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Precision farming in horticultural crops

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Abstract
An all-inclusive information-based agricultural management system, precision farming aims to detect, evaluate, and control field variability for maximum profitability, sustainability, and land resource protection. In essence, it refers to applying the appropriate quantity of treatment in the appropriate field at the appropriate time and place. The efficient use of resources through location-specific high-tech interventions, such as fertigation, protected/greenhouse cultivation, mulching for drip irrigation, micropropagation, high-density planting, and in-situ moisture conservation soil and leaf nutrient-based fertiliser management, is necessary for precision farming. By emphasising crop management with technologies like GIS, GPS, and remote sensing (RS) in conjunction with ground equipment like variable rate applicators (VRA), yield monitors, and computers with the right software, precision farming combines environmental health, economic profitability, and social and economic equity. In order to restructure the entire agricultural system towards a low-input, high-efficiency, and sustainable agriculture, precision agriculture is conceptualised using a system approach. Given the strain caused by population growth and unpredictable climate change, greater focus on the advancement of technology-driven horticulture precision farming is being examined as a potential solution.

Keywords: Precision farming, remote sensing, sustainability and global positioning system

Introduction
Precision farming is one of the most scientific ways to sustainable agriculture and horticulture. Precision farming has a long history, beginning in the early 1900s and gaining traction by the end of the century, but there is still much work to be done. Horticulture precision farming entails the use of a variety of technologies and techniques to discover, analyze, and control variability within fields in order to maximize profitability, sustainability, and land resource protection while minimizing environmental impact (Nabi *et al.*, 2017) [32]. Despite a significant amount of research, only a small percentage of farmers have used any type of precision technologies system approach to re-organize the overall system of agriculture towards low-input, high-efficiency, and sustainable agriculture. It can be thought of as a broad system for optimizing horticulture production through the use of crop-related data, contemporary and advanced technology, and management approaches. It's also known as a comprehensive system that starts with crop or commodity planning and continues through the postharvest processing stage of production.

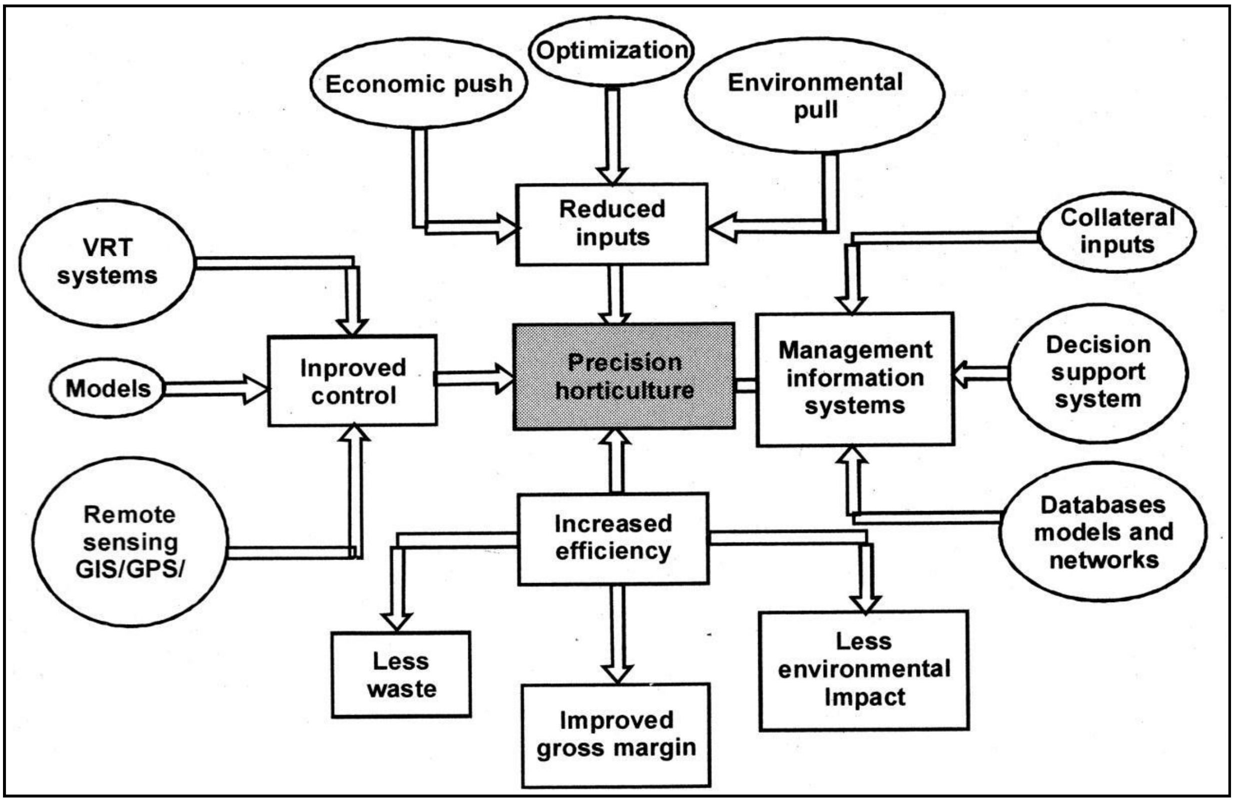
In a production system, there are primarily three keys to success: information, technology, and management. Crop information is a highly valuable resource for modern farmers. Precise data is critical at every stage of the production process, from initial planning to post-harvest management. During the field production stage, information requirements include spatial and temporal data on the soil, crop, pest, terrain, and weather. Temperature, humidity, and moisture are all key factors in the post harvest period. The rest of the data can be gleaned from past crop records. Other data must be obtained in real time so that the system can use it right away. Technology is regarded as the system's second most important component. Precision farming requires production equipment and systems that are well-suited to the operational needs of precision farming. From a mechanization standpoint, the expansion of precise planting and chemical-application technology is credited with laying the groundwork for precision farming. Variable-rate applications are possible thanks to sophisticated equipment intended for precise control and delivery of crop pesticides.

Need of Horticulture Precision Farming

Nowadays, technology changing the way of action in all the field so that agriculture is also not far too much and this field also involving technologies day by day. Horticulture precision farming is also coming from one of those technologies that provides maximum benefits i.e. quantitively and qualitatively with minimum affecting the environment. As other technology it also reduces the time and collects more accurate information through GPS and GIS like technologies. To understand the need of this technology in the field of horticulture are given in some points as follows:

1. To prevents soil degradation.
2. Efficient use of water resources.
3. Developing favourable attitudes.
4. To increase horticultural productivity.
5. Technical Employment generation.
6. To maintain the environmental balance.
7. Cutback of chemical application in crop production.
8. Precision farming technology changing the socio-economic status of farmers.
9. To help in achieve the goal of sustainable agriculture/horticulture.
10. Modern practices to improve quality, quantity and minimizing cost of production.

Components of Precision Farming in Horticulture



In horticulture, precision farming functions similarly to a well-balanced system, coordinating several elements to facilitate and facilitate crop management. As we already know, each element is essential to precision farming and functions in concert to provide the best possible crop care. These elements, which range from data sensors to automated machinery, revolutionise horticulture and usher in a period of sustainability and efficiency.

Integrating these advanced technologies and attention to detail is like a strong backbone for the modern agriculture method, ensuring an insightful and data-driven approach to cultivation. Let us look at the key components that make precision farming a powerful ally for modern horticulturists and farmers.

1. **Data Sensors:** In horticulture, data sensors serve as the watchful eyes and ears of precision farming, gathering data in real time on crop health, soil conditions, and environmental variables. A steady flow of data from these sensors enables farmers to make wise choices. Horticulturists may customise their interventions and make sure every plant gets the exact attention it needs for healthy growth by keeping an eye on these findings.
2. **Global Positioning System (GPS):** GPS technology acts as the compass for precision farming, enabling farmers to traverse their fields with exceptional accuracy. With the use of this technology, fields may be precisely mapped, enabling focused actions like harvesting and planting. Horticulturists and farmers can maximise resource utilisation, minimise overlap, and improve overall crop management efficiency by employing GPS.
3. **Automated Machinery:** The mainstay of precision farming is automated equipment, which completes jobs with unmatched accuracy and efficiency. These devices, which range from autonomous planters to harvesters, perform tasks based on insights gleaned from data. This minimises waste and increases horticultural output by lowering work intensity and guaranteeing precise execution of tasks like planting, harvesting, and spraying.
4. **Drones for aerial insights:** Precision farming is actually elevated by drones. These unmanned aerial aircraft give a bird's-eye perspective of fields by gathering high-resolution photos and data. Farmers can

evaluate plant health, spot crop differences, and spot possible problems like pest infestations using this overhead view. Drones are the finest tool for monitoring wide areas and provide a rapid and thorough overview of crops, allowing for focused and timely interventions.

5. **Data-driven Decision Support Systems:** The brains of precision farming are decision support systems, which process the massive volumes of data gathered by sensors and other technology. These tools help farmers make well-informed decisions by analysing data and producing insights that can be put into practice. Farmers and horticulturists can lower the risk of crop failure or decay, make decisions about how best to allocate resources, and carry out targeted interventions for improved crop management by utilising data analytics.

Basic Steps Involve in Horticulture Precision Farming

It is based on field variations such as crop qualities, soil qualities, and so on. These characteristics or variances are often recorded and mapped. Assessing, controlling, and evaluating variability are the main stages that contribute to the framework of horticulture precision farming.

Assessing Variability

Assessing variability is the first step in precision horticultural farming. It's an important step since it's clear that you can't manage something you don't understand. Variation in these processes is mostly caused by geographic and temporal variability, although simultaneous reporting of both variables is uncommon. Surveying, interpolation of point samples, high resolution aerial and satellite data, and modelling to infer spatial patterns are all methods that may be used to map spatial variability in the field.

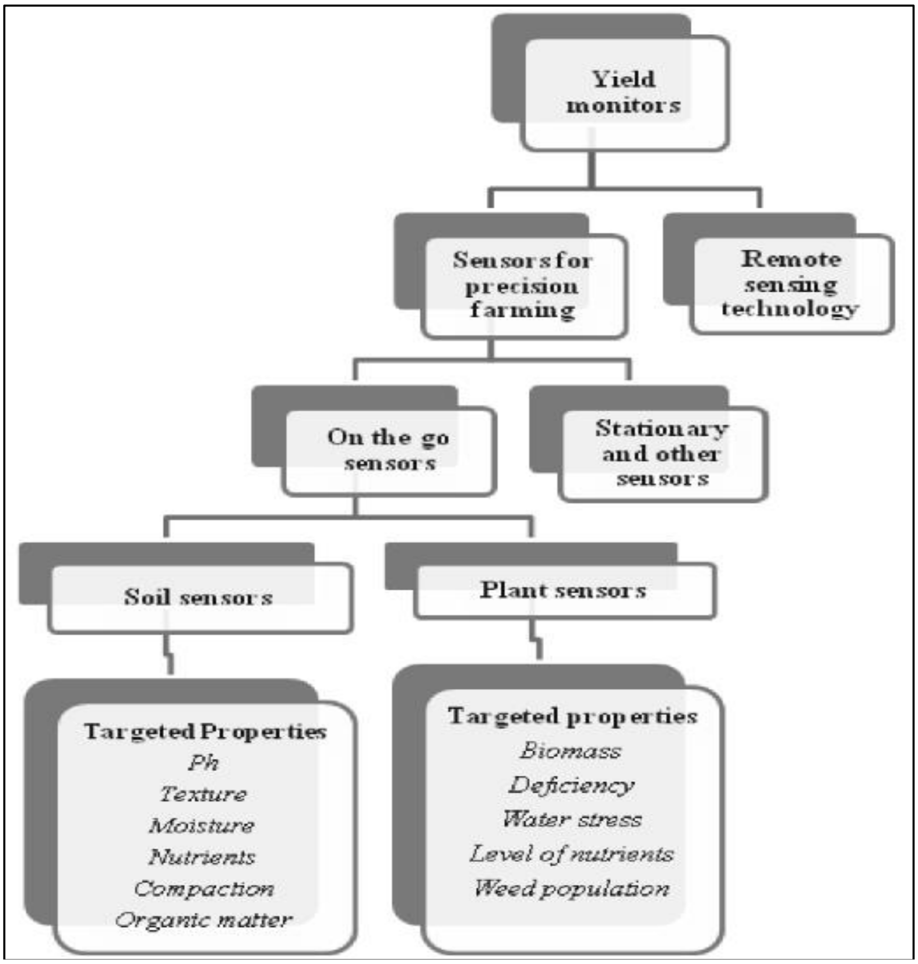
Managing Variability

Once the field variation has been sufficiently analysed, the farmer should match their crop, i.e. agronomic inputs, to known circumstances utilising site-specific management suggestions and the appropriate equipment to regulate it. Precision farming's performance is determined by how insect infestations, soil fertility, crop management, water management, stress management, and other variables are handled by farmers, as well as how precisely corrective measures are utilised in the field in response to observed variability. For successful precision farming technologies, these characteristics may be documented and mapped.

Evaluation of Precision Farming

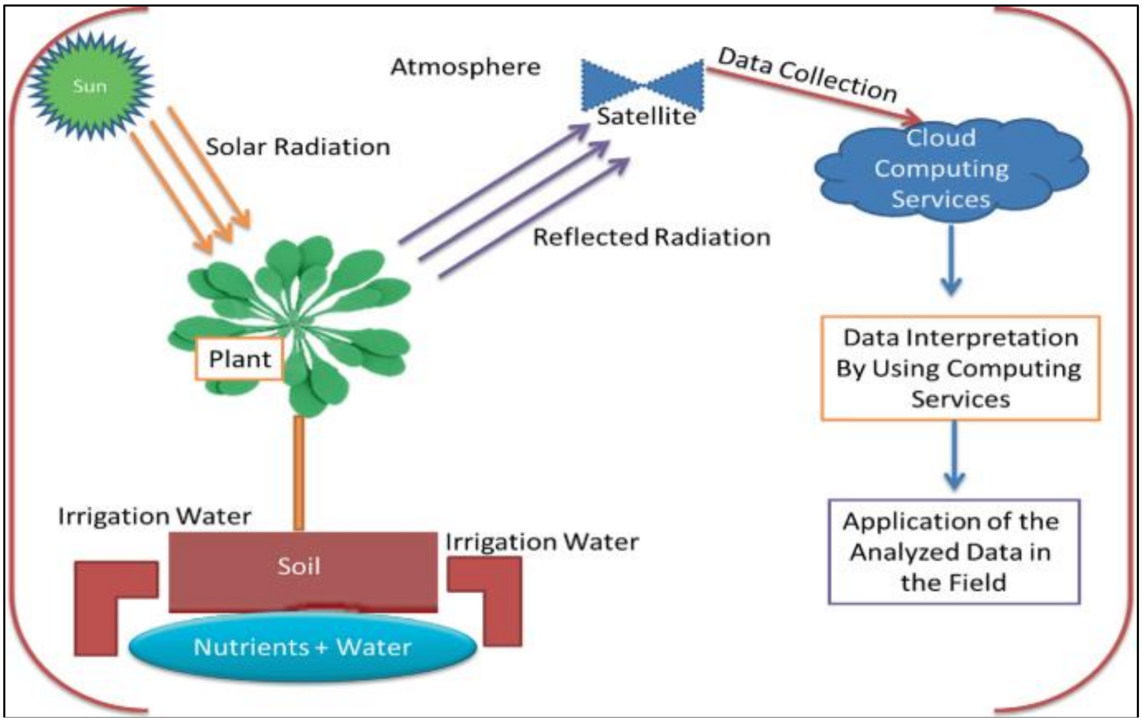
Economic variation, environmental preservation, and the prospect of precision agricultural technology transfer are the three key elements that are used to evaluate precision farming. The first is economic evaluation, which looks at whether or not the reported agricultural advantages are being converted into value via market processes. The second is an environmental assessment, which looks at whether precision farming can improve land, water, and environmental sustainability in our agricultural systems. The third and most crucial question is whether this site-specific technological farming will function on particular farms, as well as how far and how this advanced technology can be disseminated to other farmers.

Essential Tools and Technologies in Horticulture Precision



Farming

- Computer and Internet technology
- Global positioning system (GPS)
- Geographical information system (GIS)
- Remote sensing technology
- Variable rate technology (VRT)
- Yield mapping technology



Precision farming cycle

Computer and Internet Technology

Computers and Internet technology are the most important pieces of equipment in enabling any technology, including precision farming. They are the primary source of data collection, processing, and gathering. High-speed computer systems have aided in the success of technology by allowing for speedier processing, data collection, and other highly precise tasks. Its increased precision combined with a reduction in time makes it an ideal component for use in any type of technology or horticulture technology.

Global Positioning System (GPS)

The most typical applications of GPS are yield mapping and variable rate fertiliser and pesticide application. The GPS is necessary for determining the precise location in the field in order to measure spatial variability and site-specific input application. In differential mode, GPS may provide 1m location accuracy. Farmers will be able to undertake farming operations at any time in the future because to high-accuracy GPS. It may be at night, when the wind speed is quite low and spraying is more ideal. To minimise the light-induced germination of particular weeds, use night tillage. From the perspective of an agricultural positioning system, the GPS should meet the following criteria: ability to work reliably in varying landscapes, position updates at least once every second, yield mapping with a combine (cutting width 5 m), location accuracy of + 3m, and applications based on changes in soil type accuracy of 10 m.

Geographical Information System (GIS)

Precision farming's brain is the geographic information system (GIS). It's a well-organized system of computer software, hardware, geographic data, and employees that captures, stores, updates, manipulates, analyses, and displays all kinds of geographically linked data. It's referred to as GIS technology's spatial analytical capability. In two ways, it can help with horticulture. One method is to link and integrate GIS data with simulation models, such as crop, soil, and weather field records. The second objective is to assist the engineering component in the development of precision agriculture implements and GPS guided machineries (variable rate applicator). For example, if we combine soil, vegetation, and meteorological data, we may be able to determine the field's potential yield, assuming no other factors interfere with normal plant vegetative growth. Using this system, we can quickly identify problems in the area, as well as determine the cause of field reduction, and then take appropriate measures to resolve it.

Remote Sensing Technology

Information about soil conditions, plant growth, weed infestation, and other topics can be found in remotely sensed data that is collected by satellite or aeroplane and includes electromagnetic emittance and reflectance data of crops. Programs for site-specific crop management can benefit greatly from this kind of knowledge, which is also reasonably priced. Given how easily it can provide data for field parameters, this technique is helpful for precision agriculture. Generally speaking, we see reflected sunlight, which is made up of visible light (red, green, and blue), infrared, and ultraviolet wave lengths. The green plants reflect the green and the infrared while absorbing the red and blue wave lengths.

Using multispectral cameras to measure reflected wavelengths, we may assess plant health and identify issues such as disease, nutritional deficiencies, water logging, etc. The hue of the soil can be correlated with organic content, moisture, and other factors. Precision agriculture has made use of light reflection (from the sun or an artificial light source) as vegetation indices. The Normalised Vegetation Index (NDVI) is the most often utilised of them. Numerous more indices that are in good accord with specific crop features can be computed and applied. There is a correlation between crop yield and quality and NDVI. Satellites, aircraft, or ground devices can all be used to measure plant reflectance. These maps' derived NDVI data were transformed into leaf area index (LAI) maps, which demonstrated the ability to support irrigation and canopy management decision-making (Plant, R.E., 2001). By smoothing the residual errors related to each individual observation for the maize crop, the estimation of LAI spatial and temporal variation based on multi-temporal remote sensing observations processed using a simple semi-mechanistic canopy structure dynamic model (CSDM) in conjunction with a Radiative Transfer Model (RTM) enhanced the retrieval performances for LAI. Furthermore, this approach offered a means of continuously characterising the LAI time course from a small number of growth cycle measurements (Koetz *et al.*, 2005) [23].

In order to distinguish between lots that produce high-and low-quality wine, (Bramley, R., 2003) [6] employed the NDVI of the vines at Vaireson as a measure of grape quality. The farmer made money and got good outcomes from the successful plan. Good agreement was discovered in Chile between the NDVI and grape yield and quality (correlation coefficient r^2>0.7) and between the NDVI and LAI (r^2: any object emitting electromagnetic radiation at temperatures higher than absolute zero). Thermal cameras that can identify temperature variations in plants employ this. Precision agriculture has employed thermal cameras to monitor crop water status and control irrigation 2. >0.75). (Hall *et al.*, 2010) [19]. investigated the relationships between spectral pictures and grape yield and characteristics. They calculated canopy density and area, which were consistently substantially connected with berry size, yield, and fruit anthocyanin and phenolic content. However, correlations between total soluble solids were not consistent. One study used alternative satellite models to estimate the nitrogen content of sugar beetroot residue (Beeri *et al.*, 2005) [4]. Spectral reflectance was measured in situ for leaves C and N using a spectro-radiometer with a 7.1 nm bandwidth. The study's findings indicated that, in natural settings, if borehole control is available and the reflection strength is high enough, the two-way travel time to a Ground Penetrating Radar (GPR) reflection combined with a geological surface could be used to predict the average water content over a wide area. One study looked into a number of techniques for estimating the quality of tea using data from remote sensing, near infrared spectroscopy, and tea quality data (NDVI). Two high-yielding clones (TV1 and S3A3) were the focus of attention. ASTER photos were used to obtain the NDVI. Aflavins, catechins, and caffeine concentration all have an impact on liquor brightness, according to statistical studies. There are connections between remote sensing and quality measures, especially for the S3A3 clone. NDVI is positively correlated with EC, ECG, theogallin, and caffeine. Caffeine, theogallin, and catechins have a negative relationship with NIR. NDVI and Near Infrared (NIR) spectroscopy were shown to offer a great deal of potential for future usage in tea quality monitoring (Dutta *et al.*, 2011) [13]. Compared to satellite images, aerial photography (AP) has demonstrated more promising results because of its advantages, which include higher spatial resolution, correct or purposeful revisit time, and operation below clouds. Oxeye Daisy (Chrysanthemum leucanthemum) and Yellow Hawk weed (Hieracium Pratense) are distinguished using a charged-coupled-device (CCD) array camera installed on an aeroplane (Lass *et al.*, 1996). Pixel resolution of 1.8 m 28 to 1 m can be obtained via multispectral scanners (MSS), such as the Compact Airborne Spectrographic Imager (CASI) used from aircraft.

When compared to the outcome of retrieving crop chlorophyll content and leaf area index from decompressed hyper spectral data, a study found that the compression algorithm known as Successive Approximation Multi-Stage Vector Quantisation (SAMVQ) had little effect on the hyper spectral data sets obtained by CASI over maize fields (Hu *et al.*, 2004) [21]. When employed to classify the spectral features of plants and weeds, a self-organising map (SOM) neural network with an optimum Bayesian classifier has demonstrated encouraging results.

Remote sensing is a satellite-based precision farming technique in which images is collected via satellite-based sensors or CIR video digital cameras mounted on tiny planes. Various institutes are utilising this remote sensing technology owing to its high potential for monitoring temporal and geographical variations across time at high resolution, which makes it ideal for precision farming.

Variable Rate Technology (VRT)

Current field equipment can meet the variable rate input requirement if an electronic control unit (ECU) and onboard GPS are installed. Patch spraying has been done using spray booms and a spinning disc applicator with GPS and an ECU (Miller, P.C.H. and Paice, 1998) [29]. Better administration of the created zones should be the outcome of all the information acquired. VR indicates that the right rates of inputs will be used, which could result in better yields and quality or lower input costs and environmental implications. VR can be applied in two ways.

The first, referred to as map-based, is predicated on historical data from the past or present. Process control technologies enable the appropriate management of the inputs by adjusting fertiliser application, seeding rates, and pesticide selection and application rates based on information derived from the GIS (prescription maps). The latter, referred to as sensor-based, makes use of sensors that enable real-time application rate adjustments. The sensors modify the application equipment by identifying certain traits of the crop or soil. Any input can be used with VRA. There are benefits and drawbacks to both systems. Farmers are more receptive to the on-the-go sensors. The greatest future benefits will likely come from combining the two.

Variability in fruit quality and vine growth may be reduced in vineyards with variable fertiliser applications (Sethuramasamyraja *et al.*, 2010) [37]. VR fertiliser was used for four years in a vineyard (Devenport *et al.*, 2002) [10]. After analysing the soil's nutrient composition, they came to the conclusion that while P applications caused the CV to stay high, N and K applications helped the field by reducing variance. Prescription maps outlining the particular needs of each zone can be created based on management zone demarcation and historical data. As the machine travels through the field, the prescription map is fed into the application machine's controller, which modifies the adjustment (the quantity of input applied per unit of area as specified).

Electronic measurements of tree canopy height, density, and volume are possible (Giles *et al.*, 1988) [18]. Tree canopy as determined by laser or ultrasonic sensors was connected with yield in Florida citrus orchards. This characteristic was used to modify the application of the variable chemical. (Giles *et al.,* 1988) [18]. Discharge can be varied by pulse width modulation nozzles, which open or close the flow several times per second using fast reaction solenoids. Another concept involves varying the rate at which the active ingredient solution is introduced in the sprayer's distribution tubes (after the pump) (Ess, D.R. and Morgan, M.T., 2003) [14]. A variable rate application sprayer was tested on vines by Gil *et al*. (1998) [18]. The sprayer had three nozzles groups in each part of the row.

The canopy width was detected by ultrasonic sensors, which then modified the sprayer to save 58.8%. Given the scarcity of water supplies and the significance of irrigated crops in many regions of the world, variable rate irrigation is crucial. Use of prescription maps based on crop circumstances, soil characteristics, and actual field conditions in central pivot systems demonstrated significant water and energy savings48. Water and energy savings of up to 7% (range 2.5-7.2) can be obtained in a feasibility assessment of fields based on soil variability (Gemtos *et al.,* 2010) [2]. Water savings were predicted to be 12% by Perry and Milton (2007) [35] and 7% by Hedley *et al.* (2009) [20].

In order to achieve variable rate irrigation in orchards, irrigation systems must be planned from the start. Given the diversity of the soil, many networks can be created using varying water depths or application frequencies. Soil elevation and texture serve as the basis for separating the zones. During the growth season, wireless sensor devices were created to measure the water content of the soil. The controllers of autonomous irrigation systems, which can determine the appropriate application levels, can receive information directly from the sensors or from the farmer.

Existing ground machinery with ECU and GPS technology be able to fulfil the variable rate requirement of input. This technology uses the appropriate rates of inputs, reduces the costs as well as maintaining the proper balance with environment with no any compromise with yield and quality. VR system has generally two methods to apply first is map based and second is name sensor based. Map based system is generally based on present and past data. It allows the Information collection and adjust the fertilizer rate, pesticide rate, seed rate to apply on the field while in the name sensor-based technology detect the soil and crop characteristics and adjust the application equipments as per need. This system is more accepted by the Farmers.

Yield Mapping Technology

The best way to determine how different cultivation parameters vary across a field is to look at yield. The development of crop management plans for the upcoming season is therefore aided by yield mapping, interpretation, and correlation with the temporal and geographic variability of different variables. In order to offer a time-based record of the quantity of harvested crops for a specific period, current yield monitors measure the volume or mass flow rate. The location address obtained from the onboard GPS system is synchronised with time periodic yield data to build the most general colour-coded themed map. Yield mapping is easy to apply to mechanised crops.

An array of sonic beams placed over the grape discharge chute or loading cells that weighed the crop moving on a conveying belt were utilised to determine the quantity and weight of grapes gathered. The findings showed that different parts of the same parcel had yield differences of 8-10 times. According to studies, the trends in arable crops cancel out in the third year, leaving only regions with unpredictable yielding in addition to areas with consistent high and poor yielding.

Soil and crop sensing technology

It takes a lot of time and money to extract soil samples and plant tissue samples and analyse them in a lab. Direct touch and nearby remote sensing technology have been the foundation for the development of numerous devices in recent years (Sudduth *et al.*, 1997) [45]. Three instruments—the soil inductance meter, the leaf chlorophyll meter, and the infrared spectrometer—have already gained general recognition. Using grid sampling and analysis of an olive orchard that specified the soil maps and the amount of P and K fertilisation for each tree, an infrared spectrometer may be used to evaluate the water status of plants (Fountas *et al.*, 2004) [15]. A dense grid of soils has been examined by (Aggelopoulou *et al.*, 2010) [2].

They discovered inconsistent relationships between yield and soil nutrients. They proposed creating prescription maps for fertiliser application by accounting for the yield of apples and the nutrients extracted. It was discovered that there was a stronger link between yield and ECa maps but a lower correlation between soil attributes and yield parameters. Electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic, and electrochemical data served as the foundation for the soil sensors (Adamchuk *et al.,* 2004) [1]. Soil apparent electrical conductivity (ECa) is measured using electromagnetic induction (EM) and electrical resistivity. Texture, water content, organic matter, salinity, soil ions, and temperature are all closely related to this feature.

Measurements are associated with soil texture if saline soils are excluded and measurements are made close to field capacity. A link between yield and ECa has been established by numerous researchers. Real-time in situ monitoring of the photosynthetic activity of plants has been accomplished with the use of an optical sensor and a photo-multiplier tube. Data from a chlorophyll meter can be used to correlate the nitrogen status of plants. When employing laser-induced chlorophyll fluorescence measurements to forecast the canopy's N uptake, it is important to take into account the growth stage and cultivar, as these factors have a major impact on the sensor signal. The amount of polyphenolics in leaves can also be used as a measure of crop N status, in addition to the amount of chlorophyll. Soil nitrate has been effectively detected in real time using ion selective electrodes (ISE). The drawn-out nitrate extraction procedure is this system's main drawback.

DRIS and SSNM for precision farming in horticulture

Diagonis is and recommendation integrated system (DRIS) affects the integrated set of standards that represent calibration of plant tissues, soil composition, environmental parameters, and farming practices as functions of a crop's yield (Beaufils *et al.*, 1973) [3]. DRIS represents a comprehensive approach to the mineral nutrition of crops. Once these standards are established, it is feasible to diagnose the crop's circumstances and identify the variables that are most likely preventing it from growing and producing as much.

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The ability to diagnose at any point in crop growth and to rank the nutrients that are limiting output in order of significance are the two main benefits of the DRIS approach. To meet the diagnosis and prediction application of the leaf analysis, an integrated system for diagnosis and advice has been built. By optimising these elements, conditions are created that increase the likelihood of achieving improved quality and yield. DRIS uses the survey technique, which selects a large number of locations that are dispersed randomly around the region. Samples of soil and leaves are collected for analysis at each location, and information about the fertiliser and manures that were applied is documented.

The conventional method of entire field management is not the same as site-specific management. In whole field management, management techniques are implemented in accordance with the average conditions for a farm or field. Fields are separated into management zones, also referred to as grids, in site-specific management, and each zone is quantified and controlled independently. In order to implement site-specific management, producers need to have access to the information and technology needed to carry out a thorough management plan. The physical and chemical characteristics of the soil, field topography, crop diseases, pest populations, and accessible moisture are examples of spatial information requirements. The majority of soils come from basaltic parent material, and they frequently lack certain nutrients, such as N, P, Fe, Mn, and Zn (Srivastava *et al.*, 2004) [44]. Because of this, the traditional approach to nutrition management, which mostly involves applying macronutrients to orchards, has not been very effective in increasing productivity. A practical solution to these nutritional limitations and to maximising the productive potential of particular orchard sites is soil test-based site-specific nutrient management (SSNM).

Waste management in context to precision horticulture:

Horticulture produce undergoes spoilage at the time of harvesting, handing, storage, marketing, and processing resulting in huge wastage. Efficient management of this wastage can help preserving essential nutrient of our food and feeds bringing down the production cost of processed product, besides minimizing the pollution hazard and purifying the environmental condition. One of the most crucial parts of using horticultural waste in a variety of innovative ways to create new products and satisfy human needs for critical goods is recycling it.

Singh and Singh cited the nutritional makeup of several horticulture wastes. Mango seed kernels are rich in carbohydrates, fats, proteins, minerals, and fibre, among other essential components. They also observed that trash is a great source of these nutrients. Mineral maters and fat can be found in orange, pumpkin, and melon seeds. Singh *et al.* (2004) [44] have described potential by-products from processing unit waste, which could aid in the development of by-products based on waste availability. According to (Maini 2001) [26], citrus galgal peel produced the highest pectin yield jelly grade. The essential oil found in mango seed kernels is used to make soap and other cosmetics. With no negative impact on the animals' health or milk production, fresh apple pomace is used at a rate of 10.2 kg per day per animal to partially replace feed (Shah *et al*., 1994) [38]. Some of the fruit wastes can be usefully diverted for biogas generation and making manure. Fruit are not suited for active fermentation in generators due to acidic in nature. Neutralizing agent like lime slurry has to be added along with fruit wastage for the continuous active fermentation and to maintain the efficiency of gas generators. Potential of Precision Farming in India

Precision farming is a cutting-edge technology that has been demonstrated in many established and sophisticated nations worldwide. If applied properly and with the appropriate technological component, it has the ability to meet the demanding needs of any nation. The application of precision farming has so far been restricted in India. Though they are not yet well-known, several horticultural crops in India have a sizable market for profit and provide ample opportunity for precision farming. It contains a number of restrictions that restrict the extent of site-specific farming in India. Generally speaking, these limitations include small land holdings, a lack of market perfection, a lack of technical expertise, knowledge, and technological gaps at the local level, a lack of education and awareness, the differences in cropping systems in India, the socioeconomic status of Indian farmers, a lack of quality and cost data, a lack of cost-benefit analyses on precision farming, and a lack of local entrepreneurs.

Advantages

- Precision farming provides easy management of arable land in large area and reduces the time.
- It provides technological support to produce more qualitative matter than the traditional system.
- To manage the non-uniform land through divided into smaller plots according to specific need.
- Optimization of agrochemical products.
- Optimization of water resources and technical expertise
- To provide chances for better resource use and reduce wastage.
- It minimizes the maximum risk to the environmental factors.
- Global positioning system technology allows surveying of the field.
- Mapping technology allows mapping of yield and soil characteristics.

Disadvantages

- Preliminary cost may be high.
- Need of technical expertise in these areas.
- Extremely demanding effort predominantly collecting & analysing data.
- It should be seen as long-term investment.
- It may take some years to fully implement the system.

Key Technologies for Precision Horticulture

In horticulture, precision technology is a rapidly developing, cutting-edge technology that revolutionises plant cultivation and care by utilising sophisticated techniques and data. Together, these technologies offer a crop management strategy that is more accurate, sustainable, and efficient. With sensors, GPS, automated equipment, drones, and decision-feiling support systems, they are similar to a farmer's toolbox.

As the farm's eyes and ears, sensors gather data on crop health, temperature, and soil moisture in real time. With the use of this information, farmers and horticulturists can make well-informed choices and guarantee that every plant gets the proper quantity of nutrients, water, and attention to support robust growth. For instance, farmers can precisely map their fields and engage in focused activities like planting and harvesting thanks to GPS technology, which guarantees accurate field monitoring. Furthermore, automated technology can be thought of as precision horticulture's crew, carrying out activities accurately and efficiently while lessening the physical strain on farmers and boosting output. Moreover, drones provide a bird's-eye perspective of fields, recording high-resolution photographs and data, while decision support systems integrate data acquired by multiple technologies to deliver actionable insights, enabling farmers make informed decisions.

Precision agriculture vis-à-vis traditional agriculture

The degree of management involved in precision agriculture sets it apart from traditional agriculture. Small portions inside fields are managed differently than entire fields as a single unit. The necessity of good agronomic techniques is emphasised by this higher level of management. Precision agriculture requires a lot of information, in contrast to traditional crop management, which suggests average input application rates and assumes homogenous field conditions.

Objectives of precision farming

1. **Increased profitability and sustainability:** By precisely balancing inputs (seeding rate, variety, herbicide, and insecticide) with crop needs (which are influenced by weather, soil properties (nutrient availability, texture, and drainage), and past crop performance, precision farming seeks to maintain this profitability while maximising profit in each zone or site in a field.
2. **Optimising production efficiency:** Generally speaking, precision farming aims to maximise yields throughout a field. The detection of diversity in yield potential may present opportunities to improve production amount at each site or within each "zone" via differential management, unless a field has a uniform yield potential (and thus a uniform yield objective).
3. **Optimising product quality:** By employing sensors that identify the crop's quality characteristics and apply inputs appropriately, precision farming also seeks to maximise product quality. This may change the quantity of input needed to maximise profitability and agronomic responsiveness in production systems with quality premiums.
4. **Most efficient chemical and seed use:** PA entails the effective use of inputs, such as seeds, chemicals, etc., in accordance with the soil's potential yield.
5. **Effective and efficient pest management:** Reducing crop production inputs is one of precision farming's objectives, which saves money and the environment. Site-specific variable rate application places these chemicals (i.e., herbicides, insecticides, etc.) where the issue arises, as opposed to standard agricultural methods that apply them to the entire field.
6. **Energy, water and soil conservation:** Crop planning is the first step in a comprehensive approach to PA, which covers tillage techniques that conserve soil or disturb it as little as possible. Water is also applied efficiently through drip irrigation and other techniques, all of which use very little energy, so PA also contributes to energy conservation.
7. **Surface and ground water protection:** By using resources like chemicals and other materials efficiently, PA seeks to protect the environment. This stops them from running off into surface water or leaking via groundwater.
8. **Minimising environmental impact:** The net loss of any applied input to the environment must naturally reduce if better management choices are being made to customise inputs to meet production needs. Although there is a decreased chance of environmental harm, this does not imply that there is no real or possible environmental harm connected to the manufacturing system.
9. **Minimising Risk:** Today, the majority of farmers practise risk management, which may be viewed from two perspectives: financial and environmental. When a given input's unit cost is considered "low," farmers frequently err on the side of more inputs as a risk management strategy in a production system. In order to assure a profit, a farmer may apply additional fertiliser, spray, purchase additional equipment, or hire additional workers to ensure that the food is produced, harvested, and sold on schedule.

Benefits of Precision Farming in Horticulture

It's crucial to comprehend the precise areas in which precision technology might help farmers as we examine the different ways that horticulturists and farmers can profit from incorporating it into their farming operations. Although precision farming is a new technology, its goal is still to create more environmentally conscious and sustainable farms that minimise waste and maximise resources. Here are some ways that horticulture can benefit from precision farming.

1. **Resource Efficiency:** This type of targeted strategy minimises resource waste and guarantees that every plant receives just what it needs for healthy growth. Precision farming enables stringent control over critical elements such as water, fertilisers, and pesticides.
2. **Increased Crop Produce:** Precision farming helps to increase agricultural yields by refining and enhancing cultivating techniques. Harvests from the seeds seeded are healthier and more productive as a result of farmers' newfound capacity to address the unique needs of each plant, from soil composition to microclimate differences.
3. **Ensuring Sustainability:** Horticulture's negative environmental effects are lessened by precision farming. Farmers may improve irrigation and lessen their reliance on agrochemicals by knowing the precise

requirements of the plants. Additionally, it minimises pollution and protects natural resources by encouraging the sustainable use of the resources that are available.

4. **Data-Driven Decision Making:** Farmers may access real-time data and analytics through precision farming, which enables them to make well-informed decisions. Having access to precise information enhances the capacity to quickly handle issues, whether they are related to crop health monitoring or risk prediction.
5. **Labor Efficiency:** Farmers can free up human resources for more strategic and subtle parts of farming by implementing automated machinery and robotics to streamline labour-intensive operations. In addition to improving productivity, this helps the agriculture industry's workforce problem.
6. **Risk Reduction:** By enabling early identification of possible problems with crops, weather, and soil, precision farming helps with risk management. detecting pest infestations on crops or predicting unfavourable weather patterns that could compromise a crop's capacity to survive. This aids farmers in making plans in advance and acting proactively to protect crops and reduce losses.
7. **Improve Economic Viability:** Although precision farming does need an initial technological investment, the long-term advantages help to increase horticulture's economic viability. With their new, in-depth knowledge, farmers may increase yields, save money on resources, and improve operations, all of which increase the overall profitability of their farming endeavours.
8. **Adaptability to Climate Change:** With the problems posed by climate change, precision farming provides flexibility. Farmers can respond to shifting climatic conditions and provide crop resilience in an unpredictable climate by modifying agricultural procedures based on real-time data.
9. **On-farm research:** More comparison experiments can be carried out within fields thanks to the capacity to assess the spatial performance of crops. Comparing the performance of various cultivars on various soil types, for instance, is very easy when using PA.
10. **Property advantages:** Many farmers are giving preference to farmers who can create yield maps and other spatial data files for the properties they tend. This spatial history may increase the value of crops.
11. **More ground farmed:** More cropland than we previously had can be managed efficiently thanks to the records created.

Constraints involved in precision agriculture

- Small land holdings: In India, almost 58% of operational land holdings are smaller than one hectare, and these holdings are also dispersed.
- Expensive technology: Several cost-effective technologies are used in PA deployment.
- System heterogeneity in cropping.
- Technological gaps
- Insufficient local technological knowledge and expertise

Future Trends in Precision Farming for Horticulture

There are a lot of prospects for precision farming in horticulture, particularly in a nation like India. Driven by technology and the changing demands of agriculture, precision technologies have a lot to offer horticulture, particularly for younger, new-generation farmers who are interested in the latest developments in the area. Looking ahead, a number of factors are influencing precision farming and offering horticulturists a glimpse of the logical changes that will likely occur.

It is anticipated that decision-making procedures will be improved in the upcoming years by a greater combination of machine learning (ML) and artificial intelligence (AI). It is anticipated that these technologies will improve precision agricultural systems' predictive capacities, enabling more precise evaluations and pre-emptive actions. Furthermore, it is anticipated that the growth of the Internet of Things (IoT) and its many applications would strengthen the connections between sensors, equipment, and decision support systems, enabling smooth data interchange and real-time horticulture practice modifications.

Furthermore, a number of exciting developments in autonomous machinery are anticipated in the future, which will simplify chores like planting, harvesting, and monitoring. In addition to lowering manual labour, its automation guarantees accuracy and productivity in daily tasks. All things considered, horticultural precision farming trends for the future are in line with useful advancements, stressing the incorporation of cutting-edge technologies to improve agricultural operations' overall efficacy, sustainability, and production.

Specific Applications of Precision Farming in Horticulture

When it comes to horticulture, precision farming is essential. It is a state-of-the-art method of gardening that offers horticulture farmers customised solutions to improve the sustainability and efficiency of their horticultural operations. Its particular uses result in a significant change in the way crops are raised and tended.

1. **Precision Irrigation:** Using sensors and monitoring systems, precision horticulturists can assess soil moisture levels and provide water where and when it's needed. By doing this, plant root problems and waterlogging are avoided.
2. **Fertilizer and Pesticide Management:** In order to provide the crops with the exact amount of nutrients and pesticides they need, these farmers use the technology to analyse the soil and crops in real-time. This lessens the impact on the environment and conserves resources.
3. **Disease and Pest Detection:** Farmers can utilise automated systems with sensors to identify diseases and pests early thanks to precision farming. Farmers can reduce the usage of hazardous pesticides and protect the health of crops and the environment by focussing on the regions that are impacted.
4. **Yield Prediction and Harvest Optimization:** Precision farming technology helps horticulturists make well-informed decisions about when to harvest crops for optimal yield by analysing data on crop health, weather patterns, and soil conditions. Harvest quality and quantity are enhanced as a result.
5. **Protected Cultivation (Greenhouses and Tunnels):** Farmers are able to grow a range of crops that are not native to their nation thanks to the construction of greenhouses and tunnels, which provide controlled

settings with year-round ideal growth conditions for plants. In the end, this increases crop productivity and quality by enabling farmers to grow crops even in areas with harsh climates.

Application of Precision Technologies in Horticultural Crops

Precision Farming of Banana

One crop in India that has profited immensely from precision farming methods is the banana. The banana industry's success is attributed to a number of factors, including micropropagation, crop geometry, drip irrigation, green manuring, mulching, recycling of banana waste, organic farming, maintaining plantation hygiene through integrated disease and pest management, training, processing to puree transfer technology, participatory demonstration, and more.

Precision Farming of Papaya

India is the world's largest producer of papayas, a tropical fruit that is widely cultivated. Precision technologies for increased productivity include intercropping, irrigation management, plant protection, harvesting, planting season, sex expression, spacing and thinning, variety selection, and propagation and nursery production.

Precision Farming of Aonla

The Aonla live on the Indian subcontinent. The precision system for increased production includes the reproduction of real planting material, planting methods, variety selection, training and pruning, manuring and fertiliser application, mulching, effective water management, pest and disease management, harvesting, and post-harvest management.

Precision Farming of Guava

Guava is considered to be one of the most lucrative and nutritious crops. Guava fruits can be consumed both fresh and processed. Precision farming for increased productivity includes variety selection, guava orchard establishment, and the multiplication of authentic planting material. During the establishment process, factors like planting methods, training and pruning, high density planting, revitalising old plantations, growth and development, weed control, irrigation, intercropping, crop regulation, nutrition, fertilisation, judicious management of deficiencies, pests, and diseases, and harvesting are all taken into account.

Post-harvest Management through Horticulture Precision Farming

In India the post-harvest management of horticultural crops are very poor as compared to other foreign country and they loss a major part of their total yield as well as quality that directly affects the income and socio-economic condition of the farmer. Following crop harvesting, postharvest management begins. Improper handling at this point can seriously impair quality. In order to get the ideal parameters and quality of the preserve or food material, its application uses sensors to keep an eye on the conditions or circumstances during curing or storage. Regular monitoring cannot be completed by manual method that will be very laborious but with the help of sensor technology it can be easily handle. The continuous monitoring of some horticultural crops in the cold storage and adjustment can be made by their demand enhances in quality as well as income.

Conclusion

Precision farming in horticulture serves a dual objective of increasing output while also lowering environmental deterioration. Precision technology, which has a lot of promise in the international market for economic growth, also has a lot of quality. It is still in its infancy in most developing nations, despite being widely employed for commercial crops in many industrialised and a few emerging nations. Remote sensing technology can provide a crucial input (variability map) for precision farming in the horticultural industry. Although precision horticulture is a lot of work, it has a lot of potential in developing countries. It is anticipated that many of the precision farming trials that have started and are ongoing in India will yield fruit and transform Indian horticulture from a subsistence to a commercial enterprise. In India where majority of peoples are dependent on agriculture and horticulture sector the technology like precision farming and remote sensing is the way that can help in the improvement of socio-economic status of these farmers that helps in the income generation and all-around development of the country.

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