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Precision Farming: an Approach for Productivity and Resilience in Fruit Crops

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Abstract

The impact of climate change on agricultural production forced human to rethink about unscientific practices such as indiscriminate fertilizer and pesticide application, land use changes, livestock management etc. leading to emission of greenhouse gasses, 24% of which is contributed by agriculture. Fruit crops are perennial in nature and thus a proper planning needs to be adopted for maintaining a sustainable production in an orchard. Precision farming helps minimizing environmental impact by reducing resource use while maximizing productivity and it fulfills the criteria of being a potential tool for orchard management with efficient technologies such as Global Positioning System (GPS), Differential Global Positioning System (DGPS), Geographic Information System (GIS), Remote sensing, Variable Rate Technology, Soil sampling, Quality mapping, Yield mapping and monitoring, Augmented Reality in Integrative Internet of Things (AR-IoT) through assessing, managing and evaluating the real time situation in the orchard. In order to address the persisting and upcoming challenges, the fruit production techniques need to be developed by precision farming.

Introduction

Precision farming is a technology and information-based agricultural management approach to detect, analyze and control inter and intra-field variations in crops with the help of a decision support system where precise use of inputs optimizes returns while preserving resources unlike traditional cultivation practices and thus leading to maximum sustainability, profitability, and environmental safety. Professor Pierre C. Robert, widely recognized as the pioneer of precision farming, has defined precision agriculture as a concept that goes beyond simply adopting new technologies; it signifies a revolution in information supported by new technologies, resulting in a more sophisticated and precise system for managing agriculture.

The U.S. discovered Precision farming in the 1980s (Napier et al., 2000).

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During this period, the rate of adoption did not reach expectations till the first 10 to 15 years due to the two major factors responsible for rejection and identified by Nowak (1992) *i.e.* willingness and ability to adopt. He emphasized that the willingness relies on the accessibility of information technology, faith in the information, and trust that this information works as a foundation of favourable outcomes. The momentum of the implementation of precision agricultural approaches were gone down in the mid-to-late 1990s due to economic feasibility or cost-effectiveness earned by precision farming. By the early 2000s, the precision farming community had acknowledged the importance of three key factors for the successful implementation of precision farming: the ability to effectively handle farming challenges, its user-friendly nature, and its profitability for farmers (Napier et al., 2000; Kitchen et al., 2002). Despite being classified as a developing nation, the current situation in India is really grim. With more than 75% of total farm assets in the country are less than approximately 4.8 acres. Fruit plants mostly rely on seasonal rainfall for their nourishment. Additionally, the use of irrigation, which accounts for nearly 50% of the water supply, leads to reduced productivity levels. The position is highly precarious, with about 60% of the population involved in agricultural pursuits and associated endeavors. Agricultural practices have become exceedingly laborious, leading to the majority of farmers' offspring pursuing alternative means of earning a living due to inadequate machinery, insufficient profitability, and strenuous physical work, among other factors. Moreover, farmers find it more practicable to sell their fields to builders, industries, and malls than farming. All of which would eventually lead to the dwindling of farmlands that can feed the billions plus of our country. The technologies used in precision farming are continuously improving and altering, and the effects of these technologies are evident in the overall productivity, efficiency, and ecological impact of farming operations that are involved in the production of fruit.

Development Stages of Precision Farming in Fruit Crops

Mainly four stages included in the progress process are as follows

1. Abstract stage: The symbol represents a collection of numerical signals that are meaningless individually.

2. Reconnaissance stage: It provides significance to the data set gathered from the abstract stage (e.g. excessive, appropriate or deficient usage of fertilizer).

3. Decision stage: It indicates the modification of that information by some logical method, enabling to create decisions and farming guidelines.

4. Execution stage: It includes of correct analysis of obtained data, [decision making, farming & subsequently following recommendations] then proper & precise execution for optimum results.

The first three stages (Abstract stage, Reconnaissance stage, Decision stage) are mostly related to the virtual part or I.T. while the last step needs human thinking and application. For proper modification, it is important that all the stages are intimately interlinked with each other. Therefore, with positive improvement of technology together with tight association with human engagement, the concept of Precision Farming in fruit crops was formed.

Need for Precision Farming in Fruit Crops

The worldwide fruit production system presently has significant obstacles that will expand evidently in near future but, present technologies and knowledge with appropriate motivation and investment can lead to achieve a lot. The 1960s 'Green revolution' improved the country's food production significantly, from six million to 72 million tons in 1947 to the second position in the world. Increased inputs such as pesticides, irrigation, fertilizer, high-yielding cultivars, crop density, and mechanization were blamed for this development (Patil & Bhalerao, 2013; Shanwad et al., 2004).

Concerns about trade liberalization in agricultural sector, narrow opportunities in non-farming areas, climatic disparity, stagnating farm incomes, diminishing and degrading natural resources, and declining and fragmented land holdings have become paramount to growth and development of agriculture. Hence, the recently evolved technique is regarded as one of the most viable strategies to boost agricultural output in the future. Precision agriculture gives the key to automate and simplify the gathering and analysis of information by

1. Doing appropriate things in the right location at the right time
2. Higher productivity
3. Raising the efficiency of inputs
4. Using minimal land unit

The diversity in yield and quality of the food throughout the fields may be connected to management practices, soil and environmental features and adjustments can be made by obtaining and analyzing the information by means of Precision farming.

Significance of Precision Farming in Fruits Crops

- Precision farming increases crop yield.
- It gives information to help with decision-making in management.
- It helps to lower the cost of fertilizer and plant protection chemicals by applying them effectively.
- Precision farming has the ability to produce at peak efficiency with consistent and superior quality.
- More precise farm records can be kept.
- It can decrease the cultivation costs and help raise the input production efficiency.
- The reduction of chemical doses through VRT can be obtained.

• It helps in reduction of irrigation water application, which lessens nutrient leaching and deep percolation.

• Precision farming decrease runoff, erosion, and sedimentation of water bodies; and the reduction of environmental pollution.

Basic Steps in Precision Farming

The basic steps in precision farming are

1. Assessing variation
2. Managing variation
3. Evaluation

With the use of the technology at our disposal, we are able to manage variability by providing agronomic advice that are site-specific. An essential component of any precision farming system should be evaluation.

1. Assessing variation

Precision farming begins with assessing variability. Understanding the factors affecting crop yield across space and time is crucial. Quantifying this variability and identifying combinations accountable for spatial and temporal yield differences pose challenges. While readily available techniques address spatial variation, concurrent reporting of both the spatial and temporal variation remains rare. To optimize precision farming, we require both spatial and temporal statistics. Observations during crop growth and developmental stages throughout the growing season help uncover the reasons behind yield inconsistency. In essence, both space and time statistics are essential for effective precision agriculture.

2. Managing variation

Farmers should use precise agronomic inputs and management recommendations after assessing variation. Accurate applications control equipment, such as GPS instruments, can help in site-specific situations. Precise soil fertility management and precise application control are an unproven alternative to uniform field management. Identifying and interpreting field variability influences crop yield and quality. Spatial dependence of manageable soil properties helps achieve greater potential value. Precise nitrogen management may face difficulties due to larger temporal variability.

3. Evaluation

In terms of precision agriculture evaluation, there are three key concerns.

a) Economics: Application of data is more important than the use of the technology for the analysis of profitability of precision farming.

b) Environment: Precision farming is known to improve environmental quality potentially by reduced agrochemical use, improved efficiency of nutrient use and manage inputs and prevention of soils degradation. Thus, precision farming can be feasible to adopt by enabling technologies and profitable with enhanced production efficiency.

c) Technology transfer: It indicates that precision farming occurs when the technologies are acquired and used by the individuals or firms and so, much of the attention is given on how to establish a smooth communication with the farming community. As precision agriculture develops further, issues pertaining to the operator's managerial competence, the infrastructure's spatial distribution, and the suitability of the technology for specific farms will undergo significant changes.

Impact of Climate Change on Fruit Crops

Climate can influence the 'phenological shifts' in fruit crops as changing temperatures affect flowering times, reducing the vegetative phase and altering fruit development. 'Quality and Composition' of fruits are also affected by higher temperatures which impact fruit firmness, ripening, and chemical composition. Rising temperatures may lead to 'Geographical Shifts' to suitable areas for specific fruit varieties.

- **Impact on phenology:** Alteration in phenology or variation in various physiological systems throughout time is an obvious result of changing climate. In temperate fruits, temperature especially low temperatures has a major influence on flower induction; nevertheless, genotype, photoperiod, and temperature interact substantially to control flowering. For the apple varieties "Boskoop," "Cox's Orange Pippin," and "Golden Delicious," an earlier date of full bloom of up to 10 days was seen when comparing the last 20 years with the next 30 years. In Germany, this was less than 14 days.

- **Impact on blooming pattern:** Vedwan and Rhoades (2001) claim that in India's Western Himalayas, climate variations affect the pattern of flowering and bearing, which in turn causes a decline in fruit yield and apple quality. There is still a chance that apple blossoms will be damaged by frost because of the earlier flowering and springtime frost. This is due to the higher rise in winter and springtime temperatures (January to March). Frost may also be the primary factor causing weather-related crop damage in regions with temperate climates. Late spring frosts can damage temperate fruits like apple, pear etc.

- **Impact on chilling requirement:** Plants employ the technique of dormancy to shield their delicate tissue from unfavorable weather conditions. Many fruit and nut trees need to have their winter chilling requirements met in order to be grown commercially. These requirements vary depending on the variety of tree. Under temperate fruit trees, bud-break and development follow an irregular pattern when there is no chilling, as under mild winter circumstances. Warming may eventually alter temperate tree fruits' need for an overwinter chill and necessitate the replacement of such fruits with new species or cultivars. There are currently relatively few areas with safe chilling levels for cultivars like apples, cherries, and pears that have chilling requirements above 1000 hours. Modeling results indicate that almost none will remain by the middle of the century.

• **Impact on pollination:** There's a chance that climate change may affect many aspects of agricultural ecosystems, and bees are said to be impacted on many levels, including pollination efficiency. The changing climate has led to a dramatic drop in the population of pollinating insects. Fruit set is impacted by lack of fertilization when temperatures are extremely high or low. Inadequate chilling can hinder the pollination process in cross-pollinated fruits such as pistachios and walnuts leading to lower yield. For temperate fruits such as apples, pears, plums, cherries, etc., 20 to 25 °C is the optimum temperature range for successful pollination and proper fertilization.

• **Impact on disease and pest incidence:** Climate change may influence the physiology of host-pathogen interactions, host resistance, and the stages and rates at which pathogens develop. Climate change may result in altered phenological synchrony between crops and pests, altered interspecific insect interactions, altered population growth rates, increased overwintering, increased generation numbers, extended developmental seasons, and increased risk of invasion by migrant pests (Parmesan, 2007).

• **Impact on Post harvest quality:** Temperature variation can have a direct effect on crop photosynthesis. As a result, an upsurge in temperature is predicted to affect the postharvest quality parameters especially sugar, organic acid, and antioxidant, as well as peel color and firmness. When grown in high temperatures, grapes have lower levels of tartaric acid and higher quantities of sugar.

Tools and Equipment of Precision Farming for Mitigation

Technologies used in precision farming include a range of implements, software and hardware. These are:

1. Global Positioning System (GPS)

GPS offers uninterrupted positioning information consisting latitude, longitude and elevation in real time by a network of satellites in motion with an accuracy of between 100 and 0.01m. It provides the precise location information at any time such as soil type, pest incidence, weed occurrence, water holes, boundaries, obstructions and crop measurements. There is a programmed controlling system consisting of a panel guided by light or sound (DGPS), an antenna and a receiver that estimates the position by the signals broadcasted by the GPS satellites (Hakkim et al., 2016). The reliable identification of the field location allows the users to apply the inputs such as fertilizers, herbicides, irrigation water, pesticides and seeds to a certain field determined by performance standards and prior input applications. GPS receivers equipped with automated yield monitoring devices are commonly utilized for accurately collecting yield data. GPS are extensively utilized in agriculture for various purposes. These include mapping yields (using GPS in combination with a yield monitoring device), implementing variable rate planting (using GPS in conjunction with a variable rate planting system), applying variable rates of fertilizer (using GPS with a variable rate controller), creating field maps for record-keeping and insurance purposes (using GPS with mapping software), and performing parallel wrapping (using GPS with a navigation device) (Mandal & Maity, 2013). Researchers and cooperative farmers are using GPS receivers with barcode readers to locate the high-risk fruits in the orchards and thus it allows them to determine the location of the bin of fruits harvested from the orchard. This helps in tracking the fruit with quality problems eventually leading to the tree that is producing the damaged fruit.

2. Differential Global Positioning System (DGPS)

It employs a method to enhance the precision of GPS by utilizing pseudo range errors obtained from an identified position to modify the readings obtained with different GPS receivers in the surrounding geographical region. Thus, there is a crucial requirement of DGPS to ensure high level of accuracy for Precision farming. The Global Positioning System (GPS) can accurately determine the precise location of the farm implements within one meter range of its real position on land by utilizing a network of military satellites. Projection of precise location within inches can add several values to precision farming like: Soil samples' locations and the laboratory results can be linked together by using a soil map. Fertilizers and pesticides can also be tailored to match the specific characteristics of the soil, such as its clay and organic matter content, as well as the soil conditions, including drainage. One can modify tillage techniques based on the different conditions seen throughout the field, while simultaneously monitoring and documenting yield statistics. There may be substantial problems if the antenna, specially ground-based correction signals is not installed in a place where it can receive the signal without blockage.

3. Geographic information systems (GIS)

It is an arrangement of hardware and software components that produce maps by using the feature attributes and location data. An agricultural Geographic Information System (GIS) plays a crucial role in storing several layers of information, including data on yields, yield maps, soil survey maps, data from remote sensing, reports of crop scouting, and the status of soil nutrients.

Two types of data set are recorded by a GIS: (a) geographically referenced data (such as field boundaries, roads, and sample sites) and (b) attribute data that define the spatial data (such as soil drainage class and type). The spatial data is often recorded in raster (grid cell) or vector (arc-node) formats and is linked to a geographic coordinate system. In order to integrate findings and plan for distinct management zones within fields, the data provided by the

GIS are used as an input into a number of decision support system models. The variation in particular biological or environmental characteristics that influence agricultural activities, such as tillage, planting, fertilization, and managing weeds, pests, and diseases, is taken into consideration in the management plan. A critical source of feedback for assessing and modifying the management strategy for the following crop cycle is yield monitoring. A simple rule-of-thumb dictating, for instance, that lime should be added if the soil pH drops below a certain level might serve as the decision support system. In order to project the results of different weather situations and management decisions, more sophisticated decision support systems incorporate many data sources with crop simulation models.

E.g. GIS for rice fields is an interactive, easy to use system that serves to manage the paddy fields more effectively and economically (Mandal & Maity, 2013).

4. Remote sensing

With the use of data sensors that may be easily carried in the hand, installed on an airplane, or based on satellites, remote sensing technology allows a user to simultaneously collect a wide variety of information from a remote location. A tool for assessing the health of the crop is provided by the sensor data. Overhead photos are frequently used to identify elements of plant stress, such as those pertaining to moisture level, available nutrients, compaction, disease occurrence, and other issues with plant health. The unpredictability that impacts crop productivity within a given season can be identified using remote sensing, and timely management actions can increase profitability. The timing and extent of mid-season drainage, the amount and timing of nitrogenous fertilizer application, and harvesting period are just a few examples of the varied field conditions that make it challenging to identify the critical management factor, even though remote sensing technology gathers a lot of information. GIS, or geographic information systems, are ideal for these kinds of investigations. Geographic information systems (GIS) are widely used in agriculture, particularly in the areas of planning and monitoring the irrigation supply for rice cultivation, heavy metal regional distribution maps, groundwater recharge estimation and regionalization, and resource management. For instance, the ratio of leaves to trunk as well as the tree vigor can be seen in infrared images of hazelnut plantations.

4.1. Soil sampling with sensors

As part of the standard soil testing technique, representative soil samples from agricultural fields must be collected in order to determine the appropriate input quantity. This method is time-consuming and labor-intensive and typically involves determining routine parameters like pH, electrical conductivity (EC), available micronutrients, exchangeable cations, available N, P, and K, soil organic C (SOC), etc. The sensor-based technique, on the other hand, seeks to obtain location-specific values of various soil properties, which are then analyzed to make decisions about the amount of inputs at various locations. Utilizing sensors makes it possible to collect more accurate and repeatable data while cutting down on the time and labor required to identify various soil qualities.

4.1.1. Soil moisture measurement

One of the most crucial factors that requires careful attention in precision farming is soil moisture. The management of irrigation water via soil moisture sensors guarantees the best possible use of this valuable resource while providing a wealth of opportunities for field-level water conservation. There are two main categories for using moisture sensors to detect soil moisture at the field level: contact and non-contact (Roy & George, 2020).

4.1.2. Soil nutrient measurement

Variability in soil nutrient levels can happen at several levels, ranging from a field, an area, and a region, to a few centimeters at the plot level. It is difficult to match the crop's requirements with the capacity of soil to provide nutrients, and comprehending variability and adjust for it. Therefore, combined utilization of the spatial and temporal data is required. A thorough investigation of the nutrient concentration in the soil solution which is directly correlated with the amount of nutrients available to the plants would be the best approach to identify the nutrients in the soil (Roy & George, 2020).

This can be done by using nutrient sensors that are linked to GPS units to create a regional map in question and several management zones are separated from it. These segmentation enables more prudent use of fertilizer resources and aids in actual monitoring of the nutrients and its intervention.

The two main principles used by the various sensors for in situ nutrient detection are (a) diffusion controlled element measurement using solid-state electrochemical electrodes and ion-selective electrodes, and (b) chemical reaction controlled measurement (Hellebrand & Umeda, 2004). Precision agriculture can be implemented with the aid of several techniques such as fuzzy logic, geo-statistics, neural networks, and regression trees, which facilitate the understanding and analysis of distribution of soil nutrients (Liu et al., 2006; Park & Vlek, 2002; Zhang et al., 2007).

5. Variable Rate Technology

In order to precisely regulate the application rate of different components in crop production, such as fertilization, weed and pest management, and irrigation, VRT integrates agricultural equipment. It is applied in agriculture to raise crop yields at a specific unit rate or to increase inputs. Automated variable rate technology (VRT) has numerous uses in agriculture. The controller computer, locator, and actuator are the major parts of a variable rate applicator (Mandal & Maity, 2013). The computer that is mounted on a variable rate applicator loads the roadmap for application into it. The computer operates a product-delivery controller that utilizes a GPS receiver and the application map. This controller has the ability to modify the type or amount of product being supplied, guided by the information provided by the map (for example, in the case of combine harvesters having yield monitors). Here, the flow of grain is continuously measured and recorded by the yield monitors in the clean grain elevator of a combine harvester and they can provide the information necessary for producing yield maps when connected to a GPS receiver. Variable rate irrigation and fertilization can efficiently optimize the available resources and increase productivity. Canopy sprayers reportedly reduced 40% of the total pesticide consumption during the early season in grape orchard using infra-red sensors to observe the growth of canopy (Landers, 2010).

5.1. Variable Rate Fertilizer

Soil Teq, located in Waconia, Minnesota, was the first company to receive a patent for a computer-controlled variable rate fertilizer spreading equipment. The technology was initially tested with variable rate fertilizer or lime applications. Fertilizer rates changed in tandem with the digital soil maps, which is why the term "farming by soil" was first used. The term "site-specific farming" originated from the ability to alter fertilizer application rates using digital maps built with the data of soil fertility collected by grid sampling mthod, a feature of software developed by Mulla, D. from Washington State University called Soil Teq (Mulla & Khosla, 2016). Later on, this program developed into the Soil Geographic Information System (SGIS), marketed by AgChem and SoilTeq. Application of Variable rate fertilizer was regarded as an advantageous and profitable since they preserved or enhanced crop production and quality, safeguarded water quality, and increased the efficiency of agricultural inputs.

Table 1: Use of VRT in different fruit crops

Technology used	Reference
Production in Florida orchards was linked to a laser scanner or an ultrasonic canopy on a tree. The way fertilizer was applied was changed by this arrangement. When spraying, the sensors may identify absent trees and halt the nozzle's discharge. This also encourages user activity by automatically stopping the spray release at high altitudes.	Zaman et al., 2005, 2006
They used the leaf diversity in the composition of the leaves to construct site-specific fertilizer maps in the olive orchard. They found that continuous reductions on N, K, and P fertilization might be accomplished with a new fertilization scheme, based on a local alteration in the anatomy of the leaves of different tree species.	Lopez-Granados et al., 2004
They created physician fertilizer maps using information from soil analysis and apple nutrient removal.	Aggelopoulou et al. (2010)
Through soil compaction and fruit harvesting, they identified blueberry patches that received nitrogen fertilization.	Farooque et al., 2012

6. Bicarbonate Control in Irrigation for Hydroponic Precision Farming

Hydroponic agriculture uses an automated watering system that uses inexpensive, auto-calibrated pH sensors for detecting and correction of pH disparities found in the nutrient solution. The sensor consists of a pH probe and a set of micropumps that cyclically extract water specimens from the channels comprising the nutrient solution along with other liquid solutions used for sensor calibration. The greenhouse can be controlled by a wireless sensor network (WSN) that is linked to an auto-calibrated pH sensor. Intermittently, the pH sensors test the pH of every hydroponic support followed by sending the results to a data base (DB), which can help alert the farmers with the information recorded and processed by it. The information can be seen via an easy-to-use, an online interface that may be accessed by both the mobile or desktop devices having active internet connection.

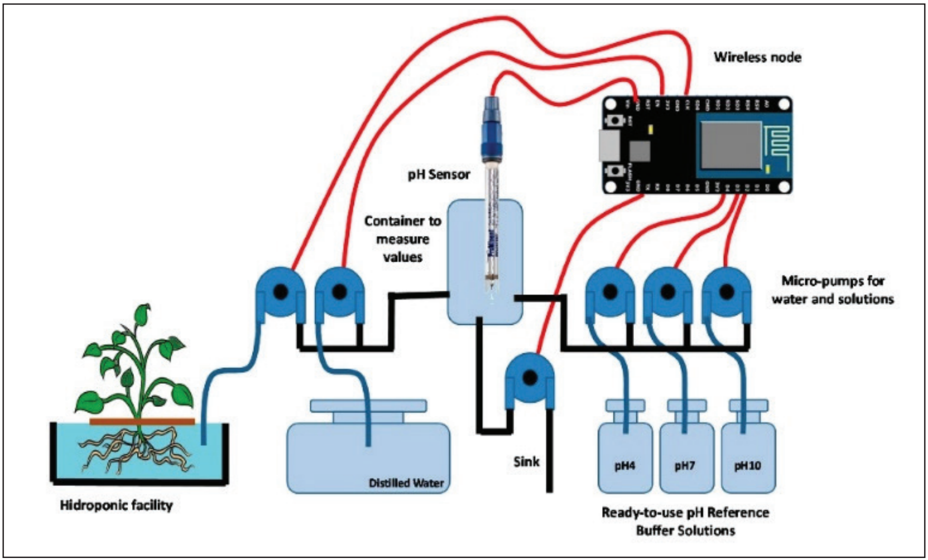

Figure 1. Auto-calibrated pH sensor and wireless node (Cambra *et al.*, 2018)

7. Yield and Quality Mapping

Several sensors are usually used in yield monitoring, along with additional parts like a task computer, storage disks, and output devices (display, keypad etc) that are all housed in the combine cab and interact with one another. The separator speed, ground speed, and quantity or volume of the flow of grain are all measured by the sensors. Mass flow sensors were created recently using the idea of sending microwave beams and measuring the amount of energy that reflects once impacting the flow of seeds passing by chutes. By using GPS receivers to pinpoint the location of the yield data, monitors may produce maps with recorded yield.

In case of hand-picked fruits, the highest accuracy of yield calculation would be obtained by recording the tree which every bag come from but unfortunately, there is no such way in a non-intrusive manner. Machine harvesting allows accurate individual tree yield mapping by measuring the harvest of mass fruit as it flows across a conveyor or accumulates in a storage component.

Schueller et al. (1999) discussed yield mapping of citrus for juice processing by working on tree canopy size determination using an experimental unit on two-wheeler trailer that can be pulled behind a tractor as it travels between rows of trees. The combination of measurement of the distance to presence or absence of foliage is measured in three dimensions to determine the yield as a function of tree size.

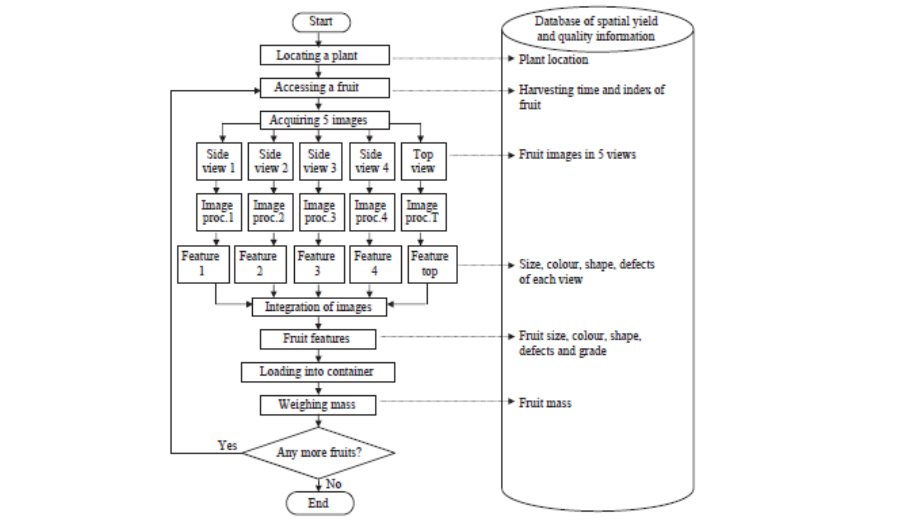

Figure 2. Yield and Quality mapping procedure through mobile fruit grading robot (Qiao *et al.* (2005)

Qualitative information contains more parameters compared to the yield information such as inner parameters (colour, shape, size, surface texture, mass etc) and outer parameters (acidity or inner diseases, sweetness) and freshness. These data can be obtained using an automatic grading mechanism installed in a factory although it is difficult to determine the ideal harvesting period for freshness and position of harvesting as often the harvested fruits get mixed without any information about the time and place of collection. To overcome this problem, a portable robot with fruit grading machine is developed for collecting the fruit quality data along with harvesting time and actual position while travelling in the field.

8. Software

Software is needed for many of the functions related to precision farming, including information layer mapping, display controller interfacing, data analysis before and after processing and its interpretation, and input accounting for the farm. The most widely used software can create maps (such as yield and soil maps), filter the data that has been collected, create maps with variable rates of application (such as fertilizers and chemicals), overlay multiple maps, and investigate complex geostatistical aspects, among other functions. A select group of global companies offer these software packages.

9. Augmented Reality in the Integrative Internet of Things (AR-IoT)

Precision farming has grown significantly thanks to the Internet of Things' (IoT) conception competencies, particularly in dynamic indoor planting. In order to improve object interaction with the IoT data superimposed directly onto the real-world stuffs, a non-destructive, inexpensive, multi-camera platform that is internet-connected is integrated into the system. This allows for the successful application of augmented reality in crop monitoring. This device has the ability to combine AR resolution with IoT data, which can help update precision agricultural methods in a way that is sustainable for the environment. The onsite environment can provide the AR-IoT with direct access to IoT data. Phupattanasilp & Tong (2019) asserted that AR-IoT technology was more promising and less prone to errors than conventional visualization techniques. In the near future, it might assist decision-makers in cutting down on waste or lost time and developing precision farming. In some situations, the energy consumption of embedded devices combined with their pricey and sophisticated technology makes them an attractive target for implementation.

10. Drone applications

Drones have revolutionized farming by increasing productivity, lowering costs, and producing extra revenue. In addition to mapping the region and reporting plant health, drones can increase spray accuracy. Drones cover large areas swiftly. Hyperspectral, multispectral or thermal sensor based drones can be useful to identify the areas requiring development or are dry. These drones enable the computation of the crop index, which depicts the temperature signature and the quantity of heat-producing plants, after the crop has grown.

10.1. Type of Drones used in orchards

Possibilities for using neighboring drones more frequently. Purchasing drones entails venturing into hazardous regions. With the help of ten drones and two operators, they can effectively plant 400,000 plants every day (Gulzar et al., 2022).

• **Weeding drones:** For farmers, weed control is a constant challenge. Recently, San Francisco created an agricultural robot that grows weeds using an entirely organic extraction process. Utilizing machine tools and computer vision. According to Sebstian Boyer, C.E.O. of the Boyer Company, one intelligent robotic machine installed in a farm, has the capacity to harvest enough produce for a city of roughly 4 lakh people.

• **Spraying drones:** In a similar vein to planting robots, computer-enabled cameras and smart sprayers are used to identify weeds that should be targeted by herbicides.

• **Harvesting drones:** The purpose of one AgriBot is to harvest strawberries. AgriBot cuts fruit beyond only the calyx and uses machine learning technologies to gauge and identify fruit maturity. By avoiding contact with the fruit, the reaper can minimize damage and scratches. Another invention is dubbed "soft harvesting," in which fruit is protected during harvest by machines equipped with pressed grabbers or soft suction cups. Abundant Robotics' developers constructed the first vaccination harvest in 2016. This counts the number of apples in a second by using a computer idea to recognize them and then suction them via a soft tube.

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

Strategies for Precision Farming in fruit crops

1. Selection of Suitable Variety
2. Water-use Efficiency
3. Balanced Nutrition
4. Manipulation of Vegetative Growth and Flowering
5. High-density Planting and Tree Canopy Management
6. Alternate Bearing Management
7. Rejuvenation of Unproductive Orchards
8. Managing disorders
9. Past and disease management
10. Harvesting and post-harvest management
11. Packaging and transport

Improvement of Precision farming Tools in Fruit Crops

The quick implementation of intelligent machine revelation techniques enables the growers to efficiently grade products by using automation systems to check fruit quality and guarantee safety. To provide comprehensive fruit processing methods, management operations like chemical spraying and fertilization can be monitored in addition to quality parameters including shape, size color, exterior faults, sugar content, titratable acidity, and further internal qualities. Due to the high cost of the tools (GIS, GPS, RS, etc.), farmer's cooperatives can be formed (Reshmika et al., 2015). Therefore, in order to create cutting-edge policies that will produce positive results, growers, the public sector, and the commercial sector must collaborate successfully.

Mango: According to Panigrahi et al. (2010), using black polythene mulches and drip irrigation help to preserve moisture, inhibit weed growth, and increase fruit production and quality in a trial at the Horticultural Farm, Precision Farming Development Center, Department of Horticulture, IGKV, Chhattisgarh during the 2009-2010 season. Efficiency of water use was shown to be lower under the basin irrigation system having V volume of water whereas it was significantly greater with drip irrigation having 0.6 V volume of water along with the plastic mulch.

Citrus: Whitney et al. (1999) conducted research on the use of precision farming in Florida oranges. A traditional fruit-loading truck, manual harvesters (more than 99% of citrus in Folrida is picked by hand), and GIS or GPS gears based on volume-based container locations were used to map citrus yields. The georeferenced aerial photos of the tree canopies were layered with these maps. In order to explore mapping weight-based yields, two weighing devices were installed on a fruit stocking carriage along with the GIS or GPS modules. According to current results, the weighing machines mounted on the cart had 1 to 6% of the certified scale weighs on 20-ton loads of fruit. When yield mapping is combined with electronically recorded harvester identity, the method becomes dependable and comprehensible for both harvesters and growers.

Grape: Together with Harvest Master, Wample et al. (2015) created a yield tracking system for industrial grape harvesters in the year 1996 for supporting an enduring study project, started in 1997 and examined the effects of machine trimming and thinning practice on crop production and quality of the grapes grown at Yakima Valley, Washington. A Concord grapes block of around 10 acre received five pruning procedures. Sub-sample counts were used to estimate the quantity of flower buds and clusters in each vine after completion of pruning. The amount of cluster in each vine and the assessed cluster weight from late June were utilized to determine the necessary degree of mechanical thinning as well as the possible yield. The thinning was done mechanically in early July. Variations in the pruning and thinning procedures as well as variations related to vineyard location were identified by a yield map. Data on fruit quality, yield, components of yield, and vegetative growth will be provided.

Blueberry: Zaman et al. (2009) discovered that a photographic approach to estimate fruit output could be a major help to precision farming in North America's wild blueberry business. During the harvest, they took pictures of the blueberry crop at thirty different sites. They then counted the blue pixels in the ripe blueberries using specialized image processing software. In order to anticipate the fruit production, the yield was calibrated using linear regression. The proportion of the blue pixels and the amount of fruit, physically gathered in both fields had a highly significant link, according to the data. The yield estimation process was impartial, according to the t-test's non-significance for actual yield compared to expected yield. According to the study, actual recording and yield mapping of blueberry can be achieved through the development of automated yield monitoring technology that makes use of DGPS, computers, and digital cameras.

Apple: Wireless sensor network (WSN) is being used as one of the components used for precision farming throughout different parts of the world for different purposes e.g. disease forecasting in apple, its identification and thus taking precautions according to the prediction (Nabi et al., 2020).

Successful Implementation in India

1. Tata Kisan Kendra (TKK)

Tata Chemicals (TCL) launched the Tata Kisan Kendra as a way to utilize technology relevant to India's farming sector. Various technologies like soil and crop health analysis, recording of pest attacks and final outcome prediction using remote sensing system is brough to the farmers by Tata Chemicals through the Tata Kisan Kendra.

Summary of results

- Healthier harvests
- Greater yields
- Increased farmers income
- Financial assistance
- Natural disaster insurance
- Buyback options

2. Tamil Nadu Precision Farming Project

Government. of Tamil Nadu gave Tamil Nadu Agricultural University the mission of developing precision farming in exchange for a cash subsidy for crop output and drip irrigation construction. Water consumption efficiency is higher with drip irrigation than with other methods because it delivers a precisely controlled distribution of water and nutrients, finely regulated at low pressure and controlled the intervals through pipelines straight into the rhizosphere of the plants.

Summary of results

- Lower need for water and fertilizer
- Lesser weed growth
- Optimal moisture management and soil aeration
- Enhanced productivity
- Water conservation
- Prevention of soil erosion

Opportunities in Precision Farming

1) Setting priorities for the execution and evaluation of the effects of

watershed projects at the national, state, district, taluka, and hobli levels.

2) Using soil water status and plant stress indicators, forecasting the infestation of pests, diseases, and insects in crops like rice, wheat, sugarcane, cotton, chili, and pigeon pea, among others.

3) Improving decision support systems to provide accurate resource management, at least in commercial, fruit, and flower crops, at the farm level.

4) Using data from Airborne Synthetic Aperture Radar to detect kharif crops and create canopy backscatter models to determine and forecast yield.

5) Making cadastral-scale soil maps with the help of radiometric, spectral, and spatial resolutions.

6) Measuring the loss of soil.

7) Water logging detection brought on by an increase in the groundwater table.

8) Identifying the boundaries of soils impacted by salt in areas with sandy and dark soils.

9) Mapping and measuring soil moisture using distant microwave, optical, and thermal sensors buried in the surface or root zone.

10) Using thermal and microwave distant sensors, estimate the surface temperature.

11) Create hyperspectral research on soils to measure the correlation between the qualities of the soil and its spectral reflectance.

12) The creation of digital methods utilizing GIS techniques for a range of applications, such as determining a piece of land's suitability for farming, classifying its capabilities, and determining its irrigability, among others.

13) The steps involved in becoming ready to use hyperspectral data to understand plant processes and create spectral response models for stress detection.

14) Enhancement of the yield models through the regional integration of crop models and biophysical simulation.

Challenges

Precision farming techniques such as remote sensing, GPS, and GIS are being applied in agricultural resource management at a rapid rate because of advancements in space science supported by computer and various communication technologies. The following challenges need to be addressed for using these technologies:

1) Determining the region, identifying, and producing short-duration crops, which are primarily planted in fragmented fields, especially in the kharif season.

2) Predicting natural disasters like floods and droughts.

3) The identification of crop stress brought on by an excess or shortage of

nutrients, insect and disease infestation, and the quantitative effects of these factors on crop output.

4) The use of GIS technology to automate land evaluation processes for various applications.

5) Insufficient knowledge of the horizons of subsurface soil.

6) Expanding the precision farming database to include a wider variety of crops on smaller farms.

7) Creation of long-lasting decision support systems for field-level management of diverse biotic and abiotic stress-related occurrences.

8) Precision farming requires the development of more precise yield models.

9) Determining reservoir water depth and evaluating groundwater quality.

10) Micro-level contours for the watershed development plan that are better than 1 m.

11) Accurate application of other precision farming technology, such as remote sensing, to intercropping and multiple cropping scenarios.

12) Finding ways to lower the cost of GIS, remote sensing, and other precision farming technologies and shorten the time between various stages, like data collection, interpretation, and distribution, to make large-scale use of these technologies more feasible. The hand-held radiometer created by Optomech Engineers Hyderabad in association with ISRO Ahmedabad's Space Application Centre is a successful example of this approach in standardizing the spectral signature in-situ for interpolating the remote sensing data.

13) There is insufficient proof of these technologies' efficacy or economic viability to garner enough backing for further study and development.

14) The development of human resources to speed up the adoption of cutting-edge, mysterious technologies with enormous promise and reach.

Challenges of Precision Farming in India

- 80% of farmers own fragmented land (less than two hectares of land);
- Poor financial situation of the farming community
- Highly diverse cropping sequences
- Inadequate software for general Indian farmers' Precision agriculture
- Uncertainty over the availability of high-quality seed or planting materials for the intended variety and crop.

Conclusion

The establishment of fruits orchard is a long-term venture and requires proper planning such as location and site selection, soil testing for the suitability, selection of crops, laying out, planting density, cultural operations, nutrient and water management, and plant protection measures to ensure less disease and pest infestation for maximum quality production. Precision farming has already been adopted by many progressive entrepreneurs as it is a perfect tool for most of these operations with more accuracy and efficiency. There are a lot more scopes for improvement in the precision farming techniques for sustainable orchard management and development.

Reference

Aggelopoulou, K. D., Wulfsohn, D., Fountas, S., Gemtos, T. A., Nanos, G. D., & Blackmore, S. (2010). Spatial variation in yield and quality in a small apple orchard. *Precision agriculture*, *11*, 538-556.

Cambra, C., Sendra, S., Lloret, J., & Lacuesta, R. (2018). Smart system for bicarbonate control in irrigation for hydroponic precision farming. *Sensors*, *18*(5), 1333.

Farooque, A. A., Zaman, Q. U., Schumann, A. W., Madani, A., & Percival, D. C. (2012). Delineating management zones for site specific fertilization in wild blueberry fields. *Applied Engineering in Agriculture*, 28(1), 57-70.

Gulzar, U., Gulzar, U., Jamwal, M., Singh, P., Kour, K., & ji Bhai, D. (2022). Precision farming in fruit crops. *Sustainable Development for Society, Industrial Development, Material, Energy and Environment: Key Issues, Opportunities and Challenges*, 2, 167-180.

Hakkim, V. A., Joseph, E. A., Gokul, A. A., & Mufeedha, K. (2016). Precision farming: the future of Indian agriculture. *Journal of Applied Biology & Biotechnology*, *4*(6), 068-072.

Hellebrand, H. J., & Umeda, M. (2004). Soil and plant sensing for precision agriculture. In: *1st Asian conference on precision agriculture, Kuala Lumpur, Malaysia*, May 11-13, pp. 11-13

Kitchen, N. R., Snyder, C. J., Franzen, D. W., & Wiebold, W. J. (2002). Educational needs of precision agriculture. *Precision agriculture*, *3*(4), 341-351.

Landers, A., & Muise, B. (2010). The development of an automatic precision canopy sprayer for fruit crops. *Aspects of Applied Biology*, 99, 29-34.

Liu, D., Wang, Z., Zhang, B., Song, K., Li, X., Li, J., & Duan, H. (2006). Spatial distribution of soil organic carbon and analysis of related factors in croplands of the black soil region, Northeast China. *Agriculture, ecosystems & environment*, *113*(1-4), 73-81.

Lopez-Granados, F., Jurado-Expósito, M., Alamo, S., & Garcıa-Torres, L. (2004). Leaf nutrient spatial variability and site-specific fertilization maps within olive (*Olea europaea* L.) orchards. *European Journal of Agronomy*, *21*(2), 209-222.

Lu, Y., Daughtry, C., Hart, G., & Watkins, B. (1997). The current state of precision farming. *Food Reviews International.* 13(2), 141-162.

Mandal, S. K., & Maity, A. (2013). Precision farming for small agricultural farm: Indian scenario. *Journal of Experimental Agriculture International*, 3(1), 200-217.

Mulla, D., & Khosla, R. (2016). Historical evolution and recent advances in precision farming. *Soil-specific farming precision agriculture*, 1-35.

Nabi, F., Jamwal, S., & Padmanbh, K. (2020). Wireless sensor network in precision farming for forecasting and monitoring of apple disease: a survey. *International Journal of Information Technology*, 14(2), 769-780.

Napier, T. L., Robinson, J., & Tucker, M. (2000). Adoption of precision farming within three Midwest watersheds. *Journal of Soil and Water Conservation*, *55*(2), 135-141.

Nowak, P. (1992). Why farmers adopt production technology: Overcoming impediments to adoption of crop residue management techniques will be crucial to implementation of conservation compliance plans. *Journal of soil and water conservation*, *47*(1), 14-16.

Panigrahi, H. K., Agrawal, N., Agrawal, R., Dubey, S., & Tiwari, S. P. (2016). Effect of drip irrigation and polythene mulch on the fruit yield and quality parameters of mango (*Mangifera indica* L.). *Journal of Horticultural Sciences*, *5*(2), 140-143.

Park, S. J., & Vlek, P. L. G. (2002). Environmental correlation of three-dimensional soil spatial variability: a comparison of three adaptive techniques. *Geoderma*, 109(1-2), 117-140.

Parmesan, C. (2007). Influences of species, latitudes and methodologies on estimates of phenological response to global warming. *Global change biology*, *13*(9), 1860-1872.

Patil S. S., & Bhalerao, S. A. (2013). Precision farming: The most scientific and modern approach to sustainable agriculture. *International Research Journal of Science and Engineering*, *1*(2), 21-30.

Phupattanasilp, P., & Tong, S. R. (2019). Augmented reality in the integrative internet of things (AR-IoT): application for precision farming. *Sustainability*, 11(9), 2658.

Qiao, J., Sasao, A., Shibusawa, S., Kondo, N., & Morimoto, E. (2005). Mapping yield and quality using the mobile fruit grading robot. *Biosystems engineering*, 90(2), 135-142.

Reshmika, P. K., Anil, S., & Gaykawad P. S. (2015). Prospects of precision farming in fruit crops in India. *International Journal of Agricultural Science and Research*, 5(6), 357-362

Roy, T., & George K, J. (2020). Precision farming: A step towards sustainable, climate-smart agriculture. In: *Global climate change: Resilient and smart agriculture*, (Eds.) Venkataraman, V., Shah, S., Prasad, R., pp. 199-220.

Schueller, J. K., Whitney, J. D., Wheaton, T. A., Miller, W. M., & Turner, A. E. (1999). Low-cost automatic yield mapping in hand-harvested citrus. *Computers and electronics in agriculture*, *23*(2), 145-153.

Shanwad, U. K., Patil, V. C., & Gowda, H. H. (2004). Precision farming: dreams and realities for Indian agriculture. Proceedings of Map India Conference, India.

Vedwan, N., & Rhoades, R. E. (2001). Climate change in the Western Himalayas of India: a study of local perception and response. *Climate research*, *19*(2), 109-117.

Wample, R. L., Mills, L., & Davenport, J. R. (1999). Use of precision farming practices in grape production. In: *Proceedings of the Fourth International Conference on Precision Agriculture* (pp. 897-905). Madison, WI, USA: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Whitney, J. D., Miller, W. M., Wheaton, T. A., Salyani, M., & Schueller, J. K. (1999). Precision farming applications in Florida citrus. *Applied Engineering in Agriculture*, 15(5), 399.

Zaman, Q. U., Percival, D. C., Gordon, R. J., & Schumann, A. W. (2009). Estimation of wild blueberry fruit yield using digital color photography. *Acta Horticulturae*, (824), 57-65.

Zaman, Q. U., Schumann, A. W., & Hostler, H. K. (2006). Estimation of citrus fruit yield using ultrasonically-sensed tree size. *Applied Engineering in Agriculture*, 22(1), 39-44.

Zaman, Q. U., Schumann, A. W., & Miller, W. M. (2005). Variable rate nitrogen application in Florida citrus based on ultrasonically-sensed tree size. *Applied Engineering in Agriculture*, 21(3), 331-335.

Zhang X. Y., Sui, Y. Y., Zhang, X. D., Meng, K., & Herbert, S. J. (2007). Spatial variability of nutrient properties in black soil of Northeast China. *Pedosphere*, 17, 19-29.