KINGS ENGINEERING COLLEGE
An Autonomous Institution
Affiliated to Anna University, Chennai

DEPT. OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE

NOTES OF LESSON

Regulation	**: 2021**
Branch	**: B.Tech. – AI & DS**
Year & Semester	**: IV Year / VII Semester**
Sub.Code / Name	**: AI3021/IT in Agricultural System**

AI3021 IT IN AGRICULTURAL SYSTEM L T P C 3 0 0 3

COURSE OBJECTIVES:

- To introduce the students to areas of agricultural systems in which IT and computers play a major role.
- To also expose the students to IT applications in precision farming, environmental control systems, agricultural systems management and weather prediction models.

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.

UNIT II ENVIRONMENT CONTROL SYSTEMS 9

Artificial light systems, management of crop growth in greenhouses, simulation of CO_2 consumption in greenhouses, on-line measurement of plant growth in the greenhouse, models of plant production and expert systems in horticulture.

UNIT III AGRICULTURAL SYSTEMS MANAGEMENT 9

Agricultural systems - managerial overview, Reliability of agricultural systems, Simulation of crop growth and field operations, Optimizing the use of resources, Linear programming, Project scheduling, Artificial intelligence and decision support systems.

UNIT IV WEATHER PREDICTION MODELS 9

Importance of climate variability and seasonal forecasting, Understanding and predicting world's climate system, Global climatic models and their potential for seasonal climate forecasting, General systems approach to applying seasonal climate forecasts.

UNIT V E-GOVERNANCE IN AGRICULTURAL SYSTEMS 9

Expert systems, decision support systems, Agricultural and biological databases, e-commerce, ebusiness systems & applications, Technology enhanced learning systems and solutions, e-learning, Rural development and information society.

TEXT BOOK:

1.National Research Council, "Precision Agriculture in the 21st Century", National Academies Press, Canada, 1997.

2. H. Krug, Liebig, H.P. "International Symposium on Models for Plant Growth, Environmental Control and Farm Management in Protected Cultivation", 1989.

REFERENCES:

1. Peart, R.M., and Shoup, W. D., "Agricultural Systems Management", Marcel Dekker, New York, 2004.

2. Hammer, G.L., Nicholls, N., and Mitchell, C., "Applications of Seasonal Climate", Springer, Germany, 2000.

COURSE OUTCOME:

CO1:The students shall be able to understand the applications of IT in remote sensing applications such as Drones etc.

CO2:The students will be able to get a clear understanding of how a greenhouse can be automated and its advantages.

CO3:The students will be able to apply IT principles and concepts for management of field operations.

CO4:The students will get an understanding about weather models, their inputs and applications.

CO5:The students will get an understanding of how IT can be used for e-governance in agriculture.

CO's-PO's & PSO's MAPPING

PO/PSO		Course Outcome					**Overall correlation of CO s to POs**
		CO1	**CO2**	**CO3**	**CO4**	**CO5**	
PO1	Knowledge of Engineering Sciences	2	3	2	3	2	2
PO2	Problem Analysis	3	3	3	3	3	3
PO3	Design/ Development of Solutions	3	3	3	3	3	3
PO4	Investigations	2	3	2	1	2	2
PO5	Modern Tool Usage	3	3	3	3	3	3
PO6	Individual and Team work	1	1	2	2	3	2
PO7	Communication	3	3	3	3	3	3
PO8	The Engineer and Society	3	3	2	3	3	3
PO9	Ethics	1	1	2	1	2	1
PO10	Environment and Sustainability	3	3	3	3	3	3
PO11	Project Management and Finance	3	3	3	3	3	3
PO12	Life Long Learning	3	3	3	3	3	3
PSO1	To make expertise in design and engineering problem solving approach in agriculture with proper knowledge and skill	1	1	2	2	3	2
PSO2	To enhance students ability to formulate solutions to real-world problems pertaining to sustained agricultural productivity using modern technologies.	1	1	2	2	3	2
PSO3	To inculcate entrepreneurial skills through strong Industry-Institution linkage.	1	1	2	2	3	2

1 - low, 2 - medium, 3 - high, '-"- no correlation

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:*

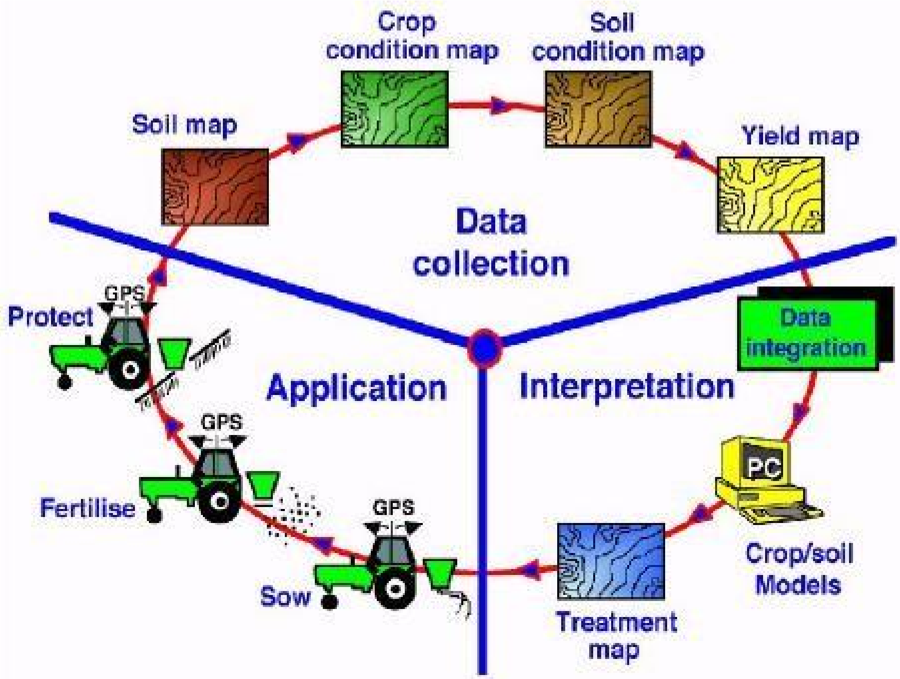
1. **Precision fertilization**: VRA technology can be used to vary the rate of fertilizer application based on soil nutrient levels, topography, and other factors. This can help to reduce waste, improve crop quality and yield, and minimize environmental impacts.
2. **Precision pesticide application**: 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.

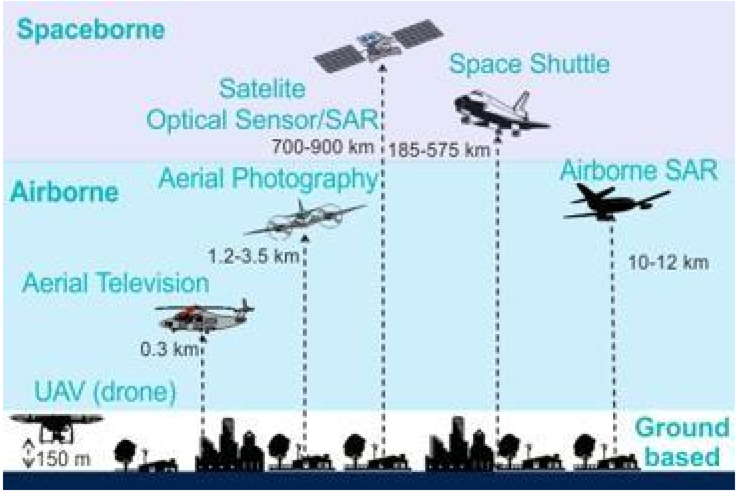
Remote sensing involves the use of various types of sensors, such as cameras and scanners, mounted on satellites, aeroplanes, or drones to collect data about the Earth's surface. The data obtained through remote sensing can be used to create detailed maps of agricultural fields, analyze crop health,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



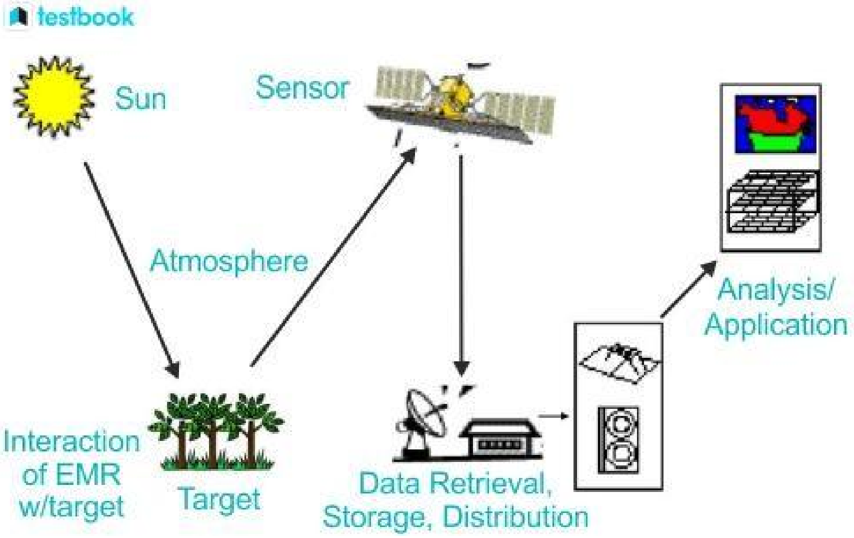
Sensors in Remote Sensing

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

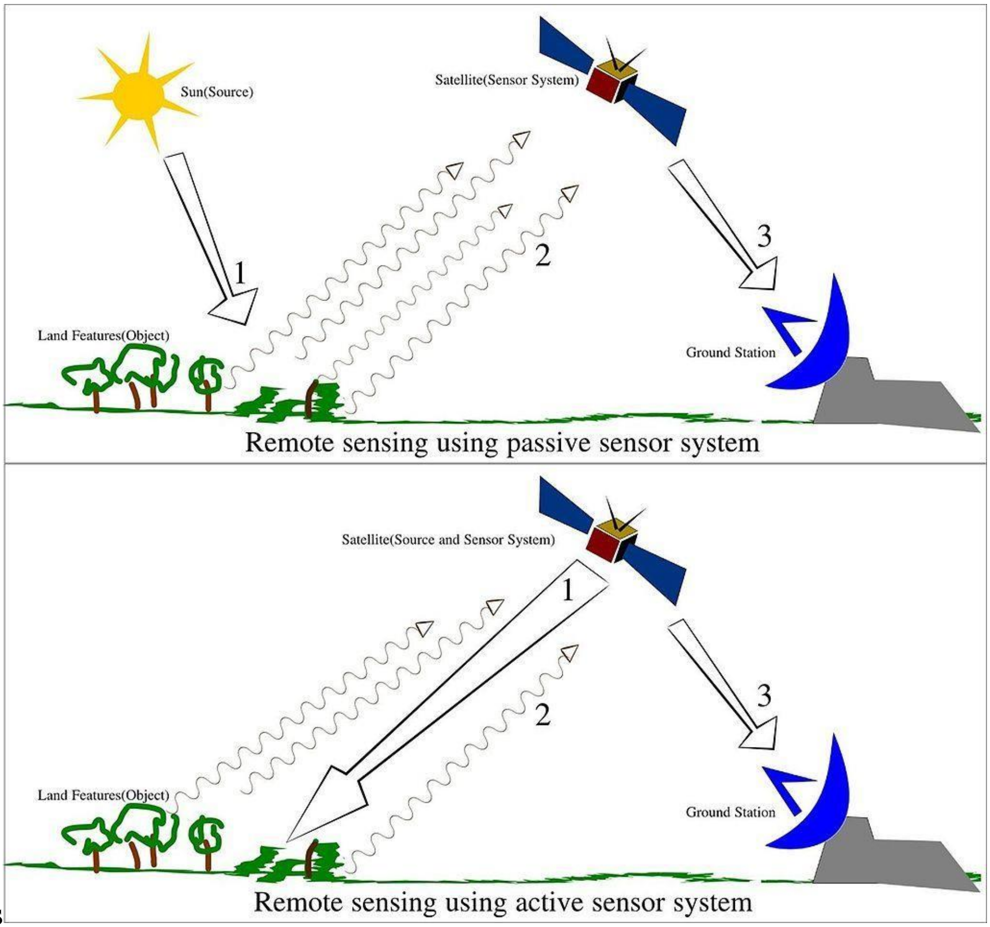
Active remote sensing utilizes an artificial source of radiation as an investigation, and the resulting signal, which scatters back to the sensor, depicts the Earth or the atmosphere.

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.



Remote sensing using passive sensor system

Remote sensing using active sensor system

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:*

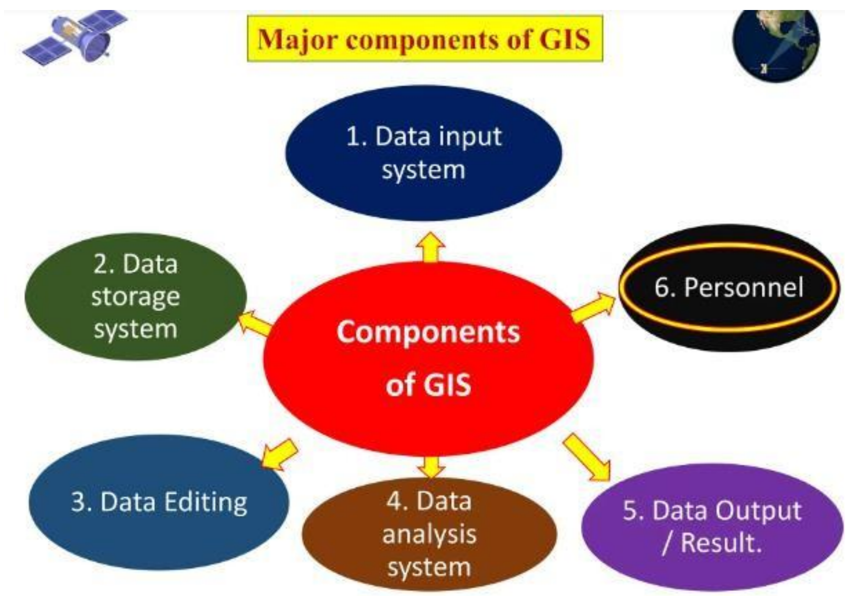
1. **Crop identification and monitoring:** Remote sensing can be used to identify and monitor different types of crops, their growth stages, and their health status. This information can help farmers make informed decisions about irrigation, fertilizer application, and pest control.
2. **Soil mapping 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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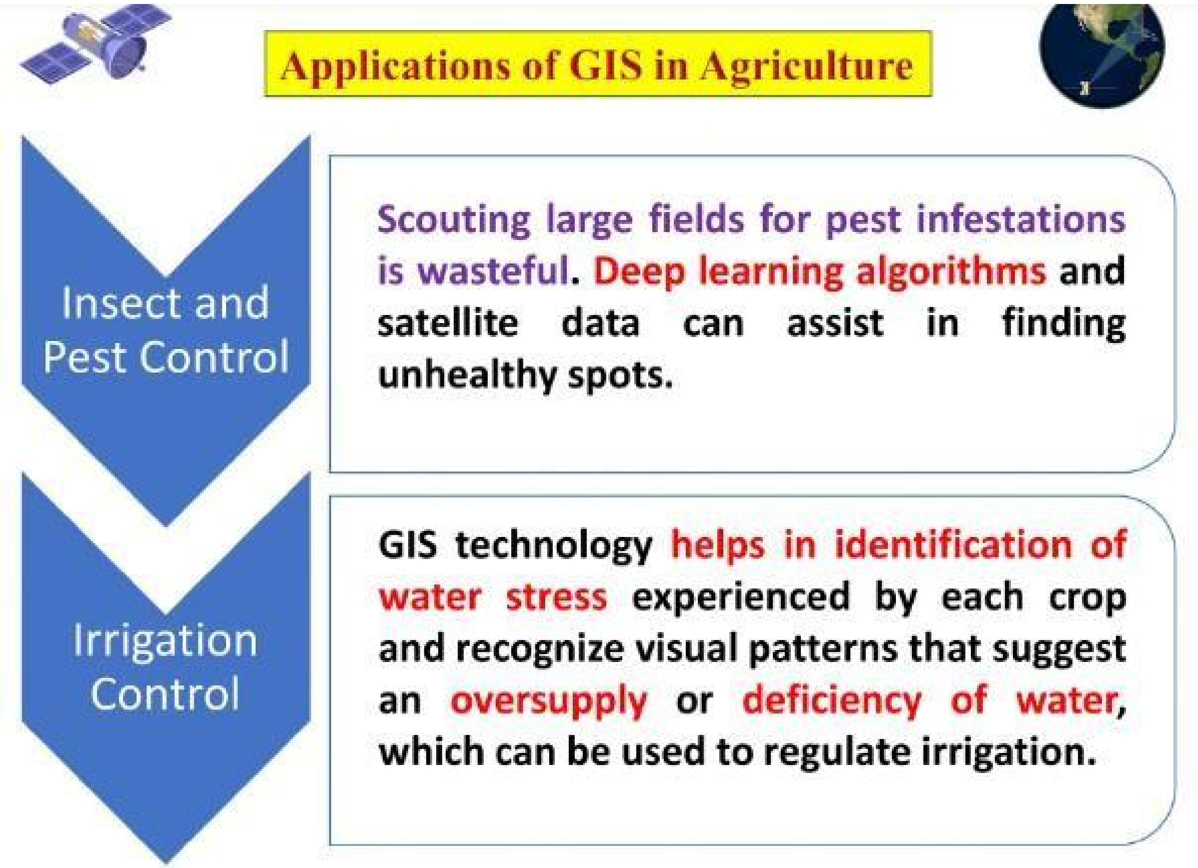
Applications of GIS in Agriculture

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.

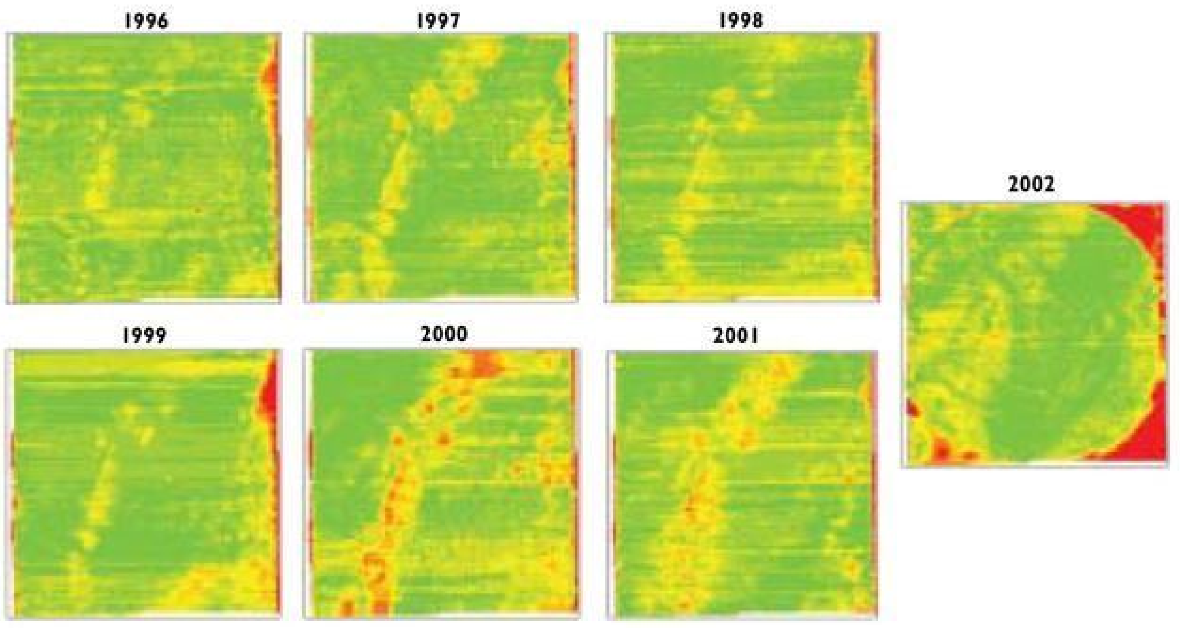
Usually a few points at the beginning and at the end of a pass should be removed as well. These are referred to as start-and end-pass delays. Start-pass delays occur when the combine starts harvesting the crop, but grain flow has not stabilized because the elevator is gradually filling up. Similarly, 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).

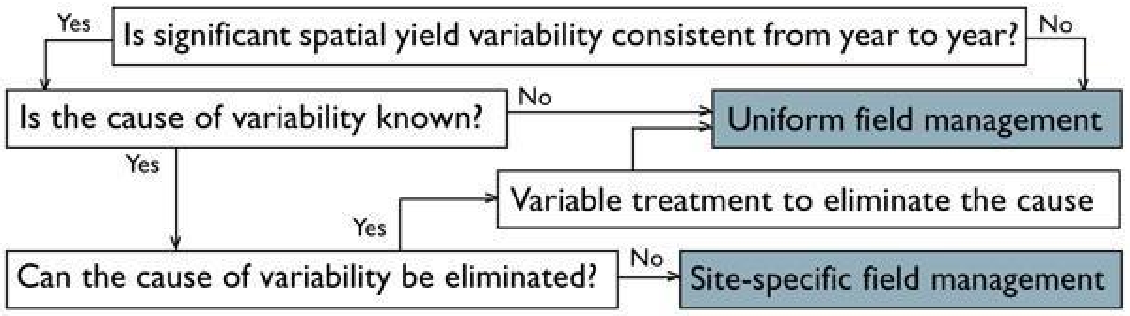


Maps of relative yield of corn and soybean grown during a seven-year period (red indicates low-yielding areas and green indicates higher than average yields).

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.

UNIT II

ENVIRONMENT CONTROL SYSTEMS

Artificial light systems, management of crop growth in greenhouses, simulation of CO2 consumption in greenhouses, on-line measurement of plant growth in the greenhouse, models of plant production and expert systems in horticulture.

Introduction:

1. **Plants and light signaling**

   Energy is transported through the air by electromagnetic waves. Microwaves, radio or television waves, X-rays, ultraviolet rays or visible light are examples of electromagnetic waves, which are characterized by having different frequencies and wavelengths. The electromagnetic spectrum represents different frequencies and wavelengths that are known under different names (microwave, radio waves, visible light, etc.).

   Electromagnetic radiation has a dual nature; radiation propagates as waves, but they exchange energy as particles (photons). It was Albert Einstein who proposed in 1905 for the first time that light has both particle and wave nature.

   A beam of light includes a set of particles, called photons. Photons corresponding to longer wavelengths (lower frequencies) carry less energy than photons from short wavelength areas.

   Human eye captures visible light between 400 and 700 nanometer (nm) wavelength area, which corresponds approximately to the region of the spectrum that plants use for photosynthesis. Light between 400 and 700 nm is therefore referred to as PAR; photosynthetically active radiation. Sunlight has a continuous spectrum within and beyond the visible wavelengths.

   Human eye transforms different wavelengths into colors in human brain. Short wavelengths close to 400 nm are perceived as blue color and longer wavelengths in the 600nm area are seen as red light. Human eye has the most sensitive region in the yellow- green wavelength area.

2. **Plant pigments, photoreceptors, and photosynthesis**

   Plants absorb the light spectrum in an almost similar range as the human eye, but unlike humans, they absorb best red and blue light.

   One of the main molecules enabling plants to absorb light and use its energy to transform water and carbon dioxide into oxygen and complex organic molecules is called chlorophyll and the process is known as photosynthesis. Chlorophyll is a plant pigment found in the intracellular chloroplasts, they are green in color and are in fact responsible of the green coloration of leaves and stems. There are two main types of chlorophyll found in the higher plants; chlorophyll a and b, which differ from each other slightly by their light absorption curves. The small difference allows them to capture different wavelengths, catching more of the sunlight spectrum. Chlorophylls absorb mainly red and blue light and reflect green wavelengths, which is why we see plants green.

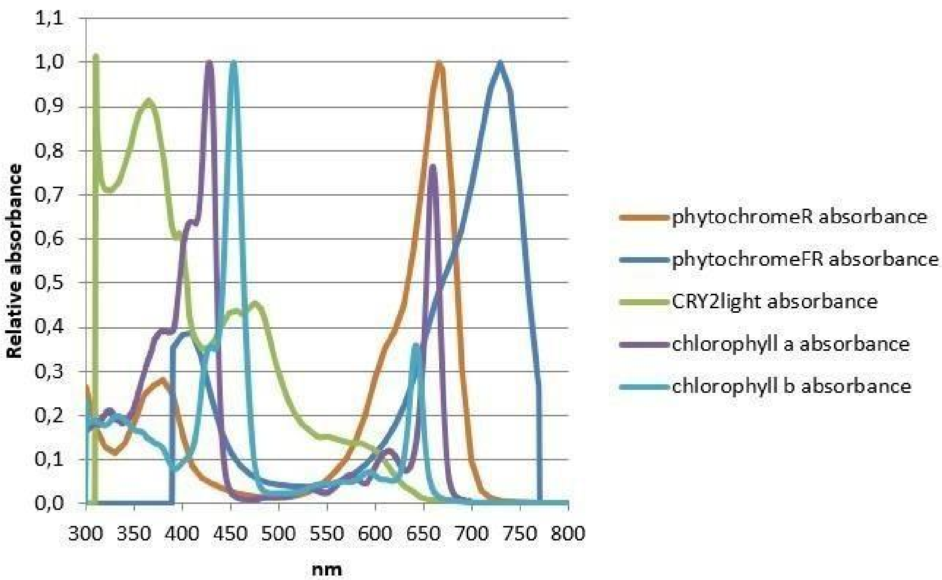
   However, chlorophyll is not the only plant pigment; the so-called accessory pigments (carotenoids, xanthophylls, etc.) and phenolic substances (flavonoids, anthocyanins, flavones and flavonoids) capture wavelengths other than only red and blue. The accessory pigments are yellow, red and violet in color. These colors attract insects and birds, as well as help protect tissues from environmental stress, such as high light irradiation.

There are also other particles absorbing light; photoreceptors. The main photoreceptor groups are phytochromes, phototropins and cryptochromes. In addition, there is a specific photoreceptor for ultraviolet light; the UVR8. All photoreceptors capture light in different wavelength areas and are responsible of different responses in plants as described below:

- Phototropins affect the location of the chloroplasts and the stomatal opening. They absorb blue light.
- Cryptochromes capture external stimuli related to light and control the internal clock of plants. In addition, they are related to morphological responses, such as inhibition of stem elongation, expansion of cotyledons, production of anthocyanins and photoperiodic flowering. Cryptochromes absorb UVA (ultraviolet), blue, and green wavelengths.
- Phytochromes are responsible for flowering induction and seed development. Phytochromes regulate stem elongation, leaf expansion, and "shade avoidance syndrome". The responses regulated by phytochromes are mediated by the ratio of surrounding red and far-red light, which affects the photostationary state of the phytochrome molecule.

These responses are mediated by wavelengths within and beyond the PAR area, including also UV and far-red irradiation. The absorption curves for phytochromes, cryptochrome and chlorophylls are presented in Figure 1

Figure 1. Relative absorbance of different photoreceptors in plant



3. Light quality

The quality of light is as important as the quantity of light.

The fact that plants cannot move and escape from bad growing conditions has resulted in a sophisticated sensor system to read ques from their environment through photoreceptors. Sensing the light environment through photoreceptors enable plants to flower in the correct time of the year when the conditions are suitable for the next generation's survival. There are numerous environmental factors affecting plant development; light, temperature, humidity, water, nutrients, gravity, etc.; light being one of the most important ones as it provides energy to photosynthesis as well as information about the plant's surroundings.

Photosynthesis is a series of processes driven by photons absorbed by the plant pigments. Photosynthesis is not very efficient since only 4-6% of the energy available in the radiation is converted into biomass. Photosynthesis can be intensified with elevated CO2 concentration, however an increase in photosynthesis rate does not translate into a linear increase in plant growth or yield increase. Plants control their own development so that they cannot grow indefinitely.

4. The colors of light

Plants respond to different wavelengths in the PAR range. McCree (1972) studied the spectrum used by plants, describing absorption peaks at different wavelengths and establishing the curve of the action spectrum of photosynthesis.

Within the spectrum of photosynthetically active radiation, McCree found that for all higher plant species (more than 20) that he studied, there were two broadly coincident highs in photosynthetic efficiency centered around 440 and 660 nm (Figure 2).

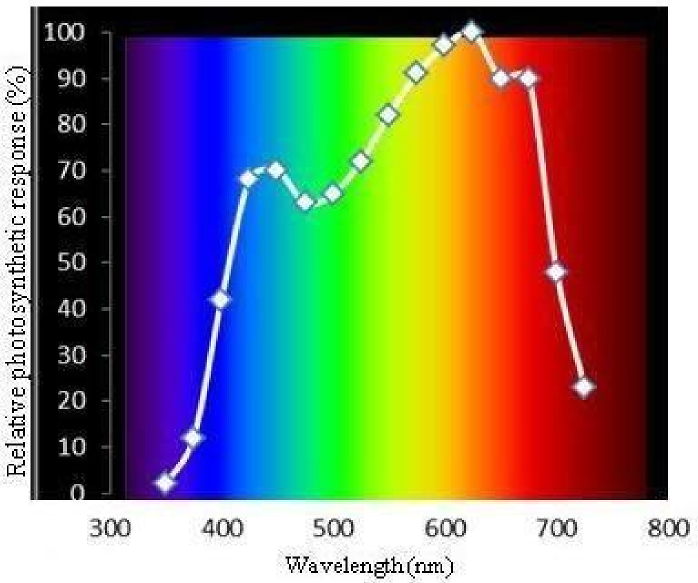


Figure 2. McCree's curve of the photosynthetic response (1972)

The effect of different wavelengths on plant growth and development:

- Ultraviolet. UV-B light is captured by the UVR8 photoreceptor. A large dose is harmful to plants, since it degrades DNA. However, in small doses, both UV-B and UV-A increase the stress tolerance of plants. In general, plants grown under ultraviolet light have thick leaves and stems and short internodes.
- Blue. Blue light is perceived by the blue light photoreceptors, phototropins and cryptochromes. Phototropins mediate stomatal regulation and plant movement towards light. Cryptochromes regulate many photomorphological responses, such as inhibition of stem elongation. Plants grown under high blue irradiation have short internodes, high dry matter content and low leaf temperature (efficient transpiration).
- Green. Green light is at least partially perceived by phototropins and cryptochromes (blue light receptors). Most green light is reflected or penetrated
through the canopy. However, green light contains valuable information about the plant's surroundings, guiding the growth accordingly. Plants grown under green light have long petioles internodes and high leaf temperature.
- Red. Red light is perceived by phytochromes. Phytochromes absorb both red and far-red light and are the main regulators of the shade avoidance syndrome. Red light converts phytochromes to their inactive state, Pr, which has an absorption peak at 660 nm. The Pr form of phytochrome is synthesized in dark conditions or in far-red light conditions. When the Pr absorbs red light, it transforms to the far- red absorbing Pfr form, which has the absorption peak at 730 nm. The conversion from Pr to Pfr can be reversed with far-red light or darkness.
- Far-red. Far-red light is absorbed by the phytochromes. Phytochromes absorb both red and far-red light and are the main regulators of the shade avoidance syndrome. High far-red irradiation causes premature flowering in many species, and elongation of stem and petioles.

5. **Vernalization**

In many species, photoperiod or R:FR ratio are not the only determining factors in flowering induction, but temperature plays a critical role as well. Temperature, especially the number of cold hours the plant senses, regulates the time of flowering of many species.

Some plants must go through a cold period prior to flowering. This phenomenon is calledvernalization and it takes place in numerous herbaceous plants. For example, cereals which are sown in autumn sense the cold winter months and are ready to produce flowerand seeds in the following spring and summer. The strength of the response is dependent on the length of the cold induction period as well as the temperature during the cold period.

Light, specifically, the light spectrum, influences also the vernalization process. It has been demonstrated that certain species or varieties require a shorter vernalization period in artificial growing conditions, if a light spectrum with low R:FR ratio has been given simultaneously. Long photoperiod together or right after the vernalization period have also been shown to fasten the time to flower.

1. Artificial lighting for plant growth

A plant grow light is a source of artificial light which has been designed to grow plants in spaces where there is little or no natural light available or when the natural day length is artificially extended.

Light for cultivation has traditionally tried to resemble sunlight in terms of the composition of the light spectrum, but it was not until the appearance of LEDs (Light Emitting Diode) that it was possible to produce customized spectra.

The most commonly used greenhouse lights, the high-pressure sodium (HPS) lamps, irradiate mainly in the yellow and red area of the visible spectrum, while fluorescent lights, which have traditionally been used in growth chambers have more blue light in their spectrum.Artificial lighting applied to greenhouses has historically been linked to areas that receive few hours of sunshine during winter, or to the modification of the photoperiod to induce flowering of ornamental crops at times of the year in which they have greater commercial value.

The use of artificial light in horticultural applications results in better growth and larger yields due to photoperiod extension and increase in the daily light integral. Artificial light can also bring benefits to the growers via the manipulation of flowering induction by giving short/long day treatments or night interruption. In closed environments artificial light is of course the only supply of light for photosynthesis and plays therefore a more critical role than artificial light in greenhouse applications. The artificial light in horticulture allows a better growth by extending the photoperiod when there are only few hours of natural daylight available and thus increases the daily light integral. Artificial light is also used to control or inhibit flowering in long-day/short-day treatments and can supply natural light in closed growth chambers.

In recent years, great development has been made in lighting technology, including the reduction of operating costs thanks to the introduction of LEDs. LEDs have been introduced already into facilities which produce flowers, vegetables, fruits, grafted seedlings, microgreens, algae, and medicinal plants, etc. Due to its environmental and productive efficiency advantages, LED lighting has been described as the most

What is LED Farming?

Growing plants indoors, in the presence of LED lights and using multiple layers to maximize production.

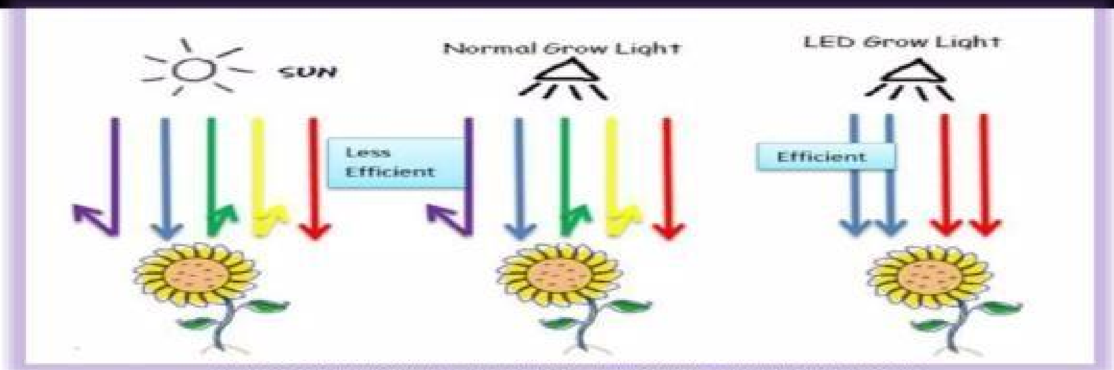
Why LED Farming?

- Population increase.
- 80% land for growing food is already in use.
- LEDs surpass 50% efficiency.
- Year round production irrespective of climatic changes.

80% OF THE EARTH'S AVAILABLE LAND IS ALREADY FARMED

LED LIGHTING VS. SUNLIGHT

- LED lighting has reduced the heat transferred onto plants.
- According to urban farming research(2013), the blue-red spectra is ideal for plant growth instead of sunlight that has a variety of colour spectra.



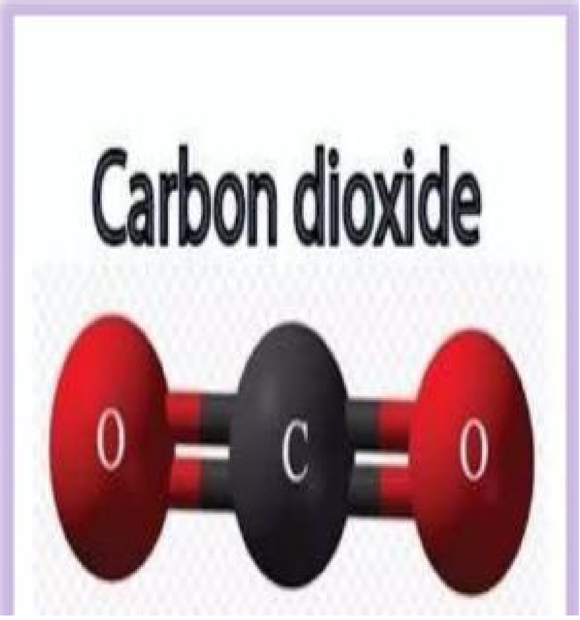
LED GROW LIGHTS ARE MORE EFFICIENT THAN SUNLIGHT

GROWTH MEDIUM

- No soil.
- Plants are suspended in a fabric made from old pop bottles.
- Hydroponics,Aeroponics, Aquaponics used.

CO_2 INJECTION

Net photosynthesis increases by 50% as CO_2 levels increase from 340–1,000 ppm (parts per million).



AIR FLOW

- In poorly ventilated rooms, the crops menaced by pests will be increased.
- 4-6 inch fans are adequate.

AEROFARMS GROWS GREENS UNDER INTENSE LED GROW LIGHTS AND FANS

LIGHTING TIME AND HANGING DISTANCE

- **Approximately 12 to 18 hours of light is required for active photosynthesis and healthy growth.**
- **Hanging distance : 12-30''**

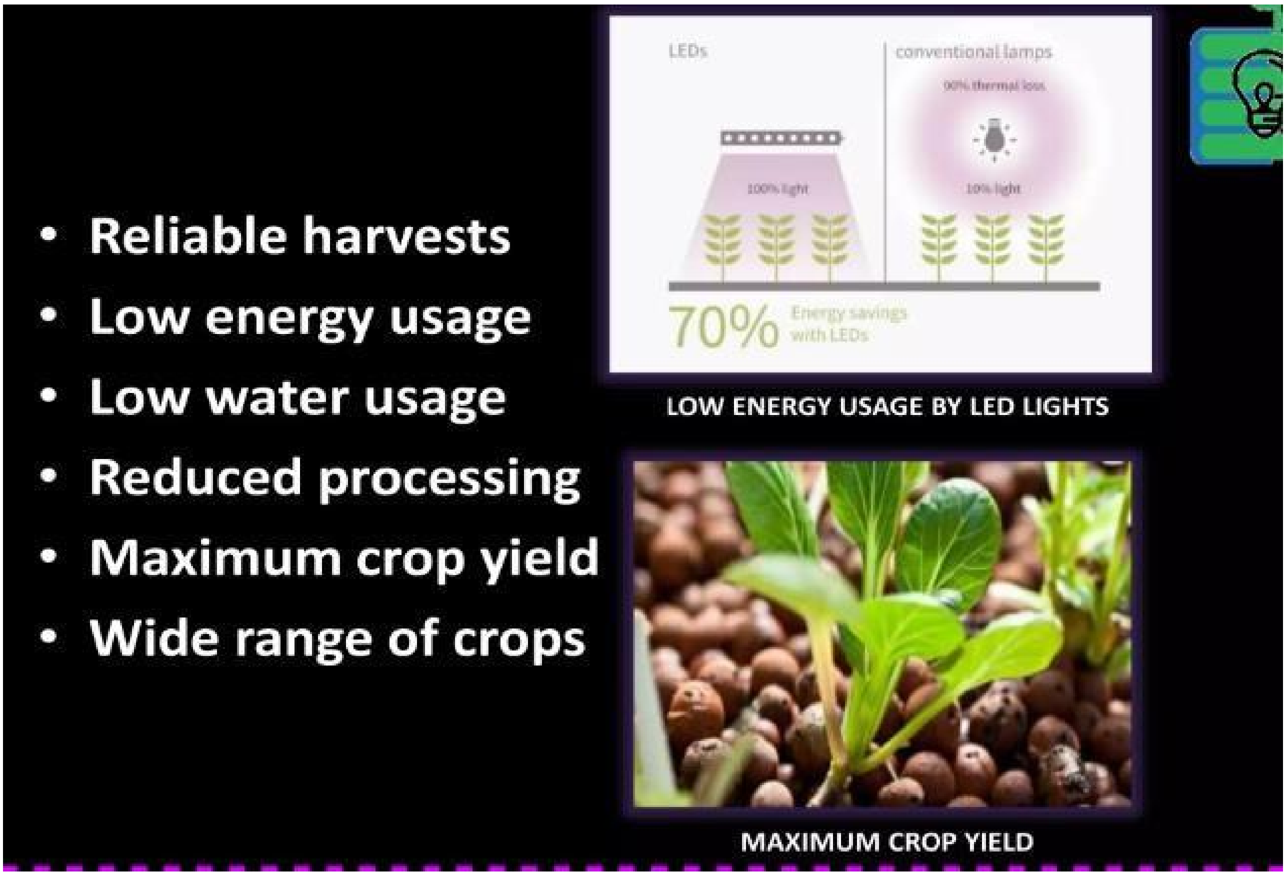
EFFECT OF LIGHTING TIME AND HANGING DISTANCE OF LEDs ON PLANTS

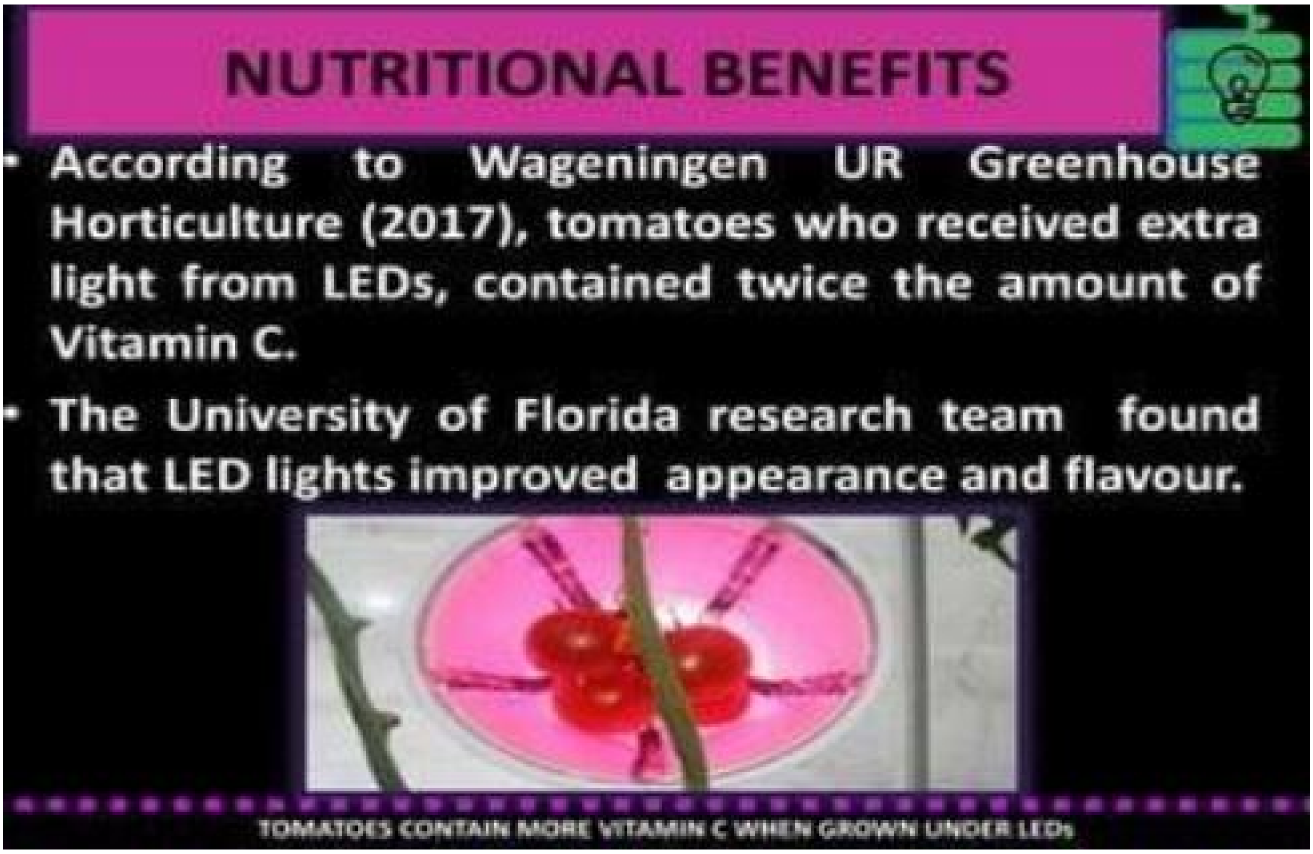
Plants grown by LED farming

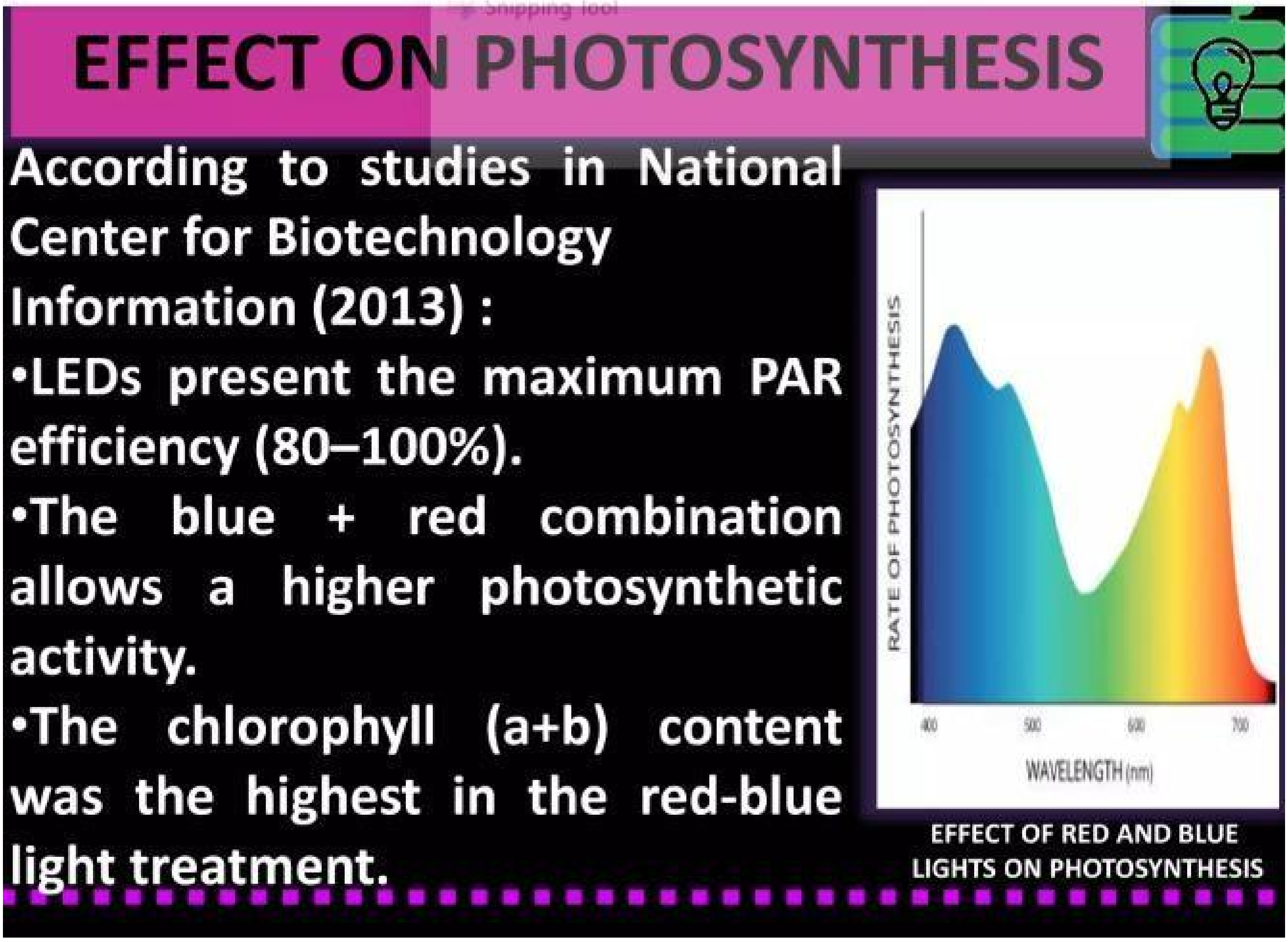
- **Basil, microgreens** (Bedford Park, Illinois)
- **Strawberry** (Ichigo Company, Tainai, Niigata, Japan)
- **Medical cannabis** (Oakland, California)
- **Tomato** (Pasona O_2, Tokyo)
- **Potato** (Astroculture, Barneveld, Wisconsin)
- **Lettuce** (Green Sense Farms, US)


Basil, microgreens (Bedford Park, Illinois)
Strawberry (Ichigo Company, Tainai, Niigata, Japan)
Medical cannabis (Oakland, California)
Tomato (Pasona O_2, Tokyo)

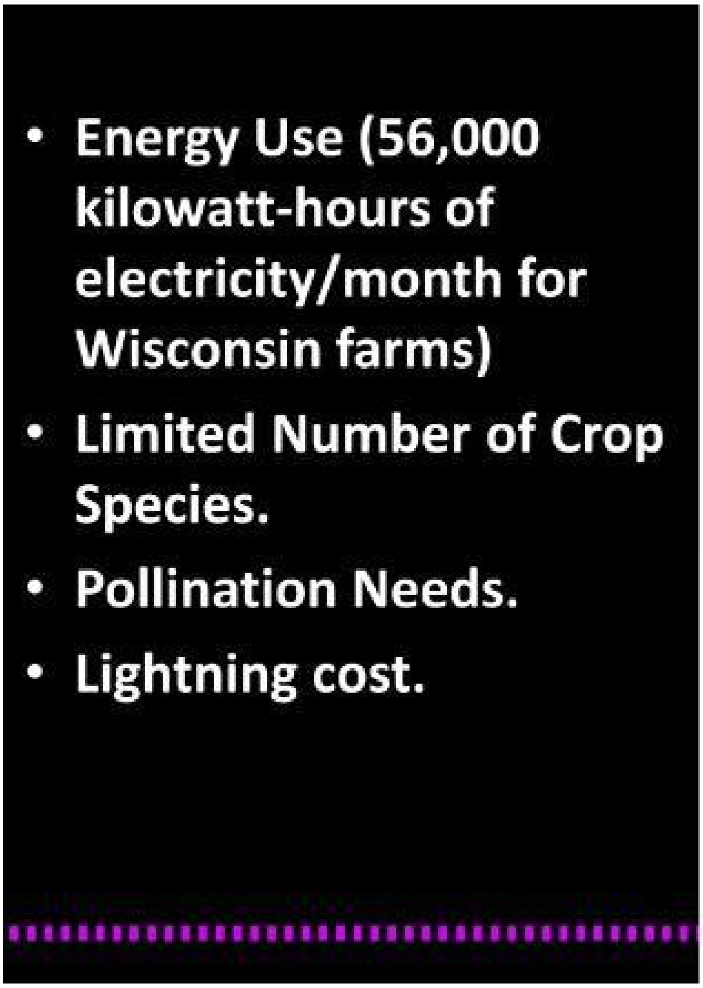
Advantages


Reliable harvests
Low energy usage
Low water usage
Reduced processing
Maximum crop yield
Wide range of crops
LEDs
conventional lamps
90% thermal loss
100% light
10% light
70% Energy savings with LEDs
LOW ENERGY USAGE BY LED LIGHTS
MAXIMUM CROP YIELD


NUTRITIONAL BENEFITS
• According to Wageningen UR Greenhouse Horticulture (2017), tomatoes who received extra light from LEDs, contained twice the amount of Vitamin C.
• The University of Florida research team found that LED lights improved appearance and flavour.
TOMATOES CONTAIN MORE VITAMIN C WHEN GROWN UNDER LEDs


EFFECT ON PHOTOSYNTHESIS
According to studies in National Center for Biotechnology Information (2013) :
•LEDs present the maximum PAR efficiency (80–100%).
•The blue + red combination allows a higher photosynthetic activity.
•The chlorophyll (a+b) content was the highest in the red-blue light treatment.
RATE OF PHOTOSYNTHESIS
400
500
600
700
WAVELENGTH (nm)
EFFECT OF RED AND BLUE LIGHTS ON PHOTOSYNTHESIS

Drawbacks



RISING ENERGY USE

MORE LIGHTNING COST

Greenhouse

Greenhouse is the most practical method of achieving the objectives of protected agriculture, where the natural environment is modified by using sound engineering principles to achieve optimum plant growth and yields.

Green House:

A greenhouse is a framed or an inflated structure covered with a transparent or translucent material in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations.

The growing of off - season cucumbers under transparent stone for Emperor Tiberius in the 1st century, is the earliest reported protected agriculture. The technology was rarely employed during the next 1500 years. In the 16^{th} century, glass lanterns, bell jars and hot beds covered with glass were used to protect horticultural crops

against cold. In the 17th century, low portable wooden frames covered with an oiled translucent paper were used to warm the plant environment.

In Japan, primitive methods using oil -paper and straw mats to protect crops from the severe natural environment were used as long ago the early 1960s. Greenhouses in France and England during the same century were heated by manure and covered with glass panes. The first greenhouse in the 1700s used glass on one side only as a sloping roof. Later in the century, glass was used on both sides. Glasshouses were used for fruit crops such as melons, grapes, peaches and strawberries, and rarely for vegetable production.

Protected agriculture was fully established with the introduction of polyethylene after the World war II. The first use of polyethylene as a greenhouse cover was in 1948, when professor Emery Myers Emmert, at the University of Kentucky, used the less expensive material in place of more expensive glass.

The total area of glasshouses in the world (1987) was estimated to be 30,000 ha and most of these were found in North- Western Europe. In contrast to glasshouses, more than half of the world area of plastic green houses is in Asia, in which China has the largest area. According to 1999 estimates, an area of 6, 82,050 ha were under plastic greenhouses (Table 1.1). In most of the countries, green houses are made of plastic and glass; the majority is plastic.

Glasshouses and rigid plastic houses are longer-life structures, and therefore are most located in cold regions where these structures can be used throughout the year. In Japan, year-round use of greenhouses is becoming predominant, but in moderate and warm climate regions, they are still provisional and are only used in winter.

In India, the cultivation in the plastic greenhouses is of recent origin. As per 1994-95 estimates, approximately 100 ha of India are under greenhouse cultivation.

Since 1960, the greenhouse has evolved into more than a plant protector. It is now better understood as a system of controlled environment agriculture (CEA), with precise control of air and root temperature, water, humidity, plant nutrition, carbon dioxide and light. The greenhouses of today can be considered as plant or vegetable factories. Almost every aspect of the production system is automated, with the artificial environment and growing system under nearly total computer control.

Greenhouse Effect

In general, the percentage of carbon dioxide in the atmosphere is 0.035% (345 ppm). But, due to the emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere. This causes the entrapping of the reflected solar radiation from the earth surface. Due to this, the atmospheric temperature increases, causing global warming, melting of ice caps and rise in the ocean levels which result in the submergence of coastal lines. This phenomenon of increase in the ambient temperature, due to the formation of the blanket of carbon dioxide is known as **greenhouse effect**.

The greenhouse covering material acts in a similar way, as it is transparent to shorter wave radiation and opaque to long wave radiation.

During the daytime, the shorter wave radiation enters into the greenhouse and gets reflected from the ground surface. This reflected radiation becomes long wave radiation and is entrapped inside the greenhouse by the covering material. This causes the increase in the greenhouse temperature. It is desirable effect from point of view of crop growth in the cold regions.

Advantages of Greenhouses

The following are the different advantages of using the green house for growing crops under controlled environment:

1. Throughout the year four to five crops can be grown in a green house due to availability of required plant environmental conditions.
2. The productivity of the crop is increased considerably.
3. Superior quality produce can be obtained as they are grown under suitably controlled environment.
4. Gadgets for efficient use of various inputs like water, fertilizers, seeds and plant protection chemicals can be well maintained in a green house.
5. Effective control of pests and diseases is possible as the growing area is enclosed.
6. Percentage of germination of seeds is high in greenhouses.
7. The acclimatization of plantlets of tissue culture technique can be carried out in a green house.
8. Agricultural and horticultural crop production schedules can be planned to take advantage of the market needs.
9. Different types of growing medium like peat mass, vermiculate, rice hulls and compost that are used in intensive agriculture can be effectively utilized in the greenhouse.
10. Export quality produce of international standards can be produced in a green house.
11. When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped heat.
12. Greenhouses are suitable for automation of irrigation, application of other inputs and environmental controls by using computers and artificial intelligence techniques.
13. Self-employment for educated youth

2 Greenhouse Structure

Greenhouse structures of various types are used successfully for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be considered as the best. Different types of greenhouses are designed to meet the specific needs.

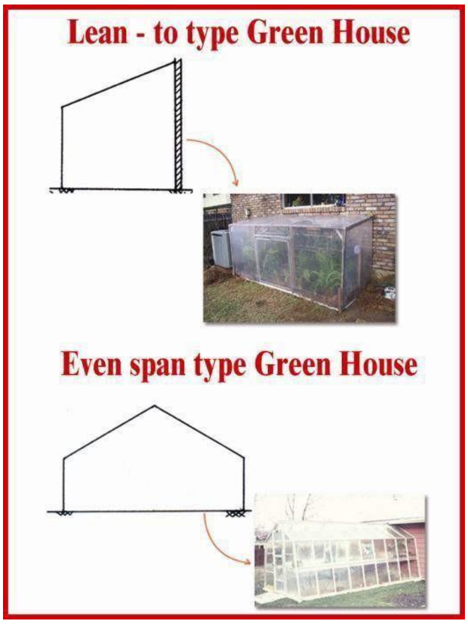
2.1 Greenhouse type based on shape

Greenhouses can be classified based on their shape or style. For the purpose of classification, the uniqueness of the cross section of the greenhouses can be considered as a factor. As the longitudinal section tend to be approximately the same for all types, the longitudinal section of the greenhouse cannot be used for classification. The cross sections depict the width and height of the structure and the length is perpendicular to the plane of cross section. Also, the cross section provides information on the overall shape of the structural members, such as truss or hoop, which will be repeated on every day.

The commonly followed types of greenhouse based on shape are lean-to, even span, uneven span, ridge and furrow, saw tooth and quonset.

2.1.1 Lean-to type greenhouse

A lean-to design is used when a greenhouse is placed against the side of an existing building. It is built against a building, using the existing structure for one or more of its sides (Fig.1). It is usually attached to a house, but may be attached to other buildings. The roof of the building is extended with appropriate greenhouse covering material and the area is properly enclosed. It is typically facing south side. The lean-to type greenhouse is limited to single or double-row plant benches with a total width of 7 to 12 feet. It can be as long as the building it is attached to. It should face the best direction for adequate sun exposure.



The advantage of the lean-to type greenhouse is that, it usually is close to available electricity, water, and heat. It is a least expensive structure. This design makes the best use of sunlight and minimizes the requirement of roof supports. It has the following disadvantages: limited space, limited light, limited ventilation and temperature control. The height of the supporting wall limits the potential size of the design. Temperature control is more difficult because the wall that the greenhouse is built on, may collect the sun's heat while the translucent cover of the greenhouse may lose heat rapidly. It is a half greenhouse, split along the peak of the roof.

2.1.2 Even span type greenhouse

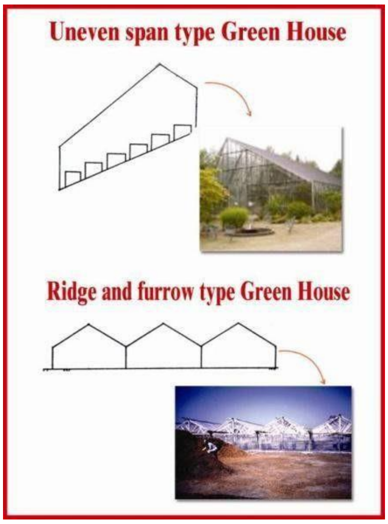
The even-span is the standard type and full-size structure, the two roof slopes are of equal pitch and width (Fig.1). This design is used for the greenhouse of small size, and it is constructed on level ground. It is attached to a house at one gable end. It can accommodate 2 or 3 rows of plant benches. The cost of an even-span greenhouse is more than the cost of a lean-to type, but it has greater flexibility in design and provides for more plants. Because of its size and greater amount of exposed glass area, the even-span will cost more to heat. The design has a better shape than a lean-to type for air circulation to maintain uniform temperatures during the winter heating season. A separate heating system is necessary unless the structure is very close to a heated building. It will house 2 side benches, 2 walks, and a wide center bench. Several single and multiple span types are available for use in various regions of India. For single span type the span in general, varies from 5 to 9 m, whereas the length is around 24 m. The height varies from 2.5 to 4.3 m.

2.1.3 Uneven span type greenhouse

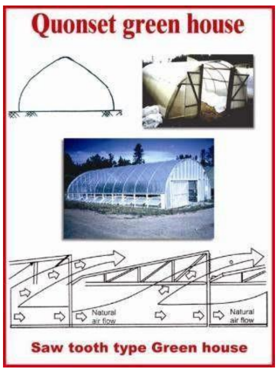
This type of greenhouse is constructed on hilly terrain. The roofs are of unequal width; make the structure adaptable to the side slopes of hill (Fig. 2). This type of greenhouses is seldom used now-a-days as it is not adaptable for automation.

2.1.4 Ridge and furrow type greenhouse

Designs of this type use two or more A-frame greenhouses connected to one another along the



length of the eave (Fig. 2). The eave serves as furrow or gutter to carry rain and melted snow away. The side wall is eliminated between the greenhouses, which results in a structure with a single large interior, Consolidation of interior space reduces labour, lowers the cost of automation, improves personal management and reduces fuel consumption as there is less exposed wall area through which heat escapes. The snow loads must be taken into the frame specifications of these greenhouses since the snow cannot slide off the roofs as in case of individual free standing greenhouses, but melts away. In spite of snow loads, ridge and furrow greenhouses are effectively used in northern countries of Europe and in Canada and are well suited to the Indian conditions.



2.1.5 Saw tooth type Greenhouse

These are also similar to ridge and furrow type greenhouses except that, there is provision for natural ventilation in this type. Specific natural ventilation flow path (Fig. 3) develops in a saw- tooth type greenhouse.

2.2 Greenhouse type based on utility

Classification of greenhouses can be made depending on the functions or utilities. Of the different utilities, artificial cooling and heating of the greenhouse are more expensive and elaborate. Hence based on the artificial cooling and heating, greenhouses are classified as green houses for active heating and active cooling system.

2.2.1 Greenhouses for active heating

During the night time, air temperature inside greenhouse decreases. To avoid the cold bite to plants due to freezing, some amount of heat has to be supplied. The requirements for heating greenhouse depend on the rate at which the heat is lost to the outside environment. Various methods are adopted to reduce the heat losses, viz., using double layer polyethylene, thermo pane glasses (Two layers of factory sealed glass with dead air space) or to use heating systems, such as unit heaters, central heat, radiant heat and solar heating system.

2.2.2 Greenhouses for active cooling

During summer season, it is desirable to reduce the temperatures of greenhouse than the ambient temperatures, for effective crop growth. Hence suitable modifications are made in the green house so that large volumes of cooled air is drawn into greenhouse, This type of greenhouse either consists of evaporative cooling pad with fan or fog cooling. This greenhouse is designed in such a way that it permits a roof opening of 40% and in some cases nearly 100%.

2.3 Greenhouse type based on construction

The type of construction is predominantly influenced by the structural material, though the covering material also influences the type. Span of the house inurn dictates the selection of structural members and their construction. Higher the span, stronger should be the material and more structural members are used to make sturdy truss type frames. For smaller spans, simpler designs like hoops can be followed.

2.3.1 Wooden framed structures

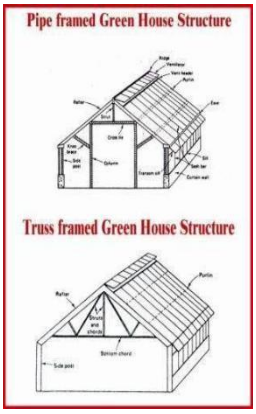
In general, for the greenhouses with span less than 6 m, only wooden framed structures are used. Side posts and columns are constructed of wood without the use of a truss. Pine wood is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for the construction.

2.3.2 Pipe framed structures

Pipes are used for construction of greenhouses, when the clear span is around 12m (Fig. 4). In general, the side posts, columns, cross ties and purlins are constructed using pipes. In this type, the trusses are not used.

2.3.3 Truss framed structures

If the greenhouse span is greater than or equal to 15m, truss frames are used. Flat steel, tubular steel or angular iron is welded together to form a truss encompassing rafters, chords and struts (Fig. 4). Struts are support members under compression and chords are support members under tension. Angle



iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide truss frame houses of 21.3 m or more. Most of the glass houses are of truss frame type, as theseframes are best suited for pre-fabrication.

2.4 Greenhouse type based on covering materials

Covering materials are the major and important component of the greenhouse structure. Covering materials have direct influence on the greenhouse effect inside the structure and they alter the air temperature inside the house. The types of frames and method of fixing also varies with the covering material. Based on the type of covering materials, the greenhouses are classified as glass, plastic film and rigid panel greenhouses.

2. 4.1 Glass greenhouses

Only glass greenhouses with glass as the covering material existed prior to 1950. Glass as covering material has the advantage of greater interior light intensity. These greenhouses have higher air infiltration rate which leads to lower interior humidity and better disease prevention. Lean-to type, even span, ridge and furrow type of designs are used for construction of glass greenhouse.

2.4.2 Plastic film greenhouses

Flexible plastic films including polyethylene, polyester and polyvinyl chloride are used as covering material in this type of greenhouses. Plastics as covering material for greenhouses have become popular, as they are cheap and the cost of heating is less when compared to glass greenhouses. The main disadvantage with plastic films is its short life. For example, the best quality ultraviolet (UV) stabilized film can last for four years only. Quonset design as well as gutter-connected design is suitable for using this covering material.

2.4.3 Rigid panel greenhouses

Polyvinyl chloride rigid panels, fibre glass-reinforced plastic, acrylic and polycarbonate rigid panels are employed as the covering material in the quonset type frames or ridge and furrow type frame. This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse when compared to glass or plastic. High grade panels have long life even up to 20 years. The main disadvantage is that these panels tend to collect dust as well as to harbor algae, which results in darkening of the panels and subsequent reduction in the light transmission. There is significant danger of fire hazard.

2.5 Shading nets

There are a great number of types and varieties of plants that grow naturally in the most diverse climate conditions that have been transferred by modern agriculture from their natural habitats to controlled crop conditions. Therefore, conditions similar to the natural ones must be created for each type and variety of plant. Each type of cultivated plant must be given the specific type of shade required for the diverse phases of its development. The shading nets fulfill the task of giving appropriate micro-climate conditions to the plants.

Shade nettings are designed to protect the crops and plants from UV radiation, but they also provide protection from climate conditions, such as temperature variation, intensive rain and winds. Better growth conditions can be achieved for the crop due to the controlled micro-climate conditions "created" in the covered area, with shade netting, which results in higher crop yields.

All nettings are UV stabilized to fulfill expected lifetime at the area of exposure. They are characterized of high tear resistance, low weight for easy and quick installation with a 30-90% shade value range. A wide range of shading nets are available in the market which are defined on the basis of the percentage of shade they deliver to the plant growing under them.

Plant response to greenhouse environments

Plant response to greenhouse environments - light, temperature, relative humidity, ventilation and carbon dioxide and environmental requirement of agriculture and horticulture crops inside green houses.

The productivity of a crop is influenced not only by its heredity but also by the microclimate around it. The components of crop microclimate are light, temperature, air compositions and the nature of the root medium. In open fields, only manipulation of nature of the root medium by tillage, irrigation and fertilizer application is possible. The closed boundaries in greenhouse permit control of any one or more of the components of the micro climate.

3.1 Light

The visible light of the solar radiation is a source of energy for plants. Light energy, carbon dioxide (Co_2) and water all enter in to the process of photosynthesis through which carbohydrates are formed. The production of carbohydrates from carbon dioxide and water in the presence of chlorophyll, using light energy is responsible for plant growth and reproduction. The rate of photosynthesis is governed by available fertilizer elements, water, carbon dioxide, light and temperature.

The photosynthesis reaction can be represented as follows

Chlorophyll Co_2 + water+ light energy------------ carbohydrates + oxygen Plant nutrients

Considerable energy is required to reduce the carbon that is combined with oxygen in CO_2 gas to the state in which it exists in the carbohydrate. The light energy thus utilized is trapped in the carbohydrate. If the light intensity is diminished, photosynthesis slows down and hence the growth. If higher than optimal light intensities are provided, growth again slows down because of the injury to the chloroplasts.

The light intensity is measured by the international unit known as Lux. It is direct illumination on the surrounding surface that is one meter from a uniform point source of 1 international candle. Green house crops are subjected to light intensities varying from 129.6kluxon clear summer days to 3.2 Klux on cloudy winter days. For most crops, neither condition is ideal. Many crops become light saturated, in other words, photosynthesis does not increase at light intensities higher than 32.2klux. Rose and carnation plants will grow well under summer light intensities. In general, for most other crops foliage is deeper green if the greenhouse is shaded to the extent of about 40% from mid spring (May) to mid fall (August and September). Thus, it is apparent that light intensity requirements of photosynthesis are vary considerably from crop to crop.

Light is classified according to its wave length in nanometers (nm). Not all light useful in photosynthesis process. UV light is available in the shorter wavelength range, i.e less than 400nm. Large of quantities of it is harmful to the plants. Glass screens are opaque to the most UV light and light below the range of 325nm. Visible and white light has wavelength of 400 to 700nm.Far red light (700 to 750nm) affects plants, besides causing photosynthesis. Infrared rays of longer wavelengths are not involved in the plant process. It is primarily, the visible spectrum of light that is used in photosynthesis. In the blue and red bands, the photosynthesis activity is higher, when the blue light (shorter wavelength) alone is supplied to plants, the growth is retarded, and the plant becomes hard and dark in colour. When the plants are grown under red light (longer wavelength), growth is soft and internodes are long, resulting in tall plants. Visible light of all wavelengths is readily utilized in photosynthesis.

3.2 Temperature

Temperature is a measure of level of the heat present. All crops have temperature range in which they can grow well. Below this range, the plant life process stop due to ice formation within the tissue and cells are possibly punctured by ice crystals. At the upper extreme, enzymes become inactive, and again process essential for life cease. Enzymes are biological reaction catalyst and are heat sensitive. All biochemical reactions in the plant are controlled by the enzymes. The rate of reactions controlled by the enzyme often double or triple for each rise of temperature by 10^0C, until optimum temperature is reached. Further, increase in temperature begins to suppress the reaction and finally stop it.

As a general rule, green house crops are grown at a day temperature, which are 3 to 6^0C higher than the night temperature on cloudy days and 8^0C higher on clear days. The night temperature of green house crops is generally in the range of 7 to 21^0C. Primula, mathiola incana and calceolaria grow best at 7^0C, carnation and cineraria at 10^0C, rose at 16^0C, chrysanthemum and poinsettia at 17 to 18^0C and African violet at 21 to 22^0C.

3.3 Relative humidity

As the green house is a closed space, the relative humidity of the green house air will be more when compared to the ambient air, due to the moisture added by the evapo-transpiration process.

Some of this moisture is taken away by the air leaving from the green house due to ventilation. Sensible heat inputs also lower the relative humidity of the air to some extent. In order to maintain the desirable relative humidity levels in the green houses, processes like humidification or dehumidification are carried out. For most crops, the acceptable range of relative humidity is between 50 to 80%. However for plant propagation work, relative humidity up to 90% may be desirable.

In summer, due to sensible heat addition in the daytime, and in winters for increasing the night time temperatures of the green house air, more sensible heat is added causing a reduction in the relative humidity of the air. For this purpose, evaporative cooling pads and fogging system of humidification are employed. When the relative humidity is on the higher side, ventilators, chemical dehumidifiers and cooling coils are used for de- humidification.

3.4 Ventilation

A green house is ventilated for either reducing the temperature of the green house air or for replenishing carbon dioxide supply or for moderating the relative humidity of the air. Air temperatures above 35^0C are generally not suited for the crops in green house. It is quite possible to bring the green house air temperature below this upper limit during spring and autumn seasons simply by providing adequate ventilation to the green house. The ventilation in a green house can either be natural or forced. In case of small green houses (less than 6m wide) natural ventilation can be quite effective during spring and autumn seasons. However, fan ventilation is essential to have precise control over the air temperature, humidity and carbon dioxide levels.

3.5 Carbon dioxide

Carbon is an essential plant nutrient and is present in the plant in greater quantity than any other nutrient. About 40% of the dry matter of the plant is composed of carbon. Under normal conditions, carbon dioxide (CO_2) exits as a gas in the atmosphere slightly above 0.03% or 345ppm. During the day, when photosynthesis occurs under natural light, the plants in a green house draw down the level of Co_2 to below 200ppm. Under these circumstances, infiltration or ventilation increases **carbon dioxide levels,** when the outside air is brought in, to maintain the ambient levels of CO_2. If the level of CO_2 is less than ambient levels, CO_2 may retard the plant growth. In cold climates, maintaining ambient levels of CO_2 by providing ventilation may be un-economical, due to the necessity of heating the incoming air in order to maintain proper growing temperatures. In such regions, enrichment of the green house with CO2 is followed. The exact CO_2 level needed for a given crop will vary, since it must be correlated with other variables in greenhouse production such as light, temperature, nutrient levels, cultivar and degree of maturity. Most crops will respond favorably to Co_2 at 1000 to 1200 ppm.

Equipment required for controlling green house environment – summer cooling and winter cooling, natural ventilation, forced ventilation and computers.

Precise control of various parameters of green house environment is necessary to optimize energy inputs and thereby maximize the economic returns. Basically, the objective of environmental control is to maximize the plant growth. The control of green house environment means the control of temperature, light, air composition and nature of the root medium. A green house is essentially meant to permit at least partial control of microclimate within it. Obviously green houses with partial environmental control are more common and economical. From the origin of greenhouse to the present there has been a steady evolution of controls. Five stages in this evolution include manual controls, thermostats, step-controllers, dedicated micro processors and computers. This chain of evolution has brought about a reduction in control labour and an improvement in the conformity of green house environments to their set points. The benefits achieved from green house environmental uniformity are better timing and good quality of crops, disease control and conservation of energy.

4.1 Active summer cooling systems

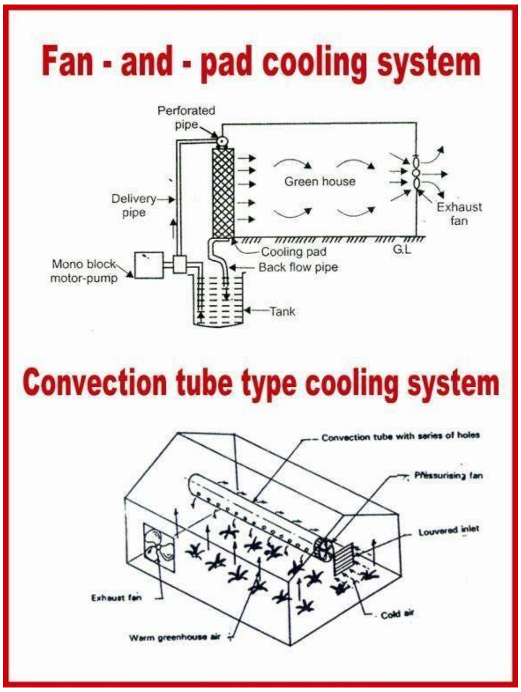
Active summer cooling is achieved by evaporative cooling process .The evaporative cooling systems developed are to reduce the problem of excess heat in green house. In this process cooling takes place when the heat required for moisture evaporation is derived from the surrounding environment causing a depression in its temperature. The two active summer cooling systems in use presently are fan-and pad and fog systems. In the evaporative cooling process the cooling is possible only up to the wet bulb temperature of the incoming air.

4.1.1 Fan-and Pad cooling system

The fan and pad evaporative cooling system has been available since 1954 and is still the most common summer cooling system in green houses (Fig.5). Along one wall of the green house, water is passed through a pad that is usually placed vertically in the wall. Traditionally, the pad was composed of excelsior (**wood shreds**), but today it is commonly made of a **cross-fluted-cellulose material** some what similar in appearance to corrugated card board. Exhaust fans are placed on the opposite wall. Warm outside air is drawn in through the pad. The supplied water in the pad, through the process of evaporation, absorbs heat from the air passing through the pad as well as from surroundings of the pad and frame, thus causing the cooling effect. Khus-khus grass mats can also be used as cooling pads.

4.1.2 Fog cooling system

The fog evaporative cooling system, introduced **in** green houses in 1980, operates on the same cooling principle as the fan and pad cooling system but uses quite different arrangement (Fig.5). A high pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 microns using suitable nozzles. These droplets are sufficiently small to stay suspended in air while they are evaporating. Fog is dispersed throughout the green house, evaporation of the water is not taking place because of bigger droplet size in fad and pad, whereas in the fog cooling system, there will be complete evaporation because of the minute size of the water droplets. Thus lesser the dryness of the air, greater evaporative cooling is possible.



4.2 Active winter cooling systems

Excess heat can be a problem during the winter. In the winter, the ambient temperature will be below the desired temperature inside the green house. Owing to the green house effect the entrapment of solar heat can rise the temperature to an injurious level if the green house is not ventilated. The actual process in winter cooling is tempering the excessively cold ambient air before it reaches the plant zone. Otherwise, hot and cold spots in the green house will lead to uneven crop timing and quality .This mixing of low temperature ambient air with the warm inside air cools the green house in the winter. Two active winter cooling systems commonly employed are convection tube cooling and horizontal air flow (HAF) fan cooling systems.

4.2.1 Convection tube cooling

The general components of convection tube are the louvered air inlet, a polyethylene convection tube with air distribution holes, a pressurizing fan to direct air in to the tube under pressure, and an exhaust fan to create vacuum. When the air temperature inside the green house exceeds the set point, the exhaust fan starts functioning thus creating vacuum inside the green house. The louver of the inlet in the gable is then opened through which cold air enters due to the vacuum. The pressurizing fan at the end of the clear polyethylene convection tube, operates to pick up the cool air entering the louver. A proper gap is available for the air entry, as the end of the convection tube is separated from the louvered inlet by 0.3 to 0.6m and the other end of the tube is sealed. Round holes of 5 to 8 cm in diameter are provided in pairs at opposite sides of the tube spaced at 0.5 to 1m along the length of the tube.

Cold air under pressure in the convection tube shoots out of holes on either side of the tube in turbulent jets. In this system, the cold air mixes with the warm greenhouse air well above the plant height. The cool mixed air, being heavier gently flows down to the floor level, effects the complete cooling of the plant area. The pressurizing fan forcing the incoming cold air in to the convection tube must be capable of moving at least the same volume of air as that of the exhaust fan, thereby avoiding the development of cold spots in the house. When cooling is not required, the inlet louver closes and the pressurizing fan continues to circulate the air within the greenhouse. The process minimizes the temperature gradient at difference levels. The circulation of air using convection tube consumes more power than a circulation system.

4.2.2 Horizontal air flow cooling

HAF cooling system uses small horizontal fans for moving the air mass and is considered to be an alternative to convection tube for the air distribution. In this method the green house may be visualized as a large box containing air and the fans located strategically moves the air in a circular pattern. This system should move air at 0.6 to 0.9 $m^3/min/m^2$ of the green house floor area. Fractional horse power of fans is 31 to 62 W (1/30 to 1/15hp) with a blade diameter of 41cm are sufficient for operation. The fans should be arranged in such a way that air flows are directed along the length of the greenhouse and parallel to the ground. The fans are placed at 0.6 to 0.9m above plant height and at intervals of 15m.They are arranged such that the air flow is directed by one row of the fans along the length of the greenhouse down one side to the opposite end and then back along the other side by another row of fans (Fig. 6). Greenhouses of larger widths may require more number of rows of fans along its length.

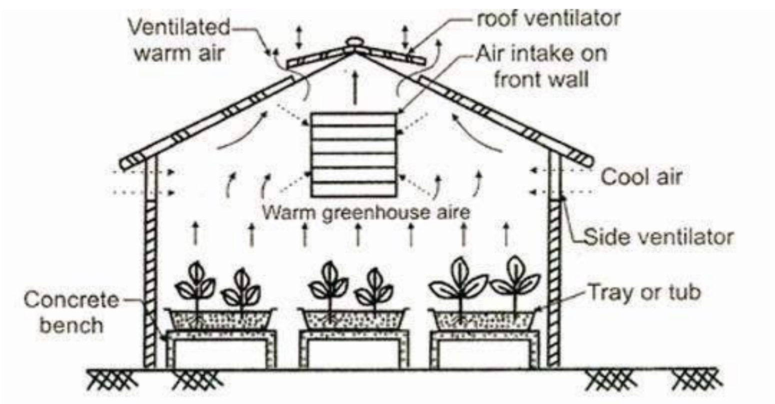
Temperatures at plant height are more uniform with HAF system than with convection tube system. The HAF system makes use of the same exhaust fans, inlet louvers and controls as the convection tube system. The only difference is the use of HAF fans in the place of convection tubes for the air distribution. Cold air entering through the louvers located at the higher level in the gables of the green house is drawn by the air circulation created by the net work of HAF fans and to complete the cycle, proper quantity of air is let out through the exhaust fans. The combined action of louvered inlet, HAF fans and the exhaust fans distribute the cold air throughout the greenhouse.

4.3 Green house ventilation

Ventilation is the process of allowing the fresh air to enter in to the enclosed area by driving out the air with undesirable properties. In the green house context, ventilation is essential for reducing temperature, replenishing COo_2 and controlling relative humidity. Ventilation requirements for green houses vary greatly, depending on the crop grown and the season of production. The ventilation system can be either a passive system (natural Ventilation) or an active system (forced ventilation) using fans. Usually green houses that are used seasonally employ natural ventilation only. The plant response to specific environment factor is related to the physiological processes and hence the latter affects the yield and quality. Hence, controlling of environment is of great importance to realize the complete benefit of CEA. Manual maintenance of uniform environmental condition inside the green house is very difficult and cumbersome. A poor maintenance results in less crop production, low quality and low income. For effective control of automatic control systems like micro processor and computer are used presently to maintain the environment.

4.3.1 Natural ventilation

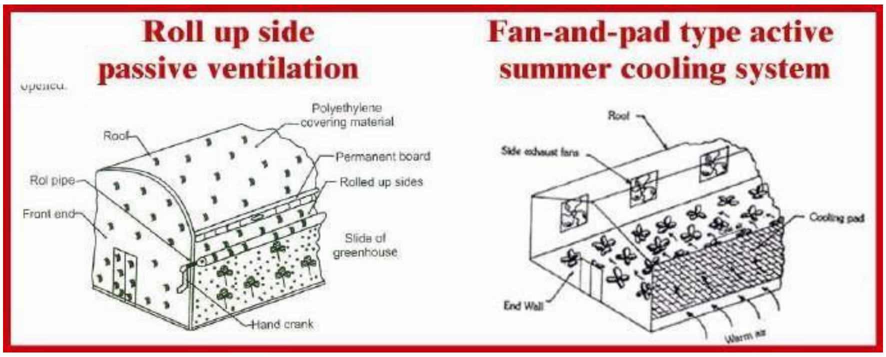
In the tropics, the sides of greenhouse structures are often left open for natural ventilation. Tropical greenhouse is primarily a rain shelter, a cover of polyethylene over the crop to prevent rainfall from entering the growing area. This mitigates the problem of foliage diseases. Ventilators were located on both roof slopes adjacent to the ridge and also on both side walls of



the greenhouse. The ventilators on the roof as well as those on the side wall accounts, each about 10% of the total roof area. During winter cooling phase, the south roof ventilator was opened in stages to meet cooling needs. When greater cooling was required, the north ventilator was opened in addition to the south ventilator. In summer cooling phase, the south ventilator was opened first, followed by the north ventilator. As the incoming air moved across the greenhouse, it was warmed by sunlight and by mixing with the warmer greenhouse air. With the increase in temperature, the incoming air becomes lighter and rises up and flows out through the roof ventilators. This sets up a chimney effect (Fig. 7), which in turn draws in more air from the side ventilators creating a continuous cycle. This system did not adequately cool the greenhouse. On
hot days, the interior walls and floor were frequently injected with water to help cooling.

4.3.1.1 Roll up side passive ventilation in poly houses

In roll up method of ventilation, allowing the air to flow across the plants. The amount of ventilation on one side, or both sides, may be easily adjusted in response to temperature, prevailing wind and rain (Fig.8). During the periods of excessive heat, it may be necessary to roll the sides up almost to the top. Passive ventilation can also be accomplished by manually raising or parting the polyethylene sheet. The open vent areas must be covered with screens to prevent virus diseases. The holes must be large enough to permit free flow of air. Screens with small holes blocks air movement and cause a build up of dust. Rollup side passive ventilation on plastic greenhouses is only effective on free standing greenhouses and not on gutter connected greenhouses.



4.3.2 Forced Ventilation

In forced or active ventilation, mechanical devices such as fans are used to expel the air. This type of ventilation can achieve uniform cooling. These include summer fan-and-pad and fog cooling systems and the winter convection tube and horizontal airflow systems. For mechanical ventilation, low pressure, medium volume propeller blade fans, both directly connected and belt driven are used for greenhouse ventilation. They are placed at the end of the green house opposite to the air intake, which is normally covered by gravity or motorized louvers. The fans vents, or louvers, should be motorized, with their action controlled by fan operation. Motorized louvers prevent the wind from opening the louvers, especially when heat is being supplied to the green house. Wall vents should be placed continuously across the end of the greenhouse to avoid hot areas in the crop zone.

Evaporative cooling in combination with the fans is called as fan-and-pad cooling system. The fans and pads are usually arranged on opposite walls of the greenhouse (Fig.8). The common types of cooling pads are made of excelsior (wood fiber), aluminum fiber, glass fiber, plastic fiber and cross-fluted cellulose material. Evaporative cooling systems are especially efficient in low humidity environments. There is growing interest in building greenhouses combining both passive (natural) and active (forced) systems of ventilation. Passive ventilation is utilized as the first stage of cooling, and the fan-pad evaporative cooling takes over when the passive system is not providing the needed cooling. At this stage, the vents for natural ventilation are closed. When both options for cooling are designed in greenhouse construction, initial costs of installation will be more. But the operational costs are minimized in the long run, since natural ventilation will, most often meet the needed ventilation requirements.

Fogging systems is an alternative to evaporative pad cooling. They depend on absolutely clean water, Free of any soluble salts, in order to prevent plugging of the mist nozzles. Such cooling systems are not as common as evaporative cooling pads, but when they become more cost competitive, they will be adopted widely. Fogging systems are the second stage of cooling when passive systems are inadequate.

4.3.3 Microprocessors

Dedicated microprocessors can be considered as simple computers. A typical microprocessor will have a keypad and a two or three line liquid crystal display of, sometimes, 80-character length for programming. They generally do not have a floppy disk drive. They have more output connections and can control up to 20 devices. With this number of devices, it is cheaper to use a microprocessor. They can receive signals of several types, such as, temperature, light intensity, rain and wind speed. They permit integration of the diverse range of devices, which is not possible with thermostats. The accuracy of the microprocessor for temperature control is quite good. Unlike a thermostat, which is limited to a bimetallic strip or metallic tube for temperature sensing and its mechanical displacement for activation, the microprocessor often uses a thermistor. The bimetallic strip sensor has less reproducibility and a greater range between the ON and OFF steps. Microprocessors can be made to operate various devices, for instance, a microprocessor can operate the ventilators based on the information from the sensor for the wind direction and speed. Similarly a rain sensor can also activate the ventilators to prevent the moisture sensitive crop from getting wet. A microprocessor can be set to activate the CO_2 generator when the light intensity exceeds a given set point, a minimum level for photosynthesis.

4.3.4 Computers

Now-a-days, computer control systems are common in greenhouse installation throughout Europe, Japan and the United States. Computer systems can provide fully integrated control of temperature, humidity, irrigation and fertilization, CO_2, light and shade levels for virtually any size growing facility. Precise control over a growing operation enables growers to realize saving of 15 to 50% in energy, water, chemical and pesticide applications. Computer controls normally help to achieve greater plant consistency, on-schedule production, higher overall plant quality and environmental purity.

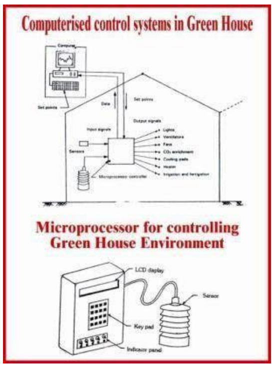
A computer can control hundreds of devices within a green house (vents, heaters, fans, hot water mixing valves, irrigation valves, curtains and lights) by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, CO_2 levels and even the time of the day or night. Computer systems receive signals from all sensors, evaluate all conditions and send appropriate commands every minute to each piece of equipment in the greenhouse range thus maintaining ideal conditions in each of the various independent greenhouse zones defined by the grower (Fig.9). Computers collect and record data provided by greenhouse production managers. Such a data acquisition system will enable the grower to gain a comprehensive knowledge of all factors affecting the quality and timeliness of the product. A computer produces graphs of past and current environmental conditions both inside and outside the greenhouse complex. Using a data printout option, growers can produce reports and summaries of environmental conditions such as temperature, humidity and the CO_2 status for the given day, or over a longer period of time for current or later use.

As more environmental factor in the greenhouse is controlled, there comes a stage when individual controls cannot be coordinated to prevent system overlap. An example is the greenhouse thermostat calling for heating while the exhaust fans are still running. With proper software program, which uses the environmental parameters as input from different sensors, can effectively coordinate all the equipment without overlap and precisely control all parameters affecting plant development as desired. Despite the attraction of the computer systems, it should be remembered that the success of any production system is totally dependent on the grower"s knowledge of the system and the crop management. Computers can only assist by adding precision to the overall greenhouse production practice, and they are only as effective as the software it runs and the effectively of the operator. The advantages and disadvantages of computerized control system are as follows:

Advantages

1. The computer always knows what all systems are doing and, if programmed properly, can coordinate these systems without overlap to provide the optimum environment.
2. The computer can record the environmental data, which can be displayed to show current conditions or stored and processed ones to provide a history of the cropping period, and if desired it may also be displayed in table or graph form.
3. A high-speed computer with networking facility can control several remotely located greenhouses, by placing the computer in a central area and the results can be monitored frequently by the management.
4. With proper programming and sensing systems, the computer can anticipate weather changes and make adjustments in heating and ventilation systems, thus saving the energy.

5. The computer can be programmed to sound an alarm if conditions become unacceptable to and to detect sensor and equipment failure.



Disadvantages

1. High initial cost investment.
2. Requires qualified operators.
3. High maintenance, care and precautions are required.
4. Not economical for small scale and seasonal production.

CO2 Consumption in Greenhouses:

Carbon Dioxide (CO_2)

Photosynthesis is the process which involves a chemical reaction between water and carbon dioxide in the presence of light, to make food (sugars) for plants and as a byproduct releases oxygen in the atmosphere. Carbon dioxide currently comprises .04% (400 ppm) of the atmospheric volume. It is a colorless and odorless minor gas in the atmosphere, but has an important role for sustaining life. Plants take in CO_2 through small cellular pores called stomata in the leaves during the day. During respiration (oxidation of stored sugars in plants producing energy and CO_2) plants take in oxygen (O_2) and give off CO_2 , which complements photosynthesis when plants take in CO_2 and give off O_2 . The CO_2 produced during respiration is always less than the amount of CO_2 taken in during photosynthesis. So, plants are always in a CO_2 deficient condition, which limits their potential growth.

CO_2 Concentration in Relation to Plants Photosynthesis utilizes CO_2 in the production of sugar which degrades during respiration and helps in plant's growth. Although atmospheric and environmental conditions like light, water, nutrition, humidity and temperature may affect rate of CO_2 utilization, the amount of CO_2 in the atmosphere has a greater influence. Variation in CO_2 concentration depends upon the time of day, season, number of CO_2 -producing industries, composting, combustion and number of CO_2 -absorbing sources like plants and water bodies nearby. The ambient CO_2 (naturally occurring level of CO_2) concentration of 400 ppm can occur in a properly vented greenhouse. However, the concentration is much lower than ambient during the day and much higher at night in sealed greenhouses. Carbon dioxide level is higher at night because of plant respiration and microbial activities. Carbon dioxide level may drop to 150-200 ppm during the day in a sealed greenhouse because CO_2 is utilized by plants for photosynthesis during daytime. Exposure of plants to lower levels of CO_2 even for a short period can reduce rate of photosynthesis and plant growth. Generally, doubling ambient CO_2 level (i.e. 700-800 ppm) can make a significant and visible difference in plant yield. Plants with a C3 photosynthetic pathway (geranium, petunia, pansy, aster, lily and most dicot species) have a 3-carbon compound as the first product in their photosynthetic pathway, thus are called C3 plants and are more responsive to higher CO2 concentration than plants having a C4 pathway (most of the grass species have a 4-carbon compound as the first product in their photosynthetic pathway, thus are called C4 plants). An increase in ambient CO2 to 800-1,000 ppm can increase yield of C3 plants up to 40%–100% and C4 plants by 10%–25% while keeping other inputs at an optimum level. Plants show a positive response up to 700-1,800 ppm, but higher levels of CO2 may cause plant damage.

CO2 Supplementation In general, CO2 supplementation is the process of adding additional CO2 in the greenhouse, which increases photosynthesis in a plant. Although benefits of high CO2 concentration have been recognized since the early 19th century, growth of the greenhouse industry and indoor gardening since the 1970s has dramatically increased the need for supplemental CO2 . The greenhouse industry has advanced with new technologies and automation. With the development of improved lighting systems, environmental controls and balanced nutrients, the amount of CO2 is the only limiting factor for maximum growth of plants. Thus, keeping the other growing conditions ideal, supplemental CO2 can provide improved plant growth. This is also called CO2 enrichment' or 'CO2 fertilization.

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Advantages

- Increase in photosynthesis results in increased growth rates and biomass production.
- Plants have earlier maturity and more crops can be havested annually. The decrease in time to maturity can help in saving heat and fertilization costs.
- In flower production, supplemental CO2 increases the number and size of flowers, which increase the sales value because of higher product quality.
- Supplemental CO2 provides additional heat (depending upon the method of supplementation) through burners, which will reduce heating cost in winter.
- It helps to reduce transpiration and increases water use efficiency, resulting in reduced water use during crop production.

Disadvantages

- Higher production cost with a CO2 generation system.
- Plants may not show a positive response to supplemental
- CO2 because of other limiting factors such as nutrients, water and light. So, all factors need to be at optimum levels.
- Supplementation is more beneficial in younger plants.
- Incomplete combustion generates harmful gases like sulphur dioxide, ethylene, carbon monoxide and nitrous oxides. These gases are responsible for necrosis, flower malformation and senescence if left unchecked, resulting in lower quality products.
- Additional costs required for greenhouse modification. Greenhouses need to be properly sealed to maintain a desirable level of CO2.
- Excess CO2 level can be toxic to plants as well as humans.
- On warmer days it is difficult to maintain desirable higher

CO2 levels because of venting to cool the greenhouses.

Effect of supplemental CO2 on different growing factors CO2-light

The rate of photosynthesis cannot be increased further after certain intensity of light termed as the light saturation point, which is the maximum amount of light a plant can use. However, additional CO2 increases the light intensity required
to obtain the light saturation point, thus increasing the rate
of photosynthesis. Mostly in the winter, photosynthesis is limited by low light intensity, and an additional lighting system will enhance the efficiency of CO2 and increase the rate of photosynthesis and plant growth. Thus, supplemental CO2 integrated with supplemental lighting can decrease the number of days required for crop production.

CO2-water:

Supplemental CO_2 affects the physiology of plants through stomatal regulation. Elevated CO_2 promotes the partial clo- sure of stomatal cells and reduces stomatal conductance.

Stomatal conductance refers to the rate of CO_2 entering and exiting with water vapor from the stomatal cell of a leaf. Because of reduced stomatal conductance, transpiration (loss of water from leaf stomata in the form of water vapor) is minimized and results in an increased water use efficiency (WUE) (ratio of water used in plant metabolism to water lost through transpiration). Lower stomatal conductance, reduced transpiration, increased photosynthesis and an increase in WUE helps plants to perform more efficiently in water-stressed conditions. Supplemental CO_2 reduces water demand and conserves water in water-scarce conditions.

CO2 -temperature

Temperature plays a big role in the rate of plant growth.

Most biological processes increase with increasing tempera- ture, this includes the rate of photosynthesis. But the optimum temperature for maximum photosynthesis depends on the availability of CO_2. The higher the amount of available CO_2, the higher the optimum temperature requirement of crops (Fig 2). In a greenhouse supplemented with CO_2, a dramatic increase in the growth of plants can be observed with increas- ing temperature. Supplemental CO_2 increases the optimum temperature requirement of a crop. This increases produc- tion even at higher temperature, which is not possible at the ambient CO_2 level.

CO2 -nutrient

A major effect of CO_2 supplementation is the rapid growth of plants because of enhanced root and shoot growth. The enhanced root system allows greater uptake of nutrients from the soil. It is recommended to increase fertilizer rate with increasing CO_2 level. The normal fertilizer rate can be exhausted quickly and plants may show several nutrient deficiency symptoms.

Control and Distribution of CO2

Depending on the size of the greenhouse and type of system installed, the CO_2 level in the greenhouse is controlled manually or through a computer-based system. A CO_2 gas sensor (Fig. 5) gives the level of CO_2 concentration in the greenhouse atmosphere and a generator is manually turned on and off based on the readings of the sensor. The sensor measures temperature and humidity along with CO_2 and helps in developing a crop management strategy. However, in the case of the computer-based system, sensors signal the current CO_2 level to the control system and a control system turns on and off the generator based on the set points created by the grower. CO_2 diffuses slowly, so proper air circulation is essential to distribute CO_2 evenly. Generally, a small greenhouse with a single CO_2 generator uses fan jets or horizontal air flow fan for distribution. However, a large connected greenhouse with a flue gas generator generally uses plastic tubes underneath the bench (right below the crop level) and are perforated at different intervals to diffuse CO_2. The main advantage of such tubing is to supply adequate CO_2 to the boundary layer of a leaf even in dense canopy conditions.

ON-LINE MEASUREMENT OF PLANT GROWTH IN THE GREENHOUSE:

- Traditionally, greenhouse environmental control has been relying on feedback from the environmental.
- On-line control and optimization of plant production will require feedback directly from the crop.
- Therefore non-destructive measurements of "plant growth" have been developed and tested.
- For determination of fresh weight and transpiration of plants an electronic balance is used in combination with a hydroponic system.
- The second method, a CCD-camera and an image processing system allows on-line measurement of leaf area.
- An evaluation of the relation between fresh weight and recorded leaf area gives the best accordance with an exponential regression equation.
- The third method is the measurement of net CO_2-uptake using the greenhouse as a cuvette or maintaining inside the greenhouse the same CO_2-concentration as outside.

OUTLINE OF ON-LINE MEASUREMENT OF PLANT GROWTH IN THE GREENHOUSE

- The use of microcomputers allows to control the climate conditions in a greenhouse according to the plant response.
- This requires information about plant reaction and physiological processes, such as photosynthesis, transpiration, fresh weight and leaf area development in short intervals.
- It is likely that control of plant production will require feedback directly from the crop.
- Three kinds of feedback information from the plants are distinguishable:

1. Potentials, such as leaf temperature, turgor pressure, stem diameter or leaf colour.
2. Fluxes, such as transpiration or assimilation rates. –

3. State variables, such as fresh weight, leaf area or height of plants.

- Unfortunately, direct feedback from the plants is not easy to measure.
- Especially on-line measurement in greenhouses is difficult because of disturbances

MATERIAL AND METHODS

The following methods have been tested under greenhouse conditions.

1. Image Processing system

- The image processing system consists of the image sensor, the image processing unit and the computer system.
- The plant image is recorded by a CCD-camera and converted to a digital picture with at maximum 64 grey levels.
- These are stored in a buffer memory. Digitization logic, D/A-converter and buffer memory are located on the image processing board in the process computer.
- Mouse and keyboard allow corrections and manipulations of the picture. In the same way it is possible to set the grey level, which is a scale for the brightness of the picture.
- To eliminate disturbances caused by short wave radiation a red filter is used cutting off radiation shorter than 700 nm.
- For small plants a two-dimensional measurement of leaf area is sufficient, whereas for higher plants a three dimensional evaluation is necessary using two cameras with different angles.
- The first tests have shown a high fluctuation of measured leaf area during daytime. With changing radiation intensity, the values increase and decrease, while at constant radiation level. e.g. at night, they are relatively constant.
- It could be observed, that at high radiation level the contrast between soil and plant is decreasing. Because the contrast of the image is influenced by the grey level, this must be changed according to the radiation.
- A linear regression has been used to adapt the grey level to light intensity. Thus, the influence of global radiation on the measurement error could be eliminated.
- The main Tash of image processing is to estimate fresh weight. Several regression models have been tested. The best correlation between fresh weight and leaf area gives an exponential equation, which can be expressed by:

  FG = 1.74 * EXP (0.02 *LF)

  (FG = fresh weight; LF = leaf area)

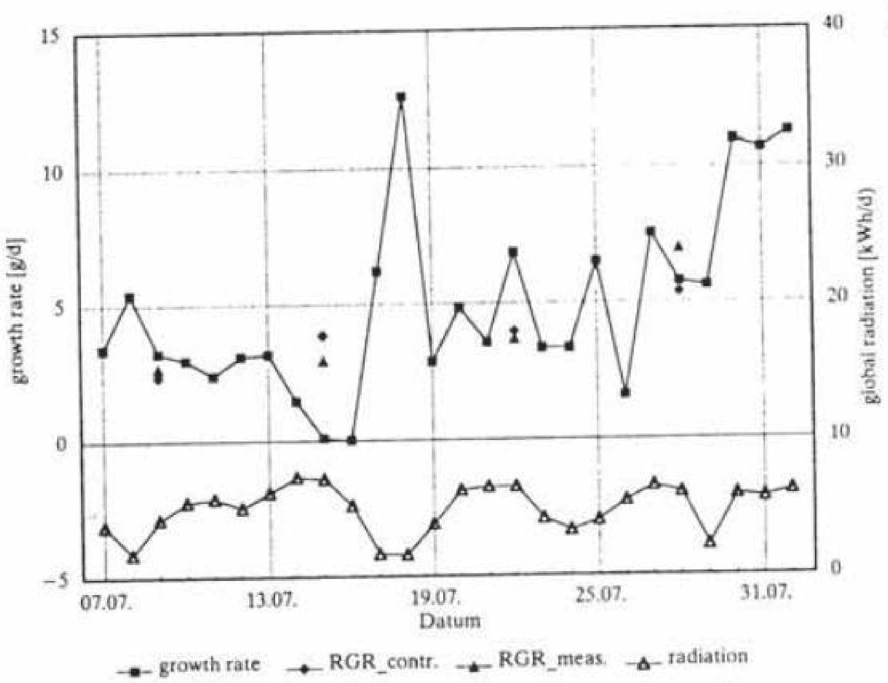


Fig. 1. Growth rate, relative growth rate and solar radiation for the time of 7.7. to 31.7.

- Fig. 1 shows an example for the estimation of growth rate, relative growth rate and solar radiation. The measured growth rate using image processing fits very well into the real growth rate.

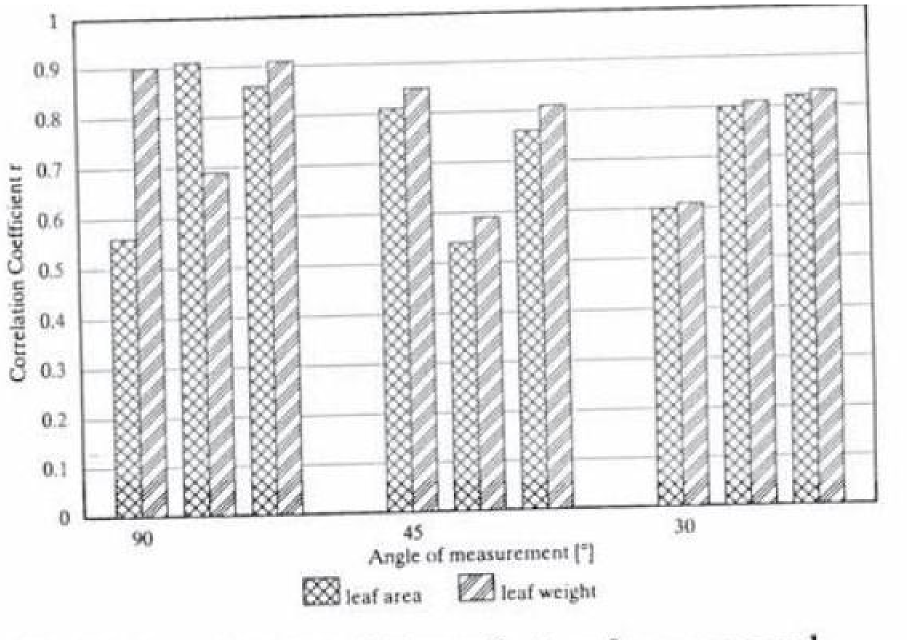


Fig. 2. Correlation coefficients for 1 or 2 cameras and different measurement angles.

- As mentioned earlier, for higher crops (e.g. tomato) a three-dimensional measurement is necessary using two cameras with different angles.
- Fig. 2 shows the correlation coefficient using 1 or 2 cameras and different angles of measurement.

2. Electronic balance and hydroponic system

- This method can be used especially for hydroponic culture.
- The pot with the plant stands on the balance. By means of a controlled inlet nutrient solution is added up to a fixed level.
- At first a run-off system has been used. That means surplus water will be returned ("run-off').
- After a few minutes there is a water balance in the system with always the same defined amount of water.
- For the second period of experiments the system has been changed, using a sensor to detect the level of water in the pot and to switch off the inlet at a fixed level.
- The weight differences between the actual and the preceding adding present the increase of the fresh weight of the plant.
- Until to the next adding the system can be used as a lysimeter and measurements of the evapotranspiration are possible with an interval of one minute.
- The hourly changes of plant fresh weight and evapotranspiration show an antagonistic daily course (Fig. 3).

- The evapotranspiration rate depends mainly on the solar radiation (Fig. 3). That means the minimum is in the night.
- During daytime the evapotranspiration rate increases according to solar radiation. When the transpiration losses exceed the water uptake of the plant, the fresh weight of the plant decreases.
- At night with low transpiration rates the fresh weight increases steadily.

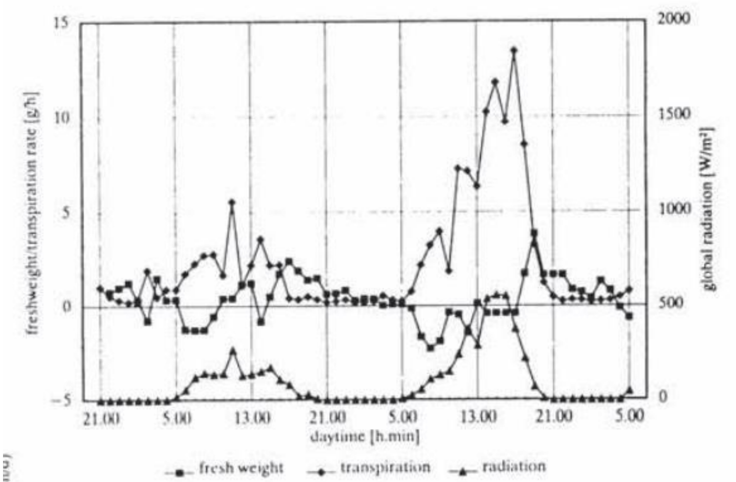


Fig. 3. Daily course of transpiration rate and fresh weight for days with low and high solar radiation

- The experiments have shown that on-line measurement of plant reaction due to a change of climate conditions is possible.
- The described methods allow non-destructive measurements. The accuracy of the

measurements is limited.

- For image processing the grey level must be adapted to light intensity.
- The time interval between measurements has to be selected in accordance to the intensity of plant growth.
- For overlapping leaves, fruit or head development a correction of the regression model is necessary.
- For higher plants a three-dimensional measurement, using 2 cameras gives a better correlation.
- Using the electronic balance the information of short term plant reaction is available directly with a high accuracy.
- **A disadvantage** of this method is that it is limited to hydroponic cultivation system and that only a few plants can be measured which must be representative.

MODELS OF PLANT PRODUCTION AND EXPERT SYSTEMS IN HORTICULTURE.

- Expert Systems are intelligent encoded domain specific expert's computer program solutions. Generalized computerized farm management and Expert System have good scope for managing and coordinating optimal production in agriculture.
- Horticultural crops, by improving the income in the rural areas, play a unique role in Indian economy.
- Though these crops hardly occupy 7% of the area and they contribute over 18% to the GDP in the country.
- Litchi is one of them and is called the Queen of the fruits which play a significant role in our national economy. Horticultural crops are affected by insect-pests and diseases causing destruction if mismanaged.
- It is therefore essential that the identification of pests, diseases and disorders and application of suitable remedies.
- For this purpose, application of ES in the management of horticultural crops can be helpful for minimizing losses and thereby increase productivity

Why we need an Expert System?

- The major problem is scarcity of real experts in a particular field, if available then there may be a problem of inaccessibility.
- Consultation may be expensive, and the expert may feel the repetitive job uninteresting, which may affect efficiency.
- The other major problem faced by experts is the memory limitation affecting processing

of essential knowledge and information required for decision-making.

- Research and developments in every discipline render relevant and accurate advice available from updated experts, which is not an easy task.
- Experts are subject to limitations, and it is impossible to access all the essential factors, while taking decisions.
- Some factors are always missed and unconsidered.
- This necessitates computer-based tools for assistance, like Decision support system, Decision making system or Expert system to update knowledge and render help in making decisions.

SOLUTION:

- In this respect, ES has been a very useful tool. ESs of today support problem solving activities such as decision making, knowledge fusing, designing and planning, forecasting, regulating, controlling, monitoring, identifying, diagnosing, prescribing, interpreting, explaining or training using different techniques, while future expert systems will support many more activities.
- In the beginning, Expert Systems were developed by the end of 1970s and were operating in the medicine, chemical, education, natural resources and science. ES started to gain popularity in the early 1980s.

EXPERT SYSTEM

- Expert Systems (ES) are intelligent computer program encoded, domain specific knowledge and reasoning of experts to produce solution.
- ES derived its knowledge from experts, supported by literature on application. ES differs from conventional computer program in many ways: uses knowledge rather than data for controlling solutions.
- Knowledge is encoded as an entity separate from the control of the program, it can explain how and why a particular solution is obtained, it uses symbolic representation for knowledge (rules, semantic nets or frames), it often reasons with meta knowledge i.e., knowledge about itself and has self-learning capabilities.
- The rule-based expert system has five components:

(i) the knowledge base, (ii) the database, (iii) the inference engine, (iv) the explanation facilities, and (v) the user interface.

- The basic components of rule-based expert system are shown in fig.1.

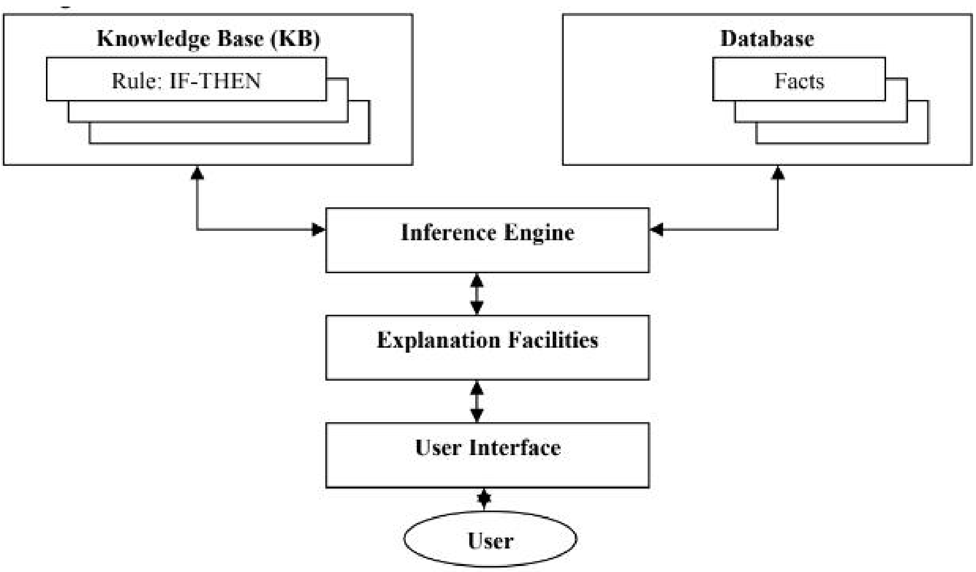


Fig.1 Components of Expert System and User interface

The expert system developed in the Prolog programming language functions as an inference engine in the backward chaining.

(i) **Knowledge Base:** It is a declarative representation of the expertise, often in IF- THEN rules including such things as simple facts about the domain, rules or constraints that describe relation or phenomena in the domain, and possibly also methods, heuristics and ideas for solving problems in this domain.

(ii) **Database:** It is the data or a set of facts which is specific to a problem being solved used to match against the IF (condition) parts of the rules stored in the knowledge base.

(iii)**Inference Engine:** It carries out the reasoning by interplaying the information or facts obtained from the user with the knowledge stored in the knowledge base whereby the expert system reaches a solution.

(iv) **Explanation Facilities**: It explains about how a particular conclusion is reached and why a fact is needed and explains its reasoning and justifies its advice, analysis or conclusion.

(v) **User Interface:** It provides communication between the user and expert system.

APPLICATION OF THE EXPERT SYSTEM IN HORTICULTURE:

- The agricultural practices as performed by farmers are traditionally based and non-scientific. Computer based general farm management and Expert System can be helpful in providing solutions to the problems in horticulture.
- ES can provide a comprehensive management of orchards. It can help in disease, pest and disorder management of plants. Since, plants and fruits are affected by insect-pests and diseases, which cause considerable loss, if not properly managed.
- So, proper management of orchard for diagnostic purposes can be helpful to increase total production and minimizing losses. Computer based general support and ES can be helpful in creating awareness and giving timely preventive suggestions.
- It can also help in insect identification, monitoring, insecticide selection, and disease

management.

- It can be cost effective as users need not wait for experts. By repeated consultations, farmers can develop self- skill and awareness for care-taking and ES can become advisory-cum-training tools.
- The transfer of knowledge from consultants, scientists, researchers and experts to extension workers in any area is very important for the development of agriculture and horticulture.
- The ES technology provides a good platform to facilitate the transfer of knowledge from expert to extension workers or farmers.
- The ES technology around horticulture has been developed especially related with decision-making, pests, diseases, or disorders diagnosis.
- Some of the Expert Systems developed for the horticulture applications are: CUPTEX- for cucumber crop production, TOMATEX- for tomatoes, CITEX- for orange production, LIMEX- for lime production, PLANT/ds- for the disease diagnosis among Soyabean, AMRAPALIKA- for the diagnosis of pests , diseases, and disorders in Indian mango , POMME for apple orchard management
- The application of the ES in horticulture is well justified and many developed countries have developed the expert system for their use.
- Although adoption of this technology in Indian agricultural practices is rather slow in comparison to developed countries, Indian farmers felt the need for such technology to increase agricultural productivity.
- Since, signs and symptoms of the pests, diseases and disorders have due geographical variations, expert system developed for a particular climatic and geographical region does not apply to different geographical region.
- Therefore, it is necessary to develop a new one or modify the existing system for that geographical region. Since, the concept of ES technology in agriculture has enough potential to revolutionize the agricultural practices, its use in India is urgently needed to enhance the productivity.
- ES can also help in finding nutrient status using visual symptoms in the plant and use of proper fertilizers to control the nutrient disorders and preventing damage to that tree.
- The information provided by farmers during consultation can be used to develop database of specific orchard for region-specific agricultural practices and problems. Such database will become valuable research resources in the future.
- In the modern days the concept of agro clinic has come into practice as shown in fig 2. Such clinics are being established near the agricultural land in the rural areas.

Obviously, farmers will seek these clinics to get solutions for problems encountered.

- For this purpose, ES can also be installed for consultation in local agro-clinics or like ATM machines where farmers can have direct access. The person managing this clinic will need expert knowledge to help farmers.
- Under such conditions, ES will be highly useful and will attract farmers to these clinics. The ES available at agro clinics in remote area can be linked with central remote sensing center to make predictions about disease spread and weather conditions, enabling advance planning in caretaking of orchards. Such scheme will be highly helpful in alerting farmers in rural area for taking preventive steps to save crops in adverse weather conditions.

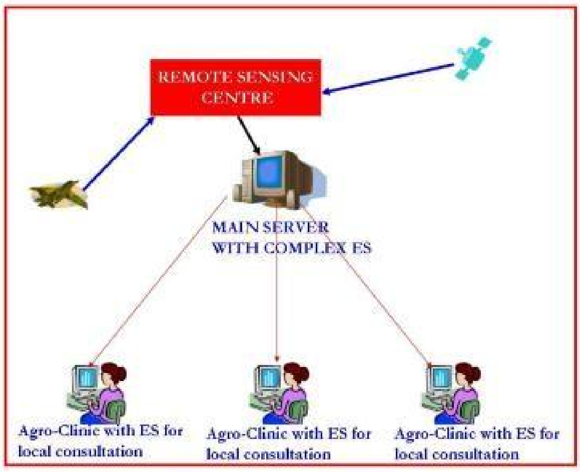


Fig 2. Role of ES in agro-clinics

CASE STUDY

Brief description of horticultural crop 'Litchi'

Horticultural crops play a major role in Indian economy by improving the income of the rural people. Cultivation of crops requires labor generating employment opportunities for the rural population. Fruits and vegetables are also rich source of vitamins, minerals, proteins, and carbohydrates, referred to as protective foods and assumes importance as a nutritional security. Cultivation of horticultural crops plays a vital role in the prosperity of a nation and is directly linked with the health and happiness of the people. It is estimated that all the horticulture crops put together cover nearly 11-6 million hectares area with an annual production of 91 million tons. Though these crops occupy hardly 7% of the area and they contribute over 18% to the GDP in the country. India with more than 28.2 million tons of fruits and 66 million tons of vegetables is the second largest producer in the world, next only to Brazil and China. With the present population level, the annual requirement of fruits and vegetables will be of the order of 32.58 million tons and 83 million tons respectively. However, per capita consumption of fruits and vegetables in India is only around 46 kg and 130 g [Minimum of about 92 g and 300 g recommended by Indian Council of Medical Research (ICMR) and National Institute of

Nutrition (NIN), Hyderabad]. In different agro climatic zones of India, various fruits are grown. Litchi is one of them and is called the Queen of the fruits which play a significant role in our national economy. Litchi (Litchi chinensis Sonn.) is one of the most important evergreen subtropical fruit known for its fragrance and quality aril.

It is an important commercial fruit crop with tremendous export potential. India is the second largest producer of litchi in the world after China. The total production of litchi in India is 4,

33,000 tons from an area of 60,000 ha and productivity level is 7.4 t/ha [3]. The other important growing countries are China, Taiwan, Thailand, Vietnam, Brazil, Malaysia, Myanmar, Mauritius, South Africa, Australia, New Zealand, Madagascar and USA. The area, production and productivity (2002-03) of litchi at global level have been given in table 1.

Table 1: Global production of litchi

Country	Area (ha)	Production (tonnes)	Productivity (t/ha)
China	5,88,000	1,280,000	2.18
Taiwan	12,000	108,000	9.00
Vietnam	30,000	50,000	1.70
Thailand	23,000	81,000	3.50
India	56,200	4,29,000	7.70
Bangladesh	4,800	12,800	2.70
Nepal	2,300	14,000	6.10
South Africa	1,500	8,000	5.30
Madagascar	3,000	20,000	6.67
Israel	300	2,000	6.67
Australia	1,500	5,000	3.33
USA	240	1,000	4.20
Mauritius	1,000	12,000	12.00
Brazil	350	2,120	

n India, commercial cultivation of litchi is restricted in northern part, particularly in foothills of the Himalayas from Tripura to Jammu & Kashmir and Gangetic plains. The major litchi growing states are Bihar, Bengal, Uttrakhand, Jharkhand, Assam, Tripura, Orissa and Punjab. Bihar produces 75% of total litchi production of the country and occupies nearly 54% of the area under litchi plantation. State-wise area, production and productivity of litchi (2004-05) in India have been given in table 2

Table 2: State-wise production of litchi in India

State	Area ('000 ha)	Production ('000tonnes)	Productivity (t/ha)
Bihar	28.4	284.9	10.0
West Bengal	7.2	69.9	9.8
Assam	4.5	22.5	5.0
Jharkhand	1.4	16.5	12.0
Tripura	2.2	12.4	5.6
Punjab	1.3	12.6	10.0
Orissa	3.9	11.9	3.0
Uttrakhand	6.7	8.9	1.3
Himachal Pradesh	3.4	3.6	1.1
Chhattishgarh	0.5	3.4	7.0
Haryana	0.2	1.0	6.2
Others	0.5	1.0	2.0
Total	**60.2**	**448.6**	**7.4**

In India, there are large numbers of varieties (approximately 52 cultivars) grown in different parts under different climates and soil conditions. Approximately 90% of the produce utilized as fresh at various stages and post harvest losses exceed 30% sometimes followed by market glut. Litchi plants and fruits are also affected by insect-pests and diseases, which cause considerable losses, if not properly managed. In general, litchi plants are least affected by diseases but fruits are prone to certain diseases and disorder if not managed properly. So, proper management of litchi orchard can be helpful to increase total production as well as minimizing losses.

UNIT III

Agricultural systems - managerial overview, Reliability of agricultural systems, Simulation of crop growth and field operations, Optimizing the use of resources, Linear programming, Project scheduling, Artificial intelligence and decision support systems.

AGRICULTURAL SYSTEMS MANAGEMENT AGRICULTURAL

SYSTEMS DEFINED

- An agricultural system is a specified group of components, operational functions, and processes that are integrated to accomplish a well-defined purpose.
- Agricultural systems managers (ASMs) usually plan, evaluate, and adjust a system or some group of components of a system. In a complex agricultural system one can easily identify or envision systems within systems.
- We might call those systems within systems subsystems, but the main concern is that the system performs to the highest level we can achieve within the parameters or resources at hand.
- The ASM must learn quickly to manage and evaluate subsystems concurrently.

CHARACTERISTICS OF AGRICULTURAL SYSTEMS

- Each agricultural system has some well- defined purpose. The purpose might be stated simply, or more often it might be stated as a group of objectives.
- And those objectives might include some very definite specifications or measures of performance.
- As an example, let's consider an agricultural system that produces potato chips. The overall purpose might be to produce six 1 2= -ounce bags of chips for the consumer market.
- However, the well-defined purpose for the line technical mangers of the processing plant might be production objectives of 1500 bags per hour, less than 0.05% of bags over 0.675 ounces, with less than 8.00% waste, less than 1% under 0.6355 ounces, with less than 0.5 hours line downtime per shift, less than 1 recorded human accident per 6 months, at a cost of less than $0.233 per bag, and meeting the 2002 EPA guidelines regarding odor control in the community.
- In real life this specification list could be much longer, involving hours of planning and discussion with managers, engineers, accountants, labour unions, and lawyers.

We could easily identify the same level of complexity in a production farming operation. The overall purpose might simply be to grow hogs for meat processing. The well-defined purpose might be to produce 1000 barrows, with weight range limited to 205–215 lb, loin eyes of not less than 4.14 sq in or
more than 5.01 sq in, average rates of gain of not less than 1.98 lb/day, at a cost of less than $0.21 per pound, utilizing non GMO feeds, and meeting all local and federal EPA requirements. And, once again, the real pork producers reading this chapter know that an actual specification list for this agricultural system would be much longer. This discussion of the ''well-defined purpose'' portion of the definition is well served by the two examples. Looking back at our potato chip processing plant example, we know that to fulfil the well-defined purpose (specifications), numerous operational functions and processes need to be performed. The operational functions and processes are key parts of our definition. Some of those operational functions and processes involving our complete definition of the potato chip agricultural system might be:

- Purchasing of potatoes
- Transportation
- Unloading at the plant
- Storage
- Grading and inspection
- Sorting
- Chemical wash
- Storage
- Waste disposal
- Purchasing of frying oils
- Transportation of oils
- Storage of oils
- Least-cost formulation of ingredients
- Cutting processes
- Line movement of product
- Frying
- Salting
- Packaging/weighing
- Boxing
- Quality control
- Pricing
- Loading
- Distribution and storage
- Sales
- Transport

In this agricultural system each operation or process might require humans, machine components, or a chemical or biological process. And each process will have management-defined parameters for successful operation. We could construct elaborate diagrams or computer programs to inspect or evaluate each component or operational activity. But our mission is to manage agricultural systems to achieve goals. To do that, we must fully understand how each component of a system works and the interacting effect its application might have on other components and the outcome of the system. To predict those impacts, we can rely on mathematical models and tools to forecast outcomes of decision alternatives.

EXPECTED OUTCOMES OR ‘‘DELIVERABLES’’ OF AGRICULTURAL SYSTEMS

There is a real need for the system to deliver well-defined products. Today’s consumer-oriented market demands truth and performance. A system often must meet standards either the consumer wants or governments might demand. Let us consider the challenge a small organic fertilizer bagging plant might have. The manager must meet the desires of the company for profit, of the public for performance, and of the government for truth in packaging. The manager and the company must design a product that meets the specification that satisfy company upper management for profit, establish product features that entice a certain market share of buyers and meets state and federal analysis on the package label. Each fertilizer product becomes very well defined, and the agricultural processing system must meet the goals. Many people from many arenas give critical input.

It is expected that the products the production line delivers are profitable. Agriculture is a business Every business must in the end meet a profit goal. In this small organic fertilizer bagging business we must set production volume targets, estimate fixed and variable costs, and establish costs per bag, pricing, and target profits. If this was all there was to management of this line, it would be easy. However, agricultural systems have to satisfy many other conditions. Profitability is not enough. The product must be safe for use. The manufacturer must also guarantee the safety of the production workers and perhaps meet union work conditions. If the product were edible or a drug it would have to be safe for human consumption Certain aspects of quality control would have to be met and verified.

Our bagging plant would probably produce ''secondary'' compounds or wastes. They must be managed as well. Those processes and costs become part of the total agricultural system too. The plant is responsible in American society to maintain or enhance the environment. Or at the very least, the product must be produced at environmental costs that society (and the law) deems acceptable. It is not unusual to expect that the bagging plant system also contribute to the general community economic development and well-being.

THE PRIMARY GOALS OF AGRICULTURAL SYSTEMS MANAGERS

An all-too-common mistake of technical management is a failure to identify performance criteria against which the system must be evaluated. These criteria and their measures need to be well established before we ''flip the switch'' and a system begins to operate.

The goals, criteria for success, and performance measurement assessment should be part and parcel of every planning process and evaluation process. These performance criteria should be established up front and agreed upon by all management.

It is not unusual to see these measures as part of monthly, quarterly, and annual reports. Some primary goals agricultural systems managers must attain are:

1. Optimization of economic costs, profits, and benefits
2. Production of defined levels of product quality and
3. quantity
4. Meeting timelines and schedules
5. Delivery of value-added products and product attributes
6. Attaining acceptable process reliability
7. Maximization of e efficiencies
8. Realization of environmental and regulatory guidelines
9. Optimization of human factors—safety, job satisfaction,
10. performance factors, and perhaps labor union issues

CRITERIA OF EVALUATION

Obviously, production costs per bag of chips would be a key criterion to evaluate, or maybe the total volume over a week, or total production in bags over the year.

So, costs, volumes, and profits are key criteria. Efficiency of the processes can be measured, equipment adjustments made, or replacement of processes effected.

Some of the processes included truck unloading, storage, belt movement, cutting, frying, salting, sorting, weighing, bagging, and boxing. Product quality must also be assessed.

Yes, we all like a beautiful, unbroken chip! The size, colour, weight, etc can all be assessed. Storage life and condition of the package itself can be evaluated and goals set No one likes a wrinkled bag or a misprinted label.

And who wants a six-ounce bag of chips labelled as seven ounces? If we forget that the whole system must have a very high-performance reliability, we cannot achieve any other goals.

To achieve this, we must meet timelines and schedules and attain serviceability and machine replacement goals. In a production plant we are always scrutinizing resource utilization, waste reduction, risk minimization, performance, stability, environmental impacts, FDA guidelines, food safety guidelines, and state and federal regulations.

Today, food processes must meet purity and process standards. Then there is the human element.

Are the plant meeting union agreements? Some additional criteria for evaluation would be meeting goals in plant safety, personnel satisfaction, health, comfort, and plant security.

The ASM must approach the system management from a team perspective. Many have input. Many must be informed and empowered. It becomes quite clear that a good technical manager manages far more than money.

Managing means managing all the resources. The good technical manager must also consider machine replacement, new products, new technologies, and training of personnel.

FACTORS AFFECTING THE AGRICULTURAL SYSTEM AND THE ASM'S DECISION MAKING

1. Changes in Weather, Seasonality, or Biological Intrusions

Perhaps the most significant and unique factor in agricultural systems management is dealing with the weather or seasonality of commodity production.

In our organic bagging plant example, an unknown or unplanned warm weather span could greatly spur biological activity of stored wood chips or manure.

Rising temperatures or microbe levels in the potato storage sheds would cause the potato chip manger to have to adapt to these conditions. Many processed products of agricultural systems are live biological entities requiring heating, cooling, pasteurization, sterilization, fermentation, or even radiation.

Seasonal changes or unusual weather patterns can greatly change schedules in Beld planting of corn or harvesting of soybeans. A meat processor knows that biological processes occur in known time frames. He or she must acknowledge and respond to unusual temperatures.

Processing changes must occur, or product quality is lost—or the product itself could be lost entirely.

A Florida citrus grower must change processes if an unusual cold snap jeopardizes the life of a young fruit tree Or if a disease such as aflatoxin enters a corn Beld nearing harvest, an immediate response by the ASM is required.

In production agriculture one must always be prepared to alter decisions when plant or animal diseases enter or threaten. The threat of SDS (sudden death syndrome) to a soybean crop would require changes in variety selection, planting dates, and harvest dates.

Likewise, a dry year would certainly spur the ASM of a grape vineyard to engage irrigation scheduling. The same dry year would spur the ASM of a winery to change the formulation of his winemaking process, since the soluble solids count of the grape juice would increase in a dry year.

In a wet year, the count may drop and the ASM might add sugar to fermentation processes.

2. CHANGES IN TECHNOLOGY

All so often dramatic changes in technology or innovations impact the agricultural system so much that the ASM is required to completely change the components, functions, or processes of the systems. In other words, we completely change the way we do things.

One dramatic example of this is the impact of biotechnology techniques and nanotechnology equipment on the development of plant seeds. The new technology completely changed how we exchange genetic information to form new varieties.

Processes were changed, new skills were required, and old seed technology was rendered noncompetitive. While this new technology changed forever how we promulgate plants, it also changed how we grow them in the Beld Genetically modified plants are now collegial in being resistant to certain herbicides.

Thus, we also have modified the cultivation and pesticide application in the production Beld systems of agriculture. Changing a technological process is not the only impact of changing technology. The development of a new product can
greatly change an agricultural system.

The invention of the large round hay baler is a good example. The introduction of the machine completely revolutionized haymaking in the Midwest, where labour costs are high. The old system of baling hay in small rectangular bales was rendered economically noncompetitive, except in specialty markets. Likewise, another biotechnological breakthrough is allowing us to grow pharmaceutical proteins and compounds in corn.

Several billion dollars a year is now generated by growing this new ‘‘Pharma’’ corn product, but the system of growing and handling requires new and unusual techniques to ensure biological security of plant growing regions ‘‘Pharming’’ requires many changes in the agricultural system.

Sometimes the breakthroughs can come from other industries or other countries. Agricultural industries and systems were greatly affected when other manufacturing industries began to adopt and develop different sweeteners.

Corn growers benefited from high-fructose sweetener, while sugar cane growers were forced to change production methods to remain competitive.

Better irrigation technology in Israel and Brazil forced growers of citrus in Florida, Arizona, and Texas to completely change irrigation technology to remain competitive. Some examples of technology changes of great impact
would be:

- Analog/digital interfacing with microcomputers
- Global positioning systems (GPS)
- Introduction of microcomputers for data handling and
- controls
- Spreadsheet software
- New plastic extrusion methods
- Ethanol processing from corn
- Rotary threshing mechanisms in combines
- Ergonomic engineering of tractor cabs
- Soil conservation practices
- The cotton gin
- Evaporative cooling for greenhouses
- Hydra cooling of fruits and vegetables
- Irradiation of meats, fruits, and vegetables

The list is very long and continues to grow daily. One of new technologies having the most impact is the use of the Internet for marketing and purchasing—commonly called e-commerce. E-commerce now allows an ASM to purchase and market worldwide. Top ASMs will need information systems that allow them to be educated rapidly regarding new developments. The Internet itself is a technological addition that has had perhaps the most dramatic effect on 21st century agriculture.

3. LEGAL/POLITICAL FACTORS

New laws and regulations can have great impacts on decisions regarding Beld production, manufacturing and processing, and technical marketing areas of agricultural systems. Even without new laws, new rulings by regulatory agencies can have consequences.

Changes in the tax structure can have significant impacts on management. Throughout the 1970s and early 1980s, farmers enjoyed federal tax exclusions from an investment credit deduction. Farmers could derive great benefits that encouraged buying capital equipment such as tractors, combines, and portable buildings. Federal tax reform removed these advantages, and equipment replacement planning strategies changed greatly. Because many did not know their income status until late in the year, there was a lot of lastminute December purchasing. This last-minute buying ceased. This change affected not only farmer purchasing but the way money was spent. Manufacturing schedules, technical sales programs and activities, and managerial decisions were changed. Even tax accountants had to change their schedules of activity.

Some of the most significant laws now affect the livestock production industry. Some small rural cities now have ‘‘influence’’ up to three miles from their city limits regarding odor control. Many local agencies in counties now control animal unit limits. Changes in fees for grazing on public lands in the West are another example where ranchers are forced to manage differently under different rate structures.

Laws affecting migrant labor, labor camp conditions, and wage rates greatly affect the fruit and vegetable industries. The trade-off between labor and mechanization greatly changes.

Likewise, Occupational Safety and Health Administration (OSHA) regulations and labor laws impact management decisions in processing plants.

On the technical marketing scene, the North American Free Trade Agreement (NAFTA) has changed the playing Beld considerably. Some industries have greatly benefited, while others have suffered. Changes in EPA guidelines and standards now have great managerial impact regarding the use of fertilizers and pesticides.

Nonpoint and point sources of watershed runoff are now more controlled. The ASM must keep abreast of key local, national, and international issues. Some key governmental agencies are:

1. Bureau of Land Management
2. EPA
3. State Departments of Agriculture
4. Water management districts
5. Farm Services
6. US Forest Service
7. Zoning commissions
8. Department of the Interior
9. Bureau of Indian AAairs
10. Agricultural Plant Health Inspection Service (APHIS)
11. Homeland Security

4. **The Economy**

Since the events of Sept. 11, 2001, we have learned how catastrophes can send an economy reeling for many months. Numerous factors in the economy can affect agricultural systems decisions. Managers in the manufacturing and processing areas certainly must be in tune with changes in the economy. Some key factors of change include oscillating inventory levels for supplies, available disposable income, new housing starts, changes in gross domestic product (GDP), expansion/failures of businesses, price levels, and changes in exports or imports.

Today, agriculture faces many changes in marketing channels for livestock, increasing mergers of seed and chemical companies, and consolidation of equipment suppliers. Yet new opportunities abound in the emergence of alternative fuel processors and new crop initiatives.

5. Changing Societal Trends

Society's attitudes are constantly changing and evolving. A number of attitude changes have greatly impacted agricultural systems. Perhaps the most important has been in the attitude toward the environment.

A growing spirit of conservation and preservation of wildlife and habitat has spurred numerous changes in agricultural systems management. In the early 1990s, support for the Pacific Northwest's spotted owl changed many lives. The giant logging industry, through public opinion, was forced to change its cultural and harvesting practices.

The industry continues, but not until after many systems changes were implemented. Managers must look ahead and be considerate of society's attitudes or perhaps pay a larger price—being forced out of existence. Society now focuses more keenly on the effects of production practices, including biotechnology, waste disposal, water quality, chemical waste, and odor generation.

Other attitude changes during the past decade have included:

1. Change in attitude toward the use of electronics and
2. computing technologies
3. Change in attitude toward the use of credit
4. Change in attitude toward increased leisure time
5. Change in attitude toward the use of foreign products
6. Change in attitude toward health and Fitness
7. Change in attitude toward cultural diversity
8. Change in attitude toward higher education
9. Change in attitude toward human and animal health
10. Increased desire for food safety
11. Increased desire for protection from terrorism

Unfortunately, many of these attitude changes have brought about increased regulation of a system manager's activities. In order for the technical manager to be successful in the long run, he or she must not limit his or her continuing education activities to technical updates alone. One must develop a good
''crystal ball'' by following and participating in many cross educational
activities, including local, state, federal, and international politics. Some of these changes in attitudes have encouraged whole ''new'' industries. The desire for increased leisure and the desire to enjoy the ''good life'' have generated the new area of agritourism. Industries such as hunting preserves, Bushing resorts, bed-and-breakfast inns, grape vineyards and wineries, farmers markets, maple syrup festivals, and equine events now abound.

6. The Competition

Someone else is always playing the same game. Decisions by the competition sometimes affect the strategy of another ASM's planning and ultimately the outcome of those decisions. Often, we may be affecting one and the same system. Awareness of what others are doing to that system is important.

Competitors' decisions or actions can affect the economic well-being of other firms or entities. The entry of new competitors does not always mean disaster for existing firms, but it can—especially if management does nothing to secure its position. A new competitor may force expansion in order to get lower cost per unit benefits. A new competitor may force the changing of hours of operation, additional investments, review of the product lines, expansion, or closures. Competition may come from foreign markets, such as lower-cost produced pork from Argentina or Brazil.

The competition's addition of a new or improved product often changes the business or management of a system. A seed company may add a new biotechnology-developed seed. A steel building system might have improved life. The introduction of retort packaging or irradiated food could change marketing, processing, or packaging systems.

Competition might introduce new selling or marketing strategies. Promotion of Angus beef might encourage growers to produce more Angus beef and less of other breeds of cattle. New marketing strategies might change how one would package the product. Or sometimes the new package itself creates the need for changes in processing.

Competition might obtain new customers, which gives them either economies of scale or a new niche market. In the late 1980s the Florida corporation Naples Tomato Growers landed the account to supply all tomatoes used by McDonald's Corporation. The security of a contracted major account afforded them a number of new managerial options.

New markets are always being sought. Competitors who might find them first win the opportunity, at least briefly, to attain economies of scale. The adoption of NAFTA opened many doors and opportunities for many agricultural industries. Clearly, irrigation sales, food equipment sales, and aquaculture equipment sales to Mexico were some of those new markets open for a short time. Perhaps one of the most exciting new markets exists in China. Without a doubt China can be America's largest new market for corn, soybeans, and other commodities.

The adoption of new, more efficient processes or management strategies can change cost structure rapidly as well. In the 1970s Japan adopted new steel-making technologies that forever changed the world industrial markets for steel. And in the decade of 2000, the American technological expansion of Internet and software technologies is greatly changing the face of all systems management.

Changes in Clients' Needs

The customer is always changing, and so are customers' needs. The ASM must develop mechanisms that allow timely interaction as clients develop strategic plans. Regrettably, many ASMs have become so engrossed in their own firm's plan that they simply overlook the changing needs of the customer. And before long another firm is taking care of those changing needs.

Consumer needs change constantly. A good case study is that of the consumer acceptance of genetically modified products (GMs), or products from genetically modified organisms (GMOs). European consumers and those in the United Kingdom are keenly aware of food safety issues. Their perception (right or wrong) is that GMO- developed food products may not be safe. Hence, they do not want GMO products mixed with non-GMO products. ASMs in the United States may have to change many operations, functions, and equipment pieces in order to have a food system that can deliver a 100% non-GMO product.

And Americans have grown, literally. The average American is taller, larger, and overweight. Clothes makers have to make those shirts bigger!

Changes in the ASM's or Firm's Purpose

The ASM and his or her firm is an entity that also changes, grows, adds and drops obligations, and responds to new opportunities and challenges. The agricultural system must change in personnel, functions, purpose, activities, and goals. A self-assessment process is a vital part of ongoing management of the total system.

In summary, the performance of the system is greatly influenced by the ASM's decisions. Success is determined by how well the ASM adjusts for changes in:

- Weather

- Seasonality
- Biological intrusions
- Technology
- Legal and political regulation
- The economy
- Societal trends

- Competition
- Customer or client needs

TOOLS FOR PLANNING, MANAGING, AND EVALUATING

The bottom line as to whether management is good or not is whether the system is meeting performance specifications or improving. Validating that the system is on the upswing can be very difficult. Verification requires measuring and analysis techniques. To do this, a process requires a six-step loop:

1. Sensing
2. Information storage
3. Information processing and analysis
4. Evaluation
5. Decision
6. Action or change
7. And back to sensing, etc

A manager might utilize this testing process to improve the system on a weekly basis or even a daily basis. Imagine the potato chip processing line manager we discussed earlier. The chip process might be sampled and adjusted every few minutes or even seconds. Improvement requires planning and management tools. Mathematical models are often used for planning and evaluation. Any agricultural system can be analyzed utilizing mathematical tools if it can be described logically. In most cases, approximation, record- keeping, sensing devices, electronic monitors, satellite imaging, or statistical sampling techniques will yield enough accurate data for management to begin planning and evaluation.

Quite a number of today's best technical management tools are mathematical models disguised as computer software packages. Many of those packages will be explored in the upcoming chapters of this book. Good examples are spreadsheets, linear programs, scheduling routines, and simulations.

One can begin to see that the skills required to be a successful ASM have a wide range, based on the varied activities this technical manager must oversee. Managerial skills are needed in:

- Accounting and finance

- Organizational planning
- Scheduling
- Systems reliability planning
- Personnel
- Human factors and human safety
- Environmental planning
- Pricing and costing
- Data information and management
- Transportation analysis
- Biological, chemical, and physical management
- Decision systems
- Systems integration
- Promotion and sales planning
- Legal and regulatory planning

Ideally, a strong ASM will have an academic preparation that is strong in engineering technology, the sciences, and business. The use of statistics and computer tools is paramount. Fortunately, there are many good software packages today to assist the ASM. And the Internet can be an excellent source of current information. The upcoming chapters will tie some of today's common agricultural systems challenges to a problem- solving framework utilizing some of the more popular mathematical models and contemporary software packages available today.

RELIABILITY OF AGRICULTURAL SYSTEMS

The goal of every agricultural systems manager (ASM) is to develop a total system that functions without fail. We know that this is an unobtainable goal, yet we strive to approach this by setting a goal of some successful percentage, such as 97% of the time the system operates as we need it. In order to obtain a high reliability for a system we must set a reasonable goal and plan for how to get there. The planning involves analysis of each component and function of the system. Then we consider what devices are replaced, which require backup, and how much we can afford to spend on our way to attaining the system reliability goal.

Measuring performance of a system can be done in several ways, all depending on which of the criteria we wish to evaluate. The technical manager spends a high proportion of time evaluating the performance of the system. Every agricultural system can be viewed as a group of processes and components (including humans) that must perform satisfactorily and in a timely fashion to achieve the output we have specified. Within our context we shall consider reliability to generally mean the probability that our system performs successfully. And we as managers will predetermine what "success" is.

We will now explore some of the management implications of our working definition of reliability within the context of agricultural systems. In production management reliability is most often viewed as the probability that the system will perform satisfactorily when called upon under specified conditions. Thus, reliability of a system, a subsystem, a function, or a component is measured in terms of probabilities. Quantitatively, a component or system is expressed as 0.9999 or 0.94 or some positive value less than 1.00. It should be noted that not all the system components necessarily have to perform at the same time, but each component must operate at the proper time for a sufficient period of time to ensure that the system accomplishes its purpose. Operation of the jet propulsion engine on a space shuttle launch is a good example. The engine must perform for only a few critical minutes in the proper way to be deemed successful.

A critical part of the definition of reliability is the "specified conditions" under which a unit or component is to function. Systems that would perform under all extremes of heat, dust, humidity, poor field or manufacturing conditions, vibration, and mismanagement and all possible conditions would be ideal—ideal but not very realistic. Systems must be evaluated within the limits of their intended use. These conditions should be explicitly stated or recognized before evaluating the performance reliability of a system. For example, it would not be a fair evaluation to state that the reliability was poor if a citrus harvest system failed because the hydraulic lift truck for moving pallets was stolen, or if a computer designed to operate in an air-conditioned working environment failed because it was exposed to 125°F temperatures in an incubation chamber. It is the job of the technical or agricultural systems manager to assist in planning and in setting needed, reasonable expectations.

Some critical processes may require component performances of extremely high reliability (launching astronauts, embryo incubation, refrigeration, evaporators, etc.). The words perform satisfactorily also carry great significance in the definition and in understanding the performance reliability concept. Tolerances must be specified so as to establish what acceptable reliability means. From the very beginning of the existence of a system degradation begins. As each component within the system ages, wears, or depletes with use, the output or system performance begins to vary. For a substantial period, the variance may be so minimal that it is not worthy of notice. Eventually the system may continue to function, but not at an acceptable level. A corn harvesting system consisting of a combine, tractor, wagons, augers, bucket elevators, grain drier, and storage bins is a good example. As the combine ages, field losses of grain increase. As the augers and bucket elevators wear, grain kernel damage increases and system flow rates decline. Drying rates may increase and fuel costs rise. There eventually comes a time when the unacceptable level is reached, and the system is deemed no longer reliable. One day the value may be 0.91 and the next day it can be deemed inoperable (zero). The manager can elect to replace components, change the system, get backup units, or even hire another system to perform the task.

Setting the acceptable levels of performance of various components is not always easy.

First, one must recognize what criteria are typical. The following criteria often need acceptability levels established in field production agriculture:

- Speed of operation
- Crop loss acceptability
- Quality and condition of crop
- Timeliness of completion date or times
- Cost–profitability trade-offs
- Field efficiency
- Capacity of each system needed

To dwell on this topic of acceptability for just a moment, we might consider a farmer evaluating the levels of acceptability regarding capacity of his soybean harvest system. Due to the limited days of good weather in his Midwest fall season, he may know that his harvest system must maintain the overall daily capacity of 55 acres per day. If harvest capacity is less, he does not get all of the crops in before the snow arrives and ends the season. Low reliability or high downtime, as he may phrase it, would not be acceptable. Likewise, a corn producer must view the quality of the harvested crop. It would do no good to continue running a combine if the threshing unit had become so worn that the machine produced a crop with

20% of kernels cracked. The crop would be evaluated poorly when graded at the grain terminal and deemed a very low market grade (sample grade would yield a very low price)!
In biological processing, packaging, or food processing, added factors such as the following could be determinants:

- Percent loss
- Yield
- Critical time durations met
- Cost per unit
- Food quality
- Food safety
- Contamination
- Cost of rework

Let's suppose a pecan processor is making bagged, crushed nuts for a candy manufacturer. The pecan processor delivers several truckloads of nuts. It is found that the nuts contain many pieces of shell. The candy manufacturer rejects the product (they do not want lawsuits from customers who break their teeth). If it is found that the screening devices are no longer capable of use because they are too worn, then the reliability of the processing line becomes zero.

HUMAN INTERACTIONS

Most agricultural systems consist of mechanical equipment and humans. In some cases biological, chemical, or physical processes are components as well. Humans are often required for planning, initiation, maintenance, operation, vigilance, ending operations, or any variety of tasks. They may provide the "backup" to any number of potentially failed components.

If one considers only equipment or process factors in systems planning, then one is assuming operator performance to have the probability of $r = 1.00$. Obviously, the reliability of humans is not perfect, or 1.00. Leaving out the valuation of human elements would give grossly inflated systems reliabilities, as often happens. However, the proper management of human interaction can lead toward exceptionally high systems reliability, as we will see later in this chapter.

Humans are much more complex than any machine or process used in agricultural systems today. The challenge of duplicating higher human functions such as perception, recognition, and decision making has just begun, through artificial intelligence algorithms and electronic circuitry. The field of robotics is still expensive and in its infancy.

Human limitations are numerous. They are less stable than machines and are influenced by and more responsive to the work environment. Human performance is affected by physiological conditions, fatigue, noise, incentives, rewards, previous learning, and conditioning (good and bad). However, thanks to the study of human factors, or ergonomics, it is possible to treat human operators mathematically, as one does for other components and processes as we estimate reliability of systems. In terms of inputs and outputs, a common descriptive language exists from empirically derived research. This permits a mathematical treatment that can be applied to man, machine, or processes. We will return to this topic.

ESTIMATING THE SYSTEMS RELIABILITY VALUES

There are many questions for which estimation of reliability can assist in providing technical management answers. Always remember: The system must work when you need it. If it doesn't, all other aspects of a system are irrelevant. Here are just a few of the decisions that quantification can help answer:

- What percent of the time does this system really work?
- Which machine should be replaced to gain reliability?
- Should a new machine (or person) be purchased, or can a used machine be utilized?
- If other machines are available for "backup," how will this affect performance?
- How many "backup" units are needed?
- Which is more profitable renting, buying, or leasing?
- Will the system work if a particular unit fails?
- How does the human operator or manager in the system affect the probability of success? Do we need more management or less?
- How much will I gain in efficiency and capacity by increasing reliability or decreasing it and saving costs?
- What level of reliability is economically acceptable?

Production managers, salespersons, service personnel, and design engineers need to fully understand that system reliability is inherently the absolute bottom line in selecting equipment, people, and resources. Granted, selections are often made for other reasons (economic, safety, etc.), but reliability must always be at an acceptable level.

Estimating System Reliabilities

Components in Series

Many agricultural systems are arranged in series. The successful operation of a series system depends upon the successful performance of each component in the system: man; machine; or process. Two conditions often exist:

(1) Failure of any given unit results in a complete system failure, and

(2) the component failures are independent of each other.

Gordon showed that in series systems the probability that a system operates acceptably is the product of the reliabilities of the individual units or components.

If, for example, there are three components in a system, each with a reliability of 0.90, the reliability of the system would be a product of the three, or 0.729. Lusser presented the original formula for sequential events as:

$$R_{\text{system}} = R_1 * R_2 * R_3 * \cdots * R_n \qquad (2\text{-}1)$$

The inherent weakness of most agricultural systems is the sequential nature, leading to overall low system performance reliability [4]. Think of a simple wheat harvesting system consisting of a tractor (0.90) to pull a wagon (0.90) that the combine (0.85) unloads into a storage tank (Fig. 2-1). The system reliability is only 0.6885. One unit fails and the whole system stops. As more units are added to an agricultural system, each unit must be very close to unity (1.00) if the system is to remain acceptable. There are three possibilities for improving a system:

1. Replace components of lowest reliability with higher-valued units.
2. Use only components of high reliability (new equipment).
3. Use redundant components (provide dedicated "backup" units).

Figure 2-1 Three units in series: R_{system} = 0.90 * 0.90 * 0.85 = 0.6885.

With parallel units, there are two or more that are performing the same function or are available to perform the same function at any particular time. This is referred to as either "backup" or redundancy. NASA missile research showed that parallel system reliability of like units can be estimated by combining the probabilities of unit success (reliabilities) of the individual units using the following formula [2]:

$$R_{\text{system}} = [1 - (1 - r)^m]^n \qquad (2\text{-}2)$$

where:

- Rsystem is the reliability of the system.
- r is the reliability of a single unit.
- m is the number of components in parallel for each function.
- n is the number of functions the unit must perform.

Suppose one were baling hay and a tractor is needed to pull and power the baler. The farmer needs only a single functioning tractor at one time to pull the hay baler. However, if he had two identical tractors, both available 100% of the time if needed and, say, with unit reliabilities of 0.90, the joint probability of having a tractor available to pull the baler would be (Fig. 2-2):

$$\begin{aligned} R_{\text{tractor fuction}} &= [1 - (1 - 0.9)^2]^1 \\ &= 0.99 \end{aligned}$$

Thus, even with relatively low component reliabilities such as 0.70, a system with four units in parallel could achieve a system reliability of 0.992. In some systems the components could be very different types, such as a human backing up a machine unit, or vice versa.
Achieving redundancy, or "backup," in a system can be accomplished in several ways. Some common management alternatives are:

- Purchasing another machine
- Borrowing a "backup" machine when needed
- Using a unit from another operation
- Leasing another unit
- Renting another unit
- Assured availability warranty from manufacturer

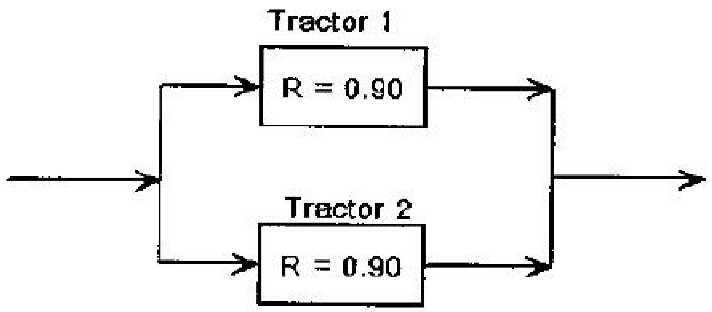


Figure 2-2 Parallel identical units: $R_{sys} = [1 - (0.1)^2]^1 = 0.99$.

Equation (2-2) is very useful because it expresses the real world of agricultural systems fairly well. The equation, however, applies only where the components in parallel for each of the n functions is exactly the same and unit reliability of each component is the same. Where these conditions do not apply, the derivation becomes more complex. And in reality it is rare to find two components or processes that are identical. For example,

a new tractor may be in use with a reliability value of 0.95; but if the new tractor were to fail, the manager might bring in the old tractor from the shed (0.78) to back the newer unit up. This situation is very typical in field production agriculture and processing. Complexity occurs in deriving a set of equations, since the selection of the first unit is a parameter open to management. An iterative technique is essential.

Heterogeneous Units

Redundant units in parallel possessing different reliability values can be termed heterogeneous backup units. An iterative technique would work as follows: For the components in parallel, select the first. If the system only had that one, that subsystem reliability, Rs, would be equal to that of the component, R1. The reliability of the subsystem that included both components 1 and 2 (call it Rs(1,2)) would be the probability that the first unit functions (R1) plus the probability that the first unit fails (1 - R1) and the backup unit functions (R2). These last two reliabilities are multiplied to get the reliability of the backup system's functioning. Therefore, the reliability of the subsystem with a heterogeneous backup unit is

$$R_{s(1,2)} = R_1 + (1 - R_1)^* R_2 \qquad (2\text{-}3)$$

and for three parallel components is

$$R_{s(1,2,3)} = R_{s(1,2)} + (1 - R_{s(1,2)})^* R_3 \qquad (2\text{-}4)$$

Thus a general form would be

$$R_{s(1,2,3,\ldots,n)} = R_{s(1,2,\ldots,n-1)} + (1 - R_{s(1,2,\ldots,n-1)})R_n \qquad (2\text{-}5)$$

Suppose two tractors are in parallel to form some subsystem.
Let's say that tractor 1 has a unit reliability of 0.90 and
unit 2 is 0.78 (Fig. 2-3). Using Eq. (3), the reliability calculation would be:

$$R_{s(1,2)} = R_1 + (1 - R_1)R_2$$

Assuming Tractor 1 is selected first,

$$R_{s(1,2)} = 0.9 + (1 - 0.9)^* 0.78 = 0.978$$

The dynamics of production agriculture systems can become quite complex. Tractors may back up several subsystems, performing several functions, or be unable to serve as backups because of incompatibility of components or unmatched horsepower requirements. Reliabilities seldom are identical. The best approach is to calculate reliabilities for each subsystem separately and then to combine the subsystem values to attain the complete system reliability.

Suppose farmer A had two enterprises: dairy and peanuts. To some extent, the two separate agricultural systems must share equipment, such as tractors. Farmer A must recognize the strengths and weaknesses of this arrangement. Let's analyze farmer A's peanut harvesting operation, as shown in the following table and Figure 2-4. Suppose it consists of a large tractor pulling a peanut combine. A wagon attached to the combine receives the peanuts. Another small tractor pulls the wagon away, empties the load and returns just in time to exchange wagons with the combine unit. The iterative process assumes that the unit of highest reliability is always used first. This is the usual management situation.

The calculations of each subsystem would be as follows:

Subsystem 1:

- Rss1 = 0.83 + 0.17 * (0.83)^3 = 0.9272

Subsystem 2:

- Rs(1,2) = 0.85 + (1 - 0.85) * 0.72 = 0.9580

Farmer A's System

Subsystem	Machinery available	Reliabilities
1	1 100-hp tractor dedicated to pulling combine	0.83 each

1	100-hp tractor backs up pulling unit, small tractor in subsystem 5, and tractor working at the dairy operation	
2	1 peanut combine	0.85
2	1 backup combine	0.72
3	1 wagon behind combine	0.90
4	1 wagon behind tractor	0.90
4	1 extra wagon to back up either subsystem 3 or 4	0.90
5	1 40-hp tractor to pull wagon	
6	1 40-hp tractor to pull wagon	

Note: The table provides information about the machinery available for each subsystem, along with their respective reliabilities.

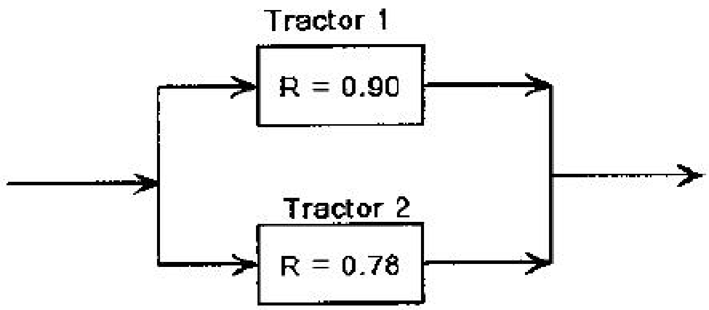


Figure 2-3 Heterogeneous parallel machines: $R = 0.90 + 0.10 * 0.78 = 0.978$.

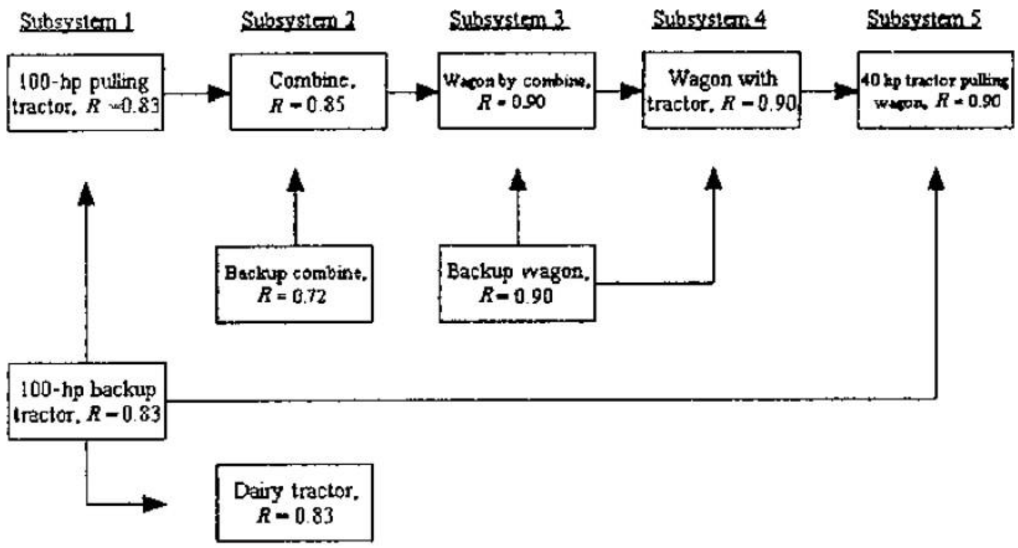


Figure 2-4 Peanut combine system with backups.

Subsystems 3 and 4. The added backup wagon is the same as having three wagons that must perform two functions. Thus, from Eq. (3):

$$R_{ss(3,4)} = 0.90 + 0.10(0.90)^2$$
$$= 0.9810$$

Subsystem 5. From Equation (3):

$$R_{ss(3,4)} = 0.83 + (1 - 0.83)*(0.83)^3$$
$$= 0.83 + 0.0972 = 0.9272$$

Total System. From Eq. (1):

$$R_{system} = 0.9272*0.958*0.9810*0.9272$$
$$= 0.8079$$

The iterative processes assume that the unit of highest reliability is always used first. In fact, one can see that doing otherwise might greatly diminish system reliability. The old philosophies of "I'll use the old ones first" and "I'll use the old ones 'until they wear out" simply do not pay.

Estimating Values of Individual Components

Just how does one attain the reliability values for machines, components, and functions? Absolutely the best way is to keep records on these units. Fortunately, computers and spreadsheet software make this task much easier today. Line foremen can record downtimes, as can mechanics or service managers. In the case of agricultural field machines, this is certainly "doable." One of the world's largest field production sugarcane growers actually tracks each field machine and keeps a life record via computer database. A farmer could keep uptime and downtime records on a spreadsheet.

In the case of processing plants, maintenance records often exist, and data estimates can be made by "recouping" the past information on items such as blenders, mixers, conveyors, bagging machines, and chemical processes. Where no life records exist, a good manager can collect sample data using good statistical techniques. Data can sometimes be gathered from other plants or the engineering firms producing the devices.

The literature in processing journals does contain some reliability data. And when all else fails, an ASM could interview users of the machines and processes to backtrack in time to find failures and downtimes. The real bottom line is that attaining accurate unit reliability data requires forward planning. However, the effort to attain the data will yield great rewards in system performance.

Estimating Human Component Values

Many situational factors affect human performance. Operator unit reliabilities can range from zero to 0.99999 reliability. It becomes quite difficult to develop generalized relationships. The trade-off considerations that can be applied are consequently qualitative. Costs, hazards, state of the technology, and other factors often influence the human role in an agricultural system. It was also shown that the reliability in a space system with a maintenance person available could be higher than that of the same system with automated devices as a monitor or "fail-safe" unit. Humans can seldom be rivaled by equipment. The following illustrates the trade-offs that exist with the use of humans.

Human long-term unit values seldom exceed 0.78. This is because there are so many time deductions one must make. Ignoring time lost for weekends and hours beyond 40 per week, the following lost time applies:

- Sick time
- Late time
- Vacation time
- Family leaves
- Strike time
- Break times
- Other

Humans are also subject to errors from repetitive tasks. The value assigned to human subjects varies greatly, depending on how they are inserted into the system. With proper managerial planning and backups, the values can be very high.

Let's take a closer look at the true value of a human in an agricultural system. Suppose a woman operates a bagging machine in a line operation that produces bags of garden mulch for the Super Duper market outlets. In a year, if she worked an eight-hour day, five days a week, she would need to be available 2080 hours per year. But she is not likely to be able to deliver this. Consider the following time losses:

Activity	Hours lost
2 weeks of vacation	80
Holidays (11 days)	88
Family leave (5 days)	40
[illegible]	43
	50
	56
	hours

$$\text{Total time lost } (\%) = \frac{457}{2080} \times 100 = 21.97\%$$

$$\text{Approximate reliability} = 78.03\%$$

The first reaction would be that this is unacceptable. But, this is just being human. It would be easy to develop a much worse scenario for an employee. So how does the plant manager cope with labor on a line that might involve 20 or more employees?

First, let's assume that the manager could back up this employee with another available employee. The manager might call in another qualified [1] individual off-shift. Or maybe there is a pool of employees available. The calculation would [2] be:

$$R_{\text{bagger}} = 0.7803 + 0.7803(1 - 0.7803) = 0.9517$$

We can see that by having a backup available raises the reliability of the human component to 95.17%.

Managerial Implications

The use of parallel or redundant units becomes a very important factor in production management decisions, such as deciding what unit to replace and whether to buy new or used equipment. Reliability and machinery labor costs are clearly traded off to attain some acceptable level of performance.

It becomes clear that the use of redundant subsystems is often more economical than simply purchasing new units with higher reliability. Comparisons between ownership and operating costs of new purchases versus several older units and their maintenance and repair operating costs are necessary. Leasing and rental units must also be considered. Individuals or corporations "starting out" or with limited capital obviously have some alternatives that may be quite viable.

The human operator can be used to great advantage. If inserted properly into a system, reliability can be increased several-fold to save capital outlay.

Weighing the Cost of Attaining System Reliability

One can come to the supposition very quickly that most systems must achieve a 0.95 total reliability or better to be considered "successful." There are almost always alternatives. And each alternative has its costs. The decision could be driven by how to get an acceptable system reliability for the lowest cost. Let's consider a struggling college graduate, Bob, desiring to farm. He owns an older combine of unit reliability of
0.88. He knows this is not good enough. So what are his alternatives?

Suppose his dad is willing to allow Bob to use his new combine of 0.96 reliability as a backup, but only when he is not combining himself. The calculation would be:

$$R_{\text{combining}} = 0.88 \times (1 - 0.88)0.96^2 = 0.9905$$

Now, if good old dad is generous and does not charge Bob, this is a no brainer. Use dad's combine as a backup! (See how much smarter dad is now?) Each method of backup could have another opportunity cost. Here are some other alternatives:

Alternative	Depreciation cost
Buy a new combine	$ 45,000
Purchase a used backup	15,000
Lease a new combine	35,000
Rent a backup	?
Hire a custom operator to harvest and sell the old combine	?
Steal a new combine (maybe you would not want to do this)	?

In a processing situation, some devices might be extremely expensive, such as a reactor in an ethanol processing plant. The backup alternative may be maintaining an extensive parts inventory or even an emergency contract with an engineering firm to perform immediate services.

Another alternative is to introduce the concept of scheduled repair versus maintenance. Suppose the huge sugarcane harvest system has hundreds of tractors. Based on past records, the managers may know what breaks down and when. They might actually shut down the operation of units with higher hours and rebuild the transmissions, hydraulics, and engines before they break down. This might be expensive and require a larger pool of tractors, but it might be cheaper than buying new units or stocking even more backup units.

This concept is often used in situations where downtime is either extremely expensive or critical (no one wants their army tank to break down during battle)! Or the grain elevator operation does not want the bucket elevator to break down during a key harvest period. In any case, the ASM needs to be a true thinker!

This type of evaluation and trade-off consideration should be ongoing. Arguably, reliability planning could be the most important agricultural systems decision—but the one most often neglected.

Simulation of Crop Growth and Field Operations

Definition: Crop growth simulation models are mathematical representations of the complex interactions between plants, the environment, and management practices. They simulate the growth and development of crops under various conditions, providing insights into potential yields, resource requirements, and the impact of different management strategies.

Key Components:

- **Plant Growth Models:** These models describe the physiological processes of plants, such as photosynthesis, respiration, and nutrient uptake. They incorporate factors like leaf area development, light interception, and dry matter accumulation.
    - **Example:** The CERES-Wheat model simulates the growth of wheat by considering factors like temperature, water availability, and nitrogen uptake.
- **Environmental Models:** These models simulate factors like temperature, precipitation, sunlight, and soil conditions that affect crop growth. They can be based on historical data, weather forecasts, or climate change projections.
    - **Example:** The EPIC (Environmental Policy Integrated Climate) model simulates the impact of climate change on crop yields in different regions.
- **Management Practices:** These models incorporate the effects of various agricultural practices, such as irrigation, fertilization, and pest control. They can be used to evaluate the impact of different management strategies on crop performance.
    - **Example:** The APSIM (Agricultural Production Systems Simulator) model can simulate the effects of different irrigation regimes on crop yields and water use efficiency.

Benefits:

- **Predicting Yields:** Simulate crop growth under different scenarios to estimate potential yields and identify the optimal management practices to maximize production.

- **Optimizing Resource Use:** Identify the optimal allocation of resources (water, fertilizer, pesticides) to maximize yields while minimizing costs and environmental impact.

- **Evaluating Management Strategies:** Assess the impact of different management practices on crop performance and sustainability. For example, simulate the effects of different tillage practices on soil erosion and crop yields.
- **Risk Assessment:** Evaluate the risks associated with climate variability and other uncertainties. For example, simulate the impact of drought or extreme weather events on crop production.

Example: A farmer is considering using a new irrigation system to improve crop yields. By using a crop growth simulation model, the farmer can simulate the impact of different irrigation regimes on crop growth and water use efficiency, helping them make an informed decision about whether to invest in the new system.

Growing degree-days (GDDs) are a measure of heat accumulation used to predict plant and pest development rates. They are calculated by adding up the daily average temperature (above a certain base temperature) over a period of time. GDDs can be used to estimate the date that a crop will reach maturity, when a pest will emerge from dormancy, or when a flower will bloom.

Here's a breakdown of the concept:

- **Base temperature:** This is the minimum temperature at which a plant or pest can begin to grow or develop. It varies among different species and can be affected by factors such as genetics and environmental conditions.
- **Daily average temperature:** This is the average of the maximum and minimum temperatures for a given day.
- **GDD calculation:** GDDs are calculated by subtracting the base temperature from the daily average temperature and adding up the values for each day. If the daily average temperature is below the base temperature, the GDD value is zero.

Here's an example of how to calculate GDDs:

- Base temperature for corn: 50°F
- Daily maximum temperature: 85°F
- Daily minimum temperature: 60°F
- Daily average temperature: (85°F + 60°F) / 2 = 72.5°F
- GDDs for that day: 72.5°F - 50°F = 22.5 GDDs

How GDDs are used:

- **Predicting crop maturity:** By tracking the accumulation of GDDs over the growing season, farmers can estimate when their crops will reach maturity and be ready for harvest.

- **Timing pest control:** GDDs can be used to predict the emergence of pests and time pesticide applications accordingly.
- **Selecting varieties:** GDDs can help farmers select varieties of crops that are well-suited to their local climate and growing season.
- **Monitoring plant health:** GDDs can be used to monitor the progress of plant growth and identify potential problems.

Limitations:

- GDDs are a simplified model of plant growth and do not account for all factors that can affect plant development.
- GDDs may not be accurate for plants that are stressed by environmental conditions or other factors.
- GDDs may vary depending on the specific location and microclimate.

Overall, GDDs are a valuable tool for farmers and agricultural researchers. By understanding how to calculate and use GDDs, farmers can make more informed decisions about crop management and improve their yields.

$$\text{GDDs per day} = (T_{\text{max}} + T_{\text{min}})/2 - 50$$

Optimizing the Use of Resources

Definition: Resource optimization involves allocating available resources (e.g., land, water, labor, capital) in the most efficient way to achieve desired objectives, such as maximizing profit or minimizing costs.

Key Techniques:

- **Linear Programming:** A mathematical optimization technique used to allocate limited resources to maximize or minimize a linear objective function subject to linear constraints. It is suitable for problems with a single objective and linear relationships between variables.
  - **Example:** A farmer wants to maximize profit by planting two crops, corn and soybeans. The farmer has 100 acres of land available and a limited budget for fertilizer. The profit per acre for corn is $100, and for soybeans is $80. The fertilizer requirements for corn are 2 units per acre, and for soybeans are 1 unit per acre. The total available fertilizer is 150 units. The farmer can use linear programming to determine the optimal allocation of land between corn and soybeans to maximize profit.
- **Nonlinear Programming:** A more general optimization technique that can handle nonlinear relationships between variables. It is suitable for problems with multiple objectives or nonlinear constraints.
  - **Example:** A farmer wants to minimize the cost of irrigation while maintaining

a certain level of crop yield. The cost of irrigation may be a nonlinear function of the amount of water applied, and the crop yield may also be a nonlinear function of water availability. Nonlinear programming can be used to find the optimal irrigation schedule.

- **Dynamic Programming:** A technique for solving optimization problems that involve sequential decisions. It is suitable for problems where decisions made at one time period affect the outcomes of decisions made in subsequent periods.
  - **Example:** A farmer wants to determine the optimal timing of fertilizer applications throughout the growing season to maximize crop yield. Dynamic programming can be used to consider the impact of fertilizer applications at different stages of crop growth.

Applications:

- **Crop Allocation:** Determining the optimal mix of crops to grow on a given piece of land, considering factors such as soil type, climate, market demand, and profitability.
- **Irrigation Scheduling:** Optimizing irrigation water use to maximize crop yields while minimizing water wastage and environmental impact.
- **Fertilizer Management:** Determining the optimal amount and timing of fertilizer application to maximize crop yields and minimize nutrient losses.
- **Machinery Allocation:** Assigning machinery to tasks in a way that maximizes efficiency and minimizes costs.
- **Farm Management:** Optimizing the overall management of a farm to maximize profitability and sustainability.

Linear Programming

Definition: Linear programming is a mathematical optimization technique used to find the optimal solution to a problem with a linear objective function and linear constraints.

Basic Components:

- **Objective Function:** The function to be maximized or minimized.
- **Decision Variables:** The variables that can be adjusted to optimize the objective function.
- **Constraints:** The limitations or restrictions on the decision variables.

Example:

- **Problem:** A farmer wants to maximize profit by planting two crops, corn and soybeans. The farmer has 100 acres of land available and a limited budget for fertilizer. The profit per acre for corn is $100, and for soybeans is $80. The fertilizer requirements for corn are 2 units per acre, and for soybeans are 1 unit per acre. The total available fertilizer is 150 units.

- **Linear Program:**
    - Maximize Profit = 100Corn + 80Soybeans
    - Subject to:
        - Corn + Soybeans <= 100 (land constraint)
        - 2*Corn + Soybeans <= 150 (fertilizer constraint)
        - Corn, Soybeans >= 0 (non-negativity constraint)

Solution:

The optimal solution is to plant 50 acres of corn and 50 acres of soybeans, which will result in a maximum profit of $9000.

Project Scheduling

Definition: Project scheduling involves planning, organizing, and coordinating tasks to ensure that a project is completed on time and within budget.

Key Techniques:

- **Gantt Charts:** Visual representations of project timelines, showing the duration of each task and their dependencies. They are useful for tracking project progress and identifying potential bottlenecks.
    - **Example:** A Gantt chart for a construction project would show the duration of each phase of the project, such as site preparation, foundation work, framing, and finishing.
- **Network Diagrams:** Graphical representations of project activities and their relationships, often using the Critical Path Method (CPM) to identify the critical path (the sequence of tasks that determine the project's overall duration).
    - **Example:** A network diagram for a crop production project would show the sequence of tasks, such as planting, irrigation, fertilization, and harvesting. The critical path would be the longest sequence of tasks that must be completed before the project can be finished.
- **PERT (Program Evaluation and Review Technique):** A probabilistic network analysis technique that considers the uncertainty in task durations. It is useful for projects with uncertain task times.
    - **Example:** A PERT chart for a research project would show the estimated duration of each task, along with the optimistic, most likely, and pessimistic estimates.

Applications:

- **Construction Projects:** Planning and managing the construction of buildings, infrastructure, or other projects.
- **Agricultural Operations:** Scheduling planting, harvesting, and other agricultural activities.

- **Research Projects:** Organizing and coordinating research tasks to ensure timely completion.

Artificial Intelligence and Decision Support Systems

Definition: Artificial intelligence (AI) refers to the development of intelligent agents that can reason, learn, and solve problems. Decision support systems (DSS) are computer-based systems that help decision-makers analyze data and make informed decisions.

Applications in Agriculture:

- **Crop Yield Prediction:** Using AI algorithms to predict crop yields based on historical data, weather forecasts, and other factors. This can help farmers make better decisions about planting, harvesting, and marketing.
- **Pest and Disease Management:** Employing AI to detect and identify pests and diseases early, enabling timely intervention to prevent crop damage.
- **Precision Agriculture:** Using AI-powered technologies (e.g., drones, sensors) to collect data on crop health, soil conditions, and other factors to optimize resource management. This can help farmers use resources more efficiently and reduce their environmental impact.
- **Decision Support Systems:** Developing DSS to help farmers make informed decisions about planting, harvesting, marketing, and other agricultural activities. DSS can provide farmers with access to relevant data, analytics tools, and expert advice.

Key AI Techniques:

- **Machine Learning:** Algorithms that allow computers to learn from data and improve their performance over time. For example, machine learning can be used to develop models that predict crop yields based on historical data.
- **Natural Language Processing:** Enabling computers to understand and respond to human language. This can be used to develop chatbots that can answer farmers' questions about agricultural practices.
- **Computer Vision:** Algorithms that allow computers to interpret and understand visual information. This can be used to develop systems that can automatically identify weeds or detect plant diseases from images.

Example: A farmer can use a DSS to analyze weather data, soil information, and crop prices to determine the optimal planting date for a particular crop. The DSS can also provide recommendations for fertilizer application, irrigation scheduling, and pest control.

Artificial Intelligence:

Benefits of AI in agriculture

Until recently, using the words AI and agriculture in the same sentence may have seemed like a strange combination. After all, agriculture has been the backbone of human civilization for millennia, providing sustenance as well as contributing to economic development, while even the most primitive AI only emerged several decades ago. Nevertheless, innovative ideas are being introduced in every industry, and agriculture is no exception. In recent years, the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming.

Data-based decisions

The modern world is all about data. Organizations in the agricultural sector use data to obtain meticulous insights into every detail of the farming process, from understanding each acre of a field to monitoring the entire produce supply chain to gaining deep inputs on yields generation process. AI-powered predictive analytics is already paving the way into agribusinesses. Farmers can gather, then process more data in less time with AI. Additionally, AI can analyze market demand, forecast prices as well as determine optimal times for sowing and harvesting.

Artificial intelligence in agriculture can help explore the soil health to collect insights, monitor weather conditions, and recommend the application of fertilizer and pesticides. Farm management software boosts production together with profitability, enabling farmers to make better decisions at every stage of the crop cultivation process.

Cost savings

Improving farm yields is a constant goal for farmers. Combined with AI, precision agriculture can help farmers grow more crops with fewer resources. AI in farming combines the best soil management practices, variable rate technology, and the most effective data management practices to maximize yields while minimizing minimize spending.

Application of AI in agriculture provides farmers with real-time crop insights, helping them to identify which areas need irrigation, fertilization, or pesticide treatment. Innovative farming practices such as vertical agriculture can also increase food production while minimizing resource usage. Resulting in reduced use of herbicides, better harvest quality, higher profits alongside significant cost savings.

Automation impact

Agricultural work is hard, so labor shortages are nothing new. Thankfully, automation provides a solution without the need to hire more people. While mechanization transformed agricultural activities that demanded super-human sweat and draft animal labor into jobs that took just a few hours, a new wave of digital automation is once more revolutionizing the sector.

Automated farm machinery like driverless tractors, smart irrigation, fertilization systems, IoT-powered agricultural drones, smart spraying, vertical farming software, and AI-based greenhouse robots for harvesting are just some examples. Compared with any human farm worker, AI-driven tools are far more efficient and accurate.

Applications of artificial intelligence in agriculture

Traditional farming involves various manual processes. Implementing AI models can have many advantages in this respect. By complementing already adopted technologies, an intelligent agriculture system can facilitate many tasks. AI can collect and process big data, while determining and initiating the best course of action. Here are some common use cases for AI in agriculture:

Optimizing automated irrigation systems

AI algorithms enable autonomous crop management. When combined with IoT (Internet of Things) sensors that monitor soil moisture levels and weather conditions, algorithms can decide in real-time how much water to provide to crops. An autonomous crop irrigation system is designed to conserve water while promoting sustainable agriculture and farming practices. AI in smart greenhouses optimizes plant growth by automatically adjusting temperature, humidity, and light levels based on real-time data.

Detecting leaks or damage to irrigation systems

AI plays a crucial role in detecting leaks in irrigation systems. By analyzing data, algorithms can identify patterns and anomalies that indicate potential leaks. Machine learning (ML) models can be trained to recognize specific signatures of leaks, such as changes in water flow or pressure. Real-time monitoring and analysis enable early detection, preventing water waste together with potential crop damage.

AI also incorporates weather data alongside crop water requirements to identify areas with excessive water usage. By automating leak detection and providing alerts, AI technology enhances water efficiency helping farmers conserve resources.

Crop and soil monitoring

The wrong combination of nutrients in soil can seriously affect the health and growth of crops. Identifying these nutrients and determining their effects on crop yield with AI allows farmers to easily make the necessary adjustments.

While human observation is limited in its accuracy, computer vision models can monitor soil conditions to gather accurate data necessary for combatting crop diseases. This plant science data is then used to determine crop health, predict yields while flagging any particular issues. Plants start AI systems through sensors that detect their growth conditions, triggering automated adjustments to the environment.

In practice, AI in agriculture and farming has been able to accurately track the stages of wheat growth and the ripeness of tomatoes with a degree of speed and accuracy no human can match.

Detecting disease and pests

As well as detecting soil quality and crop growth, computer vision can detect the presence of pests or diseases. This works by using AI in agriculture projects to scan images to find mold, rot, insects, or other threats to crop health. In conjunction with alert systems, this helps farmers to act quickly in order to exterminate pests or isolate crops to prevent the spread of disease.

AI technology in agriculture has been used to detect apple black rot with an accuracy of over 90%. It can also identify insects like flies, bees, moths, etc., with the same degree of accuracy. However, researchers first needed to collect images of these insects to have the necessary size of the training data set to train the algorithm with.

Monitoring livestock health

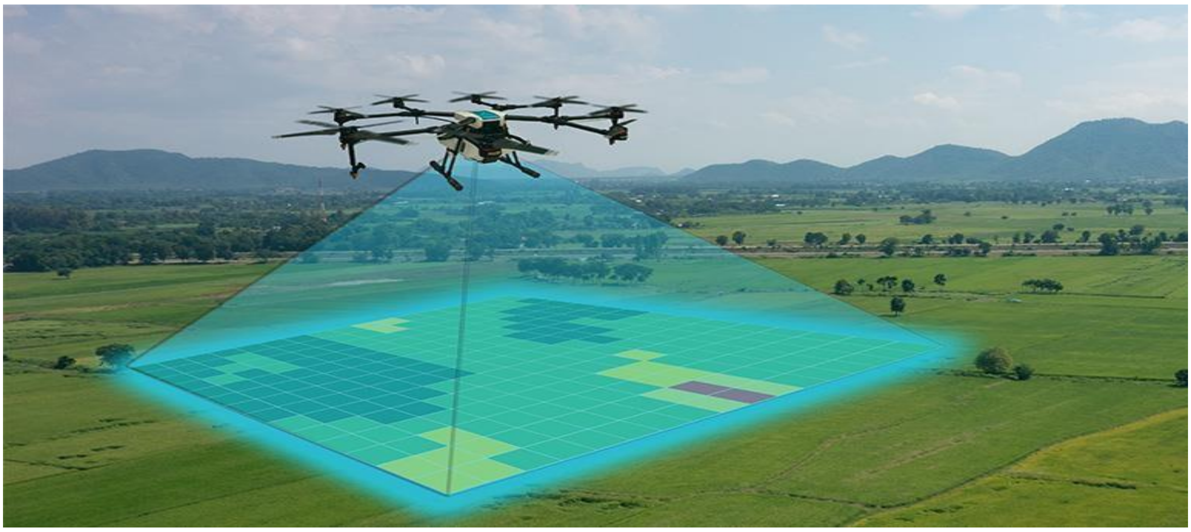
It may seem easier to detect health problems in livestock than in crops, in fact, it’s particularly challenging. Thankfully, AI for farming can help with this. For example, a company called CattleEye has developed a solution that uses drones, cameras together with computer vision to monitor cattle health remotely. It detects atypical cattle behavior and identifies activities such as birthing.

CattleEye uses AI and ML solutions to determine the impact of diet alongside environmental conditions on livestock and provide valuable insights. This knowledge can help farmers improve the well-being of cattle to increase milk production.

Intelligent pesticide application

By now, farmers are well aware that the application of pesticides is ripe for optimization. Unfortunately, both manual and automated application processes have notable limitations. Applying pesticides manually offers increased precision in targeting specific areas, though it might be slow and difficult work. Automated pesticide spraying is quicker and less labor-intensive, but often lacks accuracy leading to environment contamination.

AI-powered drones provide the best advantages of each approach while avoiding their drawbacks. Drones use computer vision to determine the amount of pesticide to be sprayed on each area. While still in infancy, this technology is rapidly becoming more precise.



Yield mapping and predictive analytics

Yield mapping uses ML algorithms to analyze large datasets in real time. This helps farmers understand the patterns and characteristics of their crops, allowing for better planning. By combining techniques like 3D mapping, data from sensors and drones, farmers can predict soil yields for specific crops. Data is collected on multiple drone flights, enabling increasingly precise analysis with the use of algorithms.

These methods permit the accurate prediction of future yields for specific crops, helping farmers know where and when to sow seeds as well as how to allocate resources for the best return on investment.

Automatic weeding and harvesting

Similar to how computer vision can detect pests and diseases, it can also be used to detect weeds and invasive plant species. When combined with machine learning, computer vision analyzes the size, shape, and color of leaves to distinguish weeds from crops. Such solutions can be used to program robots that carry out robotic process automation (RPA) tasks, such as automatic weeding. In fact, such a robot has already been used effectively. As these technologies become more accessible, both weeding and harvesting crops could be carried out entirely by smart bots.

Sorting harvested produce

AI is not only useful for identifying potential issues with crops while they're growing. It also has a role to play after produce has been harvested. Most sorting processes are traditionally carried out manually however AI can sort produce more accurately.

Computer vision can detect pests as well as disease in harvested crops. What's more, it can grade produce based on its shape, size, and color. This enables farmers to quickly separate produce into categories — for example, to sell to different customers at different prices. In comparison, traditional manual sorting methods can be painstakingly labor-intensive.

Surveillance

Security is an important part of farm management. Farms are common targets for burglars, as it's hard for farmers to monitor their fields around the clock. Animals are another threat — whether it's foxes breaking into the chicken coop or a farmer's own livestock damaging crops or equipment. When combined with video surveillance systems, computer vision and ML can quickly identify security breaches. Some systems are even advanced enough to distinguish employees from unauthorized visitors.

AI and its Application

The concept of expert systems, artificial intelligence, ''fuzzy logic,'' and knowledge-based decision support systems (information systems) was accepted rapidly in business and industry. Production control systems in factories have included these concepts so that operating problems, such as bad welds, can be either prevented or fixed much more quickly than under simpler control systems.

Robotics

Robotics has been considered a part of the overall field of artificial intelligence by many authors. A robot is not just an automatic welding machine on a car body production line, but a machine that can be programmed to do a variety of tasks and that can interact with its environment. A robot may need to make a decision about whether an object that it must select is a nut or a bolt, a green tomato or a ripe, red tomato. Thus robots need to ''see,'' recognize objects, and make decisions, so they need intelligence 'artifi cial'' intelligence.

Natural Language

For easier and greater application of the computer in our working world, we need better and more natural ways for hu- mans to communicate with the computer. The computer needs to be shown more about how we communicate so that we can spend less time learning how the computer communicates. This is a difficult field, but progress is being made. The programs that can process natural language sentences must determine which words are the noun, the verb, and the object, In addition, voice recognition by the computer is a part of this, because we often do not want to or are unable to type our input, but should speak to the computer. The development of programs that understand human natural language is a vital part of the whole artificial intelligence investigation, because this requires intelligence. We are going no further into this area.

Fuzzy Logic

To simulate human intelligence, artificial intelligence must be able to handle more than just numbers, yet the heart of any computer is just a very fast processor of data in binary form, zeros and ones. Our programming languages, such as FORTRAN, C++, and Java, have allowed us to program computers with English words and mathematical symbols, yet most programs are very precise and objective in their results. They usually produce a table of numbers, and they can rank these results numerically, evenwith huge numbers of possibilities.

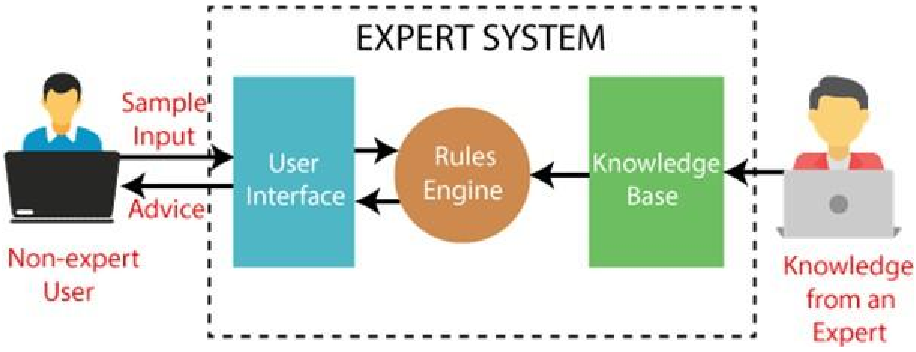
But humans often must make decisions in which the input data and the resulting output are not in neat mathematical or completely logical form. For example, a computer using a linear programming algorithm can select the one best combination of several ingredients that will result in the lowest-cost feed mixture that meets the specifications in terms of protein, fat, fiber, and total digestible nutrients from among an almost infinite number of possible combinations. However, until artificial intelligence, the computer could not solve less precise problems, such as determining the most profitable combination of crops to plant for the coming year, with prices and costs being uncertain. And managers often want a recommendation in terms somewhat like a weather forecast, such as, ''If you do not spray, chances are about

1 in 5 that the disease will cause more damage than the spraying cost.''

Expert Systems

An expert system simulates a human expert in a narrow subject matter domain. For example, to develop an expert system program to give soybean growers advice about insect problems like a consulting entomologist might give, the program needs to do the following:

1. Ask the grower some general questions to find out what the problem is.
2. Find out the farm's location, variety of soybeans, stage of growth, identification, or description of the bugs.
3. Finally, give the best estimate the system can on the type of insect, whether or not treatment is needed at this time, and when and what type of insecticide is recommended if treatment is needed.



Programs such as these probably will not replace the consultant, but they will be used by the consultant to give better advice and probably to produce good printed reports for the client. Many agricultural expert systems are diagnostic in nature, such as the example just given. In addition, expert systems may be (and a few have been) developed for making technical management decisions, such as purchase of new equipment, deciding on a crop rotation, making a marketing plan for grain, or culling livestock from a breeding herd.

Knowledge-Based Decision Support Systems

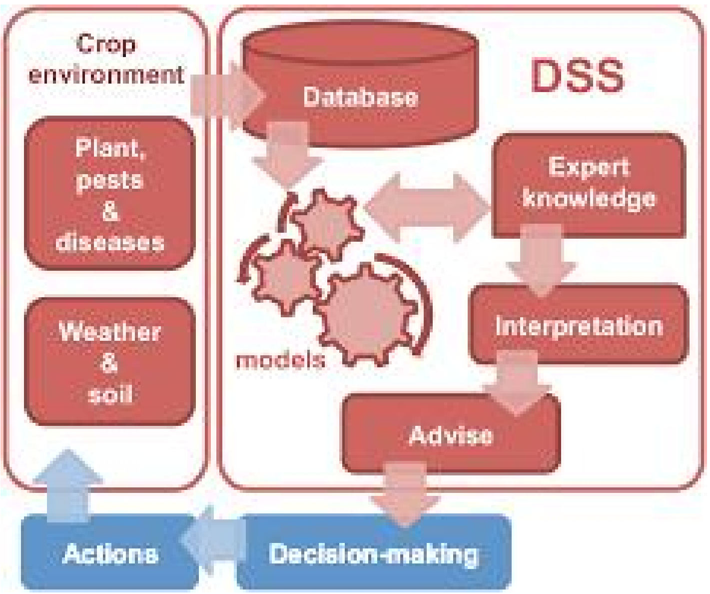
The term knowledge-based decision support systems (or decision support systems) includes expert systems but covers a broader range of program types .Often it would be advantageous. for an expert system to have available the latest data from the commodity futures market or cash markets or to be able to run a simulation program with current weather data to get crop yield estimates in order to give the user the best up-to- date expert advice. When an expert system uses a database, a spreadsheet, or some other external program, such as a simulation program, the whole integrated system is referred to as a decision support system. An expert system is also a knowledge- based decision system or decision support system, because it contains the knowledge of the expert and it helps, or supports, the user in making a decision.

The word support emphasizes the important idea that the computer is not controlling the decision. It is not the decision maker. It helps (supports) the human decision maker by keeping track of many factors, whereas the decision maker is also likely taking into account other factors, especially more subjective ones. A citrus production manager in Florida makes a very sound point about the use of computers in management: ''Use the computer for what it can do best, calculating and remembering lots of data, and use the human for what the person can do best, integrating the output of the decision sup- port system and other factors, including the human's experience, and come to a decision based on all these things.''

More recently, a broader common term has come to include decision support systems: information systems; the field has become known as information technology (IT).

Models of Decision Support system

Eg: Decision support system for crop disease.



Decision Support System Applications

Potential applications are innumerable, but many of them will fit under one of the following types.

- Diagnostics
- Marketing
- Systems operations management
- Automatic control
- Strategic planning

Static and Dynamic Decision Support Systems

Especially for agricultural systems, the idea of dynamic vs. static decision support systems is important for the development and operation of these systems. Static systems are those that are used, usually, at a single point in time; and each use is a new one, keeping no information from the last time it was used or ‘‘run.’’ A diagnostic system telling the user with a poor- looking crop what the problem is—disease, some nutrient lacking, drought, etc.—is a typical static system. An early ex- ample of such a system was used to identify soybean insect problems and recommend treatment.

However, many agricultural problems may be used throughout a growing season. Once the user enters data about the crop to assess the threat of an early-season disease, for example, the user may want to do it a week later to check on the same disease or on a question such as irrigation needs. These subsequent uses can take advantage of the earlier data entered to give decision support based on the history of the crop up to that point. These programs are called dynamic decision sup- port systems, and they must keep earlier data from one use to the next.

UNIT IV WEATHER PREDICTION MODELS

Importance of climate variability and seasonal forecasting, Understanding and predicting world's climate system, Global climatic models and their potential for seasonal climate forecasting, General systems approach to applying seasonal climate forecasts.

Importance of Climate Variability and Seasonal Forecasting

Climate variability and seasonal forecasting play crucial roles in understanding and managing environmental, economic, and social systems. Here's a detailed exploration of their significance:

1. Understanding Climate Variability

Definition: Climate variability refers to variations in climate parameters (temperature, precipitation, etc.) over different timescales, influenced by both natural and human factors.

Types of Climate Variability:

- **Natural Variability**: Includes phenomena such as:
  - **El Niño and La Niña**: These ocean-atmosphere interactions significantly affect global weather patterns, leading to changes in rainfall and temperature across many regions.
  - **Volcanic Eruptions**: Eruptions can inject aerosols into the atmosphere, temporarily cooling the climate.
  - **Solar Cycles**: Variations in solar energy influence climate over long periods.
- **Anthropogenic Variability**: Human activities, such as burning fossil fuels and deforestation, contribute to climate variability by altering greenhouse gas concentrations and land use patterns.

Importance:

- **Understanding Trends**: Recognizing patterns in climate variability helps scientists understand long-term climate change and its potential impacts.
- **Impact on Ecosystems**: Variability can affect biodiversity, ecosystems, and species distributions, highlighting the need for conservation strategies.

2. Significance of Seasonal Forecasting

Definition: Seasonal forecasting predicts climate conditions (such as temperature and precipitation) over the upcoming months, typically ranging from one month to a year.

Importance:

- **Agriculture**:
  - **Crop Management**: Farmers can make informed decisions about planting and harvesting based on expected rainfall and temperature. For example, knowing an impending dry season can prompt early planting or alternative crop choices.
  - **Risk Mitigation**: Forecasts can help mitigate risks related to extreme weather events, allowing farmers to implement protective measures, such as irrigation or crop insurance.

- **Water Resource Management**:
  - **Supply Planning**: Seasonal forecasts inform water resource managers about expected water availability, helping in reservoir management and allocation for agricultural and urban needs.
  - **Drought and Flood Preparedness**: Understanding potential seasonal droughts or floods allows for better planning and infrastructure development to manage these risks.
- **Disaster Preparedness**:
  - **Early Warning Systems**: Timely forecasts help governments and agencies prepare for extreme weather events (e.g., hurricanes, floods), improving response strategies and potentially saving lives.
  - **Infrastructure Resilience**: Knowledge of seasonal weather patterns aids in designing resilient infrastructure, such as roads and drainage systems.
- **Public Health**:
  - **Disease Management**: Seasonal patterns can influence the spread of diseases (e.g., malaria, dengue fever). Forecasting helps health organizations anticipate outbreaks and deploy resources effectively.
  - **Heatwaves and Cold Spells**: Predictions can guide public health responses to extreme temperature events, ensuring vulnerable populations receive support.
- **Energy Sector**:
  - **Demand Forecasting**: Understanding seasonal temperature fluctuations helps energy providers anticipate demand for heating or cooling, aiding in efficient energy distribution.
  - **Renewable Energy Management**: Seasonal forecasts inform the production potential of renewable energy sources, such as hydroelectric and solar power, based on expected precipitation and sunlight.

3. Economic Implications

- **Insurance and Risk Management**: Accurate seasonal forecasts can help insurance companies assess risks more effectively, leading to better pricing of agricultural and disaster-related insurance products.
- **Investment Planning**: Businesses can use climate forecasts to make informed investment decisions, especially in sectors like agriculture, construction, and energy.

4. Policy Development

- **Adaptation Strategies**: Policymakers can create and implement strategies that enhance resilience to climate variability based on reliable seasonal forecasts.
- **Sustainable Practices**: Integrating seasonal forecasting into land use planning encourages sustainable agricultural and environmental practices, contributing to long-term ecological health.

Understanding and Predicting the World's Climate System

Understanding and predicting the world's climate system involves analyzing the complex interactions between various components of the Earth's environment, including the atmosphere, oceans, land surfaces, and biological systems. Here's a detailed exploration of this topic:

1. Components of the Climate System

The climate system is made up of several interconnected components, each playing a critical role in determining the overall climate:

- **Atmosphere**:
  - Composed of layers of gases surrounding the Earth, the atmosphere regulates temperature and weather patterns.
  - Contains greenhouse gases (like carbon dioxide and methane) that trap heat, influencing global temperatures.
- **Hydrosphere**:
  - Encompasses all water bodies, including oceans, rivers, lakes, and ice.
  - The oceans play a key role in climate regulation through heat storage and distribution, as well as influencing weather patterns through currents and evaporation.
- **Cryosphere**:
  - Includes all frozen water on the planet, such as glaciers, ice caps, and sea ice.
  - Changes in the cryosphere significantly affect sea levels and regional climates, and melting ice contributes to feedback mechanisms that can amplify warming.
- **Land Surface**:
  - Comprises soil, vegetation, and urban areas, influencing heat and moisture exchange with the atmosphere.
  - Land cover changes (e.g., deforestation, urbanization) can alter local climates and contribute to global climate change.
- **Biosphere**:
  - The ecological component that includes all living organisms.
  - Plants and animals interact with the climate system, affecting processes such as photosynthesis, respiration, and decomposition, which in turn influence atmospheric composition.

2. Climate Dynamics and Feedback Mechanisms

- **Energy Balance**:
  - The Earth's climate system operates on an energy balance, where incoming solar energy is balanced by outgoing heat energy.
  - Changes in this balance, due to factors like greenhouse gas emissions or changes in land use, can lead to warming or cooling.
- **Feedback Mechanisms**:
  - **Positive Feedback**: Amplifies changes (e.g., melting ice reduces albedo, leading to further warming).
  - **Negative Feedback**: Dampens changes (e.g., increased cloud cover can reflect sunlight and cool the surface).

3. Climate Variability and Change

- **Natural Variability**:
  - Influenced by factors such as volcanic eruptions, solar cycles, and oceanic phenomena (e.g., El Niño and La Niña).
  - These events can lead to short-term fluctuations in climate patterns.
- **Anthropogenic Climate Change**:
  - Driven by human activities, particularly the burning of fossil fuels, deforestation, and industrial processes, leading to increased greenhouse gas concentrations.

    - This change results in long-term warming trends, altered precipitation patterns, and more extreme weather events.

4. Climate Prediction Models

To understand and predict the climate system, scientists employ a variety of models that simulate its components and interactions:

- **Global Climate Models (GCMs)**:
    - Comprehensive models that use mathematical equations to represent physical processes in the climate system, incorporating interactions between the atmosphere, oceans, land, and ice.
    - GCMs are essential for projecting future climate scenarios and understanding potential impacts of different greenhouse gas emission trajectories.
- **Regional Climate Models (RCMs)**:
    - Focus on specific regions, providing higher resolution forecasts that are useful for localized climate impacts (e.g., regional precipitation patterns).
    - RCMs often use outputs from GCMs as input data.
- **Statistical Models**:
    - Use historical data to identify patterns and correlations, allowing for predictions based on observed relationships.
    - These models are often simpler and can provide insights into expected climate variations based on past trends.

5. Applications of Climate Understanding and Prediction

- **Adaptation and Mitigation Strategies**:
    - Understanding climate dynamics allows governments, businesses, and communities to develop strategies to adapt to changes and mitigate impacts.
    - This includes developing resilient infrastructure, adjusting agricultural practices, and implementing conservation efforts.
- **Disaster Preparedness**:
    - Accurate climate predictions enable effective disaster planning and response strategies, reducing risks from extreme weather events and climate-related hazards.
- **Policy Development**:
    - Policymakers rely on climate models to inform decisions regarding emissions reductions, land use planning, and resource management, ensuring sustainable development.

6. Challenges in Climate Prediction

- **Complexity of Climate Systems**: The interactions between various components of the climate system are intricate and not fully understood, making predictions challenging.
- **Data Limitations**: Historical climate data can be sparse or of varying quality, particularly in remote regions, affecting model accuracy.
- **Uncertainty in Projections**: Variability in climate models and potential future human activities introduce uncertainties into predictions.

Global Climatic Models and Their Potential for Seasonal Climate Forecasting

Global Climatic Models (GCMs) are powerful tools used to simulate and understand the Earth's climate system. They play a crucial role in seasonal climate forecasting, enabling scientists to predict climate variations over periods ranging from a month to a year. Here's a detailed explanation of GCMs and their applications in seasonal forecasting.

1. What Are Global Climatic Models (GCMs)?

Definition: GCMs are complex, computer-based simulations that represent the physical processes governing the climate system. They incorporate interactions between the atmosphere, oceans, land surface, and ice.

Components of GCMs:

- **Atmospheric Models**: Simulate atmospheric processes, including temperature, pressure, humidity, and wind patterns.
- **Ocean Models**: Represent ocean currents, temperature profiles, and interactions with the atmosphere.
- **Land Surface Models**: Capture the effects of vegetation, soil moisture, and land use on climate.
- **Cryospheric Models**: Account for ice and snow cover, including their dynamics and feedback mechanisms.

Grid System: GCMs divide the Earth into a grid, where each grid cell represents a specific geographic area. The size of these cells determines the model's resolution, affecting the detail of simulations. Higher resolution models provide more precise local forecasts but require significantly more computational power.

2. How GCMs Work

Mathematical Equations: GCMs use a set of mathematical equations based on physical laws (e.g., fluid dynamics, thermodynamics) to simulate interactions among climate components. These equations describe how energy is exchanged, moisture is transported, and temperature varies over time.

Time Steps: GCMs operate over discrete time steps (e.g., hours or days), advancing the simulation iteratively. This allows for dynamic modeling of weather and climate processes.

Data Input: GCMs require vast amounts of input data, including:

- Historical climate data (temperature, precipitation, etc.)
- Greenhouse gas concentrations
- Land use patterns
- Solar radiation and volcanic activity data

Calibration and Validation: Models are calibrated using historical data to ensure accuracy. They are also validated by comparing their outputs with observed climate data to assess performance.

3. Seasonal Climate Forecasting with GCMs

Definition of Seasonal Forecasting: Seasonal forecasting involves predicting climate conditions over a period of one month to a year. It is particularly valuable for agriculture, water resource management, and disaster preparedness.

Potential of GCMs for Seasonal Forecasting:

1. **Dynamic Predictions**: GCMs can simulate the complex interactions in the climate system, allowing for more accurate forecasts of seasonal climate patterns (e.g., temperature and precipitation).
2. **El Niño and La Niña Events**: GCMs are instrumental in predicting these significant climate phenomena that affect global weather patterns. Accurate forecasts of these events can lead to better preparedness for their impacts.
3. **Regional Insights**: While GCMs provide global forecasts, they can be downscaled to provide regional predictions. This helps in understanding local climate impacts, which are crucial for effective planning.
4. **Multi-Model Ensembles**: Combining outputs from multiple GCMs (ensemble forecasting) can enhance prediction accuracy by averaging out individual model biases and uncertainties.
5. **Climate Change Scenarios**: GCMs can simulate future climate scenarios based on different greenhouse gas emission pathways, helping to understand potential seasonal shifts under climate change.

4. Applications of Seasonal Climate Forecasting

- **Agriculture**: Farmers can optimize planting and harvesting schedules based on seasonal forecasts, improving crop yields and reducing losses from adverse weather conditions.
- **Water Resource Management**: Forecasts inform water allocation decisions, especially in regions prone to droughts or floods, ensuring sustainable water use.
- **Disaster Preparedness**: Timely seasonal forecasts help governments and organizations prepare for extreme weather events, enhancing response strategies and reducing risks.
- **Public Health**: Understanding seasonal climate variations can aid in anticipating disease outbreaks linked to climate conditions, such as vector-borne diseases.

5. Challenges and Limitations

- **Uncertainty**: GCMs inherently involve uncertainties related to model structure, parameterization, and input data. This uncertainty can affect the reliability of seasonal forecasts.
- **Resolution Limitations**: While GCMs provide valuable insights, their coarse resolution may not capture local climatic features, necessitating downscaling techniques.
- **Complexity of Climate Systems**: The interactions within the climate system are complex, and models may not fully account for all feedback mechanisms, leading to potential inaccuracies.
- **Computational Requirements**: High-resolution GCMs require substantial computational resources, which can limit their accessibility and usability for some institutions.

6. Future Directions

- **Advancements in Technology**: Improvements in computational power and data collection (e.g., satellite observations) are enhancing the capabilities of GCMs and seasonal forecasting.
- **Integrating AI and Machine Learning**: These technologies can improve model predictions by identifying patterns in large datasets and optimizing model parameters.

- **Stakeholder Engagement**: Collaborating with farmers, policymakers, and communities ensures that seasonal forecasts are relevant and actionable, enhancing the societal benefits of climate predictions.

General Systems Approach to Applying Seasonal Climate Forecasts

A General Systems Approach (GSA) to applying seasonal climate forecasts involves integrating diverse components of a system to understand and address complex interactions between climate, environmental, social, and economic factors. This holistic perspective helps stakeholders effectively utilize climate forecasts to make informed decisions and enhance resilience to climate variability. Here's a detailed exploration of this approach:

1. Understanding the General Systems Approach

Definition: The General Systems Approach is a framework that emphasizes the interconnectedness of various elements within a system. It considers how components interact and influence each other, recognizing that changes in one part of the system can have cascading effects.

Key Principles:

- **Holistic Perspective**: Viewing the system as a whole rather than focusing solely on individual components.
- **Interdependencies**: Acknowledging that components (e.g., climate, agriculture, water resources) are interdependent and influence one another.
- **Feedback Loops**: Understanding how outputs from one part of the system can serve as inputs for another, creating feedback mechanisms that can amplify or dampen changes.

2. Applying Seasonal Climate Forecasts within a General Systems Framework

Integrating Climate Data:

- **Seasonal Climate Forecasts** provide critical information on expected weather patterns (e.g., temperature, precipitation) over the coming months.
- These forecasts should be integrated with local knowledge and historical data to enhance their relevance and accuracy.

Stakeholder Engagement:

- Involve various stakeholders (farmers, water resource managers, urban planners, public health officials) to understand their needs and how climate forecasts can be utilized in their decision-making processes.
- Engagement fosters collaboration and builds trust among stakeholders, ensuring forecasts are applied effectively.

3. Components of the Systems Approach

1. **Climate Data and Modeling**:
   - Utilize Global Climate Models (GCMs) and regional climate models to generate seasonal forecasts.
   - Analyze uncertainties and limitations of the models, incorporating multi-model ensembles for improved reliability.
2. **Socioeconomic Factors**:
   - Assess how socioeconomic conditions (e.g., income levels, agricultural practices, infrastructure) influence vulnerability and adaptive capacity.
   - Understand how climate impacts (e.g., droughts, floods) affect communities differently based on their socioeconomic status.
3. **Environmental Interactions**:
   - Evaluate how seasonal climate forecasts influence land use, water resources, and biodiversity.
   - Consider the ecological impacts of climate variability, such as changes in species migration patterns or shifts in agricultural viability.
4. **Feedback Mechanisms**:
   - Analyze how stakeholder actions based on seasonal forecasts create feedback loops in the system (e.g., over-irrigation leading to soil degradation).
   - Develop strategies to mitigate negative feedback effects while enhancing positive ones.

4. Decision-Making Processes

- **Adaptive Management**: Implement adaptive management practices that allow stakeholders to adjust strategies based on real-time observations and changing conditions.
- **Scenario Planning**: Utilize forecasts to develop scenarios for different climate outcomes, helping stakeholders visualize potential impacts and prepare accordingly.
- **Risk Assessment**: Integrate seasonal forecasts into risk assessment frameworks, allowing for the identification of vulnerable areas and proactive planning.

5. Benefits of a General Systems Approach

- **Improved Resilience**: By considering the interconnectedness of various factors, communities can develop more resilient systems that better withstand climate variability.
- **Enhanced Decision-Making**: A holistic view enables stakeholders to make informed decisions that account for the complexities of the system, reducing the risk of unintended consequences.
- **Sustainable Practices**: Encourages the adoption of sustainable agricultural, water management, and urban planning practices that align with climate forecasts.

6. Challenges and Considerations

- **Complexity of Systems**: The intricate nature of systems can make modeling and predicting outcomes challenging.
- **Data Availability**: Access to high-quality, localized data is essential for effective integration of forecasts into decision-making.
- **Capacity Building**: Stakeholders may require training and resources to effectively utilize seasonal forecasts in their planning processes.

7. Case Studies and Applications

- **Agricultural Planning**: Farmers using seasonal forecasts to adjust planting schedules based on expected rainfall patterns, leading to improved crop yields and reduced losses.
- **Water Resource Management**: Water managers incorporating climate forecasts to optimize reservoir operations, ensuring water availability during drought periods.
- **Public Health**: Health officials using climate data to anticipate and mitigate disease outbreaks influenced by climatic conditions, such as heatwaves or flooding.

Unit V
E-GOVERNANCE IN AGRICULTURAL SYSTEMS

Expert systems, decision support systems, Agricultural and biological databases, e-commerce, ebusiness systems & applications, Technology enhanced learning systems and solutions, e-learning, Rural development and information society.

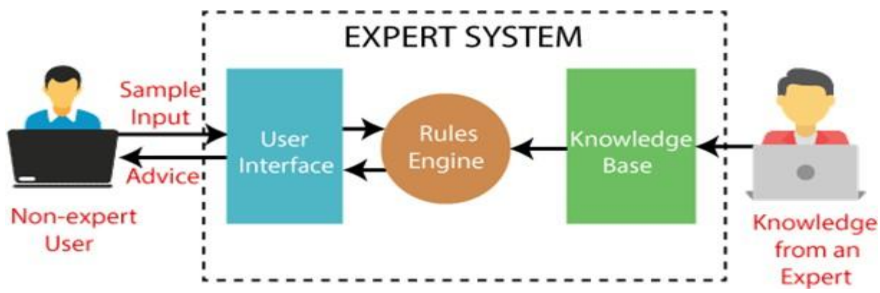
EXPERT SYSTEM

An expert system is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert. It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.

The expert system is a part of AI, and the first ES was developed in the year 1970, which was the first successful approach of artificial intelligence. It solves the most complex issue as an expert by extracting the knowledge stored in its knowledge base. The system helps in decision making for compsex problems using **both facts and heuristics like a human expert**. It is called so because it contains the expert knowledge of a specific domain and can solve any complex problem of that particular domain. These systems are designed for a specific domain, such as **medicine, science,** etc.

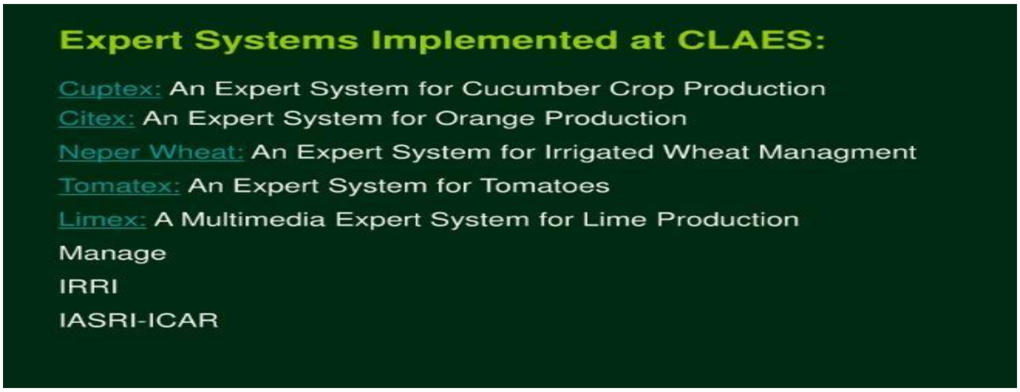
The performance of an expert system is based on the expert's knowledge stored in its knowledge base. The more knowledge stored in the KB, the more that system improves its performance. One of the common examples of an ES is a suggestion of spelling errors while typing in the Google search box.

Below is the block diagram that represents the working of an expert system:



Note: It is important to remember that an expert system is not used to replace the human experts; instead, it is used to assist the human in making a complex decision. These systems do not have human capabilities of thinking and work on the basis of the knowledge base of the particular domain.

Below are some popular examples of the Expert System:



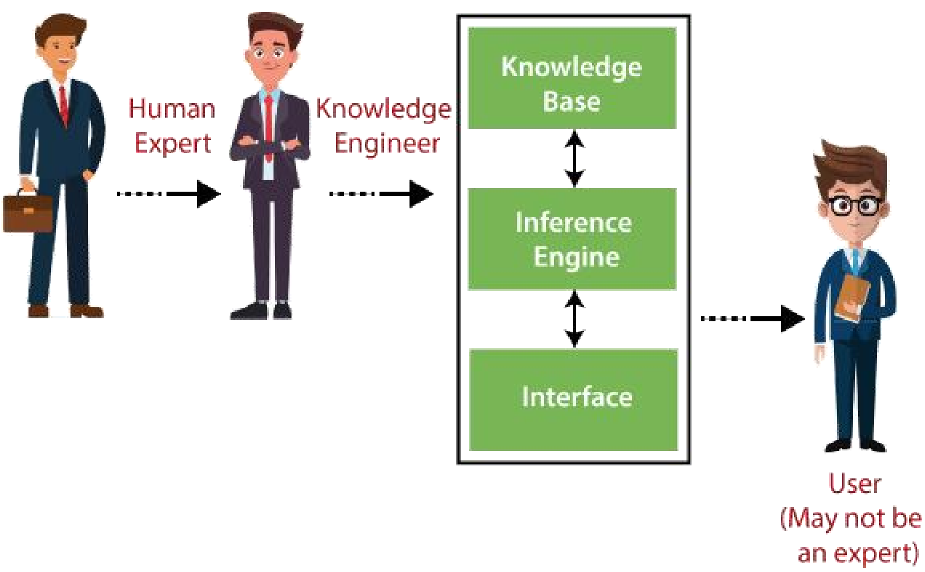
Characteristics of Expert System

- **High Performance:** The expert system provides high performance for solving any type of complex problem of a specific domain with high efficiency and accuracy.
- **Understandable:** It responds in a way that can be easily understandable by the user. It can take input in human language and provides the output in the same way.
- **Reliable:** It is much reliable for generating an efficient and accurate output.
- **Highly responsive:** ES provides the result for any complex query within a very short period of time.

Components of Expert System

An expert system mainly consists of three components:

- **User Interface**
- **Inference Engine**
- **Knowledge Base**



1. User Interface

With the help of a user interface, the expert system interacts with the user, takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user. In other words, **it is an interface that helps a non-expert user to communicate with the expert system to find a solution**.

2. Inference Engine(Rules of Engine)

- The inference engine is known as the brain of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution of queries asked by the user.
- With the help of an inference engine, the system extracts the knowledge from the knowledge base.

There are two types of inference engine:

- **Deterministic Inference engine:** The conclusions drawn from this type of inference engine are assumed to be true. It is based on **facts** and **rules**.
- **Probabilistic Inference engine:** This type of inference engine contains uncertainty in conclusions, and based on the probability.

Inference engine uses the below modes to derive the solutions:

- **Forward Chaining:** It starts from the known facts and rules, and applies the inference rules to add their conclusion to the known facts.
- **Backward Chaining:** It is a backward reasoning method that starts from the goal and works backward to prove the known facts.

3. Knowledge Base

- The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as big storage of knowledge. The more the knowledge base, the more precise will be the Expert System.
- It is similar to a database that contains information and rules of a particular domain or subject.
- One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

Components of Knowledge Base

- **Factual Knowledge:** The knowledge which is based on facts and accepted by knowledge engineers comes under factual knowledge.
- **Heuristic Knowledge:** This knowledge is based on practice, the ability to guess, evaluation, and experiences.

Knowledge Representation: It is used to formalize the knowledge stored in the knowledge base using the If-else rules.

Knowledge Acquisitions: It is the process of extracting, organizing, and structuring the domain knowledge, specifying the rules to acquire the knowledge from various experts, and store that knowledge into the knowledge base.

Development of Expert System

Here, we will explain the working of an expert system by taking an example of MYCIN ES. Below are some steps to build an MYCIN:

- Firstly, ES should be fed with expert knowledge. In the case of MYCIN, human experts specialized in the medical field of bacterial infection, provide information about the causes, symptoms, and other knowledge in that domain.
- The KB of the MYCIN is updated successfully. In order to test it, the doctor provides a new problem to it. The problem is to identify the presence of the bacteria by inputting the details of a patient, including the symptoms, current condition, and medical history.
- The ES will need a questionnaire to be filled by the patient to know the general information about the patient, such as gender, age, etc.
- Now the system has collected all the information, so it will find the solution for the problem by applying if-then rules using the inference engine and using the facts stored within the KB.
- In the end, it will provide a response to the patient by using the user interface.

Participants in the development of Expert System

There are three primary participants in the building of Expert System:

1. **Expert:** The success of an ES much depends on the knowledge provided by human experts. These experts are those persons who are specialized in that specific domain.
2. **Knowledge Engineer:** Knowledge engineer is the person who gathers the knowledge from the domain experts and then codifies that knowledge to the system according to the formalism.
3. **End-User:** This is a particular person or a group of people who may not be experts, and working on the expert system needs the solution or advice for his queries, which are complex.

Need of Expert System

Before using any technology, we must have an idea about why to use that technology and hence the same for the ES. Although we have human experts in every field, then what is the need to develop a computer-based system. So below are the points that are describing the need of the ES:

1. **No memory Limitations:** It can store as much data as required and can memorize it at the time of its application. But for human experts, there are some limitations to memorize all things at every time.
2. **High Efficiency:** If the knowledge base is updated with the correct knowledge, then it provides a highly efficient output, which may not be possible for a human.
3. **Expertise in a domain:** There are lots of human experts in each domain, and they all have different skills, different experiences, and different skills, so it is not easy to get a final output for the query. But if we put the knowledge gained from human experts into the expert system, then it provides an efficient output by mixing all the facts and knowledge
4. **Not affected by emotions:** These systems are not affected by human emotions such as fatigue, anger, depression, anxiety, etc.. Hence the performance remains constant.
5. **High security:** These systems provide high security to resolve any query.

6. **Considers all the facts:** To respond to any query, it checks and considers all the available facts and provides the result accordingly. But it is possible that a human expert may not consider some facts due to any reason.

7. **Regular updates improve the performance:** If there is an issue in the result provided by the expert systems, we can improve the performance of the system by updating the knowledge base.

Capabilities of the Expert System

Below are some capabilities of an Expert System:

- **Advising:** It is capable of advising the human being for the query of any domain from the particular ES.
- **Provide decision-making capabilities:** It provides the capability of decision making in any domain, such as for making any financial decision, decisions in medical science, etc.
- **Demonstrate a device:** It is capable of demonstrating any new products such as its features, specifications, how to use that product, etc.
- **Problem-solving:** It has problem-solving capabilities.
- **Explaining a problem:** It is also capable of providing a detailed description of an input problem.
- **Interpreting the input:** It is capable of interpreting the input given by the user.
- **Predicting results:** It can be used for the prediction of a result.
- **Diagnosis:** An ES designed for the medical field is capable of diagnosing a disease without using multiple components as it already contains various inbuilt medical tools.

Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query.

Limitations of Expert System

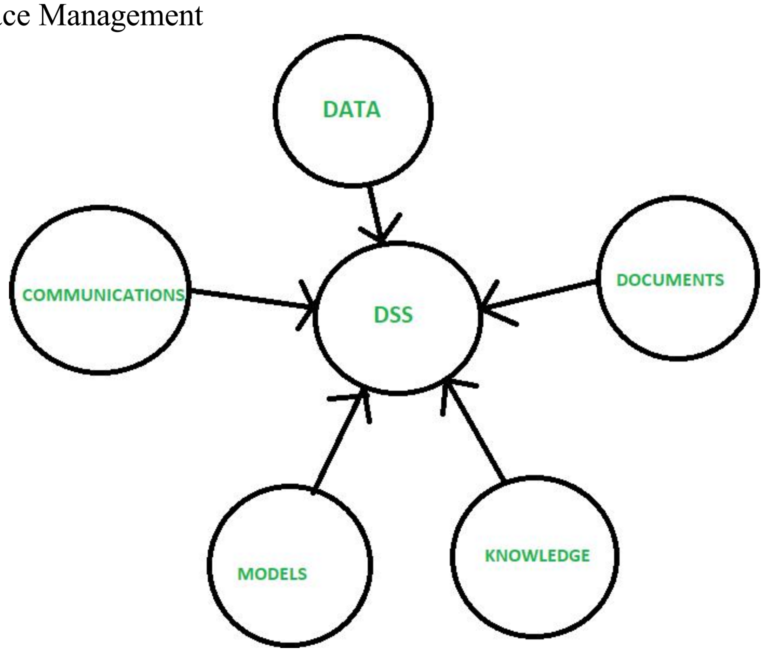
- The response of the expert system may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates.

Applications of Expert System

- **In designing and manufacturing domain**
  It can be broadly used for designing and manufacturing physical devices such as camera lenses and automobiles.
- **In the knowledge domain**
  These systems are primarily used for publishing the relevant knowledge to the users. The two popular ES used for this domain is an advisor and a tax advisor.
- **In the finance domain**
  In the finance industries, it is used to detect any type of possible fraud, suspicious activity, and advise bankers that if they should provide loans for business or not.
- **In the diagnosis and troubleshooting of devices**
  In medical diagnosis, the ES system is used, and it was the first area where these systems were used.
- **Planning and Scheduling**
  The expert systems can also be used for planning and scheduling some particular tasks for achieving the goal of that task.

Decision Support System (DSS):

- It's a computer-based system that aids the process of decision-making. It is an interactive, flexible and adaptable computer system. It is specially developed for supporting the solution of a non-structured management problem for improved decision-making. DSS is a specific class of computerized information systems that supports business and organizational decision-making activities.
- **Components of DSS:**
- Model Management
- Data Management
- User Interface Management



Advantages:

- It saves time.
- Enhances efficiency
- Reduces the cost
- It improves personal efficiency
- It increases the decision-maker satisfaction.

Disadvantages:

- Information Overload
- Status reduction
- Over-emphasize decision-making.
- **Types of Decision Support systems** are Document-driven, Data-driven, Knowledge-driven, Model-driven, and Communication-driven.
- **Applications** include medical diagnosis, business management, agriculture, rail projects, and many more.
- **Examples:** GPS route planning, Crop-planning, ERP dashboards, and others.

Difference between DSS and Expert System:

S. No.	DSS	Expert System
1.	DSS is an interactive system that enables decision-makers to solve unstructured or semi-structured problems by taking help from models and data.	An Expert System is a problem-solving computer program that excels at a particular issue domain that is difficult to solve and takes specialized knowledge and ability.
2.	It facilitates decision-making.	It automates decision-making.
3.	The decision environment is unstructured.	The decision environment has structure.
4.	It extracts or gains knowledge from a computer system.	Inject expert knowledge into a computer system.
5.	Alternatives still may not be completely understood.	Alternatives and goals are frequently predetermined.
6.	Characteristics of the problem domain are complex and broad.	In this, it is limited and specialized.
7.	The type of data manipulation is numeric.	The type of data manipulation is symbolic.
8.	It has limited capacity.	It has a full capacity.

AGRICULTURAL AND BIOLOGICAL DATABASES IN E-GOVERNANCE

Agricultural and biological databases are digital repositories that store a wide range of information related to crops, livestock, genetics, soil, pests, diseases, and more. In the context of e-governance in agricultural systems, these databases serve as valuable tools for collecting, organizing, analyzing, and disseminating critical information to various stakeholders, including farmers, researchers, policymakers, and extension workers. Here's a detailed explanation of how agricultural and biological databases contribute to e-governance in agricultural systems:

Data Collection and Integration

These databases collect and centralize diverse data sources, such as research studies, surveys, field observations, and sensor data. This integration supports comprehensive data analysis and informed decision- making.

Crop and Livestock Information

Databases store detailed information about different crop varieties, livestock breeds, growth characteristics, nutritional requirements, and management practices. This information aids in selecting the right species and optimizing cultivation techniques.

Genetic Resources

Genetic databases store genetic sequences, marker data, and breeding information. Researchers use these resources for genetic improvement of crops and livestock, enhancing productivity, resilience, and quality.

Biodiversity and Conservation

Databases contain information about plant and animal species, ecosystems, and conservation efforts. This data helps in preserving biodiversity and making informed decisions about land use and development.

Soil and Weather Data

Databases store soil profiles, characteristics, and fertility data. Coupled with weather information, these databases enable precision agriculture by guiding decisions on irrigation, fertilization, and planting times.

Pest and Disease Management

Information about pests, diseases, and their management strategies is stored in these databases. Farmers and policymakers can access this data to implement effective pest control measures and disease management practices.

Market Data and Trends

Some databases include market-related information, such as crop prices, demand trends, and supply chain dynamics. This data supports farmers in making informed decisions about what to produce and when to sell.

Research Findings and Publications

Databases store research articles, reports, and publications related to agriculture and biology. These resources facilitate knowledge dissemination, inform policy formulation, and guide agricultural research.

Extension Services and Advisory

E-governance platforms can integrate databases to provide farmers with advisory services. These platforms can deliver recommendations for crop management, pest control, and other best practices based on the stored data.

Decision Support Systems

Databases serve as backbones for decision support systems, offering data and insights that aid policymakers in formulating evidence-based agricultural policies.

Collaboration and Data Sharing

Agricultural and biological databases enable collaboration among researchers, institutions, and organizations. They provide a platform for sharing data, fostering innovation, and accelerating research.

Standardization and Interoperability

These databases often adhere to standardized formats and protocols, enhancing data interoperability and integration across different information systems.

Incorporating agricultural and biological databases into e-governance initiatives enhances the efficiency, transparency, and effectiveness of agricultural systems. By providing accurate and accessible information, these databases empower stakeholders to make informed decisions, adopt sustainable practices, and contribute to the overall development of the agricultural sector.

Policymakers can leverage these databases to design evidence-based policies. promote technological adoption, and ensure the well-being of farmers and rural communities.

INTRODUCTION TO E-COMMERCE IN AGRICULTURE

Traditional agricultural value chains involve multiple intermediaries between farmers and consumers. Typically, farmers sell their produce at the farm gates to middlemen. Produce then passes through multiple intermediaries before reaching the end customer. As a result, farmers receive only a small proportion of the price paid by the end consumer as each intermediary in the value chain earns a margin.

- In e-governance for agricultural systems, e-business systems and applications play a crucial role in streamlining processes, facilitating transactions, and connecting stakeholders.
- Online marketplaces connect farmers directly with buyers, reducing intermediaries and potentially increasing profit margins for farmers.

Platforms can facilitate:

Selling agricultural products (crops, livestock, processed goods)

• Purchasing agricultural inputs (seeds, fertilizers, pesticides)
• Provide farmers with centralized access to: Government schemes and subsidies
• Weather forecasts and market data: Agricultural best practices and extension services and educational resources and training materials

Allow farmers to interact with government agencies electronically for tasks like:
• Land record management
• Applying for licenses and permits
• Online grievance redressal mechanisms

EMERGING AGRI E-COMMERCE BUSINESS MODELS

Emerging agri e-commerce business models are transforming the agricultural sector by integrating digital technologies with traditional farming practices. These models aim to improve market access, enhance efficiency, and increase profitability for farmers and other stakeholders in the agricultural value chain. Here are some detailed descriptions of the emerging agri e-commerce business models:

Online Marketplaces

Online marketplaces connect farmers directly with consumers, retailers, and wholesalers through digital platforms. These platforms act as intermediaries, facilitating transactions and providing a space for farmers to list their products.

Key Features:

Direct Sales: Farmers can sell their produce directly to consumers, reducing dependency on middlemen.

Price Transparency: Consumers can compare prices from different sellers, ensuring competitive pricing.

Wide Reach: Access to a broader market beyond local boundaries.

Input E-commerce Platforms

These platforms focus on selling agricultural inputs like seeds, fertilizers, pesticides, and machinery to farmers. By providing an online marketplace for inputs, these platforms help farmers access quality products at competitive prices.

Key Features:

Convenience: Farmers can order inputs from the comfort of their homes. Product Information: Detailed descriptions, reviews, and ratings of products.

Bulk Purchase Options: Discounts and deals for bulk purchases. Subscription-based Models

Subscription-based models offer regular delivery of agricultural inputs or produce. Farmers or consumers subscribe to a service, ensuring a steady supply of products over a specified period.

Key Features:

Consistency: Regular and reliable supply of inputs or produce.

Cost Savings: Often cheaper than purchasing items individually.

Customization: Subscriptions can be tailored to the specific needs of the farmer or consumer.

Farm-to-Table Models

These models focus on delivering fresh farm produce directly to consumers' doorsteps. They emphasize freshness, quality, and traceability of food products.

Key Features:

Direct Sourcing: Products are sourced directly from farms.

Quality Assurance: Emphasis on organic and fresh produce.

Customer Trust: Transparency in sourcing and delivery process.

Digital Cooperatives

Digital cooperatives bring together small and marginal farmers to collectively sell their produce online. These cooperatives leverage digital platforms to aggregate supply and enhance bargaining power.

Key Features:

Collective Bargaining: Better prices through collective sales.

Resource Sharing: Shared resources for marketing and logistics. Support Services: Access to advisory services and market information.

Agri-Fintech Platforms

These platforms provide financial services tailored to the agricultural sector. including credit, insurance, and payment solutions. By leveraging digital tools, they offer financial products that cater to the unique needs of farmers.

Key Features:

Access to Credit: Loans and credit facilities for purchasing inputs or expanding operations.

Insurance: Crop and weather insurance to mitigate risks.

Digital Payments: Seamless transactions through digital wallets and payment gateways.

Traceability and Blockchain Platforms

Platforms that use blockchain technology to ensure the traceability of agricultural products from farm to fork. These platforms provide transparency and build trust among consumers regarding the origin and quality of their food. Key Features:

Transparency: Detailed information about the product's journey.

Security: Secure transactions through blockchain technology.

Trust: Enhanced consumer confidence in product authenticity.

B2B Marketplaces

Business-to-business (B2B) marketplaces connect farmers and agribusinesses with bulk buyers such as retailers, food processors, and exporters. These platforms facilitate large-scale transactions and supply chain integration.

Key Features:

Bulk Transactions: Large volume sales to businesses.

Supply Chain Efficiency: Streamlined logistics and inventory

management.

Market Expansion: Access to new markets and business opportunities.

Agricultural Advisory Services

These platforms offer expert advice and support to farmers through digital means. They provide recommendations on best farming practices, pest management, weather forecasts, and market trends.

Key Features:

Expert Guidance: Access to agricultural experts and consultants.

Timely Information: Real-time updates and recommendations.

Decision Support: Tools and analytics to aid in decision-making.

The integration of e-commerce in agriculture is revolutionizing the sector by making it more efficient, transparent, and accessible.

These emerging business models are not only helping farmers increase their income but also ensuring that consumers get access to fresh and quality produce. As technology continues to evolve, the scope and impact of agri e-commerce are expected to grow, further transforming the agricultural landscape.

BENEFITS OF AGRI E-COMMERCE

Improved market access: E-commerce platforms connect farmers to wider markets, potentially fetching better prices.

Enhanced transparency: Online information portals provide easy access to government schemes and resources.

Streamlined processes: E-governance services reduce paperwork and expedite interactions with government agencies.

Empowered farmers: Access to information and e-commerce opportunities empowers farmers to make informed decisions and improve their livelihoods.

Agri e-commerce provides an opportunity to streamline the agricultural value chain and reduce inefficiencies in the distribution of farm produce. It represents a new way for farmers to sell their produce to an array of buyers, including agri businesses, retailers, restaurants and consumers.

Agri e-commerce also increases farmers' access to new markets and adds transparency to the value chain. It enables farmers to bypass several intermediaries, resulting in higher income for the farmers, reduced wastage, and the potential to deliver fresher produce to customers.

Such benefits are especially significant in developing regions, where more than 97% of people employed in agriculture live and where the sector's contribution to GDP is in double digits.

E-COMMERCE IN E-GOVERNANCE

E-commerce, or electronic commerce, involves buying and selling goods and services over the internet. In the context of e-governance in agricultural systems, e-commerce platforms play a pivotal role in connecting farmers, agribusinesses, consumers, and government entities. These platforms facilitate the online exchange of agricultural products, services, and information, contributing to improved market access, transparency, and efficiency.

E-commerce is related to e-governance in agricultural systems is as follows:

Market Access and Reach: E-commerce platforms provide farmers with access to a broader customer base, including both local and global markets. This access eliminates geographical constraints and enables farmers to showcase their products to a wider audience.

Transparency and Price Discovery: E-commerce platforms promote price transparency by allowing farmers to list their products along with prices. This transparency aids in fair price discovery, reducing information asymmetry between producers and buyers.

Direct-to-Consumer Sales: Farmers can sell their products directly to consumers through e-commerce platforms, bypassing intermediaries. This eliminates middlemen and ensures that farmers receive a higher share of the final selling price.

Efficient Supply Chains: E-commerce enables streamlined supply chains by connecting producers, processors, distributors, and retailers. This efficiency reduces delays, wastage, and costs in the agricultural value chain.

Access to Information: E-commerce platforms provide valuable information to farmers about market trends, consumer preferences, and demand patterns. This information helps farmers make informed decisions about what to produce and when to sell.

Quality and Standards Assurance: E-commerce platforms often include features that allow sellers to showcase their products' quality, certifications, and compliance with standards. This assures buyers of the product's authenticity and adherence to quality norms.

E**-Payments and Financial Inclusion**: E-commerce platforms integrate digital payment systems, enabling secure online transactions. This is particularly beneficial in regions with limited banking infrastructure, enhancing financial inclusion for farmers.

Data Analytics and Insights: E-commerce platforms generate data about sales, customer preferences, and product performance. Governments can analyze this data to understand market trends, formulate policies, and design interventions that support agricultural growth.

Traceability and Food Safety: E-commerce platforms can incorporate traceability features that allow consumers to trace the origin of their food products. This enhances food safety and quality assurance by providing information about production practices and supply chain processes. • Support for Smallholder Farmers: E-commerce platforms level the playing field for smallholder farmers by providing them with equal access to markets and buyers. This can contribute to poverty reduction and rural development.

Online Training and Extension Services: E-commerce platforms can include training modules, extension services, and advisory resources for farmers. This helps farmers improve their skills, adopt best practices, and enhance productivity.

E-commerce platforms within the framework of e-governance in agricultural systems have the potential to transform the way agricultural products are marketed, sold, and distributed. These platforms enhance market access, transparency, efficiency, and data-driven decision-making, thereby contributing to the growth and sustainability of agricultural economies.

BUSINESS MODELS OF AGRI E-COMMERCE BUSINESSES

To maximize the emerging opportunity, agri e-commerce businesses require scalable and sustainable business models. The choice of business model depends on the operational functions the agri e-commerce business performs in the context of their local market. It also depends on factors such as product category and the strategic objectives of the business.

A sustainable business model balances these considerations to build trad increase user loyalty. The business models of agri e-commerce businesses in developing regions can be grouped into five levels. Each is defined by the operational functions and capital intensity of the business model, with businesses that perform the least functions at level 1 and those with the most integrated approach at level 5.

Mobile operators can add value to agri e-commerce businesses in several ways: Mobile operators can play a central role in the emerging agri e-commerce space. At a foundational level, mobile operators provide the connectivity that enables online services and, increasingly, facilitates digital payments through mobile money. Beyond connectivity and payments, there is scope for mobile operators to leverage other key assets, such as Application Programming Interface (APIs). investment capital and distribution channels, to increase their footprint in agri e-commerce.

As mobile operators are increasingly participating in both agriculture and e- commerce segments by launching their own products and working in partnerships the emerging opportunity in agri e-commerce is a key strategic consideration.

The integration of operator-led mobile money services into agri e-commerce platforms can increase mobile money adoption and usage by meeting the demand for digital payments.

Mobile operators' scale and existing relationships with customers could serve as a platform to expand services more quickly for agri e-commerce businesses. In addition, agri e-commerce can deliver benefits to operators' core services, in rural areas through improved customer acquisition and retention, as well as increasing network usage and average revenue per user (ARPU).

Digital Payments and Transactions: E-business platforms integrate digital payment systems, enabling secure online traction. This eliminates the need for cash transactions and enhances financial inclfor farmers.

Supply Chain Management: E-business applications line supply chains by connecting various stakeholders involved in production processing, distribution, and retail. This enhances transparency and reduces delays.

Precision Agriculture Solutions: E-business systems provide tools for precision agriculture, including remote sensing. GPS-based, and data analytics. These tools optimize input we, improve productivity, and minimize environmental impact.

Agri-Input E-Commerce: Farmers can purchase agricultural inputs like seeds, fertilizers, and pesticides through e-business platforms. These platforms offer product information, prices, and delivery options.

Market Information and Advisory Services: E-business systems can deliver real-time market information, weather updates, and advisory services to fumes. This information assists formers in making informed decisions.

E-Extension Services: E-business applications can provide extension services online, offering training modules, best practices, and advisory resources to farmers and extension workers

Traceability and Certification: E-business platforms can incorporate features that provide consumers with information about the origin. production practices, and certification of agricultural products, enhancing transparency and trust.

Feedback Mechanisms: E-business systems allow buyers to leave reviews and ratings for products and services. This feedback loop promotes accountability and encourages quality improvements.

Integration with Government Initiatives E-business platforms can Integrate with government initiatives such as subsidies, insurance, and financial assistance, enhancing the reach and importance of these programs.

E-BUSINESS SYSTEMS & APPLICATIONS

E-business refers to the use of digital technologies to conduct business activities, including buying, selling, marketing, and managing operations. In the context of e-governance in agricultural systems, e-business systems and applications play a vital role in transforming how agricultural products and services are traded, marketed, and managed. These digital platforms facilitate efficient transactions, enhance market access, and improve overall agricultural value chains.

E-business systems and applications revolutionize the agricultural sector within the framework of e-governance. These digital platforms empower farmers, promote efficient trading, enhance supply chain management, and improve

access to information and services.

By fostering transparency, efficiency, and inclusivity, e-business solutions contribute to the growth, sustainability, and overall development of agricultural economies, while government support ensures that these systems align with national development goals and promote the welfare of farmers and rural communities.

The applications of e-business systems are as follows:

Online Marketplaces: E-business platforms offer online marketplaces where farmers, agribusinesses, and consumers can buy and sell agricultural products. These platforms enable direct interactions between producers and buyers, eliminating intermediaries and reducing transaction costs.

Mobile Applications: Mobile apps provide farmers with easy access to e- business platforms from their smartphones. This allows them to check market prices, receive real-time information, and manage their operations on the go.

E-Commerce Websites: E-commerce websites enable farmers to showcase their products to a global audience. Consumers can browse products, place orders, and make payments online, enhancing market reach for agricultural producers.

Auction Platforms: E-business systems can host virtual auctions for agricultural commodities. Farmers can list their products, and buyers can bid online, creating a competitive environment that can result in fair prices.

Digital Payments and Transactions: E-business platforms integrate digital payment systems, enabling secure online transactions. This eliminates the need for cash transactions and enhances financial inclusion for farmers.

Supply Chain Management: E-business applications streamline supply chains by connecting various stakeholders involved in production, processing, distribution, and retail. This enhances transparency and reduces delays.

Precision Agriculture Solutions: E-business systems provide tools for precision agriculture, including remote sensing. GPS-based guidance, and data analytics. These tools optimize input we, improve productivity, and minimize environmental impact

Agri-Input E-Commerce: Farmers can purchase agricultural inputs like seeds, fertilizers, and pesticides through e-business platforms. These platforms offer product information, prices, and delivery options.

Market Information and Advisory Services: E-business systems can deliver real-time market information, weather updates, and advisory services to farmers. This information assists farmers in making informed decisions.

E-Extension Services: E-business applications can provide extension services online, offering training modules, best practices, and advisory resources to farmers and extension workers.

Traceability and Certification: E-business platforms can incorporate features that provide consumers with information about the origin production practices, and certification of agricultural products, enhancing transparency and trust.

Feedback Mechanisms: E-business systems allow buyers to leave reviews and ratings for products and services. This feedback loop promotes accountability and encourages quality improvements.

Integration with Government Initiatives: E-business platforms can integrate with government initiatives such as subsidies, insurance, and financial assistance, enhancing the reach and import of these programs.

Data Analytics and busights E-business applications generate dats about transactions, customer preferences, and madiet trends. Governments can analyze this data to understand market dynamics and formate policies.

STEPS INVOLVED IN E-BUSINESS

E-Business in agriculture systems involves leveraging electronic technologies and digital platforms to streamline various business processes, improve efficiency, and enhance interactions within the agricultural value chain.

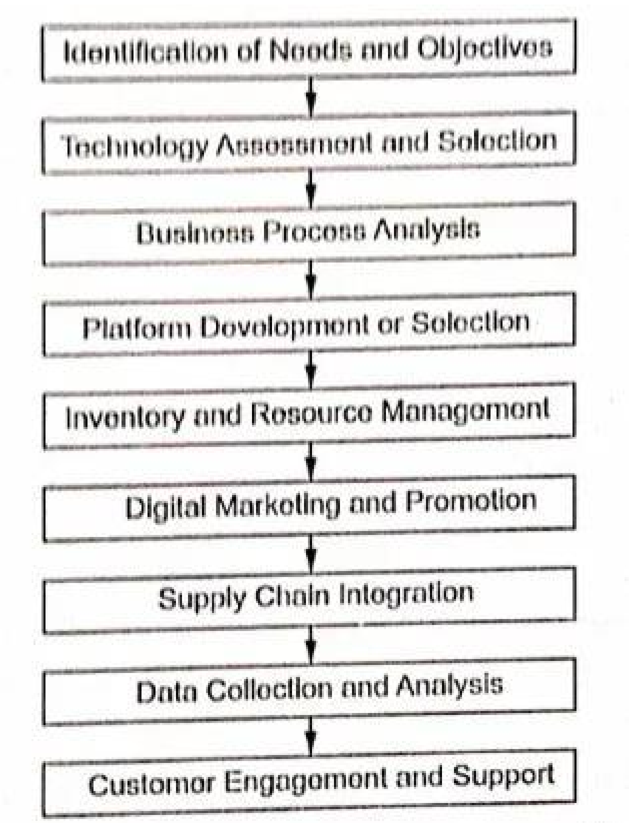


Fig. 5.1. shows the steps involved in implementing e-business within agriculture systems

Identification of Needs and Objectives: Define the specific goals and objectives of adopting e-business in agriculture. Identify pain points challenges, and areas where digital solutions can provide value.

Technology Assessment and Selection: Evaluate available technologies and platforms that align with your agricultural business needs. This could include e-commerce platforms, farm management software, loT devices. data analytics tools, and more.

Business Process Analysis: Analyze your existing business processes, from production and procurement to marketing and distribution. Identity areas that can he optimized through digital solutions.

Platform Development or Selection: Choose or develop the appropriate e-business platform that meets your requirements. This could involve creating a website, mobile app, or integrating with existing e-commerce platforms.

Inventory and Resource Management: Implement digital tools to manage inventory, resources, and inputs more efficiently. This includes tracking seeds, fertilizers, equipment, and other assets using loT devices or RFID technology.

Online Store Setup (if applicable): If selling products online, set up an online store with features such as product listings, shopping cart functionality, secure payment gateways, and order processing systems.

Digital Marketing and Promotion: Utilize digital marketing strategies such as social media, email campaigns, and search engine optimization (SEO) to promote your products or services to a wider audience.

Supply Chain Integration: Integrate e-business solutions with your supply chain partners, including suppliers, distributors, and retailers. This ensures seamless information flow and efficient collaboration

Data Collection and Analysis: Collect data from various sources such as loT devices, weather sensors, and customer interactions. Use data analytics tools to gain insights into crop health, market trends, customer preferences, and more.

Customer Engagement and Support: Implement tools for customer engagement, such as chatbots, online customer support, and feedback mechanisms. This enhances the customer experience and builds trust.

E-Extension Services: Offer digital advisory services to famers, providing real-time guidance on crop management, pest control, and best practices through digital platforms.

Training and Capacity Building: Provide training so farmers and stakeholders on how to use the e-business platform effectively. This ensures that users can leverage the technology to its fullest potential.

Security and Privacy Measures: Implement robust security i protect sensitive data, tresactions, and customer information. This includes secure payment gateways and encryption protocols.

Continuous Monitoring and Improvement: Regularly monitor the performance of your e-business operations and gather feedback from users. Continuously improve the platform based on user needs and changing market dynamics

Sealing and Expansion: Once the e-business operations are established, consider sealing and expanding your digital presence to reach new markets and serve a larger customer hase.

Implementing e-business in agriculture systems requires careful planning, technological integration, and a commitment to enhancing overall efficiency and value across the agricultural value chain.

DIFFERENCE BETWEEN E-COMMERCE AND E-BUSINESS IN AGRICULTURE SYSTEMS

"E-commerce" and "e-business" are related terms often used interchangeably. but they have distinct meanings when applied to agriculture systems. Here's a breakdown of the differences between the

E-Commerce	E-Business
E-Commerce (Electronic Commerce): E-commerce refers to the online buying and selling of goods and services. It involves transactions conducted over the internet, typically through online marketplaces, websites, or platforms.	E-Business (Electronic Business): E-business encompasses a broader scope than e-commerce. It includes not only buying and selling online but also all aspects of business operations conducted electronically, such as customer service, supply chain management, marketing, collaboration, and more.
E-commerce primarily focuses on the online sale and purchase of products and services. It emphasizes the transactional aspect of business.	E-business encompasses a wider range of activities, including online transactions, but also involves other electronic interactions and operations that contribute to the overall business process.
specifically deals with the electronic exchange of goods and services between buyers and sellers.	electronic interactions within an organization and its stakeholders, including customers, suppliers, partners, and employees.
E-commerce typically involves an online storefront, shopping cart functionality, payment gateways, and order processing systems.	E-business includes multiple components such as online marketing, customer relationship management (CRM), inventory management, electronic procurement, and more.
In agriculture systems, e-commerce refers to online platforms where farmers can sell their produce directly to consumers or businesses. For instance, farmers selling their products through an online farmers' market or a dedicated agricultural e-commerce platform.	E-business in agriculture systems goes beyond just transactions. It involves using technology for various activities, such as managing the supply chain, tracking inventory, monitoring crop health through IoT devices, providing digital advisory services, and utilizing precision agriculture techniques.

TECHNOLOGY ENHANCED LEARNING SYSTEMS AND SOLUTIONS

Technology-enhanced learning (TEL) involves the use of digital tools and platforms to facilitate learning and training. In the context of e-governance in agricultural systems, TEL plays a crucial role in imparting knowledge, building skills, and promoting best practices among farmers, extension workers, and other stakeholders.

Technology-Enhanced Learning Systems:

E-learning Modules: Interactive online courses and tutorials delivered through:

- Websites
- Mobile apps
- Video lectures and demonstrations
- Localized content in regional languages
- Digital Literacy Training: Programs to equip farmers with basic skills like:
- Using smartphones and accessing online platforms
- Navigating government websites and apps
- Downloading and using relevant agricultural applications

These systems leverage technology to deliver educational content, suppor capacity building, and enhance overall agricultural development. Here's a detailed explanation of how technology-enhanced learning systems and solutions are related to e-governance in agricultural systems:

Online Training Modules: TEL. platforms provide farmers and agricultural professionals with access to online training modules covering a wide range of topics, from crop management to agribusiness skills. These modules can be designed by experts and accessed at any time. promoting continuous leaming.

Virtual Classrooms: TEL solutions offer virtual classrooms and webinars, allowing farmers and extension workers to participate in interactive sessions with experts. This remote learning approach facilitates knowledge sharing without geographical constraints.

Multimedia Content: TEL incorporates multimedia elements such as videos, animations, and interactive simulations. These engaging formats enhance understanding and retention of complex agricultural concepts.

Mobile Learning Applications: Mobile apps deliver TEL content directly to farmers' smartphones, enabling them to learn on the go. These apps can offer localized content, weather updates, market information, and advisor services.

Interactive Assessments: TEL. systems include assessments and quizzes that help users evaluate their understanding of the material. Immediate feedback fosters a culture of continuous improvement.

E-Extension Services: TEL platforms serve as e-extension services. delivering advisory content related to crop management, pest control irrigation techniques, and more. Farmers can access tailored recommendations based on their specific needs.

Language and Literacy Support: TEL systems can offer content in local languages and include literacy support features. This ensures that educational resources are accessible to a wider range of farmers

Capacity Building for Extension Workers: TEL solutions provide training opportunities for extension workers, equipping them with up-to- date knowledge and tools to better serve farmers in their regions

Best Practices Dissemination: TEL platforms showcase best practices, case studies, and success stories from different regions. This encourages knowledge sharing and adoption of proven methods.

Data-Driven Decision Support: TEL. systems integrate with data analytics to offer insights and recommendations based on real-time data. This helps farmers and policymakers make informed decisions.

Agricultural Innovation Adoption: TEL platforms introduce farmers to innovative practices, technologies, and crop varieties. This promotes the adoption of sustainable and efficient agricultural methods.

Collaboration and Networking: TEL solutions can include social features that enable farmers and learners to connect, share experiences, and collaborate on projects.

Tailored Learning Paths: TEL systems can provide personalized learning paths based on users' interests, skill levels, and specific needs, ensuring relevant and engaging content delivery.

Monitoring and Evaluation: TEL platforms can track users' progress, completion rates, and assessment scores. This data helps in assessing the effectiveness of the learning initiatives.

Incorporating technology-enhanced learning systems and solutions into e- governance initiatives enhances the capacity and skills of agricultural stakeholders, ultimately leading to improved productivity, sustainability, and rural development.

By providing access to quality education, training, and advisory services. vents can empower farmers and extension workers to embrace modem practices, leverage technology, and make informed decisions that contribute to the growth and prosperity of the agricultural sector.

TECHNOLOGIES DEVELOPED FOR AGRICULTURE SYSTEM

The National e-Governance Plan in Agriculture is a centrally sponsored Mission Mode Project.

Major services under the plan include pesticide registration, seed testing results, prices, and arrival details, GIS-based systems for prices and arrival details, information on pesticides, information on fertilisers and seed and district-level agro-met advisories. Farmers can avail the benefits of the services of this project using two distinct methods.

Mobile Applications

Various mobile applications have been developed for this project. Some of the major mobile applications developed include:

Kisan Suvidha - This application gives information about the weather, dealers, market price, plant protection and expert advisories, among others. Pusha Krishi - It provides information on the latest farming and crop technologies.

Crop Insurance - The Crop Insurance application provides information about various insurance schemes that are present for crops and their premium rates.

Agri Market- Using this application, the farmer can know about the existing market prices of various crops.

India Weather - It provides information on the weather prevailing for the next three or four days in 300 different cities across the country.

Web Applications

Besides mobile applications, there are also plenty of web applications that have been developed. These applications include:

Farmers' Portal - The website is exclusively meant for farmers and provides information about various seed, fertilisers, pesticides, dealers, and ethical farming practices.

mKisan Portal The platform enables scientists and other officials to send targeted text and voice messages to the farmers, advising them about various issues persisting in agriculture and the sectors related to it.

Crop Insurance Portal - This website provides information relined to getting crops insured and various crop insurance schemes available throughout the country.

Participatory Guarantee System of India (PGS) Portal - This portal helps farmers to take an organic approach towards farming.

BENEFITS FOR FARMERS BY ADOPTING TECHNOLOGY- ENHANCED LEARNING SYSTEMS.

Farmers in India can experience several benefits by adopting technology- enhanced learning systems:

Access to Knowledge: Technology-enhanced learning systems provide farmers with easy access to a wealth of agricultural knowledge, including best practices, modern techniques, and crop management strategies. Skill Development: Farmers can acquire new skills and stay updated on the latest agricultural trends through online training modules, videos, and interactive resources.

Timely Information: E-learning platforms offer real-time updates on weather forecasts, market prices, and disease outbreaks, enabling informed decision-making for better crop planning and marketing strategies.

Cost-Effectiveness: E-learning eliminates the need for physical travel and training, reducing costs associated with attending workshops or seminars Flexibility: Farmers can learn at their own pace and convenience, allowing them to balance their learning with their busy farming schedules. **Language Accessibility**: Many e-learning platforms provide contest in local languages, making educational resources more accessible so farmers who might not be proficient in English.

Improved Productivity: By learning about advanced agricultural practices, farmers can implement improved techniques that lead to higher yields and enhanced productivity.

Enhanced decision-making: Access to real-time data and best practices empowers farmers to make informed decisions about their crops and finances.

Risk Mitigation: Learning about pest and disease management practices can help farmers identify early signs of problems and take preventive measures, reducing the risk of crop losses.

Access to Market Information: Fanners can use e-learning to stay informed about market demand, pricing trends, and consumer preferences, enabling them to make informed decisions about what to produce and when to sell.

Empowerment: Technology-enhanced leaming empowers farmers with knowledge, enabling them to negotiate better prices for their produce and make informed decisions about adopting new technologies.

Transparency and accountability: E-governance promotes transparency in government schemes and facilitates grievance redressal

Empowerment and inclusion: Technology-enhanced learning bridges the digital divide and empowers even small-scale farmers.

Financial Literacy: E-learning platforms often include modules on financial management, helping farmers understand budgeting, savings, and investment strategies.

Entrepreneurship: Farmers can explore opportunities beyond traditional farming by learning about value addition, agribusiness, and diversification. Technology-enhanced learning systems offer Indian farmers a pathway to acquiring new knowledge and skills, making informed decisions, and adopting modem practices that can significantly enhance their agricultural productivity, profitability, and overall livelihoods.

E-LEARNING RESOURCES

There are several e-learning resources available in India specifically tailored to agricultural systems. These resources provide valuable information, training, and knowledge to individuals involved in various aspects of agriculture.

Here are some e-learning resources available in India for agricultural systems:

(i) e-Krishi Shiksha: An e-learning platform that offers courses, videos, and learning materials covering a wide range of agricultural topics, including crop cultivation, livestock management, and agribusiness.

(ii) AgMOOCs (Agriculture Massive Open Online Courses: An initiative by the Indian Council of Agricultural Research (CAR) that provides free online courses on various agricultural subjects, allowing leamers to access lectures, videos, and resources from experts

(iii) National Institute of Agricultural Extension Management (MANAGE) Offers e-learning courses and resources for extension workers, focusing on agricultural extension and advisory services

(iv) SWAYAM: Offers online courses on agriculture-related subjects from reputed institutions, providing learners with access to high-quality educational content.

(v) MKisan Portal: Provides e-leaming resources, including videos, articles, and training modules, covering toples relevant to farmers and agricultural professionals

(vi) ICAR-Courses: Offers a range of e-courses developed by the Indian Council of Agricultural Research, covering subjects such as horticulture, animal science, and agricultural engineering

(vii)-PG Pathshala Offers postgraduate-level courses and resources related to agricultural sciences, providing in-depth knowledge for advanced learners

(viii) Indian Institute of Technology (IIT) and National Programmer Technology Enhanced Learning NPTEL Offers courses on agriculture-related topics, including sustainable agriculture practices and agribusiness.

(ix) Agriculture Skill Council of India (ASCI): Provides skill development courses for individuals in the agricultural sector, including courses on fam management, organic farming, and agri-inputs

(x) Indian Institute of Soil Science (ISS) e-Courses: Offers online courses related to soil science, soil health management, and sustainable agricultural practices.

(xi) State Agricultural Universities and Colleges: Many state-level agricultural institutions have developed their own e-learning resources, offering courses on crop production, pest management, and rural Development

(xii) National Institute of Agricultural Economics and Policy Research (NIAP): Offers courses and resources related to agricultural economics,

policy analysis, and agribusiness.

These e-leaming resources cater to a diverse audience, including farmers, students, researchers, extension workers, and agricultural entrepreneurs. They contribute to capacity building, knowledge dissemination, and the adoption of innovative and sustainable practices within the realm of agricultural systems in

India.

5.9. RURAL DEVELOPMENT AND INFORMATION SOCIETY IN E-GOVERNANCE

- Rural development involves improving the economic, social, and environmental well-being of rural areas and communities. In the context of e-governance in agricultural systems, the concept of an information society plays a crucial role in driving rural development by leveraging digital technologies, connectivity, and access to information
- E-governance initiatives that focus on rural development aim to bridge the digital divide, empower rural populations, and enhance agricultural practices for sustainable growth.
- Rural development and the information society intersect significantly in the context of agriculture systems in India. The integration of information and communication technologies (ICT) with rural development, initiatives has transformed the agricultural landscape, empowering rural communities, enhancing productivity, and fostering sustainable growth.
- Rural development and the information society are interconnected within India's agriculture systems are as follows:

1. **Digital Inclusion and Empowerment**: The information society aims to bridge the digital divide by providing rural communities with access to ICTs. This inclusion empowers farmers with digital tools, allowing them to access agricultural information, market prices, weather forecasts, and advisory services, thus enabling informed decision-making.
2. **Access to Agricultural Knowledge**: The information society facilitates the dissemination of crucial agricultural knowledge to remote areas. Farmers can access e-learning platforms, mobile apps, and online resources to learn about modern farming practices, sustainable techniques. and market trends.
3. **Market Access and E-Commerce:** Real development initiatives leverage e-commerce and digital marketplaces, enabling farmers to directly connect with buyers and consumers. This reduces interme expands market reach, and improves farmers income.

4. **Financial Inclusion and Services**: The information society prem financial inclusion by connecting reel populations to digital banking credit, and insurance services. This enables farmers to access financial resources for investments and risk management
5. **Precision Agriculture and Data Analytics**: Rural development integrates precision agriculture techniques, leveraging loT devices and data analytics Farmers can monitor soil health, crop growth, and resource utilization optimizing inputs for improved yields
6. **Weather Information and Disaster Management**: The information society provides real-time weather information and early warning systems for natural disasters. This helps farmers take preventive measures. protecting their crops and livelihoods
7. **Entrepreneurship and Diversification**: The availability of information encourages rural entrepreneurship. Farmers can explore value-added products, agribusiness ventures, and diversified income sources beyond traditional farming.
8. **Skill Development and Capacity Building**: Rural development initiatives offer e-leaming platforms and digital training resources. This capacity building equips farmers with new skills, such as using firm management apps and adopting advanced agricultural practices
9. **Extension Services and Advisory Support**: The information society enhances extension services by offering digital platforms for remote advisory support. Extension workers can provide real-time guidance farmers, addressing their queries and challenges.
10. **Sustainable Agriculture Practices:** The information society promotes awareness of sustainable agriculture practices. Farmers can learn about organic farming, crop rotation, and integrated pest management, contributing to environmental conservation.
11. **Data-Driven Policy and Planning**: Rural development initiatives leverage data analytics to inform policy decisions. Data on agricultural practices, market trends, and rural development indicators guide policymakers in designing effective interventions.
12. **Community Participation and Networking**: The information society encourages community engagement through digital platforms. Farmers can share experiences, exchange knowledge, and collaborate on collective initiatives.

By combining rural development efforts with the principles of the information society. India's agriculture systems experience a transformative impact Empowered by digital tools and knowledge, rural communities are better equipped to address challenges, embrace innovation, and contribute to the sustainable growth and prosperity of the agricultural sector.