Course Name: Precision Farming and Protected Cultivation

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Prepared By: Dr. Akhilesh Tiwari, Senior Scientist (Horticulture), JNKVV, Jabalpur

**PRECISION FARMING**

Precision farming or precision agriculture is about doing the right thing, in the right place, in the right way, at the right time. Managing crop production inputs such as water, seed, fertilizer etc to increase yield, quality, profit, reduce waste and becomes eco-friendly. The intent of precision farming is to match agricultural inputs and practices as per crop and agro-climatic conditions to improve the accuracy of their applications.

**Why Precision Farming?**

1. To enhance productivity in agriculture with respect to profit.
2. Prevents soil degradation in cultivable land.
3. Reduction of chemical use in crop production
4. Efficient use of water resources
5. Dissemination of modern farm practices to improve quality, quantity & reduced cost of production in agricultural crops

**Advantages:**

- **Agronomical perspective**: Use agronomical practices by looking at specific requirements of crop
- **Technical perspective**: allows efficient time management
- **Environmental perspective**: eco-friendly practices in crop
- **Economical perspective**: increases crop yield, quality and reduces cost of production by efficient use of farm inputs, labour, water etc

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, analyse 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.

**TOOLS AND EQUIPMENT**

Precision Farming is a combination of application of different technologies. All these combinations are mutually inter related and responsible for developments. The same are discussed below:

1. **Global Positioning System (GPS):** It is a set of 24 satellites in the Earth orbit. It sends out radio signals that can be processed by a ground receiver to determine the geographic position on earth. It has a 95% probability that the given position on the earth will be within 10-15 meters of the actual position. GPS allows precise mapping of the farms and together with appropriate software informs the farmer about the status of his crop and which part of the farm requires what input such as water or fertilizer and/or pesticides etc.

2. **Geographic Information System (GIS):** It is software that imports, exports and processes spatially and temporally geographically distributed data.

3. **Grid Sampling:** It is a method of breaking a field into grids of about 0.5-5 hectares. Sampling soil within the grids is useful to determine the appropriate rate of application of fertilizers. Several samples are taken from each grid, mixed and sent to the laboratory for analysis.

4. **Variable Rate Technology (VRT):** The existing field machinery with added Electronic Control Unit (ECU) and onboard GPS can fulfill the variable rate requirement of input. Spray booms, the Spinning disc applicator with ECU and GPS have been used effectively for patch spraying. During the creation of nutrient requirement map for VRT, profit maximizing fertilizer rate should be considered more rather than yield maximizing fertilizer rate.

5. **Yield Maps:** Yield maps are produced by processing data from adapted combine harvester that is equipped with a GPS, i.e. integrated with a yield recording system. Yield mapping involves the recording of the grain flow through the combine harvester, while recording the actual location in the field at the same time.

6. **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.

7. **Proximate Sensors:** These sensors can be used to measure soil parameters such as N status and soil pH) and crop properties as the sensor attached tractor passes over the field.
8. **Computer Hardware and Software**: In order to analyze the data collected by other Precision Agriculture technology components and to make it available in usable formats such as maps, graphs, charts or reports, computer support is essential along with specific software support.

9. **Precision irrigation systems**: Recent developments are being released for commercial use in sprinkler irrigation by controlling the irrigation machines motion with GPS based controllers. 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 use efficiency.

10. **Precision farming on arable land**: The use of PA techniques on arable land is the most widely used and most advanced amongst farmers. CTF (controlled Traffic Farming) is a whole farm approach that aims at avoiding unnecessary crop damage and soil compaction by heavy machinery, reducing costs imposed by standard methods. Controlled traffic methods involve confining all field vehicles to the minimal area of permanent traffic lanes with the aid of decision support systems. Another important application of precision agriculture in arable land is to optimize the use of fertilizers especially, Nitrogen, Phosphorus and Potassium.

**Laser Land Leveler**

**Introduction:**
Uneven soil surface has a major impact on the germination, stand, and yield of crops due to inhomogeneous water distribution and soil moisture. Therefore, land levelling is a precursor to good agronomic, soil, and crop management practices. The advanced method to level or grade the field is to use laser-guided leveling equipment. Laser land leveling is leveling the field within certain degree of desired slope using a guided laser beam throughout the field.

**Components of Laser Leveling System:**
A laser-controlled land leveling system consists of the following five major components:

(i) **Drag Scrapper/bucket**: The drag bucket can be either 3-point linkage mounted on or pulled by a tractor. This system is preferred as it is easier to connect the tractor’s hydraulic system to an external hydraulic by the 3-point-linkage system.

(ii) **Laser transmitter**: The laser transmitter mounts on a tripod, which allows the laser beam to sweep above the field.

(iii) **Laser receiver**: The laser receiver is a multi-directional receiver that detects the position of the laser reference plane and transmits this signal to the control box.
(iv) **Control box:** The control box accepts and processes signals from the machine mounted receiver. It displays these signals to indicate the drag buckets position relative to the finished grade.

(v) **Hydraulic system:** The hydraulic system of the tractor is used to supply oil to raise and lower the leveling bucket.

**Working mechanism of Laser Leveler:**
The system includes a laser-transmitting unit that emits an infrared beam of light that can travel up to 700m in a perfectly straight line. The second part of the laser system is a receiver that senses the infrared beam of light and converts it to an electrical signal. The electrical signal is directed by a control box to activate an electric hydraulic valve. Several times a second, this hydraulic valve raises and lowers the blade of a grader to keep it following the infrared beam. Laser leveling of a field is accomplished with a dual slope laser that automatically controls the blade of the land leveler to precisely grade the surface to eliminate all undulations tending to hold water. Laser transmitters create a reference plane over the work area by rotating the laser beam 360 degrees. The receiving system detects the beam and automatically guides the machine to maintain proper grade. The laser can be level or sloped in two directions. This is all accomplished automatically without the operator touching the hydraulic controls.

**Benefits of laser land leveling over conventional land leveling:**
- Reduction in time and water for irrigation
- Uniform distribution of water
- Less water consumption in land preparation
- Precise level and smoother soil surface
- Uniform moisture environment for crops
- Lesser weeds in the field
- Good germination and growth of crop
- Uniformity in crop maturity
- Reduced seed rate, fertilizers, chemicals and fuel requirements

**Benefits of precise land leveling:**
- Saves irrigation water >35 %
- Reduced weed in the field
- Increase in field areas about 3.5 %
- Reduce farm operating time by 10 %
- Assist top soil management
- Saves labor costs
- Saves fuel/electricity used in irrigation
- Increase productivity up to 50 %
**Mechanized Direct Seed Sowing**

Plant development uniformity is strongly influenced by the seedling uniformity, general qualitative characteristic to be similar in terms of growth in height, thickness, fresh crop weight, floral primordial evolution and health or the hybrid variety. The sowing technologies are also very important because can be used to sow the majority of treated vegetable and flower seeds which aims to destroy the germs of diseases or pests (seed disinfection) or prevent their contamination after seeding. Because the seed treatments can be performed, or chemically (wetting or dusting with different chemicals) or physical (heat, cold, UV rays, X-rays, etc.), depending on the species, therefore in the sowing process, it is proper to use automatic sowing equipments, because only in this way the seeding process it is done safely and reduce the intoxication risks with deadly substances.

**Small and very small seed material properties**

In most technical equipments which deal with small and medium size seeds are very important to have great precision because there are difficult to pick and manipulate, and their size and shape represents a great challenge, especially when not used performing sorting equipments.

**1. Hand Instruments - rudimentary devices:** This category includes sowing devices that encourage the manual seeding, respectively seed by seed, like: tweezers (Fig.1); mechanical devices (Fig.2 - 5); electrical device (Fig.6) and pneumatic seed handling (Fig.7 - 8).

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<th>Fig.1. Planting by hand</th>
<th>Fig 2 Seeding with tweezers</th>
<th>Fig.3. Mechanical device</th>
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<td>Fig.4. Mechanical device with resilient</td>
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<td>Fig.6. Seed Electric Device</td>
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2. Manual seeders
The most affordable models for small farmers and research groups are the manual seeders, because they draw a great number of seeds and planting them in nutrient cubes from alveolar trays and have a higher productivity than the hand seeding devices.

3. Semiautomatic seeders
This category includes the seeder models designed to be commanded by only one operator, which previously has adjusted the machine working parameters in accordance with the seed typo-dimension and alveolar trays configuration.

4. Automatic sowing machines
Large development companies have designed alveolar seeders dedicated for large horticulture seedlings producers or farms, fully automated in order to be able to meet the demand for high precision sowing equipments for small and medium seeds.
Seedling and sapling transplanting

A mechanical transplanter should perform the following three functions:

(i) open the soil in the form of narrow furrow;
(ii) place seedlings vertically upright in it, and
(iii) close and compact the soil around these seedlings without damaging them.

The vegetable transplanters can be classified as automatic (AVT) and semi-automatic type transplanter (SVT). The existing systems developed are generally semi-automatic type which consists of either pocket-type, cup- or bucket-type or conveyor-type metering mechanism that uses bare root, plug or paper-pot-type seedlings for transplanting. According to the metering mechanism, the vegetable transplanter can also be classified into different types (Figure 1). Also, it has been observed that the existing system is costly, labour-intensive and has less field efficiency. However, based on the available literature, the limiting values for performance of vegetable transplanters can be classified as very good, good, satisfactory and inadequate.
Pocket-type tractor drawn two-row semi-automatic vegetable transplanters

Tractor operated semiautomatic onion transplanter to mechanize onion transplanting operation. The physical properties of 50, 60 and 70 days old onion seedlings relevant for the design of metering mechanism and prototype transplanting machine were determined. An experimental plug and finger type transplanting mechanisms were designed and fabricated. Soil bin studies were conducted on experimental transplanting mechanisms to study the effect of seedling parameters ie. age of seedlings and machine parameters (speed of operation, height of seedling drop, finger material on plant spacing, planting depth, success of transplanting, furrow closure, filling efficiency and damage). The data observed in soil bin study was analyzed using SAS software to obtain optimum operating conditions and design values for successful transplanting of onion seedlings.

In semi-automatic machines, the transplants are fed by hand into the plant-placing device. several researchers have conducted countless experiments to increase the productivity and efficiency of mechanical transplanting [2, 3]. Different types of metering mechanisms were developed and evaluated to improve performance of semi-automatic vegetable transplanters such as a single row semiautomatic transplanter with cone type metering mechanism [4], a transplanter with finger type metering mechanism for holding and placing the seedling [5], a tractor mounted two row semi-automatic vegetable transplanter having a picker wheel type metering mechanism [6], and a two row vegetable transplanter with revolving magazine type metering mechanism [7].

The mechanical transplanting can be able to reduce the labor intensity of farmers, increase production and income. The jujube transplanter for the high-density jujube plantation can be capable of reducing the labor intensity and guaranteeing planting perpendicularity and jujube's
neat and unity because of the new principle and structures. (1) According to the technological program, design the sapling supporting system that complete planting automatically and the process of sapling folder—sapling sending—sapling investing—sapling releasing. (2) Design the transmission to ensure that the movement relationship of the manipulator with the machine so that seedlings planted in the upright; (3) Design the whole machine to be sure of completing all the operation for casing and compaction preliminary in the stage of sapling supported. (4) Design the adjusting device of depth limited to regulate the plating depth in a certain range according to the quality of the saplings.
Soil Mapping

Soil mapping is traditionally done by experienced soil surveyors who know the area well, spend much time in the field, take augerings at regular intervals, and in this way draw a field soil map that is later digitized and printed.

Soil map is a geographical representation showing diversity of soil types and/or soil properties (soil pH, textures, organic matter, depths of horizons etc.) in the area of interest. It is typically the end result of a soil survey inventory, i.e. soil survey. Soil maps are most commonly used for land evaluation, spatial planning, agricultural extension, environmental protection and similar projects. Traditional soil maps typically show only general distribution of soils, accompanied by the soil survey report. Many new soil maps are derived using digital soil mapping techniques. Such maps are typically richer in context and show higher spatial detail than traditional soil maps. Soil maps produced using (geo) statistical techniques also include an estimate of the model uncertainty.

In this context, soil maps are only visualizations of the soil resource inventories commonly stored in a Soil Information System (SIS), of which the major part is a Soil Geographical Database. A Soil Information System is basically a systematic collection of complete (values of the target soil variables available for the whole area of interest) and consistent gridded or vector soil property and/or class maps with an attached report, user manual and/or metadata. A SIS is in the most cases, a combination of polygon and point maps linked with attribute tables for profile observations, soil mapping units and soil classes. Different elements of an SIS can be manipulated and then visualized against the spatial reference (grids or polygons). For example, soil profiles can be used to make spatial prediction of different chemical and physical soil properties. In the case of pedometric mapping, both predictions and simulations (2D or 3D — geographic location plus soil depth) of values are visualized and used for GIS modeling.

It is important to distinguish between the following types of soil maps:

- hand-drawn soil polygon maps representing distribution of soil types;
- simulated or predicted 2D/3D soil property maps (primary or secondary soil properties);
- simulated or predicted (2D) soil-class maps;

One should also distinguish soil maps that display primary soil attributes, i.e. the soil attributes originally described or measured in the field, and the soil inferred attributes also called secondary soil information, i.e. the properties of the soils in the context of the soil use: soil production capacity, soil reaction to certain use, soil functions, soil degradation measures etc.

Digital Soil Mapping (DSM) in soil science, also referred to as predictive soil mapping or pedometric mapping, is the computer-assisted production of digital maps of soil types and soil properties. Soil mapping, in general, involves the creation and population of spatial soil information by the use of field and laboratory observational methods coupled with spatial and non-spatial soil inference systems.
The international WORKING GROUP ON DIGITAL SOIL MAPPING (WG-DSM) defines digital soil mapping as "the creation and the population of a geographically referenced soil databases generated at a given resolution by using field and laboratory observation methods coupled with environmental data through quantitative relationships.

DSM can rely upon, but is considered to be distinct from traditional soil mapping, which involves manual delineation of soil boundaries by field soil scientists. Soil maps (paper sheets) produced as result of manual delineation of soil mapping units may also be digitized or surveyors may draw boundaries using field computers, hence both traditional, knowledge-based and technology and data-driven soil mapping frameworks are in essence digital. Unlike traditional soil mapping, Digital Soil Mapping is, however, considered to make an extensive use of:

1. technological advances, including GPS receivers, field scanners, and remote sensing, and
2. computational advances, including geostatistical interpolation and inference algorithms, GIS, digital elevation model, and data mining

In digital soil mapping, semi-automated techniques and technologies are used to acquire, process and visualize information on soils and auxiliary information, so that the end result can be obtained at cheaper costs. Products of the data-driven or statistical soil mapping are commonly assessed for the accuracy and uncertainty and can be more easily updated when new information comes available.[6]

Digital Soil Mapping tries to overcome some of the drawbacks of the traditional soil maps that are often only focused on delineating soil-classes i.e. soil types. Such traditional soil maps:

- do not provide information for modeling the dynamics of soil conditions and
- are inflexible to quantitative studies on the functionality of soils.

**Crop Scouting**

**Precision Technology Uses in Crop Scouting**

Crop scouting, also known as field scouting, is the very basic action of traveling through a crop field while making frequent stops for observations. Crop scouting is done so that a farmer can see how different areas of his or her field are growing. If there are problems during the growing season, the farmer can work to mitigate them so those problems do not affect yield at harvest time. Should problems go unnoticed or uncared for during the growing season, they can potentially limit the total yield, thus reducing the revenue from the sale of the crop or other intentions for the crop, such as livestock feed.

There are many different methods of crop scouting. While the traditional methods can include walking through the field and observing plants manually, particular pieces of equipment are still used, including field notes so the farmer can keep account of plants and areas that need more attention, a pocket knife and bags for sample taking, and finally a hand magnification lens so the farmer can get a close look and better idea of the health of his or her plants.
Crop and field scouting are crucial for each stage of the crop lifespan. Pre-seeding field scouting can show a farmer weed populations, including what weeds are growing and what growth stage the weeds are in. When it’s time to seed, field scouting can show the farmer information to lead them to choose what seed depth or seed rate they should plant at, as well as early indicators of seed treatments or selection. After the seeding is completed, frequent scouting will help to show farmers damaged seeds, early signs of pests, and many other factors. When crops begin to germinate and become established and rooted, continued scouting can help to prevent weed damage, pest damage, and post-spray pesticide or fertilizer performance. It is important to keep scouting on regular intervals through the plant’s life, as this scouting could reveal pest issues, soil moisture issues, and a variety of other risk that could be fought against. Crop Scouting tells farmers a huge amount about their plants, and can help them to improve yield, and maximize crop efficiency.

As precision agriculture technologies have advanced, farmers have been helped greatly when it comes to crop scouting. For example, instead of field notebooks, there are several different mobile apps that are compatible with different types of mobile devices, including tablet computers and smartphones that help farmers keep accurate logs of their fields, while also giving them the opportunity to cross compare these notes with previous years or different areas of the fields. Also with the advancement of global positioning systems (GPS) and unmanned aerial vehicles (UAVs), farmers don’t even need to walk through their fields. These new technologies can help to show farmers information that humans cannot see with the naked eye, as well as accurately pin-point where target areas are to provide assistance.

**GPS Use in Crop Scouting**

Global positioning systems are an extremely useful tool when it comes to the advancement of crop scouting in precision agriculture. Crop scouting has always relied on farmers remembering where they have scouted and taking note of that, although with the use of GPS, farmers now have an accurate recording of up to one foot of where they have been. With this precise location data they can make notes and have specific locations of where pests, poor soil temperature or moisture are located. With the preciseness of global positioning systems farmers can also accurately mitigate threats that they find in their fields.

GPS has now been incorporated into many different pieces of technology which help farmers to scout their fields much more efficiently and accurately. An example of these technologies includes different apps that are available for tablets or smartphones. These apps help farmers to not only mark their exact location in a field, but also make field notes, compare notes from previous years and more. These apps can help to show a farmer where exactly on an aerial photo of their farm target areas of issue are, as well as helping farmers to make future decisions based on past crop issues they have had.

**UAV in Crop Scouting**

UAV's are one piece of technology that have been developed and perfected for agricultural purposes in the past 10 years. UAV's also known as unmanned aerial vehicles, are constantly being perfected and developed to be more efficient, easy to use, and effective. Two main models
of UAV’s used in agriculture are the fixed wing platform, which is very similar to a plane, although it is scaled down and controlled with a remote control or GPS. The second model is the multi-copter - this model is similar to a helicopter although it generally has more propellers - some multi-copters have anywhere between 4 – 8 propellers. The more propellers that are added to a multi-copter typically provide more stability and power to the machine, this makes it easier to fly and maneuver in different weather conditions. Typically multi-copters are preferred on smaller farms where landing space is limited, while planes are usually better suited for extremely large farms.

UAV’s have assisted the agricultural sector by combining their technology with that of infrared cameras. These two pieces of technology combined mean that a farmer can get a bird’s eye view of his or her farm and see their crops from a whole new perspective. UAV’s are also capable to use these infrared cameras to render a variety of different information, including: what species are in their fields (weed and crop scouting), moisture levels of the soil or plants, plant development stages, plant health, and much more. These UAV’s give farmers a more holistic view of what is happening in their fields and with the use of these UAV’s, farmers are able to better understand their crops not just on a field by field basis, but on a plant by plant basis. This is because some UAV’s are carry cameras capable of showing one pixel as one foot of land, this means that the farmer can see each foot of land on their field and understand a wide range of information about that particular piece of field. UAV’s are helping farmers to undertake more accurate farming practices and with this precision comes better yield.

**Precision Maps**

Precision maps are an extremely useful tool in precision agriculture and are becoming more and more commonly used in the agriculture industry. Precision maps assist farmers by showing them precise locations in the field and providing them specific information about that location. A precision map is a map that is made up of geo-referenced data that can then be used to show information about a precise location in a field, as well as information on crop moisture levels, soil nutrients levels, crop yield and much more.

Precision maps work by using a variety of different physical sensors along with GPS information to analyze variables such crop or soil moisture, crop yield, and more. The benefit of precision maps is a farmer can use this type of information to accurately locate areas of need, low crop yield or low moisture levels, and react accordingly. Precision maps can help to save farmers money by preventing overspray, if a farmer utilizes precision maps, he or she will be able to mitigate their spraying by only spraying pesticides, fertilizers or replanting seeds in areas of need; this helps to not only save the farmer money, but also aids the environment.

There are many different types of precision maps that can be generated by farmers and these different types of maps can be used alongside each other to show many different things about field conditions that a farmer would not otherwise be able to easily see with his or her own eye. Precision maps can help farmers in a variety of different ways, one way is in their decision making process. When a farmer is using and utilizing precision maps to their full potential, they can make less guesses about what they think about soil nutrient levels or potential crop yield, and use precision maps to make educated and strategic choices for their fields. These maps could
help to make decisions including fertilizer or pesticide application, field conditioning, or crop rotation.

**Types of Precision Maps**

A precision map is any map that shows data in a geo-referenced manor. For example, although UAV’s can take pictures of fields and show a variety of different information, these are not precision maps due to their lack of precision. While on the other hand, some combine harvesters equipped with the proper technology can collect area specific data that is precise to a specific point in the field, not the field itself.

**Soil Maps**

Soil Maps can be collected in a variety of different ways, although geo-referenced soil maps are collected in different methods. One method is to divide the field into a grid pattern and sample each individual grid block, the more grid blocks and samples, the more accurate soil map you will have. Another method is to take samples of the field in zones that are designated by previous information such as yield maps, topography or other precision maps. In both of these examples, all of the soil samples are geo-referenced - which means that the location of the sample is recorded. This is so that specific samples can represent soil fertility levels in any particular zone of the field.

This geo-referenced map of soil samples that is eventually built-up can be used to cross reference other types of precision maps and determine nutrient levels, possible yield and many other pieces of information. These maps can also be paired with other pieces of precision agriculture technology such as VRT (variable rate technologies), like planters, sprayers or spreaders. These technologies connect with the GPS location of soil maps and or other precision maps to help accurately dispense a precise amount of product. This technology helps to prevent over seeding, fertilizing or pesticide use and applies product at a different rate in relation to what the field actually needs.

**Yield Maps**

A yield map is a map that focuses on crop yield - for example, how much more fruitful one area of the field is in comparison to another. This map is used as a visual tool and can help to show farmers relationships between crop yield and field condition variables. A yield map is best utilized when layered with many different types of maps so that it can accurately show farmers a variety of different information that is supported by other sources. Similar to soil maps and many other different types of precision maps, yield maps can be used alongside other technologies like VRT to help aid farmers even more as they harvest, or spread seed, fertilizer or apply pesticides.

These two types of maps are not the only type of precision maps, although they are two extremely common maps that help to aid farmers with decision making information.
Tools and Equipment Needed for Precision Mapping

For a farmer to accurately and precisely develop a precision map, a variety of different tools and equipment are needed, including sensors that are attached directly to farm machinery. These pieces of equipment help to read and evaluate many different aspects of crop and soil conditions and help to provide the farmer with valuable information about their fields.

Some Typical Precision Mapping Tools Include:

1. A Grain Moisture Sensor- This sensor detects grain moisture levels and can tell the farmer if an area of crops needs more or less irrigation.
2. A GPS Antenna- a GPS or Global Positioning System antenna is a piece of equipment that receives signals from global positioning satellites to provide and record specific locations.
3. A Grain Flow Sensor- This sensor helps to determine the volume of grain that has been harvested.
4. GPS Receiver and Yield Monitor- the Yield Monitor and GPS receiver work together to gather the information collected by the sensors and collect them in one central location while geo-referencing the data.
5. Grain Elevator Speed Sensor- this sensor is very similar to a grain flow sensor and gathers data of grain flow measurements, although having both sensors in place helps to improve the accuracy of measurements.

Although there are still a great deal of other tools and pieces of equipment that are used in precision mapping, these five are the most basic pieces of equipment and sensors that are used for this type of mapping. A variety of other sensors can be added to equipment for more accurate readings or a different variety of readings.

Site specific Input Application

Site-specific management is used to detect and measure the differences within fields, record these differences at specific locations and then use this information to guide changes in management or inputs. Site-specific farming is managing areas within fields, rather than using the same management on the entire field. To conduct site-specific farming, a producer must be able to do three things:

1. Know where you are: Use of GPS or more specifically Differential GPS provides accuracy of the location where the input has to be applied.
2. Gather information at that location: Information about locations within fields can be gathered by using sensors or by sampling. Use of sensors is by far the easiest method, but sometimes information on certain inputs, such as crop nutrient requirements, is best determined with sampling. Sensors that are commercially available include:
   - yield monitors
   - soil electrical conductivity or electro-magnetic sensors
   - remote imagery, including satellite images, aerial photography and hand-held active sensors
   - soil compaction sensors
   - on-the-go soil pH (alkalinity or acidity) sensors
3. **Site Specific Application:** Variable-rate controllers are available for whatever inputs need site-specific management. Liquid materials including fertilizers and manure, dry materials including fertilizers and manure, anhydrous ammonia, seed, agricultural chemicals and planter applied starter fertilizers all can be varied with any number of pieces of equipment. Existing flow-monitoring consoles also can be modified to control the application of materials site specifically. The data-input device can be as small as a PDA (personal digital assistant) or a laptop computer. Variable-rate application equipment can be as large as a commercial fertilizer applicator or as personal as a variable-rate seeder or anhydrous ammonia applicator. Most controller consoles today have been developed to work with several application devices. Checking with equipment manufacturers to determine which consoles would work best for a certain suite of application needs would be wise. Many companies also have site-specific experts on staff to aid in selection of the appropriate tools for making site specific farming work for growers.

**Weed Management**

The basic parts of site-specific weed control technologies comprise three key elements:

1. A weed sensing system, identifying, localising and measuring crop and weed parameters:
   - An automated weed sensing system that recognises weed species and plants is a prerequisite for saving herbicides for site-specific weed management. A sensing platform may be used to map the weeds and to make a treatment map with a weed management model prior to the weed control is carried out.

2. A weed management model, applying knowledge and information about crop–weed competition, population dynamics, biological efficacies of control methods and decision-making algorithms, and optimising treatments according to the density and composition of weed species, economic goals and environmental constraints.

3. A precision weed control implement, e.g. a sprayer with individual controllable boom sections or a series of controllable nozzles that enable spatially variable applications of herbicides.

Several sprayers have been developed for weed control in the field at resolution 3 and 4. Most of the sprayers have systems based on GIS that contain the weed and treatment maps. Another category of precision sprayers is the direct injection sprayers, which allow online adaptation of herbicide type and dosage to the site-specific demand for weed control.

**Insect-Pest and Disease Management**

Insect pests and diseases are significant issues in crop protection. For this reason, improved sensors for precision farming are constantly being improved. Such modern technology includes pest detection sensors which detect disease and insect pest occurrence on crops. Basically, the sensors provide real-time data from the field.

**Sensors for Accurate Insect Pest Detection**
Farmers can use various sensors for insect pest detection on crops. These range from simple to the most complex work principle. Some of the most common sensor types are:

1. **Low-power Image Sensors**

The low-power image sensor is an wireless autonomous monitoring system that is based on a low-cost image sensor. Placed in a single trap, the wireless sensor periodically captures images of the trap contents and sends them remotely to a control station. Sent images are then used for determination of the number of pests found at each trap. Based on insect population number, a farmer can plan when to start with crop protection and in which field areas.

Farmers use this sensor to monitor large areas with very low energy consumption. Low image sensors provide many benefits in farm production. Some of them are:

- Significant reduction of pest monitoring costs
- No human intervention in the field required
- Applicable for small and big areas
- Low maintenance cost
- Real-time insect pest monitoring

2. **Acoustic Sensors**

An acoustic sensor is an insect pest detection sensor which works by monitoring the noise level of the insect pests. How does it work? Wireless sensor nodes connected to a base station are placed in the field. When the noise level of the pest crosses the threshold, a sensor transmits that information to the control room computer, which then accurately indicates the infestation area.

These sensors help detect an infestation at a very early stage, thus greatly reducing crop damage. These are a great tool for the monitoring of large field areas with very low energy consumption.

The occurrence of insect pests can be also monitored with sensors for Leaf Area Index (LAI) measuring. Insect pest feeding destroys leaves. This causes plants to lose chlorophyll. This leads to a reduction in the total leaf area, and as a result, the reduction of the plant's capacity to photosynthesize. By measuring the leaf area index, the sensor can identify an insect attack at an early stage and warn farmers to take the appropriate actions.

This sensor uses radiation measurements and other parameters to accurately calculate leaf area index in real-time, in the field. This type of sensor is also used for crop disease detection.
Sensors for Early Crop Disease Detection

Crop diseases, if not treated timely and properly, can significantly reduce the yield, thus endangering global food security. For this reason, disease protection is the most important task for every farmer. Since early detection can successfully control disease, farmers use modern farm measures to protect their crop. These measures include direct and indirect disease identification methods.

Direct detection methods are mainly laboratory-based techniques of disease detection. The most common are polymerase chain reaction (PCR), immunofluorescence (IF), fluorescence in-situ hybridization (FISH), enzyme-linked immunosorbent assay (ELISA), flow cytometry (FCM), and gas chromatography-mass spectrometry (GC-MS). Although providing accurate data, these methods can’t be used for on-field disease detection.

Unlike direct, indirect methods are used directly in the field. Based on plant stress and levels of plant volatility, indirect method sensors can identify biotic and abiotic stresses, as well as pathogenic diseases in crops. These are optical sensors which, based on thermography, fluorescence imaging, and hyperspectral techniques, are able to predict plant diseases.

1. Thermography Disease Detection Method

Thermography sensors measure the differences in surface temperature of the plant leaves and canopy. The sensor captures infrared radiation emitted from the plant surface.

If there is a pathogen infection, the plant surface temperature will increase due to the transpiration reduction. Based on the change in temperature, the sensor can analyze disease presence. Thermography sensors can detect the changes due to the disease before it even appears.

Precision disease control is limited due to its high sensitivity to the change of environmental conditions during measurements. Another problem is that the thermography method can’t be used to identify the type of infection.
2. Fluorescence Disease Detection Method

Sensors using the fluorescence method measure the chlorophyll fluorescence on the leaves and measure the incident light and the change in fluorescence parameters. It measures changes in chlorophyll and photosynthetic activity, thus detecting the pathogen presence.

Although fluorescence measurement provides sensitive detection of abnormalities in photosynthesis, the practical application of this technique in a field setting is limited.

3. Hyperspectral Disease Detection Method

Sensors implementing the hyperspectral method use a wide range of spectrum, between 350 and 2500 nm, to measure plant health. They measure the changes in reflectance that are the results of the biophysical and biochemical characteristic changes experienced upon infection. Hyperspectral cameras collect the data in three dimension, with X- and Y- axis for spatial, and Z- for spectral, thus providing more detailed and accurate information about plant health. In order to monitor a large field area, sensors are usually fitted to an unmanned aerial vehicle (UAV).

Hyperspectral sensors are used for early crop disease detection, thus allowing a farmer quick and timely crop protection.
4. Gas Chromatography Disease Detection Method

This is a non-optical sensor used for crop disease detection and is used to determine volatile chemical compounds released by the infected plants. Pathogens on plants release specific volatile organic compounds (VOCs) that are characteristic of each pathogen type. The same thing happens when the plant is stressed due to mechanical damage. In this regard, sensors using gas chromatography can accurately identify the type and nature of infection.

The only lack of this method is required sampling of pre-collected volatile organic compounds for a longer time before data analysis, which severely limits its on-field application.

The Future of Pest Detection Sensors

Along with the aforementioned, there are many more sensors that can be used for crop disease and insect pest detection using electrical, chemical, electrochemical, optical, magnetic, or vibrational signals. However, farm technology is modernizing rapidly. New sensors are constantly being developed in order to support early pest identification based on bio-recognition elements such as DNA/RNA, antibody, and enzymes.

In aiming to produce enough food to feed the growing population and to secure a sustainable future for society, farmers need all the help they can get in order to get the best from their farmland. This can be achieved by using sensors in crop production. Knowing what is going on in the field at any given time makes farming easier, secures harvests, and boosts yields, all of which work to protect the environment.