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PRECISION FARMING: COMPONENTS AND APPLICATIONS–A REVIEW

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ABSTRACT: Agriculture is the backbone of our country and economy, which accounts for almost 30 per cent of GDP and employs 70 per cent of the population. Over the last decade, technical methods have been developed to utilize modern electronics to respond to field variability. Such methods are known as spatially variable crop production, geographic positioning system (GPS)-based agriculture, site-specific and precision farming (precision agriculture). The term 'spatially variable crop production' seems to be more accurate and descriptive than the term precision agriculture. The concept of Precision Agriculture avails the recent developments in sensors, green-house and protected agriculture structures. This technology can be meaningfully deployed for hot and extremely dry regions where water is scarce, soil is salty, temperature is high and rainfall is low. It is also certain that even in developing countries, availability of labour for agricultural activities is going to be in short supply in future. The time has now arrived to exploit all the modern tools available by bringing information technology and agricultural science together for improved economic and environmentally sustainable crop production. Precision Agriculture is an integrated crop management system that attempts to match the kind and amount of inputs with the actual crop needs for small areas within a farm field.

Keywords: *Precision farming, GPS, information technology, management.*

Precision Farming is defined as the principles and application of information technology to identify, analyze and manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality. Precision Farming is also referred to as Prescription Farming or Site Specific Farming, Global Positioning System (GPS) based farming and Variable rate farming (Nadanassababady, 8). Precision Farming is concerned with the management of variability in dimensions of both space and time. Variability of resources therefore is a key factor of precision farming. Any component of production system ranging from natural resources plants, production inputs, farm machinery and farm operations that is variable in some way, is included in the realm of precision farming. Aspects of precision farming, therefore encompass a broad array of topics, including variability of soil resource base, weather, plant genetics, crop diversity, machinery performance and most of the physical, chemical and biological inputs used in the production of a crop. These are closely linked to the socio-economic aspects of production system, because to be successful on the farm, precision farming should fit the needs and capabilities of farmer and should be profitable. Success in precision farming is directly related to how well it can be applied to manage the space-time continuum in production system. The prospects of precision management increase as the degree of spatial dependence increases. However, degree of difficulty in achieving precision management increases as the degree of spatial dependence increases. Similarly, degree of difficulty in achieving precision management increases with temporal variance. Thus, for management parameters that vary spatially, those with high temporal correlations will be more easily managed with precision farming rather than those with large temporal variance. Within a given management parameter, the success to the date of precision management is to a large extent determined by the degree to which the spatial variability is temporally stable.

Precision farming in the Indian context is still

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in its infancy stage. A vast amount of data on various aspect like soil characteristics, climatic parameters, topographic features, crop requirement in terms of consumptive use and nutritional requirements have been generated and instruments needed for recording these parameters are also available. Technology for delivering the required amounts of inputs to the crop through fertigation/chemigation has also been developed in the country. However, application of precision farming as a package in farmer's field has received little attention, although some aspects of precision farming have been practiced. This has been primarily due to lack of awareness about potential for increasing productivity and improving the quality of produce with minimum use of inputs. Use of *in vitro* plants, fertigation and nutrient management based on soil analysis in banana have increased the yield manifold and improved the quality. Use of fertigation in grape coupled with nutrient applications based on petiole analysis added with bunch management has increased the yield and quality. There are many other examples wherein a few components of precision farming have been adopted to enhance the efficiency of inputs to get higher output in given time frame.

ASPECTS OF PRECISION FARMING

1. Precision Farming is taking care of each and every plant in a farmer's field through its crop cycle.

2. Precision farming is a technology enabled information based and decision focused.

3. Information, technology and management are key elements of Precision Farming.

OBJECTIVES

1. To identify the variability of soil physical and chemical properties.

2. To understand the impact of soil variability on crop growth, yield and profitability.

3. To increase agricultural production, profit and quality of the produce

4. To reduce environmental pollution.

COMPONENTS OF PRECISION FARMING

1.Geographical Information System (GIS)

2.Global Positioning System (GPS)

3.Sensors

4.Variable Rate Technology

5.Yield Monitoring and Mapping

1. Geographical Information System (GIS)

Geographical Information System is an organized collection of computer hardware, software, geographical data and designed to efficiently capture, store, update, manipulate analyze and display all forms of geographically referenced information. It provides data storage, retrieval and transformation of spatial (field) data. A fully functional GIS can be used to analyze characteristics between layers to develop application maps.

Functions of GIS

1. Store data such as soil type, nutrient level etc. in layers and assign that information to the particular field location.

2. Develop application maps showing variability of nutrient level, soil type, topography, pest incidence and yield etc.

Types of GIS

1. Software that automatically creates maps from a given data set with a minimum ability to modify the default map attributes. Examples of this software include JD Maps, Agleader Precision Map 2000, Micro-Trak utilities and Farm Works Quick Yields.

2. Software provides more flexibility to the change map parameters and creates maps of several attributes. Examples include SGIS, Crop Growers VisAg, Farmsite and AgINFO.

3. Software has a front-end added to it so that it can be used for agricultural mapping. Examples

include such as SSToolbox, FarmHMS, RDIAgMAPP, AgLink and GIS.

Uses of GIS

GIS provides means of visualizing and modeling the distribution of potato plants and pests by using maps (Seem, 10).

GIS was used in identifying the suitable areas for production of crops like maize and potato (Ceballos and Lopez, 2).

Use of GIS-N model system to assess nitrate leaching in vegetables (Paz-J-De *et al.*, 9).

Estimation of global severity of potato late blight with GIS linked disease forecast models (Hijmans *et al.,* 5).

2. Global Positioning System (GPS)

GPS is a set of 24 satellites in high altitude orbit above the earth for pinpointing objects on the surface of the earth. A GPS receiver requires at least four satellites to determine its position on earth. The accuracy of the calculated position is reduced by a deliberate offset in the signal and atmospheric conditions. The degraded signal reduces accuracy to about 300 feet; therefore, the raw GPS signal is not sufficiently accurate to determine position within a field. An additional signal from a known position (reference) is needed to provide the necessary accuracy. This additional signal can come from a land-based reference signal, or from another satellite. GPS that utilizes a reference signal to gain more accurate positional data is a Differential Global Positioning System (DGPS).

Functions of GPS

1. Satellites continuously transmit radio signals that are picked up and decoded by special receivers.

2. GPS tells the location of a particular object on earth.

Uses of GPS :

Use of GPS and sensors on yield mapping during potato harvest (Ehlert, 4).

GPS for precision farming in beet and potato (Stafford *et al.,* 14).

3. Sensors

Sensors are the devices that transmit an impulse in response to a physical stimulus such as heat, light, magnetism, motion, pressure and sound with computers to record the sensor impulse. Sensors are being developing to determine crop stress, soil properties and pest incidence. Sensors can be used to measure soil and crop properties, as the tractor passes over the field, as a scout goes over the field on foot, or as an airplane or satellite photographs the field from the sky.

Types of Sensors

Remote sensor

I. A sensor that measures the characteristics of a field (soil and plant) without having contact with the characteristic being sensed.

II. Remote sensors are generally categorized as aerial or satellite sensors that can provide instant maps of field characteristics.

III. An aerial photograph is a sensor that can show variations in field colour that corresponds to the changes in soil type, crop development, field boundaries, roads and water etc.

"On the go" sensor

These sensors make measurements "on the go" when a tractor passes over the field.

Sensor carried by a scout

These are sensors that can be carried by a scout to a field and used to spot-check the health of plants and soil properties.

Uses of Remote Sensing

Remote sensing of potato canopy provide

the information for detection of nutrients deficiencies in visible and infra red radiations (Wang *et al.,* 17).

A colour infrared digital camera was used to acquire multiangular images on potato cultivar Monalisa to detect water stress (Casa *et al.,* 1).

Feasibility in assessing seasonal trends in potato acreage using Indian Remote Sensing-Wild Field Sensor (IRS-WiFS) data was determined (Singh *et al.,* 13).

Use of remote sensing with multispectral imaging for nondestructive measurements of growth and physiological status of Chinese cabbage in greenhouse (Suming *et al.*, 16).

Nondestructive detection of water stress in tomato plants by microwave sensing (Shimomachi *et al.*, 11).

Targeted control of potato cyst nematode using remote sensing (Stephens *et al.,* 15).

Application of remote sensing in quantifying crop growth and yield in tomato (Koller *et al.,* 6).

4. Variable Rate Technology

Consist of following parts :

1. Control computer : It coordinates the field operation.

2. Locator : It tells the accurate position of equipment in the field as it is linked to GPS.

3. Actuator : It does the input application in the field.

5. Yield Monitoring and Mapping

A yield monitor measures the crop as it is harvested. As the yield is measured, data is stored on computer along with GPS coordinates at that point where the field was measured. Mapping software creates a yield map and this map provides information of variability and yield production. Commercial yield monitors have been introduced for cotton only. Yield monitors are in the development stages for pecan, citrus, peaches and vegetables.

PROFIT MAPPING

A profit map can be created using records of field inputs and records of crop yield and sales. The profit map can be created to determine what areas of the field are making or loosing money.

P = GI-I

P = Profit

GI = Gross Income

I = Costs (Fixed and Variable)

STEPS IN PRECISION FARMING

Assessing variability

Mapping variability

Managing variability

ASSESSING VARIABILITY

1. Survey: Surveys can be done manually and we can know about variability like soil type, nutrient level, pest and insect infestation and yield distributions etc.

2. Remote sensing: With the help of aerial photographs, instant maps of fields can be taken and by seeing these maps variability can be assessed.

MAPPING VARIABILITY

Components of Variability

1. Spatial Variability : Climate, infrastructure, soils and yield distributions.

2. Temporal Variability : Climate, nutrient requirement, pest, diseases, weeds and yield distribution.

3. Projected Variability : Crop forecast and weather forecast

Types of Variability

1.Yield Variability: Yield distributions

2. Field Variability: Field topography and elevation

3. Soil Variability

(i) Soil fertility (N, P, K, Ca, Mg, C, Fe, Zn and C)

(ii) Soil physical properties (texture, density, moisture content and electrical conductivity)

(iii) Soil chemical properties (organic matter, salinity, CEC, soil depth and water holding capacity)

4. Crop Variability: Crop density, crop height, crop nutrient status, crop water stress, leaf chlorophyll content and leaf area index.

MANAGING VARIABILITY

1. Map Based: In GIS, there are different maps showing variations in soil type, nutrient status and yield distributions etc. This variability can be managed with the help of a VRT applicator, by applying accurate amount of inputs in a particular location in the field.

2. Sensor Based: Sensors are used in this method. Sensors tell about different soil and plant variations and these variations are managed by VRT applicator, by applying exact amount of inputs in particular location in the field.

APPLICATIONS OF PRECISION FARMING

Soil Fertility Management

Nutrient input to crop production is important because soils don't supply nutrients in sufficient quantities naturally to meet nutrient demands of commercial crops. Important inputs to crop production, fertilizers and manures are also identified as major sources of nutrient contamination of surface and ground water in agriculture areas. Soils vary in their ability to supply nutrients to plants and crops vary in their demand for nutrients. Since soil supply and plant demand vary in space and time and nutrient losses through leaching, erosion and runoff also vary temporally and spatially indicates that significant opportunities nay exist for precision management of soil fertility. The potential for improved precision in soil fertility management combined with increased precision in application control make precision soil fertility management an attractive, but largely unproven, alternative to uniform field management (Laxmanan, 7).

Management of phosphorus and potassium

Precision management of P and K was an early focus of precision farming because there was an established basis for fertilizer recommendations in soil testing that could theoretically be applied at any scale. Moreover, the technology to apply fertilizer variably became available in the mid-1980s. Spatial variability in P and K was already known and was not difficult to measure within agriculture fields. The concept of VRT was very intuitive and easy to understand and implement. The temporal component of the spatial variability of P and K is low, making it easy to soil test at a convenient time and requiring only periodic/validation. The current basis for precision management of P and K, therefore, is fertilizer recommendations based on traditional soil fertility tests using various sampling schemes to assess within field variability.

Management of nitrogen

The precision management of N is applicable to situations in which the factors that control total N in soils and N variability to plants vary spatially. However, precision N management is increasingly more difficult but may in fact have increasingly more environmental benefits as the temporal component of spatial variability N availability increases. For this reason, precision management is more complex than precision management of lime, P and K but may have significantly more value. Both N deficiency and excess N availability creates problems for production agriculture. Most fertility concerns are focused on deficiencies in N availability to plants because they reduce yield and quality of crop. Excess nitrate-N in soil can lead to N losses to the environment that reduce water quality and can reduce yield and quality for some crops. Leaching, runoff and de-nitrification are processes that result in loss of N from the soil plant system creating the potential for N deficiency in crops and degradation of water and air quality. The environmental threat of N losses from soil is further compounded by application of manures at rates in excess of crop nutrient needs. Thus, where soils or landscape consistently regulate water availability, precision management would have potential.

Pest management

Weeds, insects and diseases are an ever-present costly management problem to crop production because significant infestations reduce crop yield and quality and if severe can limit crop production options. Public concerns regarding the impacts of pesticide use include health risks related to food safety, water quality and worker safety and concerns over wild life and ecosystem health. Therefore, agricultural management practices that reduce pesticides use, to improve pest management or reduced risks of pesticides to human and ecosystem heath is very desirable. The potential direct economic benefit of precision pest management is the reduction in chemical /non-chemical pest management costs, crop damage or both due to more efficacious or efficient application of pest control measures. A reduction in pesticide use, however, does not translate into profit if, the cost of obtaining information about pest populations and distributions exceeds the savings. Environmental benefits are presumed to result from a reduction in pesticide usage, particularly in sensitive environments. However, the results of the few studies on the potential of precision farming to provide environmental benefits have been inconclusive regarding its effect on pesticide use.

Weed management

The application of precision farming to weed management is potentially benefit agriculture because (1) it offers an opportunity to reduce chemical/non chemical inputs into crop production through site-specific weed control and the use of precise application techniques and (2) the acquisition of spatial and temporal information on weed occurrence and distribution made possible with precision agriculture technologies, will lead to a improved understanding of weed biology and ecology needed to develop more efficient weed management strategies. Precision weed management is possible because weeds are spatially aggregated and not randomly distributed within most agronomic fields and because the efficacy, efficiency and fate of weed control inputs vary with weed and crop conditions and with soil physical and chemical properties. All of which can vary spatially and to a varying extent, temporally. A common approach to precision weed management is site-specific weed control achieved by (1) applying herbicides only where weeds are present or above economic threshold levels, termed intermittent herbicide application or patch spraying (2) varying herbicide application (type, formulation or rate) according to soil physical and chemical properties or weed characteristics (species, growth stage and density), (3) some combination of the two approaches. For prevention or pre-emergence weed control, site-specific application requires prior knowledge of historical wed distributions since no weeds are visible at the time of application. This knowledge can be obtained by mapping weed aggregation in previous years. Weed control treatment or intensity can also be varied based on soil properties according to the label or other recommendations, if, knowledge of the spatial variation of these properties is adequately known.

Insect management

Precision insect management has potential because distributions of insect populations are spatially variable, in part because insects are mobile during at least part of their life cycle and in part because during the relatively non-mobile stages insects cluster in response to environmental and behavioral responses. Therefore, precision insect management has the potential to reduce insecticide application and improve the efficacy of both prevention and intervention insect management strategies. A major difficulty with the management of insects is that their populations are highly dynamic and prediction of insect density is difficulty or uncertain.

Soil moisture management

Soil moisture forms one of the most important factors of crop production. Its supply to crop in adequate quantity is essential. Depending upon the soil and land features, the variability of the soil moisture varies. Besides the moisture requirement of the crop would vary depending upon the stage of growth. The fact that crop water requirements vary over time and space indicate the scope of precision management of soil moisture. Irrigation scheduling suing VRT combines knowledge of spatially variable soil water holding capacity, spatial and temporal variability of applied water, system delivery specifications and weather-driven crop evapo transpiration (ET) calculation. On the other hand under conventional systems, a single value of crop ET is typically used for entire field for use in irrigation scheduling software.

Cultivars selection

In GIS, there are different maps showing different climates of different regions. Which cultivar will suit to which climate can be known from these maps.

Yield estimation

Yield monitors tell about the yield of different locations. Which part of the field is loosing money and which part is making money can be estimated by these yield monitors.

Yield Monitoring and Mapping

Use of yield monitors on commercial fields in potato (Davenport *et al.,* 3).

Variable Rate Technology

Application of variable rates of P, K and lime in potato enhanced the potato yield and tuber quality (Simard *et al.,* 12).

CONSTRAINTS OF PRECISION FARMING IN INDIA

1. Smaller farm size
2. Heterogeneity of cropping systems
3. Market imperfections
4. Lack of technical expertise
5. Lack of data availability
6. Cost involved

SCOPE OF PRECISION FARMING IN INDIA

Precision farming technology in India can be adopted for almost all the crops. Computer literacy and high initial investment is needed all over the country. In state like Kerala, Precision Farming can be successfully followed in commercial crops like rubber, cardamom, tea, coffee and cocoa for improving the yield.

PRECISION FARMING SCENARIO IN INDIA

The initiative for promoting the precision farming concepts in India commenced recently in year 2001.In the year 2001, 17 Plasticulture Development Centers (PDC) were re-designated as Precision Farming Development Centers (PFDC) and 5 more PFDCs were started in the year 2008-09.

ADVANTAGES OF PRECISION FARMING

1. Provides more accurate farm records.
2. Improves crop yield.
3. Provides information to make better management decisions.
4. Reduces chemical and fertilizer costs through more efficient application.
5. Increases profit margin.
6. Reduces pollution.

DISADVANTAGES OF PRECISION FARMING

1.High initial cost involved.

2.Lack of technical experts.

FUTURE STRATEGIES

1. Adoption of Precision farming technology commercially.

2. Technology development and refinement in Precision farming.

3. Dissemination of Precision farming technology by trainings, seminars and workshops.

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