Precision cultivation of vegetable crops to increase productivity: A review

ABSTRACT

Precision cultivation is an innovative agricultural approach that leverages advanced technologies and data-driven methodologies to enhance the productivity and sustainability of vegetable crops. The precision agriculture techniques, including remote sensing, soil moisture sensors, GPS-guided machinery and data analytics which use to optimize various aspects of vegetable farming. These technologies facilitate informed decision-making regarding planting schedules, irrigation management, fertilization strategies and pest control which leading to improved crop yields and resource efficiency. Precision cultivation offers the potential for reduced environmental impact by minimizing chemical inputs and maximizing land use efficiency. Case studies demonstrate the successful implementation of precision practices across diverse climatic and geographical contexts which highlighting significant increases in productivity and quality of vegetable crops. The findings suggest that embracing precision cultivation not only addresses the challenges of food security but also contributes to sustainable agricultural practices that align with global environmental goals. Future research directions and technological advancements will be essential to further refine these methods and expand their applicability to diverse vegetable crops and farming systems.

Key words: Precision farming, Vegetable productions, Pest control, Nutrient management, Irrigation.

1. INTRODUCTION

Now a day, the global population has been steadily increasing which leading to an ever-growing demand for food. As a result, there is an urgent need to maximize crop yields and enhance the quality of agricultural produce. In the realm of vegetable cultivation, precision farming techniques have emerged as a promising solution (Abdul *et al.*, 2016). Precision cultivation involves the application of advanced farming techniques to optimize crop growth, minimize resource wastage, and ultimately maximize both yield and quality (Sasse *et al.*, 2016).

2. UNDERSTANDING PRECISION CULTIVATION

Precision cultivation is an approach that integrates technology, data analysis and agronomic expertise to create the ideal growing conditions for vegetable crops (Bhattacharyay *et al.*, 2020). It involves the precise application of inputs such as water, fertilizers and pesticides as well as the implementation of targeted cultivation practices (Alex *et al.*, 2005). By combining real-time data, satellite imagery and sensor technologies, farmers can monitor and manage their crops more effectively which leading to improved efficiency and productivity (Reyns *et al*., 2002).

3. NEEDS FOR PRECISION CULTIVATION

3.1 For assessing and managing field variability: "we know that our field have variable yield across the landscape because of variations to management practices, soil properties or environmental characteristics. One's mental information database about how to treat different areas in a field requires years of observation and implementation through trial-and error. Today, that level of knowledge of field conditions is difficult to maintain because of the variable farm size and changes in area farmed due to annual shifts in leasing arrangements. Precision agriculture offers the potential to automate and simplify the collection and analysis of information" (Alex *et al*., 2005).

3.2 For doing the right thing in the right place at right time: "After assessing the variability precision agriculture allow management decisions to be made and implemented in right time in right places on small area within large field" (Zhang *et al.*, 2002).

3.3 For higher productivity: "Since precision farming, proposes to prescribe tailor made management practices, it will definitely increase the yield per unit of land, provide nature's other uncontrollable factors are in favour" (Balafoutis *et al.*, 2017).

3.4 For increasing the effectiveness of inputs: "Increased productivity per unit of input used indicates increased efficiency of the inputs" (Raj *et al*., 2022).

3.5 For maximum use of minimum land unit: "After knowing the land status, a farmer tries to improve each and every part of land uses it for the production purpose" (Banu, 2015).

4. TECHNOLOGIES USED IN PRECISION FARMING

4.1 Global Positioning System (GPS)

"One of the key technologies used in precision farming is the Global Positioning System (GPS). GPS enables farmers to accurately determine the location and position of their machinery and equipment within the fields. This information is crucial in guiding automated machinery such as self-driving tractors, to operate precisely and efficiently. By utilizing GPS, farmers can ensure that every inch of their land is utilized optimally, minimizing wastage and maximizing productivity" (Nemenyi *et al.*, 2003).

4.2 Remote Sensing

Remote sensing is another technology that has greatly contributed to precision farming. It involves collecting data about crops and fields from a distance, typically through satellite imagery or drones equipped with sensors. Remote sensing provides farmers with valuable information on crop health, soil moisture levels and nutrient deficiencies. By analyzing this data, farmers can make informed decisions regarding irrigation, fertilization and pest control which resulting in improved crop yields and reduced input costs (Wu *et al.*, 2010).

4.3 Variable Rate Technology (VRT)

Variable Rate Technology (VRT) is a technology that allows farmers to apply inputs, such as fertilizers and pesticides at variable rates across different areas of their fields. By using sensors and GPS technology, VRT systems can precisely determine the nutrient requirements of specific areas within a field. This enables farmers to apply the right amount of inputs at the right place which reducing wastage and environmental impact while optimizing crop growth. VRT systems can be integrated into machinery such as sprayers and seeders which making the application process automated and efficient (Clark and Mcguckin, 1996).

4.4 Data Management and Analytics

The abundance of data generated through precision farming requires effective management and analysis. Data management systems combined with advanced analytics which allow farmers to make data-driven decisions and optimize their farming practices. These systems can integrate data from various sources such as weather forecasts, soil sensors and machinery sensors, to provide real-time insights and recommendations. By analyzing historical data, farmers can identify patterns, trends and potential areas for improvement which leading to enhanced productivity and profitability (John and Port, 2018).

4.5 Robotics and Automation

Robotics and automation play a significant role in precision farming, particularly in labor-intensive tasks. Autonomous robots can perform various activities, such as planting, weeding, and harvesting, with precision and efficiency. These robots are equipped with sensors and cameras that enable them to navigate through fields, identify weeds or damaged crops, and perform targeted actions. By automating repetitive tasks, farmers can reduce labor costs, improve accuracy, and optimize resource utilization (Yan *et al.*, 2020).

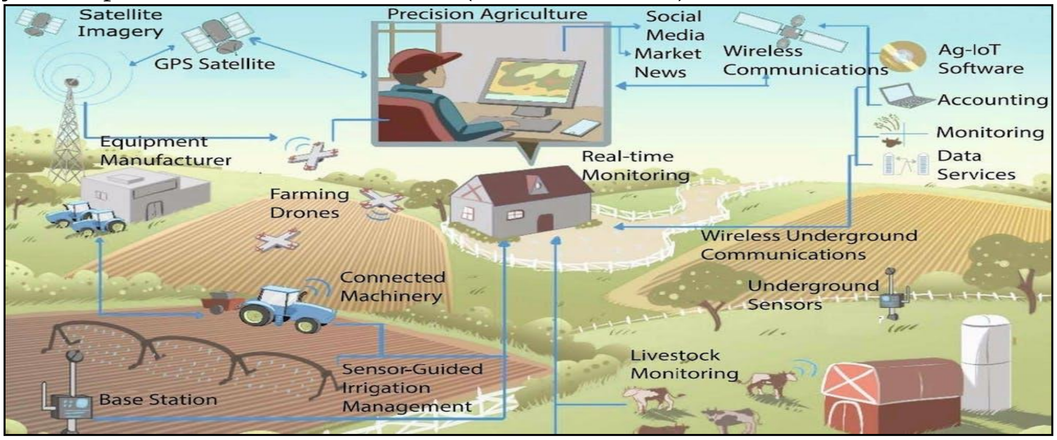

Figure 1: Precision cultivation cycle

5. APPLICATIONS OF PRECISION CULTIVATION

5.1 Precision Irrigation

Water is a vital resource in crop production and its efficient use is essential for sustainable agriculture. Precision irrigation systems enable farmers to deliver the right amount of water to plants at the right time and in the right place. By utilizing soil moisture sensors and weather data farmers can ensure that crops receive adequate water without wastage, thereby reducing water usage and optimizing plant growth (Abioye *et al.*, 2020).

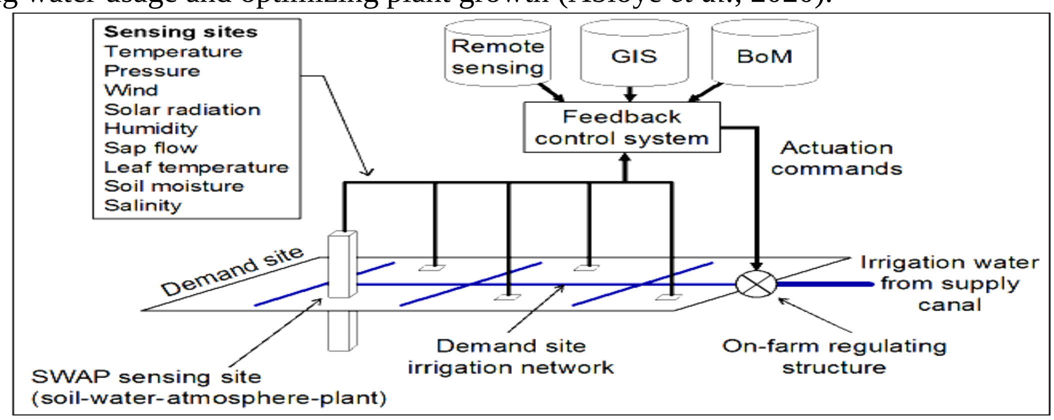

Figure 2: Precision irrigation

5.2 Precision Fertilization

Nutrient management is a critical aspect of precision cultivation. By analyzing soil nutrient levels and crop requirements, farmers can apply fertilizers in a targeted manner which minimizing waste and environmental impact. Different areas of a field receive different amounts of nutrients based on their needs, it can significantly enhance crop productivity and reduce nutrient runoff (Chen *et al.*, 2014).

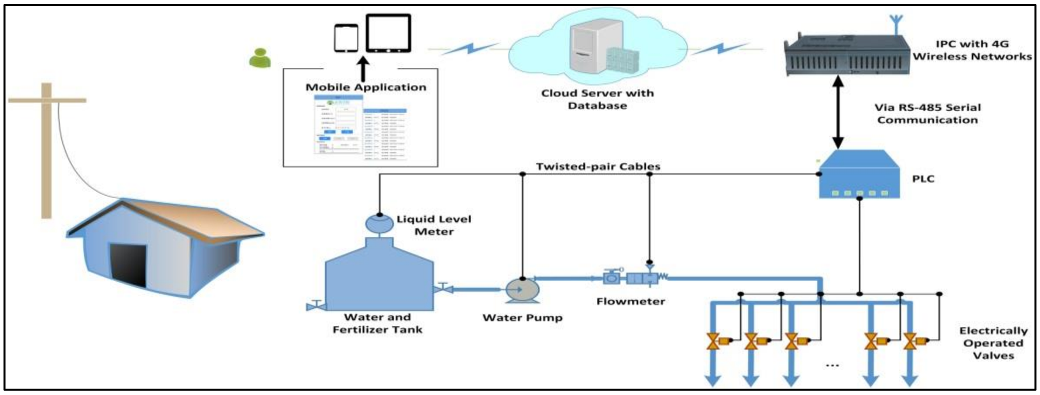

Figure 3: Precision fertilization

5.3 Integrated Pest Management

Precision cultivation emphasizes the use of integrated pest management (IPM) strategies to minimize the use of pesticides while effectively controlling pests and diseases. By monitoring pest populations, implementing biological control methods and utilizing precision spraying techniques, farmers can reduce chemical inputs, protect beneficial organisms and safeguard crop quality (Chouraddi *et al.*, 2011).

5.4 Data Analytics and Decision Support Systems

"Precision cultivation relies heavily on data collection, analysis and interpretation. By integrating data from various sources, such as weather stations, soil sensors and remote sensing technologies, farmers can gain valuable insights into crop growth, yield potential and resource utilization. Decision support systems equipped with predictive models can assist farmers in making informed decisions regarding crop management practices which leading to improved outcomes" (Venkatalakshmi and Devi, 2014).

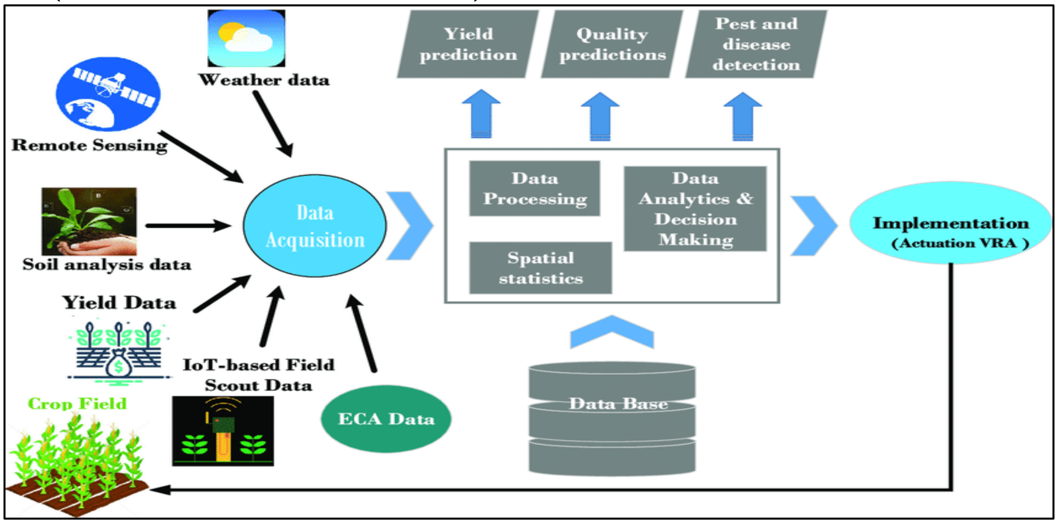

Figure 4: Data analytics and decision support systems

5.5 Automated Seeding and Transplanting Systems

Automated seeding and transplanting systems have emerged as a significant breakthrough in vegetable production. These systems utilize robots equipped with precise sensors and algorithms to efficiently plant seeds or transplant seedlings. By automating these labor-intensive tasks, farmers can save time, reduce costs, and ensure uniformity in plant spacing, resulting in higher crop yields. Additionally, these systems can operate continuously, enabling farmers to increase their production capacity and meet the growing demand for vegetables (Khadatkar *et al.*, 2018).

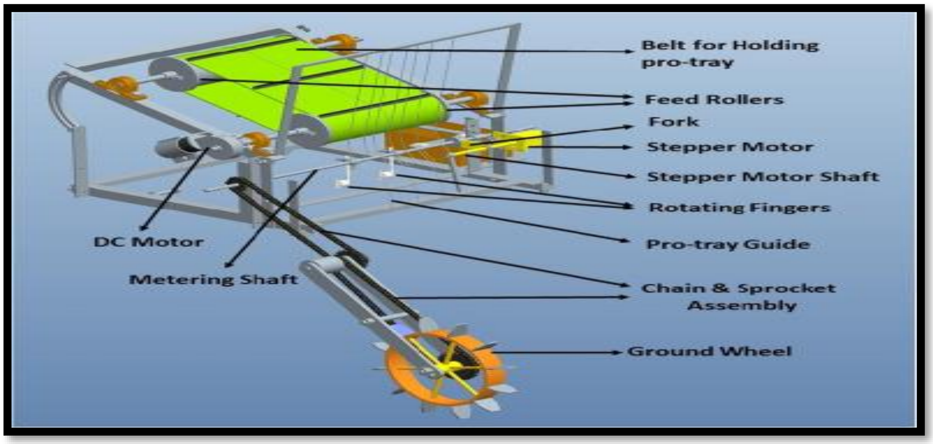

Figure 5: Automated Seeding and Transplanting Systems

5.6 Automated Weeding Systems

Weeding is crucial aspects of vegetable production, as invasive plants can significantly impact on crop growth. Robotic technologies, such as automated weeding systems, offer a sustainable and efficient solution. These robots can identify and remove weeds without the need for harmful chemicals, reducing the environmental impact of farming practices. Moreover, these systems can target specific areas, minimizing crop damage and increasing overall productivity (Steven *et al.*, 2016).

Figure 6: Automated Weeding Systems

5.7 Harvesting and Sorting Robots

One of the most labor-intensive and time-consuming tasks in vegetable production is harvesting and sorting. Robotic technologies have made significant strides in automating these processes, resulting in increased efficiency and reduced labor costs. Harvesting robots equipped with advanced sensors and algorithms can identify ripe vegetables, pick them gently without causing damage, and sort them based on size, shape, and quality. This level of precision ensures that only the highest quality vegetables reach the market, enhancing the reputation of farmers and improving consumer satisfaction (Bachche, 2015).

Figure 7: Harvesting and Shorting Robots

5.8 Grafting robots

"The first commercial model of a grafting robot (GR800 series, Iseki & Co. Ltd., Matsuyama, Japan) became available for cucurbits back in 1993. Since then, semi- or fully-automated grafting robots were invented by several agricultural machine industries and several commercial models are available in East Asia, Europe, and more recently in the U.S. Semi-automated grafting robots generally graft at a speed of 600-800 grafts per hour (speed equivalent of 5-6 skilled workers for cucurbit, and 2-3 skilled workers for tomato), but require a minimum of two workers and one trained worker to inspect the grafting quality" (Kai *et al.*, 2012).

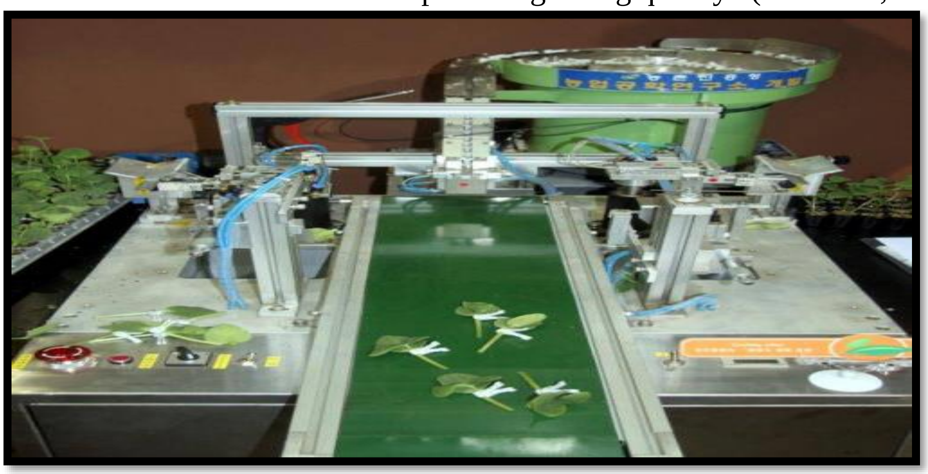

Figure 8: Grafting robot

5.9 Drones

Drones have been increasingly used in vegetable production for various purposes, including crop monitoring, pest control, and precision agriculture. Here are some key roles of drones in vegetable production (Oksana *et al.*, 2021):

1. **Crop monitoring:** Drones equipped with high-resolution cameras and sensors can capture detailed aerial imagery of vegetable fields. This imagery can be used to monitor crop health, detect nutrient deficiencies, identify diseases or pests, and assess overall crop growth.
2. **Irrigation management:** Drones can help monitor soil moisture levels in vegetable fields by using thermal or multispectral sensors. This information can be used to optimize irrigation schedules and ensure efficient water usage, thereby improving crop yield and quality.

3. **Pest control:** Drones can be equipped with sprayers or release devices to apply pesticides or beneficial insects precisely and efficiently. This targeted approach helps reduce chemical usage, minimize environmental impact, and control pests effectively in vegetable production.
4. **Crop mapping and analysis:** Drones can create accurate 3D maps of vegetable fields using advanced imaging techniques like photogrammetry. These maps can provide valuable insights into plant density, canopy cover, and growth patterns, enabling farmers to make data-driven decisions for crop management.
5. **Precision agriculture:** By integrating drone data with other technologies like GPS and GIS, farmers can implement precision agriculture techniques. Drones can help generate prescription maps for variable rate application of fertilizers or other inputs, leading to optimized resource utilization and improved crop performance.

6. OBJECTIVES OF PRECISION CULTIVATION

6.1 Increased Yield

One of the primary goals of precision cultivation is to maximize crop yield. By utilizing advanced technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS) and remote sensing farmers can gather precise data on soil conditions, moisture levels and nutrient content. This information enables them to tailor their cultivation practices to meet the specific needs of each crop which resulting in optimal growth and increased yield. Precision cultivation also allows for early detection and management of pests and diseases which further enhancing crop productivity.

6.2 Resource Optimization

Another key objective of precision cultivation is the efficient utilization of resources. By accurately mapping and analyzing soil variability farmers can apply fertilizers, water and other inputs only where they are needed which reducing waste and minimizing environmental impact. This targeted approach ensures that resources are used efficiently which resulting in cost savings for farmers and a more sustainable agricultural system.

6.3 Environmental Sustainability

Precision cultivation plays a crucial role in promoting environmental sustainability. By reducing the use of agrochemicals and optimizing resource allocation, this technique helps mitigate the negative impacts of conventional farming practices on ecosystems. Precision cultivation also enables farmers to adopt conservation tillage methods which help in minimizing soil erosion and preserving soil health. Additionally, by monitoring and managing irrigation systems more effectively water usage can be reduced. By implementing precision cultivation farmers contribute to the preservation of biodiversity and the overall health of the environment.

6.4 Economic Viability

The economic viability of vegetable crop cultivation is a significant objective of precision farming. By adopting precision cultivation techniques farmers can achieve higher yields, reduce input costs and increase profitability. The precise application of inputs and the timely detection of crop stressors enable farmers to optimize their production processes which resulting in improved financial outcomes. Furthermore, precision cultivation allows farmers to make informed decisions regarding crop selection, crop rotation and market demand which enhancing their competitiveness in the agricultural sector.

7. BENEFITS OF PRECISION CULTIVATION

Precision cultivation offers numerous benefits to both farmers and consumers. Firstly, it enables farmers to optimize resource utilization, reducing input costs and minimizing environmental impact (Kunz *et al.*, 2015). By using inputs more efficiently, farmers can achieve higher yields and improve profitability (Griffin *et al.*, 2018). Secondly, precision cultivation enhances crop quality by ensuring that plants receive the precise amounts of water, nutrients and protection they need (Robert *et al.*, 2019). This leads to the production of visually appealing and nutritionally dense vegetables that meet consumer demands (William *et al.*, 2021). Precision cultivation promotes sustainable agriculture by reducing water and chemical usage, minimizing soil erosion and preserving biodiversity (Hermann, 2001).

8. CHALLENGES

Despite its potential, precision cultivation faces several challenges. The initial investment in technology and infrastructure can be a barrier for small-scale farmers (Achim *et al*., 2004). Additionally, the integration of different data sources and the interpretation of complex data require technical expertise (Patil *et al*., 2002). To overcome these challenges, governments research institutions and agricultural organizations need to provide support, training and financial incentives to farmers. Furthermore, continuous research and development are necessary to refine precision cultivation techniques and adapt them to different crop types and farming systems (Michael *et al.*, 1996).

9. ROLE OF PRECISION CULTIVATION IN VEGETABLE CROPS

9.1 Tomato

Candiago *et al.* (2015) "recorded that Unmanned Aerial Vehicles (UAV) based remote sensing offers great possibilities to acquire in a fast and easy way field data for precision agriculture applications". "The comparative study of the three networks (ZigBee, DigiMesh and LabVIEW) made evident that the configuration of the DigiMesh network is the most complex for adding new nodes, due to its mesh topology, however DigiMesh maintains the bit rate and prevents data loss by the location of the nodes as a function of crop height and it has been also shown that the WiFi network has better stability with larger precision in its measurements which examined" by Rodas *et al.* (2018). Sandor *et al.* (2018) "revealed that very good uniformity is achievable both in the IR100 and IR50 application rates of irrigation". Tien *et al.* (2020) "observed that the wild relatives of cultivated tomatoes possess a rich source of genetic diversity but have not been extensively used for the genetic improvement of cultivated tomatoes due to the possible linkage drag of unwanted traits from their genetic backgrounds but with the advent of new plant breeding techniques (NPBTs) especially Cas-based genome engineering tools, the high-precision molecular breeding of tomato has become possible". Ramrsh *et al.* (2021) achieved an accuracy of 94% on average tomato leaf disease by using Using Neural Networks.

9.2 Brinjal

Bebitha *et al.* (2015) evident that application of fipronil @ 50 g a.i/ha recorded the highest mean per cent reduction of leaf hopper population and aphid population under precision farming system. Shanmugam *et al.* (2015) recorded that the bio-rational approaches recorded lower shoot damage and fruit damage during *kharif* and *rabi* season where higher damage was observed in farmer practices. Kumar *et al.* (2022) revealed that maximum fruit per plant and total yield was observed in best available water which applied through drip irrigation system.

9.3 Chilli

Shinde *et al*. (2015) observed that the precision farming increased social and economic status of farmer by increasing yield, quality of produce, economic use of water and C: B ratio.

Swadia (2017) examine that the 95 percent of the irrigation water can be used efficiently and the production may be increased by 30- 50 percent by using drip system of irrigation. Islam *et al.* (2021) revealed that the achieved weed detection accuracy are 96% using RF, 94% using SVM and 63% using KNN, from UAV images.

9.4 Potato

"The performance of Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI) were successfully tested with the measured and predicted data of yield by using GIS, GPS, sensors, soil sampling, yield monitoring and crop growth models which studied" by Sharkawy *et al.* (2013). Liu *et al.* (2017) "recorded tha the DSS (Decision Support System) based strategy was identified as the most effective approach to manage late blight in terms of disease suppression, net return per 0.41 ha, and risk-adjusted net return as compare to calendar-based strategy and unsprayed control".

10. CONCLUSION

Precision cultivation offers a paradigm shift in vegetable crop production, enabling farmers to maximize yield and quality while minimizing resource usage. By harnessing advanced farming techniques and data-driven decision-making, precision cultivation has the potential to revolutionize the way we grow vegetables. As the global population continues to grow, it is imperative that we embrace innovative approaches like precision cultivation to ensure food security, sustainability, and the provision of high-quality produce for generations to come.

11. REFERENCES

Abdul VM, Joseph EA, Ajay AJ, Mufeedha.. Precision farming: the future of Indian agriculture. *J. App. Biol. and Biotchnol*. 2016;**4**(6): 68-72.

Abioye EA, Shukri M, Abidin Z, Mahmud MS.. A review on monitoring and advanced control strategies for precision irrigation. *Computers and Electronics in Agric.* 2020;**173**: 105441.

Achim D, Simon B, Simon EC, Viacheslav IA. Precision farming: challenges and future directions. *Proceeding of 4th Int. Crop Sci. Congress*. 2004;**26**: 189-201.

Alex M, Brett W, Ancev T, Johan B. Future directions of precision agriculture. *Precision Agric.* 2005;**6**: 7-23.

Bachche S. Delibration on design strategies of automatic harvesting system: a survey. *Robotics*. 2015;**4**(2): 194-222.

Balafoutis A, Beck B, Fountas S, Jurgen V, Tamme V, Soto I. Precision agriculture technologies positively contribute to GHG emissions mitigation, farm productivity and economics. *Sustainability*. 2017;**9**(8): 1339.

Banu S. Precision agriculture: tomorrows technology for today's farmer. *J. Food Processing and Technol.* 2015;**6**(8): 1.

Bebitha B, Muthiah C, Chinniah C, Chandramani P. Management of pest of brinjal using never insecticide molecules under precision farmingsystem. *Annals of Pl. and Soil Res.* 2015;**17**(1): 373-376.

Bhattacharyay D, Sagar M, Pine S, Shankar T, Pedda SK. Future of precision agriculture in India. *Protected Cultivation and Smart Agric.*2020;**1**: 289-299.

Candiago S, Fabio R, Giglio M, Marco D, Mario G. Evaluating multispectral images and vegetation indices for precision farming applications from UAV image. *Remote Sens*. 2015;**7**(4): 4026-4047.

Chaouraddi M, Balikai RA, Mallapur CP, Nayaka P. Pest management strategies in precision farming. *Int. J. Pl. Protection*. 2011;**4**(1): 227-230.

Chen C, Pan J, Lam SK. A review of precision fertilization research. *Environ. Earth Sci*. 2014;**71**: 4073-4080.

Clark RL, McGuckin RL. Variable rate technology: an overview. *Precision Agric.* 1996;**4**: 855-862.

Griffin T, Shockley JM, Mark TB. Economics of precision farming. *Precision Agric. Basics*. 2018;221-230.

Hermann A. Precision farming: the environmental challenge. *Computers and Electronics in Agric.* 2001;**30**(3): 31-43.

Islam N, Rashid MM, Santoso W, Cheng YX, Ashan M, Saleh AW, Steven M, Rahman SM. Early weed detection using image processing and machine learning techniques in an Australian chilli farm. *Integrated Weed Management in Agril. Systems*. 2021;**11**(5): 387.

John PF, Port K. Precision agriculture data management. *Precision Agric. Basics*. 2018;169-187.

Kai J, Zheng W, Qian Z, Rui G, Feng Q. Development and experiment of vegetable grafting robot. *Transactions of the Chinese Society of Agril. Eng*. 2012;**28**(4): 8-12.

Khadatkar A, Muthur SM, Gaikwad, BB. Automation in transplanting. *Curr. Sci.* 2018;**115**(10): 1884-1892.

Khadatkar A, Muthur SM, Gaikwad BB. Automation in transplanting. *Curr. Sci.* 2018;**115**(10): 1884-1892.

Kumar KP, Choudhary G, Singh AK, Choudhary A, Kumar R, Didal B. Performance of brinjal to water quality under drip irrigation system. *J. Eco-friendly Agril.* 2022;**2**(17): 290-292.

Kunz C, Felix J, Roland G. Benefits of precision farming technologies for mechanical weed control in soyabean and sugar beet comparison of precision hoeing with conventional weed control. *Agronomy*. 2015;**5**(2): 142.

Lan Y, Thomson SJ, Huang Y, Hoffmann WC, Zhang H. Current status and future directions of precision aerial application for sit-specific crop management in the USA. *Computers and Electronics in Agric.* 2010;**74**(1): 34-38.

Liu Y, Micheal RL, Lan MS, Joseph L, William EF. Risk management strategies using precision agriculture technology to manage potato late blight. *Agron. J.* 2017;**109**(2): 560-575.

Michal DW. Precision farming and spatial economic analysis: research challenges and opportunities. *Americal J. Agril. Economics*. 1996;**78**(5): 1275-1280.

Nemenyi M, Mesterhazi PA, Pecze Z, Stepan Z. The role of GIS and GPS in precision farming. *Computers and Electronics in Agric.* 2003;40(3): 45-55.

Oksana D, Volodymyr M, Oleg S. Accounting automation in agro industrial enterprises using drones. *Adv. Computer Info. Technol*. 2021;337-341.

Patil VC, Ajit M, Shashidhara GB, Shanwad UK. Remote sensing, geographical information system and precision farming in India: opportunities and challenges. *Proceeding of the 3rd Asian Conference for Info. Technol. In Agric*. 2002;26-28.

Raj EF, Appadurai M, Athiappan K. Precision farming in modern agriculture. *Data Analytics and Machine Learning*. 2022;**1**:61-87.

Ramesh NV, Reddy MB, Deepika B, Suresh N, Rao KR, Reddy BN. Identification of tomato crop diseases using neural networks-CNN. *Int. Conference on Computing Communication and Networking Technol.* 2021;51-52.

Reyns P, Missotten B, Ramon H, Beardemaeker JD. A review of combine sensors for precision farming. *Precision Agric.* 2002;**3**: 169-182.

Robert F, Scott MS, Nadja EB, Walter A. Precision farming at the nexus of agricultural production and the environment. *Annual Review of Resource Economics*. 2019;**11**: 313-335.

Rodas ME, Mary SM, Sergio MR, Monica H, Devid R, Naranjo C, Jose LR. Multiparametric monitoring in equatorian tomato greenhouse: wireless sensor network benchmarking. *Sensors*. 2018;**18**(8): 2555.

Sandor T, Tibor BL, Zoltan P. Variable rate precision irrigation technology for deficit irrigation of processing tomato. *Irrigation and Drainage*. 2018;**68**(2): 234-244.

Sasse MZ, Fountas Z, Gemtos TA, Khalaf NA. Applications of precision agriculture in horticultural crops. *European J. Hortic. Sci.* 2016;**6**: 51-58.

Shanmugam PS, Indhumathi K, Vennila MA, Tamilselvan N. Evaluation of biointensive pest management modules against brinjal shoot and fruit borer under precision farming system. Pest management in Hortic. *Ecosystems*. 2017;**2**(21): 154-158.

Sharkawy MM, Hady AM, Arafat SM, Aggag AM. Precision farming using remote sensing and GIS to improve soil and potato crop management. *J. Agric. and Environ. Sci.* 2013;**21**(2): 8-16.

Shinde SM, Deshmukh SB, Turkhade PD, Narkhede GW. Influence of precision farming technology on chilli cultivation in Maharashtra state India. *Eco. Environ., and Cons.* 2015;**21**(2): 581-584.

Steven AF, David C, Mark C, Ramon G, Mazin N. Technology for automation of weed control in specialty crops. *Weed Technol*. 2016;**30**(4): 823-837.

Swadia BU. Study of adoption behavior of drip irrigation system on chilli crop in Ahmedabad district of Gujarat India. *A Referred Int. J. Multidisciplinary Res.* 2017; **4**(1): 1-5.

Tien VV, Das S, Mil TT, Jong CH, Jae YK. Precision genomic engineering for the breeding of tomato: recent progress and future perspectives. *Frontiers*. 2020;**2**(10): 3389-3399.

Venkatalakshmi B, Devi P. Decision support system for precision agriculture. *Int. J. Res. in Engineering and Technol.* 2014;**3**(7): 849-852.

William H, Frida RM, Bedir T. Augmented reality in precision farming: concepts and applications. *Computers and Electronics in Agric.* 2021;4(4): 1454-1468.

Wu B, Meng J, Zhang F, Xin D, Zhang M, Chen X. Applying remote sensing in precision farming: a case study in Yucheng. *Word Automation Congress*. 2010;**38**(2): 1-6.

Yan XT, Biacon A, Niu C, Roberto P, Henry G, Li H. The agrirover: a reinvented mechatronic platform from space robotic for precision farming. *Reinvented Machatronics: Devloping Future Directions for Mechatronics.* 2020;55-73.

Zhang N, Wang M, Wang N. Precision agriculture: a word wide overview. *Computers and Electronics in Agric.* 2002;**36**(2): 113-132.