Precision Agriculture - An effective tool to provide nutrients to plants, especially in the Sugarcane Industry

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Abstract

Precision farming (PF) contributes to the development of a sustainable, ecologically friendly agriculture and is becoming a more widely accepted crop production approach. Furthermore, it will be of interest in automated data gathering and information processing to develop it towards better farm management and a general ability to trace agricultural crop output. In Precision Agriculture (PA), inputs are utilized in precise amounts to increase yields. PA is how well the fertiliser is used and how well other inputs are used so that farmers could save more money.

Study Design: The study was planned in accordance with the report that was at hand, thus it was decided to structure the research project to gather as much data as possible, including case studies.

Methodology: This research is basically focused on the work done so far about Precision Farming.

Results: Randomly adopting PA technologies wouldn't be profitable because their impact on farm profitability varies. Grid soil sampling should boost farm profits. The technology's potential has been proved, but considerable execution is difficult because it requires extensive commercial application. Precision Agriculture aims to optimize production with minimal input and pollution. Farmers' notion that PA will boost farm profitability is erroneous. Most PA technologies haven't been proven to boost agriculture economics always.

Conclusion: ICT and big data analytics can be combined to increase crop productivity. This can be used in the future to effectively monitor the crops in fields. The development of an effective decision-making system that serves as a guiding tool for small-scale farmers makes use of big data analytics. However, the assumption that PA adoption will increase farm profitability is a little flawed for farmers to make. The bulk of PA technologies have not yet been proven to always impact agricultural economics positively.

Key Words: Precision Agriculture (PA), Remote Sensing, Yield mapping, GPS, GNSS, GIS

Introduction

As per Keniyo, Raphael. (2022), the population of people on earth is predicted to reach around 10 billion by the year 2050. It will need technology and ingenuity to feed the world responsibly while also considering the planet's finite natural resources. Precision agriculture is a data-driven method of managing farms that can boost output and productivity. It reduces the demand for inputs like water, synthetic fertilizers, and pesticides. Applications for precision agriculture are getting easier for medium and small farmers in developing countries to use. Large farms use sophisticated equipment to collect data on soil parameters, yields, and plant greenness. This data must be examined after collection to generate agronomic advice. Farmers must be able to follow the instructions in the field and have access to the necessary inputs. The adoption of precision agriculture by 15–25% of farms could boost world production by 10%–15% by 2030. This would reduce greenhouse gas emissions and

water consumption, respectively, between 50% and 66% of all the carbon that is lost from soil can be sunk back underground.

Definition of Precision Agriculture:

The term 'precision' refers to exactness or accuracy. Precision agriculture is a management strategy that collects, processes, and analyses time, space, and individual data. (International Society of Precision Agriculture) and combines it with other information to support management decisions based on estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production.

Precision farming is a collection of technologies that work together to maximize resource utilization. Precision agriculture uses precise amounts of inputs to achieve higher average yields than traditional cultivation techniques. Precision farming, also known as precision agriculture, is a modern management strategy that employs site-specific nutrient management, remote sensing, a global information system, a global positioning system, and variable rate application to precisely manage production input. Precision farming, also known as precision

agriculture, is about doing the right thing at the right time, in the right place, using the right procedures. Managing crop production inputs such as water, seed, fertilizer, and so on to increase yield, quality, profit, reduce waste, and become more environmentally friendly. Precision farming aims to improve the accuracy of their applications by matching agricultural inputs and practices to crop and agro-climatic conditions.

Why precision farming is required:

Precision agriculture (PF) has two major challenges: educational and economic. PF increases agricultural productivity while preventing soil degradation, reducing the use of chemical applications, improving quality and quantity, and reducing production costs. It also reduces the need for fertilizer,

pesticides, and herbicides, allowing farmers to better budget and keep costs to a minimum. PF has become a good way to deal with climate change, a lack of water, and the need for sustainable farming methods.

The sugarcane industry is an important part of agriculture that makes a big difference in the world economy. But growing sugarcane is hard because of climate change, a lack of water, and the need for sustainable farming methods. Precision farming has become a good way to deal with these problems because it lets farmers grow more crops while wasting less and having less of an effect on the environment.

Objectives:

- Promoting new initiatives in the "Agriculture and its Allied Sector," bringing together various agricultural components to take advantage of the variability.
- Lower cultivation costs because of site-specific crop management techniques
- Enhanced input production efficiency because of site-specific input management
- Reduced application of nutrients, particularly nitrogen fertilizer, which reduces nitrate in groundwater and nitrous oxide in the atmosphere.
- Reduced use of chemicals due to variable rate application technology.
- Reduced use of irrigation water, which reduces the application of nutrients and deep percolations.
- Reducing water body erosion, runoff, and sedimentation

Concept of Precision Farming

Precision farming is a method of modern farming that maximizes crop production while minimizing waste. It is based on the notion that different parts of a field have distinct needs and that by managing each area separately, farmers can increase productivity and profitability while lessening their impact on the environment. Data collection, analysis, and data-driven decision making are the three main elements of precision farming. It improves crop yield and quality, enables farmers to identify potential

issues, and reduces environmental impact. There are ongoing efforts to advance and broaden the technology and data analysis tools used in precision farming. In India, especially in the sugar cane industry, precision farming is a promising method of agricultural management. In the production of sugar cane, precision farming has the potential to significantly increase crop yields, input efficiency, and environmental sustainability, according to a study by Rane et al. (2018).

Precision farming can be advantageous in the production of sugarcane in several ways. First, it can assist farmers in determining which parts of the field need water and nutrients, resulting in more effective input use and higher crop yields. In India, precision farming has been shown to increase sugarcane yield by 20–25%, per a study by Tiwari et al. (2019). Second, precision agriculture can assist farmers in managing and monitoring soil health, which is essential for the development of sugar cane. Precision farming has been demonstrated to enhance soil health and lessen soil erosion in sugar cane fields, according to a study by Singh et al. (2017). Finally, by using fewer inputs and reducing the chance of pollution, precision farming can help to lessen the environmental impact of sugar cane production.

Precision farming has been applied in various ways to the cultivation of sugarcane in India. For instance, farmers have mapped the soil fertility of their fields and developed site-specific nutrient management plans using remote sensing and GIS. Additionally, some farmers have

applied pesticides and fertilizers to their fields with pinpoint accuracy using GPS technology. These methods have been demonstrated to raise crop yields, cut back on input use, and boost profitability.

In conclusion, there is a lot of room for improvement in crop yields, input effectiveness, and environmental sustainability using precision farming in India's sugar cane industry. In the upcoming years, it is likely that more farmers in India will adopt this technology due to the growing accessibility and affordability of precision agriculture tools (Tiwari et al., 2019).

Component/tools or techniques of precision farming

Precision farming involves the use of various components, tools, and techniques to collect, analyse, and apply data in a targeted and efficient manner. Modern agricultural management practices such as precision farming make use of technological developments to raise crop yields, input effectiveness, and environmental sustainability. Precision farming has been applied in the Indian sugar cane industry in several ways to increase crop productivity and sustainability. Here are some examples of key components of precision farming.

- **Geographic Information Systems (GIS**): A GIS is a software tool that allows farmers to map and analyze spatial data in their fields. Farmers can use GIS to find patterns and trends in how crops grow and how much they produce. This helps them make better decisions about how to use and manage their resources.
- **Sensors in automated irrigation systems** check how wet the soil is and change the amount of watering as needed. Farmers can boost crop yields and save water by making sure plants get the right amount of water.

- **GPS and remote sensing**: GPS technology enables farmers to accurately map their fields and track the movement of machinery and equipment. Satellite imagery, for example, can provide additional data on soil moisture, crop health, and other factors.

- **Variable rate technology (VRT):** Variable rate technology (VRT) allows farmers to apply inputs like fertilizer and seed at variable rates based on site-specific data. This aids in crop yield optimization and waste reduction.
- **Automated machinery**: Self-driving tractors and drones, for example, can be programmed to perform specific tasks based on data collected by sensors and other technologies. This can aid in increasing efficiency and lowering labor costs.

- **Data analysis and decision support tools**: Crop modelling software and predictive analytics, for example, can help farmers make more informed decisions about when to plant, irrigate, and harvest crops. These tools can also be used to forecast how weather events and other factors will affect crop yield.

Procedure of Precision Farming:

Precision farming implementation procedures vary depending on the specific context, but generally include the following steps:

- **Evaluate the current farming system**: Evaluate the current farming system to identify areas where precision farming practices could be used. Data analysis on soil quality, crop yields, irrigation practices, and other variables could be included.
- **Create a strategy**: Create a strategy for implementing precision farming practices. This includes determining which precision farming technologies and tools will be used, as well as how they will be integrated into the farming system.
- **Collect and analyse data**: Using various technologies such as sensors, drones, and GPS, collect and analyse data on soil moisture, nutrient levels, weather patterns, and other variables. Analyse the data using software and algorithms to identify patterns and trends.

- **Make data-driven decisions**: Make informed decisions about when to plant, fertilize, irrigate, and harvest crops based on the data collected. Use tools like variable rate technology to target inputs and reduce waste more precisely.
- **Monitor and adjust:** Continuously monitor the performance of the farming system and make necessary adjustments. Based on new data, this could include making changes to irrigation, fertilization, or pest management practices.
- **Evaluate and optimize**: Compare crop yields, input costs, and environmental impacts with previous years to determine the effectiveness of precision farming practices. Use this data to

improve precision farming practices in future seasons. Precision farming, in general, entails the use of various tools and technologies to collect and analyse data to make more significant crop management decisions. Farmers can improve crop yields, cut input costs, and reduce environmental impact by implementing these practices.

Table 1: Matrix to evaluate the effectiveness of precision farming practices, identify areas for improvement, and track progress over time.

S.No.	Category	Factors	Benefits
1.	Yield Optimization	Soil analysis, remote sensing, precision irrigation, variable rate fertilization	Increased yields, higher quality crops, reduced input costs
2.	Resource management	Precision planting, conservation tillage, cover crops, crop rotation	Reduced resource waste, water conservation, reduced greenhouse gas emissions
3.	Pest management	Automated pest detection, precision spraying, crop monitoring	Reduced use of pesticides, reduced pest damage, improved crop health
4.	Labor efficiency	Autonomous vehicles, precision seeding, machine learning	Reduced labor costs, increased efficiency, improved safety
5.	Sustainability	Reduced environmental impact, increased biodiversity, conservation of natural resources	Improved sustainability, reduced waste, increased public trust

This matrix categorizes precision farming practices into five categories: Yield optimization, resource management, pest management, labor efficiency, and sustainability. Several factors that contribute to the effectiveness of precision farming practices are listed for each category. Finally, the matrix emphasizes the advantages of each category, such as higher yields, lower input costs, improved environmental sustainability, and increased public trust.

Precision Agriculture, according to Mandal Subrata et al; 2013, strives to boost revenues while lowering energy use and environmental effect. Meaningful delivery necessitates commercial

applicability, which improves Precision Agriculture (PA) by increasing the likelihood that agriculture will modernize and stop using old. methods by utilizing the appropriate resources. Agriculture that is environmentally sustainable is produced through its management. The best way to solve this issue is through smart agriculture, which involves implementing innovative agricultural techniques.

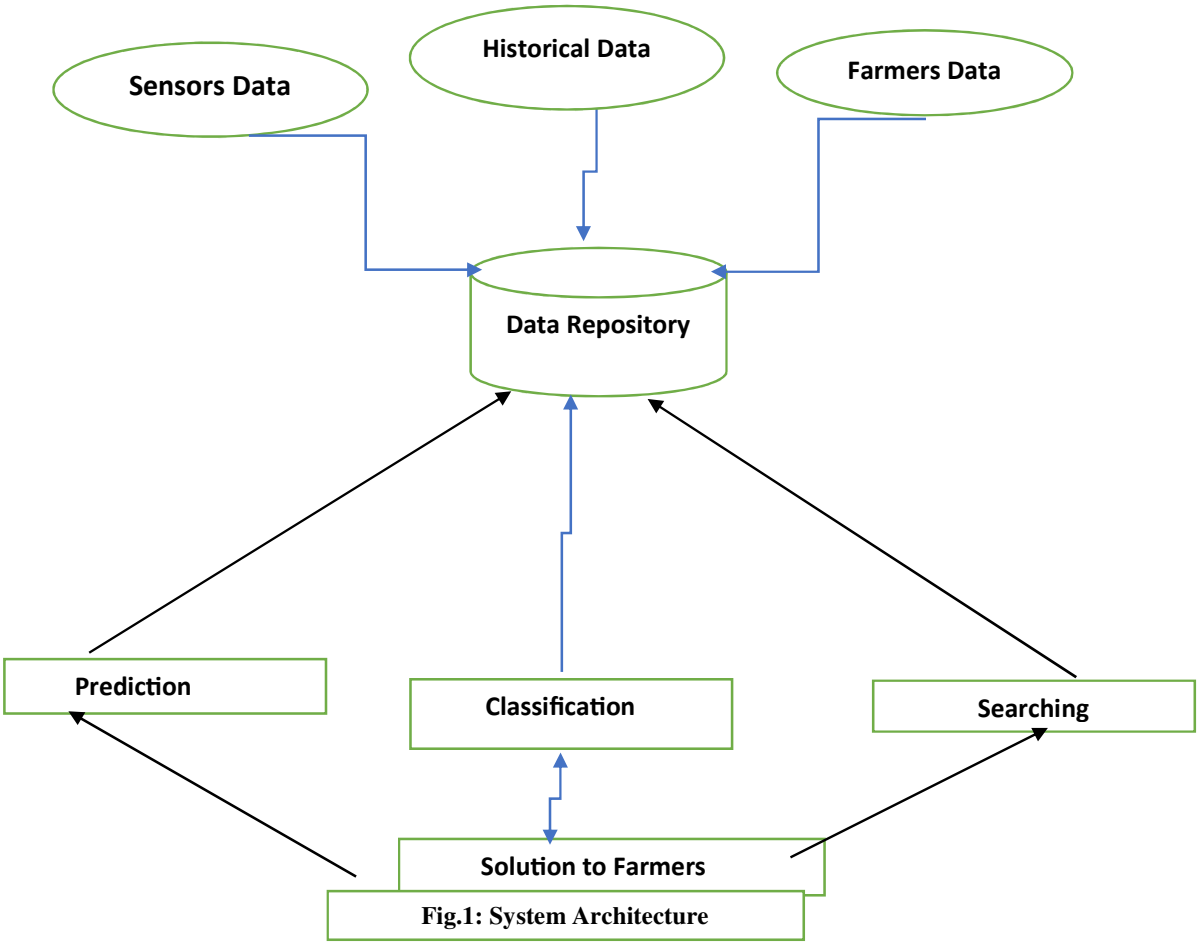

Fig.1: System Architecture

Precision agriculture (PA) is a variable-rate technology that uses georeferenced data to govern agricultural systems. It is based on a detailed analysis of georeferenced data using monitoring, procedures and the incorporation of soil, plant, and climate variables. Around 10% of Brazil's total sugarcane cultivation is done through PA, and the simplest way to incorporate PA into sugarcane crops

is to apply inputs at different rates depending on the soil's properties. Precision agriculture (PA) is a farm management strategy that considers the variability of the land and the associated fluctuations in production. It is linked to devices like GPS, GIS, and variable-rate applicators and is used to check the yield of the crop. A technical report funded by the Sugar Research and Development Corporation found that PA offers potential for the sector and identified research and development needs.

Challenges in adoption of Precision Agriculture:

The main challenges are as follows:

1. **Cost**: Precision agriculture technologies can be expensive, and the upfront costs associated with implementing these technologies may be a barrier for some farmers, particularly small-scale farmers.
2. **Access to finance**: Access to finance is a major challenge for many farmers in India, and this can limit the ability of farmers to invest in precision agriculture technologies.
3. **Lack of technical expertise**: Precision agriculture involves the use of sophisticated technologies and data analysis, and there may be a shortage of skilled personnel to operate and maintain these systems.
4. **Resistance to change**: Some farmers may be resistant to adopting new technologies due to a lack of understanding or awareness of the benefits, or due to cultural and economic factors.
5. **Data security and privacy**: The collection and storage of large amounts of data raises important questions around data security and privacy, and there may be concerns about the potential misuse of this information.
6. **Lack of infrastructure**: In some areas, the lack of basic infrastructure such as electricity and internet connectivity may limit the ability of farmers to adopt precision agriculture technologies.

Precision Agriculture (PA) adoption is hindered by the long growth season, lack of a dependable yield monitor, grower's risk, different farm size vs. technology cost, lack of cost-benefit analysis data, and lifestyle preferences. However, it is essential for the sugar business to promote PA adoption for the sector's future.

Implementation of Precision Agriculture:

The implementation of precision agriculture in the sugarcane industry requires careful planning, investment in technology and infrastructure, and the development of a supportive ecosystem.

PA is to optimise production efficiency, optimise crop quality, minimise environmental impacts, and minimise risk to the grower. However, PA involves more than just utilizing GPS or other technologies. A PA management plan might make use of a variety of technologies. The PA process should be included in a comprehensive farm management plan with specific objectives that the grower intends to accomplish. (As per Sugar Research, Dr Rob Bramley, CSIRO Adelaide et al).

Advantages of Precision Agriculture: For both farmers and the environment, precision farming has several benefits. First, it raises crop yield and quality by enabling farmers to better manage and utilize inputs like water, fertilizer, and pesticides. According to studies like Tiwari et al. (2019) on sugarcane production in India, this leads to higher crop yields. Second, precision farming enables farmers to spot potential problems like nutrient shortages or disease outbreaks before they become major issues, allowing for prompt intervention and prevention.

Thirdly, precision farming lessens the environmental impact of agriculture by using fewer resources, such as water and fertilizers, and by using fewer chemicals, which results in less pollution. Overall, using precision farming to increase crop production efficiency while lowering environmental impact is a promising strategy. (Sources: Gebbers and Adamchuk, 2010, Tiwari et al., 2019, Zaman et al., 2019).

Research Methodology: Authors used secondary data and studied many research papers, available in the form of journals, periodicals, books, and websites. To ensure the accuracy of the information, data has been gathered from numerous books, research journals, research papers, articles, and other print media. The literature published between 2010 and 2022 was searched for using the following databases: Academia (https://www.academia.edu/), Researchgate (https://www.researchgate.net), Google Scholar (https://scholar.google.com/), Springer (https://www.springer.com/), Elsevier (https://ieeexplore.org), Google Scholar (https://scholar.google.com) etc. applying "variable rate application," "precision agriculture," and "soil mapping". This study was written using the descriptive technique, case study method and a careful and in-depth analysis of accessible literature by the writers.

Case study: Tata Kisan Kendra (TKK)

Tata Group launched TKK alongside Tata Chemicals Limited (TCL) to address social and economic challenges in India. The TKKs' use of precision farming could help rural India transition from old methods to the new one of satellites and IT. TCL sells TKKs to farmers to check soil, provide information on crop health, pest infestations, and predict agricultural yields. This helps farmers adapt to changing conditions. Healthy crops will enhance yields and farmer's earnings. Small Indian farmers worry about money. Kendra fulfils this criterion. Farmers can get buybacks, loans, and insurance to protect their crops.

Precision farming is extensively used in industrialized countries, but it hasn't caught on in India due to its unusual landholding pattern, insufficient infrastructure, and risk-averse farmers.

Findings:

Here are some key findings from the papers with corresponding citations:

PA techniques and technologies can significantly improve nutrient management in the sugarcane industry (Kaur et al., 2017; Kumar et al., 2021).

PA technologies such as soil analysis, remote sensing, and variable rate technology can help farmers optimize nutrient application and increase yields (Gao et al., 2019; Singh et al., 2020; Wu et al., 2021).

The adoption of PA practices can result in increased income for farmers, especially in large-scale sugarcane farming operations (Mishra et al., 2020; Singh et al., 2018).

The use of PA can reduce environmental impact by minimizing the use of fertilizers and pesticides (Chen et al., 2018; Kumar et al., 2021).

The adoption of PA practices requires significant investment in technology and training, which may be a barrier to small-scale farmers (Kumar et al., 2021; Wu et al., 2021).

Policymakers and stakeholders in the sugarcane industry should prioritize the adoption of PA practices and provide financial and technical support to farmers to help them invest in PA technology and training (Gao et al., 2019; Mishra et al., 2020; Singh et al., 2018).

Recommendations and need of Precision Agriculture in India:

The implementation of contemporary technology in Indian agriculture is unavoidable to fulfil the country's enormous food grain demand, which is expected to reach 480 million tonnes (Mt) by the year 2050, given the growing difficulties associated with biotic and abiotic stresses experienced by crops. IoT can be used in Precision Agriculture in real time. Precision agriculture controls geographical and temporal variability in agricultural production to improve output and environmental quality. It reduces operating costs to boost farmers' margins. Precision farming allows farmers to operate by producing zones rather than fields. Farmers can save time and money by using less fertilizer, petroleum, pesticides, and other inputs.

Conclusion

Random adoption of PA technologies wouldn't be profitable, given their contribution to farm-level profitability differs. Grid soil sampling is anticipated to increase net agricultural returns.

Although the technology's potential has previously been shown, substantial execution is challenging because it requires extensive commercial use to reap the rewards. The primary goal of Precision Agriculture is to maximize yield with the least amount of input and least amount of environmental pollution. The assumption that PA adoption will increase farm profitability is a flawed one for farmers to make. The bulk of PA technologies have not yet been proven to positively impact agricultural economics.

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