Lecture 1&2. Precision agriculture: concepts and techniques; their issues and concerns reference for Indian agriculture

- **Precision Agriculture:** - An information and technology based farm management system to identify, analyze and manage variability within fields by doing all practices of crop production in right place, at right time and in right way for optimum profitability, sustainability and protection of the land resource. Precision agriculture is a systems approach to fanning for maximizing the effectiveness of crop inputs.
- **Precision agriculture (PA)** is an approach to farm management that uses information technology (II) to ensure that the crops and soil receive exactly what they need for optimum health and productivity.
- The **goal of PA** is to ensure **profitability**, **sustainability and protection of the environment.**
- PA is also known as **satellite agriculture, as-needed farming and site-specific crop management (SSCM).**
- **Precision Farming or Precision Agriculture** is generally defined as information and technology based farm management system to identify, analyse and manage spatial and temporal variability within fields for optimum productivity and profitability, sustainability and protection of the land resource by minimizing the production costs.
- The concept of **precision agriculture** offers the promise of increasing productivity while decreasing production cost and minimizing environmental impacts.
- **Precision Agriculture:** - is the technique of applying the right amount of input (fertilizer, pesticide, water etc.) at ***the right location at the right time*** to enhance production, decrease input, and/or protect the environment.
- **Precision farming** is defined as the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production (Pierce and Nowak, 1999).

- **Precision farming** is an integrated, information and agricultural management system that is designed to improve the whole farm production efficiency with the low cost effect while avoiding the unwanted or harmful effects of chemicals in the environment. The focus under Precision Farming is to gather information regarding the soil and crop condition and capture the sequence on the soil and crop conditions at spatial level.

- **Precision agriculture** relies upon specialized equipment, software and IT services. The approach includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as hyper-local weather predictions, labor costs and equipment availability.

PRECISION AGRICULTURE: CONCEPT

Concept is simple

i) Right input

ii) At right time

iii) In right amount

iv) At right place

v) In right manner

The concept of precision farming is strictly based on the Global Positioning System (GPS), which was initially developed by U.S. (United States of America) defense scientists for the exclusive use of the U.S. Defense Department. The unique character of GPS is precision in time and space. Precision agriculture (PA), as the name implies, refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. The use of inputs (i.e. chemical fertilizers and pesticides) based on the right quantity, at the right time and in the right place. This type of management is commonly known as "Site-Specific Management".

Precision Farming or Precision Agriculture is generally defined as information and technology based farm management system to identify, analyze and manage spatial and temporal variability within fields for optimum productivity and profitability, sustainability and protection of the land resources by minimizing the production costs. The productivity gain in global food supply have increasingly relied on expansion of irrigation schemes over recent decades, with more than a third of the world's food now requiring irrigation for production. Rapid socio-economic changes in some developing countries, including India, are creating new scopes for application of precision agriculture (PA). All-together, market-based global competition in agricultural products is challenging economic viability of the traditional agricultural systems, and requires the development of new and dynamic production systems.

Precision farming / satellite farming

- When implemented correctly, **precision farming** is a process that allows users todeal with every possible variation found in fields and field sections..
- When implemented correctly, precision farming is a process that allows users to deal ,vith every possible variation found in fields and field sections. Just as no two fields are exactly the same, no two sections of any field will be the same.
- Your soil's ability to use and retain nutrients is affected by the its texture and composition, the pH levels, and the various amounts of organic matter present. Field work practices, weeds, cover crops, drainage, and previous years' yields can all cause nutrient levels to fluctuate.
- As you gain more knowledge with respect to your fields and its variances, along with implementation of well-planned precision farming, your farm will benefit from increased yields and higher profits.

Farm management and optimizing returns

- Two things are worth immediate consideration: farm management and optimizing returns on inputs. What does that mean? The best path to optimization of your returns is by applying the appropriate inputs in the right place and in the correct amounts.

NEED OF PRECISION FARMING

- The global food system faces formidable challenges today that will increase markedly over the next 40 years.
- Much can be achieved immediately with current technologies and knowledge, given sufficient will and investment.
- But coping with future challenges will require more radical changes to the food system and investment in research to provide new solutions to novel problems.
- The decline in the total productivity, diminishing and degrading natural resources, stagnating farm incomes, lack of eco-regional approach, declining and fragmented land holdings, trade liberalization on agriculture, limited employment opportunities in non-farm sector, and global climatic variation have become major concerns in agricultural growth and development.
- Therefore, the use of newly emerged technology adoption is seen as one key to increase agriculture productivity in the future.
- Instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, a precision farming approach recognizes site-specific differences ,vithin fields and adjusts management actions accordingly.
- Farmers usually are aware that their fields have variable yields across the landscape.
- These variations can be traced to management practices, soil properties and/or environmental characteristics.
- The level of knowledge of field conditions is difficult to maintain because of the large sizes and changes due to annual shifts in leasing arrangements in the farm area.
- So the entire farm area has to be divided into small farm units of 50 cents or less. Precision agriculture offers the potential to automate and simplify the collection and analysis of information.

- It allows management decisions to be made and quickly implemented on small areas within larger fields.

TOOLS AND EQUIPMENT/TECHNIQUES IN PRECISION AGRICULTURE:-

1. **Global positioning system (GPS)** :- 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 information, 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. 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.
2. **Sensor technologies:-Various** technologies such as electromagnetic, conductivity, photo electricity and ultra sound are used to measure humidity, vegetation, temperature, texture, structure, physical character, humidity, nutrient level, vapour, air etc. Remote sensing data are used to distinguish crop species, locate stress conditions, identify pests and weeds, and monitor drought, soil and plant conditions. Sensors enable the collection of immense quantities of data without laboratory analysis.
3. **Geographic information system (GIS)** :-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 beextrapolated when needed. Computerized GIS maps are different from conventional maps and contain various layers of information (e.g. yield, soil survey maps, rainfall, crops, soil nutrient levels and pests). GIS is a kind of computerized map, but its real role is using statistics and spatial methods to analyze characters and geography. 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. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios.

4. Grid soil sampling and variable-rate fertilizer (VRT) application:-

Variable-rate technologies (VRT) are automatic and may be applied to numerous farming operations. 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, herbicide selection and application at a variable rate in the right place at the right time. VRT is perhaps the most widely used PFS technology in the United States.

Grid soil sampling uses the same principles of soil sampling but increases the intensity of 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 a map of nutrient needs, called an application map. Samples may be collected for more than one area of a field which fall in to the same range of yield, soil colour, etc. and thus the same zone. Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples. The application map is loaded into a computer mounted on a variable-rate fertilizer spreader. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map.

5. **Crop management:-**

Satellite data provide farmers 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.

6. **Soil and plant sensors** :-

Sensor technology is an important component of precision agriculture technology and their use has been widely reported to provide information on soil properties and plant fertility/water status. A comprehensive list of current sensors as well as desirable features for new sensors to be developed in the future. One of the most popular ways to characterize soil variability is surveying the field with soil apparent electrical conductivity (ECa) sensors that collect information continuously when pulled over the field surface. Because ECa is sensitive to changes in soil texture and salinity, these sensors provide an excellent baseline to implement site-specific management.

7. **Global Positioning System (GPS)** :-

Global Positioning System satellites broadcast signals that allow GPS receivers to calculate their position. This position information is provided while in motion. Having precise location information at any time allows soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas. Uncorrected GPS signals have an accuracy of about 300 feet.

8. **Rate controllers:-**

Rate controllers are devices designed to control the delivery rate of chemical inputs such as fertilizers and pesticides, either liquid or granular. These rate controllers monitor the speed of the tractor/sprayer traveling across the field, as well as the flow rate and pressure (if liquid) of the material, making delivery adjustments in real-time to apply a target rate. Rate controllers have been available for some time and are frequently used as stand-alone systems.

9. Precision irrigation in pressurized systems :-

Recent developments are being released for commercial use in sprinkler irrigation by controlling the irrigation machines motion with GPS based controllers. In addition to motion control, wireless communication and sensor technologies are being developed to monitor soil and ambient conditions, along with operation parameters of the irrigation machines (i.e. flow and pressure) to achieve higher water application efficiency and utilization by the crop. These technologies show remarkable potential but further development is needed before they become commercially available.

10. Software:-

Applying precision agriculture technologies will frequently require the use of software to carry out diverse tasks such as display-controller interfacing, information layers mapping, pre and post processing data analysis and interpretation, farm accounting of inputs per field, and many others. The most common are software to generate maps (e.g. yield, soil); software to filtering collected data; software to generate variable rate applications maps (e.g. for fertilizer, lime, chemicals); software to overlay different maps; and software to provide advanced geostatistical features. All are excellent options for precision agriculture farm management and record keeping to keep up with the needs of modem, information-intensive farming systems. There are a few companies that operate world-wide and provide integrated software packages from generating all different types of maps, having statistical analysis tools and also record keeping. The machinery companies that provide yield meters also offer software to generate yield maps and fertilizer companies provide software to generate variable rate applications maps. Some of the packages are very complicated for farmers to use and they are fairly expensive, while some others are considerably simpler and cheaper with fewer options. The packages are more user-friendly and have many options for the farmer to use.

11. Yield monitor:-

Yield monitors are a combination of several components. They typically include several different sensors and other components, including a data storage device, user interface (display and key pad), and a task computer located in the combine cab, which controls the integration and interaction of these components. The sensors measure the mass or the volume of grain flow (grain flow sensors), separator speed, ground speed, grain. In the case of grains, yield is continuously recorded by measuring the force of the grain flow as it impacts a sensible plate in the clean grain elevator of the combine. A recent development of a mass flow sensor works on the principle of transmitting beams of microwave energy and measuring the portion of that energy that bounces back after hitting the stream of seeds flo,ving through the chutes. In all yield monitors, GPS receivers are used to record the location of yield data and create yield maps. Other yield monitoring systems include devices used in forage crops to keep track of weight, moisture, and other information on a per-bale basis.

12. Precision farming on arable Iand:-

The use of PA techniques on arable land is the most ,videly used and most advanced amongst farmers. Another important application of precision agriculture in arable land is to optimize the use of fertilizers, starting with the three main nutrients Nitrogen, Phosphorus and Potassium. In conventional farming these fertilizers are applied uniformly over fields at certain times during the year. This leads to over-application in some places and under-application in others. The environmental cost is directly related to over-application which allows nitrogen and phosphorus leaching from the field into ground- and surface waters or to other areas of the field where they are not desired. With the use of precision agriculture methods, fertilizers can be applied in more precise amounts, with a spatial and temporal component to optimize the application. The technology that allows the farmer to control the amount of inputs in arable lands is the Variable Rate Application (VRA), which combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs. VRs are decided on the basis of prior measurement, e.g. from remote sensing or machine mounted sensors.

13. Precision farming within the fruits & vegetables and viticulture sectors:-

In fruit and vegetable fanning the recent rapid adoption of machine vision methods allows growers to grade products and to monitor food quality and safety, with automation systems recording parameters related to product quality. These include colour, size, shape, external defects, sugar content, acidity, and other internal qualities. Additionally, tracking of field operations such as chemicals sprayed and use of fertilizers can be possible to provide complete fruit and vegetable processing methods. This information can be disclosed to consumers for risk management and for food traceability as well as to producers for precision agriculture to get higher quality and larger yields ,vith optimized inputs. In recent years several new approaches were developed that take into account the actual size of the tree, the condition of the crop, but also the environmental conditions.

The development and adoption of PA technologies and methodologies in viticulture (termed Precision Viticulture, PV) is more recent than in arable land. However, driven by the high value of the crop and the importance of quality, several research projects already exist in wine production areas of the world. Grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential ,vine qualities. The parcels with greatest opportunities for PV are those which reveal a high degree of yield variation. A high degree of variation will mean higher VRA of inputs and, therefore, greater economic and environmental benefit in comparison with uniform management.

14. Precision livestock farming (PLF):-

Precision livestock farming (PLF) is defined as the management of livestock production using the principles and technology from precision agriculture. Processes suitable for the precision livestock farming approach include animal growth, milk and egg production, detection and monitoring of diseases and aspects related to animal behaviour and the physical environment such as the thermal micro-environment and emissions of gaseous pollutants. Systems include milk monitoring to check fat and microbial levels, helping to indicate potential infections, as well as new robotic feeding systems, weighing systems, robotic cleaners, feed pushers and other aids for the stockman such as imaging systems to avoid direct contact with animals. New systems for data monitoring for feed and water consumption can be used to the early detection of infections is available now. Other developments include the monitoring on the growing herd where measurement of growth in real time is important to provide producers with feed conversion and growth rates.

15. On-line resources for precision agriculture :-

There is a wealth of information available over the internet on new technology for farm production. Most

manufacturers of farm equipment, GPS receivers, sensors, and other PA technologies use this media to inform growers on new products, technical specifications, trouble-shooting information, software upgrades, and a variety of services.

16. Remote Sensors:-

These are generally categories of aerial or satellite sensors. They can indicate variations in the colours of the field that corresponds to changes in soil type, crop development, field boundaries, roads, water, etc. Arial and satellite imagery can be processed to provide vegetative indices, which reflect the health of the plant.

ADVANTAGES OF PRECISION FARMING (PF)/PRECISION AGRICULTURE (PA):-

1. Precision agriculture can contribute to reduced waste,
2. It help to increase total profit from agriculture
3. Help to protect the environment by precise application of inputs.
4. Precision agriculture can provide both environmental and economic benefits as consequences from reduced or targeted placement of crop inputs that include water, pesticides, and nutrients.

- **Precise nutrient applications** can give important environmental and economic benefits. The aim is to apply only the nutrients that the plants require and can use. Rates of application will differ within the field based on the type of soils, levels of fertility, and sensitivity to the environment. There is some type of soils in a field that does not have the potential to validate maximum rates of nutrient application. On the other hand, there might be areas that need to be reduced rates because of sensitivity to the environment.
- **Precise pesticide applications** can offer both economic and environmental benefits. One of the cheapest and fastest environmental payoffs for applications of pesticides is the use of light bar guidance systems. These affordable light bar guidance systems offer an easy method to lead equipment across a field to prevent overlapping when pesticides are being sprayed.
- **Precision Soil preparation :- Soil preparation** is the first step before gro,ving a crop. The ultimate objective is to produce a firm and weed-free seedbed for rapid germination and emergence of the crop. One of the most important tasks in soil preparation is tilling (or ploughing): turning the soil and loosening it.

Precision Seeding :-

- **Seeding (or: sowing)** is a critical step in crop growing. For a successful seeding process, two challenges need to be overcome:
- **Correct depth:** if sown too deep into the soil, roots will not be able to breath. If sown on the surface, birds may damage the seeds.
- **Proper distance:** if plants are overcrowded, they will not to get enough water, nutrients and sunlight, resulting in yield loss. If they are planted too far from each other, valuable land is left unused.

Precision Crop Management :-

During their growth phase plants need:

- The right amount of nutrients - **FERTILISATION**
- Adequate protection from pests and diseases - **CROP PROTECTION / SPRAYING**
- The right amounts of water - **IRRIGATION**
- In all three areas, precision farming solutions help farmers to **produce more with less.**

Precision Harvesting :-

- For the farmer, **harvesting** is a critical point in time. Speed, accuracy, and timing determine whether the harvest will be successful. Until recently, harvesting was the most burdensome and laborious activity of the entire growing season. Today, the task is taken over by some of the most sophisticated farm machines such as:

Precision Livestock Fanning :-

- **Livestock farming is facing tremendous challenges today:**
- **Increasing production:** over the next 15 years, global demand for meat is expected to increase by 400/o triggered by a growing number of people adopting protein-richer diets. According to the UN's Food and Agriculture Organisation (FAO), technology solutions in agricultural and livestock production systems will play a key role to address this challenge and ensure an adequate food supply for an expected population of 9.7 billion by 2050
- **Promoting sustainability & animal welfare:** while increasing production, it will be important to find ways to minimize the environmental footprint of livestock farming and ensure high levels of welfare and health for animals.
- **Alleviating farmers' workload and ensuring economic viability of farm operations:** it will be important find solutions that will enable farmers to manage large number of animals in an adequate and profitable manner.

Precision Livestock Farming (PLF) systems:-

PLF systems:

- help farmers to increase livestock production and quality of production in a sustainable manner
- offer tailored care for the animals in terms offeeding, milking and housing
- make many of the farmer's daily tasks much easier to handle

Examples of PLF systems include:

Precision feeding systems: feeding systems allow farmers to feed their cows accurately, precisely and with minimal expenditure of work at all times (24/7).

Precision milking robot: a good example of large adoption of PLF systems are automatic milking machines. These robotic systems can handle up to 65 cows on an average of 2.7 times per day.

Stable and farm management systems: various PLF support and monitoring systems exist, which use cameras and microphones and thus act as theeyes and ears of the farmer at all times.

Benefits of PLF systems:

a. **Greater sustainability & higher productivity:** recent studies show PLF management systems can raise milk yields, while also increasing cows' life expectancy and reducing their methane emissions by up to 30%.
b. **Increased animal welfare through an individual 'per animal' approach:** PLF systems allow farmers to follow and manage the individual animal's status and well-being closely at all times. They can detect diseases at an early stage, for instance, acoustic sensors can pick up an increase in coughing of pigs. PLF systems can also alert farmers of specific needs of animals by sending an SMS.
c. **Easier farm operations:** PLF systems enable livestock farmers to take care of a large number of animals per farm, while providing individual attention to each animal and complying - and documenting compliance - with high quality and welfare standards.

DISADVANTAGES

I. Precision farming cannot be utilized completely in every crop.
2. Precision farming needs the good economic condition of the farmer for adoption
3. It requires technical and skilled persons
4. Initial cost is very high as well as maintenance cost also high
5. For adoption of precision farming farmers must have a technical knowledge.

DIFFERENCE BETWEEN TRADITIONAL FARMING AND PRECISION FARMING

Traditional fanning	Precision fanning
Unit of treatment and organisation: the field that is regarded as a homogenous arable site	Unit of treatment and organisation: arable site that is regarded as different from one point to the other and at ·'field level'' as heterogeneous
Nutrient ma.nagement based on average sample taking	Nutrient management based on GPS and point-like sample taking
Average SUIYey on plant deceases and damage and intervention if necessary	Plant protection treatments based on GPS and point-like plant survey
Sowing with same plant number and variety	Plant species and plant variety-specific sowing
Same machine operation practice	Machine-operation adjusted to the arable site
Unified plant stock in space and time	Unified plant stock o.rga.nised into homo11;eneous blocks at arable sites
Few data influencing decision preparation	A lot of data influencing decision or..-naration

BENEFITS OF PRECISION FARMING :-

a) Precision fanning not only is potentially more economical, but it also reduces the amounts of chemicals released into the environment.

b) Improves crop yield and profit

c) Provides better information for making management decision.

d) Provides more details and useful farm records.

e) Reduces fertilizer costs.

I) Reduces pesticide costs.

g) Reduces pollution.

COMPONENTS OF PRECISION FARMING :-

1. Remote sensing (RS)
2. Geographical information system (GIS)
3. Global Positioning System (GPS)
4. Soil testing
5. Yield monitors
6. Variable Rate technology (VRT)

ADVANTAGES OF PRECISION FARMING SYSTEM (PFS) TO FARMERS :-

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.

Efficiency improvement :- Advanced technologies, including machinery, tools and information, help farmers to increase the efficiency of labour, land and time in farming.

Reduced production cost :- Application of exact quantities at the appropriate time reduces the cost of agrochemical inputs in crop production.

Better decision making in agricultural management :- Agricultural machinery, equipment and tools help farmers acquire accurate information which is processes and analysed for appropriate decision making.

Reduced environmental impact :- Timely application of agrochemicals at an accurate rate avoids excessive residues in soils and water and thus reduces environmental pollution.

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

STEPS IN PRECISION FARMING :-

- There are **two basic steps** in precision agriculture.

1. Identification and Assessment of Variability :-

a) 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**

b.) 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 analyse 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.

c) 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 be helpful for explaining the variations in yield maps.

d) Use of precision technologies for assessing variability: - Faster and real time assessment of variability is possible only through advanced tools of precision agriculture.

2. Management of Variability:-

a) **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 GPS receiver to direct a product delivery controller that changes the amount and kind of input according to the application map.

b) 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.
- Yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices.

c) Quantifying farm variability: Every farm presents a unique management. 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.

d) Flexibility: - All farms can be managed precisely. Small scale farmers often have highly detailed knowledge of their lands based on personal observations and could already be modifying their management accordingly. Appropriate technologies here might make this task easier or more efficient.

SCOPE AND ADOPTION OF PRECISION FARMING IN INDIA:

PA for small farms can use small farm machinery and robots which will not compact the soil and may also run on renewable fuels like bio oil, compressed biogas and electricity produced on farms by agricultural residues. For small farms, precision agriculture may include sub-surface drip irrigation for precise water and fertilizer application, weed removal, harvesting and other cultural operations. Some of these robots are already being used on small farms in the US and Europe and it is expected that they may be deployed in large scale in the near future. For small farms, precision agriculture may help in sub-surface drip irrigation for precise water and fertilizer application and robots for weed control, harvesting and other operations. Similarly, drones have also been introduced in Japan and the U.S. for mapping the farms, identifying diseases and so on. Most robotic machines and drones are compact and thus suitable for small farms. India's small farms, therefore, are ideal for the large-scale application of precision agriculture.

SCOPE AND LIMITATION IN ADOPTION OF PRECISION FARMING IN INDIA

1. Precision Farming concepts are applicable to all agricultural sectors like animal farming, fisheries and forestry. Precision Agriculture (PA) can be classified into two categories namely 'Soft' PA and 'Hard' PA.
2. 'Soft' Precision Agriculture mainly depends on visual observation of crop and soil and management decision based on experience and intuition, rather than statistical and scientific analysis.
3. Whereas, 'Hard' PA utilizes all modern technologies like GPS, GIS, VRT, etc.
4. In India 96 million farms out of a total 105.3 million farms have less than 4 hectares (ha) area.
5. Though only fragmented lands are cultivated, the present food grain production in India is nearly 200 Million Tone, which has made India self sufficient in food production.
6. To compete with the world production, the crop yield per hectare must be economic and without environment degradation.
7. In India, overall fertilizer consume-tion rate is 84.3 Kg/ha, which must be reduced by systematic soil testing and creating nutrient maps along with fertilizer recommendations.
8. Along with nutrient zones pest control, disease and weed management also plays an important role in high yield of crop. Using advance technology, it is possible to monitor and control the pest and disease at lower costs.
9. Some states like Punjab, Haryana use high doses of fertilizer and pesticides.
10. For example, the state of Punjab has 1.5% of total geographical area of India, but uses 1.38 million tones (nearly 10% of all India fertilizer consumption) of NPK fertilizer along with 60% of weedicides used in India.
11. Overall exploitation of land as well as excessive use of agriculture input are typical problems of these areas.

12. Stress management is another area where Precision Framing can help Indian farmers in scheduling irrigation more profitably by varying the timing, quantity and placement of water.
13. Mechanization of farming helps the farmers to reduce the labor cost and to improve the accuracy of farming including quality seed selection, weed removing, pesticide and fertilizer application, harvesting and sorting of the crop as per the quality.
14. There are many limitations to adoption of Precision Farming in developing countries in general and India in particular.
15. Some of these limitations are common to those in other regions; however, following are specific to Indian conditions: 1. The culture and perceptions of the users, 2. Small farm size, 3. Lack of success stories, 4. Heterogeneity of cropping systems and market imperfections, 5. Land ownership, infrastructure and institutional constraints, 6. Lack of local technical expertise, 7. Availability, quality and cost of data.

KEY CHALLENGES TO PRECISION FARMING IN INDIA

Though widely adopted in developed countries, the adoption of precision farming in India is yet in infancy primarily due to its unique pattern of land holdings, poor infrastructure, lack of farmers' inclination to take risk, socio-economic and demographic conditions. The small size of farms and fields in most of Indian agriculture limits economic gains from currently available precision farming technology, while the population density, and public concerns for the environment, food safety and animal welfare means that those potential benefits are being given more attention.

OPPORTUNITIES AND CHALLENGES

Precision Agriculture can have a positive impact on environmental quality. The opportunity exists to show producers how changing production practices will not place crops at risk and produce positive economic and environmental benefits. Conducting experiments on precision agriculture will require field or farmscale studies and perhaps watershed-scale adoption of new management practices.

Completing this type of study will require:

1. Appropriate questions that can beaddressed at the field scale.
2. Methods for measuring environmental endpoints that will demonstrate the efficacy of management practices.
3. Commitment to multiple years of study to overcome meteorological variation.
4. Adequate monitoring equipment for crop production, soil properties, and environmental quality in order to understand the changes occurring due to the management practices.
5. Use of comparison fields or farms in which no changes are made to provide a validation of the improved practices.
6. Cooperation of producers to implement the practices ,vith minor modifications across years so that variations can be isolated to the management practice and not producer influence.
7. Data base structure that includes geographic information layers and accurate global positioning system equipment to position any treatments in the same area across years.
8. Funding sources that will allow for long-term studies across large areas.
9. Interdisciplinary teams that will address the critical problems in experimental design, implementation, and evaluation of results.

10. Commitment from the scientists, producers, and educators involved to maintain interest in the project over a sufficient period of time to allow the original objectives to be achieved.

PRECISION FARMING CONCERNS FOR INDIAN AGRICULTURE :-

1. Farmers in developed countries typically own large farms (10-1000 ha or more) and crop production systems are highly mechanized in most cases.
2. Large farms may comprise several fields in differing conditions.
3. 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.
4. 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.
5. Optimum growth and development are thus not achieved.
6. Furthermore, there is inefficient use of inputs and lab Labour.
7. Availability of information technology since the 1980s provides farmers ,vith 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/ISSUES IN PRECISION AGRICULTURE/FARMING

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.
5. Infrastructure and institutional constraints including market imperfections.

STEPS TO BE TAKEN FOR IMPLEMENTING PF IN INDIA :-

a) Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of PA.

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

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

d) Pilot study should be conducted on farmer's field to show the results of PA implementation.

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