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Smart Farming in Agriculture

[1] Dr. G. Bhaskar, [2] Dr. S.V. Srikant

[1] Assistant Director (IT) (Selection Grade) and Head (Knowledge Management), Manage, Hyderabad

[2] Joint Director, CDAC, Hyderabad

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ABSTRACT

Smart farming is an emerging approach that integrates advanced technologies to revolutionize traditional agricultural practices. It leverages tools like the Internet of Things (IoT), Artificial Intelligence (AI), drones to improve productivity, sustainability, and decision-making in agriculture. In India, where over 70% of the rural population depends on farming, precision agriculture offers a powerful solution to challenges faced by farmers and also to adopt the climate changes. IoT sensors enable real-time monitoring of soil moisture, weather, and crop health, optimizing irrigation and input use. AI-driven analytics support early detection of pests and diseases and guide farmers on crop management strategies. Smart farming significantly boosts crop yield, reduces resource wastage, and improves market access for farmers. Customized models for small and large landholders ensure affordability and scalability. Real-world implementations like Harita-Priya, AgSpeak, Cropin, and AgriRain have shown measurable success in improving yields and farmer incomes, which was included as uses case in this paper. This paper attempts to address the needs of farmers of below 5 acres and above 5 acres and suggests the smart farming technology required and cost of implementation suits to both categories of farmers groups. As the country advances toward a digital agricultural ecosystem, smart farming will be pivotal for achieving food security and climate resilience and marks the beginning of a transformative era in Indian agriculture, promoting environmental sustainability.

INTRODUCTION

Agriculture plays a dominant role in Indian rural community and over seventy percent of rural community depends on it. The agricultural sector contributes approximately 17% of total GDP of India. Since independence of the country, the agricultural sector has seen tremendous changes to meet the needs of population by increasing food production in multiple times, and started exporting excess produce. This all showcased because of the green revolution, policy level interventions and adopting various technologies in the agricultural sector. The Information and Communication Technologies (ICTs) plays vital role in farming. The advancement of technologies, communication facilities, smart phone usage helping the farmers to avail timely information from experts on weather, inputs, best practices, crop health and marketing.

Smart farming as an emerging concept that refers to managing agriculture farms using modern Information and Communication Technologies (ICTs) such as Internet of Things (IoTs), Artificial Intelligence (AI), Drones, Robotics and communication facilities to increase the efficiency in farming practices that optimises the use of water, input applications-fertilizers, pesticides, crop management practices, which enhance the quality of produce and also improves the yields. The concept of smart faming also optimizing the human labour required in the farming.

Smart farming, also known as precision agriculture, leverages modern technology to enhance agricultural productivity, efficiency, and sustainability. With the global population rising and natural resources becoming scarce, adopting smart farming techniques is crucial to ensuring food security and environmental conservation.

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The smart farming is a need in our country where vast agricultural landscape and diverse climate conditions exist to overcome the traditional faming challenges.

Technologies Used in Smart Farming

Internet of Things (IoT)

Internet of Things (IoT) devices help in monitoring soil moisture, temperature, and crop health through sensors installed in fields. These sensors provide real-time data to farmers through mobile applications, enabling precision agriculture and optimizing resource usage. Smart irrigation systems using IoT technology help in automating watering schedules based on soil moisture levels, thereby reducing water wastage and improving crop yield.

Artificial Intelligence (AI) and Machine Learning (ML)

AI and ML are revolutionizing agriculture by analysing vast amounts of data to predict weather conditions, detect crop diseases, and optimize farming practices. AI-powered chatbots and mobile applications provide real-time guidance to farmers on pest control, weather updates, and soil conditions, reducing reliance on traditional trial-and-error methods.

Automated Irrigation Systems

Smart irrigation systems use sensor-based controllers to automate watering schedules, reducing water wastage and improving crop health. These systems can be integrated with weather forecasts to optimize water usage efficiently. In water-scarce regions an automated irrigation will be a game-changer in sustaining agricultural productivity.

Robotics and Automated Machinery

The use of robotic harvesters, autonomous tractors, and automated seed planters enhances efficiency in agricultural operations. These technologies minimize labor costs, reduce human error, and increase overall productivity. In India, agri-tech startups are developing affordable robotic solutions for small and medium-scale farmers.

Drones, Remote Sensing and Geographic Information Systems

Drones equipped with cameras and multispectral sensors offer high-resolution imagery of farmlands. These images help farmers detect crop diseases, pest infestations, and irrigation issues at an early stage. In India, government initiatives are promoting drone technology for pesticide spraying, land mapping, and farm monitoring, ensuring efficient use of resources and minimizing manual labour.

GIS technology plays a crucial role in soil mapping, land classification, and crop monitoring. GIS-based analysis helps farmers identify soil nutrient deficiencies, assess weather risks, and determine the best planting strategies. This technology is widely used for precision farming, enabling farmers to make informed decisions about fertilization and irrigation schedules.

Benefits of Smart Farming

In Smart Farming scenario, the sensors and other IoT enabled devices collect data on various aspects of the farm, such as soil moisture, temperature, crop health, and weather conditions. This data is then analysed using AI based application tools to identify trends, patterns, analyse crop data to predict yields and potential problems of the crop. Based on the analysis, farmers can make informed decisions about irrigation, fertilization, pest control, and other aspects of their operations. Automated systems can then implement the decisions such as adjusting irrigation schedules, recommendations will be suggested for farmers on crop

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management practices. Smart farming promotes sustainable farming practices by reducing the use of water, fertilizers, and pesticide and also better crop management practices.

The major benefits envisaged from Smart Farming is as given below:

Efficient Resource Utilization

Precision agriculture ensures the optimal use of water, fertilizers, and pesticides, reducing waste and minimizing environmental impact. IoT-enabled smart irrigation and soil monitoring systems enhance resource efficiency.

Operational and Labour Cost Reduction

Automated machinery, AI-driven insights, and data analytics reduce operational costs by minimizing labour dependency and optimizing input usage. This is particularly beneficial for smallholder farmers who operate on tight budgets.

Robotics and Drones for better Crop Management

Robots can be used to automate tasks like planting, weeding, and harvesting. Drones can be used to monitor crop health, identify pests and diseases, and assess crop yields.

Increased Crop Yield and Better Decision-Making

Smart farming techniques optimize growing conditions, leading to higher crop yields and improved food security. AI-driven analytics help in identifying the best sowing and harvesting times, reducing losses due to climatic uncertainties. Real-time data and insights empower farmers to make more informed decisions, leading to better outcomes.

Climate Resilience

Smart farming tools help farmers adapt to changing climate conditions by providing predictive insights on weather patterns, pest infestations, and soil health. This improves preparedness and mitigates potential losses.

Smart Farming models

In India, farmers' land holdings are categorized in to marginal (below 1 hectare), small (1-2 hectares), semi-medium (2-4 hectares), medium (4-10 hectares), and large (over 10 hectares). Based on the landholding size in the country, two smart farming models are proposed in this paper. (1) Smart Farming Model for upto 5 Acres of land which covers Marginal and Small farmers and (2) the model for above 5 acres of land size, which covers medium and large farmers. The first model ensures that more than 80 per cent of farmers will be covered where the smart farm technology is adoptable. The second model focus an intensive one to implement reasonable good smart farming technologies where the farmers in this category can comfortable for investment.

Smart Farming Model for Farmers with up to 5 Acres (Marginal & Small Farmers)

Objectives:

- Low-cost automation
- Improved yields with minimal input waste
- Access to advisories and market linkage

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Key Components:

- IoT-based soil moisture & temperature sensors (LoRa/low-power tech)
- Smart irrigation kits (drip or sprinkler with mobile-based control)
- Pest & disease forewarning (using shared community sensors or mobile apps like Plantix)
- Mobile advisory platforms (SMS/IVR support)
- Community-shared drone service (for periodic health check)
- Affordable weather stations (installed at village/community level)

Smart Farming Model for Farmers with more than 5 Acres (Semi-Medium & Above)

Objectives:

- Full-field automation
- Resource optimization at scale
- High precision and data-driven decision-making

Key Components:

- Precision agriculture using GNSS-enabled equipment
- Multi-zone smart irrigation & fertigation systems
- Farm-specific weather stations
- AI-based dashboards for crop growth and market prediction
- Drones and satellite imagery for real-time crop monitoring
- Advanced pest prediction models using micro-climate sensing
- Data analytics for supply chain optimization
- Integration with blockchain-based traceability systems

Table 1: Adoption of Smart Farming Technologies by Landholding Size

Technology Category	Up to 5 Acres (Marginal & Small Farmers)	More than 5 Acres (Semi-Medium & Above)
Land Size	**≤ 5 acres (≈2 hectares)**	**> 5 acres**
Affordability Focus	Low-cost, shared or subsidized solutions	Scalable, capital-intensive technologies
Irrigation	Smart drip/sprinkler with mobile control	Multi-zone precision irrigation & fertigation

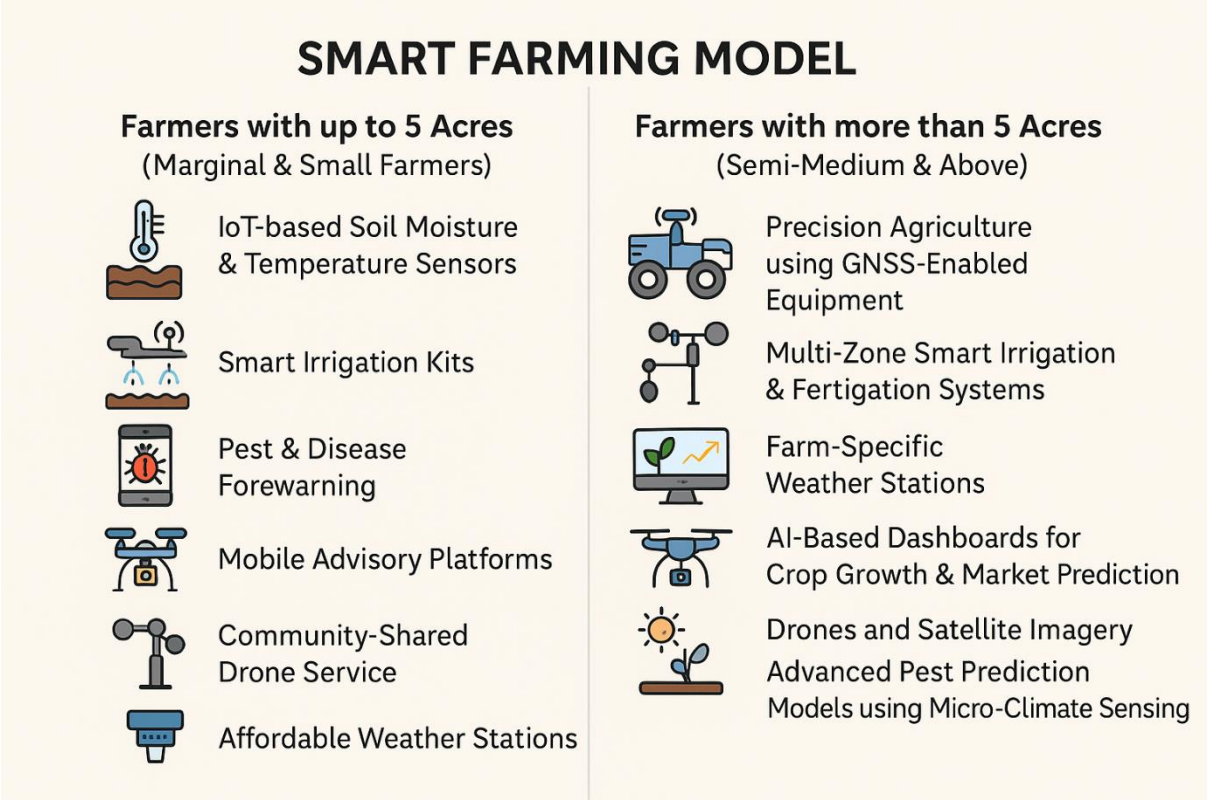
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Monitoring Tools	Soil moisture sensors, community weather stations	Farm-specific sensors, advanced weather stations
Pest & Disease Alerts	Mobile apps (e.g., Plantix), pheromone traps	AI-driven pest models, microclimate-based prediction
Data Access	Mobile apps in local languages, SMS/IVR advisories	AI dashboards, cloud analytics
Drone Usage	Community-shared drone services	Own or commercial drone monitoring & spraying
Remote Sensing	Periodic drone access, satellite via FPOs or govt channels	High-frequency satellite + UAV imagery
Machinery & Equipment	Manual/semi-automatic tools	GNSS/RTK-enabled tractors, autonomous sprayers
Traceability & Supply Chain	eNAM, FPO-based produce sales	Blockchain-based tracking, cold chain integration

Table 2: Implementation Cost of Smart Farming Technologies by Landholding Size

Technology Category	Up to 5 Acres (Marginal & Small)	Above 5 Acres (Semi-Medium & Above)
Basic IoT Sensors	₹15,000 – ₹25,000 (shared or limited sensors)	₹40,000 – ₹1,00,000 (per field block)
Mobile App Integration	₹1,000 – ₹3,000/year (e.g., Fasal, Plantix)	₹5,000 – ₹15,000/year with analytics
Irrigation Automation	₹20,000 – ₹35,000 (basic drip controller)	₹50,000 – ₹2,00,000 (zonal fertigation systems)
Pest & Disease Forecasting	₹5,000 – ₹10,000/year (subscription-based)	₹20,000 – ₹50,000/year (with custom models)
Drones & Imaging	₹0 (via community/FPO)	₹1,00,000+ or rental at ₹500–1,000/acre
Total Estimated Cost (Rs.)	**₹40,000 – ₹75,000**	**₹1.5 – ₹4 lakhs** (initial setup)

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Use Cases in India

Smart farming in India is gaining momentum due to the increasing need for sustainable agriculture, higher yields, and efficient resource management. Here are few **use cases of smart farming in India**, categorized by technology and application area:

Use Case: Harita-Priya Project in Andhra Pradesh

The Harita-Priya (Harmonized Information of Agriculture, Revenue, and Irrigation for a Transformation Agenda – Precision Technology for Agriculture) project is a pioneering initiative by the Government of Andhra Pradesh, developed in collaboration with the Centre for Development of Advanced Computing (CDAC) Hyderabad. This project aims to enhance agricultural productivity through the integration of advanced technologies and real-time data analytics.

Objectives

Microclimate Monitoring: Deploy Wireless Sensor Networks (WSNs) to collect real-time microclimatic data from agricultural fields.

Personalized Advisories: Provide farmers with location-specific advisories on irrigation schedules, pest control, and disease management.

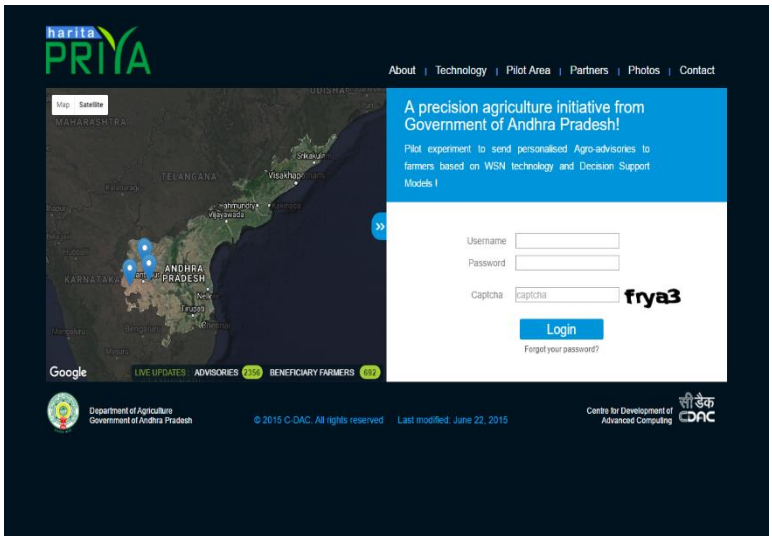
Resource Optimization: Enhance water use efficiency and reduce crop losses by enabling timely interventions based on sensor data.

Implementation

In the pilot phase, the project was implemented in five villages of Anantapur district, focusing on groundnut cultivation. Each village was equipped with 20 WSN nodes, spaced approximately 150 meters apart, covering around 80 acres. These nodes measured parameters such as temperature, humidity, soil moisture, soil

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temperature, and leaf wetness. The data collected was transmitted to a central server via gateways, where it was analyzed to generate actionable insights.



Outcomes

Enhanced Decision-Making: Farmers received timely SMS alerts in their local language, enabling them to make informed decisions regarding irrigation and pest management.

Recognition: The project was awarded the World Summit on the Information Society (WSIS) 2016 Prize in the e-Agriculture category, acknowledging its innovative approach to integrating technology in agriculture.

Significance

The Harita-Priya project demonstrates the potential of integrating IoT and data analytics in agriculture, particularly for small and marginal farmers. By providing real-time, location-specific information, the project empowers farmers to optimize resource use, enhance crop yields, and reduce environmental impact.

Use Case 2: AgSpert Technologies (AgSpeak) – Smart Farming Innovation in Assam

AgSpeak is a data powered Direct-to-consumer smart farming application for agribusinesses and enterprises to directly discover and engage with farmers. AgSpeak empowers agribusinesses with remote farm management, location-based advisory broadcasting, and product or service promotion through a web-based application integrated with a free multilingual smartphone application available for the farmers. AgSpeak was launched in December 2020 and is helping agri-businesses discover, reach and engage over 6,000 plus farmers, 5 Farmer Producer Companies (FPOs), 600 farmers from 6 Krishi Vigyan Kendras and 10,000 handloom weavers of Assam-Northeast India digitally.

AgSpeak solution was developed as an agritech startup based in Jorhat, Assam by AgSpert Technologies, co-founded by Siddhartha Siddarth Bora, an alumnus of NIT Silchar. The company is pioneering smart farming solutions in the North East region of India, aiming to enhance agricultural productivity and sustainability through the integration of advanced technologies.

Objectives

Empower Smallholder Farmers: Develop affordable and accessible smart farming tools tailored for small and marginal farmers.

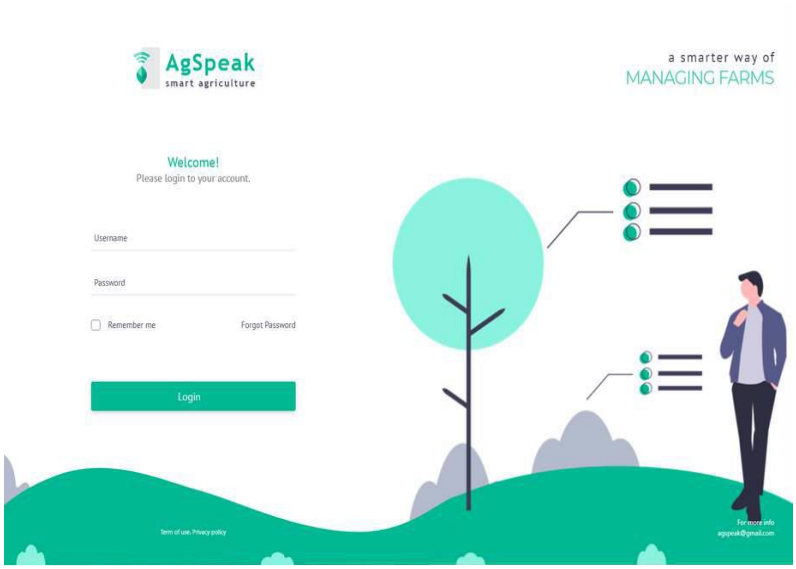
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Integrate Advanced Technologies: Leverage IoT, AI, robotics, and drones to optimize farming practices and resource utilization.

Enhance Crop Monitoring and Management: Provide real-time data and predictive analytics to assist farmers in decision-making processes.

Implementation

AgSpeak, is a multilingual AI-powered mobile application designed to assist farmers in managing their farms efficiently. The app supports local languages, including Assamese, making it user-friendly for the regional farming community. AgSpeak is a free platform for individual rural entrepreneurs to build discoverability for their small businesses-farming, livestock. For our enterprise users, AgSpeak provide the best in class tools to digitize and engage with rural businesses by analysing location specific data on a pay-per-use model.



Key features of AgSpeak

Real-Time Monitoring: Utilizes IoT devices and satellite data to monitor up to 20 crop health parameters such as temperature, rainfall, sunlight hours, and soil health.

Predictive Analytics: Employs machine learning algorithms to forecast potential crop threats like diseases and pest infestations, enabling proactive measures.

Resource Optimization: Provides recommendations for efficient use of water, fertilizers, and pesticides, reducing waste and environmental impact.

Supply Chain Integration: Facilitates connections between farmers and buyers, enhancing market access and transparency.

- Digital stakeholder on boarding and remote asset digitization to eliminate the need for costly and unorganized offline on boarding.
- Precise location specific information to facilitate better e-governance practices up to individual beneficiary level profiling.
- Efficient remote monitoring powered with Geo-Spatial analytics. Greater geographic distribution with location specific profiles.

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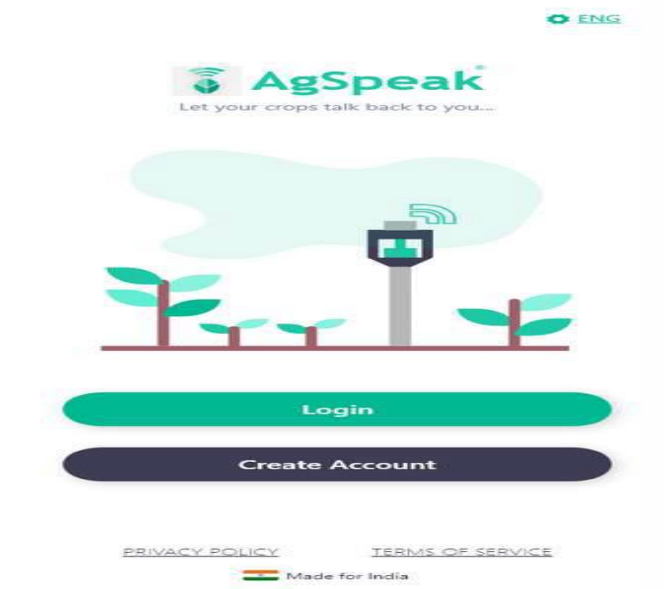
- Real-time data in organized location specific nature to boost fast decision making.
- Block chain powered supply chain digitization for End-to-End traceability of agro-products
- Easy accessibility and communication among enterprises and their rural stakeholders.
- Engagement amongst multi-level stakeholders and mass digital communication in vernacular languages.

Outcomes

Increased Productivity: Farmers reported improved crop yields due to timely interventions and optimized resource usage.

Early Threat Detection: The system successfully predicted issues like blight in potatoes and tea mosquito bug infestations, allowing for prompt action.

User Adoption: Approximately 250 farmers received hands-on training, with many more adopting the app due to its intuitive design and language support.



Significance

AgSpeak showcased how localized, technology-driven solutions can address the unique challenges faced by smallholder farmers in India's North East. By integrating advanced technologies into traditional farming practices, and is contributing to a more sustainable and prosperous agricultural sector in the region. This case study highlights the potential of smart farming initiatives like AgSpeak in transforming agriculture, particularly in regions with small and marginal farmers. The success of such projects underscores the importance of accessible technology, local language support, and farmer-centric solutions in driving agricultural innovation.

Use Case 3: Cropin's Precision Farming Initiatives in India

Cropin Technology Solutions, established is a leading AgriTech company based in India. The company specializes in providing Software as a Service (SaaS) solutions that integrate advanced technologies like Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) to digitize and optimize agricultural practices. Cropin's flagship platform, SmartFarm, is designed to enhance farm productivity, ensure sustainability, and improve traceability across the agricultural value chain.

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Implementation

Smart Farm is a comprehensive farm management solution that enables stakeholders to monitor and manage farm operations effectively.

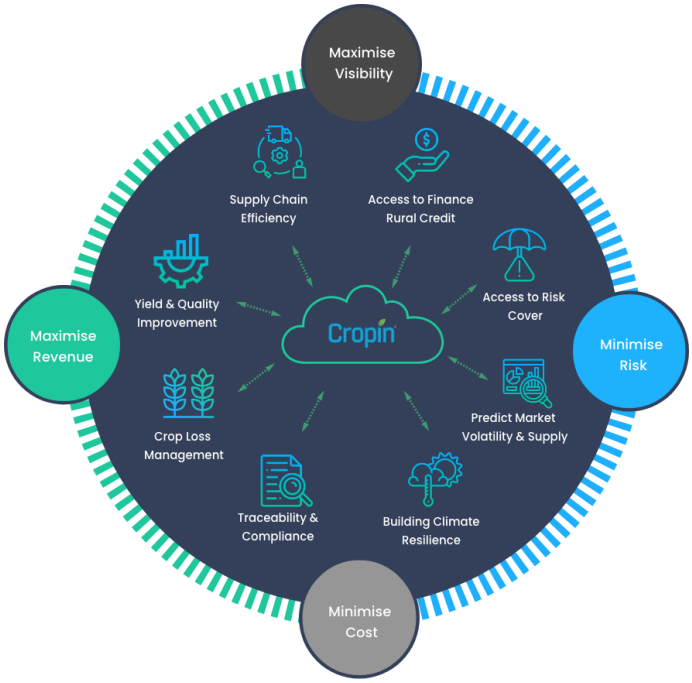
Key features include

Real-time Monitoring: Utilizes satellite imagery and IoT sensors to provide real-time data on crop health, soil conditions, and weather patterns.

Predictive Analytics: Employs AI and ML algorithms to forecast potential risks such as pest infestations and diseases, allowing for timely interventions.

Customized Advisory: Delivers tailored reco mmendations to farmers based on specific crop requirements and local conditions, enhancing decision-making processes.

Traceability: Ensures end-to-end traceability of produce, meeting compliance standards and enhancing market access.



Impact and Outcomes

Cropin's SmartFarm has been instrumental in transforming agricultural practices across various regions in India. The technologies used in the Cropin’s SmartFarm are IoT sensors, drones, satellite imagery and AI/ML.

Notable outcomes include:

Enhanced Productivity: In Andhra Pradesh, farmer Lokeswara Reddy reported an increase in net profit from ₹5,000–10,000 to ₹20,000 per acre after adopting Cropin's satellite data-driven advisories.

Climate Resilience: Under the Sustainable Livelihoods and Adaptation to Climate Change (SLACC) project, Cropin collaborated with State Rural Livelihood Missions in Bihar and Madhya Pradesh to provide climate-smart advisories, aiding farmers in adapting to climatic uncertainties.

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Supply Chain Efficiency: In partnership with the Punjab government, Cropin implemented a Seed Potato Traceability program to improve the quality of potato seed production, ensuring better marketability and compliance.

Significance

Cropin's precision farming solutions have demonstrated the potential to revolutionize agriculture in country by:

Empowering Smallholder Farmers: Providing accessible technology that enables informed decision-making and improved yields.

Promoting Sustainable Practices: Encouraging efficient resource utilization and reducing environmental impact.

Enhancing Market Access: Facilitating compliance with quality standards and improving traceability, thereby opening up new market opportunities.

This use case underscores the transformative impact of Cropin's precision farming initiatives in India, highlighting the integration of technology in enhancing agricultural productivity and sustainability

Use Case 4: AgriRain's Automated Irrigation System – Empowering Small Farmers through Smart Irrigation

In India, small farm holders rely on erratic rainfall or sub-optimal irrigation methods, leading to stagnant incomes and increased vulnerability to climate change. Traditional mechanized irrigation systems are often too expensive and complex for small farmers, requiring significant capital investment, technical expertise, and ongoing maintenance. To address these challenges, AgriRain provide an economical and effective solution tailored for small farmers offering Irrigation as a Service (IaaS).



Irrigation as a Service (IaaS)

AgriRain pioneered the world's first "Irrigation as a Service" (IaaS) model, eliminating the need for capital expenditure by small farmers. The key components of this model include:

Mobile Hosereel Technology: Trained operators use fully integrated and mobile hosereel systems to provide hassle-free, on-demand irrigation.

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Water Entrepreneurs: Rural youth are trained as water entrepreneurs responsible for precision irrigation at critical crop stages.

Mobile Application: An app collects geospatial data, crop information, weather forecasts, and historical weather data to provide customized irrigation schedules for each farmer.

Automated Notifications: Farmers receive automatic notifications, and water entrepreneurs deploy irrigation calibrated to soil moisture and estimated precipitation.

Implementation and Impact

AgriRain's IaaS model has been implemented across various regions in India - Buldhana (Maharashtra), Bettiah (Bihar), Anantapur (Andhra Pradesh), and Raichur (Karnataka). The technologies such as IoT, LoRa, cloud-based control, solar-powered pumps are used in the project. The impact of this model includes:

- **Yield Increase**: Farmers experienced a 20% to 60% increase in yield compared to rainfed conditions.
- **Income Growth**: An average increase of Rs.14000 in farmer income was observed.
- **Water Conservation**: Approximately 125,000 m^3 of water was saved through efficient irrigation practices.
- **Farmer Reach**: The service has benefited 7,784 small farmers, irrigating 21 crops across three countries.

Significance

AgriRain's innovative approach addresses the unique challenges faced by smallholder farmers in India by providing affordable, efficient, and scalable irrigation solutions. By integrating technology with community engagement, AgriRain enhances agricultural productivity, promotes water conservation, and empowers rural youth through entrepreneurship.

Challenges and the Way Forward

Challenges

The fragmented land holding is the major challenge in implementing smart farming technologies in the country. More than 80 percent of farmers owning less than five acres of land, making the adoption of technologies economically challenging. The advanced technologies are more effective on larger farm holdings, making it difficult to scale them down for smallholder farmers. Implementation of smart farm technologies in smaller farm holding find the high initial cost of smart farming equipment, such as IoT sensors, drones, and AI-driven analytics. The initial investment required is often beyond their financial reach, making widespread adoption difficult.

Many farmers are having skill gap in using digital tools, unfamiliar with digital technologies, modern agricultural practices and lack the necessary skills to operate smart farming tools. Limited exposure to modern agricultural practices further hampers their ability to leverage technology effectively. And, traditional farming practices have been followed for generations, and farmers are often reluctant to adopt new technologies. There is a lack of trust in digital solutions, and many farmers fear the risks associated with transitioning to smart farming.

The Way Forward

1. Policy Support: The Government shall extend the policy support to adopt the smart farming technologies suitable to their landholding size-specific subsidies and incentives. The financial assistance required for (1) IoT-based Irrigation Systems, (2) Drone services for crop monitoring and spraying, (3) Community weather stations

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and (4) Decision support digital tools to support with timely alerts on crop management practices for efficient farm practices.

2. Capacity Building Support: The agricultural departments officials needs to focus on awareness campaigns, training and workshops to understand the smart farming technologies for adapting in their fields. Regular awareness programs, field demonstrations, and hands-on training should be conducted by ATMA, KVKs and Agricultural Departments to build digital literacy and trust among farmers.

3. Public-Private Partnership: The collaboration between government departments, private entrepreneurs, start-ups and technology based institutions can drive innovation in smart farming. The start-up to be encouraged in large number to implement smart farming technologies in small holding farms with cost effective solutions, which are implementable. The government should come out with a policy to implement in PPP mode on affordable smart farming technologies.

4. Shared Infrastructure Models: Promote cost-sharing mechanisms such as Farmer Producer Organizations (FPOs), cooperative drone services, and community-owned sensor networks to reduce per-farmer expenses. More focus to be given smart IoT based Irrigation Systems and application of effective inputs on farm.

5. Localized and Language-Specific Solutions: Developing AI based chotbots as mobile app for advisory services in regional languages, voice and video-based solutions to ensure ease of access and usability, especially for marginal farmers in their own local dialect.

CONCLUSION

Smart farming represents a transformative shift in Indian agriculture, offering solutions to longstanding challenges such as low productivity, inefficient resource usage, and climate variability. By integrating advanced technologies like IoT, AI, drones, GIS and robotics, it empowers farmers to make data-driven decisions, optimize inputs, and improve crop health and yield. The adoption of smart farming technologies has demonstrated positive outcomes in the country, shown significant improvements in income, sustainability, and operational efficiency. Tailored smart farming models for both small and large landholders ensure that technological advancements are inclusive and scalable. However, several barriers remain, including high initial investment, digital illiteracy, and reluctance to abandon traditional methods. Bridging this gap requires targeted policy support, subsidies, training, and collaborations between public and private sectors.

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