalization of smallholder farmers.

Generally, AI and robotics alter job structures through reducing demand for manual labour while increasing the need for digital skills. Inadequate educational and institutional support, risks deepening inequalities, productivity and poverty. Policies have to be in place that support training, capacity-building, and the formalization of AI-oriented rural employment. The synergistic use of AI holds great promise for agricultural productivity and food security. There has to be systemic alignment across technical, social, and institutional domains to realize the true potential of AI application in agriculture.

Additionally, the shortage of trustworthy and high-quality data needed for effective AI application poses a substantial challenge with issues relating to data privacy and security; further the sheer volume data complicates the adoption processes. Data-related issues are critical and essential to maximize the potential of AI in agriculture and enable decision-making and carry out sustainable agricultural practices. Key challenges remain limited digital record-keeping, weak data collection infrastructure, and inconsistent data-sharing mechanisms compounded by economic disparities in the agrarian landscape of India.

There is always an apprehension in agricultural AI adoption led by multi-national corporations; small farmers perceive a threat on monopoly that exploitation. There can be situations when farmers will have limited choices to exercise for the agricultural inputs resulting in a disadvantaged position.

AI robotics has the potential to revolutionize agriculture but its ethical and social implications need serious attention and proactive rectifying measures in case of a breach. Genuine efforts are needed to made for percolating only context-specific AI models, developed using local data with inputs from indigenous farmers to ensure fairness and accuracy.

Participatory governance, equitable data policies, labour transition plans, and inclusive digital infrastructure are necessary to ensure that AI in agriculture does not entrench inequality but instead promotes shared benefits and sustainability across all scales of farming systems.

8.4 Human resource development and deployment

There is a significant shortage of trained manpower in the areas of artificial intelligence and robotics within agricultural research as well as at the field application level. This critical gap is limiting the effective development, deployment, and scaling of advanced digital and automation technologies in the sector. It is therefore imperative to bridge this deficit at the earliest by ensuring a minimum threshold of qualified AI experts, data scientists, and robotics engineers across R&D institutions, extension systems, and grassroots implementation platforms. Strategic capacity building through targeted recruitment, specialized training programs, and industry–academia collaboration will be essential to accelerate innovation, improve technology adoption, and enhance productivity and sustainability in Indian agriculture.

8.5 Bridging the gap and way forward

In order to realize the vision of Viksit Bharat@2047, India must accelerate the adoption and scaling of Emerging Agricultural Technologies (EAT) through coordinated, multi-stakeholder action. Immediate priorities include increased investment in farmer-centric digital innovations, research on digital inclusion, Responsible AI, and quantum computing, and the development of a Standard Spectral Library for Indian soils. Emphasis should be placed on advancing low- cost sensor technologies for soil and water management, as well as promoting digital and data-driven innovations for last-mile technology adoption. Precision monitoring of agricultural ecosystems using remote sensing, IoT sensors, and drones will enable real-time, data-based decision-making and climate resilience. The chronology for the future needs to cater the following areas with a methodological and systematic approach:

- By 2035: Integrate high-resolution mapping, IoT-based irrigation, carbon standards, microbial technologies, and renewable-powered production systems to boost productivity and cut agricultural GHG emissions by 50%.
- By 2040: Transition to a circular agricultural economy with 40% recycling of Agri-waste and wastewater, and wider application of AI-driven system integration for sustainable production.
- By 2047: Achieve climate-resilient, net-zero, and zero-waste agriculture, establishing an ecologically and economically sustainable farming ecosystem for modern India.

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