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Precision farming in vegetables

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Abstract
Precision agriculture is a popular new concept in production. Precision agriculture can be defined as a comprehensive system designed to optimise agricultural production through the application of crop information, advanced technology and management practices. A truly comprehensive approach to precision agriculture begins with crop planning and includes tillage, planting, chemical applications, harvesting and post harvest processing of the crop. A more holistic agricultural approach uses information technology to bring data from multiple sources to bear on decisions associated with agricultural production, logistics, marketing, finance and personnel. Technological interventions in precision horticulture include genetic conservation, genetic engineering, integrated nutrient management, protected cultivation, post harvest technology, micro irrigation and fertigation etc. Modified crop geometry further improved B:C ratio to 3.26 without subsidy and 4.0 with subsidy. Precision farming is a comprehensive system designed to optimise production. This can increase production efficiency, improve product quality, improve the efficiency of crop chemical use, conserve energy and protect environment with the use of key elements of information, technology and management. Technology and management practices such as field scouting, field mapping, variable rate control, yield mapping and post harvest processing can be readily adopted to vegetable crop production. However, the technology related to precision farming needs refinement to realize benefits.

Keywords: Precision farming, post harvest

Introduction

Precision agriculture can be defined as a comprehensive system designed to optimise agricultural production through the application of crop information, advanced technology and management practices. To be a truly comprehensive system, it must begin during the planning stages of the crop and continue through the post harvest-processing phase of production. Information, technology and management are the keys to success in this production system (Arora, 2005) [3].

The concepts of precision agriculture were introduced by the pioneering initiative of C.M. Linsley and F.C. Bauer in Bulletin 346 of the Experimental Agricultural Station of the University of Illinois in 1929, as cited by Goering (1993) [5]. Researchers concluded that the need for lime application “varied a lot for the same plot” and “systematic and detailed tests were needed in the field so that the lime could be applied according to its needs”. This concept was used for sometime when animal traction was available, but was abandoned when mechanical traction appeared in the North American market. It remained forgotten for quite a long time, until the availability of microcomputers, sensors and positioning systems that became available at reasonable cost. According to Goering (1993) [5] the increasing concern with environmental factors, brought back that concept since the application of agricultural chemicals in a site specific basis would decrease the chances of leaching of these products and environment contamination.

Precision agriculture is also known as precision farming, precision horticulture, site-specific farming (SSF), site-specific management (SSM), site-specific crop management (SSCM), variable rate application (VRA) etc.

Definition: US House of representatives, 1997 have given following two definitions of precision agriculture:

1. **Precision Agriculture (PA):** “is an integrated information and production based farming system that is designed to increase long term, site specific and whole farm production efficiency, productivity and profitability while minimising unintended impacts on wildlife and the environment”.

2. **Site-specific crop management (SSCM):** "A form of precision agriculture whereby decisions on resource application and agronomic practices are improved to better match soil and crop requirements as they vary in the field".

Precision agriculture vis-à-vis traditional agriculture

Precision agriculture distinguishes itself from traditional agriculture by its level of management. Instead of managing whole fields as a single unit, management is customised for small areas within fields. This increased level of management emphasises the need for sound agronomic practices. Unlike traditional crop management, which assumes uniform field conditions and recommends average input application rates, precision agriculture is information intensive.

Objectives of precision farming

1. **Increased profitability and sustainability:** Maximum profit can be obtained in each zone or site in a field by balancing precise amounts of inputs (seeding rate, variety, herbicide and insecticide) with crop needs, which can be determined by weather, soil characteristics (nutrient availability, texture and drainage) and historic crop performance. At the very same time, precision farming aims at sustaining this profitability.
2. **Optimising production efficiency:** In general the aim of precision farming is to optimise returns across a field. Unless a field has a uniform yield potential (and therefore, a uniform yield goal), the identification of variability in yield potential may offer possibilities to optimise production quantity at each site or within each "zone" using differential management.
3. **Optimising product quality:** Precision farming also aims at optimisation of product quality by way of using sensors which detect the quality attributes of the crop and thus inputs are to be applied accordingly. In production systems where quality premiums exist, this may alter the amount of input required to optimise profitability and agronomic response.
4. **Most efficient chemical and seed use:** PA involves efficient use of inputs i.e. chemicals, seeds etc. according to the yield potential of the soil.
5. **Effective and efficient pest management:** One goal of precision farming is to cut crop production inputs, which result in cost and environmental savings. Whereas conventional farming methods apply herbicides, insecticides etc. to the entire field, site-specific variable rate application puts these chemicals (i.e. herbicides, insecticides) where the problem appears.
6. **Energy, water and soil conservation:** A comprehensive approach to PA begins from crop planning and thus includes such tillage practices which conserve the soil or disturb the soil to its minimum. Besides, water is efficiently applied by using techniques like drip irrigation etc. In all these cases, very less energy is used and thus PA leads to conservation of energy also.
7. **Surface and ground water protection:** PA aims at safeguarding the environment by way of efficient use of inputs like chemicals etc. This prevents their leaching through ground water or as runoff through surface water.
8. **Minimising environmental impact:** If better management decisions are being made to tailor inputs to meet production needs then by default there must be a decrease in the net loss of any applied input to the environment. This is not to say that there is no actual or potential environmental damage associated with the production system, however, the risk of environmental damage is reduced.
9. **Minimising Risk:** Risk management is a common practice today for most farmers and can be considered from two points of view – income and environmental. In a production system, farmers often practice risk management by erring on the side of extra inputs while the unit cost of a particular input is deemed 'low'. Thus a farmer may put an extra spray on, add extra fertilizer, buy more machinery or hire extra labour to ensure that the produce is produced/ harvested/sold on time thereby guaranteeing a return.

Potential benefits of precision farming

Precision agriculture's effectiveness is highly dependent on how much variability exists within the fields and the ability of a producer to identify and put into use the best management practices for each field's sub-area. If the spatial data provided by PA is properly used, the following potential benefits can be realized:

- **Increased profits through increased efficiency:** With PA, one can use farming inputs more efficiently by applying more of them where more are needed and less where less are needed.
- **Reduced agronomic inputs:** Many producers who adopt PA technologies find their overall use of production inputs (fertilizer, lime and chemicals) decreases because they can better adjust to a field's fertility level, the amount of inputs applied.
- **Better record keeping:** PA technology generates large amounts of data that are spatial records of inputs and outputs for fields. These data can help to create more accurate management plans.
- **Improved production decisions:** PA can be used to make land use decisions. Profit maps, which show the spatial distribution of a field's profitability can help to make decisions about which cropping systems work best. We may also be able to identify areas that should be enrolled in government programmes such as the federal Conservation Reserve Programme (CRP) or removed from production, if low yields cannot be profitably corrected.
- **On-farm research:** The ability to quantify the spatial performance of crops allows to conduct more comparison trials within fields. For example, it is relatively simple to compare the performance of different varieties on different soil types, when practising PA.
- **Reduced environmental impact:** If we apply and use production inputs more efficiently, less material will leave the field through surface water and ground water. Reduced environmental impact can only improve the public's perception and acceptance of producers agricultural practices.
- **Property advantages:** Many landlords are giving preference to farmers who can create yield maps and other files of spatial data for the fields they farm. This spatial history may also increase the value of cropland.
- **More ground farmed:** The records generated can allow to effectively manage more cropland than we had in the past.

Constraints involved in precision agriculture

- Small land holdings: More than 58 per cent of operational land holdings in India have size less than one hectare, besides these land holdings are fragmented.

- High cost technology: PA implementation involves many cost effective technologies.
- Heterogeneity of cropping systems.
- Lack of local technical expertise and knowledge
- Technological gaps

Misconceptions carried by precision agriculture

Like many new concepts, PA carries with it some misconceptions

- ♦ PA is often confused with yield mapping. Yield mapping is a tool that is one of the first steps towards implementing a SSCM strategy.
- ♦ PA is sometimes misinterpreted as sustainable agriculture. PA is a tool to help make agriculture more sustainable however, it is not the total answer. PA aims at maximum production efficiency with minimum environmental impact. Initially it was the potential for improved productivity (and profitability) that drove the development of SSCM as a form of PA.
- ♦ Finally, machinery guidance and auto steer systems are examples of the successful adoption of new technology on farms. However, these again are tools that help with SSCM. By themselves they are not PA.

Elements of precision farming

A) Information
B) Technology
C) Decision support (management)

A) Information includes data on

- Crop characteristics like stage of crop, crop health, nutrient requirement etc.
- Detailed soil layer with physical and chemical properties, depth, texture, nutrient status, salinity and toxicity, soil temperature, productivity potential etc.
- Microclimate data (season and daily) about the canopy temperature, wind direction and speed, humidity etc.
- Surface and sub-surface drainage conditions
- Irrigation facilities, water availability and other planning inputs of interest.

B) Technology

PA is an integrated agricultural management system incorporating several technologies. The technological tools often include:

1. **Global positioning system (GPS):** A global positioning system (GPS) is one of the cutting edge technologies of the information age. It asks the basic question "where is it"? It is a versatile navigational aid. It is computer based and the key components in this technology are satellites. GPS depends on 24 satellites (courtesy of the US Department of Defence) that are strategically positioned in orbits such that, at any given time and place on earth, one can have a line of sight to atleast four of these satellites. Using the technique of "Trilateration", a user is able to access atleast three satellite signals, each producing a surface that will overlap each other to locate the site in question, providing both longitude and latitude. A fourth satellite signal allows the altitude of the site to be calculated.
2. **Geographical information system (GIS):** A geographic information system (GIS) is a computer based system for storing very large amounts of data (collected based on spatial location), retrieving, manipulating, and displaying them for easy interpretation. The term "geographic" should be interpreted to mean "space" or "spatial". For crop production, some of the data of importance are soils, land use, vegetation, fertility, hydrology, and rainfall averages. Spatial analysis is concerned with analysing data involved with changes with space on location within an area. GIS has the capability of linking multiple sets of data (in layers) to study relationships among various attributes and creating new relationships. GIS is an aid for decision making. It can be used to answer the location question "what is there"? It can also be used to study trends that is, answer the question "what has changed since a certain point in time"? Another application of GIS is in the area of prediction of change or modelling.
3. **Yield monitors:** Yield monitors are crop yield measuring devices installed on harvesting equipment. The yield data from the monitor is recorded and stored at regular intervals along with positional data received from the GPS unit. GIS software takes the yield data and produces yield maps.
4. **Variable Rate Technology:** consists of farm field equipment with the ability to precisely control the rate of application of crop inputs and tillage operations. Typical VRT system components include a computer controller, GPS receiver, and GIS map database. The computer controller adjusts the equipment application rate of the crop input applied. The computer controller is integrated with the GIS database, which contains the flow rate instructions for the application equipment. A GPS receiver is linked to the computer. The computer controller uses the location coordinates from the GPS unit to find the equipment location on the map provided by the GIS unit. The computer controller reads the instructions from the GIS system and varies the rate of the crop input being applied as the equipment crosses the field. The computer controller will record the actual input being applied as the equipment crosses the field.
5. **Remote Sensing:** is the art and science of obtaining information from a distance, i.e. obtaining information about objects or phenomena without being in physical contact with them. The science of remote sensing provides the instruments and theory to understand how objects and phenomena can be detected. The art of remote sensing is in the development and uses analysis techniques to generate useful information (Aronoff, 1995) [2].

Application of Remote Sensing in Precision Agriculture

1) Soil and drainage maps

Soil maps: The grid sampling technique takes separate soil samples from uniform sized grids laid out over the field. A problem with this type of sampling is the variability that can exist in soil types within each grid. This variability makes it much tougher to determine soil characteristics within the grid for crop input management purposes. To minimise this problem smaller grids are required which then requires many more soil samples to be taken for a larger number of grids.

Drainage maps: colour infrared (CIR) aerial photographs have been shown to be an effective tool in locating unknown subsurface tile lines. The image data is digitised for pre-processing and then geo-referenced using ground control points. The CIR photographs show different tones of grey depending on soil type and moisture. By filtering out spectral reflectance differences due to soil type, soil moisture content in dry soils that have a higher reflectance can be identified from lower reflectance wet soils. The resulting image shows where the tile lines are located and whether they are working properly (Verma *et al.*, 1997) [11].

2) Monitor crop health

Remote sensing data and images provide farmers with the ability to monitor the health and condition of crops. Multispectral remote sensing can detect reflected light that is not visible to the naked eye. The chlorophyll in the plant leaf reflects green light while absorbing most of the blue and red light waves emitted from the sun. Stressed plants reflect various wave lengths of light that are different from healthy plants. Healthy plants reflect more infrared energy from the spongy mesophyll plant leaf tissue than stressed plants. By being able to detect areas of plant stress before it becomes visible, farmers will have additional time to analyse the problem area and apply a treatment.

3) Water stress

The use of remote sensors to directly measure soil moisture has had very limited success. Synthetic Aperture Radar (SAR) sensors are sensitive to soil moisture and they have been used to directly measure soil moisture. SAR data requires extensive use of processing to remove surface induced noise such as soil surface roughness, vegetation and topography.

A crop evapotranspiration rate decrease is an indicator of crop water stress or other crop problems such as plant disease or insect infestation. Remote sensing images have been combined with a crop water stress index (CWSI) model to measure field variations (Moran *et al.*, 1997) [7].

4) Weed management

Aerial remote sensing has not yet proved to be very useful in monitoring and locating dispersed weed populations. Some difficulties encountered are that weeds often will be dispersed throughout a crop that is spectrally similar, and very large-scale high resolution images will be needed for detection and identification (Ryerson, *et al.*, 1997) [9].

The use of machine vision technology systems to detect and identify weeds places remote sensors directly on the sprayer equipment. Being close to the crop allows for very high spatial resolutions. Machine vision systems have the ability to be used in the field with the real time capabilities that are necessary to control sprayer equipment (Steward and Tian, 1998) [10].

5) Insect detection

Aerial or satellite remote sensing has not been successfully used to identify and locate insects directly. Indirect detection of insects through the detection of plant stress has generally not been used in annual crops. The economic injury level for treatment is usually exceeded by the time plant stress is detected by remote sensing. Entomologists prefer to do direct in field scouting in order to detect insects in time for chemical treatments to be effective and economical.

6) Nutrient stress

Plant nitrogen stress areas can be located in the field using high resolution colour infrared aerial images.

The reflectance of near infrared, visible red and visible green, wavelengths have a high correlation to the amount of applied nitrogen in the field. Canopy reflectance of red provides a good estimate of actual crop yields (Geopalapillai *et al*., 1998) [4].

7) Yield forecasting

Plant tissue absorbs much of the red light and is very reflective of energy in near infrared (NIR) wavebands. The ratio of these two bands is referred to as the vegetation index (VI). The difference of red and NIR measurements divided by their sum is normalised difference VI (NDVI).

For crops such as grain sorghum, production yields, leaf area index (LAI), crop height and biomass have been correlated with NDVI data obtained from multispectral images (Anderson *et al.*, 1996) [1]. In order to get reasonably accurate yield predictions this data must be combined with input from weather models during the growing season (Moran *et al.*, 1997) [7].

C) Decision support (management)

Just having information about variability within the field does not solve any problems unless there is some kind of decision support system (DSS) in order to make VRT recommendations. Russo and Dantinne (1997) [7] have suggested the following steps for a DSS:

1. Identify environmental and biological states and processes in the field that can be monitored and manipulated for the betterment of crop production.
2. Choose sensors and supporting equipment to record data on these states and processes.
3. Collect, store and communicate the field recorded data.
4. Process and manipulate the data into useful information and knowledge.
5. Present the information and knowledge in a form that can be interpreted to make decisions.
6. Choose an action associated with a decision to change the identified state or process in a way that makes it more favourable to profitable crop production.

Methods for implementing a precision farming strategy

1. **Map based technologies –** This is currently the most widely used method. It may involve a GIS-based method of pre-sampling and mapping of the field. The computer generated maps are then converted into a form that can be used by the variable rate applicator. The applicator's controller then calculates the desired amount of an agronomic input to apply at each moment in time as the equipment traverses the field. The farmer knows how much of the agronomic input is needed before starting the application. A DGPS (Differential Global Positioning System) must be used to constantly evaluate the location in the field with a coordinate on the map and the desired application rate for that coordinate.
2. **Sensor-based technologies –** This method offers real-time sensing and variable rate control. The strategies provide on –the - go sensing of field characteristics, thereby eliminating the need for a positioning system. The sensors must be mounted strategically (e.g. at the front of the tractor) to allow the variable rate applicator's controller adequate time to adjust the rate of the agronomic input accordingly, before it passes the sensed location.

Steps involved in precision agriculture adoption

1. **Purchase a mapping programme:** The first and most essential acquisition will be an entry level mapping programme, which will allow to import, overlay and manage spatial data. This software will enable to develop a geographically referenced database for the operation
2. **Collect spatial data:** Look for existing geographically referenced data on the Internet. These and other layers of information will form the basis of the farm's geographic database.

3. **Map field boundaries:** Service providers will map your fields for a nominal fee, or you can obtain a digital global positioning system (DGPS) receiver and a laptop or hand held PC do it yourself.
4. **Keep records:** Farm records should be organised on a field by field basis. These records should include:
   - Historical yields (whole field)
   - Field boundary locations
   - Soil test values
   - Management history, including past fertility, tillage, pest management practice and financial records.

   To the extent possible, these records should be archived electronically in the mapping system.
5. **Obtain remote images:** Aerial or remotely sensed images of the fields should be obtained one or more times during each growing season. These images can be used to identify management problems that cannot be seen from the ground e.g., we can locate areas where inputs such as nitrogen have been misapplied. It may also be possible to detect moisture or pest stresses
6. **Purchase a yield monitor:** A yield monitor on the combine will allow to determine total yields for fields or areas within fields without a weigh wagon or scales. This yield information will make it possible to do side by side comparisons of hybrids or management practices. In addition, the dynamic yield indicator in the combine's cab will enable the combine operator to observe quantitative differences in yield throughout the field.
7. **Purchase a DGPS receiver:** We can greatly expand what a yield monitor can do if we add a differential global positioning system (DGPS) receiver. The yield monitor will record DGPS position along with yield, enabling to create yield maps and evaluate how the yields vary according to location.
8. **Generate yield maps:** With the yield monitor in place and a DGPS receiver connected, we are ready to create yield maps. Most yield monitors have companion software that will create yield maps from field data. The mapping programme can also create yield maps.
9. **Use yield maps for scouting:** One of the fundamental uses of yield maps is to locate trouble spots in a field. The yield map will help to locate problems we may not have been aware of. Once we identify them, we can decide if they can be profitably corrected.
10. **Generate profit maps:** If we have been keeping good records, including accurate yield maps, we will then be ready to get the field's profitability. Use yield information along with the cost of all inputs and field treatments, such as tillage, to generate a profitability map of the field. Locate areas of high and low profitability.
11. **Use yield and profit maps for land – use decisions:** A land use decision is the first decision most farmers make about a tract of land. We can use PA technologies to identify certain areas of the field that are low yielding or unprofitable year after year and remove these areas from production and/or enroll them in government programmes, such as the CRP. We can also combine profit maps with other field information, such as soil types, to identify areas suitable for different crops or rotations.
12. **Take site-specific soil fertility samples:** Both grid and directed sampling are used to describe soil properties for management of variable rates of fertility. In either system, collect atleast five or six subsamples from each cell or zone and mix them into one sample container. When soil fertility data is returned from the soil testing lab, we can enter the data into the mapping programme to create fertility maps.
13. **Manage subfields:** Once fertility maps have been created, we can use them to make spot applications in parts of fields that are especially low in pH or other plant nutrients. This relatively crude application can be accomplished without specially equipped machines. Simply look at the fertility map and try to make applications in the deficient areas. If we have a DGPS receiver and computer, we may be able to increase our accuracy of application by following the cursor on the field map.
14. **Adopt variable rate technology (VRT):** Variable rate management is the continuous adjustment of inputs to match local field conditions. Variable rate controllers are required on application equipment for automatic control of application or seeding rates in the field. They are used along with a task computer (a laptop PC) and DGPS receiver. In addition, the software must be able to generate application files to control the process.

Precision agriculture: is really needed in India's context?

1. On the one hand there are depletions of ecological foundations of the agro-ecosystems, as reflected in terms of increasing land degradation, depletion of water resources and rising trends of floods, drought and crop pests and diseases. On the other hand, there is imperative socio-economic need to have enhanced productivity per units of land, water and time.
2. At present, 3 ha of rainfed areas produce cereal grain equivalent to that produced in 1 ha of irrigated. Out of 142 m ha. Net sown areas, 92 m ha are under rainfed agriculture in the country.
3. From equity point of view, even the record agricultural production of more than 200 Mt is unable to address food security issue. A close to 60 Mt food grains in the storehouses of Food Corporation of India (FCI) is beyond the affordability and access to the poor and marginalized in many pockets of the country.
4. Globally, there are challenges arising from the globalisation especially the impact of WTO regime on small and marginalized farmers.
5. Some other unforeseen challenges could be anticipated. Global warming scenario and its possible impact on diverse agro-ecosystems in terms of alterations in traditional crop belts, micro-level perturbations in hydrologic cycle and more uncertain crop weather interaction, etc.

At this stage, agriculture needs new paradigms to deal with the present situation. The strategy lies in integration of the dynamic information and scientific knowledge into the management of agro-ecosystems, and thereby optimising the radiation, water and nutrient usages. Agriculture needs transition from high inputs material inputs to the optimum level, through the appropriate use of information, knowledge and strategies for efficient resource usages. In such case, productivity of agriculture may not be the function of the quantum of agricultural input use alone, but will include information, knowledge and efficiency while managing the agricultural practices.

Precision farming development centres (PFDC) in India

There are about 16 Precision Farming Development Dentres (PFDC) in india namely:

1. PFDC Jorhat Assam.
2. PFDC Samastipur Bihar.
3. PFDC HAU Hissar.
4. PFDC Bikaner Rajasthan.
5. PFDC Raipur Chatisgarh.
6. PFDC Hyderabad.
7. PFDC IARI.
8. PFDC KAU Kerala.
9. PFDC Bhubaneshwar Orissa.
10. PFDC Bangalore.
11. PFDC Rahuri Maharashtra.
12. PFDC Navsari Gujarat.
13. PFDC Lucknow.
14. PFDC Pantnagar.
15. PFDC Coimbatore TN.
16. PFDC IIT Kharagpur W.Bengal.

Conclusion

- A truly comprehensive approach to precision agriculture must cover all phases of production from planning to post harvest.
- Information, technology and management are combined into a production system that can increase productivity, improve product quality, allow more efficient chemical use conserve energy and provide for soil and ground water protection.
- Technology and management practices such as field scouting, field mapping, variable rate control, yield mapping and post harvest processing can readily be adapted to vegetable crop production. However, the technology related to precision farming needs refinement to realize benefits (Kalia, 2005) [6].
- Questions remain about cost effectiveness and the most effective ways to use the technological tools we now have, but the concept of doing the right thing in the right place at the right time has a strong initiative appeal.
- Ultimately, the success of precision agriculture depends largely on how well and how quickly the knowledge needed to guide the new technologies can be found.

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