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Precision Farming a Promising Technology in Horticulture: A Review

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ABSTRACT

Precision farming is a comprehensive information based farm management system to identify, analyse and manage variability within fields for optimum profitability, sustainability and protection of land resources. It basically means adding the right amount of treatment at the right time and the right location within a field. Precision farming calls for an efficient management of resources through location specific high tech interventions which includes fertigation, protected/ greenhouse cultivation, soil and leaf nutrient based fertilizer management, mulching for in-situ moisture conservation, micro-propagation, high density planting, drip irrigation etc. Precision farming integrates environmental health, economic profitability and social and economic equity by giving emphasis on crop management using technologies like GIS, GPS, remote sensing (RS) along with ground equipment like variable rate applicators (VRA), yield monitors and computers along with appropriate software. Thus, precision agriculture is conceptualized by a system approach to re-organize the total system of agriculture towards a low-input, high-efficiency, and sustainable agriculture. Looking to the pressure arising population and erratic climatic variation, more attention required towards the development of technology driven horticulture precision farming is being reviewed as a promise in this regard.

Key words: *Precision farming, Remote sensing, sustainability and Global positioning system*

INTRODUCTION

With increasing population, urbanization and contagious depletion of natural resources, there has to be a paradigm shift in farmer's perception from production to productivity and to profitability. In this present scenario, the major challenge arising are shrinking land and depleting water and other related resources in agriculture. There is need for promoting farmer friendly location specific production system management technologies in a concerted manner to achieve vertical growth in horticulture production dully ensuring quality of produce and better remuneration per unit of area with judicious use of natural resources. In this endeavour, precision farming aims to have efficient utilization of resources per unit of time and area for achieving targeted production of horticultural produce.

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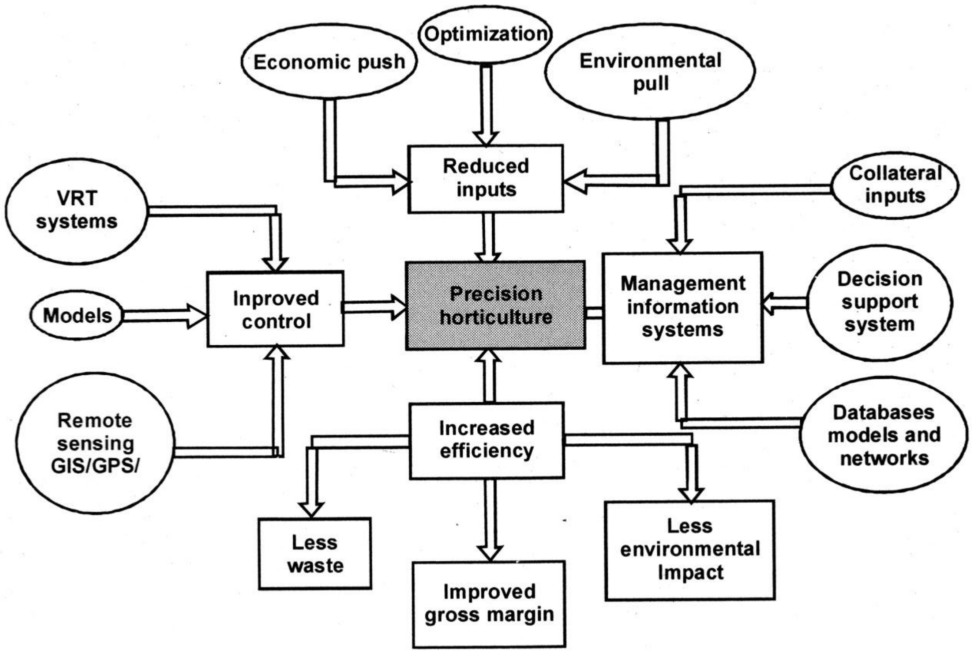
Professor Pierre C. Robert who is considered as the father of precision farming defined precision farming as precision agriculture is not just the injection of new technologies but it is rather an information revolution, made possible by new technologies that result in a higher level, a more precise arm management system. It basically means adding the right amount of treatment at the right time and the right location within a field. Precision farming uses modern technology like remote sensing and in country like India where majority of the farmers are having land holding average of 1-2 acres only, it was felt difficult to use aerial remote sensing to get detailed information of natural resources, particularly soil and other alike details. Remote sensing with increased special solution to the possibility of applying precision farming method to smaller areas have also been made applicable[45]. It is a scientific approach to improve the agricultural management by application of information technology (IT) and satellite based technology to identify, analyze and manage the special and temporal variability of agronomic parameters (e.g. soil, disease, nutrient water etc.) within field by timely application of only required amount of input to optimize profitability, sustainability, with a minimize impact on environment[42]. Recent researches in 'Integrating farmer knowledge, precision agriculture tools, and crop simulation modelling to evaluate management options for poor-performing patches in cropping fields' can be very useful for country like India[46]. In India also there are some relatively developed areas which can act as incubators for new ideas and sophisticated technologies based on the domestic conditions[36].

Components of precision farming



Technologies for precision farming

Primarily, precision farming the management and understanding of variability over time and space. This system is based on use of information generated through survey to manage this variability by matching inputs to conditions within field using site-specific inputs.

Computer system

Computers have help to define precision farming in terms of management strategy that uses information technologies for decision making. Precision farming requires the acquisition, management, analysis and output of large amount of spatial and temporal data. Computer software in precision agriculture has become better with time. For precision farming, the knowledge needed is that for managing variability on the farm, knowledge that is requisite for decisions making. Therefore, in this system, computers and related software have become capital inputs.

Global Positioning System (GPS):

Positioning system works by the help of different constellations of satellites. Developments of these different positioning systems are the main technological milestone, which made precision agriculture concept a reality. GPS provide accurate positioning system for field implementation of variable rate technology. It controlled application of inputs by equipments, identify the precise location of farm equipment within inches, fertilizer and pesticides can be prescribed according to the soil properties. Global positioning system (GPS) developed by US Department of Defense (DOD). Similar positioning system is Russian GLONASS positioning system. A European global navigation satellite system (GNSS), "Galileo" is under discussion[58] and for that a 'definition study' funded by European Union (EU) and the European Space Agency[60] is going on. In GPS all the position data should be stored and distributed from only one system, installed at a central vehicle (e.g. the tractor), for any task[41]. The basic advantage of central system is that position data are calculated in accordance with the application and transferred directly to the point at which they will be used[56]. Kinematic GPS (KGPS) is more accurate positioning technology with centimetric accuracy, but not used in precision agriculture due to cycle ambiguity problem. Real time Kinematic (RTK) DGPS uses double differencing technique[57] and can be used for detailed topographic mapping. The RTK technique can provide elevation accuracy of as good as 5 cm. This is possible because RTK systems extract additional information by examining the carrier wave of the GPS signal[61]. One study has been carried out to know the Spatial Influence of Topographical Factors on Yield of Potato (*Solanum tuberosum* L.)

Geographic Information System (GIS)

Geographic Information System (GIS) is an important system which includes organised collection of computer hardware, software, geographic data and personal designed to efficiently captured, stored, update, manipulate, analyse and display all forms of geographically referenced information. The science of GIS includes data management and modelling, enabling a shift form mapping to spatial reasoning. GIS contain base map like topography, soil type, nutrient level, soil moisture, pH, fertility, weed and pest intensity map it can also integrate all types information and interface with other decision support tools, so these maps and information are used for application of recommended rates of nutrients or pesticides.

Remote sensing (RS)

Remotely sensed data, obtained either by aircraft or satellite, containing electromagnetic emittance and reflectance data of crop can provide information useful for soil condition, plant growth, weed infestation etc. This type of information is cost effective and can be very useful for site-specific crop management programs[50]. It is a useful technology for precision agriculture as it can give data for parameters of the field relatively easily. In general, we see the reflected sun light that is formed by the ultraviolet wave lengths, the visible light (Red, Green and Blue) and the infrared. The green plants are absorbing the red and blue wave lengths and reflect the green and the infrared. Measuring the reflected wavelengths with multi spectral cameras we can measure the vigour of the plants or any problem like disease, nutrient deficiency or water logging etc. We can correlate soil colour to the organic matter, moisture etc. Light reflectance (sun or some artificial light source) has been used in precision agriculture in the form of vegetation indices. The most used of them is the Normalised Vegetation Index (NDVI). Several other indices can be calculated and used offering good agreement with certain characteristics of the crop. NDVI has been correlated to crop yield and quality. The measurements of plant reflectance can be carried out by satellites, airplanes or ground instruments. Derived NDVI data from these maps were converted to leaf area index (LAI) map, which showed potentiality to provide decision support for irrigation and canopy management[29]. 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) coupled with a Radiative Transfer Model (RTM) improved the retrieval performances for LAI mainly by smoothing the residual errors associated to each individual observation for maize crop. In addition, this method provided a way to describe in a continuous manner the LAI time course from a limited number of observations during the growth cycle[32]. Bramley *et al*[12]., have used NDVI of vines at Vaireson as an indication of grapes quality and used it to separate the product into high and low wine quality producing lots. The idea was successful and gave a good results and a profit to the farmer. Best *et al*[8]., in Chile, found good agreement between NDVI and yield and quality of a vineyard (correlation coefficient r2>0.7) and between LAI and NDVI (r2 any object when have a temperature above absolute zero emits electromagnetic radiation. This is used in thermal cameras that can detect differences in temperature in plants. Thermal cameras have been used in precision agriculture to assess water status of crops and regulate irrigation[2]. >0.75). Hall *et al*[24]., studied the correlations between spectral images and the properties of the grapes and yield. They estimated canopy area and canopy density, which were consistently significantly correlated to fruit anthocyanin and phenolic content, berry size and yield. But total soluble solids correlations were not stable.

One study was made for estimation of sugar beet residue nitrogen by alternate satellite models[7]. 1 nm bandwidth spectro-radiometer was used to take spectral reflectance to measure in situ leaf C and leaf N. Results of that study suggested that the two-way travel time to a Ground penetrating radar (GPR) reflection along with a geological surface could be used to predict average water content over a large area, under natural conditions if borehole control is available and the reflection strength is sufficient.

One study has been made to investigate several methods for estimating tea quality based on tea quality data, near infrared spectroscopy and remotely sensed data (NDVI). Attention focused on two high yielding clones (TV1 and S3A3). NDVI was obtained from ASTER images. Statistical analysis shows that liquor brightness is affected by the levels of caffeine content, theaflavins and catechins. Relationships exist between quality parameters and remote sensing in particular for the S3A3 clone. NDVI has a positive relation with caffeine, theogallin, EC, and ECG. NIR is negatively related to caffeine, theogallin, and catechins. It was concluded that NDVI and Near Infrared (NIR) spectroscopy have a large potential to be used for monitoring tea quality in the future[17].

Aerial Photography (AP) method has shown more promising result than satellite imagery method due to some benefits like operation below cloud, proper or intentional revisit time, higher spatial resolution etc. A charged-coupled-device (CCD) array camera mounted on a aircraft is used for discrimination of Yellow Hawk weed (*Hieracium Pratense*) and Oxeye Daisy (*Chrysanthemum leucanthemum*)[34]. Multispectral scanners (MSS), like Compact Air borne Spectrographic Imager (CASI) used from aircraft, can give pixel resolution of 1.8 m[28] to 1 m. A study revealed that there was not much effect of compression of hyper spectral data sets acquired by CASI over corn fields, by the compression algorithm called Successive approximation multi-stage vector quantization (SAMVQ), when compared with the result of retrieval of crop chlorophyll content and leaf area index from decompressed hyper spectral data[26]. A self-organizing map (SOM) neural network with an optimal Bayesian classifier, used for classification of plant and weed spectral properties, shown promising result[39].

Variable Rate Technology (VAT)

Existing field machinery with added electronic control unit (ECU) and onboard GPS can fulfil the variable rate requirement of input. Spray booms, spinning disc applicator with ECU and GPS have been used for patch spraying[37]. All information gathered should result in a better management of the formed zones. VR means that the appropriate rates of inputs will be applied leading either to reduced inputs, costs and environmental effects or improved yields and quality. Two methods are used to apply VR. The first called map based, is based on historical data (previous or present year). Process control technologies allow information drawn from the GIS (prescription maps) to adjust fertilizer application, seeding rates, and pesticide selection and application rate, thus providing for the proper management of the inputs. The second, named sensor based, uses sensors that can adjust the applications rates on the go. The sensors detect some characteristics of the crop or soil and adjust the application equipment. VRA can be applied to all inputs. Both systems have advantages and disadvantages. The on the go sensors are more acceptable by the farmers. Probably using a mixture of both will offer most advantages in the future.

Variable fertilizer applications in vineyard could help minimizing variability in vine growth as well as fruit quality[52]. Devenport *et al*[16]., applied VR fertiliser in a vineyard for four years. They have analysed the nutrient content of the soil and concluded that N and K applications benefited the field as they reduced variation but not the P application where the CV remained high. Based on management zone delineation and historical data prescription maps can be produced defining the specific requirements of each zone. The prescription map is imported to the controller of the application machine and changes the adjustment (the amount of the input applied per unit of area as prescribed) as the machine moves through the field.

Tree canopy volume, density and height can be measured electronically[23]. In citrus orchards of Florida, tree canopy measured by ultrasonic or laser sensors was correlated to yield. This property was used to adjust the variable chemical application.[23,64]. Pulse width modulation nozzles that use fast reaction solenoids to open or close the flow several times per second can be used to vary discharge. One other idea changes the active ingredient solution by introducing it at different rates in the distribution tubes of the sprayer (after the pump)[18.] Gil *et al*[22]., tested a variable rate application sprayer in vines. The sprayer had three nozzles groups in each part of the row. Ultrasonic sensors were sensing the canopy width and adjusted the sprayer achieving 58.8% savings. Variable rate irrigation is of great importance due to the shortage of water reserves and the importance of irrigated crops in many parts of the word. Applications in central pivot systems using prescription maps based on soil properties, crop conditions and the real conditions of the field proved that considerable saving in water and energy can be achieved[48]. In a feasibility study of fields based on soil variability savings of up to 7% (range 2.5-7.2) of water and energy can be achieved[21]. Perry and Milton[47] estimated 12% water savings while Hedley *et al*[25]., at 7%. In orchards, irrigation systems have to be designed from the beginning to achieve variable rate irrigation. Knowing the soil variability, it is possible to develop more than one networks applying different water depths or frequency of application. The zones separation criteria are soil texture and soil elevation. Wireless systems of sensors were developed to measure soil water content during the growing season. The sensors can give information to the farmer or directly to the controllers of automatic irrigation systems that can define proper application levels.

Yield mapping technology:

Yield is ultimate indicator of variation of different agronomic parameters in different parts within the field. So mapping of yield and interpretation and correlation of that map with the spatial and temporal variability of different agronomic parameters helps in development of next season's crop management strategy. Present yield monitors measure the volume or mass flow rate to generate time periodic record of quantity of harvested crop for that period[50]. Time periodic yield data is then synchronized with location address obtained from onboard GPS system to create most common colour coded thematic map[49]. Yield mapping can be carried out easily in mechanized crops. By using either loading cells that weighed the crop passing on a conveying belt or an array of sonic beam mounted over the grape discharge chute to estimate the volume, and the tonnage, of fruit harvested[11]. The results showed 8-10-fold difference of yield between parts of the same parcel[13]. Research in arable crops[10,19]. showed that the trends after the third year are cancelling out and we can only define areas of stable high and low yielding and unstable yielding. Tree crops seem to have more stable yields as Bramley and Hamilton[11] and Bramley *et al*[12]., found in vineyards after five years' data. Ampatzidis *et al*[5]., have mapped the yield of peaches. They used RFID or bar code tags on the bins. A weighing machine was combined with a tag reader and a GPS to record the weight and the place of each bin. The data collected was used to produce yield maps of the orchard. Konoatski *et al*[33]., have mapped the yield of a 1.6 ha pear orchard. They measure the yield of each tree (harvested in three passes). Instantaneous combine yield monitors generally provide good results if careful attention is paid during calibration, maintenance and as well as to manufacturer's instruction[15].

Soil and crop sensing technology:

Traditional extraction of soil sample and plant tissue sample and analysis in laboratory is time andcost intensive. In recent years many instruments have been invented based on direct contact and proximate remote sensing technology[62]. Three instruments have already got widespread acceptance, namely infrared spectrometer, soil inductance meter and leaf chlorophyll meter. Plant water status can be determined by infrared spectrometer[27]. Fountas *et al*[20]., using a grid sampling and analysis of an olive orchard defined the soil maps and the amount of P and K fertilization for each tree. Aggelopoulou *et al*[3]., have analysed soils in a dense grid. They found that correlations between soil nutrients and yield were not consistent. They suggested taking into account apples' yield and the nutrients removed to produce prescription maps for fertilizers application. Best *el al*[8]., found also low correlation between soil properties and yield parameters but better between yield and ECa maps. The soil sensors were based on electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic, and electrochemical measurements[1]. Electrical resistivity and electromagnetic induction (EM) measure soil apparent electrical conductivity (ECa). This property is directly connected to soil properties like texture, water content, organic matter, salinity, ions in the soil and temperature. If we exclude saline soils and take measurements near field capacity, then measurements are correlated to soil texture. Many researchers have reported correlation of yield and ECa[31].

By using optical sensor and photo-multiplier tube, real-time in situ sensing of photosynthetic activity of plant has been done[30]. Plant nitrogen status can be correlated with the data obtained from chlorophyll meter[38]. As cultivar and the growth stage significantly influence the sensor signal, they need to be considered when predicting the N uptake of the canopy using laser-induced chlorophyll fluorescence measurements[51]. In addition to the leaf chlorophyll content, as an indicator of crop N status leaf content of polyphenolics can be used for the same purpose[14]. Ion selective electrodes (ISE) have been used successfully for real-time sensing of soil nitrate. The major disadvantage of this system is the lengthy nitrate extraction process.

DRIS and SSNM for precision farming in horticulture:

Diagnosis and recommendation integrated system (DRIS) represent a holistic approach to the mineral nutrition of crop and has an impact on the integrated set of norms representing calibration of plant tissues, soil composition, environmental parameters and farming practices as the functions of the yield of a crop[6]. Once such norms are developed, it is possible to make a diagnosis of the conditions of the crop thereby isolating the factors, which are likely to be responsible for limiting the growth and production. The most important advantages of DRIS approach are its ability to make a diagnosis at any stage of crop development and to list the nutrient in the order of importance, which are responsible for limiting the yield. Diagnosis and recommendation integrated system has been developed to fulfil the diagnosis and predictive use of the leaf analysis. Optimization these factors create conditions, which are likely to the chances of obtaining higher yield and quality. DRIS employs survey technique, where a large number of randomly distributed sites throughout the area are selected. At each site, the samples of the leaf and soil are taken for the analysis and the details of the applied manures and fertilizer are recorded.

Site-specific management differs from the traditional practice of whole field management. In whole field management, average conditions for a field or a farm are determined and management practices applied accordingly. In site-specific management, fields are divided into management zones, often called grids, where each zone is quantified and managed separately. To practice site-specific management, producers must have the necessary information and technology at their disposal so that a comprehensive management plan can be executed. Spatial information requirements include soil chemical and physical properties, field topography, pest populations, crop diseases, and available moisture. Soils are mostly derived from basaltic parent material and are commonly deficient in multiple nutrients, including N, P, Fe, Mn, and Zn[59]. That is why the conventional nutrient management strategy based mainly on macronutrient application in orchards has not been very successful in raising the productivity level[59]. Soil test-based site-specific nutrient management (SSNM) offers a tangible option to address these nutritional constraints and to harness the productivity potential of specific orchard sites.

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. Recycling the horticultural waste is one of the most important aspects of utilization it in a number of new way to yield new products and meeting the requirement of essential products requirement to mankind.

Nutritional composition of different horticultural wastes has been quoted by Singh and Singh[54]. They reported that waste is rich source of vital constituent like carbohydrate, fat, protein, minerals, and fibre etc, mango seed kernel is rich in carbohydrate, fat, protein, minerals. Orange, pumpkin, melon seed can provide fat and mineral maters. Possible by products from the waste of processing units have been described by Singh *et al*[55]., and could help to developed by-products on the basis of availabilities of waste. Maini[35] reported that maximum pectin yield jelly grade was obtained from peel of citrus *Galgal*. Mango seed kernel contain essential oil, which is used in manufacture of soap and other cosmetic products[4]. Fresh apple pomace used @ 10.2 kg per day per animal as a partial replacement of fodder without any detrimental effect on health and milk yield of the animals[53]. 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[55].

Future strategy for precision farming:

Future strategy for adoption of precision agriculture in India should consider the problem of land fragmentation, lack of highly sophisticated technical centres for precision agriculture, specific software for precision agriculture, poor economic condition of general Indian farmer etc. precision agriculture in small farms is that individual farms will be treated as if they were management zones within a field and that some centralized entity will provide information to the individual farmers on a co-operative basis[50]. The problem of high cost of positioning system for small fields can be solved by 'dead reckoning system'. The dead reckoning system, suitable for small regularly shaped fields, relies on in-field markers, such as foam to maintain consistent application[44]. This approach provided farmers with a robust and credible method for making decisions about spatial management of their fields[46]. Nature of crop and weed vary from zone to zone, country to country. So development of software and hardware for crop and weeds of India, site specific tillage technique, etc. should be started and these packages will be used for precision agriculture[9,40,43,63]. not only suitable for developed countries but also for developing countries, if applied properly and has a wider impact in farm management through more efficient machinery management.

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