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Strategic Management Approaches for Wireless Sensor Technology in Precision Agriculture

Mr. Chakradhar Borkute[1*]

[1*]PhD Research Scholar, Neville Wadia Institute of Management Studies & Research, Pune.

Dr. V N. Sayankar[2]

[2]Director, Adhalrao Patil Institute of Management and Research, Landewadi, Pune.

***Corresponding Author:** Mr. Chakradhar Borkute

*PhD Research Scholar, Neville Wadia Institute of Management Studies & Research, Pune.

ABSTRACT –

This research paper investigates strategic management approaches for the integration of wireless sensor technology in precision agriculture. It aims to explore the diverse strategies employed by agricultural management teams to influence wireless sensors for optimizing agricultural operations. By analyzing case studies and industry practices, this study examines the multifaceted considerations involved in deploying and managing wireless sensor networks in precision agriculture. The research seeks to uncover key insights into the strategic decision-making processes, resource allocation strategies, and organizational structures adopted by agricultural enterprises to effectively utilize wireless sensor technology. Additionally, it examines the challenges and opportunities associated with the adoption and implementation of wireless sensor-based solutions in agricultural management. The findings of this research contribute to a deeper understanding of strategic management practices in the context of precision agriculture, providing valuable guidance for agricultural stakeholders seeking to harness the potential of wireless sensor technology for improved farm performance and sustainability.

Keywords - Precision Agriculture, Wireless Sensor Technology, Strategic Management, Agricultural Innovation, Technology

1. Introduction

In recent years, the agricultural industry has witnessed a significant transformation driven by advancements in wireless sensor technology. Precision agriculture, which involves the use of technology to optimize farming practices, has emerged as a promising approach to address the challenges of modern agriculture. Wireless sensor technology, with its ability to collect real-time data on environmental conditions, soil moisture, crop health, and machinery performance, has become a foundation of precision agriculture initiatives. The strategic management of wireless sensor technology plays a pivotal role in maximizing its potential to enhance farm productivity, efficiency, and sustainability.

This research paper aims to explore strategic management approaches for the integration of wireless sensor technology in precision agriculture. By delving into the diverse strategies employed by agricultural management teams, this study seeks to uncover the key factors influencing the successful deployment and management of wireless sensor networks in agricultural settings. The integration of wireless sensors offers opportunities for agricultural enterprises to optimize resource utilization, improve decision-making processes, and enhance overall farm performance. One of the primary objectives of this research is to analyze case studies and industry practices to identify best practices and lessons learned in strategic management within the context of precision agriculture. By examining the strategic decision-making processes, resource allocation strategies, and organizational structures

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adopted by agricultural enterprises, this study aims to provide valuable insights into effective management approaches for wireless sensor technology in agriculture.

Furthermore, this research will explore the challenges and opportunities associated with the adoption and implementation of wireless sensor-based solutions in agricultural management. Issues such as data privacy and security, interoperability of sensor systems, and scalability of solutions will be examined to provide a comprehensive understanding of the strategic considerations involved in managing wireless sensor technology in precision agriculture. Ultimately, the findings of this research paper are expected to contribute to a deeper understanding of strategic management practices in precision agriculture. By offering guidance and recommendations for agricultural stakeholders, including farmers, agribusinesses, and policymakers, this study seeks to facilitate the effective utilization of wireless sensor technology for improved farm performance, sustainability, and resilience in the face of evolving agricultural challenges.

The rest of the paper is organized as follows; section-2 gives details about the literature surveyed in the precision agriculture field. Section-3 describes the research methodology. Section-4 gives details about the system principles used in the precision agriculture domain and the paper concludes in section-5.

2. Literature Survey

The literature surrounding the integration of wireless sensor technology in precision agriculture provides valuable insights into the strategic management approaches adopted by agricultural stakeholders. Studies in this field have explored various aspects of wireless sensor technology deployment, management strategies, and their impacts on farm performance and sustainability.

Research by Liakos et al. (2018) highlights the significant role of wireless sensor networks (WSNs) in precision agriculture, emphasizing their potential to revolutionize farm management practices [1]. The study emphasizes the importance of strategic planning and decision-making in leveraging WSNs effectively to optimize resource use, enhance crop yields, and minimize environmental impacts. Furthermore, the work of Gebbers and Adamchuk (2010) emphasizes the importance of data management and analysis in maximizing the benefits of wireless sensor technology in agriculture [2]. The study emphasizes the need for strategic approaches to data collection, processing, and interpretation to derive actionable insights for farm management decisions. In addition to technological considerations, strategic management literature offers insights into organizational structures and governance mechanisms that facilitate the successful integration of wireless sensor technology in agriculture. Research by Tregear et al. (2019) explores the role of leadership and organizational culture in driving innovation and technology adoption in agricultural enterprises [3]. Moreover, studies have examined the economic implications of adopting wireless sensor technology in precision agriculture. Research by Sánchez et al. (2015) analyzes the cost-effectiveness of wireless sensor networks compared to traditional monitoring methods, highlighting the potential for long-term savings and increased profitability through strategic investment in sensor technology [4]. While the literature provides valuable insights into the strategic management approaches for wireless sensor technology in precision agriculture, gaps remain in understanding the specific challenges and opportunities faced by agricultural stakeholders. Further research is needed to explore the contextual factors influencing the adoption and implementation of wireless sensor-based solutions, as well as to develop frameworks for evaluating the effectiveness of management strategies in enhancing farm performance and sustainability.

Overall, the literature review highlights the multidisciplinary nature of strategic management in precision agriculture, encompassing technological, organizational, economic, and environmental considerations. By synthesizing existing knowledge and identifying research gaps, this study aims to contribute to a deeper understanding of strategic management approaches for wireless sensor technology in agriculture, ultimately facilitating informed decision-making and sustainable farm management practices.

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3. Research Methodology

This study employs a mixed-methods approach, comprising a comprehensive literature review and a qualitative survey, to investigate strategic management approaches for wireless sensor technology in precision agriculture. The literature review synthesizes existing knowledge on wireless sensor technology adoption, focusing on technological advancements, organizational strategies, and economic and environmental implications. The qualitative survey involves purposive sampling of agricultural stakeholders and semi-structured interviews to gather firsthand insights on decision-making processes, resource allocation strategies, and challenges and opportunities related to wireless sensor technology adoption. Thematic analysis of interview data will be integrated with literature review findings to provide a comprehensive understanding of effective strategic management practices in precision agriculture [5,6].

In addition to qualitative data, quantitative analysis will be conducted to supplement the findings from the literature review and qualitative survey. Descriptive statistics, such as frequencies and percentages, will be used to summarize survey responses and demographic information. Inferential statistics, such as correlation analysis and regression modelling, may be employed to examine relationships between variables and identify factors influencing technology adoption and management strategies.

The findings from the literature review, qualitative survey, and quantitative analysis will be integrated to provide a holistic understanding of strategic management approaches for wireless sensor technology in precision agriculture. Data triangulation will be used to validate findings and enhance the reliability and validity of the research. The integrated results will be synthesized to develop actionable recommendations and insights for agricultural stakeholders seeking to leverage wireless sensor technology for improved farm management and sustainability. Irrigation is meeting your crop needs without wasting important inputs like water and nutrients. It helps you to monitor and control valves remotely so we can improve the operation of your entire farm, combined with water monitoring you can save, hours, on time and improve productivity by automating your farm system. We can help you monitor these levels and set alerts via your Smartphone, tablet, and/or computer. Water levels are crucial to ensuring you reduce risks and efficiently manage your water supplies.

The impact on different soil moisture, plant leaves relative moisture content, and water consumption handling on stem weight, total biomass is notable, root weight, only when the soil moisture content is higher than a certain threshold value, volume per plant decrease with the reduction of soil water, higher soil moisture content could ensure greater ownership of plant biomass. the plants could survive, and because of too much irrigation, water infiltration will take away large fertilizer when the soil moisture content is too high, it will not only cause decay of the root but also a waste of moisture. Resources at the same time, pollution of groundwater resources causes a waste of fertilizer.

4. Proposed System for Precision Agriculture

There are various irrigation monitoring systems designed for different plant types and soil conditions. Soil water sensors acquire data from two different depths, providing both soil water information and transmission data. An irrigation monitoring controller or computer analyzes this data to make informed irrigation decisions and control the startup and shutdown of sprinkler irrigation systems. This ensures adequate soil moisture for plant roots and meets the growth demands of the plants [7]. The controller initiates irrigation by sending a startup signal to the corresponding valve, activating the nozzle, and commencing irrigation. This process helps maintain stable soil moisture levels near a default value, preventing excessive irrigation runoff, fertilizer leaching, and groundwater pollution [8,9]. Soil water sensors continuously monitor soil water levels in real time. Additionally, when the measured value of substratum soil moisture deviates by more than 5% from the set value, irrigation is triggered. The controller then sends a stop signal to the corresponding valve, closing the nozzle. Moreover, when the plant viability analyzer indicates insufficient water, and the upper soil water

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sensor detects a moisture level lower than the upper soil moisture setting, irrigation is initiated. Figure 1 shows the wireless technology in precision agriculture domain.

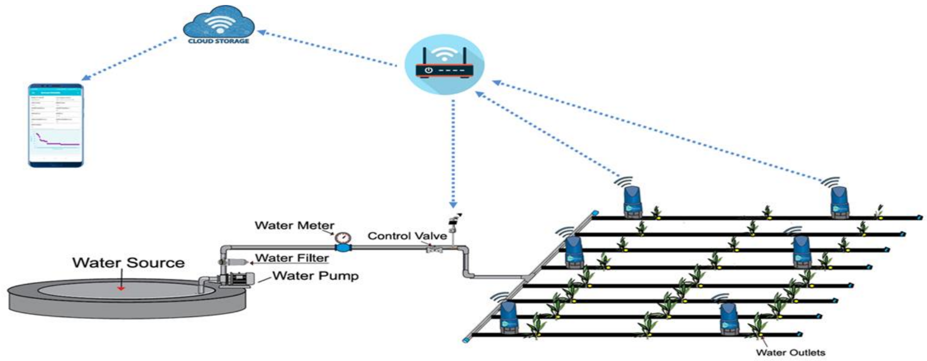

Figure 1 Wireless Sensor Technology in Precision Agriculture

Within the irrigation system, the smallest operational unit is the irrigation area, comprising multiple points for soil water information. Functionality is distributed across irrigation areas, round irrigation areas, and sets of round irrigation areas, alongside acquisition points for plant water demand and numerous electromagnetic valves. This structure ensures stable soil moisture levels near default values, with electromagnetic valve control tailored to soil water content and plant demand data. Default soil moisture varies across areas due to vegetation types, growth stages, and seasonal changes. Round irrigation areas, containing multiple zones, are managed by irrigation monitoring controllers, accounting for topographical and soil differences. These controllers treat round irrigation areas as a cohesive unit, establishing consistent strategies within zones. However, strategies may differ based on factors such as water resource competition or interrelated systems. Control is executed by respective irrigation monitoring controllers in automatic, semi-automatic, or manual modes, utilizing data on plant and soil water content to estimate irrigation needs and regulate system operation.

5. Results and Discussions

This project includes 22 acre of agricultural land out of which 16 acre is under Cultivation. Nine farmers included in this project. In all 40 sensors are installed in the plots. The sensors determine the soil moisture level and according to that the farmers irrigate their farm. Table 1 shows the crop and sensor details. The Project is implemented at Village Buchakewadi located in Taluka-Junnar of Pune district in Maharashtra. The latitude and longitude of that area are 19° 9'3.01"N & 73°49'18.00"E. Total 40 sensors installed according to each crop in all the plots. There are total 11 plots having different crops such as Onion, Marigold, Guava, Brinjal, Sweet potato, Chilli etc. In all plots valves are installed and with the help of sensor, valves are controlled. Water requirement reference of each crop is determined with the help of Phulejal app. The sensors senses moisture and the optimized level of moisture is detected by the sensors. From the feedback of sensors irrigation has been maintained using automatic controllable valves. Table –2 shows the practices followed during pre and post sensor installation. Table-3 shows the impact of Strategic Management Approaches for Wireless Sensor Technology in Precision Agriculture.

Table 1: Crop and sensor details

SN	Plot No.	Crop Name	No. Of Sensors	Value of Sendor ID	Sensor ID
1	Plot 1	Onion	3	15000246	15000289
2	Plot 2	Bajra	2	15000245	15000289
3	Plot 3	Onion	3	15000244	15000289

Table 2- Practices followed during Pre & Post Sensor Installation

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Pre Sensor-Installation	**Post Sensor Installation**
Farmers used to irrigate the farm regardless of time	Farmer doesn't need to go to the field to irrigate his farms as valves are operating automatically
There is no fix time limit to irrigate the farm as he didn't know the quantity of water that needs to crops	The culture that the farmer should be present on the farm while, providing water to crops was mostly reduced
Farmer irrigate the farm over his experience or overview	Labors quantity that was required was mostly reduced
As he didn't know the time of irrigation, there is a lot of wastage of water and also electricity	Maximum water saving, as water given to the crop is at required quantity

Table 3 – Impact of Project

SN	**Crop Name**	**Title**	**Before Installation**	**After Installation**	**Savings**
1	Guava	Crop Period	1 year		1 Labor
		Irrigation Interval	4		
		Total no. of irrigation	96		
		Amount of Water applied/irrigation	35000 lit	29100 lit	5900 lit/irrigation
		Irrigation time	60 min	49 min	11 min
		Production	4 tonnes	5.2 tonnes	1.2 tonnes
		Labor Required	1	0	1
2	Pomegranade	Crop Period	3 Year		
		Irrigation Interval	Twice in a month		
		Total no. of irrigation	72		
		Amount of Water applied/irrigation	50000 lit	41600 lit	8400 lit/irrigation
		Irrigation time	45min	38min	7 min
		Production	7.5 tonnes	9 tonnes	1.5 tonnes
		Labor Required	2	0	2
3	Wheat	Crop Period	8 Months		
		Irrigation Interval	Twice in a month		
		Total no. of irrigation	16		
		Amount of Water applied/irrigation	208600 lit	156500 lit	52100 lit/irrigation
		Irrigation time	2 Hours	1.5 Hours	30 Min
		Production	10 Quintal	15 Quintal	5 Quintal
		Labor Required	3	0	3
4	Onion	Crop Period	4 Months		
		Irrigation Interval	5 Days		
		Total no. of irrigation	24		
		Amount of Water applied/irrigation	112000 lit	75000 lit	37000 lit/irrigation
		Irrigation time	30 min	20 min	10 min
		Production	20 tonnes	25 tonnes	5 tonnes
		Labor Required	2	0	2

5. Conclusions

In conclusion, this study has examined strategic management approaches for integrating wireless sensor technology into precision agriculture. Through literature review and qualitative survey, it has revealed significant insights into technology adoption, organizational strategies, and economic considerations. Despite challenges, such as data privacy concerns, the findings suggest a positive outlook for the transformative potential of wireless sensor technology in optimizing farm management practices and enhancing sustainability in agriculture. Moving forward, continued collaboration and innovation will be key to maximizing the benefits of wireless sensor technology for the agricultural sector.

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