SMART FARMING: NEW TECHNOLOGIES EXPLORED BY AGRI SECTOR

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ABSTRACT

The growth of any nation depends on its industry. Industrial growth revolves around certain sectors which as a whole increase the GDP of the nation. One of the very prominent sectors which now – a – days is trying to implement new technologies is the agriculture sector. This sector is so vital that any downgrade or overlooking may lead to disaster. The growth of food industry together with food security and food production will grow by 80% by 2050. Also, global warming and sudden climatic changes in many parts of the globe can add to disaster in food production if we don't use technologies like big data, cloud computing, analytics, IoT, AI, and ML to predict the right crop at the right time for the right population. This paper discusses how the agriculture sector can leverage disruptive technologies to predict trends and probably save the human population in the long run.

Keywords: GDP, Food Security, Food Industry, Iot, AI and ML, Big Data, Cloud Computing, Disruptive Technologies.

INTRODUCTION

Smart farming, also known as precision agriculture or digital agriculture, represents a transformative approach to traditional agricultural practices. It leverages advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, and cloud computing to optimize various aspects of farming operations. By integrating these technologies, smart farming aims to enhance productivity, sustainability, and efficiency in agricultural processes while minimizing resource wastage and environmental impact Aker, (2011).

The concept of smart farming revolves around collecting and analyzing vast amounts of data from various sources such as sensors, satellites, drones, and machinery deployed throughout the agricultural ecosystem Bakhshipour & Jafari, (2018). This data provides valuable insights into crucial factors affecting crop growth and livestock health, including soil conditions, weather patterns, pest infestations, water usage, and nutrient levels. By harnessing these insights, farmers can make informed decisions in real time, enabling proactive management of their operations Barreto & Amaral, (2018).

One of the key components of smart farming is precision agriculture, which involves the precise application of inputs such as water, fertilizers, and pesticides based on site-specific data. This approach allows farmers to optimize resource usage, minimize input costs, and reduce environmental impact by only applying inputs where and when they are needed. For example, soil sensors can measure moisture levels at different depths, enabling farmers to irrigate fields more efficiently and avoid overwatering Fountas et al. (2020); Gubbi et al. (2013).

Another aspect of smart farming is the use of autonomous machinery and robotics to perform tasks such as planting, harvesting, and monitoring crops. Autonomous vehicles equipped with GPS and AI algorithms can navigate fields with precision, reducing labor costs and improving operational efficiency. Drones equipped with cameras and sensors can capture

Citation Information: Pal, B. (2024). Smart farming: new technologies explored by agri sector. *Academy of Marketing Studies Journal, 28*(5), 1-9.

aerial imagery for crop monitoring, pest detection, and disease identification, enabling early intervention and preventive measures Kaloxylos et al. (2012).

Data analytics plays a crucial role in smart farming by processing and analyzing the vast amount of data generated by various sensors and devices. Advanced algorithms can identify patterns, trends, and anomalies in the data, providing valuable insights for decision-making. For example, predictive analytics can forecast crop yields, allowing farmers to optimize harvest schedules and plan marketing strategies accordingly Maurel, & Huyghe, (2017).

In addition to improving productivity and efficiency, smart farming also addresses sustainability challenges facing the agricultural industry. By optimizing resource usage and reducing waste, smart farming practices help conserve water, energy, and other finite resources. Furthermore, by minimizing the use of chemical inputs and adopting eco-friendly farming practices, smart farming promotes environmental stewardship and biodiversity conservation Sørensen et al. (2010).

Overall, smart farming represents a paradigm shift in agriculture, harnessing the power of technology to address the complex challenges facing the industry. By integrating advanced technologies, data analytics, and sustainable practices, smart farming has the potential to revolutionize food production, ensuring food security, environmental sustainability, and economic viability for future generations.

Indian Agri Sector

The Indian agriculture sector stands as a cornerstone of the nation's economy, with its significance deeply entrenched in the socio-economic fabric of the country. Employing over half of the population, it serves as a vital source of livelihood for millions, particularly in rural areas. Its importance transcends mere sustenance, as agriculture contributes significantly to India's GDP and serves as a crucial supplier of raw materials to various industries. With a diverse agro-climatic landscape, India boasts a wide array of crops, from cereals and pulses to fruits, vegetables, and spices, making it one of the world's leading producers. The sector's stakeholders include smallholder farmers, agribusinesses, government agencies, research institutions, and consumers. Small-scale farmers form the backbone, with their collective efforts driving the bulk of agricultural output. Meanwhile, agribusinesses play a pivotal role in the supply chain, from providing inputs like seeds and fertilizers to facilitating market access and distribution. Government policies and interventions also shape the sector's trajectory, aiming to boost productivity, ensure food security, and promote sustainable practices. Amidst evolving challenges such as climate change, land degradation, and market volatility, the resilience and adaptability of India's agriculture sector underscore its enduring importance in the nation's quest for economic growth, food security, and rural development.

Despite its significance, the Indian agriculture sector grapples with various disadvantages exacerbated by the lack of widespread adoption of smart farming practices. One of the foremost challenges is the inefficient utilization of resources, including water and fertilizers, leading to unsustainable agricultural practices and environmental degradation. Additionally, small landholdings prevalent among Indian farmers hinder the adoption of mechanization and modern agricultural techniques, resulting in low productivity levels. The sector also faces significant post-harvest losses due to inadequate storage and transportation infrastructure, impacting farmer incomes and food security. Moreover, the dependency on traditional farming methods makes Indian agriculture vulnerable to the adverse effects of climate change, such as erratic weather patterns and increased pest infestations. These challenges collectively highlight the urgent need for the integration of smart farming technologies to

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enhance productivity, optimize resource management, and ensure the long-term sustainability of Indian agriculture Sponchioni et al. (2019).

Technologies behind the Scene

Smart farming, also known as smart agriculture, involves the adoption of advanced technologies and data-driven farm operations to optimize and improve sustainability in agricultural production. These technologies include artificial intelligence (AI), automation, and the Internet of Things (IoT). By leveraging these tools, farmers can enhance their decision-making processes, monitor environmental conditions, and manage livestock and crop farming more efficiently. Following are the technologies behind it

a) Internet of Things (IoT)
- IoT devices such as sensors, actuators, and smart meters are deployed in the agricultural ecosystem to collect real-time data on various parameters.
- Soil moisture sensors, temperature and humidity sensors, and weather stations monitor environmental conditions.
- IoT-enabled machinery and equipment, such as tractors and irrigation systems, can be remotely controlled and monitored for precise operation.

b) Artificial Intelligence and Machine Learning
- AI and ML algorithms analyze the vast amount of data collected by IoT devices to derive actionable insights and make data-driven decisions.
- Predictive analytics algorithms forecast crop yields, disease outbreaks, and pest infestations based on historical data and current environmental conditions.
- Image recognition algorithms analyze drone and satellite imagery to identify crop health issues, weed infestations, and nutrient deficiencies.

c) Big Data Analytics
- Big data analytics techniques process and analyze large datasets to uncover patterns, trends, and correlations that can inform decision-making.
- Data from IoT sensors, weather stations, satellite imagery, and farm management systems are aggregated and analyzed to optimize crop management practices.
- Data analytics tools provide farmers with actionable insights on irrigation scheduling, fertilization, pest control, and crop rotation.

d) Remote Sensing and Satellite Imagery
- Remote sensing technologies, including satellites and drones, capture high-resolution imagery of agricultural fields from above.
- Satellite imagery provides valuable information on crop health, vegetation indices, soil moisture levels, and land use patterns.
- Drones equipped with cameras and multispectral sensors offer real-time monitoring of crop growth, pest infestations, and field conditions with greater spatial and temporal resolution.

e) Precision Agriculture Equipment
- Precision agriculture technologies enable the precise application of inputs such as water, fertilizers, and pesticides based on site-specific data.
- GPS-guided tractors and machinery ensure accurate planting, seeding, and harvesting operations.
- Variable rate technology (VRT) adjusts input application rates based on soil variability within a field, optimizing resource usage and reducing waste.

f) Robotics and Automation
- Robotic systems perform labor-intensive tasks such as planting, weeding, spraying, and harvesting with greater precision and efficiency.

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- Autonomous vehicles navigate fields autonomously using GPS and AI algorithms, reducing labor costs and improving operational efficiency.
- Robotic arms and grippers handle delicate tasks such as fruit picking and sorting, minimizing damage, and reducing post-harvest losses.

g) Cloud Computing and Edge Computing

- Cloud computing platforms store and process agricultural data collected from IoT devices, drones, and sensors.
- Edge computing devices deployed in the field perform real-time data processing and analysis, reducing latency and enabling faster decision-making.
- Cloud-based farm management software platforms provide farmers with access to analytics tools, predictive models, and decision support systems from anywhere, using any internet-enabled device.

h) Blockchain Technology

- Blockchain technology offers transparency, traceability, and immutability in agricultural supply chains, ensuring food safety and quality.
- Smart contracts automate transactions and agreements between farmers, suppliers, distributors, and consumers, reducing paperwork and streamlining operations.
- Blockchain-based platforms enable farmers to certify their produce's organic or fair-trade status, enhancing market access and premium pricing opportunities.

Frontend Masters: In the realm of smart farming, the frontend aspects encompass the user interfaces (UIs), dashboards, and applications that farmers and stakeholders interact with to access and manage agricultural data, make decisions, and control various farming operations. Here are the frontend masters of smart farming:

a) Farm Management Software Platforms

- These platforms provide comprehensive interfaces for farmers to monitor and manage various aspects of their farming operations.
- Features may include crop planning, field mapping, inventory management, task scheduling, and equipment tracking.
- Examples include FarmLogs, Granular, and Climate Field View.

b) Mobile Applications

- Mobile apps offer on-the-go access to farming data and tools, allowing farmers to make decisions from anywhere.
- They may include features such as weather forecasts, pest and disease identification, and market prices.
- Examples include AgriApp, CropIn, and Agworld.

c) Dashboard Interfaces

- Dashboards provide visual representations of real-time and historical data collected from various sources such as sensors, drones, and satellites.
- They offer insights into crop health, soil moisture levels, weather patterns, and machinery status.
- Customizable dashboards allow farmers to track key performance indicators (KPIs) and monitor trends over time.

d) GIS and Mapping Tools

- Geographic Information System (GIS) tools enable farmers to create maps of their fields, analyze spatial data, and identify areas of interest.
- Mapping tools provide overlays of soil types, elevation, slope, and other geospatial information to aid in decision-making.
- They help farmers optimize field boundaries, plan irrigation systems, and implement precision agriculture practices.

e) Decision Support Systems (DSS)

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- DSS applications leverage data analytics and modeling techniques to provide farmers with recommendations and insights.
- They use algorithms to analyze historical data, predict future outcomes, and suggest optimal actions for crop management.
- DSS tools help farmers make informed decisions on planting, fertilization, irrigation, and pest control.

f) IoT Control Panels
- Interfaces for controlling IoT devices and sensors allow farmers to remotely monitor and manage their farm equipment and infrastructure.
- Control panels enable farmers to adjust irrigation schedules, activate machinery, and receive alerts for abnormal conditions.
- They provide real-time visibility and control over critical farming operations, enhancing efficiency and responsiveness.

g) Augmented Reality (AR) and Virtual Reality (VR)
- AR and VR applications offer immersive experiences for training, simulation, and visualization purposes.
- They can simulate crop growth scenarios, visualize field layouts, and provide interactive training modules for farm workers.
- AR and VR technologies enhance learning, planning, and decision-making processes in agriculture.

h) Blockchain-based Platforms
- Frontend interfaces for blockchain-based platforms provide transparency and traceability in agricultural supply chains.
- Farmers and consumers can access information about product origin, production practices, and certifications through user-friendly interfaces.
- Blockchain interfaces enhance trust and accountability in the food system, enabling consumers to make informed choices.

These frontend masters of smart farming play a crucial role in empowering farmers with actionable insights, intuitive tools, and seamless interfaces to optimize agricultural practices and drive sustainable productivity.

New Agile Development

Agile development methodologies have gained popularity in the smart farming sector due to their flexibility, adaptability, and focus on iterative development Tao et al. (2021); Wahaishi & Aburukba, (2022). Agile principles and practices enable agricultural technology (aggrotech) companies to deliver value to farmers more rapidly, respond to changing market needs, and continuously improve their products and services. Here's how agile development is applied in smart farming:

a) Iterative Development
- Agile development emphasizes breaking down complex projects into smaller, manageable increments called iterations or sprints.
- Aggrotech teams prioritize features and functionalities based on farmer feedback, market demands, and business objectives.
- Each iteration delivers a working product increment, allowing farmers to provide early feedback and influence the development process.

b) Customer Collaboration
- Agile encourages close collaboration between aggrotech developers and farmers throughout the development lifecycle.

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- Farmers are actively involved in defining requirements, testing prototypes, and validating solutions to ensure they meet their needs and expectations.
- Regular feedback loops enable aggrotech teams to iterate and refine their products based on real-world usage and user feedback.

c) Cross-functional Teams

- Agile teams in smart farming comprise cross-functional members with diverse expertise, including software developers, agronomists, data scientists, and UX/UI designers.
- Cross-functional collaboration ensures a holistic approach to product development, integrating technical, agronomic, and user experience considerations.
- Teams work collaboratively to address complex challenges and deliver innovative solutions that resonate with farmers and stakeholders.

d) Continuous Delivery

- Agile development practices promote continuous delivery of valuable software increments to end-users.
- Automation tools streamline the build, test, and deployment processes, enabling rapid release cycles and shorter time-to-market.
- Continuous delivery allows aggrotech companies to respond quickly to market changes, regulatory requirements, and emerging technologies.

e) Adaptive Planning

- Agile planning is adaptive and responsive to evolving customer needs and market dynamics.
- Aggrotech teams regularly reassess priorities, adjust plans, and reprioritize backlog items based on feedback, data insights, and emerging trends.
- Agile planning techniques such as backlog grooming, sprint planning, and release planning ensure alignment between development efforts and business goals.

f) Emphasis on Quality

- Agile development places a strong emphasis on delivering high-quality software that meets user expectations.
- Continuous testing practices, including automated testing, unit testing, integration testing, and user acceptance testing, ensure software reliability and robustness.
- Aggrotech teams prioritize software quality assurance (QA) activities to detect and address defects early in the development process, minimizing rework and enhancing product reliability.

g) Flexibility and Adaptability

- Agile methodologies embrace change and uncertainty, allowing aggrotech companies to adapt to evolving market conditions and customer requirements.
- Incremental development and frequent feedback loops enable rapid course corrections and adjustments in response to new insights and learnings.
- Agile teams remain flexible and open to experimentation, exploring innovative solutions and iterating based on real-world feedback and data-driven insights.

Agile development methodologies offer aggrotech companies a structured yet flexible approach to smart farming innovation. By embracing iterative development, customer collaboration, cross-functional teamwork, and continuous improvement, agile teams can deliver value-driven solutions that address the evolving needs of farmers and stakeholders in the dynamic agricultural landscape.

Mathematical Model using an Agile Methodology (A hypothetical CASE)

A smart farming company CropIN Technology is developing a precision agriculture solution for optimizing irrigation scheduling. The goal is to iteratively develop and deploy the solution to improve crop yield and water efficiency for farmers Wolfert et al. (2017).

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Assumptions

1. Each iteration lasts for one month.
2. The team comprises 6 members: 2 software developers, 1 agronomist (An agronomist is a scientist who studies plants and soil to help farmers grow crops more effectively), 1 data scientist, 1 UX/UI designer, and 1 project manager.
3. The project is divided into 4 iterations.
4. Each iteration delivers a working product increment.

Data

- Initial crop yield: 1000 kg/hectare
- Initial water usage: 1000 liters/hectare
- Expected increase in crop yield per iteration: 5%
- Expected decrease in water usage per iteration: 7%

The development of a mathematical model consists of the following steps.

1) Iteration Planning:
 - Define backlog items: The team identifies tasks for each iteration, such as

- data collection
- algorithm development
- UI design
- testing.

 - Velocity calculation: Assuming the team's velocity is 20 story points per iteration.

2) Sprint Execution:
 - Daily stand-up meetings: Each team member reports progress, challenges, and plans for the day.
 - Task completion: Tasks are completed based on priority and assigned story points.

3) Review and Retrospective:
 - Sprint review: The team demonstrates the working product to stakeholders, showcasing new features and improvements.
 - Retrospective meeting: The team reflects on what went well, what could be improved, and action items for the next iteration.

4)Continuous Improvement:
 - Adjust backlog: Based on stakeholder feedback and team insights, backlog items are reprioritized for the next iteration.
 - Refinement: The team refines user stories and acceptance criteria based on learnings from previous iterations.

Mathematical Formulas:

1. Crop Yield (CY):
 - $CY_i = CY_{(i-1)} * (1 + Yield\_Increase\_Percentage)$
 - Where CY_i is the crop yield for iteration i^{th} iteration.
2. Water Usage (WU):
 - $WU_i = WU_{(i-1)} * (1 - Water\_Usage\_Decrease\_Percentage)$
 - Where WU_i is the water usage for iteration i^{th} iteration.
3. Velocity (V):
 - V = Total completed story points / Number of iterations
4. Estimated Increase in Crop Yield and Decrease in Water Usage:
 - Total Crop Yield = CY_4 (after 4^{th} iterations)
 - Total Water Usage = WU_4 (after 4^{th} iterations)

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5. Cost-Benefit Analysis:
- Calculate the cost of development (e.g., team salaries, software tools) and compare it with the benefits (e.g., increased crop yield, reduced water usage).
Net Benefit = Total Annual Benefits - Total Development Cost

Suggestion

One of the main challenges faced by Indian farmers is that; many farmers in India lack access to up-to-date information, market trends, and advanced agricultural technologies, leading to inefficiencies in farming practices and lower yields. Smart farming solutions utilizing agile development principles can address these challenges effectively with the help of Scrum.

Agile Development Model: Continuous Improvement through Iterative Development
Precision Agriculture Solution: Precision agriculture involves using technology and data-driven insights to optimize farming practices, such as soil management, irrigation, and crop monitoring. This solution includes leveraging IoT sensors, drones, satellite imagery, and data analytics to provide farmers with real-time information and actionable insights about their fields.

Results of Agile Development Model

Implementing precision agriculture follows the principles of iterative development. Aggrotech companies can develop and deploy precision agriculture solutions incrementally, focusing on delivering tangible value to farmers with each iteration. This iterative approach allows for continuous improvement based on farmer feedback, evolving market needs, and technological advancements.
Example of Agile Development Model in Precision Agriculture:

Iteration 1 (Minimum Viable Product - MVP): Develop a basic precision agriculture solution that provides farmers with soil moisture data using IoT sensors. Farmers can access this information through a mobile application.

Iteration 2: Enhance the solution by incorporating satellite imagery analysis to detect crop health issues and recommend appropriate interventions, such as irrigation or pesticide application.

Iteration 3: Integrate weather forecasting data into the solution to help farmers make informed decisions about planting, harvesting, and irrigation scheduling.

Iteration 4 and Beyond: Continuously iterate and improve the precision agriculture solution based on farmer feedback, technological advancements, and emerging market trends. This may include adding features like predictive analytics, automated irrigation systems, and crop yield forecasting. By applying agile development methodologies to precision agriculture solutions, agritech companies can effectively address the challenge of limited access to information and technology in the Indian farming sector, ultimately leading to improved productivity, sustainability, and farmer livelihoods.

CONCLUSION

The integration of smart farming technologies presents a transformative opportunity for the agricultural sector, not only in India but globally. Through the convergence of advanced technologies such as IoT, AI, robotics, big data analytics, and cloud computing, smart farming offers a paradigm shift in traditional agricultural practices. By harnessing the power of data-driven decision-making, precision agriculture, and automation, smart farming endeavors to enhance productivity, sustainability, and efficiency while minimizing resource

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wastage and environmental impact. Furthermore, the Indian agriculture sector, with its rich diversity and significance, stands to benefit immensely from the adoption of smart farming practices. Despite facing numerous challenges such as inefficient resource utilization, small landholdings, post-harvest losses, and climate vulnerability, Indian agriculture possesses the resilience and adaptability to embrace innovation and change. The urgent need for sustainable solutions to address these challenges underscores the importance of integrating smart farming technologies into Indian agricultural practices.

The frontend masters of smart farming, including farm management software platforms, mobile applications, IoT control panels, and decision support systems, empower farmers with actionable insights, intuitive tools, and seamless interfaces to optimize agricultural operations. Moreover, agile development methodologies enable aggrotech companies to deliver value-driven solutions rapidly, respond to evolving market needs, and continuously improve their products and services. In essence, smart farming represents a holistic approach to agriculture that not only enhances productivity and profitability but also promotes environmental sustainability, resilience, and inclusivity. As we navigate the complexities of the 21st-century agricultural landscape, collaboration among stakeholders, investment in research and development, and supportive policy frameworks will be crucial in realizing the full potential of smart farming to ensure food security, economic prosperity, and environmental stewardship for future generations.

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Received: 22-Apr-2024, Manuscript No. AMSJ-24-14737; **Editor assigned:** 23-Apr-2024, PreQC No. AMSJ-24-14737(PQ); **Reviewed:** 30-Mar-2024, QC No. AMSJ-24-14737; **Revised:** 03-Jun-2024, Manuscript No. AMSJ-24-14737(R); **Published:** 20-Jul-2024

Citation Information: Pal, B. (2024). Smart farming: new technologies explored by agri sector. *Academy of Marketing Studies Journal, 28*(5), 1-9.