Precision Agriculture; an Evolution and Prospect for the Future: A Review

Abstract

A farm management system that uses information and technology to identify, analyze, and control the temporal and spatial variability within a field is known as precision farming or precision agriculture. Its goals are to maximize productivity and profitability, preserve the land resource, and minimize production costs. The public's growing environmental consciousness is forcing us to alter agricultural management techniques in order to maintain economic profitability while preserving natural resources like water, air, and soil quality. The application of inputs (such as chemical pesticides and fertilizers) in accordance with the proper amount, timing, and location. "Site-Specific Management" is the term used to describe this kind of management. With over a third of the world's food now requiring irrigation for production, the productivity increase in the global food supply has depended more and more on the expansion of irrigation schemes in recent decades. The overall economic viability of traditional agricultural systems is being challenged by market-based global competition in agricultural products, which calls for the creation of new, flexible production systems.

Key words:GPS, GIS, precision agriculture, remote sensing, technology and techniques.

1. INTRODUCTION

When compared to conventional cultivation methods, precision farming increases average yields by precisely calculating the amount of inputs used [1]. Thus, it is a comprehensive system created to maximize production through the application of essential information, technology, and management components in order to boost output, enhance product quality, optimize crop chemical use, conserve energy, and safeguard the environment [2].Precision farming is therefore a compelling idea, and its principles naturally raise the expectation that farming inputs can be used more efficiently, improving profits and producing less that harms the environment[3].The technological advancements in precision farming today can supply the means for tomorrow's environmentally sustainable agriculture. Precision farming offers significant yield improvements with low external input use, especially for small farmers in developing nations [4].

The world's population is growing at a geometric rate, which means that smart farming techniques are required to feed everyone[5]. Growing more crops and raising more cattle won't be enough to meet the needs of the growing population[6]. Precision Agriculture (PA) technology can help with this. To put it simply, it's the process of integrating technologies into traditional farming practices in order to become a smarter farmer [7]. The use of precision agriculture is anticipated to boost productivity, which will ultimately benefit farmers and society by increasing sustainability and boosting the economy [8]. It is a fundamental strategy in the agriculture industry that connects economic and environmental interests [9]. The Global Positioning System (GPS), mobile devices, robotics, driverless tractors, Internet of Things, sensors, variable rate seeding, weather modeling, unmanned aerial vehicles (UAVs), etc. are some of the technologies integrated with precision agriculture [10]. By incorporating these technologies, farming methods have become more efficient, the global food crisis can be controlled, crop and animal health can be monitored to increase yield, and smarter ways to grow food can be developed to control land use [11]. The weather, crop conditions, irrigation testing, and boundary of field remote sensing are all included in the data collection process[12]. In the analysis phase, the amount of variability, its potential causes, the degree to which soil and crop characteristics are measured, and the degree to which variations impact crop yield and crop quality are all determined[13]. During the management and decision-making phase, we determine whether or not variability can be changed, how to change yield and quality while reducing input, and how to put these changes into practice[14]. We put the decisions into practice during the farming phase, which is the fourth phase[15]. This paper provides an overview of the latest techniques in precision agriculture, including crop management, pest and disease management, soil and irrigation management, livestock farming, and the challenges associated with it[16]. The techniques are based on artificial intelligence and image processing.

2. NEED OF PRECISION AGRICULTURE

The world food system is currently facing enormous challenges, and these will only get worse over the next forty years. With today's knowledge and technologies, a lot can be accomplished quickly with enough effort and money[17]. However, facing the challenges of the future will call for even more drastic adjustments to the food system as well as funding for research to produce fresh answers to original issues. Major concerns in agricultural growth and development now include the decline in overall productivity, the depletion and degradation of natural resources, stagnating farm incomes, a lack of an eco-regional approach, declining and fragmented land holdings, trade liberalization on agriculture, limited employment opportunities in the non-farm sector, and global climatic variation[18]. Consequently, it is believed that utilizing recently developed technologies will be essential to raising agricultural productivity in the future[19]. A precision farming approach takes into account site-specific differences within fields and modifies management actions accordingly, as opposed to managing an entire field based upon some hypothetical average condition that might not exist anywhere in the field. Most farmers are aware that the yields in their fields vary depending on the terrain[20].These differences can be linked to environmental factors, soil characteristics, and/or management techniques. Large sizes and yearly changes in the farm area's leasing arrangements make it challenging to maintain the current level of field knowledge[21]. Thus, all of the farmland must be split up into tiny farms that are worth no more than 50 cents each. The collection and analysis of data can be made simpler and more automated with precision agriculture[22]. It makes it possible to swiftly and locally apply management decisions on smaller portions of larger fields.

3.TOOLSANDEQUIPMENT

3.1Globalpositioningsystem (GPS)

With an accuracy of between 100 and 0.01 meters, GPS is a navigation system that uses a network of satellites to record positional data (latitude, longitude, and elevation) [23]. Farmers can use GPS to pinpoint the precise location of field data, including the type of soil, the presence of pests, weed invasion, water holes, boundaries, and obstacles. With an antenna, receiver, and light or sound guiding panel (DGPS), there is an automatic controlling system[24]. GPS receivers can determine their position thanks to signals that GPS satellites broadcast. Based on performance criteria and past input applications, the system enables farmers to accurately locate fields so that inputs (seeds, fertilizers, pesticides, herbicides, and irrigation water) can be applied to a specific field [25].

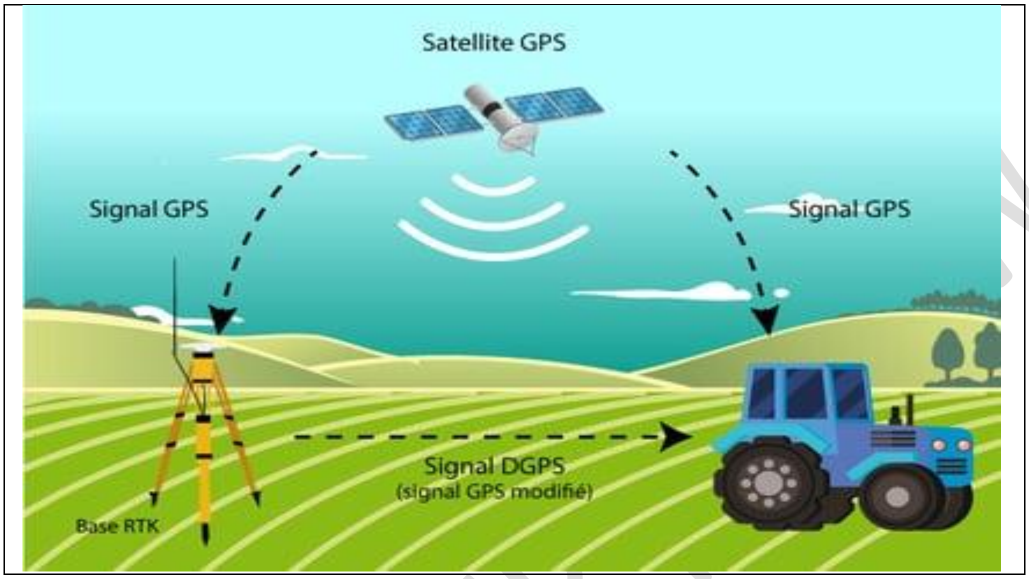

Fig 1: Sensor technologies in agriculture

3.2Sensor technologies

Many technologies are used to measure different aspects of life, including temperature, texture, structure, physical character, vapor, air, humidity, vegetation, and nutrient level. These technologies include electromagnetic, conductivity, photoelectricity, and ultrasonic sound[26]. Data from remote sensing are used to identify pests and weeds, track drought, and assess soil and lant conditions, as well as to differentiate between different crop species. Sensors make it possible to gather vast amounts of data without the need for laboratory analysis [27].

3.3Geographic information system (GIS)

In order to facilitate the collection, storing, retrieval, and analysis of feature attributes and location data for the purpose of producing maps, this system is composed of hardware, software, and procedures[28]. GIS connects data in a single location so that it can be expanded upon as needed. In contrast to traditional maps, computerized GIS maps are more detailed and include multiple layers of data (e.g. yield, soil survey maps, rainfall, crops, soil nutrient levels and pests). Although GIS is a type of computerized map, its true function is the analysis of characters and geography through the use of statistics and spatial methods[29]. Information on field topography, soil types, surface and subsurface drainage, irrigation, chemical application rates, soil testing, and crop yield can all be found in a farming GIS database. After analysis, this data is used to comprehend the connections among the different factors influencing a crop at a particular location [30]. By combining and modifying data layers to create an analysis of management scenarios, the GIS can be used for more than just storing and displaying data; it can also be used to assess current and alternative management[31].

3.4 Grid soil sampling and variable-rate fertilizer (VRT) application

Automatic in nature, variable-rate technologies (VRT) can be used in a wide range of agricultural applications. Using a soil map to identify the type of soil, VRT systems determine how quickly farm inputs are delivered[32]. Processes like seeding, fertilizer and pesticide application, herbicide selection and application at a variable rate in the right place at the right time can all be controlled with information extrapolated from the GIS. In the US, VRT is conceivably the most popular PFS technology [33]. The same principles of soil sampling are applied to grid soil sampling, but the level of sampling intensity is increased. Data mapping is made possible by the location information included in soil sample collections that follow a systematic grid[34].An application map, or need map, is the end result of grid soil sampling. Samples can be taken from multiple fields within the same zone if they fall into the same range of yield, soil color, etc.[35]. In the laboratory, grid soil samples are analyzed, and each soil sample's crop nutrient requirements are interpreted. The complete set of soil samples is then used to plot the fertilizer application map. On a variable-rate fertilizer spreader, a computer is installed and loaded with the application map[36]. According to the application map, the computer directs a product-delivery controller that modifies the quantity and/or type of fertilizer product using the application map and a GPS receiver [37, 38].

3.5 Cropmanagement

Farmers can gain a better understanding of the topography and soil condition variations that affect crop performance in the field by using satellite data[39]. Therefore, in order to maximize yield and efficiency, farmers can carefully control production factors like seeds, fertilizers, pesticides, herbicides, and water control. In order to forecast the tea yield in a tea farm using the energy input, Soheili-Fard and Salvatian [40] employed artificial neural networks to identify the energy inputs in a tea farm. Field manipulators and robots for agriculture have become essential components of many facets of smart farming [41]. The robot sweeper was designed to gather pepper fruit [42]. It uses its image sensor, which has been trained with deep learning algorithms, to detect ripe fruits. It then locates the fruit by following the path that is closest to the location [43]. A tool for measuring the continuous growth of a fruit's or plant's stem's perimeter is the optoelectronic reflex sensor and microcontroller board [44].

3.6 Soil and plant sensors

Precision agriculture technology heavily relies on sensor technology, which has been reported to be able to provide information on plant fertility and water status as well as soil properties. A thorough inventory of available sensors as well as features that should be included in any future sensor development projects [45].A widely used method for characterizing soil variability is to survey the field using sensors measuring soil apparent electrical conductivity (ECa), which continuously gather data when pulled over the field surface[46]. Since ECa is sensitive to variations in salinity and soil texture, these sensors offer a great starting point for implementing site-specific management.The data collected by these sensors is often transmitted to a central system, where it can be analyzed to identify trends, assess crop health, and enhance overall farm efficiency[47]. By facilitating data-driven decision-making, soil and plant sensors contribute to sustainable agriculture practices, resource conservation, and increased productivity[48].

3.7 Rate controllers

Rate controllers are tools used to regulate the rate at which chemical inputs, like liquid or granular pesticides and fertilizers, are delivered[49]. These rate controllers make delivery adjustments in real-time to apply a target rate by keeping an eye on the tractor/sprayer's speed as it crosses the field, as well as the material's flow rate and pressure, if it's liquid. Rate controllers are widely used as standalone systems and have been around for a while[50].

3.8 Precisionirrigationinpressurizedsystems

New innovations that use GPS-based controllers to regulate the motion of irrigation machines are now available for commercial use in sprinkler irrigation[51]. Apart from motion control, efforts are underway to develop wireless communication and sensor technologies that can monitor soil and ambient conditions, as well as irrigation machine operation parameters like flow and pressure, with the goal of improving crop utilization of water and application efficiency[52]. Although these technologies have a lot of promise, more work needs to be done before they can be bought commercially.

3.9 Software

Using software to perform a variety of tasks, including display-controller interfacing, information layer mapping, pre- and post-processing data analysis and interpretation, farm accounting of inputs per field, and many more, will often be necessary when implementing precision agriculture technologies[53]. The most popular ones are those that create maps (such as those for soil, yield, or chemicals); filter data collected; create maps with variable rate applications (such as those for chemicals, fertilizer, or lime); overlay different maps; and provide advanced geostatistical features[54].

To meet the demands of contemporary, information-intensive farming systems, all of these options are excellent choices for managing farms through precision agriculture and maintaining records. A small number of businesses with global operations offer integrated software packages that include tools for statistical analysis, record keeping, and the creation of various map types[55]. In addition to yield meters, machinery manufacturers also provide software for creating yield maps, and fertilizer manufacturers offer software for creating maps with variable rate applications [56]. While some of the packages are relatively expensive and difficult for farmers to use, others are much simpler and have fewer options. The farmer can use a variety of options and the packages are more user-friendly[57]. Data transfer issues still exist, though, particularly between farmers and between farmers, cooperatives, and consultants. It can be challenging to overlay maps, particularly soil and yield maps[58].

3.10 Yield monitor

Yield monitors are made up of multiple parts. They usually consist of a number of sensors and additional parts, such as a data storage device, a user interface (keypad and display), and a task computer housed in the combine cab that manages how these parts integrate and work together[59]. The separator speed, ground speed, mass or volume of grain flow, as well as grain, are all measured by the sensors. When it comes to grains, yield is measured continuously by observing the force of the grain flow as it strikes a sensible plate in the combine's clean grain elevator[60]. A new type of mass flow sensor measures the amount of energy that returns after impacting the stream of seeds going through the chutes. It operates on the basis of microwave energy beams[61]. GPS receivers are used in all yield monitors to track the location of yield data and produce yield maps. Devices used in forage crops to monitor weight, moisture content, and other data on a per-bale basis are examples of additional yield monitoring systems [62].

3.11 Precision farming on arable land

The most popular and sophisticated farming method is the application of PA techniques on arable land [63]. CTF is a whole farm approach designed to minimize costs associated with standard methods by preventing heavy machinery from inadvertently damaging crops and compacting soil. Using GNSS technology and decision support systems, controlled traffic methods limit all field vehicles to the minimum area of permanent traffic lanes[64].Optimizing the application of fertilizers, starting with the three primary nutrients of nitrogen, phosphorus, and potassium, is another significant use of precision agriculture on arable land[65]. These fertilizers are evenly spread across fields at specific times of the year in conventional farming. This causes some situations to have over application while others have underapplication[66].Over-application of fertilizer causes nitrogen and phosphorus to leak from the field into surface and ground waters, as well as other parts of the field where they are not wanted, which directly contributes to environmental costs[67].

Fertilizers can be applied more precisely and optimally in terms of both location and timing when using precision agriculture techniques. The Variable Rate Application (VRA) system, which combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs, is the technology that gives farmers control over the amount of inputs in arable lands. VRs are determined using pre-measured data, such as that from machine-mounted sensors or remote sensing[68].

3.12Precision farming within the fruits & vegetables and viticulture sectors

With automation systems recording parameters related to product quality, growers are now able to grade products and monitor food safety and quality in fruit and vegetable farming thanks to the recent and rapid adoption of machine vision methods. These consist of sugar content, acidity, shape, size, color, external flaws, and other internal characteristics [69]. In addition, full fruit and vegetable processing methods may be provided by tracking field operations like the use of fertilizers and the chemicals sprayed.In order to help producers use precision agriculture to obtain higher quality and larger yields with optimized inputs, as well as to help consumers manage risk and ensure food traceability, this information may be made available[70]. A number of novel techniques have been developed recently that consider not only the crop's condition but also the environment and the tree's actual size [71]. Precision Viticulture, or PV, is a relatively new term for the development and application of PA technologies and methodologies in viticulture, compared to arable land. However, a number of research projects are already underway in regions of the world that produce wine due to the high value of the crop and the significance of quality [72, 73]. Maps showing grape quality and yield are crucial for preventing the mixing of grapes with varying potential wine qualities during harvest. The parcels showing a high degree of yield variation are the ones with the most PV potential. When compared to uniform management, a high degree of variation will result in higher VRA of inputs and, consequently, greater economic and environmental benefit[74].

3.13Precision livestock farming (PLF)

The management of livestock production through the application of precision agriculture technology and principles is known as precision livestock farming, or PLF for short. Animal growth, milk and egg production, disease detection and monitoring, and aspects of animal behavior and the physical environment, such as the thermal microenvironment and gaseous pollutant emissions, are among the processes that are appropriate for the precision livestock farming approach[75]. Systems include feed pushers, robotic cleaners, robotic feeding systems, weighing systems, robotic cleaners, and imaging systems that help stockmen avoid direct contact with animals[76]. Other systems include robotic cleaners and milk monitoring that checks fat and microbial levels, helping to indicate potential infections. There are new systems available that monitor feed and water consumption and can be used to detect infections early[77]. Other advancements include the tracking of the expanding herd, where real-time growth measurement is crucial to give producers information on feed conversion and growth rates. Pigs coughing more frequently is detected by acoustic sensors as a sign of a respiratory infection. These days, birthing and fertility alerts are provided by other sensors[78].

A vaginal thermometer sends an SMS to the farmer, tracking temperature, time to delivery, and rupture of the waters. In addition, an oestrus indicator and fertilization readiness indicator are detected by parameters recorded by a sensor attached to an animal's collar. The farmer can then schedule insemination thanks to an SMS message[79].

3.14On-line resources for precision agriculture

On the internet, there is a plethora of information about new technologies for agricultural production. This medium is used by the majority of producers of agricultural machinery, GPS units, sensors, and other PA technologies to update growers on new offerings, technical details, troubleshooting guides, software updates, and other services[80].

4.CHALLENGES OF PRECISION AGRICULTURE TECHNOLOGY

Fakhruddin [16] lists the following 15 difficulties and problems with precision agriculture: The first is the compatibility of various standards. Different tools and technologies don't adhere to the same operational standards. The second is that the typical farmer faces a steep learning curve. The lack of a reliable internet connection in rural areas is the third[81]. Since it is impossible to track and manage every data point on a daily and weekly basis throughout the entire growing season, the fourth challenge is making sense of big data. The fifth is ignorance of the various roles that farming plays[82]. When you apply a specific amount of fertilizer to a given soil, it implies that another soil that contains the same plant requires the same amount of fertilizer due to the soil's nutrient content. The size of the management zones is the sixth. When dividing the management zones according to the requirement for soil sampling, there aren't many references available. Entry barriers for new firms make up the seventh. Since precision agriculture is still in its infancy, not many businesses are using this technology. Low competition may make it difficult for new businesses to enter the market. The eighth is a configuration issue and a lack of scalability. Small farms should employ the same methods as commercial ones. That isn't the case, though. The risk of energy depletion is the ninth. Although the goal of PA should be energy conservation, the use of various technologies, including data hubs and centers, sensors, and other devices, results in significant energy consumption over time. The tenth is that it makes indoor farming more difficult. The majority of PA techniques are best suited for outdoor farming. The eleventh involves damages from a technical malfunction. Crop failure or a low yield could result from a malfunction in the devices. E-waste is increasing in the twelfth. Older devices become outdated due to regular updates; disposing of them in a landfill eventually pollutes the land. The loss of manual labor ranks thirteenth. The people who were needed for that work will no longer be needed since technology has replaced them with PA, which lessens the need for a lot of manual labor. The security factor is number fourteen. Security issues will arise, just like in the real world, as long as a system is linked to the internet. Finally, the advantages are not instantaneous. The benefits of PA are not instantaneous, like anything good in life, so farmers are initially reluctant to take a financial risk. Robotics could lessen human-animal interaction in livestock farming, making it impossible for farmers to get to know their animals as they would in a traditional. The average farmer's mental workload increases when they use technology. Precision agriculture may face difficulties if the farm is situated in an area without adequate national infrastructure, such as power.

5. DISCUSSION AND CONCLUSION

Precision agriculture technology and techniques represent a significant evolution in the way we approach farming, with the potential to revolutionize the agricultural sector. This approach involves the integration of advanced technologies, such as GPS, sensors, drones, and data analytics, to optimize various aspects of farming operations. The use of these technologies enables farmers to make data-driven decisions, leading to increased efficiency, reduced resource wastage, and improved yields.One key aspect of precision agriculture is the ability to collect and analyze data in real-time. This allows farmers to monitor crop health, soil conditions, and weather patterns, enabling timely interventions to address potential issues. The use of precision agriculture techniques also facilitates the implementation of variable rate technology, wherein inputs like water, fertilizers, and pesticides are applied at variable rates across a field based on specific needs. This not only optimizes resource utilization but also contributes to environmental sustainability.

The evolution of precision agriculture is promising, and its future prospects are even more exciting. As technology continues to advance, we can anticipate further integration of artificial intelligence, machine learning, and automation in precision agriculture systems. These advancements hold the potential to further enhance decision-making processes, reduce labor requirements, and increase overall productivity. Precision agriculture is a transformative force in the agricultural industry. The current integration of technology and techniques is already providing tangible benefits to farmers, and the ongoing evolution promises even greater efficiency and sustainability. As we look ahead, the continued development and adoption of precision agriculture will play a crucial role in meeting the challenges of feeding a growing global population while ensuring responsible resource management.

REFERENCES

1. Shibusawa S.(2002) Precision farming approaches to small farm agriculture. *Agro-Chemicals* Report. 2(4):13-20.
2. Fountas S, Ess D, Sorensen CG, Hawkins S, Pedersen HH, Blackmore S, Deboer LJ, (2004). Farmer experience with PrecisionAgriculture in Denmark and US Eastern Corn Belt. *Precision Agriculture.*
3. Mcconnell M, Burger WL. Precision agriculture technology: Quail Forever; 2017. Available:https://www.quailforever.org
4. European Environment Agency. Data collection on precision farming; 2018. Retrieved January 20 2019. Available:https://www.eea.europa.eu/themes/agriculture/background-note-data- collection-on/download.
5. Ullah A, Ahmad J, Muhammad K, Young Lee M, Kang B, Beom Soo O, Baik SW.(2017). A Survey on precision agriculture: technologiesand challenges. 3rd *International Conference on Next Generation Computing* (ICNGC2017b)
6. Antonio da Silva JuniorC.NanniMR, Teodoro PE, Guilherme FCS, Guerreiro de Lima M, EriM.(2016). Comparison of mapping soybean areas in Brazil through perceptron neural networks and vegetationindices. *African Journal of Agricultural Research*. 11(43):4413-4424.
7. Lang L. (1992). GPS, GIS, remote sensing: An overview. *Earth Observation Magazine*. 23-26.
8. Batte MT, Van Buren FN. Precision farming – Factor influencingproductivity In Northern Ohio Crops Day meeting, Wood County, Ohio, 21 Jan. 1999.
9. Chen F, Kissel DE, Clark R, West LT, Rickman D, Luval J, Adkin W. (1997). Determining surface soil clay concentration at a field scale for precision agriculture, *University of Georgia*, Huntsville.
10. Trimble. 2005. Precision agriculture. Available at: www.trimble.com.
11. Berntsen J, Thomsen A, Schelde K, Hansen OM, Knudsen L, Broge N, Hougaard H, Horfarter R. (2006). Algorithms for sensor-based redistribution of nitrogen fertilizer in winter wheat. *Precision Agriculture*. 7: 65-83.
12. Ferguson R., Dobermann, A. and Schepers, J. (2007). Precision agriculture: site-specific nitrogen management for irrigated corn. University of Nebraska Lincoln Extension. Bulletin.1-7.
13. Adamchuk VI, Hummel JW, Morgan MT, Upadhyaya SK. (2004). On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture.* 44: 71-91.

14. Hakkim, V. A., Joseph, E. A., Gokul, A. A., & Mufeedha, K. (2016). Precision farming: the future of Indian agriculture. *Journal of Applied Biology and Biotechnology*, *4*(6), 068-072.
15. Bowman K. (2008). Economic and environmental analysis of converting to controlled traffic farming, In 6th *Australian Controlled Traffic Farming Conference*. 61-68.
16. Fakhruddin H. Precision agriculture: Top 15 challenges and issues; 2017.
17. Retrieved Feb 1, (2019). Available:<https://teks.co.in/site/blog/precis ion-agriculture-top-15-challenges-and- issues.
18. Njoroge JB, Ninomiya K, Kondo N. (2002). Automated fruit grading system using image processing, In Proceedings of the *41st SICE Annual Conference*. 1346-1351.
19. Doruchowski G, Balsari P, Zande JC. (2009). Precise spray application in fruit growing according to crop health status, target characteristics and environmental circumstances; Proc. of 8th*Fruit, Nut and Vegetable Production Engineering Symposium*, Concepcion-Chile. 494-502.
20. Ojeda H, Carrillo N, Deis L. (2005). Precision viticulture and water status II: Quantitative and qualitative performance of different within field zones, defined from water potential mapping, in XIV *International GESCO Viticulture Congress, Geisenheim,* Germany, 741-748.
21. Ferreiro-Arman M, Da Costa JP, Homayouni S. (2006). Hyperspectral image analysis for precision viticulture, In Image Analysis and Recognition, *Springer Berlin Heidelberg*. 730-741.
22. Soheili-Fard F, Salvatian SB. (2015). Forecasting of tea yield based on energy inputs using artificialneural networks (A case study: Guilan province of Iran). *Biological Forum*. 7(1):1432-1438.
23. Shamshiri RR, Weltzien C, Hameed IA, Yule IJ, Grift TE, Balasundram SK, Lenka P, Ahmad D, Chowdhary G. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal Agriculture & Biological Engineering*. 11(4):1-4.
24. Sweeper Sweet Pepper harvesting robot. Retrieved January 20, 2019.Available:http://www.sweeper-robot.eu/.. 2018
25. Bannerjee G, Sarkar U, Das S, Ghosh I. (2018). Artificial in telligence in agriculture: A literature survey. *International Journal of Scientific Research in Computer Science Applications and Management Studies. 7*(3), 1-6.
26. Boissard P, Martin V, Moisan S. (2010). A cognitive vision approach to early pest detectionin greenhouse crops. *Computers and Electronics in Agriculture, Elsevier*. 6(2):81-93.
27. Sarma SK, Singh KR, Singh A. (2010). An expert system for diagnosis of diseases in rice plant.*InternationalJournalofArtificialIntelligence*.1(1):26-31.
28. Cha´vez P, Yarleque C, Loayza H, MaresV, Hancco P, Priou S, Marı´a del Pilar M,PosadasA,Zorogastu´aP,FlexasJ,QuirozR.(2011).

Detectionofbacterialwiltinfectioncausedby Ralstoniasolanacearuminpotato(*Solanumtuberosum* L.) through multifractal analysisapplied to remotely sensed data. *Springer:PrecisionAgric*.13:236–255.

29. Gowrishankar V, Venkatachalam K.(2018). ICTbased precision agriculture using Agribot.*GlobalResearchand DevelopmentJournalforEngineering*.3(5):2455-5703.
30. Massaro A, Meuli G, Savino N, Galiano N.(2018). AprecisionagricultureDSSbasedonsensorthresholdmanagementforirrigationfield.*Signal&ImageProcessing:AnInternationalJournal(SIPIJ)*.9(6):40-58.
31. Frits KV, Gaitan-Cremaschi D, Fountas S,Kempernaar C. (2017).Can precision agricultureincreasethe profitabilityand sustainabilityof the production of potatoes and olives?*Sustainability*.9(10):1863.
32. Norton T. Precision livestock farming: Useoftechnologiestooptimizeanimalproduction;2017.
33. Retrieved January 21 2019.Available:http://www.livestockforum.com/documents/5645614/c57271f2-a91a-42c0-989a-661e483d4ae9.
34. Banhazi T, Lehr H, Black J, Crabtree H,SchofieldP, Tscharke M,BerckmansD. (2012).Precisionlivestock farming: Aninternationalreviewofscientificandcommercial aspects. *International JournalAgriculture&BiologicalEngineering*(3):1-10.
35. Hostiou N, Fagonn J, Chauvat S, Turlot A.,Kling-EveillardF,BoivinX,Allain C. (2017).Impactofprecisionlivestockfarmingonworkandhuman-animalinteractionsondairyfarms.Areview.*Biotechnology.Agron.Soc. Environ*. 21(4):268-275.
36. Berckmans D. (2014).Precision livestock farmingtechnologiesforwelfaremanagementinintensivelivestocksystems.*Rev.Sci.Tech.off.Int.Epiz*.33(1):189-196.
37. Eastwood C, Klerkx L, Ayre M, Rue B. (2017). Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural & Environmental Ethics*. 1:28.
38. Adrian Anne, Norwood Shannon, Mask Paul. (2005). Producers’ perceptions and attitudes toward precision agriculture technologies. *Computers and Electronics in Agriculture*. 48:256-271.
39. Mulla DJ. (2013). Twenty-five years of remote sensing in precision agriculture: key advances and remaining knowledge gaps. *Biosyst. Eng*. 114(4):358-371.
40. National Research Council. Precision agriculture in the 21st century. *Washington DC: National Academy Press*; 1997.
41. Bhattacharyay D, Maitra S, Pine S, Shankar T, Pedda Ghouse Peera SK. (2020). Future of precision agriculture in India. *Protected Cultivation and Smart Agriculture.* 289-299.

42. Ahmad L, Mahdi SS. Components of precision agriculture. In: *Satellite Farming. Springer Cham*; 2018. DOI:https://doi.org/10.1007/978-3-030-03448-1_2.
43. Robert P, Rust R, Larson W. Site specific management for agricultural systems. Proceedings of the *2nd International Conference on Precision Agriculture Madison WI*. ASA/ CSSA/SSSA; 1994.
44. Shearer SA, Fulton JP, McNeill SG, Higgins SF. (1999). Elements of precision agriculture: basics of yield monitor installation and operation. *Cooperative Extension Service University of Kentucky College of Agriculture.*
45. Price M. Mastering ArcGIS. New York: *McGraw-Hill.* 2006;10200(2).
46. Bharteey P, Deka Bipul, Dutta M, Parit Rajat Kumar, Maurya Prakhar. Remote sensing application in precision agriculture: A review; 2019.
47. Hakkim V, Joseph E, Gokul A, Mufeedha K. (2016). Precision farming: The future of Indian Agriculture. *Journal of Applied Biology and Biotechnology*.068-072. DOI: 10.7324/jabb.2016.40609
48. Grisso R, Alley M, Thomason W, Holshouser D, Roberson GT. Precision farming tools: Variable-rate application. *Virginia Cooperative Extension College of Agriculture and Life Sciences Virginia Polytechnic Institute and State University;* 2011.
49. Wójtowicz M, Wójtowicz A, Piekarczyk J. (2016). Application of remote sensing methods in Agriculture. *Commun. Biometry Crop Sci.* 11(1):31-50.
50. Whitley KM, Davenport JR, Manley SR. Difference in nitrate leaching under variable and conventional nitrogen fertilizer management in irrigated potato systems. Proceedings of Fifth *International Conference on Precision Agriculture* (CD) July 16 2000. Bloomington MN USA; 2000.
51. Schumacher JA, Lindstrom M, Schumacher T. An analysis of tillage and water erosion over a complex landscape. Proceedings of Fifth *International Conference on Precision Agriculture (CD).* Bloomington MN USA; 2000.
52. Sigrimis N, Hashimoto Y, Munack A, De Baerdemaeker J. Prospects in agricultural engineering in the information age: Technological developments for the producer and the consumer. *CIGR e-journal;* 1999.
53. Stafford JV. (2000). Implementing precision agriculture in the 21st century. *Journal of Agricultural Engineering Research.* 76(3):267-275.
54. Young SL, Meyer GE, Woldt WE. (2014). Future directions for automated weed management in precision agriculture. In: Young S, Pierce F. (eds) Automation: The Future of Weed Control in Cropping Systems. *Springer Dordrecht;* DOI:https://doi.org/10.1007/978-94-007-7512-1_15.
55. Shadrin D, Menshchikov A, Ermilov D, Somov A. (2019). Designing future precision agriculture: detection of seeds germination using artificial intelligence on a low-power embedded system. *IEEE Sensors Journal.* 19:11573-11582.

56. Gyarmati G, Mizik T. (2020). The present and future of the precision agriculture. *IEEE 15th International Conference of System of Systems Engineering (SoSE).* 593-596 DOI: 10.1109/SoSE50414.2020.9130481.
57. Boissard, P., Martin, V. & Moisan, S. (2016). A cognitive vision approach to early pest detection in greenhouse crops. *Journal of Computers and Electronics in Agriculture.* 2(3). pp. 81-93.
58. Cancela, J. Fandango, M. Rey, B. & Martinez, E. (2015) Automatic irrigation system based on dual crop coefficient, soil and plant water status for precision agriculture. *Journal of Agricultural Engineering Research.* 12 (4). pp. 150–157.
59. Díaz, S. Pérez, J. Mateos, A. Marinescu, M. Guerra, B. (2012) A novel methodology for the monitoring of Precision agricultural production process based on wireless sensor networks. *International Journal of Science, Engineering and Technology Research (IJSETR).* 7(6).pp. 252–265
60. Faical, B. Larson, J. Roberts, B. Kennedy, G. (2016) An adaptive approach for UAV-based pesticide spraying in dynamic environments. *Journal of Computers and Electronics in Agriculture.* 13 (8).pp. 210-223.
61. Halimi, K., & Moussa, T., (2015) A Guelph Intelligent Greenhouse Automation System (GIGAS) for greenhouse based precision agriculture. *In IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 12th – 14th May. 25(6): pp. 686-693
62. Irmak, A. Jones, J. Batchelor, W. Irmak, S. Boote, K. (2015) Artificial neural network model as a data analysis tool in precision farming. *International Journal of Precision Agriculture*. 9 (6).pp.227–237.
63. Jones, D. & Barnes, M. (2014) Fuzzy composite programming to combine remote sensing and crop models for decision support in precision crop management. *Journal of Agricultural Systems*. 6 (2). pp. 137–158.
64. Karimi, Y. Prasher, O. Patel, M. & Kim, H. (2014) Application of support vector machine technology for weed and nitrogen stress detection in Precision Agriculture. *Journal of Computers and Electronics in Agriculture*. 51 (1–2). Pp.99–109.
65. Kim, Y. Yang, Y. Kang, W. & Kim, D. (2013) Design of beacon based wireless sensor network for precision agricultural monitoring systems. *Journal of Agricultural Engineering Research.* 12 (6). pp. 134–138.
66. Lamorski, K. Pachepsky, Y. Slawinski, C. & Walczak, T. (2013) Using support vector machines to develop functions for water retention of soils. *Journal of Soil Science Society of America*. 4(6). Pp.1243–1247.
67. Lee, K. Zhang, N. & Das, S. (2016) A comparative research study of classification algorithms and their application in yield prediction in precision farming systems. *International Journal of Science, Engineering and Technology Research (IJSETR).* 5 (2). pp. 472-475.
68. Navarro, H., Torres-Sánchez, R., Soto-Valles, F., Albaladejo, C., Riquelme, J., Domingo, R., (2015) Wireless sensors architecture for efficient irrigation water management. In

Proceedings of the Fourth *International Conference on Precision Agriculture*. Madison, Wisconsin. 12th June 2015. pp. 1089–1100.

69. Pahuja, R. Verma, H. & Uddin, A. (2015). A wireless sensor network for greenhouse climate control. *Journal of Agricultural Engineering Research.* 4(2). pp. 49-58.
70. Pydipati, Y. Burks, F. Lee, S. (2015) Statistical and neural network classifiers for citrus disease detection using machine vision. *Transactions of the ASAE.* 8 (5). Pp.320–324.
71. Rani, M., & Kamalesh, S., (2014). Energy efficient fault tolerant topology scheme for precision agriculture using wireless sensor network. *In Proceedings of the International Conference on Advanced Communication Control and Computing Technologies* (ICACCCT). Ramanathapuram, India, 8–10th May 2014. pp. 1208–1211.
72. Ratasuk, R., Vejlgaard, B., Mangalvedhe, N., Ghosh, A., (2016). IoT system for M2M Wireless sensor communication for smart farming. In Proceedings of the *IEEE Wireless Communications and Networking Conference*. Doha, Qatar, 3–6 April 2016. pp. 1–5.
73. Sabri, N. Aljunid, S. Ahmad, R. Kamaruddin, R. & Salim, M. (2014). Smart prolong fuzzy wireless sensor-actor network for smart agricultural application. *International Journal of Science, Engineering and Technology Research (IJSETR).* 6 (1). pp. 172-175.
74. Sai, Z. Fan, Y. Yuliang, T. Lei, X. & Yifong, Z. (2016). Optimized algorithm of sensor node deployment for intelligent agricultural monitoring. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*. 3(2).pp. 76–86.
75. Srbinovska, M. Gavrovski, C. Dimcev, V. Krkoleva, A. & Borozan, V. (2015). Environmental parameters monitoring in precision agriculture using wireless sensor networks. *International Journal of Precision Agriculture.* 5 (3). pp. 297–30.
76. Tang, L. Tian, L. & Steward, L. (2014). Color image segmentation with genetic algorithm for in-field weed sensing. *Transactions of the ASAE.* 43 (4). pp. 1019–1027.
77. Tan, Y. Panda, K. (2013). Review of energy harvesting technologies for sustainable wireless sensor network for precision agriculture. *International Journal of Advanced Computer Technology* (IJACT). 8 (9). Pp. 51 – 55.
78. Thalheimer, M. & Rakesh, K. (2015). A new optoelectronic sensor for monitoring fruit or stem radial growth. *Journal of Computers and Electronics in Agriculture.* 12(3). pp. 149-153.
79. Tuna, G. & Gungor, V. (2015). Sensor network for smart monitoring of maize crop for precision agriculture. *Wood head publishing*: Swanston, UK.
80. Twarakavi, C. Simunek, J. & Schaap, G. (2015). Development of functions for estimation of soil hydraulic parameters using support vector machines for Precision *Agriculture. America Journal Soil Science Society*. 73. pp.1443–1452.
81. Yang, C. Prasher, O. Whalen, J. & Goel, P. (2014). Development of an image processing system and a fuzzy algorithm for site specific herbicide applications in Precision Agriculture. *Journal of Computers and Electronics in Agriculture*. 3(5). 112 – 116.

82. Yash, S., Harsh, G., Hamish, D., Koli, A., Divya, K., & Umang, G., (2015). Comparison of Self Organizing Maps and Sammon’s mapping on agricultural datasets for precision agriculture. *In International Conference on Innovations in Information, Embedded and Communication Systems* (ICIIECS). 22(14). pp. 184-190.