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SECTION OF AGRONOMY

B.Sc. (Hons.) Agriculture

Course No. AGRO-3612
Credits = 2 (1+1)
Title: - Geo-informatics and Nano-technology and Precision Farming

Theory notes

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Syllabus for Geo-informatics and Nano technology and Precision farming (AGRO-3612)

Credits: 2(1+1)

Lecture	Topic	Weightage (%)
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Total		**100**

CHAPTER 1

Precision agriculture: concepts and techniques; their issues and concerns reference for Indian agriculture

Definition:

- An information and technology based farm management system to identify, analyze and manage variability within fields by doing all practices of crop production in right place at right time and in right way for optimum profitability, sustainability and protection of the land resource.
- Precision agriculture is a systems approach of farming for **maximizing the effectiveness of crop inputs.**
- Precision agriculture is oftenly called as **site specific agriculture or farming**

Concept of precision farming

- Precision Agriculture (PA) along with Wireless Sensor Network (WSN) is the main drivers of automation in the agriculture domain. PA uses specific sensors and software to ensure that the crops receive exactly what they need to optimize productivity and sustainability. PA includes retrieving real data about the conditions of soil, crops and weather from the sensors deployed in the fields. High-resolution images of crops are obtained from satellite or air-borne platforms, which are further processed to extract information used to provide future decisions.
- Sensors measure the physical parameters and send the collected information to the controller, which further transmits this information to the cloud or a portable device.
- **5 R's of precision farming are;**
  Precision or site specific farming gives the answers of Wh-questions….to apply?
  1) Right input (What)
  2) At right time (When)
  3) In right amount (How much)
  4) At right place (Where)
  5) In right manner (How)

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

Need of precision agriculture (PA)

1) **For assessing and managing field variability:** Today, that level of knowledge of field conditions is difficult to maintain because of the variable farm sizes and changes in areas farmed due to annual shifts in leasing arrangements. Precision agriculture offers the potential to automate and simplify the collection and analysis of information.
2) **For doing the right thing (Input) in the right place at the right time:** After assessing the variability precision agriculture allows management decisions to be made and implemented in right time in right places on small areas within larger fields.
3) **For higher productivity:** Since precision farming, proposes to prescribe utilization of management practices, it will definitely increase the yield per unit of land.
4) **For increasing the effectiveness of inputs:** Increased productivity per unit of input used indicates increased efficiency of the inputs.
5) **For maximum use of minimum land unit:** After knowing the land status, a farmer tries to improve each and every part of land and uses it for the production purpose.

Benefits or advantages of precision farming

- ✓ The concept of "doing the right thing (Input) in the right place at the right time" gives farmers the ability to use all operations and crop inputs more effectively.
- ✓ More effective use of inputs results in greater crop yield and/or quality, without polluting the environment.
- ✓ Precision agriculture can address both economic and environmental issues that surround production agriculture today.
- ✓ It helps in implementing spatially-varied farm operations such as tillage, seeding, harvesting, etc.

- ✓ It helps in on-farm testing of agronomic practices to evaluate alternative management practices
- ✓ It helps in plant breeding programs to test the performance of improved varieties.
- ✓ It helps in re-evaluations of trial procedures.

Limitations in adaption of precision farming in India

Although precision farming is a proven technology in many advanced countries of the world but its scope in India (also in other developing countries) are limited. Different scientists have reported certain constraints, which limited the scope for site-specific farming in India, are as given follows:

1. Small farms size, heterogeneity of cropping systems, and land tenure/ownership restrictions High cost of obtaining site-specific data
2. Complexity of tools and techniques requiring new skills
3. Culture, attitude and perceptions of farmers including resistance to adoption of new techniques and lack of awareness of agro-environmental problems
4. Infrastructure and institutional constraints including market imperfections
5. PA as new story to Indian farmers needs demonstrated impacts on yields
6. Lack of local technical expertise
7. High initial investment
8. Uncertainty on returns from investments to be made on new equipment and information management systems, and
9. Knowledge and technological gaps including

- Inadequate understanding of agronomic factors and their interaction,
- Lack of understanding of the geostatistics necessary for displaying spatial variability of crops and soils using current mapping software, and
- Limited ability to integrate information from diverse sources with varying resolutions and intensities.

Scope of precision farming in India

- ✓ When contiguous fields with the same crop and similar crop management can be considered for the purpose of initiating the implementation of precision farming.
- ✓ Similar implementation can also be carried out on the state farms.
- ✓ There is a scope of implementing precision agriculture for crops like, rice and wheat especially in the states of Punjab and Haryana where is overused of water.

- ✓ Commercial as well as horticultural crops also show a wider scope for precision agriculture in the cooperative farms.
- ✓ Nearly two-third (2/3) arable land in India is rain-fed. Potential exists for increasing productivity of rain-fed Cropping systems.
- ✓ Some crops have a very high value per acre, making excellent cases for site specific management.
- ✓ **Nutrient and water stress management** is another area where precision farming can help Indian farmers.
- ✓ In semi-arid and arid tropics, precision technologies can help growers in **scheduling irrigation** more profitably by varying the timing, amounts and placement of water.
- ✓ Remote sensing combined with GIS and GPS can help in **site-specific weed management.**
- ✓ Remote sensing can help in detecting small problem areas caused by pathogens, which help in **optimizing timing of applications of fungicides** can be.

COMPONENTS OF PRECISION AGRICULTURE

1. Information or data base
2. Technology
3. Management

1. Information or data base

- ❑ **Soil:** Soil Texture, Structure, Physical Condition, Soil Moisture, Soil Nutrients, etc.
- ❑ **Crop:** Plant Population, Crop Tissue Nutrient Status, Crop Stress, Weed patches (weed type and intensity), Insect or fungal infestation (species and intensity), Crop Yield, Harvest Swath Width etc.
- ❑ **Climate:** Temperature, humidity, rainfall, solar radiation, wind velocity, etc.

In-fields variability, spatially or temporally, in soil-related properties, crop characteristics, weed and insect-pest population and harvest data are important databases that need to be developed to realize the potential of precision farming.

2. Technology

a. Global Positioning System (GPS) receivers: GPS provides continuous position information in real time, while in motion. Having precise location information at any time allows soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas.

b. Differential Global Positioning System (DGPS): A technique to improve GPS accuracy that uses pseudo range errors measured at a known location to improve the measurements made by other GPS receivers within the same general geographic area (figure at bottom).

c. Geographic information systems (GIS): Geographic information systems (GIS) are computer hardware and software that use feature attributes and location data to produce maps. An important function of an agricultural GIS is to store layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels.

d. Remote sensing: It is the collection of data from a distance. Data sensors mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop.

e. Variable Rate Applicator:

The variable rate applicator has three components:
1. Control computer
2. Locator and
3. Actuator

- VRT consists of the machines and systems used to apply a desired rate of crop production inputs/materials at a specific time and specific location.
- The control computer co-ordinates field operations with the data base of its memory.
- Based on the desired activity, the computer from **locator** (holds a GPS) receives the current location of equipment and issue command to the **actuator** which does the input application.

f. Spatial decision support systems (SDSS): Spatial decision support systems (SDSS) are designed to help growers to solve complex spatial problems and to make decision concerning to irrigation scheduling, fertilization, use of crop growth regulators and other chemicals.

3. Management

- **Information management:** A farmer must have crucial information necessary to make decisions effectively. Effective information management requires analysis tools.
- **Decision support system (DSS):** Combination of information and technology into a comprehensive and operational system gives farmers a decision to treat the field. For this purpose, DSS can be developed, utilizing GIS, agronomic, economic and environmental software, to help farmers manage their fields.
- **Identifying a precision agriculture service provider:** Farmers are advised to take services of agricultural service providers or properly trained extension workers for precision agriculture. The most common custom services that precision agriculture service providers offer are intensive soil sampling, mapping and variable rate applications of fertilizer and lime. By distributing capital costs for specialized equipment over more land and by using the skills of precision agriculture specialists, custom services can decrease the cost and increase the efficiency of precision agriculture activities.

PRECISION FARMING CONCERNS FOR INDIAN AGRICULTURE

1. Farmers in developed countries typically own large farms (10-1000 ha or more) and crop production systems are highly mechanized in most cases.
2. Large farms may comprise several fields in differing conditions.
3. Even within a relatively small field (<30 ha) the degree of pest infestation, disease infection and weed competition may differ from one area to another.
4. In conventional agriculture, although a soil map of the region may exist, farmers still tend to practice the same crop management throughout their fields: Crop varieties, land preparation, fertilizers, pesticides and herbicides are uniformly applied in spite of variation.
5. Optimum growth and development are thus not achieved.
6. Furthermore, there is inefficient use of inputs and Labour.
7. Availability of information technology since the 1980s provides farmers with new tools and approaches to characterize the nature and extent of variation

in the fields, enabling them to develop the most appropriate management strategy for a specific location, increasing the efficiency of input application.

Future strategy

- ✓ Precision farming is practiced in developed countries and it not yet practically adoptable in developing countries like India.
- ✓ Future strategy for adoption of precision agriculture in India should consider the problem of
    - land fragmentation,
    - lack of highly sophisticated technical centers for precision agriculture,
    - specific software for precision agriculture
    - Poor economic condition of the farmers, etc.

CHAPTER 2

Geo-informatics system - definition, concepts, tools and techniques; their use in precision farming

Geo: Related to earth

Informatics: the science of processing of data for storage and retrieval.

Definition:

- **Geo-informatics (GI)** is science and technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering.
- An art, science and technology dealing with acquisition, storage, processing, production, presentation and dissemination of geo data is called Geo-informatics.
- Geo informatics aims in make maps, enable navigation, data understanding and analysis.

Concept of Geo-informatics (GI)

- GI is a multidisciplinary science that integrates the technologies and principles of digital cartography, remote sensing, photogrammetry, surveying, Global Positioning Systems (GPS), Geographic Information Systems (GIS), and automated data capture systems using high-resolution geo-referenced spatial information from aerospace remote sensing platforms.

- It is a powerful tool for assessment, monitoring, planning and management of agricultural research and development.

- GI involves study of i) existing land use and acreage under various crops, ii) soil types and extent of problem soils, iii) monitoring of surface water bodies (to determine water availability in irrigation systems) for ground water development and (iv) management of natural calamities.

Tools and techniques of Geo-informatics

1. Remote sensing
2. Geographical Information System (GIS)
3. Cartography
4. Global Navigation Satellite Systems
5. Photogrammetry

6. DBMS (Data Based Management System)
7. Surveying

1. **Remote sensing**

- Remote sensing is the acquisition of information about an object without making physical contact with the object.

- Remote sensing is technique of deriving information about objects on the surface of the earth without physically contact into them. This process involves making observations using sensors mounted on platforms (aircrafts and satellites) which are at considerable height from earth surface and recording the observations on suitable medium.

- **Principle:** different objects return different amount and kind of energy in different bands of EM spectrum incident upon it. This property of the object depends on the structural, physical and chemical composition, surface roughness, intensity and wavelength of radiant energy, hence we can identify objects by collecting and analyzing returned energy.

2. **GPS (Global Positioning System)**

- GPS is a satellite navigation system used to determine the ground position of an object.
- It is used to refer location

3. **Geographical Information System (GIS)**: A GIS is system designed to capture, store, manipulate, analyses, manage & present spatial or geographic data.
4. **Cartography:**

- Cartography is generally considered to be the science and art of designing, constructing and producing maps.
- It includes almost every operation from original field work to final printing and marketing of maps.

5. **Photogrammetry** – Photogrammetry is the science of making measurements from photographs.
6. **Surveying –** Surveying is the technique of determining the terrestrial or 3D positions of points and the distances & angles between them.
7. **Global Navigation Satellite Systems**

- Global Navigation Satellite Systems (GNSS) include constellations of Earth-orbiting satellites that broadcast their locations in space and time, of networks of ground control stations, and of receivers that calculate ground positions by trilateration.

- GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, road and mass transit.
- Positioning, navigation and timing (PNT) play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, scientific research and so on.
- They are used to control computer networks, air traffic, power grids and more.

8. **DBMS (Data Based Management System)**

- A database management system (DBMS) is a software package designed to define, manipulate, retrieve and manage data in a database.
- A DBMS generally manipulates the data itself, the data format, field names, record structure and file structure.
- It also defines rules to validate and manipulate this data.

USE OF GEO-INFORMATICS IN PRECISION FARMING:

1. **GPS**-based applications in precision farming are being used in farm planning, field mapping, tractor guidance, variable rate applications (automated precise application of pesticides, fertilizers, etc. based on data that is collected by sensors, maps, and GPS) and yield mapping.
2. **Remote sensing** is precision farming is used for crop yield modeling, identification of pests and disease infestation, soil moisture estimation, irrigation monitoring, assessment of crop damage, etc.
3. **GIS can display analysed information in maps** that allow better understanding of interactions among yield, fertility, pests, weeds and other factors, and decision-making based on such spatial relationships.
4. Geo-informatics tools like remote sensing and combining data in a GIS can help Indian farmers in **nutrient and water stress management.**
5. In semi-arid and arid tropics, geo-informatics tools like remote sensing can help growers in **scheduling irrigation** more profitably by varying the timing, amounts and placement of water.
6. Remote sensing combined with GIS and GPS can help in **site-specific weed management.**
7. Remote sensing can help in detecting small problem areas caused by pathogens, which help in **optimizing timing of applications of fungicides** can be.

CHAPTER 3

CROP DISCRIMINATION AND YIELD MONITORING

Crop discrimination

- Crop discrimination is a necessary step for most agricultural monitoring systems in which differentiate/classification of crops as per season, phonological stages, pigmentation, spatial arrangement/architecture as well as spectral features is called as crop discrimination.
- Crop discrimination types using remote sensing techniques are based on the characterization and understanding of the electromagnetic behavior of target.

Yield monitoring

- Yield monitoring is the estimation of crop yield well before the harvest at regional and national scale is imperative for planning at micro-level and predominantly the demand for crop insurance.
- **Yield monitors** allow farm equipment such as combine harvesters or tractors to gather a huge amount of information, including grain yield, moisture levels, soil properties, and much more. Due to the fact that yield monitors provide farmers with so much information, they are much more able to assess things such as when to harvest, fertilize or seed, the effects of weather, and much more.
- Yield monitors work in three very simple steps:

  Step-I The grain is harvested and fed into the grain elevator which has sensors that read moisture content of the grain.

  Step-II After that process as the grain is being delivered to the holding tank, more sensors monitor the grain yield.

  Step-III As both of these sensors work the information is sent to the driver cab and is displayed on a screen, as well, the information is geo-referenced so it can be mapped as well as closely investigated on a later time or date.

Benefits of yield monitoring:

- It helps to give the farmer accurate and often geo-referenced data about their field.
- A farmer can better understand crop yield and crop related information to mitigate potential threats or enhance possible opportunities.

- Ability for a farmer to export the information onto a personal computer, allowing this information to be available in a variety of different formats, including in equipment displays, at home, or printed.
- Also, in the home or office a farmer can used specialized computer software to asses and better understand the recorded information.
- Yield monitors can monitor grain by a field by field or load by load basis. This gives the farmer a huge amount of flexibility as well as provides him or her with instant information about the load they have gathered.

Components of Yield monitors

Mass Flow Sensor

A mass flow sensor is a sensor that helps to provide the yield monitor with enough information to establish a grain yield measurement. The mass flow sensor works by using a load cell which is fixed to the top of a clean grain elevator. When the harvested grain is fed through the combine it eventually will hit up against this load cell, this is then transformed into an electrical signal and relayed to the yield monitor. The yield monitor uses this reading to determine how much grain is being taken into the combine at any point in time. This sensing method is very common, although there are different methods used, as well as variations of the same method.

Moisture Sensor

Being aware of the moisture content in grain that has been harvested can be extremely valuable information for a farmer to know, especially for aspects including harvesting, storing and drying crops. When farmers take these moisture readings they are better able to obtain an accurate market value for their crop. The moisture sensor works when the grain moves in-between two conductive surfaces, which measure how much electric charge the grain can store – this is known as capacitance. There are various places to mount the moisture sensor, and it is a vital step of the yield monitoring process.

GPS Receiver

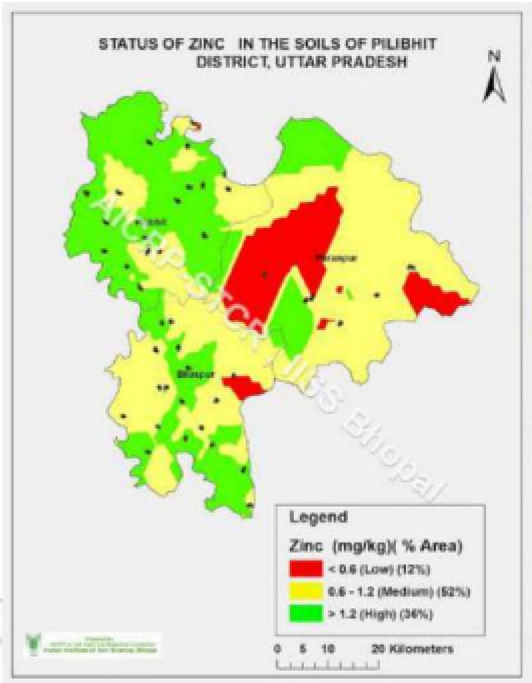
A GPS Receiver can help to transform yield monitoring data from graphs and charts, into tangible maps that the farmer can use.

CHAPTER 4

Soil mapping: fertilizers recommendation using geospatial technologies

Soil map is a geographical representation showing diversity of soil types and/or soil properties (soil pH, textures, organic matter, depths of horizons etc.) in the area of interest.

It is typically the end result of a soil.



Steps in soil mapping

Step-I Soil Sample collection

Step-II Analysis (OC, pH, Salinity, Major and minor nutrients etc.)

Step-III Data generation

Step-IV ArcGIS processing

Step-V Kriging interpolation (grid points)

Step-VI Map generation

(SHORT PROCEDURE: Soil samples collected, analysed and data was generated. The data generated was processed in ArcGIS platform to develop a database. Geostatistical analyst tool was used and kriging interpolation technique was adopted.

The analysed data was interpolated to obtain a raster surface from points (grid points) to generate fertility maps using ArcGIS)

Common interpolation techniques:

Kriging is a geostatistical interpolation technique which considers both the distance and the degree of variation between known data points when estimating values in unknown areas.

IDW (Inverse Distance Weighting)

Splines

Fertilizers recommendation using geospatial technologies

Based on soil map performance, the following recommendations can be suggested;

1. In case of soils with acidic in nature, application of organic matter is recommended.
2. In case of strongly acidic soils lime application is recommended.
3. The areas which are low in nutrient status (OC and P) need to be improved by adding organic manures (FYM/Compost) and phosphatic fertilizers preferably rock phosphate in acidic soils.
4. Saline soils can be recover by applying good quality water or and adding humus.

CHAPTER 5

SPATIAL DATA AND THEIR MANAGEMENT IN GIS

Definition:

- Information that has a geographic aspect to it, or positioning, is known as geospatial data.
- Other common names include spatial data or geographic information system (GIS) data.
- Manual digitization of paper maps, existing digital datasets, satellite remote-sensing imageries, global positioning system (GPS), field surveys, internet, etc. are the promising data input sources for spatial data development in GIS.

Geospatial data comes in two basic forms:

- **Vector-Based** consist of points, lines, and polygons which represent spatial features such as cities, streets, and rivers.
- **Raster-Based** consist of cells (often called dots or pixels on a computer) which represent spatial features. Cities are single cells, streets are lines of cells, and rivers are collections of cells.

Spatial data and their management in GIS

Spatial data is managed in file formats: **shapefiles** for vector data **imagine** and **GeoTiff** files for rasters and **file geodatabases** for both vector and raster data.

A] Vector Data File Formats

1. Shapefile

A **shapefile** is a file-based data format native to ArcMap. A shapefile is a feature class–it stores a collection of features that have the same geometry type (point, line, or polygon), the same attributes, and a common spatial extent.

Each file that makes up a "shapefile" has a common filename but different extension type.

The lists of files that define a "shapefile" are shown in the following table. Note that each file has a specific role in defining a shapefile.

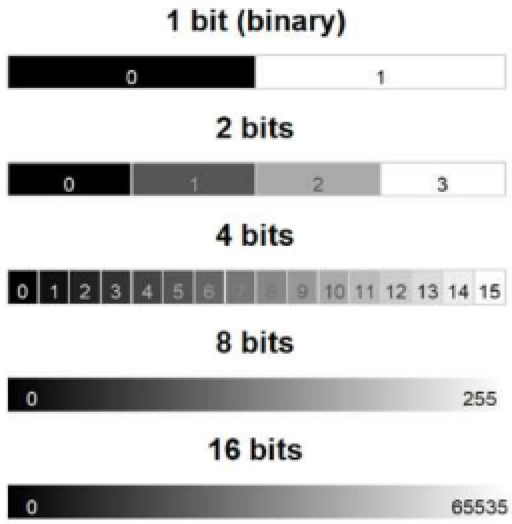
No.	File extension	Content
i	.dbf	Attribute information
ii	.shp	Feature geometry
iii	.shx	Feature geometry index
iv	.aih	Attribute index
v	.ain	Attribute index
vi	.prj	Coordinate system information
vii	.sbn	Spatial index file
viii	.sbx	Spatial index file

2. File Geodatabase

A file geodatabase is a relational database storage format. It's a far more complex data structure than the shapefile and consists of a .gdb folder housing dozens of files.

B] Raster Data File Formats

Rasters are in part defined by their pixel depth. Pixel depth defines the range of distinct values the raster can store. For example, a 1-bit raster can only store 2 distinct values: 0 and 1.



There is a wide range of raster file formats used in the GIS world. Some of the most popular ones are listed below.

1. Imagine

The **Imagine** file format was originally created by an image processing software company called ERDAS. This file format consists of a single **.img** file. This is a simpler file format than the shapefile. It is sometimes accompanied by an .xml file which usually stores metadata information about the raster layer.

2. GeoTiff

A popular public domain raster data format is the **GeoTIFF** format. If maximum portability and platform independence is important, this file format may be a good choice.

1. File Geodatabase

A raster file can also be stored in a file geodatabase alongside vector files. Geodatabases have the benefit of defining image mosaic structures thus allowing the user to create "stitched" images from multiple image files stored in the geodatabase.

Managing GIS Files

Unless you are intimately familiar with the file structure of a GIS file, it is best to copy/move/delete GIS files from within the software environment. **ArcCatalog** (part of the ArcGIS suite) acts like a Windows file management environment with the added benefit that it recognizes GIS files.

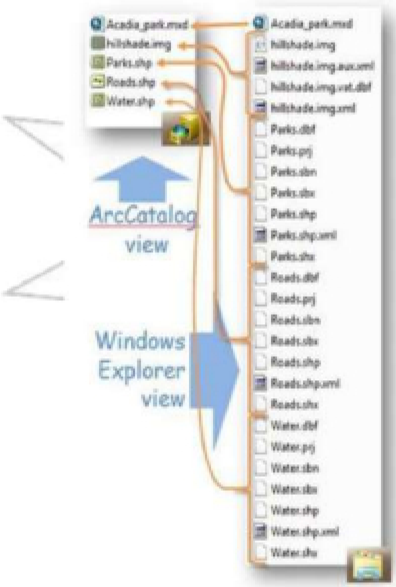


Figure 3.2: Windows Explorer view vs. ArcCatalog view. Note how the many files that make up the Parks shapefile (as viewed in a Windows Explorer environment) appears as a single entry in the ArcCatalog view. This makes it easier to rename the shapefile since it needs to be done only for a single entry in ArcCatalog (as opposed to renaming the Parks files seven times in the Windows Explorer environment).

CHAPTER 6

REMOTE SENSING CONCEPTS AND APPLICATION IN AGRICULTURE

Definition:

- Remote sensing is the acquisition of information about an object without making physical contact with the object.

Concept of remote sensing

- Remote sensing is technique of deriving information about objects on the surface of the earth without physically contact into them. This process involves making observations using sensors mounted on platforms (aircrafts and satellites) which are at considerable height from earth surface and recording the observations on suitable medium. This is shown in Fig. 6.2

Source of energy → *Target* → *Sensor* → *Processing station* → *Analysis* → *Application*

- Electro-magnetic radiation which is **reflected** or **emitted** from an object is the usual source of remote sensing data. However any media such as gravity or magnetic fields can be utilized in remote sensing.
- A device to detect the electro-magnetic radiation reflected or emitted from an object is called a "remote sensor" or "**sensor**". Cameras or scanners are examples of remote sensors.
- A vehicle to carry the sensor is called a "**platform**". Aircraft or satellites are used as platforms.
- **Working Principle:** Different objects return different amount and kind of energy in different bands of EM spectrum (Electromagnetic radiations) incident upon it. This property of the object depends on the structural, physical and chemical composition, surface roughness, intensity and wavelength of radiant energy, hence we can identify objects by collecting and analyzing returned energy.
- The remote sensing data will be processed automatically by computer and/or manually interpreted by humans, and finally utilized in agriculture, land use, forestry, geology, hydrology, oceanography, meteorology, environment etc.

TYPES OF REMOTE SENSING

There are basically two types of remote sensing

1. Active remote sensing
2. passive remote sensing

1. **Active remote sensing**
   In this type, sensors emit (generates) and uses their own source of energy.
   Example;
   LIDAR (LIght Detection And Ranging)
   RADAR (RAdio Detection And Ranging)

- On the other hand, emits energy in order to scan objects and areas where upon a sensor then detects and measures the radiation that is reflected or backscattered from the target.
- RADAR is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds and direction of an object.

2. **Passive remote sensing**
- Detect natural radiation that is emitted or reflected by the object or surrounding area being observed.
- Reflected sunlight is the most common source of radiation measured by passive sensors.
- Examples of passive remote sensors include film photography, infrared, and radiometers.

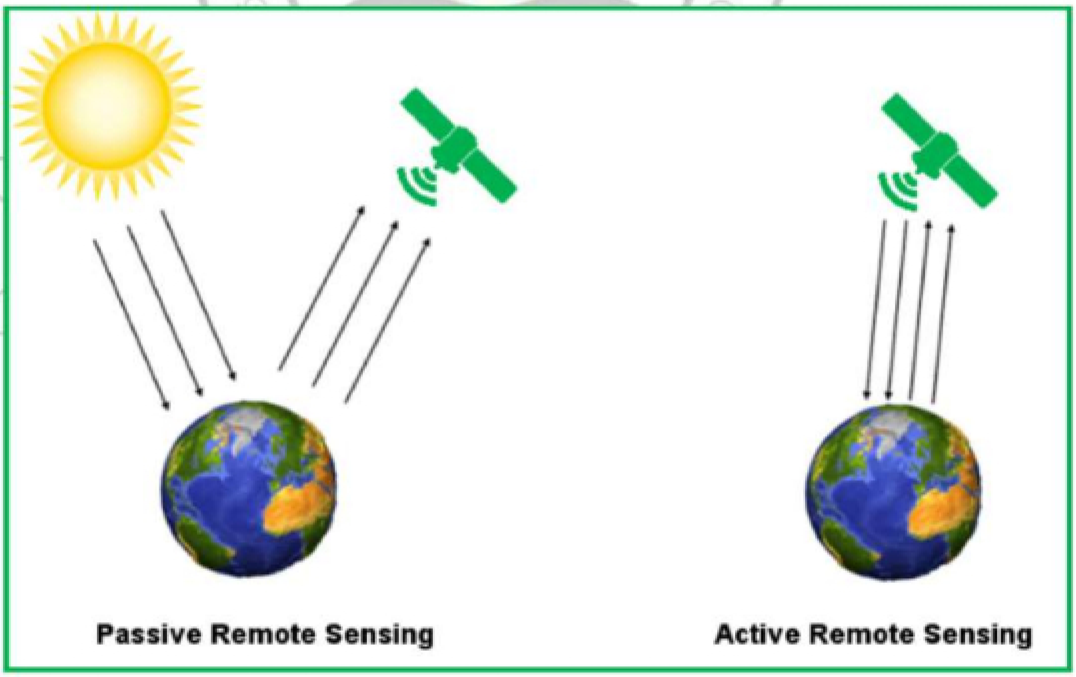


Fig. 6.1 Active and passive remote sensing

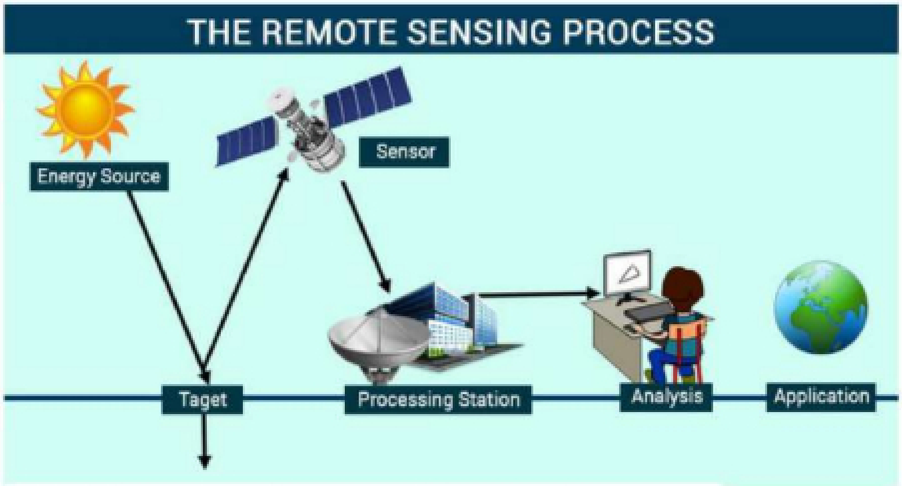


Fig. 6.2 Remote sensing process (Source to ultimate

Application of remote sensing in agriculture

1) Crop production forecasting
2) Assessment of crop damage and crop progress
3) Horticulture, cropping system analysis
4) Crop identification
5) Crop acreage estimation
6) Crop condition assessment and stress detection
7) Identification of planting and harvesting dates
8) Crop yield modeling and estimation
9) Identification of pest and disease infestation
10) Soil moisture est;estimation
11) Irrigation monitoring and management
12) Soil mapping
13) Drought monitoring
14) Land cover and land degradation mapping
15) Identification of problematic soils
16) Crop nutrient deficiency detection
17) Determination of water content5 of field crops
18) Crop yield forecasting
19) Flood mapping and monitoring
20) Collection of pest and current weather data
21) Water resources mapping
22) Precision farming
23) Climate change monitoring
24) Soil management practices
25) Air moisture estimation
26) Crop health analysis
27) Land mapping

CHAPTER 7
IMAGE PROCESSING AND INTERPRETATION

Definition:

- **Image processing** is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image.

Methods of image processing

1. **Analogue image processing**
   Analogue image processing can be used for the hard copies like printouts and photographs.
2. **Digital image processing**
   Digital Image Processing means processing digital image by means of a digital computer. We can also say that it is a use of computer algorithms, in order to get enhanced image either to extract some useful information.

The steps involved in image processing are as follows:

1. Image Acquisition
- It is basically capturing an image.
- Generally, the image acquisition stage involves pre-processing, such as scaling, etc.

2. Image Enhancement
- It is the process of filtering image (removing noise, increasing contrast, etc) to improve the quality.
- The resulting image will be more suitable than the original image.

3. Image Restoration
- It is the process of improving appearance (reducing blurring etc) of an image by mathematical or probabilistic models.

4. Color Image Processing
- It has become more popular since the use of the digital image has increased.

5. Multi-Resolution Processing
- It is the process of representing images in various degrees of resolution.

6. **Compression**
- It involves the techniques for reducing the size of the image with minimum deterioration in its quality.

7. **Morphological Processing**
- It is the process for extracting image components that are useful in the representation and description of shape.

8. **Segmentation**
- It is the process of partitioning the image into **multiple segments.**

9. **Representation and Description**
- It involves representing an image in various forms:
  Boundary Representation: It focuses on the **external shape** characteristics such as corners and inflections.
  Regional Representation: It focuses on **internal properties** such as texture and skeletal shape.

10. **Feature Matching**
- We can extract the **same features** from a different image of the same cathedral taken from a **different angle.**

11. **Recognition**
- It is the process of **assigning labels** to an object based on its **description.**

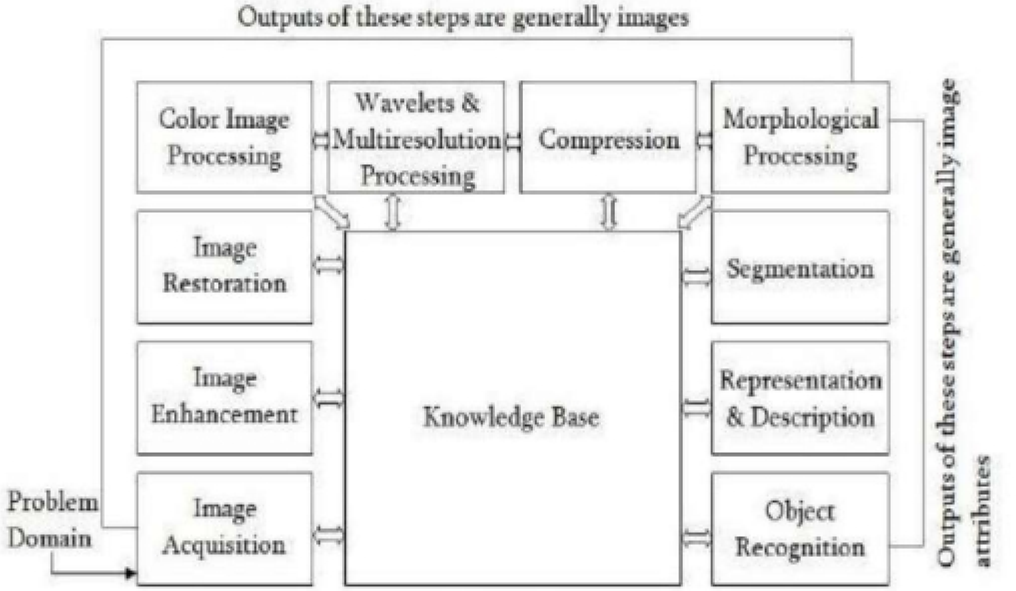


Fig 7.1. Steps involved in image processing

IMAGE INTERPRETATION

- **Image interpretation** is the process of examining an aerial photo or digital remote sensing image and manually identifying the features in that image.

  - **OR**

- **Image interpretation** is defined as the extraction of qualitative and quantitative information in the form of a map, about the shape, location, structure, function, quality, condition, relationship of and between objects, etc. by using human knowledge or experience.

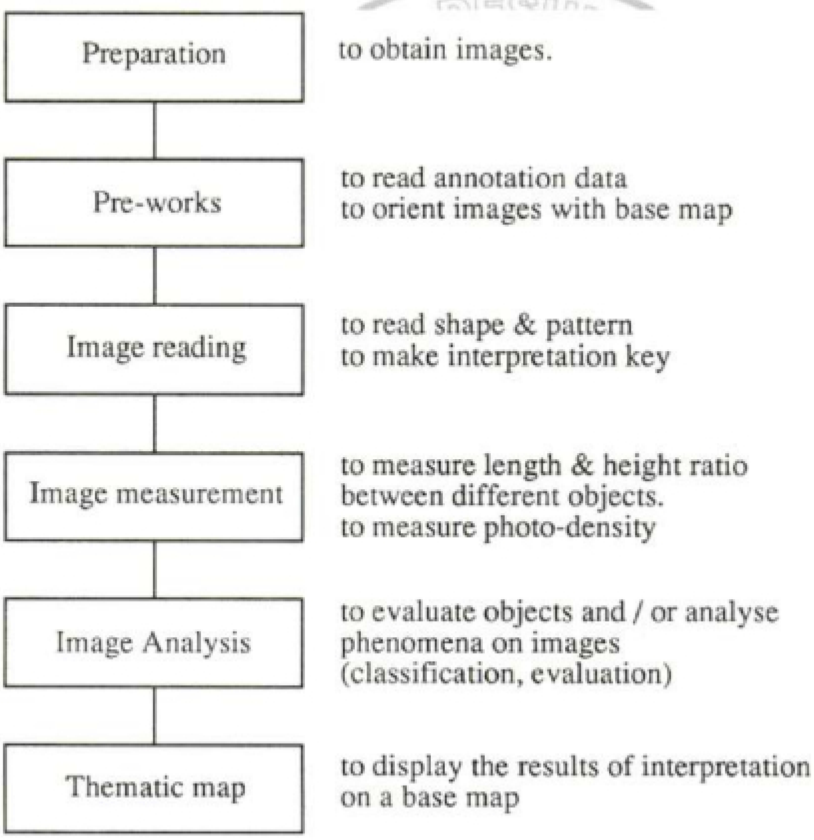


Fig 7.2 Image interpretation process

CHAPTER 8

GLOBAL POSITIONING SYSTEM (GPS), COMPONENTS AND ITS FUNCTIONS

Definition:

- The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions.

- GPS is a satellite navigation system used to determine the ground position of an object.

Components of GPS system

1) GPS Antenna
2) GPS Receivers
3) GPS Display and Storage
4) Interface
5) DGPS
6) GPS Ground Control Stations
7) GPS Satellites

Functions of GPS components

1. GPS Antenna: Antennae come in many shapes and sizes and its basic function is to receive the GPS Signal. Position data is interpreted based on antenna location.
2. GPS Receivers: Receiver is used for collection of geographical data of specific area. In differential GPS signal is corrected as data is acquired, requires an additional satellite or second receiver. Basic function of GPS receiver is to decode the signal retrieved by the antenna.
3. GPS Display and Storage: Records and reports are displayed and stored by GPS display and storage components. GPS data is available to the user numerically and graphically. Data can be integrated with the receiver or provided by handheld or laptop, computer.
4. Interface: Proprietary protocol is unique to receiver manufacturer.
5. Standardized protocol allows data exchange between many devices or interfacing with other devices. For example NMEA 0183 ASCII code, Consists of Data Sentences.
6. DGPS: is essentially a system to provide positional corrections to GPS signals.
7. GPS Ground Control Stations/Control Segment: uses measurements collected by the monitor stations to predict the behavior of each satellites

orbit and atomic clocks. Prediction data is linked up to the satellites for transmission to users.

8. GPS Satellites/Space segment: The space segment includes the satellites and the rockets that launch the satellites from Cape Canaveral in Florida, U.S. Satellite are orientating the points of solar panels towards the sun and antennas towards the earth. Each satellite contains four atomic clocks.

FUNCTIONS OF GPS (Global Positioning System)

The GPS functions include;

1. **Giving a location**

- This is the whole point of a navigation system.
- Its ability to accurately triangulate your position based on the data transmissions from multiple satellites.
- It will give your location in coordinates, either latitude and longitude or UTMs (Universal Transverse Mercators)
- UTMs are used to pinpoint a location on a map.
- Most topographical maps have UTM gridlines printed on them.

2. Point to point Navigation

- This GPS navigation feature allows you to add waypoints to your trips.
- By using a map, the co-ordinates of a road or the point where you are standing, you can create a point to point route to the place where you are headed.

3. Plot Navigation

- This feature in a GPS allows you to combine multiple waypoints and move point to point.
- Once you reach the first waypoint, the GPS can automatically point you on your way to the next one.

4. Keeping track of your track

- Tracks are some of the most useful functions of Portable Navigation Systems. You can map where you have already been.
- This virtual map is called a track and you can programme the GPS system to automatically drop track-points as you travel, either over intervals of time or distance.

CHAPTER 9

INTRODUCTION TO CROP SIMULATION MODELS

Definition:

- **A Crop Simulation Model (CSMs)** is a simulation model that describes processes of crop growth and development as a function of weather conditions, soil conditions, and crop management.

✓ Crop simulation models are use to predict the likely yield response to different levels of a particular input.

✓ Typically, such models estimate times that specific growth stages are attained, biomass of crop components (e.g., leaves, stems, roots and harvestable products) as they change over time, and similarly, changes in soil moisture and nutrient status.

✓ They are dynamic models that attempt to use fundamental mechanisms of plant and soil processes to simulate crop growth and development. The algorithms used vary in detail, but most have a time step of one day.

Why we need simulation models?

1. To incorporate knowledge gain from field experimentation.
2. To provide a structure that promotes interdisciplinary cooperation.
3. To promote the use of systems investigation for solving troubles.

4. To offer dynamic, quantitative tools for analyzing the difficulty of cropping systems.

Applications of crop model:

1) Evaluation of potential yields.
2) Assessment of yield gaps: principal causes and their contribution.
3) Yield forecasting.
4) Impact assessment of climatic variability and climatic change.
5) Optimizing management- Dates of planting, variety, irrigation and nitrogen fertilizer.
6) Environmental impact- percolation, N losses, GHG emissions, SOC dynamics.
7) Plant type design and evaluation.

8) Genotype by environment interactions

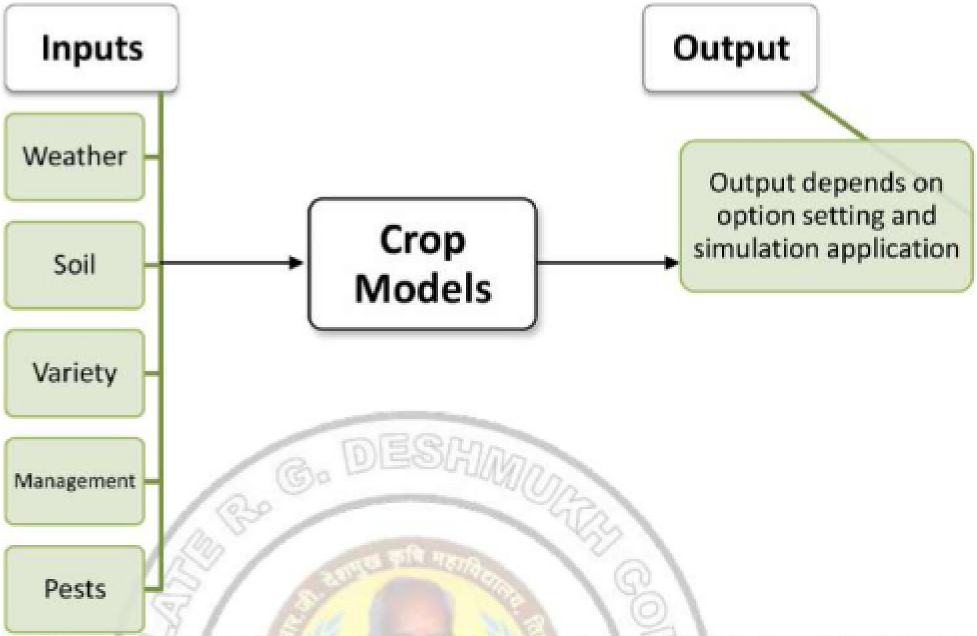
COMMONLY USED CROP SIMULATION MODELS

1. **CropSyst**: a multi-year multi-crop daily time-step crop simulation model
2. **APSIM**: the Agricultural Production Systems sIMulator is a highly advanced simulator of agricultural systems.
3. DSSAT (Decision Support System for Agrotechnology Transfer
4. AquaCrop
5. InfoCrop
6. APSIM (Agricultural Production System Simulator)

Steps in modeling

1. Define goals: Agricultural system
2. Define system and its boundaries: Crop model
3. Define key variables in system:
   - State variables are those which can be measured. e.g. soil moisture content, crop yield etc
   - Rate variables are the rates of different processes operating in a system. e.g. phosynthesis rate, transpiration rate.
   - Driving variables are the variables which are not part of the system but the affect the system. e.g. sunshine, rainfall.
   - Auxiliary variables are the intermediated products. e.g. dry matter partitioning, water stress etc
5. Quantify relationships (evaluation):
6. Calibration: Model calibration is the initial testing of a model and tuning it to reflect a set of field data or process of estimating model parameters by comparing model predictions (out-put) for a given set of assumed conditions with observed data for the same conditions.

   Validation: Testing of a model with a data set representing "local" field data. This data set represents an independent source different from the data used to develop the relation



7. Sensitivity analysis: Validated model is then tested for its sensitivity to different factors (e.g. temperature, rainfall, N dose). This is done to check whether the model is responding to changes in those factors or not.

CHAPTER 10

USES OF CROP STIMULATION MODELS FOR OPTIMIZATION OF AGRICULTURAL INPUTS

Application of Crop Simulation Modeling in Agriculture

1. Crop modeling and simulation of plant yield helps in the management of cropping systems also in the formation of stocks, making of agricultural policies and zoning and more.
2. Crop models help in comparing multiple crop models with each other, for their variability in accordance with climate factors, CO_2 levels, rainfall, etc.
3. The crop models are run with observed data which helps in improving code and relationships of crop models to give more accurate responses to climatic and genetic factors.
4. The crop models are calibrated with climate and economic models to assess the impact of different climate scenarios on crop production and food security for different regions.
5. This helps in developing methodologies for simulating climate impacts on agriculture for locations with low soil fertility and low water availability.
6. Tests of various crop models are done to test the sensitivity to temperature, to understand life cycles and yield.
7. The regional data like weather and soils are collected to understand, develop and evaluate adaptation and mitigation strategies under future climatic conditions.
8. These adaptations will include crop management and genetic improvement.

CHAPTER 11

STCR - APPROACH FOR PRECISION AGRICULTURE

Soil Test Crop Response (STCR) / Targeted Yield Concept

- ICAR established the AICRP on STCR in 1967 and the STCR concept was developed by Ramamoorthy, in 1987.
- STCR provides the relationship between a soil test value and crop yield. The soil test values are needed to be correlated with actual crop response obtained under field conditions. This is also called as **"rationalized fertilizer prescription approach"** in which inherent soil fertility and yield level of the crop are taken in to account while recommending the fertilizer doses.

Objective of STCR

1. To prescribe fertilizer doses for a given crop based on soil test value to achieve the targeted yields under irrigated condition by using mathematical equation for different crops.
2. To check the efficiency of utilization of soil and added fertilizer nutrients.

Concept of STCR

STCR approach is aiming at obtaining a basis for precise quantitative adjustment of fertilizer doses under varying soil test values and response conditions of the farmers and for targeted levels of crop production.

STCR methodology takes in to account the three factors;

1. Nutrient requirement (NR) in kg/quintal of the produce
2. Percentage contribution from soil available nutrients (SE)
3. Percentage contribution from added fertilizers towards making effective fertilizer prescriptions for specific yields (FE in %).

$$\text{i) Nutrient Requirement (NR)} = \frac{\text{Total nutrient uptake (grain + straw) kg/ha}}{\text{Yield of grain (q/ha)}}$$

(in kg for producing 1 Quintals of grain)

$$\text{ii) Fertilizer Efficiency (FE in \%)} = \frac{[\text{Total nutrient uptake (kg/ha)} - (\text{STV in treated Plot kg/ha} \times \text{SE in \%})]}{\text{Fertilizer dose applied (kg/ha)}} \times 100$$

iii) Soil Efficiency (SE in %) = $\frac{\text{Total nutrient uptake in control (kg/ha)}}{\text{Soil test value in control (kg/ha)}} \times 100$

With the help of above parameters, adjustment equations have been developed for a number of crops in various soils.

Advantages of STCR

1) Efficient and profitable site specific fertilizer recommendation for increased crop production and for maintenance of soil fertility.

2) Aims to provide balanced, efficient and profitable nutrient application rates for pre- set yield targets giving due consideration to basic fertility status of soil

Targeted yield concepts:

These are soil test based recommendations but given for different yield goals and not for a single optimum yield level. A large variety of fertilizer prescription have been made available by putting soil test values in to certain mathematical equations and finding out the amounts of nutrients needed for a given yield target.

CHAPTER 12

NANOTECHNOLOGY-DEFINITION, CONCEPTS AND TECHNIQUES

Definition:

- ✓ Nanotechnology is an art and science of manipulating matter at nanoscale.
- ✓ In other words Nanotechnology is the study, process and manipulation of material at a molecular level i.e. one of its dimension should lie in the range of **1-100 nm (10^{-9} to10^{-7}m).**

Concepts of nanotechnology

Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current work and concepts that are more advanced. It refers to the projected ability to construct items from the bottom up, using techniques and tools being developed to make complete, high performance products.

One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular life-forms, the bacteria of the genus *Mycoplasma*, are around 200 nm in length. Nanotechnology is taken as the scale range 1 to 100 nm. The lower limit is set by the size of atoms since nanotechnology must build its devices from atoms and molecules. The upper limit is more or less arbitrary but is around the size below which phenomena not observed in larger structures start to become apparent and can be made use of in the nano device. These new phenomena make nanotechnology distinct from devices which are merely miniaturized versions of an equivalent macroscopic device; such devices are on a larger scale and come under the description of microtechnology.

Two main approaches are used in nanotechnology. In the "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the "top-down" approach, nano-objects are constructed from larger entities without atomic-level control.

Different approaches / techniques in nanotechnology

A] Bottom-up approaches

These seek to arrange smaller components into more complex assemblies.

- DNA nanotechnology utilizes the specificity of Watson–Crick base pairing to construct well-defined structures out of DNA and other nucleic acids.
- Approaches from the field of "classical" chemical synthesis also aim at designing molecules with well-defined shape.
- Molecular self-assembly seeks to use concepts of supramolecular chemistry, and molecular recognition in particular, to cause single-molecule components to automatically arrange themselves into some useful conformation.
- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical upon a surface in a desired pattern in a process called dip pen nanolithography. This technique fits into the larger subfield of nanolithography.
- Molecular Beam Epitaxy allows for bottom up assemblies of materials, most notably semiconductor materials commonly used in chip and computing applications, stacks, gating, and nanowire lasers.

B] Top-down approaches

These seek to create smaller devices by using larger ones to direct their assembly.

- Many technologies that descended from conventional solid-state silicon methods for fabricating microprocessors are now capable of creating features smaller than 100 nm, falling under the definition of nanotechnology. Giant magnetoresistance-based hard drives already on the market fit this description, as do atomic layer deposition (ALD) techniques. Peter Grünberg and Albert Fert received the Nobel Prize in Physics in 2007 for their discovery of Giant magnetoresistance and contributions to the field of spintronics.

- Solid-state techniques can also be used to create devices known as nanoelectromechanical systems or NEMS, which are related to microelectromechanical systems or MEMS.
- Focused ion beams can directly remove material, or even deposit material when suitable precursor gasses are applied at the same time. For example, this technique is used routinely to create sub-100 nm sections of material for analysis in Transmission electron microscopy.
- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a resist, which is then followed by an etching process to remove material in a top-down method.

C] Functional approaches

- These seek to develop components of a desired functionality without regard to how they might be assembled.
- Magnetic assembly for the synthesis of anisotropic superparamagnetic materials such as recently presented magnetic nano chains.
- Molecular scale electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nanoelectronic device. For an example see rotaxane.
- Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar.

D] Biomimetic approaches

- Bionics or biomimicry seeks to apply biological methods and systems found in nature, to the study and design of engineering systems and modern technology. Biomineralization is one example of the systems studied.
- Bionanotechnology is the use of biomolecules for applications in nanotechnology, including use of viruses and lipid assemblies. Nanocellulose is a potential bulk-scale application.

CHAPTER 13

Brief introduction about Nano-scale effects, Nano particles

Definition

Nanoscale technology is a branch of nanotechnology in which standard size tools are used to manufacture simple structures and devices with dimensions on the order of a few nanometer s or less, where one nanometer (1 nm) is equal to a billionth of a meter (10^{-9} m).

Introduction

The **nanoscale** usually refers to structures with a length scale applicable to nanotechnology, usually cited as 1–100 nanometers. A nanometer is a billionth of a meter. The nanoscale is a lower bound to the mesoscopic scale for most solids.

The nanoscale is the size at which fluctuations in the averaged properties begin to have a significant effect on the behavior of a system, and must be taken into account in its analysis. It is marked as the point where the properties of a material change. The properties of a material are caused by 'bulk' or 'volume' effects, namely which atoms are present, how they are bonded, and in what ratios. The properties of a material change, and while the type of atoms present and their relative orientations are still important, 'surface area effects' (also referred to as quantum effects) become more apparent – these effects are due to the geometry of the material (how thick it is, how wide it is, etc.), which, at these low dimensions, can have a drastic effect on quantized states, and thus the properties of a material.

Nanparticles

Definition

A particle of any shape with dimensions in the 1×10^{-9} and 1×10^{-7} m range

Or

A nanoparticle is an object with all three external dimensions in the nanoscale, whose longest and shortest axes do not differ significantly, with a significant difference typically being a factor of at least 3.

Properties of nano particles

The properties of a material in nanoparticle form are usually very different from those of the bulk material even when divided into micrometer-size particles. A number of causes contribute to that effect.

1. Large area/volume ratio

A bulk material should have constant physical properties (such as thermal and electrical conductivity, stiffness, density, and viscosity) regardless of its size. However, in a nanoparticle, the volume of the surface layer becomes a significant fraction of the particle's volume; whereas that fraction is insignificant for particles with diameter of one micrometer or more.

2. Interfacial layer

Nanoparticles dispersed in a medium of different composition, the interfacial layer formed by ions and molecules from the medium that are within a few atomic diameters of the surface of each particle can mask or change its chemical and physical properties. These layers can be considered an integral part of each nanoparticle.

3. Solvent affinity

Suspensions of nanoparticles are possible since the interaction of the particle surface with the solvent is strong enough to overcome density differences, which otherwise usually result in a material either sinking or floating in a liquid.

4. Coatings

Nanoparticles often develop or receive coatings of other substances, distinct from both the particle's material and of the surrounding medium. Even when only a single molecule thick, these coatings can radically change the particles' properties, such as and chemical reactivity, catalytic activity, and stability in suspension.

5. Diffusion across the surface

The high surface area of a material in nanoparticle form allows heat, molecules, and ions to diffuse into or out of the particles at very large rates. The small particle diameter, on the other hand, allows the whole material to reach homogeneous equilibrium with respect to diffusion in a very short time. Thus many processes that depend on diffusion, such as sintering can take place at lower temperatures and over shorter time scales.

6. Ferromagnetic and ferroelectric effects

The small size of nanoparticles affects their magnetic and electric properties. For example, while particles of ferromagnetic materials in the micrometer range are widely used in magnetic recording media, for the stability of their magnetization state, those smaller than 10 nm can change their state as the result of thermal energy at ordinary temperatures, thus making them unsuitable for that application.

7. Melting point depression

A material may have lower melting point in nanoparticle form than in the bulk form. For example, 2.5 nm gold nanoparticles melt at about 300 °C, whereas bulk gold melts at 1064 °C.

8. Quantum mechanics effects

Quantum mechanics effects become noticeable for nanoscale objects. They include quantum confinement in semiconductor particles, localized surface plasmons in some metal particles, and superparamagnetism in magnetic materials. Quantum dots are nanoparticles of semiconducting material that are small enough (typically sub 10 nm or less) to have quantized electronic energy levels.

Quantum effects are responsible for the deep-red to black color of gold or silicon nanopowders and nanoparticle suspensions. Absorption of solar radiation is much higher in materials composed of nanoparticles than in thin films of continuous sheets of material. In both solar PV and solar thermal applications, by controlling the size, shape, and material of the particles, it is possible to control solar absorption.

Core-shell nanoparticles can support simultaneously electric and magnetic resonances, demonstrating entirely new properties when compared with bare metallic nanoparticles if the resonances are properly engineered. The formation of the core-shell structure from two different metals enables an energy exchange between the core and the shell, typically found in upconverting nanoparticles and downconverting nanoparticles, and causes a shift in the emission wavelength spectrum.

By introducing a dielectric layer, plasmonic core (metal)-shell (dielectric) nanoparticles enhance light absorption by increasing scattering. Recently, the metal core-dielectric shell nanoparticle has demonstrated a zero backward scattering with enhanced forward scattering on a silicon substrate when surface plasmon is located in front of a solar cell.

9. Regular packing

Nanoparticles of sufficiently uniform size may spontaneously settle into regular arrangements, forming a colloidal crystal. These arrangements may exhibit original physical properties, such as observed in photonic crystals.

Characterization

Nanoparticles have different analytical requirements than conventional chemicals, for which chemical composition and concentration are sufficient metrics. Nanoparticles have other physical properties that must be measured for a complete description, such as size, shape, surface properties, crystallinity, and dispersion state. Additionally, sampling and laboratory procedures can perturb their dispersion state or bias the distribution of other properties. In environmental contexts, an additional challenge is that many methods cannot detect low concentrations of nanoparticles that may still have an adverse effect. For some applications, nanoparticles may be characterized in complex matrices such as water, soil, food, polymers, inks, complex mixtures of organic liquids such as in cosmetics, or blood.

There are several overall categories of methods used to characterize nanoparticles. Microscopy methods generate images of individual nanoparticles to characterize their shape, size, and location. Electron microscopy and scanning probe microscopy are the dominant methods. Because nanoparticles have a size below the diffraction limit of visible light, conventional optical microscopy is not useful. Electron microscopes can be coupled to spectroscopic methods that can perform elemental analysis. Microscopy methods are destructive, and can be prone to undesirable artifacts from sample preparation, or from probe tip geometry in the case of scanning probe microscopy. Additionally, microscopy is based on single-particle measurements, meaning that large numbers of individual particles must be characterized to estimate their bulk properties.

Spectroscopy, which measures the particles' interaction with electromagnetic radiation as a function of wavelength, is useful for some classes of nanoparticles to characterize concentration, size, and shape. X-ray, ultraviolet–visible, infrared, and nuclear magnetic resonance spectroscopy can be used with nanoparticles. Light scattering methods using laser light, X-rays, or neutron scattering are used to determine particle size, with each method suitable for different size ranges and particle compositions. Some miscellaneous methods are electrophoresis for surface charge, the Brunauer–Emmett–Teller method for surface area, and X-ray diffraction for crystal structure, as well as mass spectrometry for particle mass, and particle counters for particle number. Chromatography, centrifugation, and filtration techniques can be used to separate nanoparticles by size or other physical properties before or during characterization.

Various nanoparticles which are commonly used in the consumer products by industrial sectors		
Sl. No	**Industrial sectors**	**Nanoparticles**
1	Agriculture	silver, silicon dioxide, potassium, calcium, iron, zinc, phosphorus, boron, zinc oxide and molybdenum
2	Automotive	tungsten, disulfidesilicon dioxide, clay, titanium dioxide, diamond, copper, cobalt oxide, zinc oxide, boron nitride, zirconium dioxide, tungsten, γ-aluminium oxide, boron, palladium, platinum, cerium(IV) oxide, carnauba, aluminium oxide, silver, calcium carbonate and calcium sulfonate
3	Construction	titanium, dioxidesilicon dioxide, silver, clay, aluminium oxide, calcium carbonate calcium silicate hydrate, carbon, aluminium phosphate cerium(IV) oxide and calcium hydroxide
4	Cosmetics	silver, titanium dioxide, gold, carbon, zinc oxide, silicon dioxide, clay, sodium silicate, kojic acid and hydroxy acid
5	Electronics	silver, aluminum, silicon dioxide and palladium
6	Environment	silver, titanium dioxide, carbonmanganese oxide, clay, gold and selenium
7	Food	silver, clay, titanium dioxide, gold, zinc oxide, silicon dioxide, calcium, copper, zinc, platinum, manganese, palladium and carbon
8	Home appliance	silver, zinc oxide, silicon dioxide, diamond and titanium dioxide
9	Medicine	silver, gold, hydroxyapatite, clay, titanium dioxide, silicon dioxide, zirconium dioxide, carbon, diamond, aluminium oxide and ytterbium trifluoride
10	Petroleum	tungsten, disulfidezinc oxide, silicon dioxide, diamond, clay, boron, boron nitride, silver, titanium dioxide, tungsten, γ-aluminium oxide, carbon, molybdenum disulfide and γ-aluminium oxide
11	Printing	toner, deposited by a printer onto paper or other substrate
12	Renewable energies	titanium, palladium, tungsten disulfide, silicon dioxide, clay, graphite, zirconium(IV) oxide-yttria stabilized, carbon, gd-doped-cerium(IV) oxide, nickel cobalt oxide, nickel(II) oxide, rhodium, sm-doped-cerium(IV) oxide, barium strontium titanate and silver
13	Sports and fitness	silver, titanium dioxide, gold, clay and carbon
14	Textile	silver, carbon, titanium dioxide, copper sulfide, clay, gold, polyethylene terephthalate and silicon dioxide

CHAPTER 14

NANO-PESTICIDES, NANO-FERTILIZERS, NANO-SENSORS

Nanomaterials

Materials, whether of natural or manufactured origin, possess one or more external dimensions in the range of 1-100nm.

Ex: Fertilizer, Plant protection things - pesticides, fungicides, Weedicides, Plant pathogen detection tools.

Nano-pesticides

Definition:

Small engineered structures with useful pesticides properties such as, it Stiffness, crystalinity permeability, biodegradability, large specific area, increased affinity to the target.

OR

Nano-scale either active ingredients or inert ingredients with a particle size of 100 nm or less

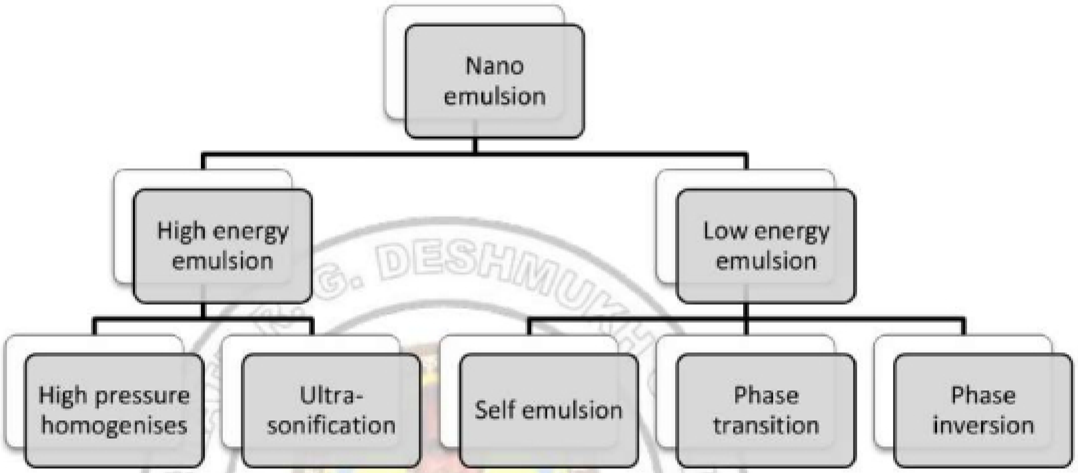
Formulation of Nano-pesticide

Nanopesticide delivery techniques are nanoemulsions, nanoencapsulates, nanocontainers, and nanocages

Nanoemulsions

- Consist of lipid or polymeric vesicles or particles
- Size 20-200 nm
- Larger surface area, slower release
- Non sedimentation or creaming

Downsizing of natural oils to form nanoemulsions could be effective as larvicidal agents



Nano suspensions

- Submicron colloidal dispersions of pure active compounds typically range from 50-500 mu -Solvent-diffusion methods
- Improvement of efficacy due to higher surface area
- Higher solubility, higher mobility
- Induction of systemic activity due to smaller particle size

Nano encapsulation

- Encapsulation -packaging the nano-scale active ingredient within a kind of tiny 'envelope' or 'shell'
- Nanotechnology enables us to manipulate the properties of the outer shell of a capsule

Uses

Protection, Increase solubility, Reduce the contact of active ingredients with agricultural workers, Environment- reducing run-off rates

Designs	
Slow release	The capsule releases over a longer period of time
Quick-release	Breaks upon contact with a surface (e.g. when pesticide hits a leaf)
Moisture release	Releases contents in the presence of water (Soil)
Heat-release	Releases when the environment warms above a certain temperature
pH release	Releases only in specific pH
Ultrasound release	Ruptured by an external ultrasound Frequency
DNA Nano capsule	Smuggles a short strand of foreign DNA into a living cell

Nanoherbicide

- Herbicides inside nano particles are developed that can be timed-release or have release linked to an environmental trigger .
- Less herbicide is required to achieve the reduction weed reduction effects .
- If the active ingredient is combined with a smart delivery system, herbicide will be applied only when necessary according to the conditions present in the field.

Nano fertilizer

- Use of nanoscale nutrients to suppress crop disease.
- Amendment protocols necessary to maximize plant health often vary with the level of infection or absence of the pathogen.
- Micronutrients are critical in the defense against crop disease, with tissue infection inducing a cascade of reactions commonly resulting in the production of inhibitory secondary metabolites.

These metabolites are often generated by enzymes that require activation by micronutrient cofactors.

- The use of nanoparticle-based micronutrient formulations may offer
- A highly effective novel platform for crop disease suppression
- Yield enhancement through more targeted
- Strategic nutrition-based promotion of host resistance.
- Nano particles may enter plant leaves through stomata and the cuticle structures.
- NP metals/metal oxides are more effectively translocated than corresponding bulk elements and that this greater transportability exists in both xylem and phloem.
- Sufficient micronutrient content in key tissues will enhance plant defense in the presence of pathogens but a number of factors may limit this supply.
- Nonessential inorganic compounds may play in the activation of host defense mechanisms

Nanosensors

- ✓ Nano sensors with immobilized bio receptor probes that are selective for target analyzing molecules.
- ✓ Nano-sensors use to determine the time of crop harvest, detect crop health and determine microbial or chemical contamination of the crop.
- ✓ Nano sensors used to diagnose disease caused by infecting soil microorganisms, such as viruses, bacteria, and fungi via the quantitative measurement of differential oxygen consumption in the respiration (relative activity) of good microbes and bad microbes in the soil.

Positive effect of nanoparticals

- Nano encapsulated agrochemicals designed in such a way that they possess all indispensable properties such as A effective concentration with high solubility, stability and effectiveness.
- Time controlled release in response to certain stimuli
- Enhanced targeted activity.
- Less Eco toxicity with harmless
- Effortless mode of delivery thus avoiding repetitive application.

Negative effect of nano particals

- Nano particles on biological systems and the environment such as toxicity generated by free radicals leading to lipid peroxidation and DNA damage.
- High concentration of nanosilica silver produced some chemical injuries on the tested plants (cucumber leaves and pansy flowers).
- Extremely high doses of these materials are associated with fibrotic lung responses and result in inflammation and an increased risk of carcinogenesis.

CHAPTER 15

USE OF NANOTECHNOLOGY IN SEED AND WATER FOR SCALING-UP FARM PRODUCTIVITY

Nanomaterials in Seed Germination, Crop Growth and Quality Enrichment

Nanoscience is a new platform of scientific innovation that involves the development of approaches to a range of inexpensive nanotech applications for enhanced seed germination, plant growth, development and acclimation to environments. The germination of seeds is a sensitive phase in the life cycle of plant, which facilitates seedling development, survival and population dynamics. However, seed germination is largely affected by different parameters including environmental factors, genetic trait, moisture availability and soil fertility. In this concern, an extensive number of studies have shown that the application of 24 nanomaterials has positive effects on germination as well as plant growth and development. For example, the application of multiwalled carbon nanotubes (MWCNTs) positively influences seed germination of different crop species including tomato, corn, soybean, barley, wheat, maize, peanut and garlic. Similarly, nano SiO2, TiO2 and Zeolite application positively stimulate seed germination in crop plants. Fe/SiO2 nanomaterials have significant potential to improve seed germination in barley and maize.

Nanomaterials, such as ZnO, TiO2, MWCNTs, FeO, ZnFeCu-oxide, and hydroxyfullerenes are reported to increase crop growth and development with quality enhancement in many crop species including peanut, soybean, mungbean, wheat, onion, spinach, tomato, potato and mustard. For example, carbon nano materials fullerols, as OH-functionalized fullerenes have commonly exerted positive effects on plant growth. Seed dressings with Fullerol not only increase fruit number, fruit size, and final yield by up to 128%, but also stimulate the content of bioactive compounds, such as cucurbitacin-B, lycopene, charantin and inulin in fruits of bitter melon. Nano-iron fertilizer not only increased the agronomic traits of Dracocephalum moldavica with sowing density, but also improved essential oil contents of plants. Similarly, foliar application of nano- zinc and boron fertilizers was found to increase fruit yield and quality, including 4.4%–7.6% increases in total soluble solids (TSS), 9.5–29.1% decreases in titratable acidity (TA), 20.6%–46.1% increases in maturity index and 0.28–0.62 pH unit increases in juice pH on pomegranate (Punica granatum) without affecting any physical fruit characteristics. The studies of nutrients on slow/controlled release or control loss of nanofertilizers carried out in water and soil have confirmed that the long term availability of all the doped nutrients to the plant over the full crop period of cultivation is crucial for promoting germination, growth, flowering and fruiting. For example, hydroxyapatite nanomaterial-coated urea fertilizer releases nitrogen slowly and uniformly over up to 60 days, whereas the traditional bulk fertilizer losses only within 30 days with uneven release that reduced the nutrient efficiency of plants and adversely affects crop growth. Conversely, the examination in different studies offers conflicting evidence about the positive nexuses of nanomaterials on seed germination and growth of crops. Such variability may arise due to a number of factors related to nanomaterial characteristics, such as size, shape, surface coating and electronic properties, dose as well as mode of application and the plant species studied.

Nanotechnology in irrigation water filtration

The depletion of the available water resources in line with an increasing population directs researchers to study the usability of emerging technologies in this area. In the agriculture industry, which is among the areas that consume water resources mostly, the quality of water to be used directly affects the crop to be produced. Therefore, effective treatment of the existing water resources for reuse, improving the quality of water used in agriculture, reducing the costs of studies conducted in this field are among the important research areas. The major disadvantage of water treatment methods is the higher costs, and it is possible to reduce these costs, thanks to nanotechnology. Nanotechnological applications provide many advantages in water treatment. The large surface to volume ratio makes some nanoparticles capable of having minimal pressure relief potential for a magnetic separation. Hypercatalyst dechlorinates (chlorine remover), which is one of the nanotechnology products, is about 1000 times faster compared with any commercial catalysts. The membranes, which include nano-sized materials, increase resistance to pollution. Nano-sized materials make the surfaces long-term durable against biopollution and biocorrosion. The water treatment techniques that feature nanotechnology include membranes and filters based on carbon nanotubes, nanoporous ceramics and magnetic nanoparticles in particular. The filters made of carbon nanotubes, which have a semiconductor and metallic characteristic depending on their geometries, can be used to remove nano-sized toxic substances and contaminants in water to be treated. The cylindrical structure is maintained in filters made of carbon nanotubes completely. In this way, the filters become durable in long-term use and can be cleaned easily. Therefore, the carbon nanotubes stand out with their capability to remove pathogens, lead, uranium, heavy metals such as arsenic in water treatment. Nanoceramics filters utilize the fact that the opposite charges attract each other. The positively charged nanoceramic filters easily remove the negatively charged viruses and bacteria in the water to be treated. This filter system separates microbial endotoxins, genetic materials, pathogenic viruses and micro-scale particles. Water sources may also contain organic particles, pesticides, and herbicides. Researchers highlight the use of nanoparticle-filters in their studies to remove the organic particles, herbicides, and pesticides accumulated in the water. Nano-scale zero valent iron is the most widely used nanomaterial for water treatment in the soil and groundwater. Macro characteristics of the particles (electrical charge, solubility, reactivity, etc.) differ in the nano-scale. Consequently, many ideas that were imaginary once now become a reality by utilizing the properties of these nano-sized particles. Thanks to magnetic nanoparticles, it is possible to separate the toxic substances present in water, even at very low magnetic field gradients. For example, nano-crystals, such as mono-dispersive magnetite (Fe_3O_4), can be used for the removal of arsenic through a strong irreversible interaction with arsenic, while maintaining their magnetic properties.

CHAPTER 16

USE OF NANOTECHNOLOGY IN FERTILIZER AND PLANT PROTECTION FOR SCALING UP FARM PRODUCTIVITY

Nanofertilizers: An Efficient Source of Balanced Crop Nutrition

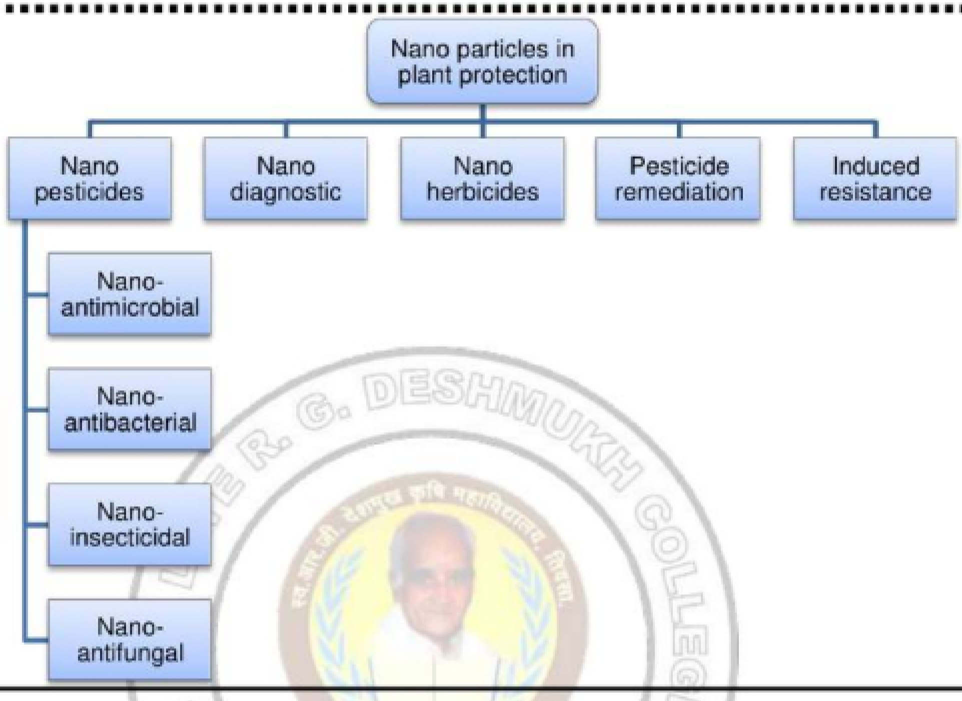
The use of engineered nanomaterials in the frame of sustainable agriculture has shown a completely new way of food production that could potentially overcome the uncertainty in crop sector with limited available resources. Nanofertilizers synthesized in specific intension to regulate the release of nutrients depending on the requirements of the crops while minimizing differential losses, have immense potentiality. For example, conventional nitrogen fertilizers are manifested by huge losses from the soil through leaching, evaporation, or even the degradation of up to 50–70%, which ultimately reduces the efficiency of fertilizers and elevates the cost of production. On the other hand, nanoformulations of nitrogenous fertilizers synchronize the release of fertilizer-N with their uptake demand by crops. Accordingly, nanoformulations prevent undesirable losses of nutrient via direct internalization by crops, and thereby avoiding the interaction of nutrients with soils, water, air and microorganisms. For instance, the application of porous nanomaterials, such as zeolites, clay or chitosan significantly reduces the losses of nitrogen by regulating the demand-based release and enhancing the plant uptake process. Ammonium charged zeolites have the potentiality to increase the solubility of phosphate minerals and thus exhibit improved phosphorus availability and uptake by crops. Graphene oxide films, a carbon-based nanomaterial, can prolong the process of potassium nitrate release, which extends the time of function and minimizes losses by leaching.

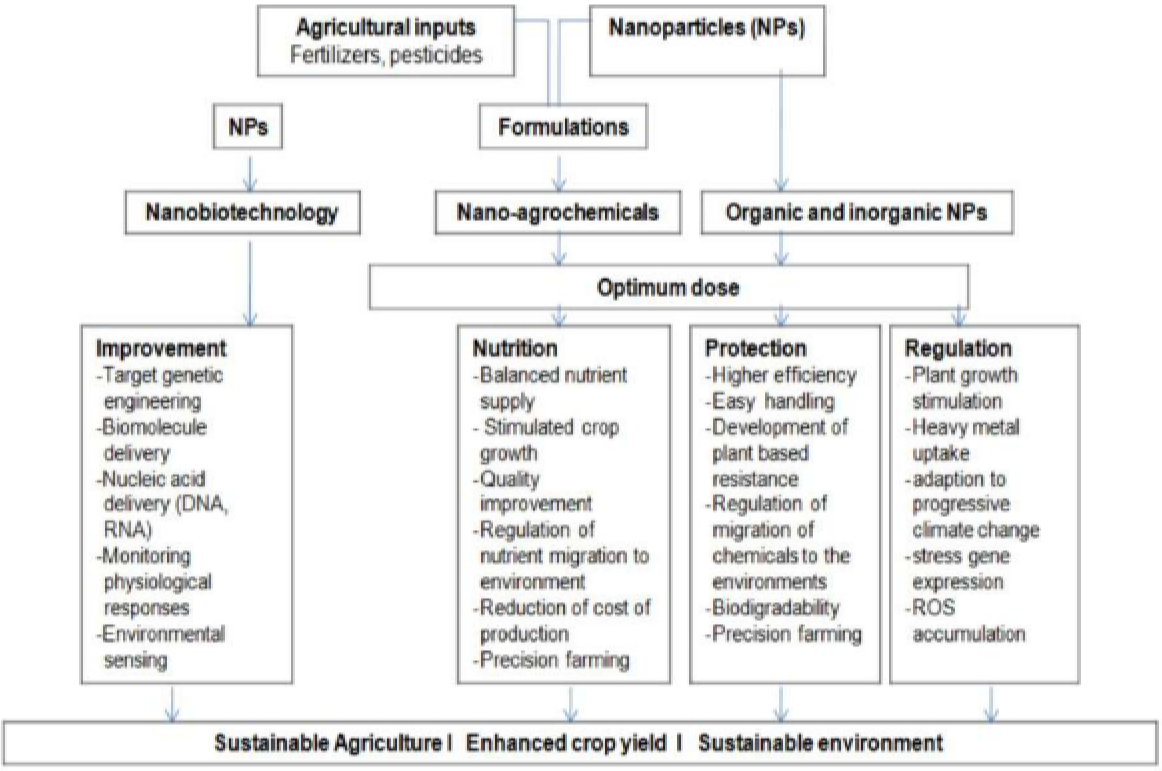
Nanomaterials in Pesticide-Based Plant Protection

Nanoformulation or encapsulation of pesticides which has revolutionized the plant protection sector. Nanoformulation of pesticides contains a very tiny number of particles that act as active ingredients of pesticides, whereas other engineered nano-structures also have useful pesticidal properties. The nanoencapsulation of pesticides is the coating of active ingredients of pesticides with another material of various sizes at nanorange where encapsulated materials are referred to as internal phase of the core material (pesticides) and capsulation materials are known as external phase, i.e., the coating nanomaterials.

IMPORTANT CHARTS AND TABLES

Applications of nanotechnology in agriculture		
Areas	**Nanomaterials and their uses**	**Appliccations**
Soil & Water management	Nanomaterials such as nano-clay, hydrogel,zeolites, filtering & binding to toxicants	Filter-membrane with TiO2 nanoparticles for hydrolysis& photo-catalysis degradation of agrochemicals
Plant Protection products	Nanoparticles, nanosensor, smart delivery systems	Improve the crop productivity & enhance the practices of sustainable agriculture
Antimicrobial	Nanoparticles & nano-capsules are effective drug delivery against bacteria	Zinc oxide & MgO are useful to the check of harmful bacterial growth
Fertilizers	Nano-capsules, nanoparticles for the enhancement of nutrients	Macronutrients fertilizers with ZnO coated nanoparticles, enhance the soil fertility
Remediation	Nanoscale particles a tool to remediate of soil & water contaminants	Nanoparticles like Fe, Zn, and Mg etc. are also act as a detoxificant to the number of chemicals
Control soil erosion	Nano-zeolite, nanoclay& nano-binder are checking the soil erosion	Nano-zeolites are act as fiber like structure & form a chelate like structure
Plastic Technology	Nano-composite bioplastic & nanopolymer, they are thermoformed plastic	Biodegradable after use, made renewable & sustainable resources (non GM corn starch)
Disease detection	Nano-sensors, carbon nanotubes & smart delivery system	Use of nano-sensors for detection of plant disease, monitoring soil condition and plant growth
Public health	Nanoparticles, nanopesticides & nanosensors etc	For control of number of disease such as malaria, filarial, dengue & cholera etc.
Recycling of agricultural wastes	Nanofiber, nanosensor& nanoparticles	Fibers can be used as chemicals& pesticides absorbent & convert agricultural waste to useful products & reduce waste size
Other than agriculture & public health	Nano particles & nano-pesticides	Control of vegetation in forests & factory sites by using fumigants


Nano particles in plant protection
Nano pesticides
Nano diagnostic
Nano herbicides
Pesticide remediation
Induced resistance
Nano-antimicrobial
Nano-antibacterial
Nano-insecticidal
Nano-antifungal


Agricultural inputs
Fertilizers, pesticides
Nanoparticles (NPs)
NPs
Formulations
Nanobiotechnology
Nano-agrochemicals
Organic and inorganic NPs
Optimum dose
Improvement
-Target genetic engineering
-Biomolecule delivery
-Nucleic acid delivery (DNA, RNA)
-Monitoring physiological responses
-Environmental sensing
Nutrition
-Balanced nutrient supply
- Stimulated crop growth
-Quality improvement
-Regulation of nutrient migration to environment
-Reduction of cost of production
-Precision farming
Protection
-Higher efficiency
-Easy handling
-Development of plant based resistance
-Regulation of migration of chemicals to the environments
-Biodigradability
-Precision farming
Regulation
-Plant growth stimulation
-Heavy metal uptake
-adaption to progressive climate change
-stress gene expression
-ROS accumulation
Sustainable Agriculture I Enhanced crop yield I Sustainable environment

Objectives on Geo-informatics and Nano-technology and Precision farming

FULL FORMS

- ISRO,1969: Indian Space Research Organisation, Bengluru (Karnataka)
- IIRS, 1966: Indian Institute of Remote Sensing, Dehradun (Uttarakhand)
- LIDAR: LIght Detection And Ranging
- RADAR: RAdio Detection And Ranging
- GPS: Global Positioning System
- STCR: Soil Test based Crop Response
- VRT: Variable-rate technologies
- GIS: Geographical Information System / Geospatial Information System
- DBMS: Data Based Management System
- IDW: Inverse Distance Weighting

One liner objectives *or* Fill in the blanks

- ICAR established the AICRP on STCR on **1967** for STCR development
- The technical term "remote sensing" was first used in the United States in the **1960's**
- Father of Nanotechnology is **Richard Feynman** (America)
- The term nanotechnology is coined by **Norio Taniguchi** (Japan)
- One of the dimensions of nano particle should lie in the range of **1-100 nm (10^{-9} to10^{-7} m).**
- Precision agriculture is oftenly called as **site specific agriculture or farming**

DEFINITIONS

- **Geographical Information System (GIS):** A GIS is system designed to capture, store, manipulate, analyses, manage & present spatial or geographic data.
- **Cartography:** Science or practice of drawing maps.
- **Remote sensing:** Remote sensing is the science of obtaining information about objects or areas from a distance typically from aircraft or satellites.
- **GPS:** GPS is a satellite navigation system used to determine the ground position of an object.
- **Photogrammetry:** Photogrammetry is the science of making measurements from photographs.
- **Surveying:** Surveying is the technique of determining the terrestrial or 3D positions of points and the distances & angles between them.