UNIT I

PRECISION FARMING **9**

Precision agriculture and agricultural management – Ground based sensors, Remote sensing, GPS, GIS and mapping software, Yield mapping systems, Crop production modeling.

PRECISION AGRICULTURE

Concepts and Techniques

Precision agriculture is a farming management approach that uses technology to improve **efficiency, reduce waste, and increase productivity**. It involves the use of various technologies, such as **GPS, GIS, remote sensing, and sensor-based systems**, to collect and analyze data about soil, crops, weather, and other factors that influence crop growth and yield. This data is then used to make more informed decisions about crop management, resource allocation, and precision application of inputs.

Three main elements of precision agriculture is

1. **Data collection,**
2. **Interpret and analyse**
3. **Implementation.**

Concepts

Here are some of the key concepts of precision agriculture:

1. **Site-specific management**: Precision agriculture involves the use of site-specific management techniques, where the **field is divided into smaller management zones based on soil type, nutrient availability, topography, and other factors**. This allows farmers to apply inputs, such as fertilizers and pesticides, only where they are needed, reducing waste and improving efficiency.
2. **Yield monitoring**: Yield monitoring involves the use of sensors and other technologies to **collect data on crop yield and quality**. This data can be used to create yield maps, which can help farmers identify areas of the field that are performing well and areas that need improvement.
3. **Variable rate application**: Precision agriculture also involves the use of variable rate application of inputs, where the application rates of fertilizers and pesticides are adjusted based on the needs of different areas of the field. This allows farmers to optimize the use of inputs and reduce waste.
4. **Remote sensing**: Remote sensing involves the use of satellite and aerial imagery to collect data on crop growth, nutrient levels, and other factors that influence yield. This data can be used to create maps of crop health and yield potential, which can help farmers make more informed decisions about crop management.
5. **GPS and GIS**: GPS and GIS technologies are used in precision agriculture to **collect and analyze data on soil type, topography, and other factors that influence crop growth and** yield. This data can be used to create maps of management zones and guide the precision application of inputs.
6. **Automated systems**: Precision agriculture also involves the use of automated systems, **such as robotic harvesters and autonomous tractors**, to reduce labour costs and improve efficiency.

Overall, precision agriculture is a promising approach to farming that can help farmers improve efficiency, reduce waste, and increase productivity. By using technology to collect and analyze data about soil, crops, and weather, farmers can make more informed decisions about crop management, resource allocation, and precision application of inputs, leading to more sustainable and profitable farming practices.

Techniques

Precision agriculture involves the use of various techniques and technologies to improve crop management, reduce waste, and increase productivity. *Here are some of the key precision agriculture techniques*:

1. **GIS**: GIS (Geographic Information System) is a **software tool** that enables farmers to **store, analyze, and display spatial data,** such as field maps, soil samples, and weather data. GIS can be used to identify patterns and relationships between different variables, such as soil type and crop yield, enabling farmers to make data-driven decisions about input application and other management practices.
2. **GPS**: GPS (Global Positioning System) is a **satellite-based navigation system that enables farmers to map and measure their fields with high precision.** This data can be used to create detailed field maps, which can help farmers to identify variations in soil type, moisture content, and other factors that can affect crop growth and yield. GPS can also be used to guide precision equipment such as tractors, sprayers, and harvesters, enabling farmers to apply inputs at precise locations in the field.
3. **Soil mapping and analysis:** Precision agriculture starts with accurate soil mapping and analysis. This involves **collecting data on soil properties** such as texture, pH, nutrient content, and water-holding capacity. The data can be collected using various technologies, such as electromagnetic induction sensors, soil coring, or gamma-ray spectrometry. Once the data is collected, it can be used to create soil maps and develop site-specific management plans.
4. **Variable rate technology (VRT):** Variable rate technology involves the use of **sensors and software** to vary the application of inputs such as fertilizers, pesticides, and seeds based on the needs of different areas of the field. This helps to reduce waste and improve yields by applying inputs only where they are needed. VRT can be used for both dryland and irrigated farming systems.
5. **Precision irrigation**: Precision irrigation involves the use of sensors and software to optimize irrigation scheduling and water application rates. This helps to reduce water waste and increase yields by applying water only where and when it is needed. Precision irrigation can be achieved using techniques such as **drip irrigation, centre pivot irrigation, or subsurface drip irrigation.**
6. **Crop monitoring and management**: Crop monitoring and management involves the **use of sensors, drones, and satellite imagery to monitor crop health, growth, and yield.** This data can be used to make informed decisions about crop management, such as adjusting nutrient application rates or applying pesticides only where needed. Crop monitoring can also involve using GPS-enabled tractors or automated robots for planting, harvesting, and other tasks.
7. **Precision livestock farming**: Precision agriculture can also be applied to livestock farming. This involves the use of sensors and other technologies to **monitor animal health, growth, and behaviour**. This data can be used to improve animal management and welfare, optimize feeding and breeding programs, and reduce environmental impacts.
8. **Data analysis and decision-making**: All precision agriculture techniques require data collection and analysis, which can be done using various software and analytical tools. This data can be used to make informed decisions about crop management, resource allocation, and precision application of inputs. Decision-making can also involve using predictive models or artificial intelligence algorithms to forecast crop yields or optimize management plans.

Overall, precision agriculture techniques are constantly evolving as new technologies are developed and tested. The goal of precision agriculture is to improve efficiency, reduce waste, and increase productivity by using data-driven approaches to crop and livestock management.

Their issues and concerns for Indian agriculture

There are several issues and concerns related to the adoption of precision agriculture in Indian agriculture. Here are some of them:

1. **Lack of infrastructure**: The adoption of precision agriculture techniques requires significant investment in infrastructure such as sensors, software, and data analysis tools. This can be a challenge for small-scale farmers who may not have the financial resources to invest in such technology.
2. **Limited access to information**: In India, there is a significant digital divide, with many farmers lacking access to information and communication technology. This limits their ability to adopt precision agriculture techniques and benefit from the potential improvements in productivity and efficiency.
3. **The complexity of technology**: Many precision agriculture techniques require specialized knowledge and training to operate and interpret data. This can be a challenge for farmers who may not have the necessary skills or education to fully utilize the technology.
4. **Cost-benefit analysis**: While precision agriculture has the potential to increase yields and reduce waste, the cost of adopting these techniques must be carefully evaluated against the potential benefits. Some farmers may be reluctant to invest in precision agriculture if they do not see a clear return on investment.
5. **Policy and regulatory framework**: The Indian government has taken steps to promote the adoption of precision agriculture, such as launching programs to provide financial assistance and training to farmers. However, there is a need for a clear policy and regulatory framework to support the adoption and use of precision agriculture technology.
6. **Environmental concerns**: Precision agriculture techniques such as precision irrigation and precision application of inputs can reduce waste and improve efficiency. However, there is also a concern that the increased use of technology could lead to environmental problems such as pollution and soil degradation.

   Overall, the adoption of precision agriculture in India requires a concerted effort from the government, the private sector, and farmers to address the issues and concerns related to the technology. With careful planning and implementation, precision agriculture has the potential to significantly improve the productivity and sustainability of Indian agriculture.

Uses of GIS, GPS &VRA in precision agriculture

_GIS

GIS (Geographic Information System) technology is widely used in precision agriculture for collecting, analyzing, and visualizing spatial data. Here are some of the specific uses of GIS in precision agriculture:

1. **Crop management**: GIS can be used to collect data on soil characteristics, weather conditions, topography, and other factors that affect crop growth. This information can be used to make informed decisions about planting, fertilizing, and harvesting crops.
2. **Precision irrigation**: GIS can be used to map soil moisture levels and create irrigation zones based on the specific water requirements of different areas of the field. This helps to minimize water waste and reduce irrigation costs.
3. **Soil analysis**: _GIS can be used to analyze soil samples and create maps of soil characteristics such as pH, nutrient levels, and texture. This information can be used to create customized fertilizer plans for specific areas of the field.
4. **Yield mapping**: GIS can be used to collect data on crop yield and create maps of the yield variability across a field. This information can be used to identify areas of the field that may require different management practices.

5. **Pest and disease management**: GIS can be used to track the spread of pests and diseases across a field and identify areas that require targeted treatment. This can help to reduce the use of pesticides and minimize the risk of resistance developing.

   Overall, GIS technology can help farmers to make more informed decisions about crop management, reduce waste, and increase yields. By using GIS to collect and analyze spatial data, farmers can tailor their management practices to the specific needs of their crops and maximize their productivity.

GPS

GPS (Global Positioning System) technology is widely used in precision agriculture for mapping and navigating fields, tracking machinery and equipment, and collecting data on crop growth and yield. *Here are some specific uses of GPS in precision agriculture:*

1. **Mapping and navigation**: GPS can be used to create maps of field boundaries, drainage patterns, and other important features. Farmers can use GPS-enabled devices to navigate fields and ensure that they are applying inputs (such as fertilizer and pesticides) to the correct locations.
2. **Guidance systems**: GPS can be used to guide tractors, harvesters, and other machinery across the field with precision, reducing overlap and minimizing soil compaction. This can help to increase efficiency and reduce input costs.
3. **Yield monitoring**: GPS can be used to collect data on crop yield as the harvest takes place. This information can be used to create yield maps and identify areas of the field that require different management practices.
4. **Variable rate application (VRA):** GPS can be used in conjunction with VRA technology to apply inputs (such as fertilizer, pesticides, and seed) at varying rates across the field. This can help to optimize inputs, reduce waste, and increase yields.
5. **Field scouting**: GPS can be used to track and record observations about crop growth and pest/disease pressure in specific areas of the field. This information can be used to create management plans that are tailored to the needs of each area.

   Overall, GPS technology can help farmers to improve the accuracy and efficiency of their management practices, reduce waste, and increase yields. By using GPS-enabled devices to map and navigate fields, track equipment and inputs, and collect data on crop growth and yield, farmers can make more informed decisions and optimize their operations for maximum productivity.

VRA

VRA (Variable Rate Application) is a precision agriculture technology that enables farmers to apply inputs (such as fertilizer, pesticides, and seed) at different rates across a field. *Here are some specific uses of VRA in precision agriculture:*

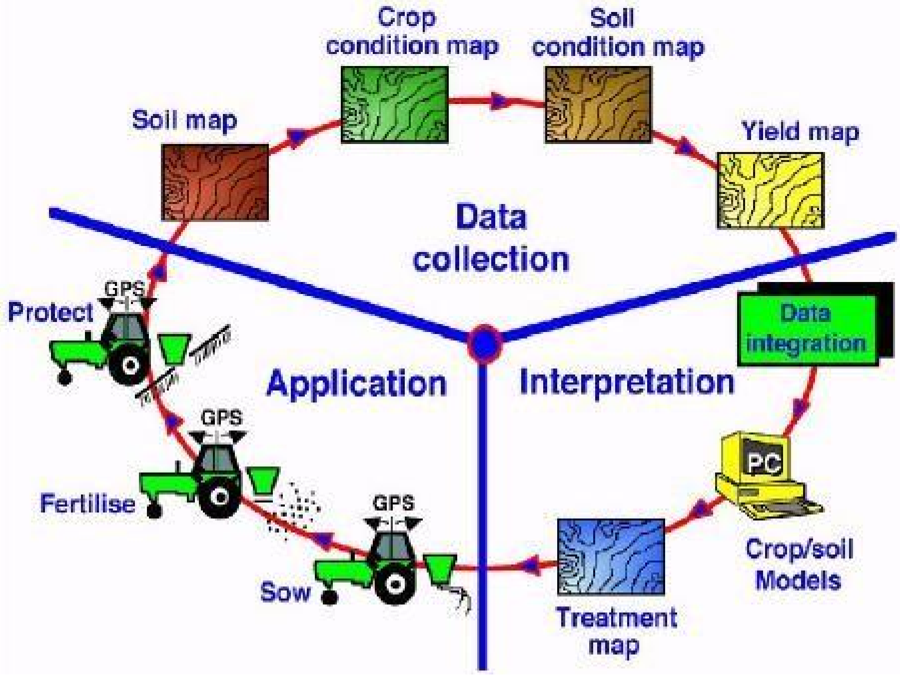
1. **Precision fertilization**: VRA technology can be used to vary the rate of fertilizer application based on soil nutrient levels, topography, and other factors. This can help to reduce waste, improve crop quality and yield, and minimize environmental impacts.
2. **Precision pesticide application**: VRA can be used to apply pesticides only where they are needed, reducing the number of chemicals used and minimizing the risk of off-target effects.
3. **Seeding rate optimization**: VRA can be used to adjust seeding rates based on soil conditions and other factors, helping to optimize plant populations and improve crop yields.
4. **Irrigation optimization**: VRA can be used to adjust irrigation rates based on soil moisture levels, weather conditions, and other factors. This can help to conserve water and reduce input costs while maintaining crop quality and yield.

5. **Soil pH management**: VRA can be used to adjust the rate of lime application to manage soil pH levels. This can help to improve soil health and nutrient availability, leading to better crop yields.

   Overall, VRA technology enables farmers to tailor their management practices to the specific needs of each area of the field, optimizing inputs, reducing waste, and increasing yields. By using VRA to apply inputs at different rates across the field, farmers can improve the efficiency and sustainability of their operations, while also maximizing profits.

COMPONENTS OF PRECISION FARMING

Precision farming should not be thought of as only yield mapping and variable rate fertilizer application and evaluated on only one or the other. Precision farming technologies will affect the entire production function (and by extension, the management function) of the farm. A brief overview of the components in precision farming is presented in Figure 1 and listed below.



Yield monitoring

Instantaneous yield monitors are currently available from several manufacturers for all recent models of combines. They provide a crop yield by time or distance (e.g. every second or every few metres). They also track other data such as distance and bushels per load, number of loads and fields.

Yield mapping

GPS receivers coupled with yield monitors provide spatial coordinates for the yield monitor data. This can be made into yield maps of each field.

Variable rate fertilizer

Variable rate controllers are available for granular, liquid and gaseous fertilizer materials. Variable rates can either be manually controlled by the driver or automatically controlled by an on board computer with an electronic prescription map.

Weed mapping

A farmer can map weeds while combining, seeding, spraying or field scouting by using a keypad or buttons hooked up to a GPS receiver and datalogger. These occurrences can then be mapped out on a computer and compared to yield maps, fertilizer maps and spray maps.

Variable spraying

By knowing weed locations from weed mapping spot control can be implemented. Controllers are available to electronically turn booms on and off, and alter the amount (and blend) of herbicide applied.

Topography and boundaries

Using high precision DGPS a very accurate topographic map can be made of any field. This is useful when interpreting yield maps and weed maps as well as planning for grassed waterways and field divisions. Field boundaries, roads, yards, tree stands and wetlands can all be accurately mapped to aid in farm planning.

Salinity mapping

GPS can be coupled to a salinity meter sled which is towed behind an ATV (or pickup) across fields affected by salinity. Salinity mapping is valuable in interpreting yield maps and weed maps as well as tracking the change in salinity over time.

Guidance systems

Several manufacturers are currently producing guidance systems using high precision DGPS that can accurately position a moving vehicle within a foot or less. These guidance systems may replace conventional equipment markers for spraying or seeding and may be a valuable field scouting tool.

Records and analyses

Precision farming may produce an explosion in the amount of records available for farm management. Electronic sensors can collect a lot of data in a short period of time. Lots of disk space is needed to store all the data as well as the map graphics resulting from the data. Electronic controllers can also be designed to provide signals that are recorded electronically. It may be useful to record the fertilizer rates actually put down by the application equipment, not just what should have been put down according to a prescription map. A lot of new data is generated every year (yields, weeds, etc). Farmers will want to keep track of the yearly data to study trends in fertility, yields, salinity and numerous other parameters. This means a large database is needed with the capability to archive, and retrieve, data for future analyses.

GROUND BASED SENSORS

What are sensors?

A sensor is a gadget that perceives and responds to certain inputs which could be illumination, locomotion, pressure, heat, or moisture, and transforms it into a representation or signals that can be read by humans for further reading and processing.

They are commonly used in various applications, from detecting motion in security systems to measuring temperature in HVAC systems. They are also used in everyday objects like smartphones, cars, and appliances.

Sensors work by detecting physical or chemical changes in the environment and converting them into electrical signals. The type of sensor used depends on the type of change being detected.

For example, a temperature sensor detects changes in temperature and converts them into electrical signals that can be interpreted by the device it is connected to.

What are the types of sensors used in agriculture?

There are various types of sensors used in agriculture that enable the need for smart agriculture incorporation.

1. Optical Sensors in Agriculture

This is the use of light to evaluate soil materials and track countless light prevalence. These sensors can be positioned on automobiles, satellites, drones, or robots thereby enabling the soil to reflect and the gathering and processing of plant color data.

Optical sensors also have the ability and capacity to condition the clay, natural matter, and humidity properties of the soil.

2. Electrochemical Sensors for Soil Nutrient Detection

The electrochemical sensors aid in the collection, processing, and mapping of the chemical data of the soil. They are usually mounted on specially designed sleds.

They supply accurate details required for agriculture. This includes the nutrient of the soil levels and pH. The soil samples are then sent out to a soil testing lab and standard procedures are carried out.

Error-free measurements especially in the area of determining pH are carried out with the use of an ion-selective electrode. These electrodes notice the pursuit of specified ions, such as hydrogen, nitrate, and potassium.

3. Mechanical Soil Sensors for Agriculture

These types of sensors are used to measure soil compression or mechanical opposition. This sensor uses an application that passes through the soil. This sensor then records the force calculated by pressure scales or load cells.

When a sensor passes through the soil, it documents the holding forces that result from the cutting, smashing, and displacing of soil. Soil mechanical resistance is recorded in a unit of pressure and points out the ratio of the force necessary to go into the soil channel to the frontal area of the tool engaged with the soil.

4. Dielectric Soil Moisture Sensors

This sensor calculates the moisture levels in the soil with the assistance of a dielectric constant. This is an electrical property that substitutes depending on the moisture content in the soil.

The moisture sensors are used in association with precipitation check locations all around the farm. This allows for the scrutiny of soil moisture positioning when vegetation level is low.

5. Location Sensors In Agriculture

They are also known as agricultural weather stations. They are positioned at different places throughout the fields. These precision agriculture sensors are used to determine the variety, distance, and height of any position within the required area. They take the help of GPS satellites for this purpose.

6. Electronic Sensors

They are installed on tractors and other field equipment to check equipment operations. Data are transmitted via cellular and satellite communication systems to computers or mailed to individuals directly. The supervisor in charge can now have access to the information either on their office computer or their personal cell phones.

7. Airflow Sensors

Its measurements can be made at particular locations while on the move. These types of sensors measure soil air penetration. The expected result is the pressure needed to push a decided amount of air into the ground at a prescribed depth. There are various soil properties, including moisture levels, soil type compaction, and structure, which produce a different identifying signature.

8. Agriculture Sensors IoT

With the increase in adoption of the Internet of Things (IoT) the ability to connect various devices have being implemented in virtually every aspect of our life. It only makes great sense that automation also finds its own application in agriculture as it will have a great impact on it.

This sensor provides real-time information on what is happening on the field such information including air temperature, soil temperature at various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation, and atmospheric pressure.

This indicates that farmers are in the know-how of when their crops are due for harvest, the quantity of water being used, the soil health, and if there's a need for any additional input. This is measured and recorded at scheduled intervals.

There is a big list of sensors used in agriculture IOT sensors which means (Solutions for Smart Farming). Making use of precision agriculture sensors will definitely transform the agricultural industry by increasing crop production, adopting a pest-free high yield variety in crops, and keeping up with the increasing demand for food.

Different Forms of Sensors in Agriculture

Although many different types of intelligent farming sensors exist, IoT sensors for agriculture are the most prevalent and widely used.

Farm aspects	Categories of sensors
Soil	Soil moisture, soil temperature
Canopy	Leaf wetness
Microclimate	Air humidity, lux meter, wind speed, and direction.

Categories of Farm Sensors

Types of sensors used in agriculture

A. **Soil sensors**

1. Soil moisture sensors

- A soil moisture sensor is a tool **used for measuring the exact moisture amount in the soil near plant root zones.**
- The data collected by these sensors is useful information for precise irrigation practices.
- The soil moisture sensors allow for much more efficient scheduling of water supply and distribution.
- For the best plant growth, such sensors aid in reducing or increasing irrigation.
- The soil moisture sensors can be divided into **primary and secondary sensors.**
- The role of these sensors is to give soil moisture readings at primary and secondary root zones.

Soil moisture sensor

2. Soil temperature sensors

- Soil temperature sensors are used for measuring the real-time temperature of the soil. These temperature readings help predict any possible soil-borne disease infections.
- In agricultural assessment and research, soil temperature sensors are frequently used.
- The soil temperature sensor can operate for an extended period of time in humid conditions with a quick response.

- It has a high measurement accuracy and consistency, allowing it to simultaneously monitor the temperature of the soil, atmosphere, and water in real-time, giving the overall temperature of the soil.

B. Canopy sensors

1. Leaf wetness sensors

- The Leaf Wetness sensor is an innovative and user-friendly tool that makes it possible to detect leaf wetness accurately and affordably.
- Many bacterial and fungal diseases only harm plants when there is moisture on the leaf surface.
- The Sensor detects dampness on the surface of a leaf, allowing researchers and growers to foresee disease & pests and preserve plant canopies.

Leaf wetness sensor

C. Micro-climate sensors

1. Air humidity sensors

- Light, water, soil, and air are the four elements that crops need to survive.
- The impact of water, however, is the most crucial factor in growing healthy crops.
- The amount of water the air can store at any particular temperature is measured by relative humidity.
- Humidity Sensors assist in predicting disease and pest attacks that might attack the farm at a specific relative humidity. This dramatically enhances farmers' efforts and lower expenses.

2. ***Windspeed and direction sensors***

- Wind speed and direction sensors monitor the wind during farming activities like spraying.
- In general, an anemometer is the best tool for measuring wind speed, whereas vane sensors assist in measuring wind direction.
- Farming activities considering the wind speed and direction measurements can draw better outcomes because the wind can impact many factors in the farm.
- The magnitude of the wind speed will influence seed transmission distance and pollination efficiency, which will impact plant reproduction and fruit set.
- In addition to having a positive effect on the environment of farmlands, wind also negatively affects agricultural output by spreading pathogens, causing widespread plant diseases,

assisting pests in migrating, and also by causing crops to fall and trees to break, as well as the phenomenon of falling flowers and fruits.

Wind speed, wind direction sensor

3. ***Rainfall sensors or Rain sensors***

- Rainfall sensors can help with plant health maintenance and water conservation by avoiding the need for frequent irrigation.
- Farmers can schedule their farming activities based on the information provided by the rainfall

sensors, which detect the quantity of rainfall that has happened.

- They can decide when to irrigate their crops at the ideal time using rainfall sensors.
- Rainfall sensors can measure the quantity of rainfall that has happened.

4. ***Lux sensor***

- Crop cultivation is a delicate balancing act. To keep plants healthy and in bloom, the ideal sun, water, and soil conditions must be met.
- An instrument known as a lux meter is used to measure brightness, more precisely, the intensity

needed for crops.

- Some diseases and pests attack at a specific intensity of sunlight. Farmers are informed whether there is a chance of a disease or pest attack on their farm based on the measurement of solar light intensity provided by lux sensors.

5. ***Temperature sensors***

- The three factors that affect plant growth the most are light, temperature, and moisture.
- By using temperature sensors, farmers can easily keep an eye on the temperature at the plant canopy level, thus reducing the risk of disease and pest infestation for their crops.

Several benefits are achieved from an automated method of capturing, storing and analyzing physical field records. Detailed analyses of the farm production management activities and results can be carried out. Farmers can look at the performance of new varieties by site specific area, measure the effect of different seeding dates or depths and show to their banker the actual yields obtained and the associated risk levels. It is imperative that trends and evaluations are also measured over longer time spans. Cropping strategies to control salinity may take several years to evaluate while herbicide control of an annual weed should only take one season. Precision farming can be approached in stages, in order to ease into a more complex level of management.

Precision farming allows for improved economic analyses. The variability of crop yield in a field allows for the accurate assessment of risk. For example, a farmer could verify that for 70 % of the time, 75 % of the barley grown in field "A" will yield 50 bushels. By knowing the cost of inputs, farmers can also calculate return over cash costs for each acre. Certain parts of the field which always produce below the break even line can then be isolated for the development of a site-specific management plan. Precision farming allows the precise tracking and tuning of production.

Precision farming makes farm planning both easier and more complex. There is much more map data to utilize in determining long term cropping plans, erosion controls, salinity controls and assessment of tillage systems. But as the amount of data grows, more work is needed to interpret the data and this increases the risk of misinterpretation. Farmers implementing precision farming will likely work closer with several professionals in the agricultural, GPS and computing sciences.

REMOTE SENSING

Remote sensing is a technology used to obtain information about the environment from a distance. In agriculture, remote sensing is used to gather data about crops, soils, weather patterns, and other environmental factors that can affect crop growth and yield.

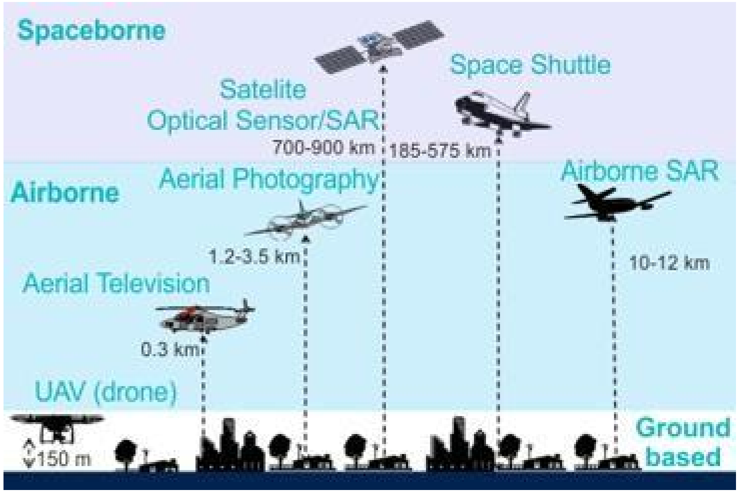
Remote sensing involves the use of various types of sensors, such as cameras and scanners, mounted on satellites, aeroplanes, or drones to collect data about the Earth's surface. The data obtained through remote sensing can be used to create detailed maps of agricultural fields, analyze crop health, and monitor changes in the environment over time.

Components of Remote Sensing Platform

It can be defined as the carrier for remote sensing sensors. There are three main remote sensing platforms, which are mentioned below:

1. Ground-level platforms – Like cranes and towers
2. Aerial platforms – Like helicopters, high altitude aircraft, and low altitude aircraft.
3. Spaceborne platforms – Like space shuttles, geostationary satellites, and polar-orbiting satellites.

Below is an image showing different types of platforms used in remote sensing.



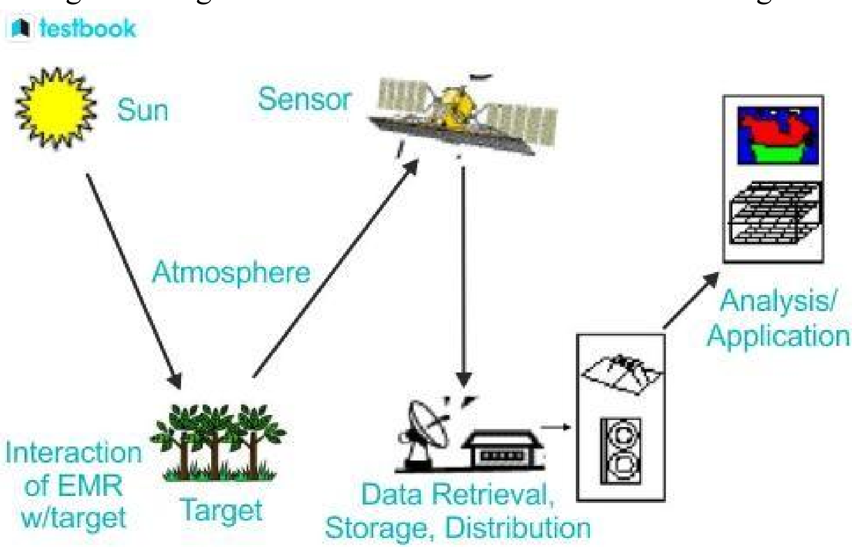
Sensors in Remote Sensing

It is a device that is used to receive electromagnetic radiation from different objects and surfaces and convert them into a signal that can be recorded and exhibited, either in the form of numerical data or in the form of an image.

There are also many elements involved in the functioning of remote sensing, which are mentioned below:

1. Source of energy (A)
2. Radiation of a source of energy in the atmosphere (B)
3. Interaction of radiation with the object (C)
4. Recording of the energy by a sensor (D)
5. Transmission, Reception, and Processing of the radiation (E)
6. Interpretation and analysis of the radiation by the sensor (F)
7. Application of that radiation (G)

Below is an image showing all the elements involved in remote sensing.



Types of Remote Sensing

There are mainly two types of sensors used, which are as mentioned below:

Active Remote Sensing

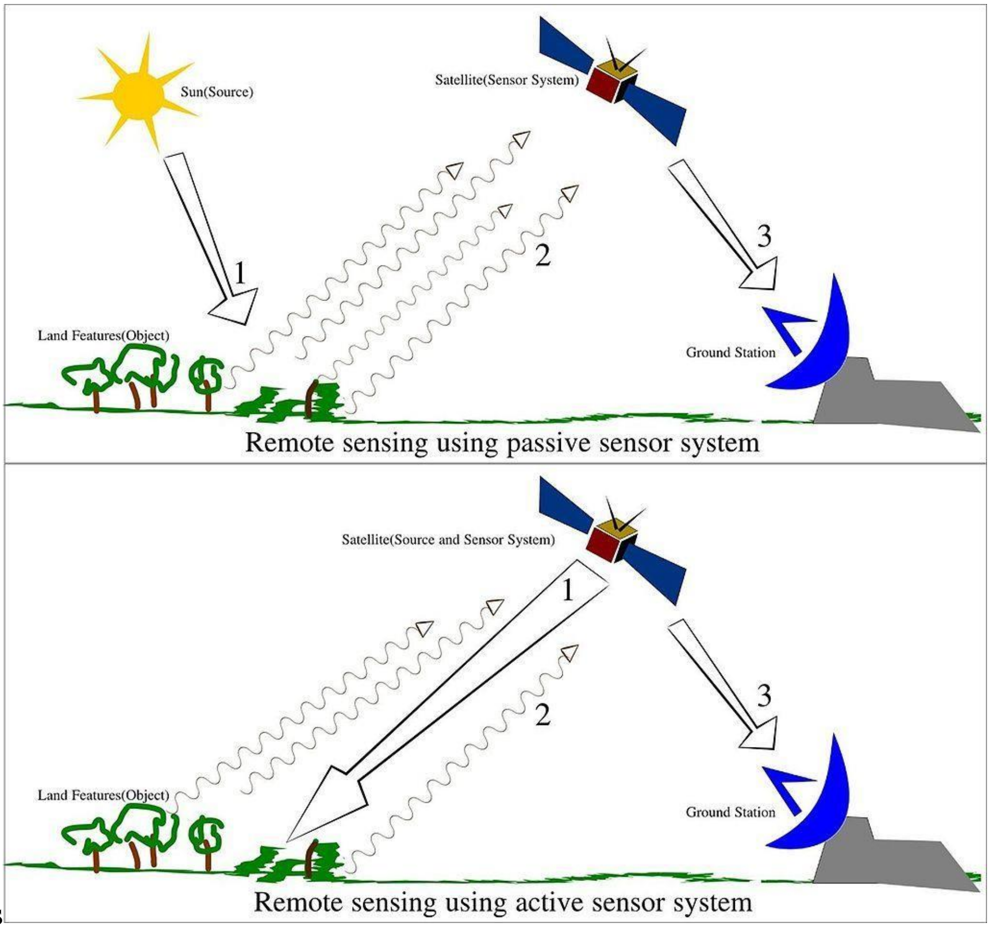
Active remote sensing utilizes an artificial source of radiation as an investigation, and the resulting signal, which scatters back to the sensor, depicts the Earth or the atmosphere.

The Synthetic-Aperture Radar system is a type of active sensor, which can emit radiation in the form of a beam coming from a moving sensor and can also measure the backscattered components returning to the sensor from the ground in the region of the microwave.

Passive Remote Sensing

Passive remote sensing depends only on solar radiation as its source of energy, which can be seen in multispectral, and hyperspectral sensors. It is mainly concentrated in the visible, near-infrared, and shortwave infrared spectral regions.

These sensors at the satellite measure the emerging radiation from the surface of the Earth's atmosphere system in the direction of sensor observation. In a remote sensing image, a grid of pixels is located to achieve image sensing by a combination of scanning in the cross-track direction and the sensor platform movement along the in-track direction.



Concepts

Some of the concepts related to remote sensing include:

1. **Electromagnetic Spectrum:** Remote sensing sensors detect different wavelengths of electromagnetic radiation, such as visible light, infrared radiation, and microwaves. Each wavelength corresponds to a specific color or energy level, and different sensors are designed to detect specific wavelengths.
2. **Spectral Signature:** Each type of material, such as **crops or soil, has a unique spectral signature**, which is a characteristic pattern of reflected or emitted radiation. By analyzing the spectral signature of different materials, remote sensing can identify and differentiate between them.
3. **Spatial Resolution:** The spatial resolution of a remote sensing image refers to the size of the smallest object or feature that can be detected. High-resolution images can provide more detailed information about crop health and soil conditions.
4. **Spectral bands:** Remote sensors typically capture data across a range of spectral bands, which are different sections of the electromagnetic spectrum. *For example,* visible light is captured in the red, green, and blue spectral bands.

5. **Temporal Resolution:** The temporal resolution of remote sensing refers to how frequently data is collected. Frequent data collection can help to monitor changes in crop growth, soil moisture, and other environmental factors over time.
6. **Data Processing**: The data obtained through remote sensing needs to be processed and analyzed to extract useful information. This can involve techniques such as image classification, which involves grouping pixels with similar characteristics into classes, and vegetation indices, which provide information about crop health.
7. **Radiometric resolution**: This refers to the ability of remote sensors to detect differences in the intensity of radiation. Higher radiometric resolution means more subtle differences in radiation can be detected.
8. **Image processing**: The data captured by remote sensors must be processed to generate useful information. This involves tasks such as filtering, enhancement, and classification to extract relevant information from the raw data.

   Remote sensing has several applications in agriculture, including crop monitoring, yield prediction, and soil mapping. It can also be used to monitor changes in the environment, such as deforestation and desertification.

Application of Remote Sensing in agriculture

Remote sensing applications in agriculture involve the use of remote sensing techniques and technologies to collect and analyze data on crops, soil, weather, and other aspects of agriculture. *Some of the key applications of remote sensing in agriculture are:*

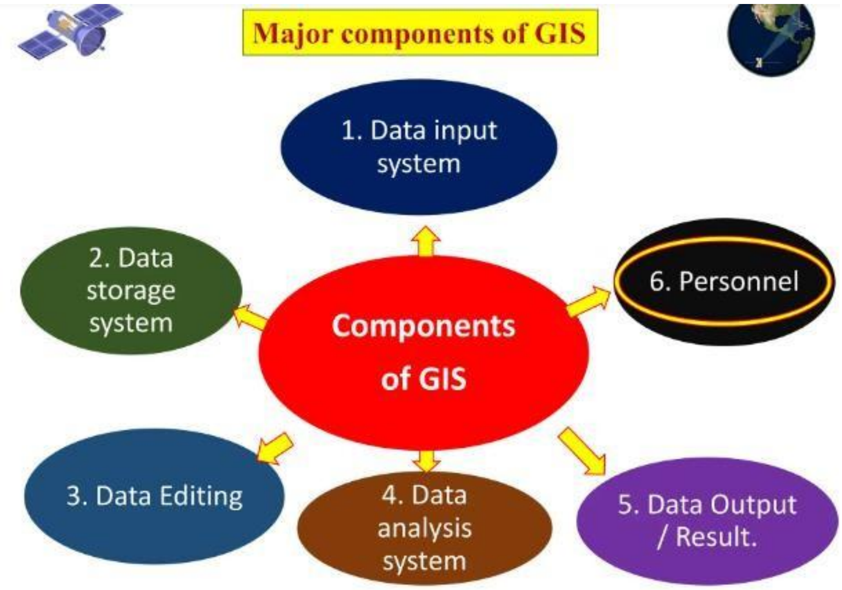
1. **Crop identification and monitoring:** Remote sensing can be used to identify and monitor different types of crops, their growth stages, and their health status. This information can help farmers make informed decisions about irrigation, fertilizer application, and pest control.
2. **Soil mapping and analysis:** Remote sensing can be used to map and analyze soil properties, such as texture, moisture, and nutrient content. This information can be used to create soil fertility maps and develop precision farming strategies.
3. **Weather monitoring and forecasting:** Remote sensing can be used to monitor weather patterns, such as temperature, precipitation, and wind speed, and to forecast weather conditions. This information can be used to plan planting and harvesting schedules, as well as to make decisions about irrigation and pest control.
4. **Water management:** Remote sensing can be used to monitor water resources, such as lakes, rivers, and aquifers, as well as to monitor irrigation and drainage systems. This information can help farmers optimize water use and conserve water resources.
5. **Yield estimation**: Remote sensing can be used to estimate crop yields by analyzing data on crop growth, vegetation indices, and environmental conditions. This information can help farmers plan for future crops and make informed decisions about marketing and distribution.
6. **Crop health assessment:** Remote sensing can be used to monitor the health of crops and detect early signs of stress or disease. This information can help farmers to take corrective measures to prevent further damage to the crops.
7. **Land use mapping**: Remote sensing can help in mapping land use patterns and changes over time, which can aid in the planning and management of agricultural landscapes
8. **Pest and disease management**: Remote sensing can be used to monitor the spread of pests and diseases, which can help in early detection and control measures.
9. **Precision agriculture:** Remote sensing can be used in combination with other geospatial technologies to support precision agriculture practices such as variable rate application of fertilizers and pesticides, and targeted irrigation.

Overall, remote sensing applications in agriculture can help improve crop productivity, reduce resource waste, and enhance environmental sustainability.
one of the benefits that can be gained from the use of remote sensing -

- Early identification of crop health and stress
- Ability to use this information to do remediation work on the problem
- Improve crop yield
- Crop yield predictions
- Reduce costs
- Reduce environmental impact
- Crop management to maximise returns through the season
- Crop management to maximise returns during harvest time.
- GIS (Geographic Information Systems)

development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS).
Thus, the activities normally carried out on a GIS include:

1. The measurement of natural and human made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: elements, attributes, and relationships.
2. The storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map. The features can be of three types: points, lines, or areas (polygons).
3. The analysis of collected measurements to produce more data and to discover new relationships by numerically manipulating and modelling different pieces of data.
4. The depiction of the measured or analyzed data in some type of display - maps, graphs, lists, or summary statistics.



Applications of GIS in Agriculture

Precision Agriculture

Precision agriculture GIS software provides detailed vegetation and productivity maps, including crop information, for making reasonable decisions.

Agriculture Mapping

Soil and crop analysis can be facilitated by satellite sensors, allowing the creation of soil index maps and maps of vegetation indices.

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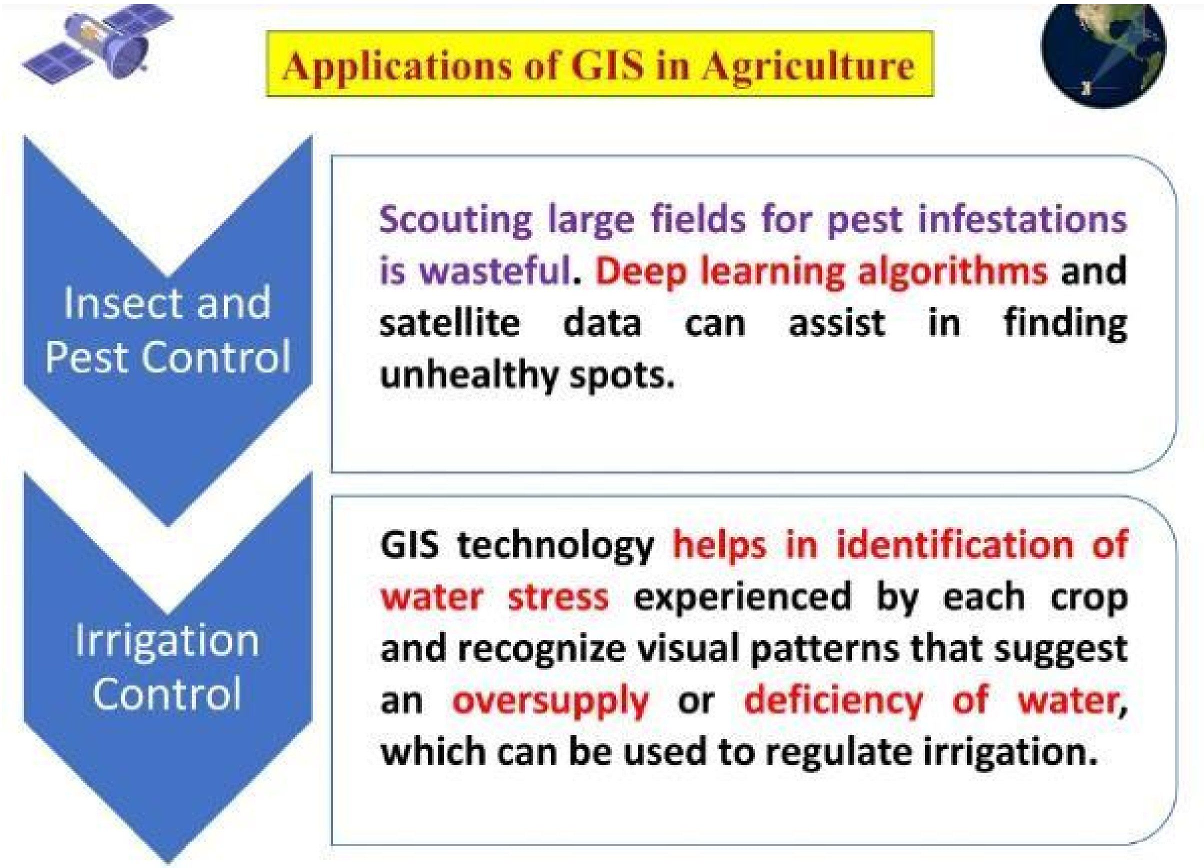
Crop Health Monitoring

Manually checking crops across a large area is the slowest and most labor-intensive method of monitoring crop health. Imagery sensors on satellites provide an advanced method for monitoring crop temperature, disease, pest infestation etc.



YIELD MONITORING AND MAPPING

Yield monitoring equipment was introduced in the early 1990s and is increasingly considered a conventional practice in modern agriculture. The pioneers of precision agriculture already have generated several years of yield history and have examined different ways of interpreting and processing these data.

Yield Mapping Concept

Yield mapping refers to the process of collecting georeferenced data on crop yield and characteristics, such as moisture content, while the crop is being harvested. Various methods, using a range of sensors, have been developed for mapping crop yields.

The basic components of a grain yield mapping system include:

- Grain flow sensor - determines grain volume harvested
- Grain moisture sensor - compensates for grain moisture variability
- Clean grain elevator speed sensor - used by some mapping sytems to improve accuracy of grain flow measurements
- GPS antenna - receives satellite signal
- Yield monitor display with a GPS receiver - georeference and record data
- Header position sensor - distinguishes measurements logged during turns
- Travel speed sensor - determines the distance the combine travels during a certain logging interval (Sometimes travel speed is measured with a GPS receiver or a radar or ultrasonic sensor.)

Each sensor has to be properly calibrated according to the operator's manual. Calibration converts the sensor's signal to physical parameters. A proprietary binary log file is created during harvest to record the output of all sensors as a function of time. This file can be converted to a text format or displayed as a map using the yield monitor vendor's software.

Processing Yield Maps

The yield calculated at each field location can be displayed on a map using a Geographic Information System (GIS) software package. The raw log file, however, contains points recorded during turns and the sensor measurements do not correspond to the exact harvest locations because grain flow through a combine is a delayed process (unless real-time correction is applied). To eliminate these obvious errors, the raw data is shifted to compensate for the combining delay, and the points corresponding to the header up position are removed. Settings for grain flow delay are combine- and sometimes even crop-specific, but typical values for grain crops range from about 10 to 12 seconds.

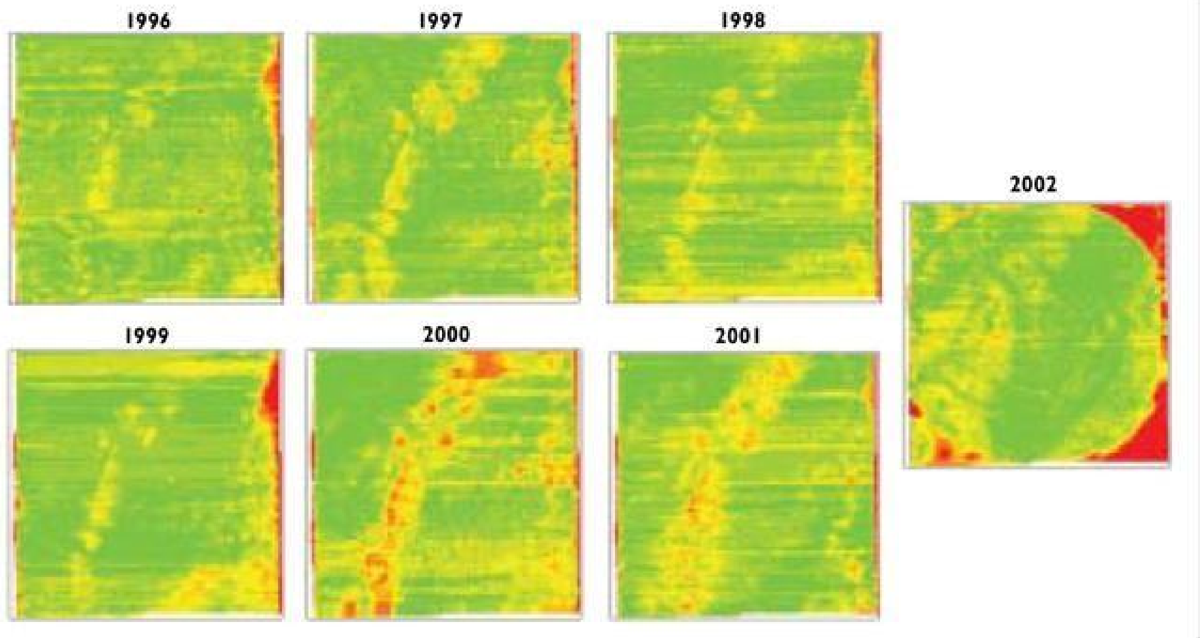
Usually a few points at the beginning and at the end of a pass should be removed as well. These are referred to as start-and end-pass delays. Start-pass delays occur when the combine starts harvesting the crop, but grain flow has not stabilized because the elevator is gradually filling up. Similarly, end-pass delays occur when the combine moves out of the crop and grain flow gradually declines to zero when the elevator is completely emptied. Consult the manufacturer of your yield monitor for the most appropriate settings to use with your combine.

Shifting of raw data to correct for grain flow delay as well as deletion of points that represent header status up and start-and end-pass delays is the primary data filtering procedure built into software supplied with yield mapping systems.

Yield History Evaluation

Evaluating the temporal (year-to-year) variation of yield distribution within the field is an essential step in defining field areas with potentially high and low yields. Several approaches can be used to evaluate temporal effects on yield. One approach is to calculate the relative (normalized) yield for each point or grid cell. Normalized yield can be defined as the ratio of the actual yield to the field average:

When growing conditions in a field vary considerably, such as irrigated and dryland areas or different crops or varieties grown in different areas, normalization should be done separately for those areas, with the resulting relative yields recombined into one data file for the whole field. The following figure shows a relative yield history for a field with corn (soybean in the southern half in 2000) grown using furrow-irrigation (until 2001) and center-pivot irrigation (in 2002).

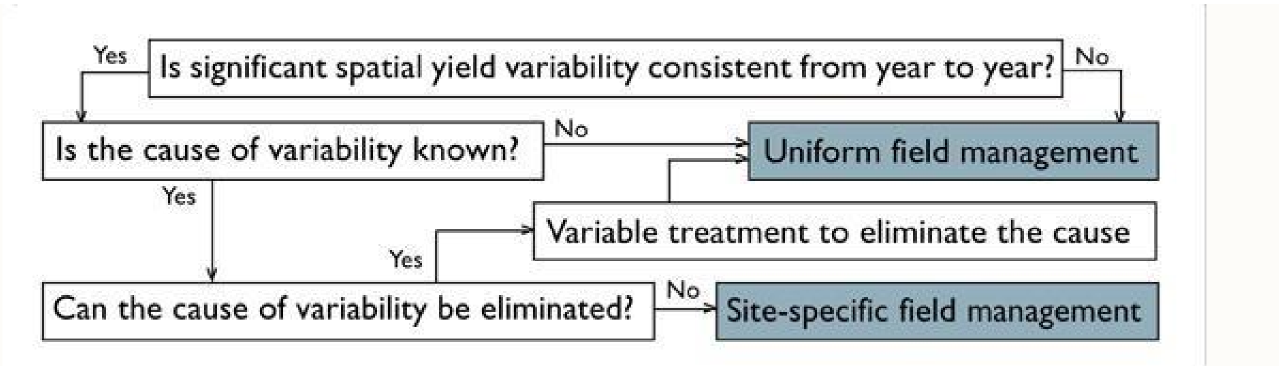


Maps of relative yield of corn and soybean grown during a seven-year period (red indicates low-yielding areas and green indicates higher than average yields).

Potential Applications

Yield maps represent the output of crop production. On one hand this information can be used to investigate the existence of spatially variable yield limiting factors. On the other hand, the yield history can be used to define spatially variable yield goals that may allow varying inputs according to expected field productivity.

The following flowchart illustrates the process one might follow in deciding whether to invest in site-specific crop management, based on analysis of yield maps. If yield variability across the field cannot be explained by any spatially inconsistent field property, uniform management may be appropriate. Site-specific management becomes a promising strategy if yield patterns are consistent from year to year and can be correlated to one or more field properties (e.g. nutrient supply, topography, past management, etc.).



If the causes for yield variation are known and can be eliminated permanently, the entire area could be brought to similar growing conditions and managed uniformly thereafter. This concept was one of the earliest philosophies behind precision agriculture, but is likely only feasible for certain field properties. For example, variable rate liming can be used to correct acidic areas in a field. In this case, the yield map is used only to investigate whether low soil pH is a yield-limiting factor, and the soil map is used to prescribe variable application rates. Another example would be localized deep soil tillage to alleviate compaction in selected field areas.

Most yield limiting factors cannot be modified permanently through single measures because of economic or practical constraints. Consequently, site-specific crop management may be used to appropriately account for the existing spatial variability in attainable yield and/or soil properties.

Summary

Yield maps are one of the most valuable sources of spatial data for precision agriculture. In developing these maps, it is essential to remove the data points that do not accurately represent the yield at a corresponding location. Map averaging or smoothing is usually done to aid data interpretation. A long yield history is essential to avoid drawing conclusions that are affected by the weather or other unpredictable factors during a particular year. Typically, at least five years of yield maps are desired. Processed yield maps can be used to investigate factors affecting the yield or to prescribe variable rate applications of agricultural inputs according to spatially variable yield goals (yield potential). Producers interested in precision farming should, however, always evaluate different management approaches to identify those that provide the greatest benefit at a particular site.

CROP PRODUCTION MODELING

A broad range of spatially explicit crop response models is needed to evaluate the efficacy of precision agriculture methods and provide the basis for precise recommendations. Many models for predicting how crops respond to climate, nutrients, water, light, and other conditions already exist, yet most of these do not include a spatial component appropriate to precision agriculture applications (Sadler and Russell, 1997).

GIS can provide the means to run the model continuously across an extensive area using data that reflect continually varying conditions. Time series and other temporal analyses can aid in predicting final crop yield. Current models may be extended to account for spatial effects, such as edge effects along field boundaries. In the ecological and biometeorological literature, however, several spatially explicit models have been developed to predict hourly, daily, and annual rates of evapotranspiration and photosynthesis, and several spatially distributed hydrologic models predict surface and subsurface flows. Meso- scale climate models can resolve cells as small as 5 to 10 kilometers for predicting weather conditions.

Pests are not dispersed evenly throughout the environment. To the extent that the factors influencing their spatial distribution are understood, their dispersion and potential for damage can be modeled. GIS can be used for spatially variable data for these factors. As with crop response models, a distinct pest model can be run continuously across a landscape, using GIS to input data to the model and display results (loosely coupled model), or a spatially explicit model can be created within the GIS software (tightly coupled model). GIS can provide the basis for multiscalar effects, for example, incorporating results of a regional pest pressure model into a system for generating within-field recommendations based on locally variable conditions.

A crop growth model could be used as a decision aid for determining different yields based on varying plant populations, which could help a producer decide when to plant or replant areas within a field based on plant population data and risk factors for various soil types. Having to make a decision to replant a field that is in a questionable condition is perhaps the hardest decision a producer faces. Any information to aid such decisions and reduce risk would be valuable.

In many crop production areas, landscape factors can cause dramatic variations in yield. Landscape elements affect many properties relevant to plant growth, including soil texture, soil organic matter, and temperature. Landscape morphology affects soil moisture available to crops by its influence on drainage and catchment area. Soil surveys typically do not have sufficient resolution to capture this variability in enough detail to support precision recommendations; even field- based sampling on a regular grid may miss relevant soil-landscape features. Stratifying sampling density on the basis of landscape features may be more cost effective and informative than a simple grid.

GIS allow users to create and manage digital elevation or digital terrain models created by photogrammetric methods (analysis of stereo pairs of aerial photographs) with new techniques using interoferometric radar or by continuous three-dimensional coordinate measurements with in-field equipment. Precise recommendations can be made to the extent that the relationships are understood between soil properties and surface morphology (i.e., slope, slope length, aspect, curvature, landscape position, catchment area, and drainage) derived from digital elevation or digital terrain models. Crop models do not offer a panacea for problem solving; they are limited in their ability to simulate various parts of a biological system.

Most of the crop and pest models available or developed to date were not designed to be used for man- aging spatial and temporal variation. It is not clear whether a predictive model, an explanatory model, or a hybrid approach will be more appropriate for precision agriculture. Alternatively, data mining and other techniques may be used to extract valuable information from large amounts of stored data. However, crop modeling is currently an important tool for gaining a theoretical understanding of a crop production system.

Crop Modeling:

Crop models are mathematical models used to quantitatively describe the effects of various factors, such as climatic and soil conditions, field management, crop varieties and more, on crop physiological processes from a systems perspective.

A model is a simplified representation of a system or a process. A model is a computer program, which describes the mechanism of the process or a system. Modelling is based on the assumption that any given process can be expressed in a form of mathematical statement or set of statements or a sets of statements to depict the real world system.

Modelling is classified into

- **Descriptive modelling and**
- **Explanatory modelling**

1. **Descriptive Modelling**

Descriptive model is a mathematical statements or a sets of statements, which describe the real world phenomena or events and the interrelationship between the factors involved in the process. The important aspects of descriptive modelling are as follows.

- Segmentation of Process The main process will be segmented into different subgroups, so that all variables of that main process will be accounted. For example, soil water availability is the main process and the sub groups are soil physical, chemical and biological properties as well as the plant community present in the soil.

- Segmentation Based on Importance The most important processes are identified in the system and due importance are given accordingly. For example in growth and development of a plant, the most important events are photosynthesis and respiration. Hence, photosynthesis and respiration process will be given more weightage than other process of the events. It does not mean that the other process will not be taken into account, the other processes are also included with due weightage.

- Interlinking of Different Processes Interlinking of interconnected process must be done for effective imitation of the processes or system of real world phenomena. For example, the soil water availability depends on rainfall, irrigation, solar radiation, soil temperature, evaporation, transpiration, soil colour, etc., and all the processes have to be interlinked in the study of soil water availability as sub process.

- Weightage of Important Processes Different weightage will be given for different processes of model based on its importance in the particular system. In the soil nutrient dynamics, much importance will be given to nitrogen followed by phosphorus, potassium and so on.

2. **Explanatory Modelling**

The explanatory models describe why and how the things works or why and how the phenomena is the way it is. The explanatory models are being used as a substitute for full explanatory model now a days, because full explanatory model is too long and cumbersome in the modelling. Hence, explanatory models describe, why and how for important process instead of all process, which is available in the model. Few examples of explanatory models are explanatory model of illness; the patient explanatory model (Kleinman model); explanatory model of health diseases among South Asian Immigrants; and explanatory model of health inequalities (WHO).

3. **Deterministic Modelling**

Deterministic model is a mathematical model, which produces outcome precisely through relationship among state variable and events with initial conditions, without any random variation. Hence, it will produce same output of the given input at all time. Example: Chemical reactions.

4. **Stochastic Model**

Stochastic model is a mathematical model, which estimates the probability distributions inputs into potential outcomes by allowing for random variation in inputs over the period of time. The standard time series techniques is being used for making random variation in fluctuations observed in historical data for a selected period. Large number of simulation (stochastic projection) is used to produce potential outcome for the random variable inputs. Simulation is the process of building models and analyzing the system. z Discrete model: The state variables change only at a countable number of points in time. These points in time are the ones at which the event occurs/change in state. Example: Statistical model , Continuous model: The state variables change in a continuous way, and not abruptly from one state to another (infinite number of states). Example: Crop Simulation Model.