Review Article

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Scope and opportunities of precision agriculture on arid horticulture-A review

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ABSTRACT

Precision agriculture (PA) is the use of mechatronics to control the fields' temporal and spatial variability. Numerous elements, including appropriate planting, weeding and interculture, irrigation, insect and pest attacks, and harvesting methods, influence the output and quality of horticultural commodities. A proactive strategy that lowers some of the risks associated with these frequent horticultural and agricultural variables is precision agriculture. Producing high-quality, highly productive fruits in the fields requires the development of an exact and accurate autonomous production system, which frequently largely depends on human involvement. In arid regions, where water and arable land are limited, precision agriculture holds significant promise for enhancing the productivity and sustainability of fruit crops. Mechanization, precision farming, and agricultural transformation are three of these important technologies. Among these, precision and mechanical engineering are the foundations of a more all-encompassing system that makes use of automated technology. Accurate farming management is based on recognizing and adjusting to in-field variation. Some of the newest technologies used to assess and analyze agricultural and agricultural output disparities include robotic control systems for real-time weed detection and control, microcontroller-based variable rate herbicide/pesticide application systems, site-specific variable rate irrigation, wireless sensor network (WSN) enabled crop stress monitoring systems, RTK-GPS enabled seed planters or transplanters for geospatial mapping of row-crop plants/transplants, automated harvesting Sensors, satellites, aerial photography, Geographic Information Systems (GIS), and Global Positioning Systems (GPS).In order to manage water resources, choose the ideal harvesting site, balance fertilizer requirements, and forecast crop performance, sensor networks are crucial. In order to satisfy the requirements of certain regions and plants, accurate farming employs a set of extremely precise methods for technology users.

Introduction

The goal of precision farming (PF), a complete knowledge-based approach in farm management, is to maximize profits, preserve sustainability, and manage local and inter-sectoral variety through identification, analysis, and management.

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It helps to prevent unwanted habits in the plant, regardless of the local soil or environment (Swain and Sharma, 2014). Precision agriculture is the management of temporal and spatial diversity in the context of ICT (information, computers, and technology). Following an analysis of the spatial and temporal changes of field and plant areas, field regions with similar characteristics are called management areas. Improved management that optimizes profitability and reduces environmental impact can result from using the appropriate inputs in management areas. The concept of precision farming first appeared in the US in the 1980s. In order to detect, analyze, and manage the unique and temporary variability of agronomic parameters (soil, disease, water, nutrients, etc.) in a sustainable way with the least amount of adverse environmental impact, this technique improves agricultural management by leveraging satellite-based technologies and information technology (IT).

The Principle

As a matter of fact, orchard performance can be enhanced by modifying precision crop production technologies to provide fruit and fruit production with exact farming methods that minimize negative environmental effects while enhancing yields and quality.

The Need for Accurate Farming

The 1960s "Green Revolution" enabled our nation to meet its food production needs. From little over six million tons of wheat produced in 1947 to over 72 million tons gathered in 1999 by our farmers, the nation now ranks second in the world for wheat output. Grain yields have more than doubled during the last 50 years, and grain production has more than tripled. This is all due to high demand, which has increased the use of HYV, pesticides, fertilizer, irrigation, and agricultural Machinery.

Fatigue of the Green Revolution

Degradation of natural resources

Agricultural strategies that can assist produce more with existing land, water, and resources without causing harm to the environment or society must be implemented in order to turn this green transition into an evergreen one (Swaminathan, 2002). This objective can be accomplished by suggesting that the tailor's management techniques be determined by exact farming.

Basic steps in precision farming

The basic steps in precision farming are (i) Assessing variation, (ii) Managing variation, and (iii) Evaluation. The available technology offers site-specific agricultural recommendations.

Assessing variation: For precise farming, flexibility testing is a crucial first step. Clearly, man cannot control what he does not understand. Crop-specific materials and procedures that govern or affect crop performance change periodically. It is difficult for accurate agriculture to assess the variety of these elements and processes and to determine the precise time and locations of the various combinations that cause temporal and geographical variation in crop yields. Accurate farming makes use of widely accessible and extensively used geographic diversity assessment methodologies.
A significant portion of accurate agriculture lies in exploring biodiversity. Temporary diversity assessment methods are also available but simultaneousreporting of local and temporary variability is not uncommon. We need both local and temporary statistics. We can see the variety of crop yields in the area but we cannot predict the reasons for the variety. Plant development and growth throughout require monitoring, which is useless without transient variability. Therefore, in order to apply precise farming techniques, we require both space and time estimates. However, this is not unique to all crop yield-determining varieties or factors. Current forms of precision management are made easier by the fact that some variables are more frequently produced in space than in time.

Managing variation: Once the diversity has been adequately explored, farmers should use management recommendations to match agronomic measurements with existing conditions. Utilizing precise application control techniques, those are site-specific. Technology is something we can use extremely well. under site-specific diversity control. The GPS technology will make it easier and more cost-effective to administer the site and disclose its specs. We should be cautious while collecting soil and plant samples because we can use the domain link sample for management purposes. This prevents spoiling and leads to an efficient utilization of inputs, which is what we desire. Their potential and capacity to handle precision increase with the degree of reliance on a regulated geographical area. The degree of difficulty, however, grows as the transient component of local variability increases. The fact that fertilizing with phosphorus and potassium is particularly beneficial in controlling precision because of the minimal transient variations can be supported by applying this theory to soil fertility. In certain situations, it can be more challenging to precisely manage N because the temporal component of the variance may exceed its partial area.

Evaluation: The fact that the value of accurate agricultural profit analysis derives from data utilization rather than technology use is its most important component. The potential to improve environmental quality often justifies accurate farming. Potential environmental benefits are frequently mentioned, including less use of agrochemicals, high nutrient efficiency, improved efficiency of controlled inputs, and higher soil output as a result of deterioration. Agricultural principles and decision-making rules can make it work and increase productivity efficiency or other types of value that can make it more profitable. Technology can enable agricultural precision.

Precision agriculture techniques for arid horticulture applications

Remote sensing: It is the process of gathering data about an object, the earth, or the water without the sensor and the object being physically in contact. An alternative method is to use a recording device that is not physically connected to or close to the object or events being examined in order to measure or collect data on their location. To obtain accurate information from above without making physical touch, one can collect, process, and evaluate data using a remote sensor. Its high-resolution tracking of spatial changes over time offers significant promise for precise farming.

Principle: Depending on their chemical, physical, and other characteristics, different materials either emit or reflect varying amounts of energy at different wavelengths of the electric spectrum. For example, when rays strike red and green apples, they emit radiation in the form of an electromagnetic spectrum that contains some information about the substance. These radiations have highly specific properties and can determine the object's characteristics. The color, shape, and glowing pattern of the fruits in this instance, for example, allow us to distinguish between a red and a green apple. The same principle applies to distant hearing as well: when radiation hits an object, it emits a pattern of radiation that is detected by the senses.

Remote sensor applications

A remote sensor is a group of methods that use the gloss or light that plants and soils release to gather data in their natural habitat without having to come into contact with the thing. The PA employed bright light, either from the sun or artificial light, to determine the plant indices. The normalization difference vegetation index (NDVI), which is found in fruits with low chlorophyll and canopy imaging, is the most widely used agricultural index. A few more indications can be approximated and used to provide a good agreement with the chemically determined leaf chlorophyll (Richardson *et al*., 2002). Consequently, there is a substantial correlation between NDVI and crop strength and production, and occasionally quality. The pigment content of the xanthophyll cycle affects the photochemical reflectance index (PRI), a standard differential index that uses two bright bands (531 and 570 nm). For example, picture prevention and water stress in plants, PRI is utilized as an indicator of stress that offers an effective indicator (Weng *et al*., 2006). Usha and Singh recently analyzed remote sensors that use hyper- and multispectral techniques (2013).

In order to forecast citrus tree yield, Xujun *et al.* (2007) developed mathematical models based on canopy features derived from airborne hyperspectral data captured over three years utilizing nine air missions at the start of each growing season. The models' performance has been good, demonstrating their capacity to forecast orange yield several months ahead of harvest. Furthermore, Liakos *et al.* (2011) discovered a connection between the apple tree crop for two years in a row and the first season of NDVI.

In order to determine plant indication, in an olive orchard, Suarez *et al.* (2008) used an aerial hyperspectral camera and found a correlation between the PRI of similar plants pointing tops and leaf-level steady-state fluorescence. While chlorophyll fluorescence kinetic analysis is still a problem in automated measurements, chlorophyll fluorescence in stable conditions was utilized to assess chlorophyll and water content in order to generate a canopy map (Ac *et al*., 2015). Using data from a multispectral fluorescence imaging system, Hsiao *et al.* (2010) created a flexible fluorescence index to gauge the water stress levels of cabbage sprouts. In recent years, the use of UAS has also seen a sharp increase (Zhang and Kovacs, 2012), when applications to high value plants begin to appear already being run by companies that provide semi-commercial solutions.

Berni *et al.* (2009) mapped the canopy conductance and crop water stress index (CWSI) on olive trees using high-resolution imagery obtained with a UAS over a two-year period in order to estimate the water condition. Furthermore, for two years in a row, Cohen *et al.* (2012) measured the CWSI in palm trees in three drip-irrigated locations using an air-conditioned thermometer. A water-based mapping variation procedure that may be utilized for irrigation planning has been successfully developed by them. In order to identify water leaks, malfunctions in muskmelon drip irrigation, and inadequate watering rates, Clarke (1997) employed a hot airborne image in plants. These are only three arbitrary instances of how Jones (1992) has been applied and developed. A recent evaluation examined the use of hot photography for plant water quality analysis (Maes and Steppe, 2012).

Ultrasound, image-based image analysis, and light and vibration detection (LiDAR) are other sensors that have the

ability to detect remotely. An ultrasonic or laser scanner can be used to assess a tree's canopy in Florida orchards (Zaman and Salyani, 2004; Zaman *et al*., 2006). According to Walklate *et al.* (2002) and Mendez *et al.* (2014), this might be considered the first publication of horticultural accuracy and sophisticated commercial applications aimed at open and closed rivers. Consequently, canopy fluctuations in terms of spectrophotometric characteristics and shape can be analyzed using a remote sensor; nevertheless, precise measurements are required to gather data on product quality.
Geographic Information System (GIS)
It is a concept of precision farming. It is a computer database management system used to calculate, store, analyze and display location data in the form of a map. GIS is the key to extracting value from a variety of information. It is aptly named the brain forprecision farming.
It facilitates the organization and compilation of simulation models and GIS data (crop, soil, climate, field history, etc.). The engineering component of creating GPS-enabled gadgets offers extra support. In order to facilitate the integration, storing, retrieval, and analysis of feature and location data for the purpose of creating maps, this application integrates computer hardware, software, and procedures. GIS connects data to a specific location so that it may be extracted when needed. Computer-based GIS maps, as opposed to traditional maps, use a wide range of data sources, such as yield, rainfall, vegetation, soil nutrient levels, insects, and soil mapping. Although GIS is a sort of computer-generated map, its true function is character and location analysis using local statistics and techniques.
Field topography, soil types, water and groundwater flow, soil tests, irrigation, rates of chemical use, and crop yields can all be found in the GIS farming database. After analysis, this data is used to comprehend how the different elements influencing a plant at a given location relate to one another. GIS can be used for more than just storing and displaying data; it can also be used to analyze management circumstances by integrating and altering data layers.

Global Positioning System (GPS)

Real-time data collection and accurate position data generation are made feasible by GPS. GPS is essential for determining the exact location in a field, measuring location volatility, and directing site utilization in inputs. With an accuracy of 100 to 0.01 meters, GPS is a satellite-based navigation system that assists users in recording location data (latitude, longitude, and altitude).
Field data, such as water holes, boundaries, barriers, insect activity, and soil type, can be precisely located by farmers using GPS. An antenna, receiver, and light or audio control panel (DGPS) make up an automatic control system. GPS satellites provide signals that enable location determination by GPS receivers. Depending on prior operation techniques and application applications, farmers can utilize the system to examine field areas and apply inputs (seeds, fertilizers, pesticides, herbicides, and irrigation water) to each field.

RTK-GPS based vegetable transplanter

The development and successful use of a real-time Kinematic-Global Positioning System (RTK-GPS) installed on a tractor allows for the mapping of the geographic location of planting activities that take place on the tractor-drawn transplanter. The tractor and transplanter's mechanical hitch interface is instrumented via orientation sensors. Transplanter odometry data, planting events, GPS location, and sensor monitoring have all been recorded using a ruggedized, real-time, embedded control system. For upcoming centimeter-scale precision plant care chores, the technology can generate extremely accurate maps of agricultural plant locations.

Variable Rate Irrigation (VRI)

One crucial element of precision irrigation is thought to be site-specific or variable rate irrigation. The majority of researchers anticipate that water use will decrease on at least some fields, if not the total amount of water used on all fields (Sadler *et al*., 2005). It has been demonstrated that variable rate irrigation (VRI) uses 10–15% less water than conventional irrigation techniques (Yule *et al*., 2008). Hedley and Yule (2009) showed that spatially diversified irrigation applications can increase application efficiency and result in water savings of about 25%. The initial results from a study by Osroosh *et al.* (2016) reported that the utilization of wireless sensor networks, decision support and monitoring software, and weather and plant-based algorithms for autonomous irrigation management of drip-irrigated orchard trees were all supported by the comparison of irrigation automation algorithms for scheduling irrigation in apple trees. A network of scattered, small sensing devices known as sensor nodes or motes that collaborate to process and share data about physical phenomena via wireless channels is known as a wireless sensor network (WSN). WSN-based irrigation control systems that use real-time soil moisture data and remote access to in-field soil water conditions could be a way to optimize water management by managing irrigation systems on a site-specific basis (Kim and Evans, 2009; Hedley *et al*., 2011).
To operate individual sprinklers on a precision irrigation system, the system must seamlessly integrate real-time soil moisture data via an ADSL or 3G cellular network. Peters and Evett (2007) assessed the extent of crop leaf warming, a symptom of water stress, on a fully automated

center-pivot irrigation system using infrared thermocouple thermometers mounted on the pivot's trusses. Although this canopy temperature method is a good way to see when water stress is starting, it can't tell you when a plant is getting close to moisture stress. If we are trying to eradicate the impact of water stress on yield reduction, it may be too late to irrigate when the plant is experiencing stress.

Precision mechanical weeder

Real-time weed control can also be achieved with robotic control systems. By cutting the stem of the weed and applying the chemical to the cut surface, the direct chemical application end effector applies the chemical directly through the vascular tissue of the plant. Two micro-pumps, a specially made circular saw with a DC motor, an applicator, a chemical tank, a flow controller, and a tiny reservoir make up the robotic system. Machines for inter-row weeding are widely available, while there are still relatively few for intra-row weeding. Both intra-row and inter-row weeds have an impact on crop quality and yield. Blades mounted on a pivoting arm comprised the intra-row weed control technology developed by Radis Mechanization (FR). For plant detection, a light sensor was employed. The weeding system's arm blade was managed by an air pressure cylinder. In order to cultivate and eradicate intra-row weeds, the pivoting arm was moved into the intra-row area when no plants were found.

According to Bakker (2003), weeds are eliminated up to 20 mm from the plant when the system is operated at a speed of 5 km/ hr. The maximum speed of 3.0 km/ hr is appropriate for weeding operations because the intra-row hoe's mechanical transition causes more plant damage (Bleeker, 2005). The system may operate with a minimum intra-row spacing of 220 mm and is intended for vegetables that are widely spaced (Bakker, 2009). Additionally, it was noted that stray foliage presents challenges because distance is determined by measuring the time it takes for an ultrasonic signal to reach and reflect back from the target; as a result, the reflected signal may come back from a weed instead of the crop.

Site Specific Nutrient Management (SSNM)

Site Specific Nutrient Management (SSNM) uses a variety of SSNM methods, including crop monitoring, GPS, GIS systems, remote sensing, and VRT, to supply plants with the nutrients they require to meet their immediate and local nutritional demands. Poor fertilization can reduce the output of horticulture plants, while over fertilizer might have negative environmental effects. Applying a fertilizer prescribed by a physician has made it feasible to control soil nutrient variations across the field since the introduction of SSNM. Another area in which SSNM might assist Indian farmers is pressure control.

In India, the majority of the cultivated soil is acidic, and the pH varies greatly from place to place. Certain field applications of fertilizers and soil amendments can benefit from the use of remote sensing and GIS data integration to identify nutrient stress. By doing this, the fertilizer's effectiveness will rise and nutrient loss will decrease. Although SSNM in India is still in its infancy. It is particularly effective for valuable plants. Therefore, the adoption of innovative tactics to attain productive success depends on efficient communication between farmers, public and private enterprises. SSNM is a versatile composting idea that has been adjusted to the need for crop protection and the soil's capacity to satisfy different needs.

Volatile Biomarker Discovery: This makes it possible to identify plant diseases quickly. When detecting citrus illness, this approach has special advantages that can be quite beneficial. The ability of a few near- and far-range sensing techniques to detect citrus huanglongbing has been shown in numerous studies. Similarly, sensors from handheld or close-by devices have been tested with aerial photography on a few forums. A number of signs of chlorosis between leaves at different growth stages, varying degrees of infection, and resemblance to other illnesses (deficiency, chemical damage, etc.) present difficulties in diagnosing huanglongbing. Diagnostic accuracy was typically significantly higher when hand-held or under-controlled sensors were used than when aerial applications were used.

Drones in farm monitoring

Drones have revolutionized farming by increasing efficiency, generating extra revenue, and reducing costs. Drones may monitor plant health, increase spray accuracy, make a map of the area, and more. Large areas are swiftly explored using drones.

Potential of drones

Drones equipped with thermal, multispectral, or hyperspectral sensors can identify areas of the field that want improvement or are dry. Drones make it possible to calculate the crop index, which reveals the temperature signature and the quantity of heat-producing plants, after the crop has grown.

Drone types used in horticulture Possibilities for further drone use in the area. Purchasing drones entails accessing hazardous regions. With a crew of two operators and ten drones, they can effectively plant 400,000 plants every day.

Spraying drones: Comparable to planting robots that employ computer-camera-equipped smart sprayers to identify weeds used in targeted herbicides.

Picking drones: The purpose of one of the Agri Bots is to harvest strawberries. Agri Bot cuts fruit other than calyx and utilizes machine learning technologies to measure and identify fruit maturity. In this manner, there is little chance of injury or scratches because the reaper never touches the fruit.

Drone pollination: Drone cooling technique is one of the most popular drone polishing technologies. Researchers in Japan and the Netherlands are developing tiny drones that can silence plants.

Harvesting drones: Another innovation is soft harvesting, in which fruit is protected during harvest by machines equipped with pressed grabbers or soft suction cups. The first vaccine harvest was constructed in 2016 by Abundant Robotics' developers. This counts the number of apples every second by using a computer idea to recognize them before sucking them through a soft tube.

Automated harvesting system

Since the early 1960s, a variety of techniques have been put forth, researched, and used for fruit harvesting by machine. In order to liberate the fruits, mechanical harvesting techniques have been employed, including limb shaking, air blasting, canopy shaking, trunk shaking, and the application of an abscission chemical agent (Li *et al.*, 2011).

Mechanical harvesting technologies are unable to preserve the selection of size and quality. A vision control system, on the other hand, may choose the size and maintain quality. An alternative to mechanical harvesting systems is the automated harvesting system for horticultural crops (Schertz and Brown, 1968). Automated harvesting systems use machine vision control systems to recognize the fruits on trees. The vision control system uses a color camera to tell the control system where the fruits are and how far away they are (Li *et al*., 2011). Due to their large initial investment, limited intelligence, and low efficiency, automated harvesting systems are not yet suitable for the commercialization stage (Zhao *et al*., 2016). A lot of academics are trying to create effective horticultural crop harvesting robots.

Table 1. Harvesting robots for horticultural produce (Zhao *et al*., 2016)

Products	Robots	Vision scheme	Success rate (%)	Speed /fruit
Fruits	Apple harvesting	Camera-in-hand and positioning sensor	77	15
	Citrus harvesting robot	A fixed camera and a camera-in-hand	NR	<8
	Melon harvesting robot	A far-vision CCD and a near-vision CCD	>85	>22
	Strawberry harvesting robot	A stereovision system and a central camera	<41.3	11.5
		A stereo camera, a camera and a laser sensor		
				7.0
			NR	
	Watermelon harvesting robot	A stereo vision sensor and a camera in hand	100	12s
		A Stereo Vision sensor		
			66.7	NR
Vegetables	Kiwifruit harvesting robot	Eight cameras (four stereo vision systems)	NR	NR
	Grape harvesting robot	A camera-in-hand	NR	NR
	Cherry harvesting robot	A red and infrared laser active sensor	66.7	14
	Tomato harvesting robot	A binocular stereo vision sensor	70.0	3-5
	Cucumber harvesting robot	A fixed camera and a camera-in-hand	80.0	74.4
	Mushroom Harvesting robot	A near-infrared camera and a camera A mono-chrome camera in hand	45	65.2
			>80	6.7
	Sweet-pepper harvesting robot	Two cameras, a stereo camera and a camera	79	NR

Canopy Sensors

These sensors are available from many leading manufacturers as additional options. In order to modify the spray volume appropriately, they employ infrared or ultrasonic technology to determine the canopy's existence, length, and density. Infrared sensors seem to be affordable and dependable. If possible, the sensors should be connected to a tractor cab so that they can be used to apply flexible fertilizer.

Spectroscopy for Identification of Disease in Horticulture Crops

Using fluorescent imaging spectroscopy, Sindhuja *et al.* (2013) created and assessed a computer vision and machine learning method for classifying healthy and diseased leaves.

Normalized graphs were used to segment fluorescence images, and co-occurrence matrices were used to extract texture properties from the segmented images.

The support vector machine classifier uses the retrieved features as an input. Artificial intelligence and machine vision control systems were utilized in Florida to identify citrus diseases, identify early infections, and apply selective fungicides (Pydipati *et al*., 2006). Plant characteristics are part of the indirect disease detection method. Stress based disease detection imaging techniques like hyper spectral and fluorescence imaging.

Opportunities for precision agriculture in arid horticulture

Increased productivity: By optimizing water, nutrient, and pest management practices, PA can significantly increase the productivity of fruit crops in arid regions. This can result in higher yields and better-quality produce, even under water-scarce conditions.

Sustainability: PA promotes the sustainable use of resources by minimizing waste, reducing chemical inputs, and promoting efficient water management. This can help conserve biodiversity, reduce carbon footprints, and ensure long-term viability of agriculture in arid regions.

Economic viability: With improved resource efficiency, farmers can reduce operational costs while maintaining or increasing output. Precision agriculture tools can also help farmers access better market opportunities by ensuring consistent quality and timely harvests.

Improved crop breeding: The data collected through precision agriculture technologies can support crop breeding programs by providing insights into plant performance under different environmental conditions. This can lead to the development of drought-resistant or salt-tolerant fruit varieties, which are vital in arid areas.

Policy and support programs: Governments and agricultural organizations in arid regions can support the adoption of precision agriculture by providing training, subsidies, or financial incentives. This would enable small-scale farmers to benefit from cutting-edge technology and improve their agricultural practices.

Conclusion

The technology and management of horticulture is a new and difficult area of agriculture. Precision agriculture holds vast potential for transforming fruit farming in arid regions. By leveraging technologies that optimize resource use, improve crop health, and predict environmental challenges, farmers can enhance productivity, sustainability, and economic viability. While the adoption of PA tools may require initial investment and technical expertise, the long-term benefits make it a compelling option for farmers in arid areas looking to improve their agricultural practices. Although this assessment might stimulate more research on other horticultural plants using the automated yield mapping method, there aren't any standard technologies or processes for evaluating yield in vegetable and orchard production at the moment. Since the majority of fruit plants are perennials, fields must be temporarily stabilized in order to establish permanent blocks or tiny blocks. Further research is still necessary to fully understand the quality pattern's transient stability. Lastly, as horticulture crops is grown on small pieces of land in many parts of the world, it is necessary to develop small-scale technologies and procedures that are practical, affordable, and easy to use for small-scale farmers. The future of arid fruit crops lies in the integration of precision agriculture, where every drop of water and every resource counts toward maximizing yield and ensuring sustainability.

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Conflict of Interest

The authors have no conflict of interest.

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