PRECISION AGRICULTURE

INTRODUCTION

Precision agriculture (PA) or precision farming (PF) aims at optimizing profitability and protecting environment through efficient use of inputs based on temporal and spatial variability of soils and crops. Both sensors based and satellite image based technologies have been developed and are being promoted in the developed world. Economic analyses of adoption of precision farming have indicated marginal profitability to already existing best management practices (BMPs) and higher productivity levels. Wide gap between potential and actual yield levels in developing world necessitates promotion of PF to achieve the intended benefits.

Gap between average farm yields and yield potential ceiling must shrink during the next 5 years because the yield potential of major crops appears to be stagnant. Rice, maize and wheat yield potentials are increasing more slowly than the expected increase in demand. Hence sustainable crop yields that exceed at least 70 per cent of yield potential barrier depends on sophisticated management of soil, water resources and other inputs. Precision agricultural approach is required to insure that the requisite resources for crop growth are available and crop protection needs are met without deficiency or excess at each point in time during the growing season. Precision management can be applied based on the requirement to the field at right time, right place, right quantity and by right method.

CONCEPTS OF PRECISION FARMING

“Precision farming is the technology which involves the targeting of inputs to arable crop production according to crop requirement on the localized basis”. (Stafford, 1996)

Aims

To Replace

- Big machinery
- High energy consumption
- Chemicals / at least over application

With

- Intelligent machines
- Intelligent processes

PRECISION FARMING v/s TRADITIONAL FARMING		
S. No.	PRECISION FARMING	TRADITIONAL FARMING
1.	Farm field is broken into "management zones"	Whole field approach where field is treated as a homogeneous area
2.	Management decisions are based on requirements of each zone	Decisions are based on field averages
3.	PF tools (e.g. GPS/GIS) are used to control zone	Inputs are applied uniformly across a field

Precision farming needs the requisition, management, analysis and output of large amount of spatial and temporal data. Mobile computing systems were needed to function on the go in farming operations because desktop systems in the farm office were not sufficient.

Basic concept of Precision Farming

- Use the right input
- At the right time
- In the right amount
- At the right place
- In the right manner

Precision farming basically depends on measurement and understanding of variability. Main components of precision farming system must address the variability.

Variability

There are 3 types of variability

- **Spatial variability:** Varies with space from one part of the field to other.
- **Temporal variability:** Varies with time from year to another.
- **Predictive Variability:** Varies with Farmers Prediction.

Precision farming is a farm management concept based on modern information technologies.

Components (enabling technologies) of precision farming include:

- Remote sensing (RS).
- Geographical information system (GIS).
- Global positioning system (GPS).
- Soil testing.
- Yield monitors.
- Variable rate technology (VRT).

Precision agriculture can be presented as management of three conceptual components: data collection, data analysis/interpretation and application/variable rate treatment. Another way of presenting these components is shown in Fig 1.3, in the form of cycles and the technology/operations involved in SSCM.

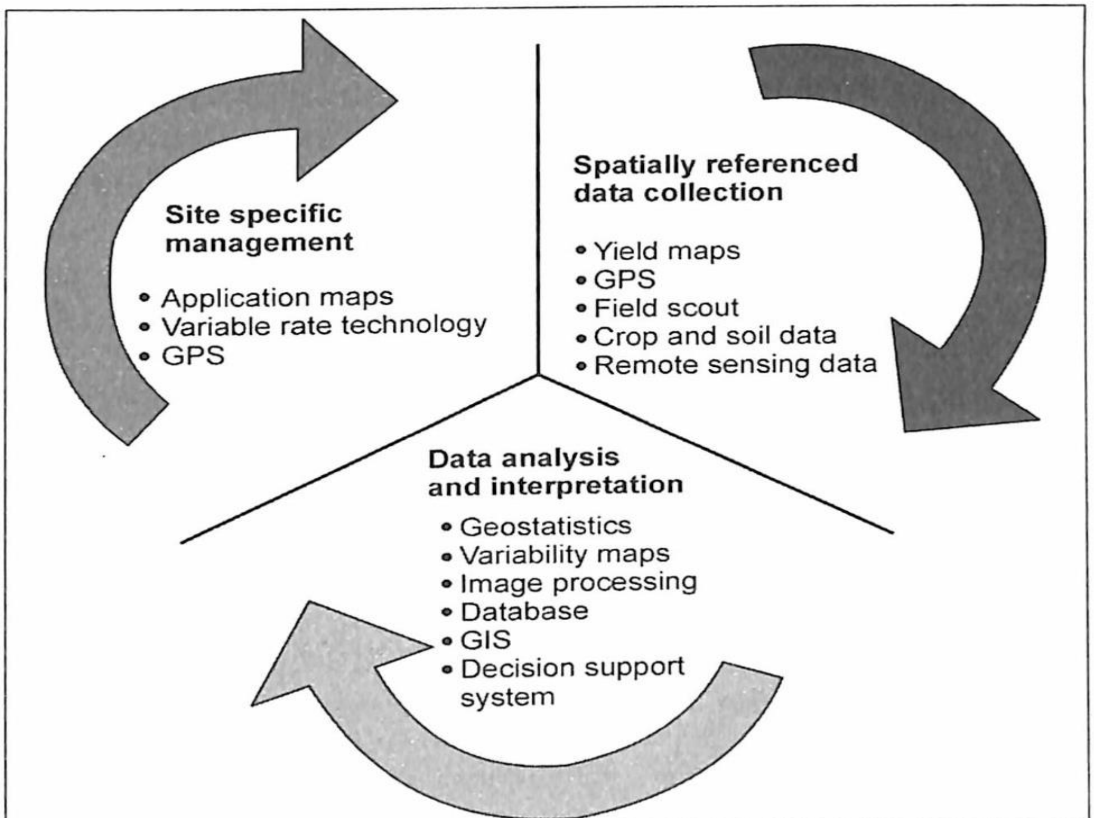


Fig 1.3. Data processing and management cycles for precision farming.

Production of food, feed and fiber are dependent on the quantity and quality of soil, plant, water and air. No matter what agricultural systems are used, without protecting the natural resources, yields will decrease until the point of no return. The concept that precision agriculture is a system, (Webster: interrelated, interacting, independent elements forming a complex whole), provides a more useful foundation for understanding precision agriculture. An agricultural system that can be used for:

- Land preparation.
- Seeding.

- Chemical application.
- Fertilizer application.
- Crop monitoring.
- Nutrient auditing.
- Soil and leaf testing.
- Pest management.
- Conservation practices.
- Gross margin analysis.

- Agro-geo-information, the agricultural-related geo-information, is the key information in the agricultural decision making and policy formulation process. Agro-geo-informatics, a branch of geo-informatics, is the science and technology about handling digital agro- geo-information, such as collecting (mainly through remote sensing and field investigation), processing, storing, archiving, preservation, retrieving, transmitting, accessing, visualization, and analyzing, synthesizing, presenting and disseminating agro-geo-information. Recent advances in geo-informatics have created new opportunities and challenges in applying agro-geo-informatics to agriculture monitoring, assessment and decision making.

STEPS IN PRECISION FARMING

Two basic steps in precision agriculture are: (1) Identification and assessment of variability and (2) Management of variability.

1. Identification and Assessment of Variability

Assessing variability:-

- In precision farming, inputs are to be applied precisely in accordance with the existing variability
- Spatial variability of all the determinants of crop yield should be well recognized, adequately quantified andproperly located
- Construction of condition maps on the basis of the variability is a critical component of precision farming
- Condition maps can be generated through (i) Surveys, (ii) Point sampling & interpolation, (iii) Remote sensing (high resolution) and (iv) Modeling

- **Grid soil sampling:** Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling compared to the traditional sampling. Soil samples collected in a systematic grid also have location information that allows the data to be mapped. The goal of grid soil sampling is to generate a map of nutrient/water requirement, called an application map.
- **Yield map:** Yield mapping is the first step to determine the precise locations of the highest and lowest yield areas of the field and to analyze the factors causing yield variation. One way to determine yields map, is to take samples from the land in a 100 x 100 m grid pattern to test for nutrient levels, acidity and other factors. Results can then be combined with the yield map to see if application levels need to be adjusted for more effective, yet more economical placement that produces higher crop yields.

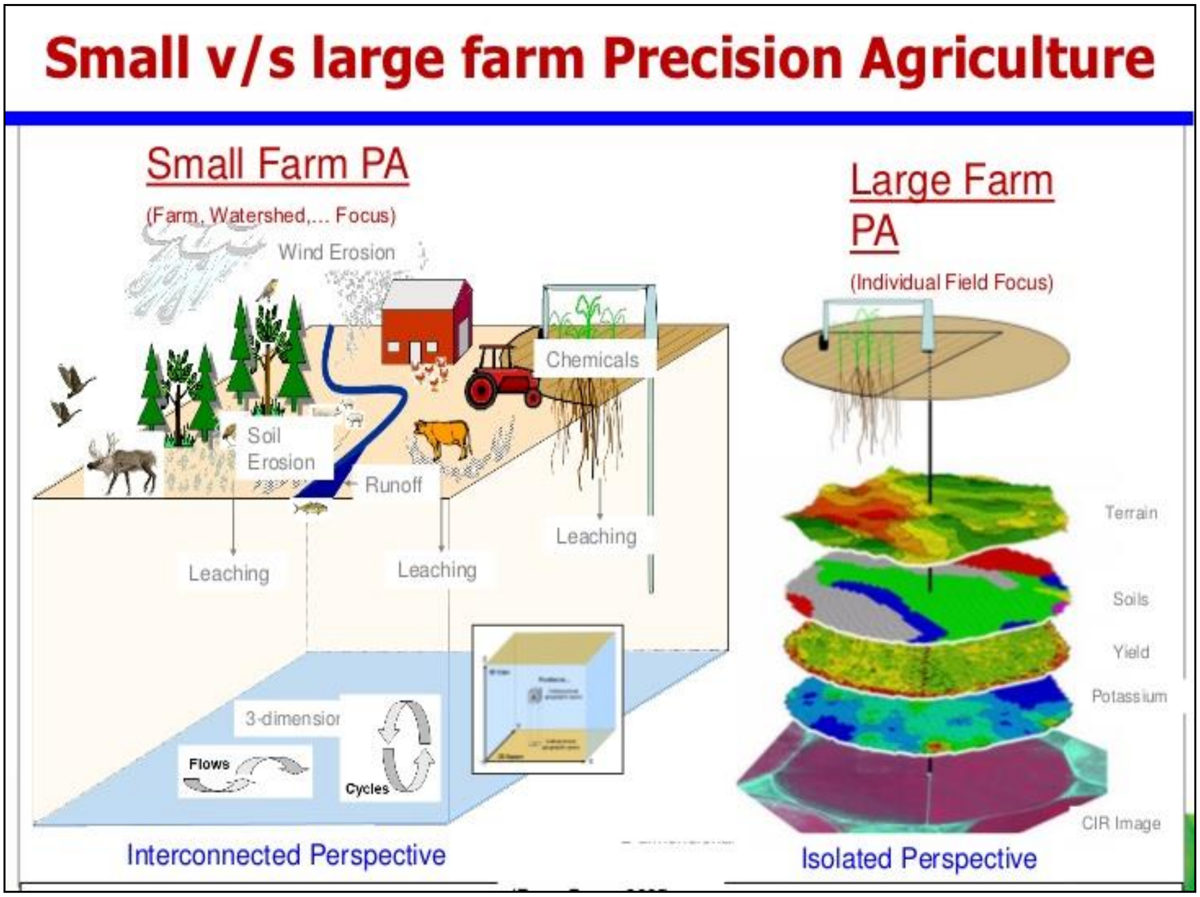
- **Crop scouting:** In-season observations of crop conditions like weed patches (weed type and intensity); insect or fungal infestation (species and intensity) and crop tissue nutrient status can helpful later when explaining variations in yield maps.
- **Use of precision technologies for assessing variability:** Faster and in real-time assessment of variability is possible only through advanced tools of precision agriculture.

2. Management of Variability

Managing variability:-

Variations occur in crop or soil properties within a field.

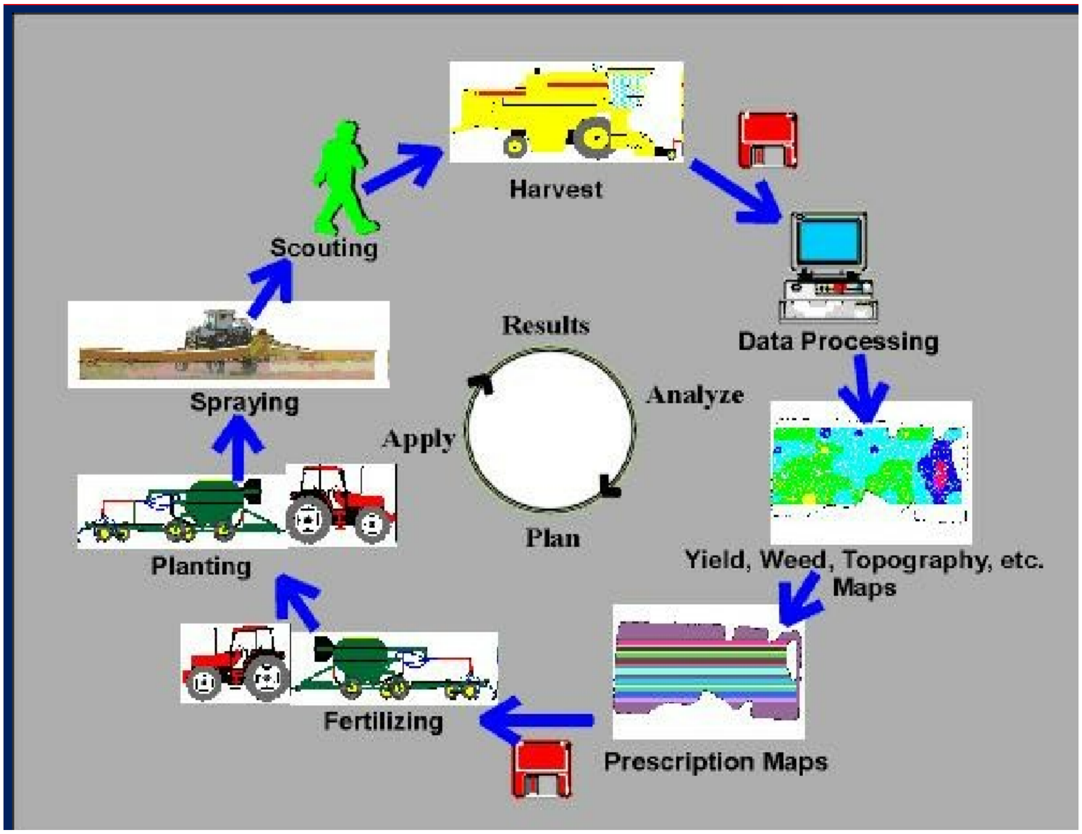
  - These variations are noted, and often mapped.
  - Management actions are taken as a consequence of the spatial variability within the field.
  - Land leveling
  - VRT
  - Site specific planting
  - Site Specific Nutrient Management
  - Precision water management
- **Variable rate application:** Grid soil samples are analyzed in the laboratory and an interpretation of crop input (nutrient/water) needs is made for each soil sample. Then the input application map is plotted using the entire set of soil samples. The input application map is loaded into a computer mounted on a variable-rate input applicator. The computer uses the input application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of input (fertilizer/water), according to the application map.
- **Yield monitoring and mapping:** Yield measurements are essential for making sound management decisions. However, soil, landscape and other environmental factors should also be weighed when interpreting a yield map. Used properly, yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices including tillage and irrigation. Since yield measurements from a single year may be heavily influenced by weather, it is always advisable to examine yield data of several years including data from extreme weather years that helps in pinpointing whether observed yields due to management or climate induced.
- **Quantifying on farm variability:** Every farm presents a unique management puzzle. Not all the tools described above will help determine the causes of variability in a field and it would be cost-prohibitive to implement all of them immediately. An incremental approach is a wiser strategy, using one or two of the tools at a time and carefully evaluating the results and then proceeding further.
- **Flexibility:** All farms can be managed precisely. Small-scale farmers often have highly detailed knowledge of their landa based on personal observations and could already be modifying their management accordingly. Appropriate technologies. Here might make this task easier or more efficient. Larger farmers may find the more advanced technologies necessary to collect and properly analyze data for better management decisions.



Advantages of PFS to farmers

1. **Overall yield increase:** Precise selection of crop varieties, application of exact types and doses of fertilizers, pesticides and herbicides and appropriate irrigation meet the demands of crops for optimum growth and development. This leads to yield increase, especially in areas or fields where uniform crop management practices were traditionally practised.
2. **Efficiency improvement:** Advanced technologies, including machinery, tools and information, help farmers to increase the efficiency of labour, land and time in farming. In developed countries like United States, a mere 2 hours are sufficient to grow 1 ha of wheat or maize.
3. **Reduced production costs:** Application of exact quantities at the appropriate time reduces the cost of agrochemical inputs in crop production. In addition, the overall high yield reduces the cost per unit of output.
4. **Better decision-making in agricultural management:** Agricultural machinery, equipment and tools help farmers acquire accurate information, which is processed and analysed for appropriate decision making - in land preparation, seeding, fertilizer, pesticide and herbicide application, irrigation and drainage and post production activities.
5. **Reduced environmental impact:** Timely application of agrochemicals at an accurate rate avoids excessive residue in soils and water and thus reduces environmental pollution.

6. **Accumulation of farmers' knowledge for better management with time:** All PFS Field activities produce valuable field and management information and the data are stored in tools and computers. Farmers can thus accumulate knowledge about their farms and production systems to achieve better management.



Precision Farming Cycle

TOOLS and TECHNIQUES

In addition to mechanization, other tools and equipment (techniques) used in PF, are briefly presented.

1. Global Positioning System (GPS)

The GPS is a navigation system based on a network of satellites that helps users to record positional information (latitude, longitude and elevation) with an accuracy of between 100 and 0.01 m. GPS allows farmers to locate the exact position of field features, such as soil type, pest occurrence, weed invasion, water holes, boundaries and obstructions. There is an automatic controlling system, with light or sound guiding panel (DGPS), antenna and receiver. GPS satellites broadcast signals that allow GPS receivers to calculate their position. In many developed countries, GPS is commonly used as a navigator to guide drivers to a specific location.

The GPS provides the same precise guidance for field operations. The system allows farmers to reliably identify field locations so that inputs (seeds, fertilizers, pesticides, herbicides and irrigation water) can be applied to an individual field, based on performance criteria and previous input applications.

Specific advantages of GPS in farm operations include:

1. Farm machines are guided along a track hundreds of meters long making only centimetre scale deviations.
2. Rows are not forgotten and overlaps are not made.
3. Number of rows can be counted during work.
4. Tools and equipment can be operated in the same way from year to year.
5. It is possible to work at night or in dirt with precision.
6. The system is not affected by wind.
7. An additional recorder can store field information to be used in making a map.

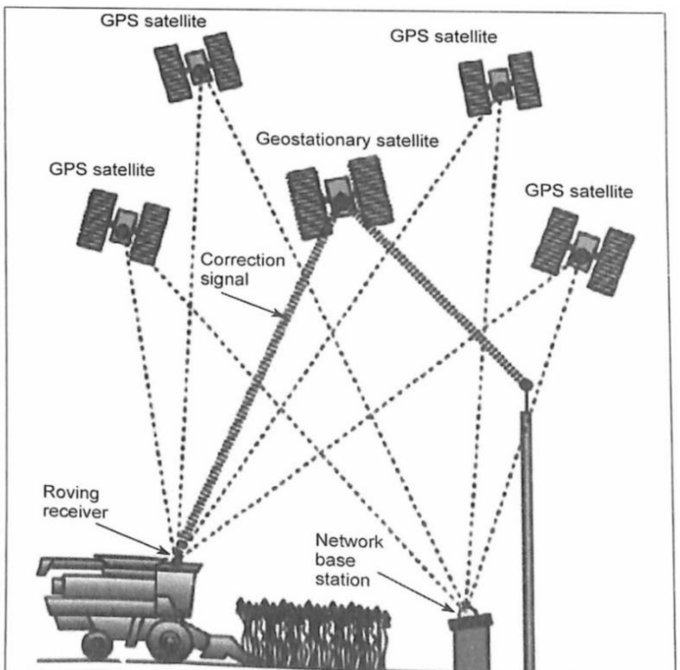


Fig 1.4. GPS for precision agriculture.

2. Sensor Technologies

Various technologies - electromagnetic, conductivity, photo-electricity, ultrasound- are used to measure humidity, vegetation, temperature, vapour, air etc. Remote sensing data are used to: distinguish crop species, locate stress conditions, discover pests and weeds and monitor drought, soil and plant conditions. Sensors enable the collection of immense quantities of data without laboratory analysis.

The specific uses of sensor technologies in farm operations are as follows:

1. Sense soil characteristics: Texture, structure, physical character, humidity, nutrient level and presence of clay.
2. Sense colours to understand conditions relating to: Plant population, water shortage and plant nutrients.
3. Monitor yield: Crop yield and crop humidity.

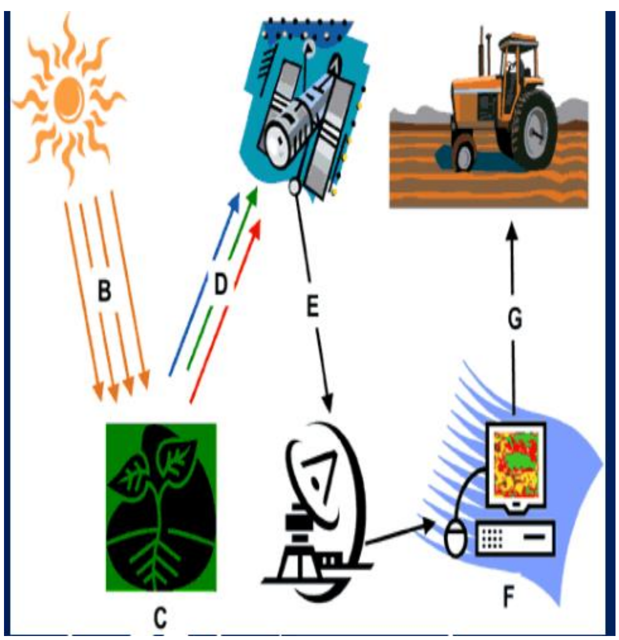
4. Variable rate system: To monitor the migration of fertilizers and discover weed invasion.

3. Geographic Information System (GIS)

Use of GIS began in 1960. This system comprises hardware, software and procedures designed to support the compilation, storage, retrieval and analysis of feature attributes and location data to produce maps. GIS links information in one place so that it can be extrapolated when needed. Computerized GIS maps are different from conventional maps and contain various layers of information (yield, soil survey maps, rainfall, crops, soil nutrient levels and pests). GIS helps convert digital information to a form that can be recognized and used. Digital images are analyzed to produce a digital information map of the land use and vegetation cover. GIS is a kind of computerized map, but its real role is using statistics and spatial methods to analyze characters and geography. Further information is extrapolated from the analysis. A farming GIS database can provide information on: filed topography, soil types, surface drainage, subsurface drainage, soil testing, irrigation, chemical application rates and crop yield. Once analyzed, this information is used to understand the relationships between the various elements affecting a crop on a specific site.

4. Remote Sensing

- Remote sensing has been used in soil mapping, terrain analysis, crop stress, yield mapping and estimation of soil organic matter, but on a scale larger
- Than what is required for precision agriculture.
- Remote sensing at high resolution can be of great use in precision farming because of its capacity to monitor the spatial variability.
- The role of satellite remote sensing in PF is to acquire spatially- and temporally-distributed information to identify and analyze crop and soil variability within fields.



5. Variable-Rate Technologies (VRT)

Variable rate technologies (VRT) are automatic and may be applied to numerous farming operations. The VRT systems set the rate of delivery of farm inputs depending on the soil type noted in a soil map. Information extrapolated from the GIS can control processes, such as seeding, fertilizer and pesticide application and herbicide selection and application, at a variable (appropriate) rate in the right place at the right time. The VRT is perhaps the most widely used PFS technology.

6. Grain Yield monitors For Mapping

A monitor mounted on a combine continuously measures and records the flow of grain in the grain elevator. When linked with a GPS receiver, yield monitors can provide data for a yield map that helps farmers to determine the sound management of inputs, such as fertilizer, lime, seed, pesticides, tillage and irrigation.

CROP MANAGEMENT

Precision farming system employs the innovations and technologies described above. With satellite data, farmers have a better understanding of the variation in soil conditions and topography that influence crop performance within the field. Farmers can, therefore, precisely manage production factors, such as seeds, fertilizers, pesticides, herbicides and water control, to increase yield and efficiency.

The management scheme of typical PFS comprises following steps:

- Determine management zones to be applied with PFS.
- Establish yield goals.
- Carry out soil sampling and data interpretation.
- Make decisions regarding management of land preparations, varieties, fertilizers and other nutrients to achieve yield goals.
- Establish maps to discover the pest population: insects, diseases and weeds, using an integrated pest management (IPM) approach.
- Apply precision irrigation.
- Apply logging and automated record keeping.
- Monitor and establish yield maps, evaluate PFS response and identify strengths and weaknesses for future improvement.

DEVELOPING SYSTEM TECHNOLOGY FOR PF

Developing system technology for precision farming is shown in Fig 1.5. First of all, it is necessary to describe and understand the variability within and between fields. Field sensors with GPS and monitors for machine application make this easier. The next stage is to develop machines, which can be operated by remote control.

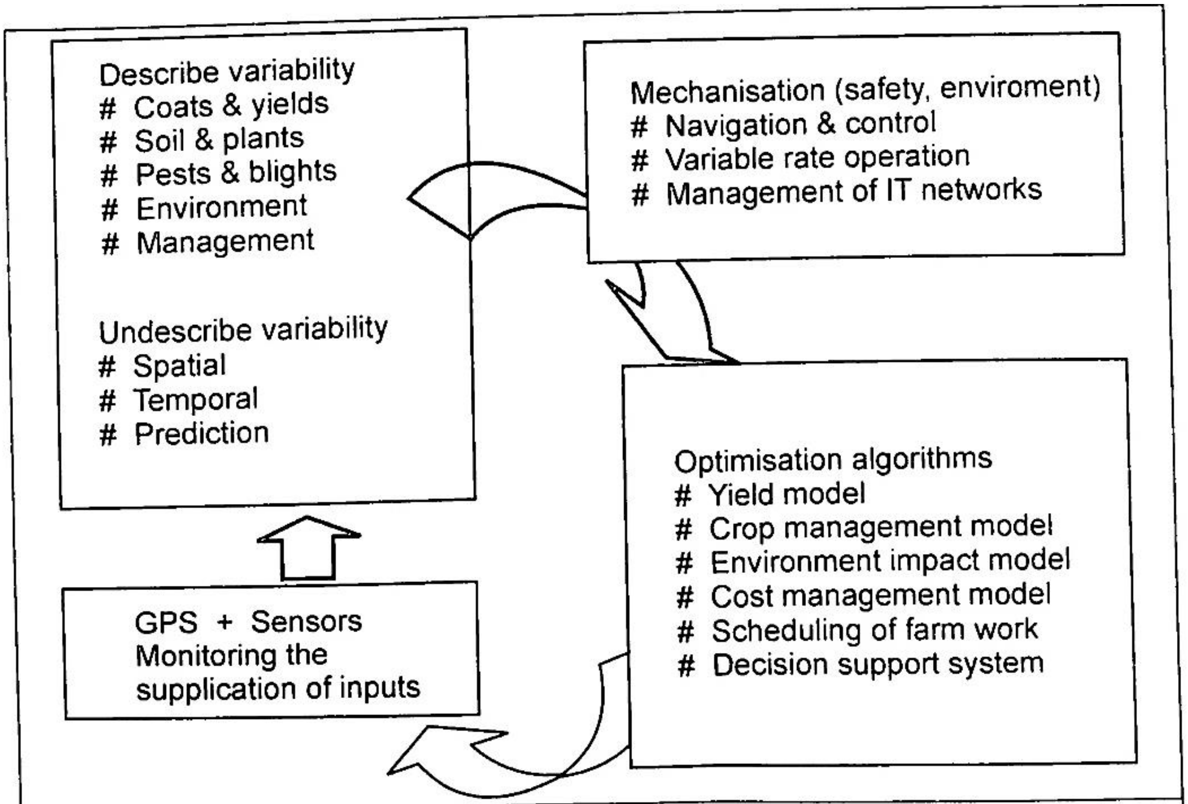


Fig 1.5. Development of PF technologies.

There are three steps and strategies in technology development for PF.

Step 1: is based on conventional farming technology, with intensive mechanisation to reduce the labour input.

Step 2: involves the development of mapping techniques.

Step 3: implies the maturity of wisdom-oriented technologies.

Scenario 1 is based on a "high-input and high-output" conventional strategy. Scenario 2 has a strategy for "low-input but constant-output". Scenario 3 aims at "optimized input- output" as the goal of precision farming. Advanced technology levels allow us to choose freely between these three scenarios. Effective regulations will encourage progress in precision farming.

Precision Farming Concerns for Indian Agriculture

Farmers in developed countries typically own large farms (10-1000 ha or more) and crop production systems are highly mechanized in most cases. Large farms may comprise several fields in differing conditions. Even within a relatively small field (<30 ha) the degree of pest infestation, disease infection and weed competition may differ from one area to another.

In conventional agriculture, although a soil map of the region may exist, farmers still tend to practice the same crop management throughout their fields: crop varieties, land preparation, fertilizers, pesticides and herbicides are uniformly applied in spite of variation. Optimum growth and development are thus not achieved. Furthermore, there is inefficient use of inputs and labour. Availability of information technology since the 1980s provides farmers with new tools and approaches to characterize the nature and extent of variation in the fields, enabling them to develop the most appropriate management strategy for a specific location, increasing the efficiency of input application.

Practical Problems in Indian Agriculture

Precision agriculture has been mostly confined to developed countries. Reasons of limitations of its implementation in developing countries like India are:

1. Small land holdings.
2. Heterogeneity of cropping systems and market imperfections.
3. Complexity of tools and techniques requiring new skills.
4. Lack of technical expertise knowledge and technology (India spends only 0.3% of its agricultural GDP in research and development).
5. Infrastructure and institutional constraints including market imperfections.
6. High cost.

In India, major problem is the small field size. More than 58% of operational holdings in the country have size less than 1 ha. Only in states of Punjab, Rajasthan, Haryana and Gujarat more than 20% of agricultural lands have operational holding size of more than 4 ha. There is scope of implementing precision agriculture for crops like rice and wheat especially in states of Punjab and Haryana. Commercial as well as horticultural crops show a wider scope for precision agriculture.

In India, broadly two types of agriculture *viz*., high input agriculture characterized by provision of assured irrigation and other agricultural inputs and subsistence farming, which is confined mostly to rainfed or Dryland regions are prevalent. Crop yields are very low (near 1.0/ha) and good potential exists for increasing productivity of rainfed cropping systems.

Steps to be taken for Implementing PF in India

In the present situation, potential of precision agriculture in India is limited by the lack of appropriate measurement and analysis techniques for agronomically important factors. High accuracy sensing and data management tools must be developed and validated to support both research and production. Limitation in data quality/availability has become a major obstacle in the demonstration and adoption of the precision technologies. Adoption of precision agriculture needs combined efforts on behalf of scientists, farmers and the government.

The following methodology could be adopted in order to operationalize precision farming in the country:

1. Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of precision agriculture.

2. Formation of farmer’s co-operatives since many of the precision agriculture tools (GIS, GPS etc.) are costly.

3. Government legislation restraining farmers using indiscriminate farm inputs and thereby causing ecological/environmental imbalance would induce the farmer to go for alternative approach.

4. Pilot study should be conducted on farmer’s field to show the results of precision agriculture implementation.

5. Creating awareness amongst farmers about consequences of applying imbalanced doses of farm inputs like irrigation, fertilizers, insecticides and pesticides.

Realizing the potential of space technology in precision farming, the Department of Space, Government of India has initiated eight pilot studies in well-managed agricultural farms of the ICRISAT, the Indian Council of Agricultural Research and the Agricultural Universities, as well as in farmers' fields. Pilot studies aim at delineating homogeneous zones with respect to soil fertility and crop yield, estimation of potential yield, yield gap analysis, monitoring seasonally-variable soil and crop conditions using optical and microwave sensor data and matching the farm inputs to bridge the gap between potential and actual yield through Spatial Decision Support Systems (SDSS). The test sites are spread over a fairly large area across a cross section of agro-climatic zones of the Indian sub-continent and cover some of the important crops like wheat, rice, sorghum, pigeon pea, chickpea, soybean and groundnut.

The next step would be to generate detailed-level information on soil resources addressing potentials and limitations of individual fields since except for states like Punjab, Haryana, Madhya Pradesh and Maharashtra where fields size is quite large, practically individual field could be treated as a homogenous management unit for the purpose of precision farming.

Agriculture has continued to be the cornerstone of Indian economy. In the years to come, precision agriculture may help the Indian farmers to harvest the fruits of frontier technologies without compromising the quality of land and produce. Adoption of such a novel technique would trigger a techno-green revolution in India which is the need of the hour.