

Natural Resources Management (NRM)
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Week - 12
Lecture - 65
Revision

My dear participants in this MOOC course on Natural Resource Management, finally, we have reached in almost at the end of these 12 weeks long MOOC course. And it was really a very pleasant journey for me to interact with you in the live session and also to be able to get this opportunity to share with you various aspect of natural resources management.

Today in this lecture, I have decided to revise the rest of the part that I could not actually carry out revision for you. You remember that, in previous one of the lectures, we have revised almost around 1 to 8 modules. And today, we will start from module 9 and then till the last lectures, which we have discussed about information communication technology and its application for efficient natural resources management. This revision lecture will actually help you to quickly go through all the aspects that we have discussed.

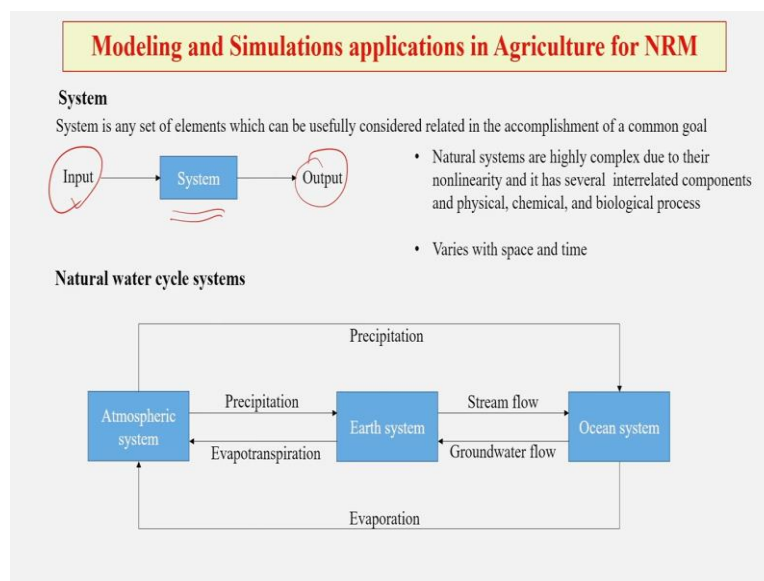
And this will not only help you for the upcoming final test of this course, but also it will help you actually to recall some of the important aspects that we have discussed over these 12 weeks of time. So, as I say that from module 1 to module 8, we have already carried out a revision exercise.

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Module-12

Today, we will do the rest of the module and I will go through this revision exercise as per the topic and not maybe exactly by the module number. But, all the topics that we could not finish revision in the last revision exercise, today we will do that.

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So, let us start with the one of the most interesting topics that we have discussed previously and that is modeling and simulation application in agriculture for NRM. What we discussed in this topic? We discussed various aspects of modeling simulation, the power of computations, how we can actually mimic the almost real field conditions and then try to utilize the information data collected from field as well as from secondary sources. And then try to predict what can happen in future. To do so, basically, we need good quality input, good system, computational tool, so, that we can get good output as simple as that.

So, various types of natural systems, which are very complex in nature, we discussed in previous lectures, how actually through various global circulation model, regional climate model, so, from there the output that we get, which can be used for some other model exercise like water model, land use model, crop model.

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Modeling and Simulations applications in Agriculture for NRM

Model
Set of tools or devices to represent the actual or natural system

Why model ✓

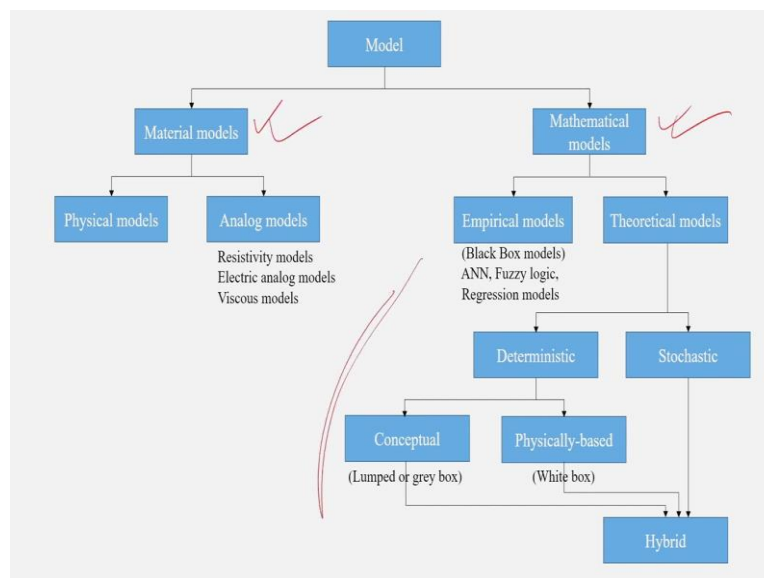
- Natural systems are highly complex and dynamic in nature. Therefore, we have limited knowledge about the dynamics and complex physical, chemical, and biological processes occurring in the system
- Limited availability of spatiotemporally distributed environmental data due to limitations in current measuring techniques
- To predict the future scenarios, uncertainties involved in the process. Thus to develop management standards and guidelines

Decision Support System (DSS) (Sprague and Carlson, 1982) ✓

Decision support systems are interactive computer-based support systems that help decision makers utilize data and models to solve unstructured problems

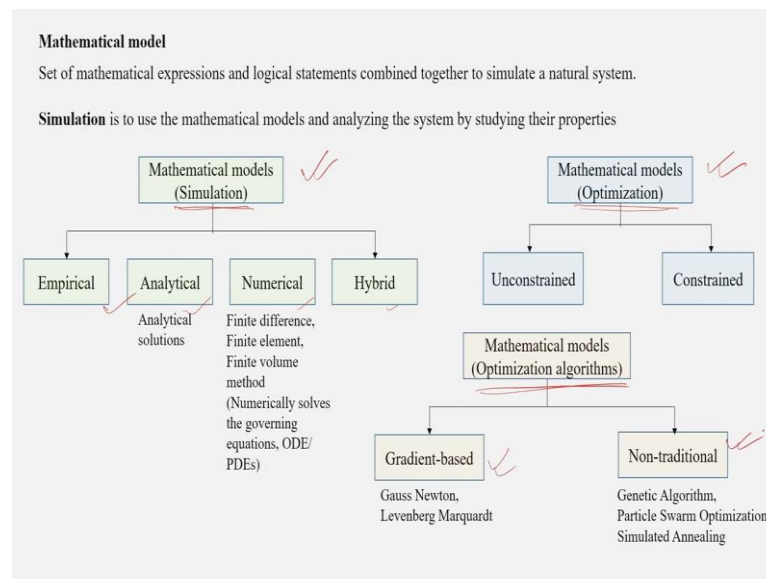
So, these are all the things that we have discussed in this modeling simulation lecture. We also discussed what is model, why we need model. Then we discussed about decision support systems, use of model.

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Then model framework actually, what kind of models that are available in public domain. We discussed about material models, mathematical models, and various type of mathematical models.

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Then we one by one also went through a various model like mathematical model we first discussed. If you recall that we discussed with the different example, how mathematical models can be used for simulation and also for optimization.

Two most important exercise for which actually mathematical model we use. There are various type of model mathematical, analytical, and numerical and hybrid type of model that can be used for simulation under mathematical model system.

Optimization also, we discussed how important is optimization. Wwe discussed about also to test validity of your model. We also talked about that how the ground truth or fill reality can be mimicked in the modeling system through various analytical processes. So, there are also various optimization algorithms available gradient based, non-traditional.

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Physical models	<ul style="list-style-type: none">• Scaled down version of real world• Model of vehicles, engineering structures
Analog models	<ul style="list-style-type: none">• Use substances analogous to (but other than) those in a real system• In an electric analog model in which the flow of electricity represents the flow of water
Empirical models	<ul style="list-style-type: none">• Based on observed input-output relationships and do not consider the information of the actual processes involved, thus also known as "Black Box" models• Regression models, AI
Theoretical models	<ul style="list-style-type: none">• They depend on the physical laws and theoretical principles and use equations derived from basic physics like mass, momentum, energy conservation, and flow and transport mechanisms

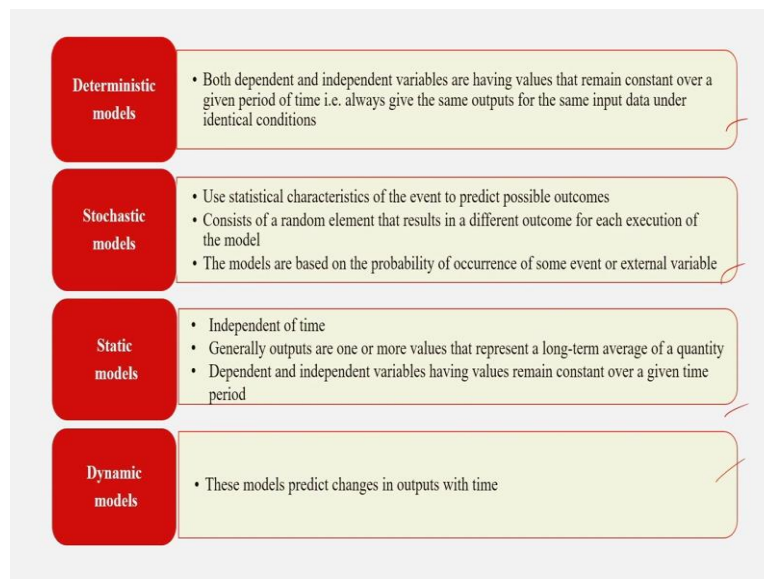
So, these we all have discussed then we went into the various kinds of nano models, physical models, analog models, empirical models, theoretical models, and how they actually function, what kind of data they require. All those things, also we have discussed.

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Conceptual models	<ul style="list-style-type: none">• Inputs to outputs through mathematical equations representing the physical process are related in a form where physical significance is not usually so clear. Not all the model parameters are physically interpretable.• Thus also known as "Grey Box Models"
Physically based models	<ul style="list-style-type: none">• These are process-based models which involve mass, energy, momentum transfer. The parameters have physical significance and the parameters can be estimated from direct measurements.• Also known as "White Box Models"
Lumped models	<ul style="list-style-type: none">• Considers a region (or watershed) as an individual unit i.e., as a point.• Inputs like soils, topography, vegetation all are each characterized by a single parameter which is a representative average value
Distributed models	<ul style="list-style-type: none">• Considers processes involved and detailed spatial variations in properties and response of a system• Includes rainfall-runoff, soil erosion, land use land cover changes, water quality, irrigation water management studies

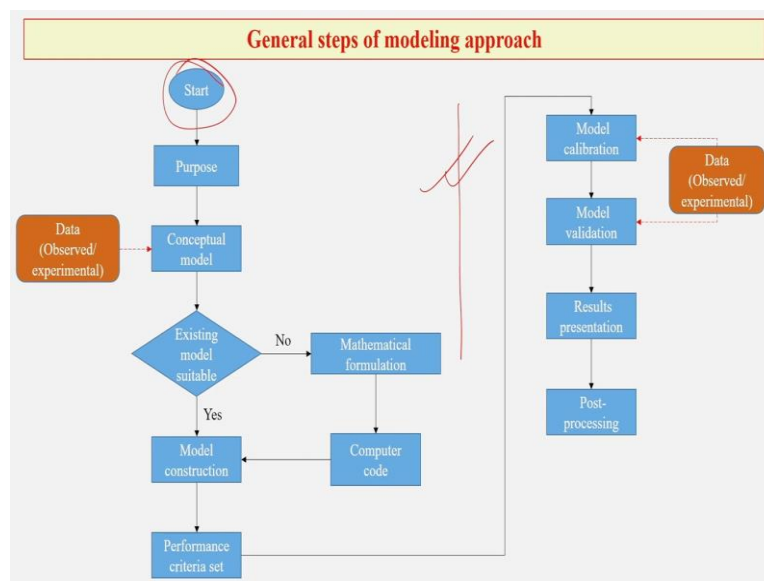
And all these slides are already shared with you in the MOOC portal, and I hope that you have critically gone through this. So, each one of these models have been discussed with a lot of details.

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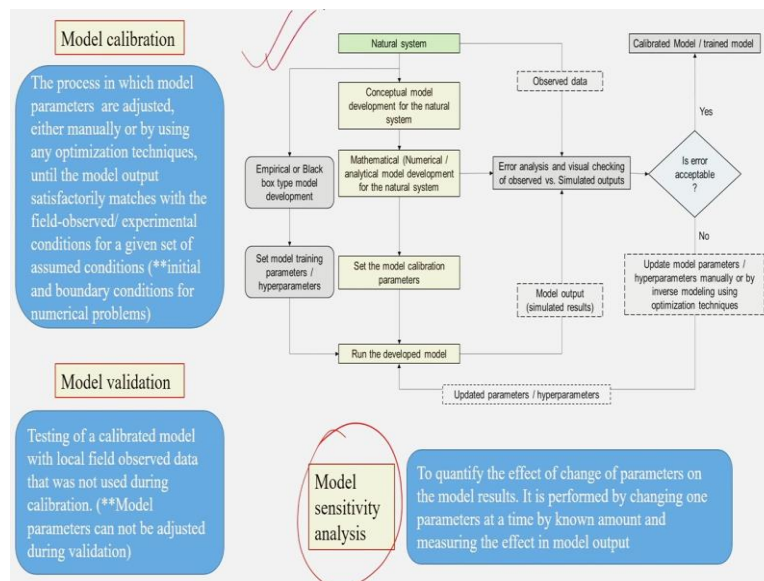
Then deterministic model, stochastic, static and dynamic model this also we have discussed that in what condition which model can be used, what are the requirements for various models.

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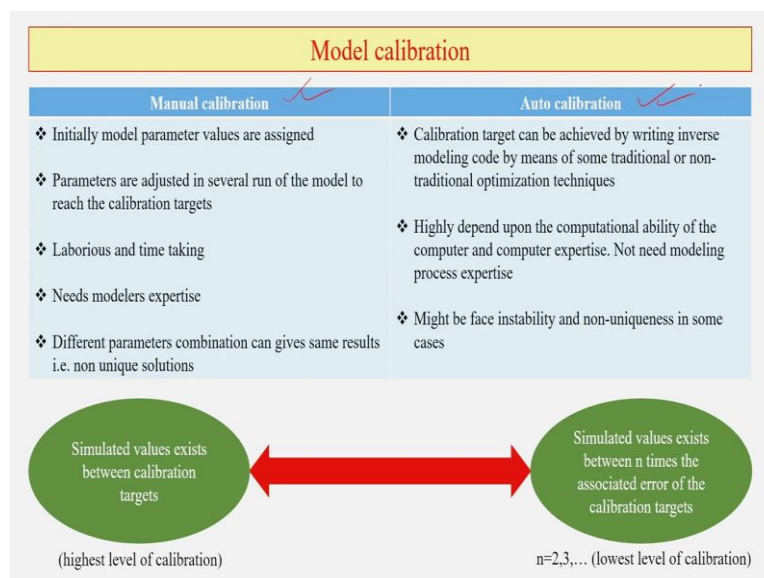
Then, we discussed about general steps of modeling approach. So, the framework, how actually you start with your basic conceptual model and then data, how you integrate it, how the different criteria that you test and then you calibrate, validate and finally, you come out with the result which you present or shared in different platform.

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So, calibration and validation, we already discussed and mentioned that these are the two very important exercise or aspect of modeling exercises. Then we talked about that how sensitivity analysis can be carried out in detail, we discussed also with example, that how actually, this kind of modeling works.

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Model calibration again, better the model calibration better would be your predicted outcome. So, we also discussed about manual calibration as well as auto calibration, how they are different from each other, what are the benefits of each one of these.

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Model performance indicators (Commonly used)		
Indicator name	Mathematical expression	Description
Mean Absolute Error (MAE) ✓	$MAE = \frac{1}{n} \sum_{i=1}^n |y_{oi} - y_{si}|$	<ul style="list-style-type: none"> Lower value gives better results Can not provide any information on the overall trend of under-estimated or over-estimated
Root Mean Squared Error (RMSE) ✓	$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_{oi} - y_{si})^2}$	<ul style="list-style-type: none"> Indicates overall discrepancy between the observed values and the simulated values lower the value of RMSE, the more accurate the simulated result is
Correlation Coefficient (r) (Pearson's correlation coefficient) ✓✓	$r = \frac{\sum_{i=1}^n [(y_{oi} - \bar{y}_o)(y_{si} - \bar{y}_s)]}{\sqrt{[\sum_{i=1}^n (y_{oi} - \bar{y}_o)^2][\sum_{i=1}^n (y_{si} - \bar{y}_s)^2]}}$	<ul style="list-style-type: none"> Denotes the degree of linear association between observed and simulated values $-1 \leq r \leq +1$ $r = 1$, perfect correlation, $r = 0$, no correlation
y_{oi} = Observed data, y_{si} = Simulated data, \bar{y}_o = Observed mean, \bar{y}_s = Simulated mean, n = no. of datapoints		

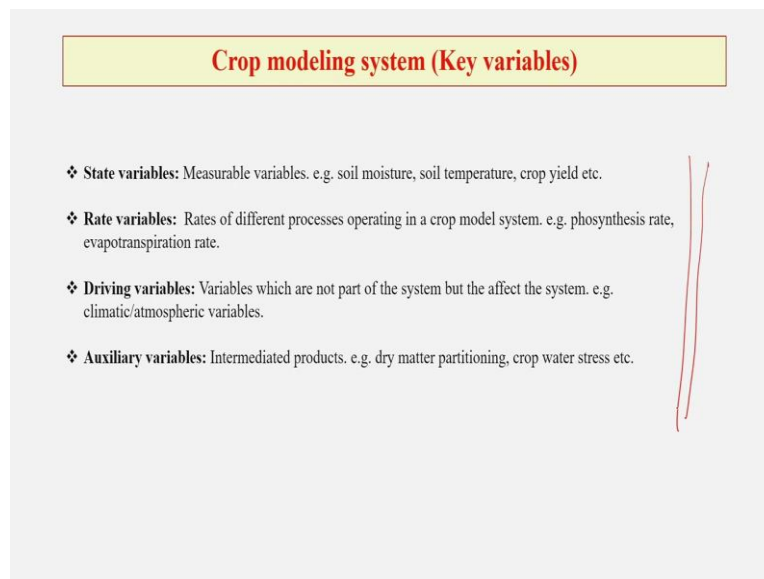
Then we also discussed about performance indicators. And we discussed about few very commonly used performance indicators, which many of you might have done already in your graduate, postgraduate or PhDs.

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Model performance indicators (Commonly used)		
Indicator name	Mathematical expression	Description
Coefficient of Determination (R^2) ✓✓	$R^2 = \left(\frac{\sum_{i=1}^n [(y_{oi} - \bar{y}_o)(y_{si} - \bar{y}_s)]}{\sqrt{[\sum_{i=1}^n (y_{oi} - \bar{y}_o)^2][\sum_{i=1}^n (y_{si} - \bar{y}_s)^2]}} \right)^2$	<ul style="list-style-type: none"> $0 \leq R^2 \leq 1$ Higher values indicating better model performance Describes the proportion of the total variance in the observed data that can be explained by the model
Nash-Sutcliffe Efficiency (NSE) Or Model Efficiency ✓✓	$NSE = 1 - \frac{\sum_{i=1}^n (y_{oi} - y_{si})^2}{\sum_{i=1}^n (y_{oi} - \bar{y}_o)^2}$	<ul style="list-style-type: none"> Widely used in hydrological modeling $-\infty \leq NSE \leq 1$ Higher value (near to 1) is desirable It is an improvement of R^2
Index of Agreement (IOA) ✓✓	$IOA = 1 - \frac{\sum_{i=1}^n (y_{oi} - y_{si})^2}{\sum_{i=1}^n (|y_{si} - \bar{y}_o| + |y_{oi} - \bar{y}_o|)^2}$	<ul style="list-style-type: none"> $0 \leq IOA \leq 1$ (similar as R^2) Higher values are required 0 and 1 for a worst and perfect fit respectively Proposed to overcome the insensitivity of NSE and R^2 to differences in the observed and simulated means and variances

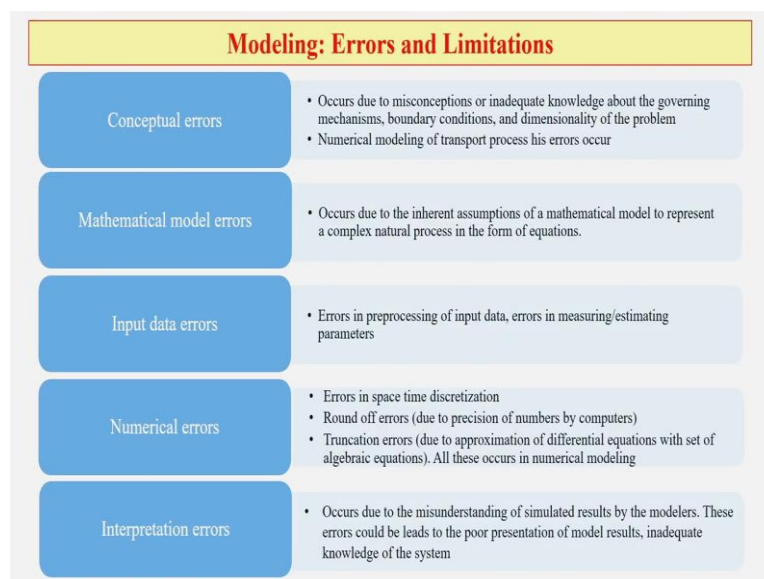
So, these things are actually carried out or analyzed to understand that how your model is actually performing.

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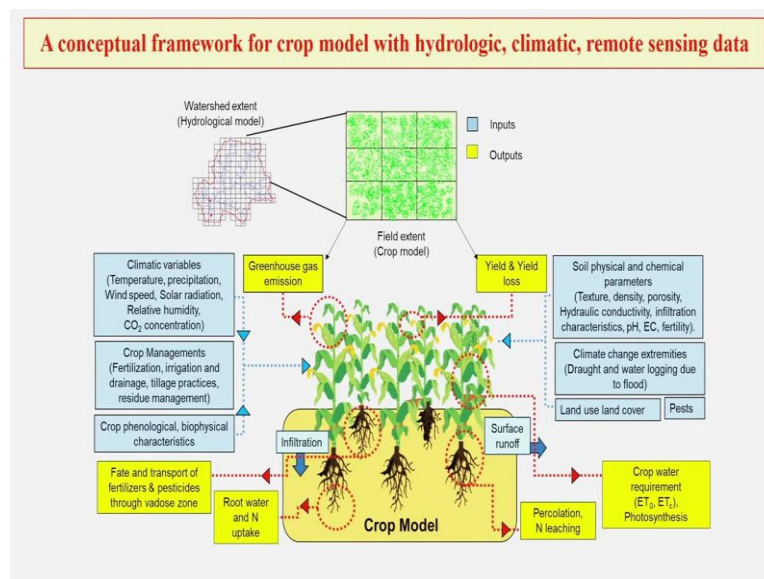
So, after model, indicate testing performance indicator, then we went into crop modeling system. One of the most important term modeling system, which actually talks about the yield means, under different kinds of conditions, how the crop yield will vary, and as that the crop yield is directly related with the livelihood of the people. So, if we talk about natural resource management, one of the major applications of natural resource management is in the agricultural field for food production. Now, we discussed about all these aspect key variables of crop modeling system.

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Then we went into different aspects of crop modeling and how actually we can minimize the errors.

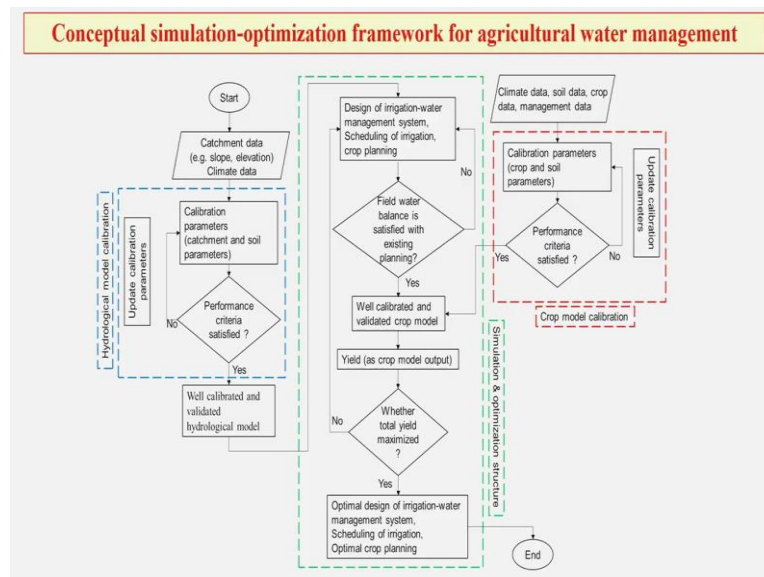
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Then, we discussed about the conceptual framework for crop model with hydrologic, climatic and remote sensing data. So, this as you see here, this is one of the work that from our lab, we have carried out this conceptual framework and this has also a very recently has been published in the Journal of climate related aspect, ecology and economics related aspect.

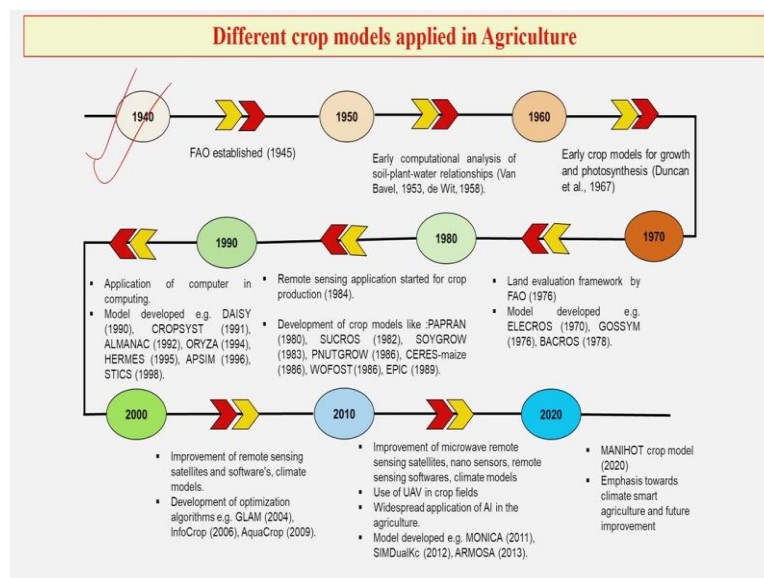
So, here as you see that we discussed also if you recall that how different kind of modeling system hydrologic, climatic remote sensing data can be integrated. Today we have very powerful computational system, where we can actually run different types of demanding software, remote sensing, hydrologic model, and climate model. So, the integration has become the art of today's modeling exercise.

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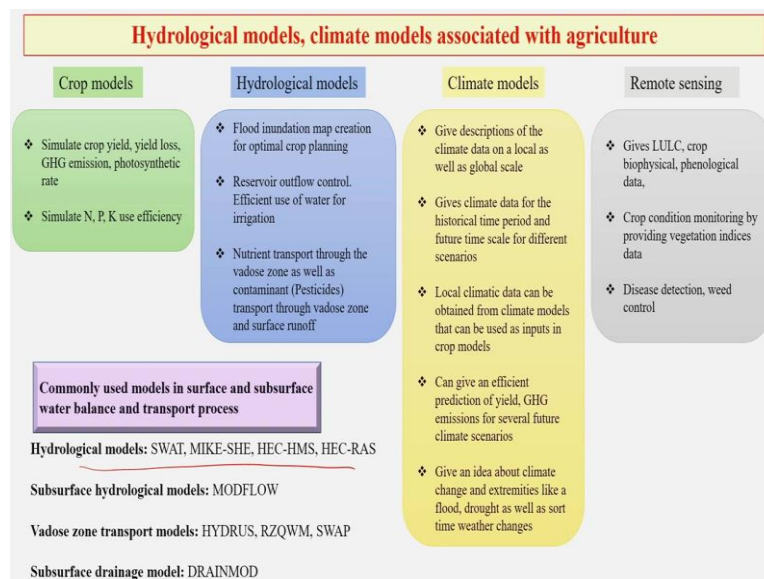
And along with that, when you bring in artificial intelligence and machine learning, then the power of your modeling systems become much higher. So, we also discussed about the conceptual simulation optimization framework for water management.

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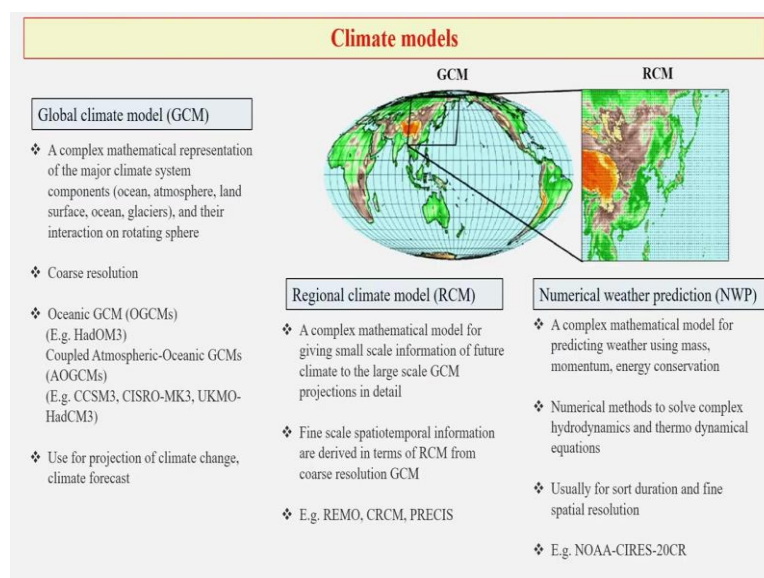
We also shared with you that how the crop models over the last few decades actually has evolved. So, we started from the very beginning of the crop modeling days and till very recently, its development.

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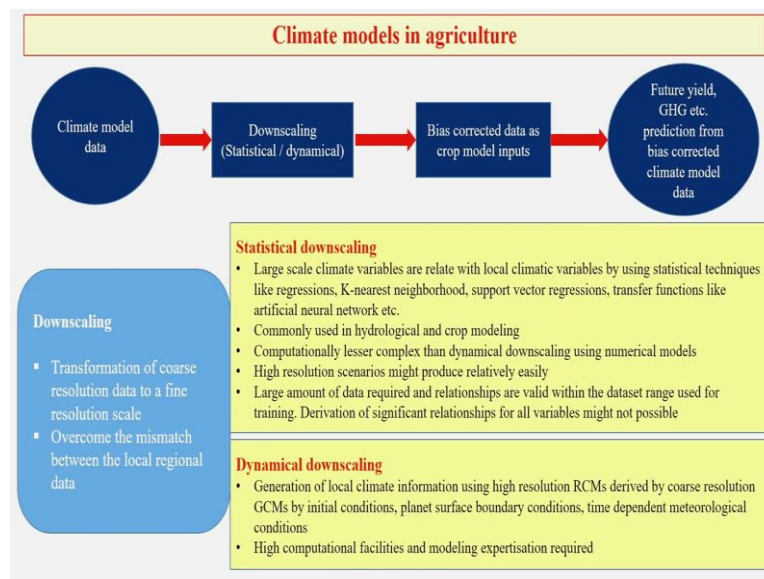
Then, we discussed about hydrological model, climate model and how they are linked with agricultural productions and how these different models can actually utilize the one of the most important resource which is water in the best possible manner to give better outcome which is food production or agricultural productions and various other uses for generating livelihood for people.

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Then we talked about GCM and RCMs, how they work.

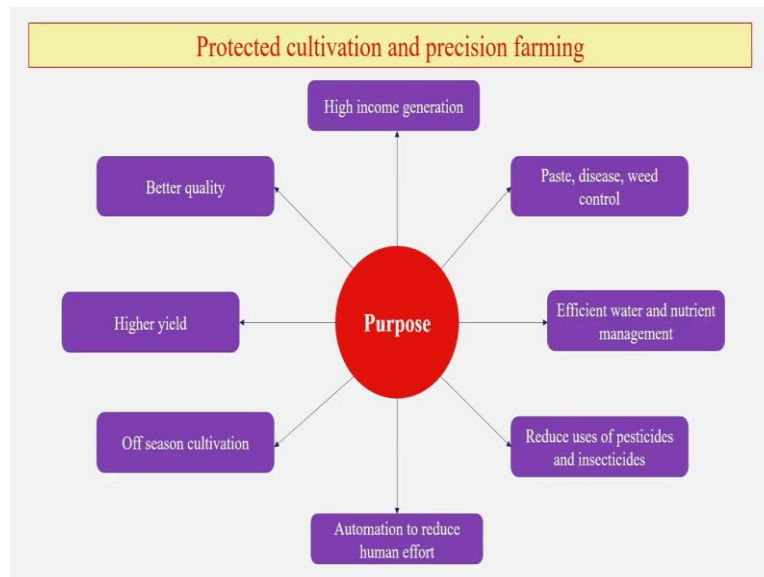
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And then how we can actually apply different kind of climate models outcome into agriculture system.

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Precision farming
and protected
cultivations



We also then discussed about about precision farming and protected cultivations which are very, very becoming popular in developed country as well as in our countries. So, we discussed about the various purposes of this kind of farming system.

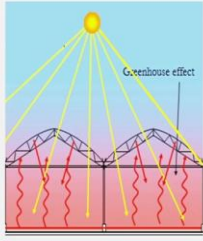
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And then, we have also discussed about various types of precision farming and how they look, like how they are maintained.

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Greenhouse (Polyhouse)




Greenhouse (schematic)

- ❖ Commonly used precision farming structures for protected cultivation
- ❖ Generally made of UV stabilized polythene film (commonly 200 μm)
- ❖ Can also be made with glass (earlier), poly carbonate, acrylic sheet
- ❖ Subjected to mainly live load, dead load and most dominant is the wind load
- ❖ Creates microclimates due to entrapment of incoming solar radiation, difference in RH, wind speed, CO_2 concentration between the polyhouse and ambient air
- ❖ Single span or multi span greenhouses are available
- ❖ Structures are made of GI pipes, low costs are also made with bamboo, wood etc.


Types of greenhouses




Quonset




Lean to




Ridge and furrow




Even span




Uneven span



Saw tooth

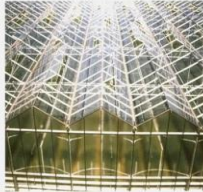


Tunnel




Maxi vent type


Commercially used multi-span type polyhouses



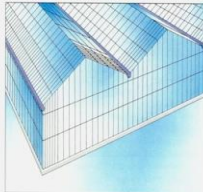
Multi span type




Arched saw tooth type




Gutter ventilation



Wide span type



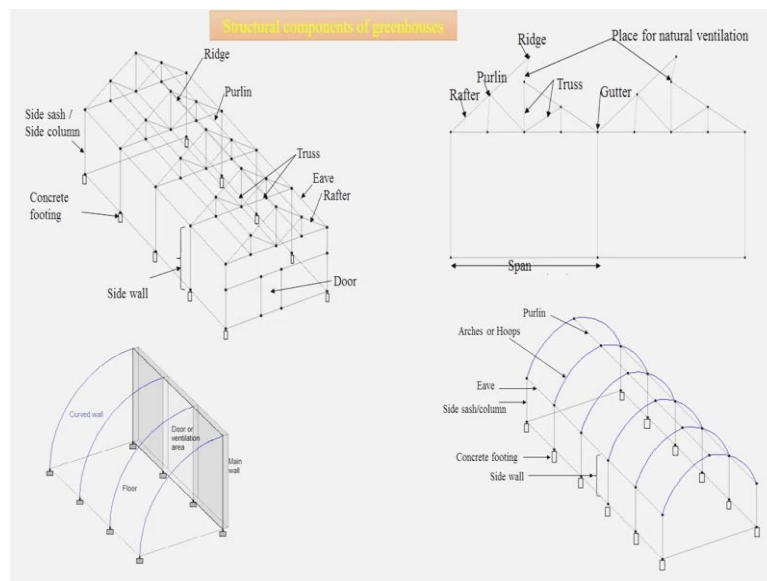
Poly tunnel type



Saw tooth ventilation

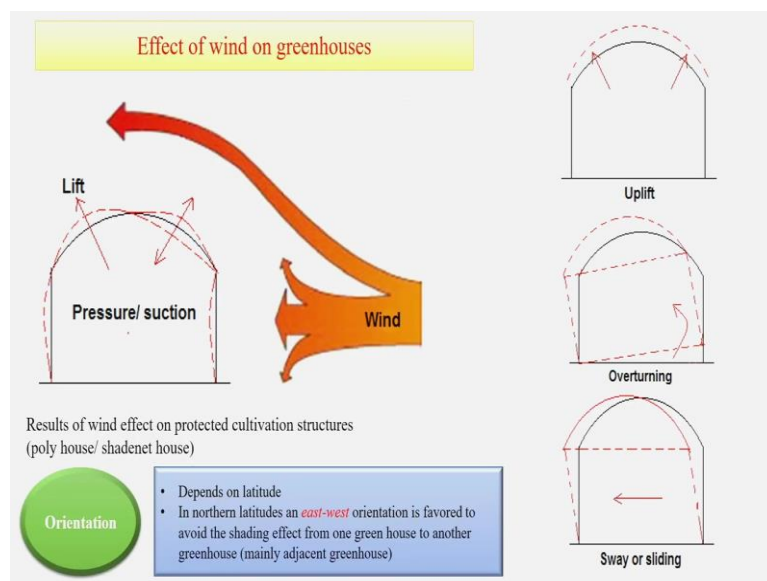
There are also some of the precision farming system which we have also discussed with the designs and engineering aspect.

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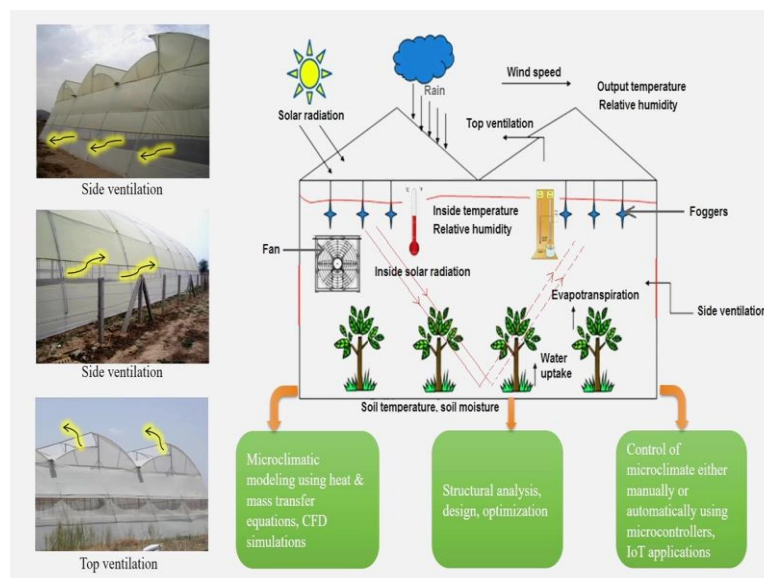
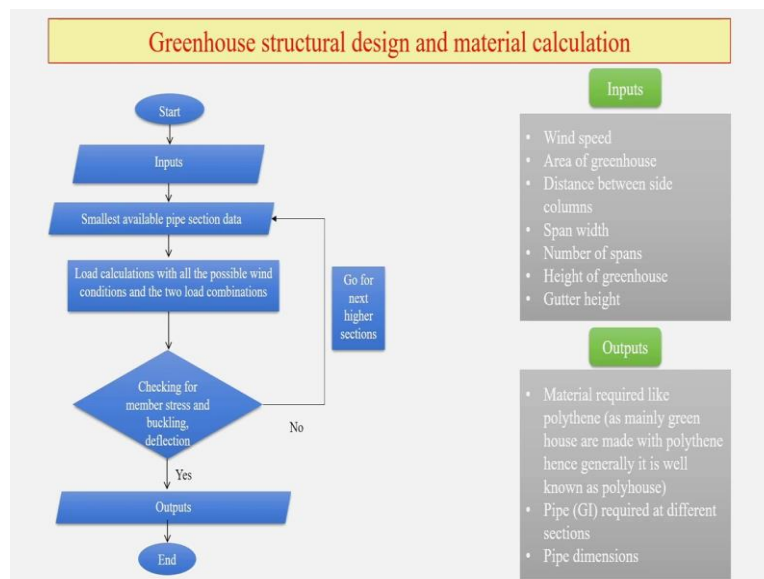
So, structural components of various greenhouses also, we have discussed.

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We discussed how wind can affect these structures and how you should modify the structures and made it such a way that your greenhouse will remain relatively stable.









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Then, we talked about various kinds of calculation of greenhouse efficiency and ventilation of air, maintaining humidity etc. So, these are the things also we have discussed.

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Other different types of protected cultivation structures









			
Net house	Shade net house (Pan boroi)	Low tunnel	MS Structure
			
Walk in tunnel	Bamboo / Wooden structure	Cement concrete pillars	Stone pillar structure

	
Commercially most commonly used poly house	
	
C-channel for polythene holding with the structures	
<div style="background-color: #FFD700; padding: 5px;">Properties of poly-film Diffused, anti dust, anti drip, anti sulfur, anti mist, anti hail</div>	GI pipe bending for arch shape

Then we also discussed about other types of protected cultivation structures and how they are used in developed as well as in developing countries.




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Agro shading applications

 Commercial nurseries	 Shadenet as windbreak	 Black X Black <ul style="list-style-type: none">Absorbs and radiates heats inside shadenet houseUsed mainly in all type of nurseries
 Commercial nurseries	 Off season vegetable growing	 White X Black <ul style="list-style-type: none">Diffuses lights inside shadenet houseUsed mainly in growing flowers like Anthurium, Gerbera
Shading percentages: 35%, 50%, 75%, 90%		 Green X Black <ul style="list-style-type: none">Cuts off unwanted UV raysUsed mainly in grape shadingAesthetic looks
		 Green X Green <ul style="list-style-type: none">Enhances photosynthesisUsed mainly for better foliage for ornamental plants

Agro shading applications also we have discussed and how different type of materials is actually used for this kind of agro shading.

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 Trellising inside insect proof net house	 Low tunnels with insect-proof nets to grow virus-free nursery	 Wooden structure to grow seedlings
 Additional door system to avoid insect infestation	 Fan pad cooling system	

We also talked about tunnel system tunnel agriculture, then to create different kind of structure, which can avoid your insect infestations.


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Mulching


- Retaining soil moisture
- Weed control
- Improved yield
- Fertilizer, pesticides reduction




Types


Black mulch


Transparent mulch

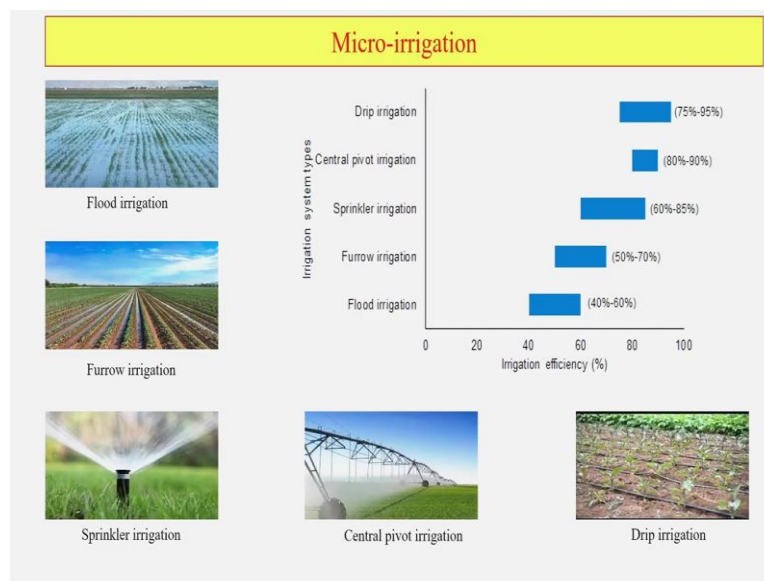

Organic mulch


Coloured mulch

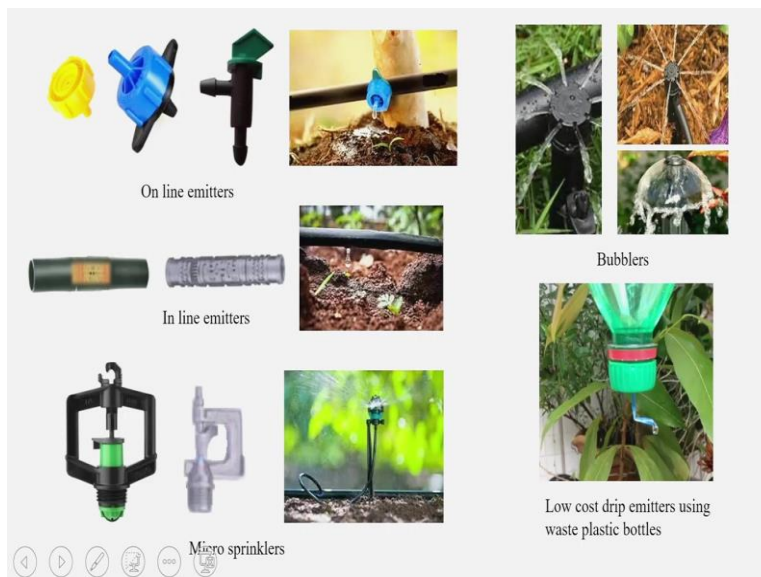
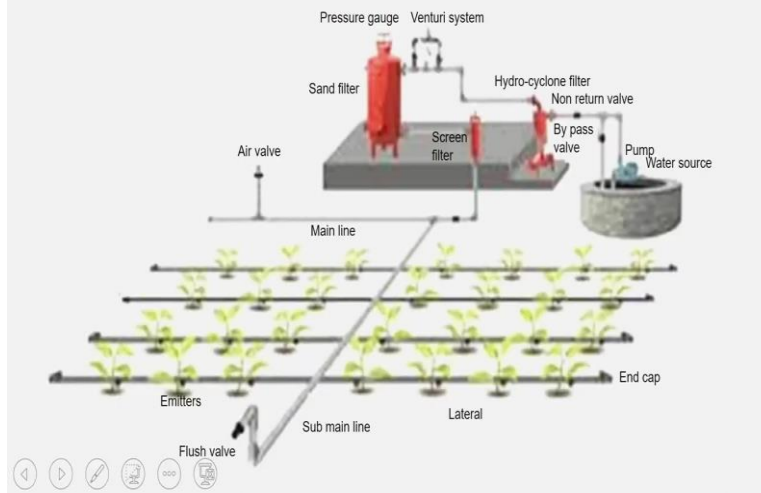
- ❖ Black mulch generally conserves moisture, absorbs heats (convective) inside soil, helps in weed control. Most commonly used mulch
- ❖ Transparent mulch helps in soil solarization by absorbing radiant heat and controls bacteria, fungi, insects, nematodes, mites, weeds, and weed seeds

So, I think that a lot quite a lot of examples have been discussed under these precision farming structures.

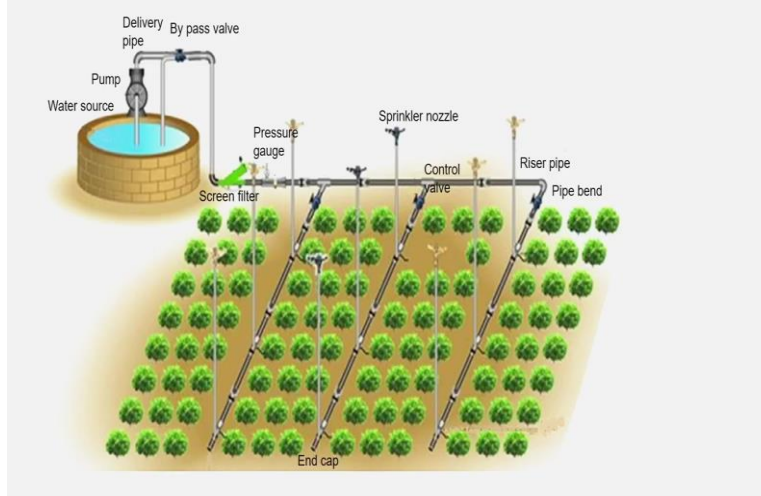
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Drip system layout



Sprinkler system layout



We talked about mulching; we talked about also micro irrigation system, drip irrigation layout, different type of deep irrigation tools and techniques, sprinkler system.

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Advantages of drip and sprinkler irrigation	
Drip irrigation	Sprinkler irrigation
Advantages <ul style="list-style-type: none"> ➤ Saving of water by 30 to 50% in comparison conventional irrigation system. ➤ Yield increase from 50 to 100%. ➤ Reduction in fertilizer usage ➤ Increased pest, weed control efficacy. ➤ Cultivation of undulated land possible. ➤ Efficient water management of heavy and light soils ➤ Also known as trickle irrigation Disadvantages <ul style="list-style-type: none"> ➤ High installation and maintenance cost ➤ Chocking problem (mainly subsurface drip system) and for inline drip emitters 	Advantages <ul style="list-style-type: none"> ➤ Occurs artificial rain by forcing water under-pressure through a small circular nozzle ➤ Rotates in a horizontal direction by the force of water and produces a circle wetting pattern ➤ Most suitable for close growing crops like oilseeds and other vegetable crops ➤ Efficient water management ➤ Suitable in high elevation areas Disadvantages <ul style="list-style-type: none"> ➤ High installation and maintenance cost ➤ Mainly drifting of droplet problems where wind speed is very high usually

Advantage of drip irrigation and also sprinkler irrigation which are which one having better uses in which conditions there are disadvantages as well as advantages.

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Soil less cultivation
❑ Perlite <ul style="list-style-type: none"> • Perlite is a siliceous volcanic rock (aluminum silicate) that when crushed and heated expands to form white particles with numerous closed air-filled cells. • Water adheres to the surface of but does not into the perlite aggregates. • Perlite is sterile, chemically inert, has a negligible EC, pH value ≈ 7.5 (nearly neutral). • Perlite has low water holding capacity and is often added to increase aeration around the root zone. Due to its limited water holding capacity, irrigation systems have to be designed to provide irrigation on constant basis when using this medium. • With Perlite all essential nutrients need to be supplied in the irrigation water. ❑ Vermiculite <ul style="list-style-type: none"> • Vermiculite is made from mica. • During its manufacturing, vermiculite is heated to very high temperatures that cause it to expand and also sterilize it. • Vermiculite is lightweight, sterile and able to absorb large quantities of water. • It does provides some nutrients in the form of potassium and magnesium, and it will retain fertilizer. • Vermiculite is often found as a component in commercially prepared media mixes, in particular those formulated for seed germination. ❑ Commercial media (Prepared media) <ul style="list-style-type: none"> • Prepared media is commercially mixed to specific proportions of materials such as peat, perlite and vermiculite with optional additives such as wetting agents, slow-release fertilizer, and mycorrhizae (a root growth promoting fungus). Pro-Mix is a trade name of one mix with different formulations.


We also talked about soil less cultivation, which is becoming very popular these days, because soil also at some places especially, if you thinking about the urban areas, almost 35 to 40 percent of the urban areas are available on the building itself. So, different kind of thoughts are going on how these built areas can be also utilized for alternative farming's and

then comes in your idea of soil less culture various kind of materials are discussed in this lecture.

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Hydroponic system

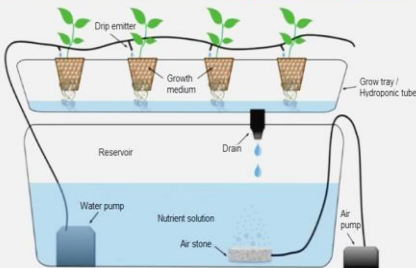
- ❖ Hydroponics is a method of growing plants in a water based, nutrient rich solution in water solvent.
- ❖ Hydroponics is a soil less cultivation system, here the root system is supported using an inert medium such as perlite, coco coir, clay pellets, peat moss, compost, vermiculite etc.
- ❖ The basic principles of hydroponics is to allow the plants roots to come in direct contact with the nutrient solution (N-P-K mix, Calcium Nitrate, Epsom salt (Magnesium sulfate), Ammonium Nitrate, Hoagland solution) while also having access to oxygen, which is essential for proper growth.
- ❖ Organic fertilizers can also be used in hydroponics with proper precautions.
- ❖ Drip systems is common and simple technique whereby a pump on a timer delivers a slow feed of the solution to the base of each plant individually. The excess solution can be either returned to the reservoir or not collected.
- ❖ It works well with growing mediums with high water retention. When the system is working correctly, it is very low maintenance and high output.



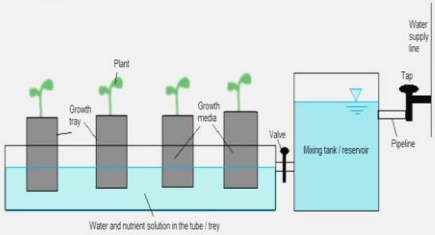
Hydroponic system on a rooftop garden

Hydroponic system (Schematic)

- ❖ One disadvantage is that the drip lines can get clogged, which results in dried out plants.
- ❖ Synthetic nutrients are the logical choice for these systems because organic materials clog lines much faster.
- ❖ Instead of the reservoir, simple tap water can be used in this system and this drip pipeline will pass through the hydroponic tube inside.
- ❖ Besides, hydroponic system can also be used with stagnant water can also be used



Hydroponic system with drip irrigation




Hydroponic system with stagnant water

We also talked about hydroponic system and how it works, what are the different kinds of benefits limitations, how it should be built. So, a lot of I think topics and aspects has been discussed under this precision farming.

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Vertical farming

- ❖ Practice of growing crops in vertically stacked layers.
- ❖ Often incorporates controlled-environment agriculture, which aims to optimize plant growth, and soilless farming techniques.
- ❖ It is an alternate farming system that can be used for small scale productions of vegetables and flowers (useful for small flower nurseries).
- ❖ Presently it is used in large scale productions in different part of the world.



- ❖ This can be done by the application of soil less cultivations in small plastic pots or even in small waste plastic bottles with cost effective small scale pipe based irrigation system by use of small pipe along with plastic bottle assembly which mimics gravity based drip irrigation systems environment. Small bottles can also be used for supply water in this vertical farming system via small pipes (or drip laterals).
- ❖ Portable solar pumps (0.1 hp to 1 hp range) can be used efficiently for this solar powered irrigation system for vertical farming, rooftop gardening, hydroponic system etc.
- ❖ Indoor gardening also required proper lightning.

Vertical farming

This vertical farming system can be applied in indoor gardening (kitchen garden system with the presence of LED light or florescent light).

❑ **Fluorescent Grow Lights:**

- Fluorescent grow lights are used for growing herbs and vegetables indoors.
- They are two types, including fluorescent tubes and Compact Fluorescent Lights (CFLs).
- Fluorescent tubes come in many different intensities.
- Don't emit excess heat, allowing farmers to keep the lights closer to the plants. This low heat feature makes it very energy efficient as well.

❑ **High-Pressure Sodium (HPS) Grow Lights:**


- HPS lights have grown in popularity and are overtaking fluorescent tubes and bulbs
- More common among commercial and experienced indoor growers
- Produces a considerable amount of heat
- Require a significant amount of investment to set up and maintain. Hence not recommended for small growers.

Vertical farming also we talked about that how different kind of waste material with plastic bottles can also be used for vertical farming, which are the different kinds of equipment that you need.

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Vertical farming

❑ LED Grow Lights:

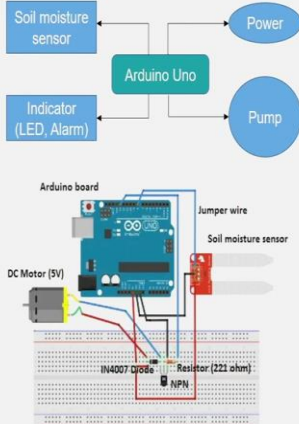


- First emerged in the early 1900s
- The red and blue LEDs perfect for indoor farming began being used just prior to the 2000s.
- Most energy efficient among all three basic types of grow lights.
- These sources can be placed farther from plants while still producing enough light without consuming much energy.
- CFLs are almost 50% less efficient than LED grow lights.
- The heat production by LED grow lights is near zero.
- LED performs best to create a perfect indoor environment to create almost any kind of food.
- The cost of LED light bulbs is higher than other two types. Additionally, workers working in indoor farms need to use eye protection as LEDs can be harmful to human eyes.

How it should be planned, what kind of plant.

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Automated irrigation systems



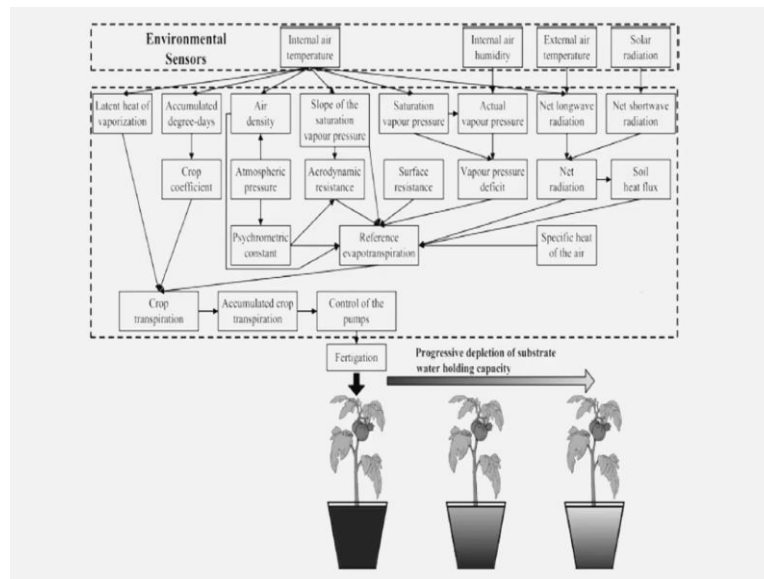
- ❖ Used For small scale indoor garden or kitchen garden or rooftop garden or garden adjacent to any house
- ❖ Reduce the labour as well as reduce the chance of infection through the contact surface
- ❖ Fabricated by using either by using simple timer to operate the control valve for scheduling the irrigations (This is a simplified system and independent of any soil moisture sensors and applicable to any soilless media) for example daily interval by the help of Arduino / Raspberry pi based project
- ❖ Improved system can be used with the help of any soil moisture sensors (generally capacitive type) (Commercially available or in-situ type circuits) associated with any microcontroller which will finally operate the valve operation for irrigation water supply to the plants based on the moisture depletion of the media

❖ For soil less media not commercially available sensors are not common, hence some capacitive circuits need to be made.

❖ Further be modified to wireless sensor network by the help of IOT Android applications.

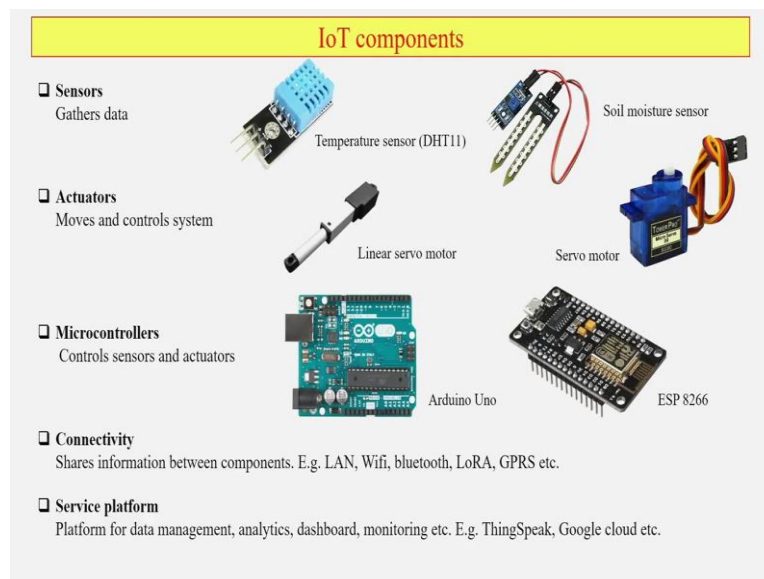
We then talked about automatic irrigation systems, because water resource has become a very scarce commodity at many places of the world. So, the option that left with us is that how we can actually maximize the utility of each drop of water. So, the concept of proper drop also has been discussed. We discussed about utilization of AI/ML in irrigation system management.

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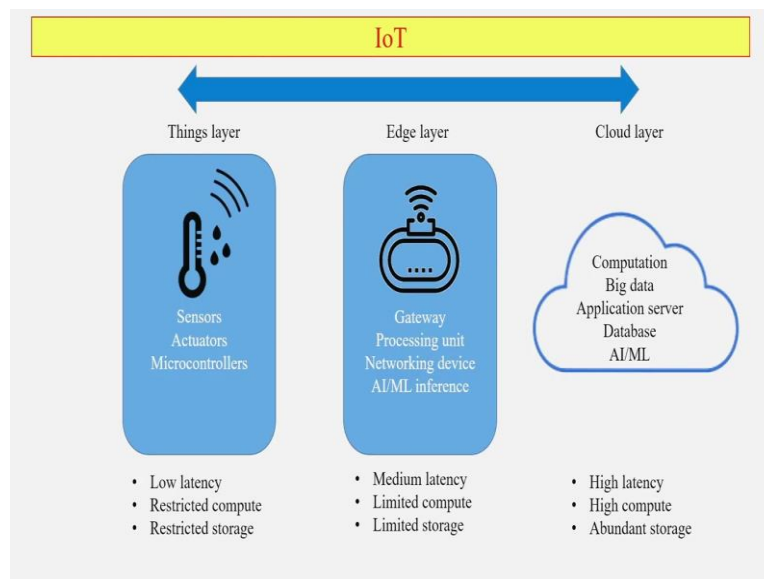
Different kind of sensors, how it can be used.

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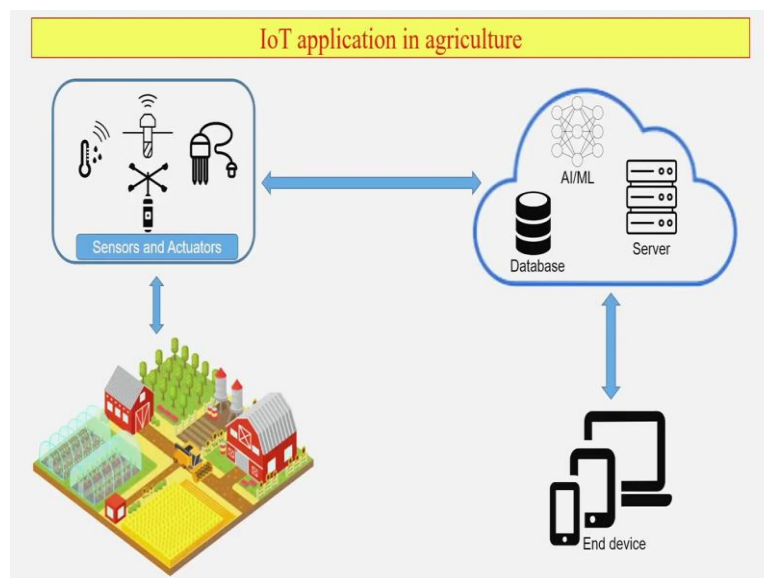
Then, we talked about IoT components, which are the components how it can be used for water management.

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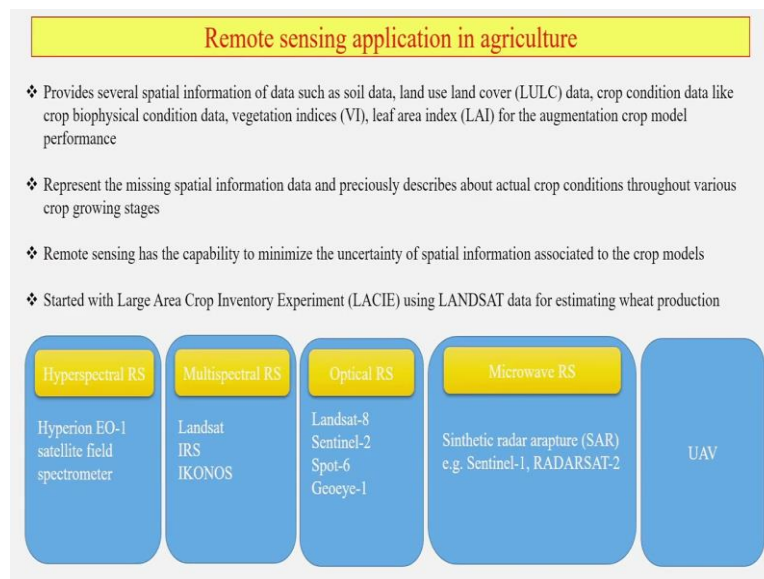
In fact, if you recall that in the lectures, we also discussed about that how IoT can be utilized for different kind of land preparations and various other farming practices.

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So, each application in agriculture is quite huge. And again, we have also discussed this particular aspect in great detail in some other forum.

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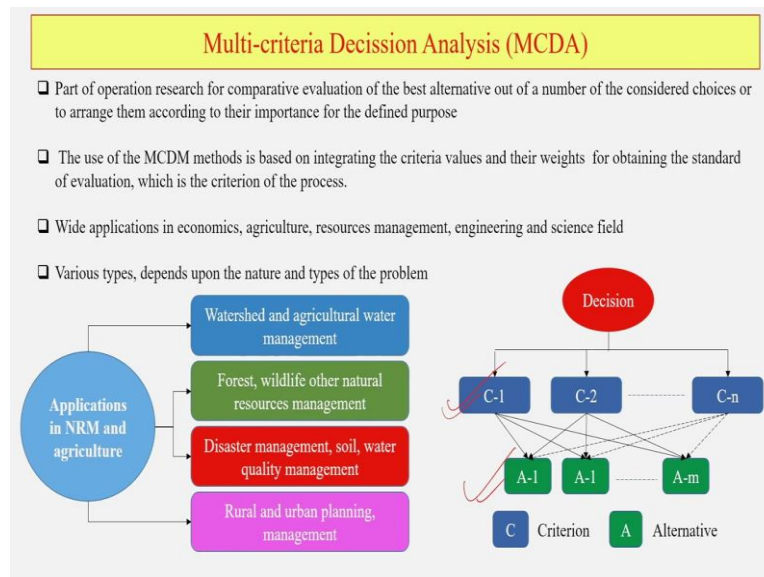
So, application of remote sensing in agriculture is a very well talked subject. And if you recall that we handled this particular topic in a separate lecture also discussing about various aspects of remote sensing and its application.

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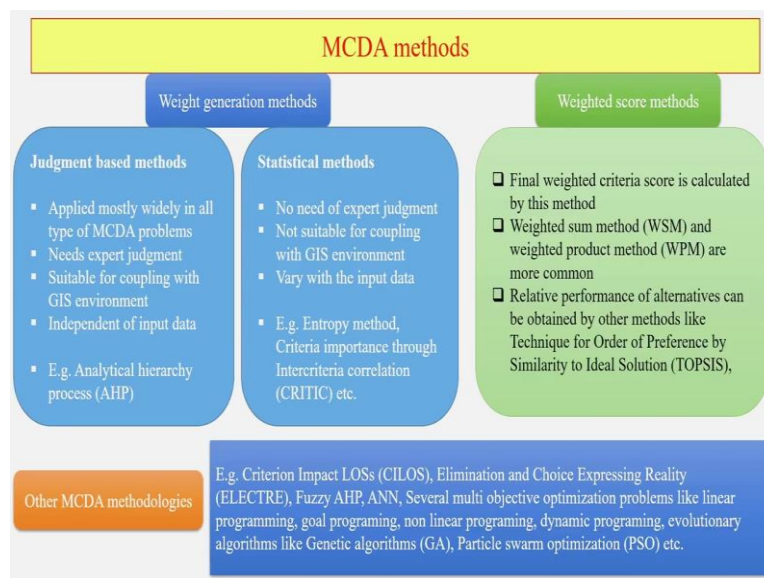
Then, we went into another a very, very important topic that is multiple criteria decision analysis and uses of MCDA in agriculture for natural resource management. Now, MCDA can be used for various aspects which we discussed.

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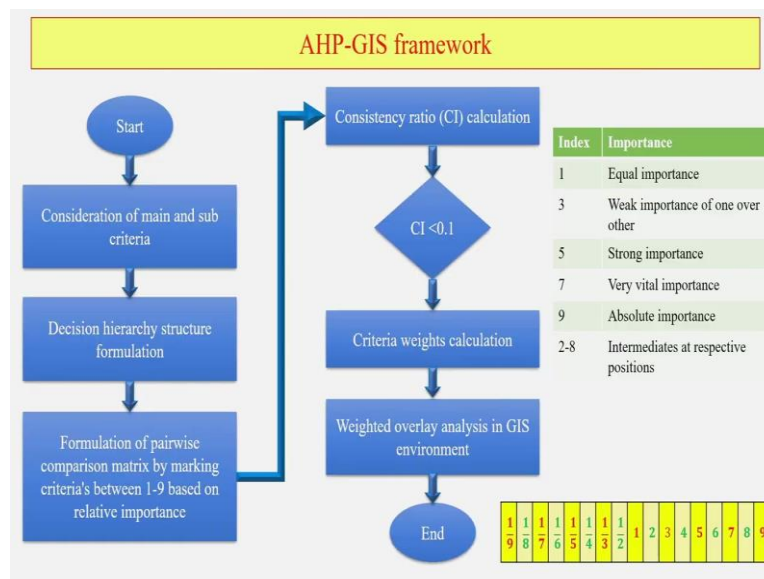
We talked about that how criteria versus alternatives you can choose the best alternatives for whatever particular criteria.

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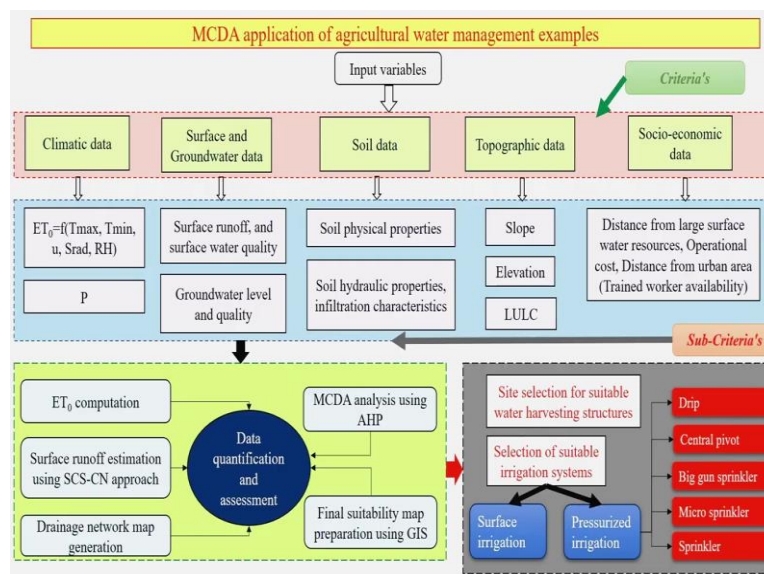
And there are various MCDA methods, we discussed about those things in great detail.

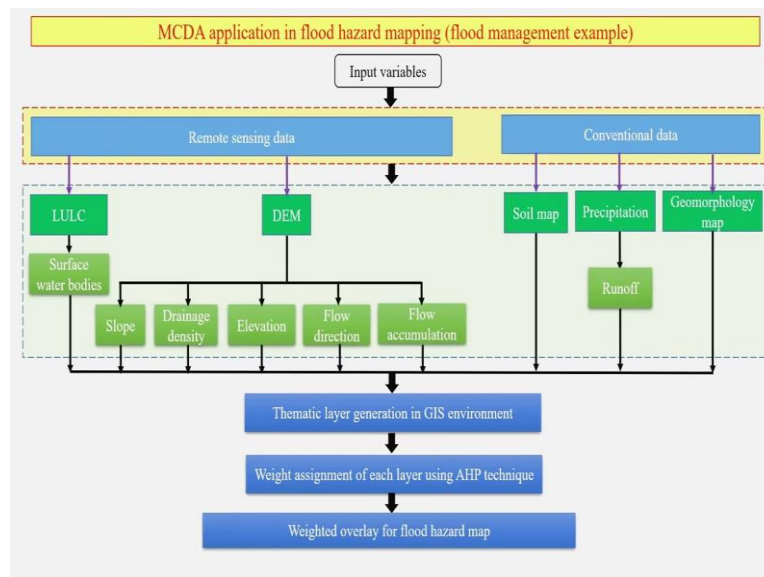
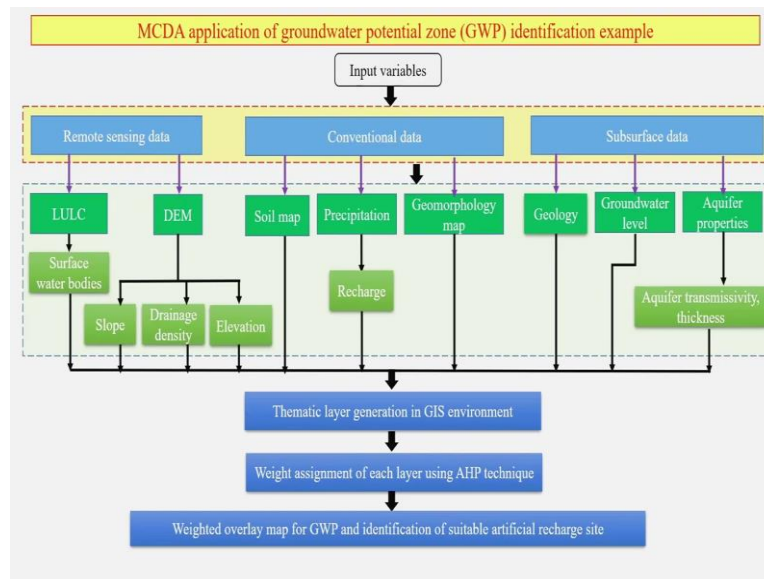
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And then one by one every MCDA method, we discussed like analytical hierarchy process AHP, how it works.

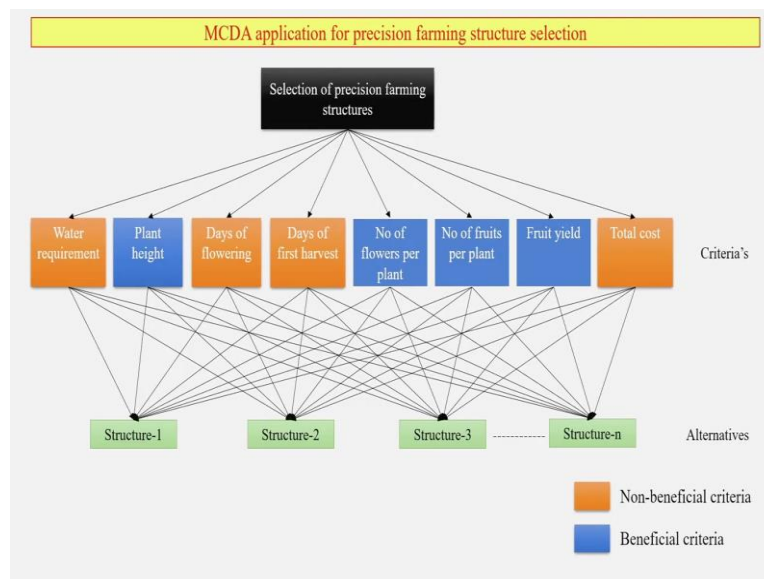
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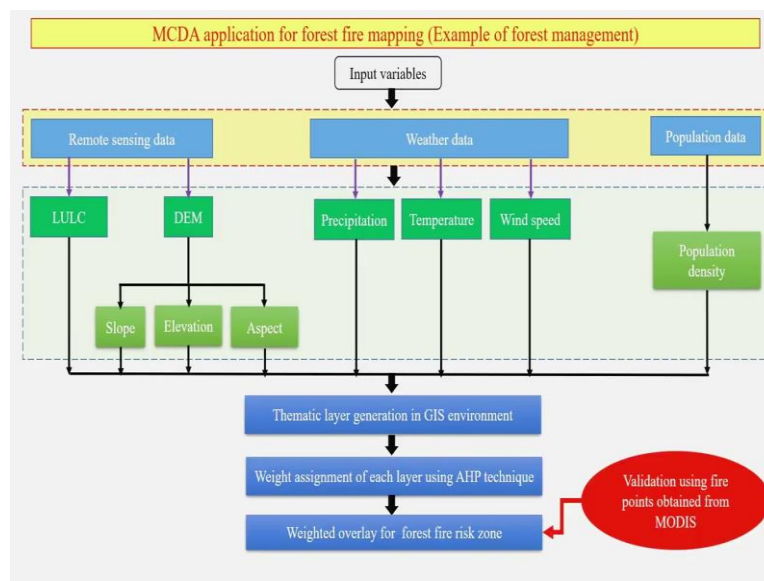
Then, we talked about how it can be used for potential water management, groundwater management, flood hazard mapping also.

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Then application of MCDA in precision farming structure selection is also in very high demand, where you can actually identify or find out the optimum solution for your purpose.

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Forest fire mapping even that also we discussed how MCDA can help, I hope that all of you have gone through these slides very carefully, you need to give some time and that is the precise reason that today's this revision exercise I am carrying out for the benefit of all of you.

So, this was the part under precision farming and MCDA; introduction of various modeling system how it works.

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Model sensitivity and uncertainty

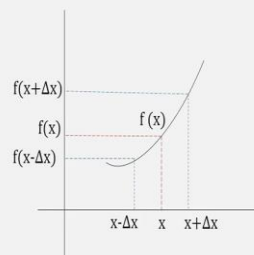
Model sensitivity analysis

- To determine the rate of change in the output of a model with respect to changes in model inputs/ or parameters
- Ranks the inputs or parameters depend on their contribution to model outputs. That is it helps to determine the most influential inputs on a model

□ Sensitivity coefficients is expressed as

$$S_A = \frac{\partial f}{\partial x}$$

Numerically $S_A = \frac{f(x + \Delta x) - f(x - \Delta x)}{2\Delta x}$



□ Δx vary from some % like 5%, 10%, 20% etc from original value of the inputs or parameters

□ Numerically done in case of a not easily differentiable function

□ If a model has a large set of inputs and parameters it is a time and computation consuming

Model sensitivity analysis example

- In a simple model for drop inlet spillway which is constructed for soil and water conservation purpose. the output of the is related to the input variables such as length of pipe (L), velocity of flow (V), entrance head loss coefficient (K_e) and acceleration due to gravity (g) as follows.

$$H_f = K_e L \frac{V^2}{2g}$$

Determine the sensitivity (%) of the variables when $L=20$ m, $K_e = 0.4$, $g = 10$ m/s² (Constant) and $V = 5$ m/s

X	$\frac{\partial H_f}{\partial X}$			S_A	$S_X(\%) = \frac{S_A}{\sum S_A} \times 100$
L	$\frac{\partial H_f}{\partial L}$	$K_e \frac{V^2}{2g}$	$0.4 \times \frac{5^2}{2 \times 10}$	0.5	1.69
K_e	$\frac{\partial H_f}{\partial K_e}$	$L \frac{V^2}{2g}$	$20 \times \frac{5^2}{2 \times 10}$	25	84.75
V	$\frac{\partial H_f}{\partial V}$	$K_e L \frac{V}{g}$	$20 \times 0.4 \times \frac{5}{10}$	4	13.56

$$\sum S_A = 29.5$$

K_e = most sensitive, L = least sensitive

Model sensitivity analysis numerical example

- In the previous problem determine the sensitivity coefficients in the case when the value changes 10% from its original values

X		$X + \Delta X$	$X - \Delta X$	$H_f(X + \Delta X)$	$H_f(X - \Delta X)$	$S_A = \frac{H_f(X + \Delta X) - H_f(X - \Delta X)}{(X + \Delta X) - (X - \Delta X)}$	$S_X(\%) = \frac{S_A}{\sum S_A} \times 100$
L	20	22	18	11	9	0.5	1.69
K_e	0.4	0.44	0.36	0.4	0.4	25	84.75
V	5	5.5	4.5	4.5	5	4	13.56

- Sensitivity coefficients may be relative (i.e. dimensionless) (S_R). That is based on the relative sensitivity coefficient direct comparison between variables or parameters may be easy as in the case of absolute sensitivity may not be directly compared as they might be influenced by units of input or output variables

$$S_R = \frac{\partial f}{\partial x} \frac{x}{f}$$

X	$\frac{\partial H_f}{\partial X}$		S_A	S_R
L	$\frac{\partial H_f}{\partial L}$	$K_e \frac{V^2}{2g}$	0.5	1
K_e	$\frac{\partial H_f}{\partial K_e}$	$\frac{L V^2}{2g}$	25	1
V	$\frac{\partial H_f}{\partial V}$	$K_e L \frac{V}{g}$	4	2

So, then let us go to the next topic for revision and that would be your modeling for NRM. If you recall that we have discussed about modeling sensitivity, uncertainty, model sensitivity analysis. How you actually carry out a various way of sensitivity analysis and with example, we have discussed.

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Model uncertainty analysis

- Uncertainty is the deficit of sureness in the phenomenon.
- A set of possible states or outcomes where probabilities are assigned to each possible state or outcome.
- In a model uncertainty occurs in output due to various reasons those are as follows
 - ❖ Uncertainty in model input variables
 - ❖ Uncertainty in model parameters
 - ❖ Uncertainty in model initial conditions, boundary conditions
 - ❖ Uncertainty in model assumptions, algorithms, objectives, stopping criteria
 - ❖ Spatiotemporal variation of parameters
- If a model output (F) depends upon different inputs like x_1, x_2, \dots, x_n and individual uncertainties of each are given as $u_{x_1}, u_{x_2}, \dots, u_{x_n}$ then overall uncertainties in the model U_F is expressed as

$$U_F = \sqrt{\left(\frac{\partial F}{\partial x_1} u_{x_1}\right)^2 + \left(\frac{\partial F}{\partial x_2} u_{x_2}\right)^2 + \dots + \left(\frac{\partial F}{\partial x_n} u_{x_n}\right)^2}$$

- If any variable x_k depends upon some other inputs like y_1, y_2, \dots, y_m then first compute the uncertainty in x_k

$$u_{x_k} = \sqrt{\left(\frac{\partial x_k}{\partial y_1} u_{y_1}\right)^2 + \left(\frac{\partial x_k}{\partial y_2} u_{y_2}\right)^2 + \dots + \left(\frac{\partial x_k}{\partial y_m} u_{y_m}\right)^2}$$

Model uncertainty analysis also, we have discussed.

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Risk and reliability

- ❑ Assists decision makers with accurate reliability assessment and making reliable systems/models for natural resources management and resource allocation
- ❑ Helps to identify, characterize, analyze and quantify the probability of any hazard
- ❑ Risk (R) = probability of failure. It is the probability of occurrence of an event ($x \geq x_T$) at least once over a period of n successive years.
- ❑ $R = 1 - (\text{probability of non-occurrence of the event } (x \geq x_T) \text{ in } n \text{ years})$

$$R = 1 - \left(1 - \frac{1}{T}\right)^n \quad \text{Where } T = \text{return period}$$

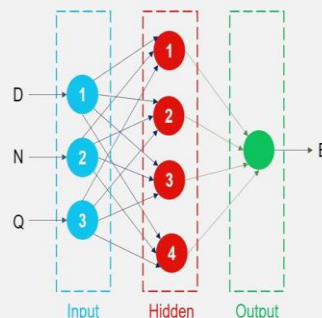
- ❑ A return period is an average time or an estimated average time between events such as disasters like earthquakes, floods, landslides, or river discharge flows to occur. It is also known as a recurrence interval or repeat interval
- ❑ The return period for which design a conservation structure also depends upon the acceptable level of risk
- ❑ Expression for reliability is given as

$$R_E = 1 - R = \left(1 - \frac{1}{T}\right)^n$$

Model sensitivity analysis of a neural network model inputs

- ❑ In a precision farming aeration system the aeration efficiency of the small pond aeration system (E) depends upon the flow velocity (Q), rpm of the machine (N), and the diameters of the blades of the machine propellers (D). A simple backpropagation artificial neural network (ANN) has been formulated. By trial and error method the model was formulated as 3-4-1 where 4 is the number of hidden layers. The neural network consists of single hidden layers. The connection weights between the **input and hidden layer neurones (N_h)** and the hidden to the **output layer neurones (N_o)** obtained are given in the table. Compute the sensitivity of D, N, and Q on the neural network model output efficiency (E). (Take 2 decimal places after point and round the values in each step)

N_h	D	N	Q	N_o
1	1.87	-0.95	0.48	-0.89
2	-2.98	-0.72	-0.03	0.18
3	-0.01	0.55	2.19	2.76
4	0.56	-3.86	-0.86	-0.73



Risk and reliability, how you can actually measure that. Model sensitivity analysis utilizing neural network, what are the inputs, what are the outputs these all we have discussed in the previous lectures. Then we go next topic after the sensitivity analysis one that is your MCDM part one.

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Weighted sum (WSM) and weighted product model (WPM)

- WSM is a simple and most common process to determine the weighted score of the alternatives.
- Simple linear combination (sum) of the weight and the values of the criteria
- Weight may be equal or unequal depending upon the purpose of the MCDM problem and objectives
- The mathematical formulation of the weighted sum model is as follows

$$S_{A_i} = \sum_{j=1}^n W_j X_{ij}$$

X_{ij} is the normalized criteria values of the alternatives

Example

$$S_{A_1} = W_1 X_{11} + W_2 X_{12} + \dots + W_n X_{1n}$$

$$S_{A_2} = W_1 X_{21} + W_2 X_{22} + \dots + W_n X_{2n}$$

$$S_{A_m} = W_1 X_{m1} + W_2 X_{m2} + \dots + W_n X_{mn}$$

S_{A_i} is the weighted sum score of i^{th} alternatives

- In many cases the weighted average score is taken instead of the weighted sum

Criteria weights	W_1	W_2	.....	W_n	S_i
Criteria (j)	C_1	C_2	.....	C_n	
Alternatives(i)					
A_1	X_{11}	X_{12}	.....	X_{1n}	S_{A_1}
A_2	X_{21}	X_{22}		X_{2n}	S_{A_2}
.....
A_m	X_{m1}	X_{m2}	.....	X_{mn}	S_{A_m}

Weighted sum (WSM) and weighted product model (WPM)

- Weighted product model is another combination of the weight and the values of the criteria for scoring the rank of the alternatives

$$P_{A_i} = \prod_{j=1}^n X_{ij}^{W_j}$$

X_{ij} is the normalized criteria values of the alternatives

Example

$$P_{A_1} = X_{11}^{W_1} \cdot X_{12}^{W_2} \dots X_{1n}^{W_n}$$

$$P_{A_2} = X_{21}^{W_1} \cdot X_{22}^{W_2} \dots X_{2n}^{W_n}$$

$$P_{A_m} = X_{m1}^{W_1} \cdot X_{m2}^{W_2} \dots X_{mn}^{W_n}$$

P_{A_i} is the weighted product score of i^{th} alternatives

- In case of max-min normalization of the variables (criteria) where $X \in [0,1]$, there in case of the lower limit of X i.e. 0 the entire weighted product will be zero. Which is a major limitation of this model

Criteria weights	W_1	W_2	.....	W_n	P_i
Criteria (j)	C_1	C_2	.....	C_n	
Alternatives(i)					
A_1	X_{11}	X_{12}	.....	X_{1n}	P_{A_1}
A_2	X_{21}	X_{22}		X_{2n}	P_{A_2}
.....
A_m	X_{m1}	X_{m2}	.....	X_{mn}	P_{A_m}

Here, if you recall that we have discussed in various aspects of MCDA with a real example, and how different methods of MCDA calculate the weightage and on that basis how we actually carry out the ranking and then you choose the top most the best one as your option. So, we discussed about WSM, weighted sum method.

(Refer Slide Time: 20:14)

Weighted aggregated sum product assessment (WASPAS)

❑ **WASPAS** is a weighted combination of the **WSM** and **WPM** processes to determine the weighted score of the alternatives.

$$R_i = \omega S_{A_i} + (1 - \omega) P_{A_i} \quad 0 \leq \omega \leq 1$$

$$R_i = \omega \sum_{j=1}^n W_j X_{ij} + (1 - \omega) \prod_{j=1}^n X_{ij}^{W_j}$$

❑ Usually in WASPAS ω is taken as 0.5 (but it depends upon the problem and the desired outcome)

Example of an MCDM problem

In an agriculture 6 different precision farming technologies are adopted. Four different criterias are enlisted in the table. Based on those criterias determine which technology is most suitable

	Criterias			
	Non beneficial		Beneficial	
Technologies	Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

Then we discussed about WASPAS and each one we have discussed if you recall with appropriate example.

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Example of an MCDM problem (cont.): WSM

If W is the **weight** associated with each criterion is **unequal** then
Let weights are 0.05, 0.8, 0.05 and 1 respectively here

	W	0.05	0.8	0.05	0.1
		C1	C2	C3	C4
A		0.26	1	0.09	0.5
B		1	0	1	0.29
C		0.33	0.21	0.38	0.05
D		0.63	0.66	0.69	1
E		0.88	0.32	0.8	0.74
F		0	0.24	0	0

→

	S	Rank
A	0.87	1
B	0.13	6
C	0.21	4
D	0.69	2
E	0.41	3
F	0.19	5

Example for row-1 i.e. for alternative A
 $(0.26 \times 0.05) + (1 \times 0.8) + (0.09 \times 0.05) + (0.5 \times 0.1) = 0.87$

Example of an MCDM problem (cont.): Weighted Sum Model (WPM)

W is the weight associated with each criterion (let **unequal** weight). The same example of the weighted sum model. Apply WPM in the example.

	W	0.05	0.8	0.05	0.1
		C1	C2	C3	C4
A		0.26	1	0.09	0.5
B		1	0	1	0.29
C		0.33	0.21	0.38	0.05
D		0.63	0.66	0.69	1
E		0.88	0.32	0.8	0.74
F		0	0.24	0	0

→

	P	Rank
A	0.77	1
B	0	5
C	0.19	4
D	0.69	2
E	0.38	3
F	0	5

Example for row-1 i.e. for alternative A
 $(0.26)^{0.05} \times (1)^{0.8} \times (0.09)^{0.05} \times (0.5)^{0.1} = 0.77$

Example of an MCDM problem (cont.): WASPAS

$$R_i = \omega S_{A_i} + (1 - \omega) P_{A_i}$$

W	0.25	0.25	0.25	0.25				
	C1	C2	C3	C4	WSM	WPM	WASPAS Rank	
A	0.26	1	0.09	0.5	0.46	0.33	0.4	5
B	1	0	1	0.29	0.57	0	0.29	3
C	0.33	0.21	0.38	0.05	0.24	0.19	0.22	4
D	0.63	0.66	0.69	1	0.75	0.73	0.74	1
E	0.88	0.32	0.8	0.74	0.69	0.64	0.67	2
F	0	0.24	0	0	0.06	0	0.03	6

Equal weight
 $(0.5 \times 0.46) + ((1-0.5) \times 0.33) = 0.4$

Weight aggregated sum product assessment with
 $\omega = 0.5$

W	0.05	0.8	0.05	0.1				
	C1	C2	C3	C4	WSM	WPM	WASPAS Rank	
A	0.26	1	0.09	0.5	0.87	0.77	0.82	1
B	1	0	1	0.29	0.13	0	0.07	6
C	0.33	0.21	0.38	0.05	0.21	0.19	0.2	4
D	0.63	0.66	0.69	1	0.69	0.69	0.69	2
E	0.88	0.32	0.8	0.74	0.41	0.38	0.4	3
F	0	0.24	0	0	0.19	0	0.1	5

Unequal weight
 $(0.5 \times 0.87) + ((1-0.5) \times 0.77) = 0.82$

Then we discussed about also WSM weighted sum model, then weighted product model. So, weighted product model is actually you multiply; weighted sum model you add. So, these are the aspects that we discussed under MCDM, part one and then in the lecture MCDA part 2.

(Refer Slide Time: 20:55)

Determination of objective criteria weights (CRITIC method)

❑ **Criteria Importance Through Inter-criteria Correlation (CRITIC)** is a weight-determining method that is used to assess performance rating basis different criteria or variables using their correlations

In CRITIC method the weights of j^{th} criterion, W_j , is computed by

$$W_j = \frac{C_j}{\sum_{j=1}^m C_j}$$

Where

$$C_j = \sigma_j \sum_{k=1}^m (1 - \rho_{jk})$$

Where, C_j is the quantity of information contained in j^{th} criterion, σ_j is standard deviation of the j^{th} criterion and ρ_{jk} is the correlation coefficient between j^{th} and k^{th} criteria in the normalized decision matrix $[r]_{n \times m}$ having elements as r_{ij} by using min-max normalization, where n is the total number of alternatives and m is the total number of criteria.

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}}$$

[** The criteria are not separate as beneficial and non-beneficial criteria]

Example of previous MCDM problem (CRITIC method)

✓ In an agriculture 6 different precision farming technologies are adopted. Four different criteria are enlisted in the table. Based on those criterias determine which technology is most suitable

Technologies	Criterias			
	Non beneficial		Beneficial	
	Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

In part 2, we have discussed about critic method, how critic method actually works again with the data and example. So, we kept a single example for all the methods of MCDA so, that you understand it better.

(Refer Slide Time: 21:13)

Example of an MCDM problem (CRITIC)				
	C1	C2	C3	C4
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

Where A, B, C, D, E and F are alternatives (i.e. technologies)
C1, C2, C3 and C4 are 4 different criterias respectively as
water requirement, cost of cultivation, yield (t/ha)

$$r_{ij} = \frac{x_{ij} - (x_j)_{\min}}{(x_j)_{\max} - (x_j)_{\min}}$$

$$\frac{621.0 - 448.2}{680.4 - 448.2} = 0.74$$

	C1	C2	C3	C4
Max	680.4	51925	9.13	68.36
Min	448.2	39925	7.35	48.34

	r_{ij}			
	C1	C2	C3	C4
A	0.74	0	0.09	0.5
B	0	1	1	0.29
C	0.67	0.79	0.38	0.05
D	0.37	0.34	0.69	1
E	0.12	0.68	0.8	0.74
F	1	0.76	0	0

Example of an MCDM problem (CRITIC)				
	r_{ij}			
	C1	C2	C3	C4
A	0.74	0	0.09	0.5
B	0	1	1	0.29
C	0.67	0.79	0.38	0.05
D	0.37	0.34	0.69	1
E	0.12	0.68	0.8	0.74
F	1	0.76	0	0

↓

	C1	C2	C3	C4
σ_j	0.39	0.36	0.40	0.39

→

Correlation (ρ_{jk})				
	C1	C2	C3	C4
C1	1	-0.33	-0.98	-0.51
C2	-0.33	1	0.44	-0.51
C3	-0.98	0.44	1	0.46
C4	-0.51	-0.51	0.46	1

↓

$1 - \rho_{jk}$				
	C1	C2	C3	C4
C1	0	1.33	1.98	1.51
C2	1.33	0	0.56	1.51
C3	1.98	0.56	0	0.54
C4	1.51	1.51	0.54	0

Determination of objective criteria weights (Entropy method)				
<p>□ Commonly used weight determining method that measures value dispersion in decision-making</p> <p>□ Higher dispersion degree means greater weight and more information by the criteria</p> <p>The entropy E_j for $j=1, 2, \dots, m$ for each criterion is calculated by</p> $E_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij}$ <p>Where, $0 \leq E_j \leq 1$; p_{ij} is the normalized value of j^{th} criterion for the i^{th} alternative which is given by</p> <p>sum-reciprocal normalization.</p> $p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad \text{[** The criteria are not separate as beneficial and non-beneficial criteria]}$ <p>Where, the degrees of variation, d_j, i.e., non-normalized values of the weights determined by the entropy method, are calculated for each criterion</p> $d_j = 1 - E_j$				

After critic methods then entropy method.

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Determination of objective criteria weights (Entropy method)

The **entropy** weights of j^{th} criterion, W_j , is computed by

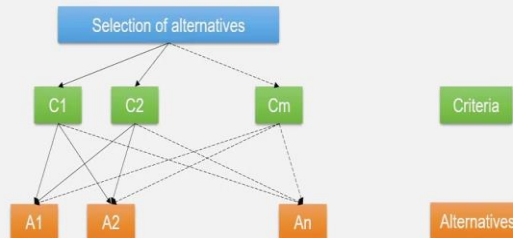
$$W_j = \frac{d_j}{\sum_{j=1}^m d_j}$$

Example of previous MCDM problem (Entropy method)

	Criterias			
	Non beneficial		Beneficial	
Technologies	Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
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F	680.4	49050	7.35	48.34

Analytic hierarchy process (AHP)

- ❑ Most widely and common method of MCDM approach.
- ❑ Depends on expert judgment.
- ❑ Relative importance should be given to each criterion on a 1 – 9 scale (Saaty, 1981). Which leads to the formation of a pair wise comparison matrix
- ❑ Commonly used with several GIS-based MCDM problems such as flood, landslide vulnerability mapping, forest fire mapping, groundwater potential zone, artificial recharge zone, critical crop cultivation zone identification, and many other socio-economic, and geological applications.
- ❑ Not required the criteria values of the alternatives



Analytic hierarchy process (AHP): previous example problem

□ Scale of relative importance is 1, 3, 5, 7, 9 and intermediate values are 2, 4, 6, 8

Index	1	3	5	7	9
Importance	Equal	Weak	Strong	Demonstrated	Absolute

C1	C2	C3	C4
Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)

Pairwise comparison matrix				
	C1	C2	C3	C4
C1	1	3	7/9	5/3
C2	1/3	1	4/7	2
C3	9/7	7/4	1	5
C4	3/5	1/2	1/5	1



Pairwise comparison matrix				
	C1	C2	C3	C4
C1	1	3	0.778	1.667
C2	0.333	1	0.571	2
C3	1.285	1.75	1	5
C4	0.6	0.5	0.2	1

Analytic hierarchy process (AHP): previous example problem

Pairwise comparison matrix				
	C1	C2	C3	C4
C1	1	3	0.778	1.667
C2	0.333	1	0.571	4
C3	1.285	1.75	1	5
C4	0.6	0.25	0.2	1
SUM	3.218	6.25	2.549	9.667



	C1	C2	C3	C4
C1	0.311	0.48	0.305	0.172
C2	0.103	0.16	0.224	0.207
C3	0.399	0.28	0.392	0.517
C4	0.186	0.08	0.078	0.103

$$1 / 3.218 = 0.311$$

$W_j \times C_{ij}$				
W	0.317	0.174	0.397	0.112
C1	0.317	0.522	0.309	0.187
C2	0.106	0.174	0.227	0.224
C3	0.407	0.305	0.397	0.56
C4	0.19	0.087	0.079	0.112



	C1	C2	C3	C4	W
C1	0.311	0.48	0.305	0.172	0.317
C2	0.103	0.16	0.224	0.207	0.174
C3	0.399	0.28	0.392	0.517	0.397
C4	0.186	0.08	0.078	0.103	0.112

$$(0.311 + 0.48 + 0.305 + 0.172) / 4 = 0.317$$

Ex. $0.317 \times 1 = 0.317$, $0.317 \times 0.333 = 0.106$ etc.

Then again AHP in great detail with the same example. So, with single example, we have discussed all the methods.

(Refer Slide Time: 21:27)

Analytic hierarchy process (AHP): Limitations

- ❑ As the pairwise comparison matrix is formulated based on decision-makers or expert judgment therefore always there is a chance of biasness.
- ❑ Multiple expert judgments need to be taken
- ❑ Solving a pairwise comparison matrix always does not lead to a consistency ratio (CR) < 0.1 hence the process is iterative until a CR < 0.1
- ❑ If any criteria consist of several subcriteria then first the weights of subcriteria need to be determined and then the subcriteria weights need to be multiplied by criteria weight to get the global weight for the final ranking
- ❑ Expertise can be recognized based on areas of expertise, diverse political views, diverse perspectives, diverse technical expertise

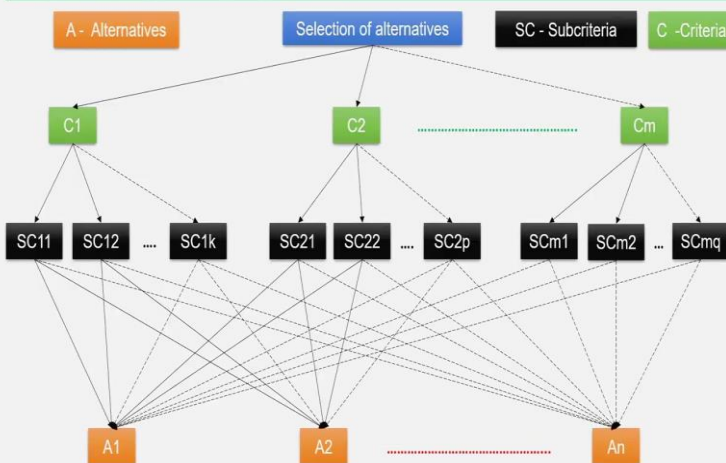
Delphi Technique

- ❑ Expert may ask specific questions and often rank choices differently
- ❑ Different experts may agree or argue with others' opinions or choices
- ❑ Responses may go to a central source that is summarized and feedback to the experts without attribution
- ❑ This process may be iterative and may be time consuming

Then we talked about the limitation of AHP, though AHP is very popular. Then Delphi technique, Delphi technique is again one of the very important tools or techniques for data collections.

(Refer Slide Time: 21:43)

Analytic hierarchy process (AHP): Sub criteria



Analytic hierarchy process (AHP): Sub criteria

W_C	W_{SC}	W_G
W_{C1}	W_{SC11}	$W_{C1} \times W_{SC11}$
	W_{SC12}	$W_{C1} \times W_{SC12}$

	W_{SC1k}	$W_{C1} \times W_{SC1k}$
W_{C2}	W_{SC21}	$W_{C2} \times W_{SC21}$
	W_{SC22}	$W_{C2} \times W_{SC22}$

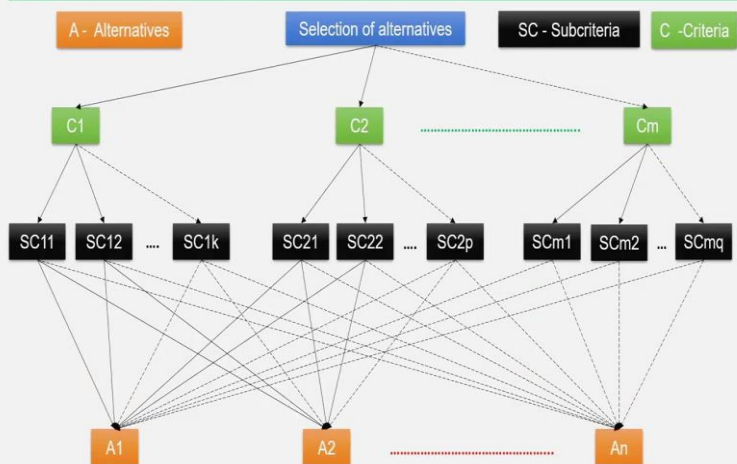
	W_{SC2p}	$W_{C2} \times W_{SC2p}$
.....
W_{Cm}	W_{SCm1}	$W_{Cm} \times W_{SCm1}$
	W_{SCm2}	$W_{Cm} \times W_{SCm2}$

	W_{SCmq}	$W_{Cm} \times W_{SCmq}$

- Compute the local weight of the subcriteria (same as AHP)
- Compute the weight of the criteria then compute the global weights

	SC11	SC12	.....	SC1k
SC11				
SC12				
.....				
SC1n				
W_{SC1}	W_{SC11}	W_{SC12}	.....	W_{SC1k}
	SC21	SC22	.....	SC2k
SC21				
SC22				
.....				
SC2p				
W_{SC2}	W_{SC21}	W_{SC22}	.....	W_{SC2p}
	SC21	SC22	.....	SC2k
SC21				
SC22				
.....				
SC2p				
W_{SC2}	W_{SC21}	W_{SC22}	.....	W_{SC2p}

Analytic hierarchy process (AHP): Sub criteria



Analytic hierarchy process (AHP): Sub criteria

W_C	W_{SC}	W_G
W_{C1}	W_{SC11}	$W_{C1} \times W_{SC11}$
	W_{SC12}	$W_{C1} \times W_{SC12}$

	W_{SC1k}	$W_{C1} \times W_{SC1k}$
W_{C2}	W_{SC21}	$W_{C2} \times W_{SC21}$
	W_{SC22}	$W_{C2} \times W_{SC22}$

	W_{SC2p}	$W_{C2} \times W_{SC2p}$
.....
W_{Cm}	W_{SCm1}	$W_{Cm} \times W_{SCm1}$
	W_{SCm2}	$W_{Cm} \times W_{SCm2}$

	W_{SCmq}	$W_{Cm} \times W_{SCmq}$

- Compute the local weight of the subcriteria (same as AHP)
- Compute the weight of the criteria then compute the global weights

	SC11	SC12	.....	SC1k
SC11				
SC12				
.....				
SC1n				
W_{SC1}	W_{SC11}	W_{SC12}	.....	W_{SC1k}
	SC21	SC22	.....	SC2k
SC21				
SC22				
.....				
SC2p				
W_{SC2}	W_{SC21}	W_{SC22}	.....	W_{SC2p}
	SC21	SC22	.....	SC2k
SC21				
SC22				
.....				
SC2p				
W_{SC2}	W_{SC21}	W_{SC22}	.....	W_{SC2p}

And then we talked about AHP criteria, sub criteria, how different sub criteria are actually choosing. So, like this way, MCDA has also been covered in great detail.

(Refer Slide Time: 22:07)

Technique for order performance by similarity to ideal solution (TOPSIS)

- ❑ TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives.
- ❑ The basic principle of TOPSIS is that the best alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution.

The **TOPSIS** procedure begins with the calculation of the normalized decision matrix $Q = [q_{ij}]_{m \times n}$ by normalizing the values of i^{th} alternatives and j^{th} criteria by **vector normalization** given as

$$q_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^n x_{ij}^2}}$$

Where q_{ij} is the normalized value of the j^{th} criteria for the i^{th} alternative

After calculation of the normalized decision matrix, the best alternatives (ideal solution) V^+ and worst alternatives (negative ideal solution) V^- were computed by

$$V^+ = \{v_1^+, v_2^+, \dots, v_m^+\} = \left\{ \left(\max_i v_{ij} | j \in J_1 \right), \left(\min_i v_{ij} | j \in J_2 \right) \right\}$$

$$V^- = \{v_1^-, v_2^-, \dots, v_m^-\} = \left\{ \left(\min_i v_{ij} | j \in J_1 \right), \left(\max_i v_{ij} | j \in J_2 \right) \right\}$$

And then we went finally, the last part of MCDM that was to talk about few other methods like TOPSIS, how TOPSIS actually can be be calculated and ranking can be made.

(Refer Slide Time: 22:17)

Complex Proportional Assessment (COPRAS)

- ❑ COPRAS is a simple technique which considers ideal and ideal worst solutions
- ❑ This method assumes proportional dependency of the significance and utilized the degrees of available alternatives under mutually conflicting criteria

The **COPRAS** procedure begins with the calculation of the normalized decision matrix $Q = [q_{ij}]_{m \times n}$ by normalizing the values of i^{th} alternatives and j^{th} criteria by **sum normalization** given as

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad [**\text{Not differentiation between beneficial and non-beneficial criteria}]$$

Where r_{ij} is the normalized value of the j^{th} criteria for the i^{th} alternative

The normalized matrix is multiplied by the weights to get the weighted normalized matrix

$$R_{ij} = r_{ij} W_j$$

The row sum of weighted normalized matrix is given as

$$S_i^+ = \sum_{j=1}^p R_{ij} \quad \text{Beneficial criteria}$$

$$S_i^- = \sum_{j=1}^q R_{ij} \quad \text{Non-beneficial criteria}$$

p = Number of beneficial criteria
 q = Number of non-beneficial criteria

Then COPRAS we also discussed with same example, like others.

(Refer Slide Time: 22:24)

Weight determination using Principal Component Analysis (PCA)

- ❑ PCA is a dimension reduction technique
- ❑ Widely used in image processing technique
- ❑ In different branches of science majorly in environmental soil, water science, pollution, etc. study it is widely used in determining the influential variables
- ❑ Also used in some regression models
- ❑ Can be done by using different statistical tools like Minitab, MATLAB, R, SPSS, XLSTAT, Python, etc.
- ❑ In MCDM the criteria weights determination by using PCA was not commonly used however in some research works the methodology is used in different forms for determining the objectives criteria weights (Zhu 1998, Dugger et al., 2022)

Weight determination using PCA

Principal components						
P	0.5976	0.374	0.0256	0.0029	ω_j	W_j
	PC1	PC2	PC3	PC4		
C	-0.6372	0.0194	-0.4946	-0.5908	0.3879	0.2884
	0.2229	-0.7522	-0.5797	0.2203	0.1623	0.1207
	0.6403	-0.0923	0.0777	-0.7586	0.3479	0.2586
	0.3666	0.6522	-0.6429	0.1642	0.447	0.3323

$$\omega_{j=1} = |P_1 C_{11} + P_2 C_{12} + P_3 C_{13} + P_4 C_{14}|$$

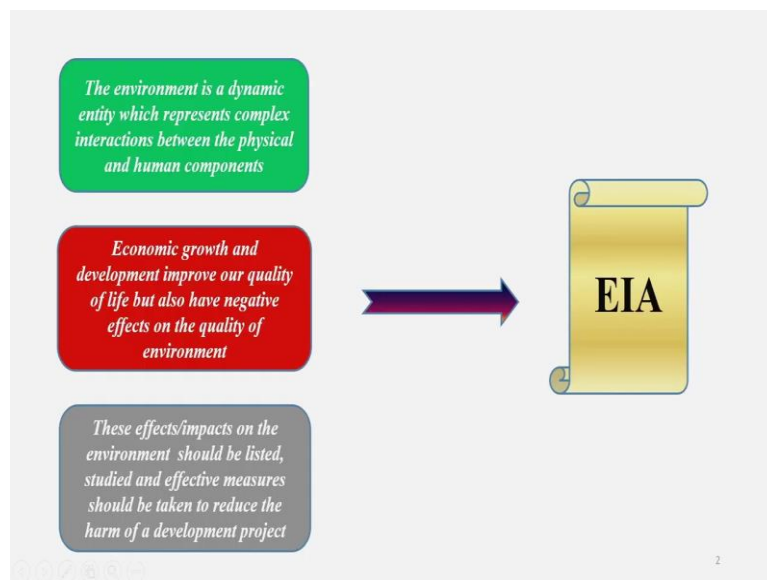
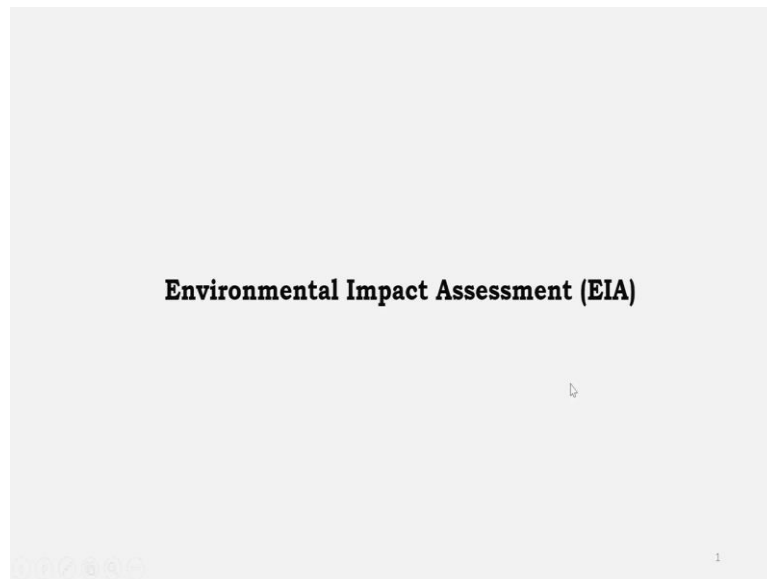
$$\omega_{j=1} = |(0.5976 \times (-0.6372)) + (0.374 \times 0.0194) + (0.0256 \times (-0.4946)) + (0.0029 \times (-0.5908))|$$

$$\omega_{j=1} = 0.3879$$

$$\sum_{j=1}^{m=4} \omega_j = 0.3879 + 0.1623 + 0.3479 + 0.447 = 1.3451 \quad W_{j=1} = \frac{\omega_{j=1}}{\sum_{j=1}^{m=4} \omega_j} = \frac{0.3879}{1.3451} = 0.2884$$

Then principal component analysis many of you might be already using it. So, how principal PCA can be also used for better ranking. So, in a sense that we discussed the MCDA, which is a very important tools or techniques for ranking, finding ranking of your alternatives, so, that you can take a decision at the field level that which one actually needs to be applied in the field.

(Refer Slide Time: 23:06)



Then, if you recall that we have discussed in great detail about environment impact assessment. Because this is one technique, which helps you to understand the environment better and environment has direct link with natural resources.

(Refer Slide Time: 23:16)

What is EIA?

The Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse.

The purpose of the assessment is to ensure that decision makers consider the environmental impacts when deciding whether or not to proceed with a project.

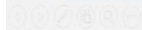
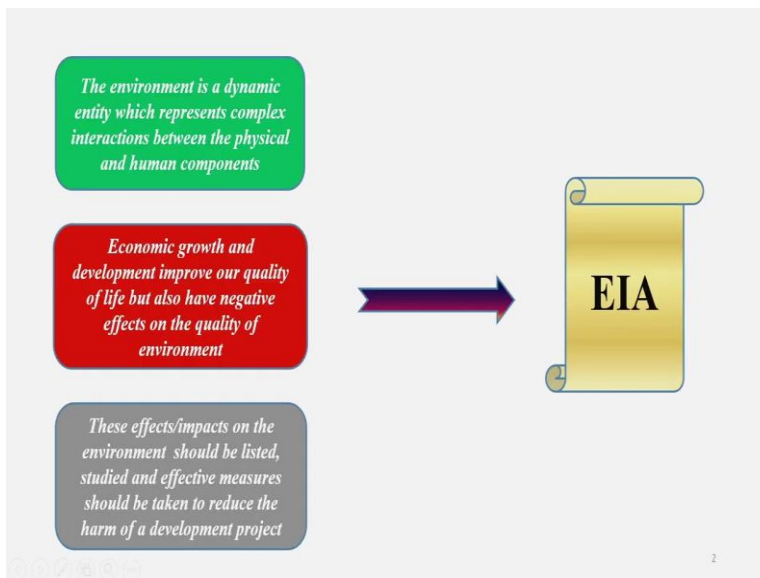
Impact assessment concerns began in the 1960s, as part of increasing environmental awareness. It obtained formal status in 1969, with the enactment of the **National Environmental Policy Act (NEPA)**.

UNEP defines EIA as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers.

By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations.



3



2

Principles of EIA

Principle I

States should not undertake or authorize activities without prior consideration of their environmental impacts, beneficial or otherwise

Principle II

The criteria and procedures for determining whether an activity is likely to effect the environment and subjected to EIA, should be clearly defined by legislation, regulation or by competent authorities.

Principle III

All environmental impacts irrespective of positive-negative, big-small, minor-major are to be considered before project sanctioning to get a complete picture

Principle IV

The environmental effects in an EIA should be assessed with a degree of detail commensurate with their likely environmental significance.

Principle V

The information provided as a part of EIA should be examined impartially prior to decision making.



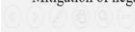
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So, we discussed about EIA in great detail about its uses, why it is done, what is the goal of EIA, principles of EIA.

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Benefits of conducting EIA


- Facilitates informed decision making by providing clear, well structured dispassionate analysis of the effect and consequences of proposed projects.
- Pre-emption or early withdrawal of unsound proposals.
- Assists in the selection of alternatives, including selection of best practical and eco-friendly option.
- Influences both project selection and design by screening out environmentally unsound projects as well as modifying feasible projects.
- Guides formal approval including the establishment of terms and conditions of project implementation and follow up.
- Results in best practice prediction and mitigation of adverse effects of projects.
- Serves as an adaptive, organizational learning process, in which the lessons of experience are feedback into policy, institutional and project design and enhancement of positive aspects.
- Incorporates stakeholder analysis.
- Mitigation of negative environmental and social impacts.



Methods to carry out EIA

1. **Life Cycle Analysis (LCA)** is used for identifying and measuring the impact on the environment of industrial products.
2. **GMP-RAM**; used for performance check of Genetically modified plants
3. **Fuzzy Arithmetic**; for subjective parameters like landscape quality, social acceptance etc,
4. **Cost benefit analysis.**
5. **Hedonic pricing.**

Data collection is performed by surveys, sampling, baseline studies, PRA, RRA, observations, prior information etc. to get a considerable amount of data to carry out the EIA process smoothly and successfully.



Then we went into benefits of conducting EIA then the methods. So, we took actually quite significant amount of time to discuss about the methods of EIA.

(Refer Slide Time: 23:41)

1. Life Cycle Analysis (LCA)

- LCA is an analysis method that measures the environmental impact of a product, service, process, or system over its total lifespan.
- An LCA measures the environmental impacts of each distinct part involved in creating and using products and services, such as energy used in production, fuel used in transport, and end-of-life ecological costs.
- This helps us compare between products, materials, and methods used, providing useful information by which to make decisions that could help the environment.
- It is a technique for assessing the potential environmental aspects and potential aspects associated with a product (or service), by:

compiling an **inventory** of relevant inputs and outputs,
evaluating the potential environmental impacts associated with those inputs and outputs,
interpreting the results of the inventory and impact phases in relation to the objectives of the study.

11

2. GMP-RAM method

- An essential step in the development of products based on biotechnology is an assessment of their potential economic impacts and safety, including an evaluation of the potential impact of transgenic crops and practices related to their cultivation on the environment and human or animal health
- Risk Assessment Method for Genetically Modified Plants (GMP-RAM) is one such method to evaluate the impact of biotechnological products to ensure their safety.
- The assessment is performed through likewise: environmental, economic, social, capability and institutional approach.
- This is coupled with GMP specific indicators related to genetic modification are grouped in common fields: genetic insert features, GM plant features, gene flow, food/feed field, introduction of the GMP, unexpected occurrences and specific indicators and characteristics (vector DNA, plasmid characteristics, pathogenicity etc.).

The information obtained from the method is organized into three tools:

(1) Worksheets to compile Prospective Range, through the Significance Index;

(2) Indicators worksheets to compile an Impact Level Performance defined by the Magnitude Index.

(3) Finally the combination of both Indexes (Significance \times Magnitude) to generate a matrix which will give the general impact value.

15

2. GMP-RAM method description

3. Genetically modified plants assessment:

The assessment is performed through the analysis of **indicators** which are arranged according to their area criteria (coded with letters) in two ways: **general or technical** such as:

General Assess:

environmental (A),
institutional (B)
capacity development (C),
economic (D),
social (E)

Technical Assess:

genetic features (F),
GM plant features (G),
gene flow (H),
food/feed field (I),
introduction of the GMP (J),
unexpected occurrences (K) and
specific indicators field (L)

19

2. GMP-RAM method description

Finally, based on these assessments, the impact matrix is formulated.

The Significance index and the magnitude index for both general and technical assess is determined:

$$\text{Biotechnology Range} \times \text{Extent} = \text{Significance Index}_{\text{Gen}}$$

$$\text{Safety test} + \text{Plantation site} + \text{Reproduction sp} + \text{Risk perception} = \text{Significance Index}_{\text{tech}}$$

$$\Sigma (\text{Total Weight of Field A; B; C; D; E}) / \text{Number of Fields Analyzed} = \text{Magnitude Index (General Impact Index)}$$

$$\Sigma (\text{Total Weight of Field F; G; H; I; J; K; L}) / \text{Number of Fields Analyzed} = \text{Magnitude Index (Technological Impact Index)}$$

20

2. GMP-RAM method description

4. Fields for indicator description, indicator weight, factors of moderation and criteria of assessment

- These summarized data on the indicators worksheet are identified and compiled with the contribution of experts from several areas of the assessment approach.
- it is done to firstly to identify and consolidate the necessary indicators and thereafter to make adjustments on indicators' weights and weight ranges of each moderation and correction factors, when necessary.
- Some tests were accomplished for adjustments not only on used parameters but also on the functionality of the support Software for the system application.
- To each indicator (A-L), the method gives a weight, which varies from 1 to 3.
- Indicators that show a higher weight are the ones with significant impact. In the case of Environmental Field the indicators of environment recovery have weight 3, since according to this item a certain environment may be recovered potentializing its future use for conservation or preservation. On the same way, it is given the maximum value (3) to the field 'unexpected events' since it brings the possibility of adverse or undesirable effects.
- On the other hand, indicators added by users have weight 1, so that the final result does not suffer great distortions.

21

2. GMP-RAM method description

5. Data/information for the evaluation field:

- Literature searches or prospective data must be the source of scientific data, described to perform the ex-ante analysis or the scenario elucidation of the GMP.
- Experimental results from GMP application must be used as the assessment basis for weight allocation.
- These collected data must be inserted in the worksheet's central column in order to ensure the acuity and support of the achieved results. These data will be shown on methodology results in electronic format (AS-GMP Software) as a 'descriptive report'.

6. Matrix of impact:

- Matrix assessment is performed to review the potential impact and establishing at which level impact management, through preventive or corrective actions, must be taken in order to allow an effective and safe use of the transgenic crop.
- The Matrix is constructed with two axes, where the x-axis stands for the classes of the Index of Magnitude (indicators performance) and the y-axis stands for the classes of the Significance Index (Prospective Analysis/Scenario for the GMP Introduction) with **scores** that dictates whether a GMP is favorable for marketability or not.

22

2. GMP-RAM method description (Impact matrices)

Significance index _{gen}	11-20 very favorable	9	10	11	12
	1-10 favorable	5	6	7	8
	-20-0 unfavorable	1	2	3	4
		-20 to -10 very low performance	-9 to 0 low performance	1-10 medium performance	11-20 high performance
Magnitude index _{gen}					
Significance index _{tech}	11-20 very favorable	9	10	11	12
	1-10 favorable	5	6	7	8
	-20-0 unfavorable	1	2	3	4
		-20 to -10 very low performance	-9 to 0 low performance	1-10 medium performance	11-20 high performance
Magnitude index _{tech}					

23

2. GMP-RAM method description

Sl no.	Assessment scenario to the GMP	Performance	Recommendation
1	Unfavorable in early implementation	Low success	Not recommended
2	Unfavorable	Low performance	Restrictions and Corrective actions recommended
3	Unfavorable	Medium performance	Monitoring with restrictions
4	Unfavorable		Recommended
5	Favorable in early implementation	Low success	Management with restrictions
6	Favorable	Low performance	Corrective actions recommended
7	Favorable	Medium performance	Management required
8	Favorable	Excellent performance	Recommended
9	Favorable in investments	Low performance	Management required
11	Favorable	Medium performance	Monitoring required
12	Favorable	Excellent performance	Highly recommended

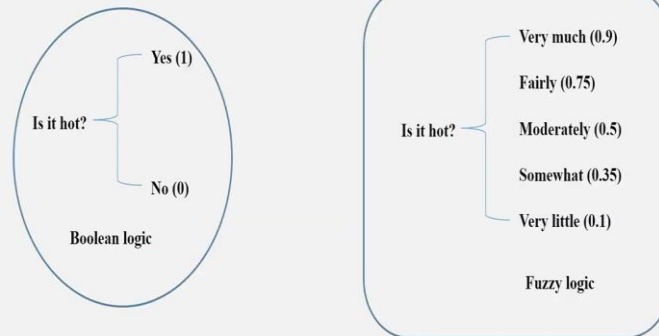
24

And there we discussed various methods like LCA and then GMP-RAM method, each one of them we have discussed if you recall with certain example.

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3. Fuzzy arithmetic

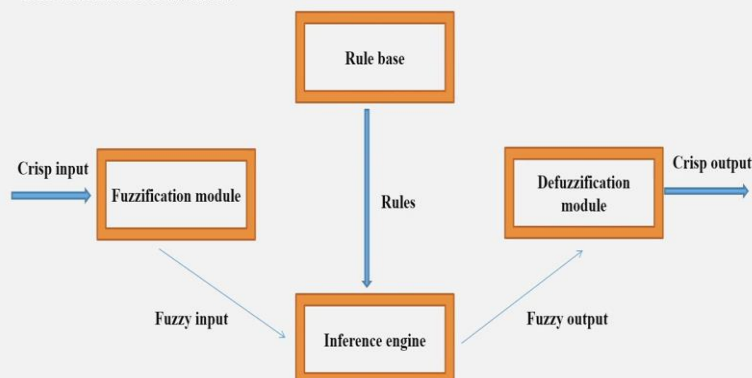
- Fuzzy arithmetic are specific types of fuzzy sets that are used for representing the values of real-world parameters when exact values are not measurable due to incomplete information or a lack of knowledge.
- Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based.



25

3. Fuzzy logic process

In EIA, Fuzzy logic systems are used to control actions and processes of a development project where a clear Yes/No information is not available.



26

3. Fuzzy logic process

Rule Base: This contains the rules and membership functions that regulate or control decision-making in the fuzzy logic system. It also contains the IF-THEN conditions used for conditional programming and controlling the system.

Fuzzifier: This component transforms raw inputs into fuzzy sets. The fuzzy sets proceed to the control system, where they undergo further processing.

Inference Engine: This is a tool that establishes the ideal rules for a specific input. It then applies these rules to the input data to generate a fuzzy output.

Defuzzifier: This component transforms the fuzzy sets into an explicit output (in the form of crisp inputs). Defuzzification is the final stage of a fuzzy logic system

27

And then fuzzy arithmetic process, fuzzy logic process.

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4. Cost Benefit Analysis (CBA)

A cost-benefit analysis is the process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project decision to determine whether it makes sense from a business perspective.

Generally speaking, cost-benefit analysis involves tallying up all costs of a project or decision and subtracting that amount from the total projected benefits of the project or decision.

If the projected benefits outweigh the costs, you could argue that the decision is a good one to make. If, on the other hand, the costs outweigh the benefits, then a company may want to rethink the decision or project.

There are enormous economic benefits to running these kinds of analyses before making significant organizational decisions. By doing analyses, critical information like a company's value chain or a project return on investment (ROI) can be known.

Costs	Benefits
Direct costs	Direct
Indirect costs	Indirect
Intangible costs	Total benefits
Opportunity costs	Net benefits
Costs of potential risks	

33

CBA, another very important aspect that we have discussed. So, please go through it with little bit of care because these aspects would be vvery helpful when you actually work in the field, whether into academics or in professions.

(Refer Slide Time: 24:24)

4. Decision criteria of Cost Benefit Analysis in EIA

The most popular and commonly used criteria for determining the economic merit of a project and for ranking alternatives are:

1. Net Present Value (NPV)
2. Internal rate of return (IRR)
3. Benefit cost ratio (B/ C)

1. Net Present Value (NPV):

$$NPV_x = (B_x - C_x)_0 + (B_x - C_x)_1 / (1+r) + (B_x - C_x)_2 / (1+r)^2 + \dots + (B_x - C_x)_t / (1+r)^t$$

Where, B_x = benefit stream, C_x = cost stream and r = discount rate.

A project or plan is accepted if its NPV is positive--the benefits of the undertaking outweigh its costs.

36

4. Decision criteria of Cost Benefit Analysis in EIA

2. Internal rate of return (IRR) (r)

The internal rate of return is the discount rate which equalizes the present values of the benefit and cost streams over the life of the project. It is calculated by setting the NPV equal to zero.

$$NPV_x = (B_x - C_x)_0 + (B_x - C_x)_1 / (1+r) + (B_x - C_x)_2 / (1+r)^2 + \dots + (B_x - C_x)_t / (1+r)^t = 0$$

Where, B_x = benefit stream, C_x = cost stream and r = return rate.

A project can only be acceptable if its IRR is higher than the opportunity cost of the funds involved. If two mutually exclusive projects are being evaluated, the one with the higher IRR will normally be chosen.

3. Benefit cost ratio (B/ C)

The Benefit-Cost Ratio offers a way of ranking projects. If one calculates the present values of a project's benefits and costs separately, then the benefit-cost ratio is PVB/PVC. A project is acceptable if PVB/PVC > 1.

37

So, CBA also we have discussed with some example.

(Refer Slide Time: 24:28)

5. Hedonic pricing

- The hedonic method is a regression technique used to estimate the prices of qualities or models that are not available on the market in particular periods, but whose prices in those periods are needed in order to be able to construct price relatives.

- In terms of EIA, the hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices.

It can be used to estimate economic benefits or costs associated with:

- environmental quality, including air pollution, water pollution, or noise
- environmental amenities, such as aesthetic views or proximity to recreational sites

- Hedonic pricing principles as such do not directly influence an EIA report as it is mostly associated with the pricing determination of the non-market goods. Its significance lies in the later stages of EIA, where the 'pricing' of a non market commodity can be used as a key role whether to go forward with the project or not.

- For example: the hedonic price of a stream with aesthetic values is quite high when compared to its neighboring area where an industry needs to be laid down. In such a situation, the aesthetic price of the stream will surpass the economic benefits of the proposed industry thereby leading to change of site of the proposed project or termination of the project if it is site specific.

38

5. Hedonic pricing in EIA

This method is extremely case specific and do not have any defined guidelines. As most of its parameters are of non-market significance, the methods are dynamic and inter-linking with other EIA strategies.

Considering the price of environmental values of an open space which is in question for an industry establishment. The values of the environmental aspects determined by Hedonic price method:

Step 1:

The first step is to collect data on the environmental quality parameters like soil, air and water quality; biodiversity; topography; and landscape type and all aesthetic amenities provided by the open space should be considered and valued in terms of capital.

Step 2:

Once the data are collected and compiled, the next step is to statistically estimate a function (regression analysis) that relates environmental values to the property characteristics, including the distance to open space. The resulting function measures the portion of the property price that is attributable to each environmental characteristic. Thus, the researcher can estimate the value of preserving the open space by looking at how the value of the open space changes when the amount of open space nearby changes.

39

5. Hedonic regression analysis

The hedonic regression function illustrates the relationship between the price of the asset (being the dependent variable) and the components/characteristics of the asset (being the independent or explanatory variables) as:

$$p_i = j(c_i)$$

Where:

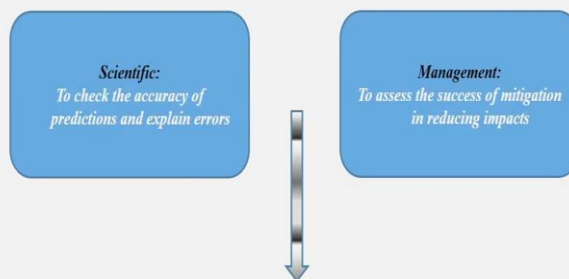
p is the price of a variety i of a good

c_i is a vector of characteristics associated with the variety of the good

The basic assumption of the hedonic function is that it has a multiplicative functional form where, as a characteristic increases, the price of a property increases but at a decreasing rate.

40

EIA considerations..



41

And then hedonic pricing also we have discussed how we actually carried out. Little bit of linkage of EIA, how it helps in to in sustainable development.

(Refer Slide Time: 24:41)

EIA legal, policy & institutional framework

EIA in international environmental law context

a) **Convention on Environmental Impact Assessment in a Trans-boundary Context (Espoo, 1991).**
The Espoo Convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of states to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across borders.

b) **Rio Declaration (1992).**
Principle 17 of Rio Declaration on Environment and Development calls for use of EIA as a national decision making instrument to be used in assessing whether proposed activities are likely to have significant adverse impact on the environment.

Agenda 21, which was also as a result of this convention, proposes that governments should:

Introduce appropriate EIA procedures for proposed projects likely to have significant impacts upon biological diversity, providing for suitable information to be made widely available and for public participation, where appropriate, and encourage the assessment of impacts of relevant policies and programs on biological diversity (15.5(k)).

42

EIA legal, policy & institutional framework

Multilateral and bilateral financial institutions with environmental safeguards

African Development Bank (AfDB)

Asian Development Bank (ADB)

European Bank for Reconstruction and Development (EBRD)

European Investment Bank (EIB)

Japanese Bank for International Cooperation (JBIC)

World Bank (WB)

45

Legal and institutional framework, how EIA plays an important role into that because environment ultimately goes into some legal system. We have environmental law also. We discussed about also different rules, laws and tribunals.

(Refer Slide Time: 25:03)

EIA process

47

EIA process

The first phase of an environmental assessment is called an **Initial Environmental Examination (IEE)** and the second is **Environmental Impact Studies (EIS)** or simply detailed EIA.

IEE is carried out to determine whether potentially adverse environmental effects are significant or not.

It contains a brief statement of key environmental issues, based on readily available information, and is used in the early (pre-feasibility) phase of project planning.

When an IEE is able to provide a definite solution to environmental problems, an EIA is not necessary.

EIA is a procedure used to examine the environmental consequences or impacts, both beneficial and adverse, of a proposed development project and to ensure that these effects are taken into account in project design.

The EIA is therefore based on predictions.

The study therefore requires a multidisciplinary approach and should be done very early at the feasibility stage of a project. In other words, a project should be assessed for its environmental feasibility.

48

And how the process of EIA actually is carried out.

(Refer Slide Time: 25:08)

Project categorization for EIA process (India)

Environment Impact Assessment Notification of 2006 has decentralized the environmental clearance projects by categorizing the developmental projects in two categories:

Category A (national level appraisal) and Category B (state level appraisal).

Category A projects are appraised at national level by Impact Assessment Agency (IAA) and the Expert Appraisal Committee (EAC).
They require mandatory environmental clearance and thus they do not undergo the screening process.

Category B projects are appraised at state level. State Level Environment Impact Assessment Authority (SEIAA) and State Level Expert Appraisal Committee (SEAC) are constituted to provide clearance to Category B process. They undergo the screening process and they are classified into two types.

**Category B1 projects (Mandatorily requires EIA).
Category B2 projects (Do not require EIA).**

49

So, in India, we have given some example to you and explain that how EIA process takes place in our country.

(Refer Slide Time: 25:15)

Project categorization for EIA process (World Bank)

The World Bank has criteria for screening projects as follows:

Category A:
These are projects likely to have significant environmental impacts that are sensitive, diverse or unprecedented. These impacts may affect an area broader than the communities benefiting from infrastructure investments.

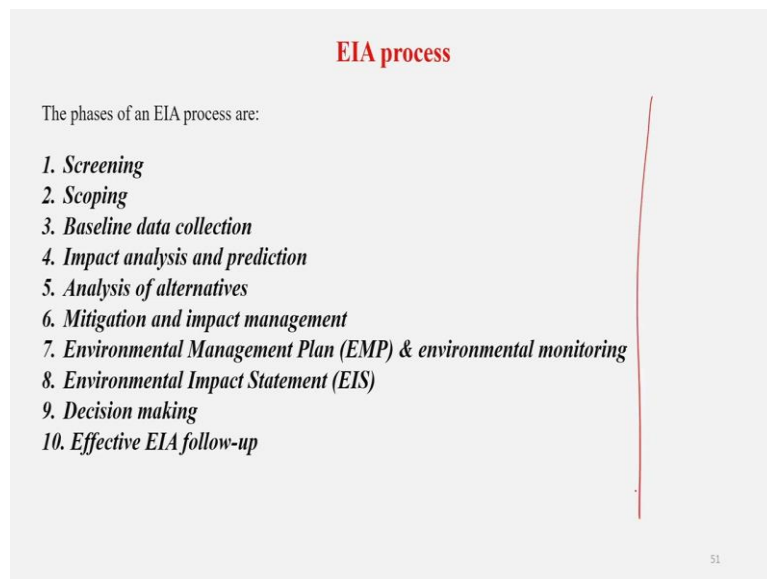
Category B:
If the projects potential adverse environmental impacts on human populations or environmentally important areas are less adverse than those of Category A projects, it comes under Category B. These impacts are site-specific; few if any of them are irreversible; and in most cases mitigation measures can be designed more readily than for Category A projects.

Category C:
If the project is likely to have minimal or no adverse environmental impacts. Once the project is assessed and determined as Category C, no further action would be required. Some examples of Category C projects include: Education, capacity-building, family planning etc.

50

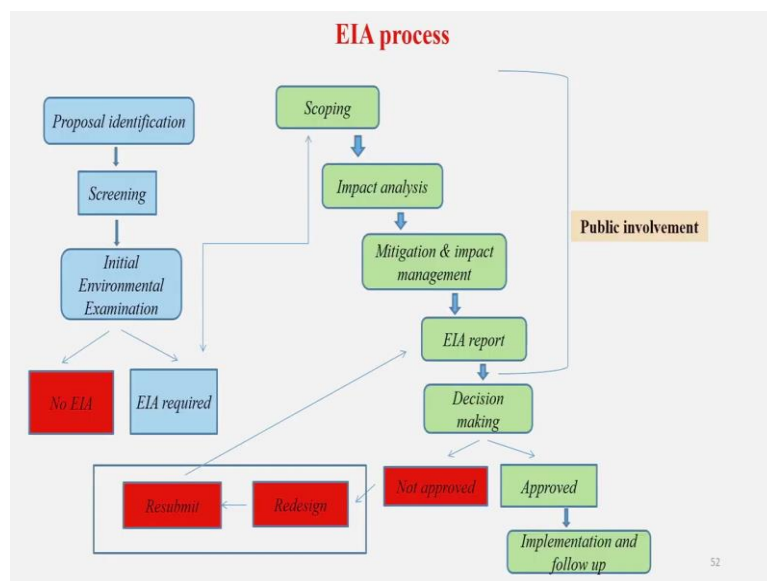
How World bank actually, which is a very active organization across the world, and especially in developing country, how they look at EIA exercise.

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EIA process we discussed about all the different processes of EIA.

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1. Screening

- The screening process determines whether a particular project warrants preparation of an EIA.
- The threshold requirements for an EIA vary from country to country – some laws provide a list of the types of activities or projects that will require an EIA, others require an EIA for any project that may have a significant impact on the environment or for projects that exceed a certain monetary value.
- In some cases, particularly if the possible impacts of a project are not known, a preliminary environmental assessment will be prepared to determine whether the project warrants an EIA.
- Development banks also screen projects presented for financing to decide whether an EIA is required using their set criteria.
- The output of the screening process is often a document called an Initial Environmental Examination or Evaluation (IEE).
- The main conclusion will be a classification of the project according to its likely environmental sensitivity. This will determine whether an EIA is needed and if so, to what detail.

53

2. Scoping

Scoping is used to identify the key issues of concern at an early stage in the planning process. The results of scoping will determine the scope, depth and terms of reference to be addressed within the Environmental statement.

Scoping is done to:

- Identify concerns and issues for consideration in an EIA
- Ensure a relevant EIA
- Enable those responsible for an EIA study to properly brief the study team on the alternatives and on impacts to be considered at different levels of analysis
- Determine the assessment methods to be used
- Identify all affected interests
- Provide an opportunity for public involvement in determining the factors to be assessed, and facilitate early agreement on contentious issues
- Save time and money
- Establish terms of reference (TOR) for EIA study

54

Terms of Reference (ToR)

- Once a project or development has gone through the screening and scoping phases, the authority responsible for processing the EIA provides the client with a **Terms of Reference (ToR)** document. The ToR provides details of all the information required for the EIA review committee to make an informed decision about awarding the Environmental licence.
- ToR varies from country to country and project to project.

The TOR should require the consultants to cover the following points:

- ☐ *Whether a range of proposals should be considered and if so whether they would be less environmentally damaging;*
- ☐ *The main environmental effects of the proposed project, both in the project area and in the surrounding area and the timescale of the impacts;*
- ☐ *The size and extent of the impacts based as much as possible on quantitative data rather than qualitative assessment. In most cases, however, it may be preferable not to mention any specific topic and make the consultant responsible for a complete review of all topics;*
- ☐ *Those groups that will benefit and those disadvantaged by the project;*

Contd..

56

Terms of Reference (ToR)

- *The impact on any rare species of plant or animal in the area;*
- *The impact on human health;*
- *The control and management aspects of the project to determine if they will be effective;*
- *The need for further baseline data collection or other specialist studies;*
- *The present policy, institutional and legislative situation and future needs;*
- *The mitigating measures needed and how they should be incorporated into the project design;*
- *The monitoring and evaluation activities that are required to ensure that mitigating measures are implemented and future problems are avoided.*

57

Terms of Reference (ToR)

ToR for Environmental impact assessment of irrigation and drainage projects:

- The TOR should commence with a brief description of the project that should include a plan of the areas affected either indirectly or directly. Basic data should be given on existing and proposed irrigation and drainage in the area and the catchment characteristics. The institutions that are involved in the proposal should also be given.
- An overview of the local environment should follow the general description. This will include socioeconomic information, land use, land tenure, water use in the area and any particular aspect of the flora and fauna. If other studies have been completed a list of available reports should be given.
- A brief description should be given of the most important institutions, including those responsible for the EIA, the project executing agency and future managers. This should be presented in the form of an organogram.
- A description of the work to be undertaken should give a general set of requirements for determining the potential impacts of, and impacts on, the proposed project.

The TOR should give an indication of the team considered necessary for the study. Depending on the scope of the study this may include one or several of the following: an irrigation specialist, drainage specialist, rural sociologist, terrestrial ecologist (of various specializations), aquatic ecologist/fisheries expert, hydrologist, agronomist, soil chemist or physicist, economist and epidemiologist.

58

3. Baseline data collection

- It refers to the collection of background information on the biophysical, social and economic settings of the proposed project area.
- Information is obtained from secondary sources, or the acquisition of new information through field samplings, interviews, surveys and consultations with the public.
- The task of collecting baseline data starts right from the period of project inception; however, a majority of this task may be undertaken during scoping and actual EIA.

Baseline data is collected for two main purposes:

- To provide a description of the current status and trends of environmental factors (e.g., air pollutant concentrations) of the host area against which predicted changes can be compared and evaluated in terms of significance, and
- To provide a means of detecting actual change by monitoring once a project has been initiated Only baseline data needed to assist prediction of the impacts contained in the ToR and scoping report should be collected.

59

4. Impact analysis and prediction

It is the core parameter of an EIA process.

Predicting the magnitude of a development likely impacts and evaluating their significance is based on the available environmental baseline of the project area.

These predictions and impact analysis are described in quantitative or qualitative terms.

Considerations in impact prediction

1. Magnitude of impact: This is defined by the severity of each potential impact and indicates whether the impact is irreversible or, reversible and estimated potential rate of recovery.

2. Extent of impact: The spatial extent or the zone of influence of the impact should always be determined. An impact can be site-specific or limited to the project area; a locally occurring impact within the locality of the proposed project; a regional impact that may extend beyond the local area and a national impact affecting resources on a national scale and sometimes trans-boundary impacts, which might be international.

3. Duration of impact: Environmental impacts have a temporal dimension and needs to be considered in an EIA. An impact that generally lasts for only three to nine years after project completion may be classified as short term. An impact, which continues for 10 to 20 years, may be defined as medium-term, and impacts that last beyond 20 years are considered as long-term.

60

4. Impact analysis and prediction

Considerations in impact prediction

4. Significance of the impact: This refers to the value or amount of the impact. Once an impact has been predicted, its significance must be evaluated using an appropriate choice of criteria. The most important forms of criterion are:

- *Specific legal requirements e.g. national laws, standards, international agreements and conventions, relevant policies etc.*
- *Public views and complaints*
- *Threat to sensitive ecosystems and resources e.g. can lead to extinction of species and depletion of resources, which can result, into conflicts.*
- *Geographical extent of the impact e.g. has trans- boundary implications.*
- *Cost of mitigation and Cumulative impacts e.g. adding more impacts to existing ones.*
- *Duration (time period over which they will occur) and Likelihood or probability of occurrence (very likely; unlikely, etc.)*
- *Reversibility of impact (natural recovery or aided by human intervention)*
- *Number (and characteristics) of people likely to be affected and their locations*
- *Uncertainty in prediction due to lack of accurate data or complex systems. Precautionary principle is advocated in this scenario.*

61

4. Impact analysis and prediction

Impact prediction methodologies

- Professional judgment with adequate reasoning and supporting data. This technique requires high professional experience.
- Experiments or tests. These can be expensive.
- Past experience.
- Numerical calculations & mathematical models. These can require a lot of data and competency in mathematical modeling without which hidden errors can arise
- Physical or visual analysis. Detailed description is needed to present the impact.
- Geographical information systems
- Risk assessment, and
- Economic valuation of environmental impacts.

62

And then in great detail, if you recall that we have discussed about each of the processes of EIA. And please go through it with the utmost care because EIA is another very important aspect which can actually provide you opportunity for some professional exposure or professional experience and can help you working in the field.

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7. Environmental Management Plan (EMP) & environmental monitoring

7.1 Environmental Management Plan (EMP)

EMP is a detailed plan and schedule of measures necessary to minimize, mitigate, etc. any potential environmental impacts identified by the EIA. Once in the EIA the significant impacts have been identified, it is necessary to prepare an Environmental Management Plan.

The EMP includes the actions needed to implement these measures, including the following features:

- Mitigation based on the environmental impacts reported in the EIA, the EMP should describe with technical details each mitigation measure.
- The EMP should then include monitoring objectives that specifies the type of monitoring activities that will be linked to the mitigation measures. Specifically, the monitoring section of the EMP provides:

A specific description, and technical details, of monitoring measures that includes the parameters to be measured, the methods to be used, sampling locations, frequency of measurements, detection limits (where appropriate), and definition of thresholds that will signal the need for corrective actions;

Monitoring and reporting procedures to ensure early detection of conditions that necessitate particular mitigation measures and to furnish information on the progress and results of mitigation.

66

7. Environmental Management Plan (EMP) & environmental monitoring

7.1 Environmental Management Plan (EMP)

- The EMP should also provide a specific description of institutional arrangements i.e. who is responsible for carrying out the mitigating and monitoring measures (for operation, supervision, enforcement, monitoring of implementation, remedial action, financing, reporting, and staff training).
- Additionally, the EMP should include an estimate of the costs of the measures and activities recommended.
- It should consider compensatory measures if mitigation measures are not feasible or cost effective.
- EMP must be operative throughout the whole Project Cycle.

67

7. Environmental Management Plan (EMP) & environmental monitoring

7.2 Environmental monitoring

Environmental monitoring is the systematic measurement of key environmental indicators over time within a particular geographic area (World Bank, 1999). Monitoring should focus on the most significant impacts identified in the EIA. Various types of monitoring activity are currently in practice.

The main types are briefly described below:

Baseline monitoring:

A survey on basic environmental parameters in the area surrounding the proposed project before construction begins. Subsequent monitoring can assess the changes in those parameters over time against the baseline.

Impact monitoring:

The biophysical and socio-economical (including public health) parameters within the project area, must be measured during the project construction and operational phases in order to detect environmental changes, which may have occurred as a result of project implementation e.g. air emission, dust, noise, water pollution etc

Compliance monitoring:

This form of monitoring employs a periodic sampling method, or continuous recording of specific environmental quality indicators or pollution levels to ensure project compliance with recommended environmental protection standards.

68

7. Environmental Management Plan (EMP) & environmental monitoring

7.2 Environmental monitoring

What to avoid in monitoring:

- *Overestimation of data needed as this can lead to drowning in data without information.*
- *Under-estimation of time and cost for data analysis*
- *Weak coordination between the data collection with project time table and seasonal factors*
- *Ignoring requirements for baselines*

69

So, from there, we went into environment management plan. We discussed about Environment Management Plan also in great detail.

(Refer Slide Time: 26:22)

8. Environmental Impact Statement (EIS)

The final EIA report is referred to as an **Environmental Impact Statement (EIS)**. The content of an EIS has the following:

- *Executive Summary*
- *Policy, Legal and Administrative Framework*
- *Description of the environment*
- *Description of the Proposed Project in detail*
- *Significant Environmental Impacts*
- *Socio-economic analysis of Project Impacts*
- *Identification and Analysis of Alternatives*
- *Mitigation Action/Mitigation Management Plan*
- *Environmental Management Plan*
- *Monitoring Program*
- *Knowledge gaps*
- *Public Involvement*
- *List of References*
- *Appendices including*
 - *Reference documents, photographs, unpublished data*
 - *Terms of Reference*
 - *Consulting team composition*
 - *Notes of Public Consultation sessions*

70

Then EIS, Environmental Impact Statement, which is very important. And these basically decide the fate of the natural resources and its utilizations.

(Refer Slide Time: 26:37)

EIA and Public participation

73

Then we discussed one very important aspect; EIA and public participation, because without our, your mind and all society's participation in this exercise, it would not be a success.

(Refer Slide Time: 26:52)

EIA and public participation

- Public participation is one of the centre pieces of the EIA process.
- The involvement of stakeholder groups, such as local people, project beneficiaries, NGOs, experts, etc. provides for quality, comprehensiveness and effectiveness.
- The International Association for Impact Assessment (IAIA), (2006) defines public participation in the context of environmental assessment as “the involvement of individuals and groups that are positively or negatively affected, or that are interested in, a proposed project, programme, plan or policy that is subject to a decision-making process”
- The use of the term ‘participation’ is appropriate only in cases where participants have significant control of the decision-making process and are thus able to influence it.
- There is an upsurge in attention paid to Public Consultation & Disclosure in recent years with increase in environmental awareness. Most international and national environmental legislations are now making specific and detailed provisions for public participation and disclosure.
- Public participation in EIA is commonly deemed to foster democratic policy-making and to render EIA more effective.

74

Public participation in Project Cycle

Project Cycle	EIA component	Public participation activity
Pre feasibility	Environmental screening	Identifies public groups and begins initial contact with groups
	Initial Environmental Examinations (IEE)	Continue consultations- public provides input to IEE report
	Scoping	Identifies major issues for scoping and ToR using public input and makes further plan for public involvement.
Feasibility	Environmental Impact Assessment (EIA)	The public reviews and comments on the draft EIA report. They also provide inputs to design and survey.
Detailed survey and design	Integration of mitigation measures	Detailed design made available to public
Construction and operation	Environmental monitoring	The public provides input to post evaluation of impacts and mitigation measures.

75

Public participation techniques

There are techniques for getting information:

- **TO the public** (one-way e.g. press releases newsletters etc),
- getting it **FROM the public** (one-way e.g. polls, survey, questionnaire) and
- **EXCHANGING information** (interaction between the proponent and the public e.g. public hearing, workshops, meetings, advisory groups/task forces etc).

When selecting a technique, it is always wise to build on existing communication channels that are familiar with the community or public involved.

There is no public participation technique that will work in all circumstances. When people talk about highly successful public participation programs they are talking about programs where the techniques matched the purpose of the program, reached the interested stakeholders, and resulted in a clear linkage between the public participation process and the decision-making process. This is not always the case because it is quite tricky to balance public good and development in a single direction.

77

Public participation monitoring

- Most EIA projects usually have no monitoring systems of PCs built into their structure.
- Techniques for monitoring and evaluating public consultations include confirmation that participants understood the consultation content (correct language, level of technicality), and assessment of stakeholders' opinions and impact on project design and implementation.
- Through appropriate use of monitoring and evaluation, public consultation strategies can be adjusted during the project cycle to improve stakeholder participation, information dissemination strategies, and mechanisms for integrating participant feedback into project design and implementation.

78

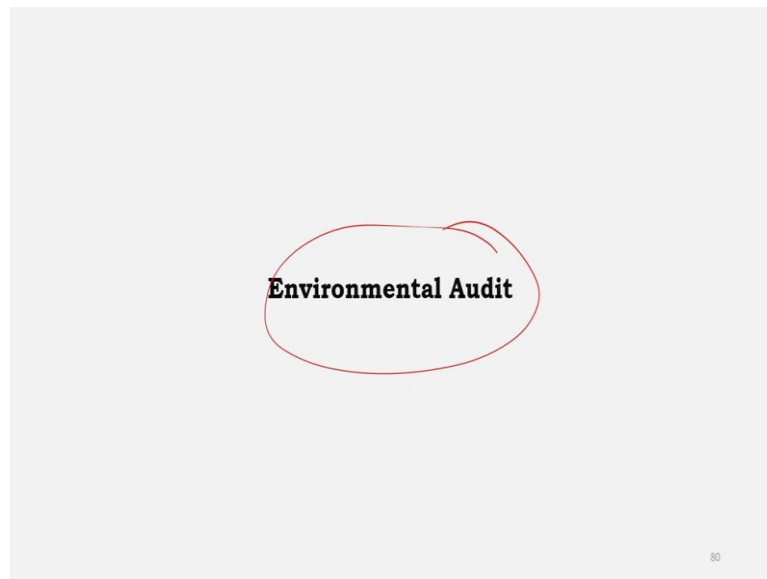
EIA review

- The draft EIA report should be submitted to the Natural resources Conservation Authority (NRCA) for review.
- Government agencies other than NRCA may also be required to participate in the review, at the discretion of the NRCA.
- The draft EIA report is distributed to organizations, such as public libraries, relevant organizations near the project site and a public presentation is arranged by the proponents and consultants.
- Strategic Environmental Assessment (SEA) is a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest stage of decision making on par with social and environmental considerations. It is an integral part of the draft review.
- Once approved, policy and statutes are defined and the draft finally becomes a full fledged EIA report with proper licence to carry on the development activity following all norms and guidelines.

79

And if you recall, that we have discussed again this aspect in great detail, how public participation in project cycle even development process itself is important because the input from the public is critical for a good EIA. If you recall that we also discussed a few examples about that.

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Environment audit also we discussed. Again, this is a very important aspect for anyone who wants to get into in a professional aspect of this.

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A presentation slide with a light gray background. The title "Environmental Audit" is centered at the top in a bold, red, sans-serif font. Below the title is a bulleted list of seven points. In the bottom right corner, the number "81" is displayed in a small, gray font.

- In order to capitalize on the experience and knowledge gained, the last stage of an EIA is to carry out an **Environmental Audit** some time after completion of the project or implementation of a programme.
- It is done by a separate team of specialists to that working on the bulk of the EIA.
- The audit includes an analysis of the technical, procedural and decision-making aspects of the EIA.
- Technical aspects include: the adequacy of the baseline studies, the accuracy of predictions and the suitability of mitigation measures.
- Procedural aspects include: the efficiency of the procedure, the fairness of the public involvement measures and the degree of coordination of roles and responsibilities.
- Decision-making aspects include: the utility of the process for decision making and the implications for development.
- The audit will determine whether recommendations and requirements made by the earlier EIA steps were incorporated successfully into project implementation. Lessons learnt and formally described in an audit can greatly assist in future EIAs and build up the expertise and efficiency of the concerned institutions.

Environmental Audit

The International Organization of Supreme Audit Institutions (INTOSAI) framework defines Environmental Auditing as:

1. *Environment auditing is not significantly different from normal auditing as practiced by Supreme Audit Institutions (SAIs).*
2. *Environment auditing encompasses all types of auditing i.e. financial, compliance and performance audits.*
3. *The concept of sustainable development can be a part of environmental audit, only if it is a part of the government policy and/or programme to be audited.*

An Environmental Audit Report (EAR) is required to be submitted for review and approval in the type of a Constructional Environmental Management plan (CEMP), an Operational Environmental Management plan (OEMP) or another Environment Impact Assessment Division (EAD) document.

82

Objectives of Environmental Audit

- i. *Establishing a baseline of existing environmental conditions with focus on natural and physical environment;*
- ii. *Understanding the current practices of sustainability with regard to the use of water and energy, generation of wastes, purchase of goods, transportation, etc;*
- iii. *Awareness generation among students concerning real issues of environment and its sustainability*
- iv. *Promotion of environmental awareness through participatory auditing process; and*
- v. *To create a report that document baseline data of good practices and provide strategies and action plans towards improving environmental quality for future*

83

Types of Environmental Audit

Compliance audits

Liability audits

Programme audits

Single issue audits

Risk definition or hazard identification audits

84

Environmental Audit process

1. Pre-audit activities:

These comprise scheduling, team selection, logistical arrangement, gathering background information and developing the audit plan.

The most crucial part is the selection of auditors. They must have adequate knowledge in all aspects of EIA with an independent and unbiased approach.

An apt for research with an inclination to develop and apply new techniques and methodologies related to good environmental performance.

2. Audit Process:

the key activities include understanding management system; assessing the strengths and weaknesses; gathering audit evidences, evaluating audit finding and reporting audit finding to management.

3. Post audit activities:

These activities are to ensure that the audit results are clearly communicated to the appropriate level of management and provide suggestions for improving future audit.

It also includes preparation of a draft report; issue a final report to legal counsel and develop an action plan and continue follow-up.

85

So, environmental audit also, we discussed all the fundamental things, the objectives of these various types of auditing process and how these auditing process are being carried out, which are the benefits, some of its limitation also has been discussed.

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Environmental Audit report (EAR)

- An EAR documents an independent, accurate and detailed assessment of environmental performance for a development project or industrial facility.
- The EAR is used to assess the implementation of a project's or facility's Environmental Management system (EMS) and compliance with legal permits.
- EARs should be clear, timely, concise and objective; providing a fair summary of all the relevant facts and demonstrate conformity with the approved environmental norms and regulations.
- The objective of an EAR is to provide interested parties with a clear indication of the environmental performance for the period covered by the audit.
- It provides information required to develop an Environmental Action Plan (EAP) in the event of any significant findings of negative impacts to the environment.
- the findings and recommendations of the audit effort should be documented clearly and concisely in the EAR. The usefulness of an EAR is measured by how well the problems are identified, evaluated, documented and addressed by adequate and straight forward mitigation measures and corrective actions.

86

Benefits of Environmental Auditing

- 1. Enabling environmental problems and risks to be anticipated and responses planned.*
- 2. To demonstrate that an organization is aware of its impact upon the environment through providing feedback*
- 3. Increases management and employee awareness of environmental issues.*
- 4. Promotes 'Good practice'.*
- 5. More efficient resource use and finance savings*
- 6. Providing better public and private image and security to top management.*

87

Then, we came into environmental audit report, EAR, another very important aspect. And if you recall that in the lecture schedule, we have actually discussed these sections in detail and with more time. So, I will again, request all of you to consider to go through this with a little bit of time and because these concepts can allow you to get into some professional exercise related to natural resource auditing, environment auditing.

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Benefits of Environmental Auditing

- 1. Enabling environmental problems and risks to be anticipated and responses planned.*
- 2. To demonstrate that an organization is aware of its impact upon the environment through providing feedback*
- 3. Increases management and employee awareness of environmental issues.*
- 4. Promotes 'Good practice'.*
- 5. More efficient resource use and finance savings*
- 6. Providing better public and private image and security to top management.*

87

EIA related studies

1. Social Impact Assessment (SIA)

Social Impact Assessment (SIA) includes the processes of analyzing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions and any social change processes invoked by those interventions (Vanclay, 1999).

The analysis should include the use of land, culture, the main economic activities e.g. tourism, agriculture, employment levels and their impact on service provision e.g. education, water use, traffic, energy use etc.

Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment.

Social Impact Assessment assumes that social, economic and biophysical impacts are interconnected. It is therefore done to ensure that there is no mismatch between the development and socio-cultural and economic of the project area.

88

EIA related studies

2. Health Impact Assessment (HIA)

In most EIAs, HIA is usually included under SIA.

HIA is now emerging as a key component of EIA because health is determined by a multiplicity of factors including socio-economic and environmental factors.

There is no clear definition about where health concerns end and where environmental or social concerns begin.

HIA is a broad concept that may be interpreted in different ways by a range of different users but all imply an interest in the safeguarding and enhancement of human health and a concern that human activities and decisions, in the form of development projects, plans, programs and policies can affect human health in both positive and negative ways.

89

Shortcomings of EIA Process

Applicability:

There are several projects with significant environmental impacts that are exempted from the notification either because they are not listed in schedule I, or their investments are less than what is provided for in the notification.

Composition of expert committees and standards:

It has been often found that the team that are formed for conducting EIA studies lacks the expertise in various fields such as environmentalists, wildlife experts, anthropologists and social scientists.

Public hearing:

Public comments are not considered at an early stage, which often leads to conflict at a later stage of project clearance.

A number of projects with significant environmental and social impacts have been excluded from the mandatory public hearing process.

The data collectors do not pay respect to the indigenous knowledge of local people.

91

Shortcomings of EIA Process

Quality of EIA:

One of the biggest concerns with the environmental clearance process is related to the quality of EIA report that are being carried out.

Lack of Credibility:

There are so many cases of fraudulent EIA studies where erroneous data has been used, same facts used for two totally different places etc.

Often, and more so for strategic industries such as nuclear energy projects, the reports are kept confidential for political and administrative reasons.

Details regarding the effectiveness and implementation of mitigation measures are often not provided.

Emergency preparedness plans are not discussed in sufficient details and the information not disseminated to the communities.

92

So, benefits also we have discussed then we discussed about how EIA actually help your society and how it helps and various kinds of assessment strategic environment assessment. Then finally, we discussed about also the limitation that EIA exercise has. So, overall, I think that if you recall, this was a very consolidated discussions that together we have gone through. Please follow it properly and it will really help you in a great way. Then we came into remote sensing and GIS in a very particular way.

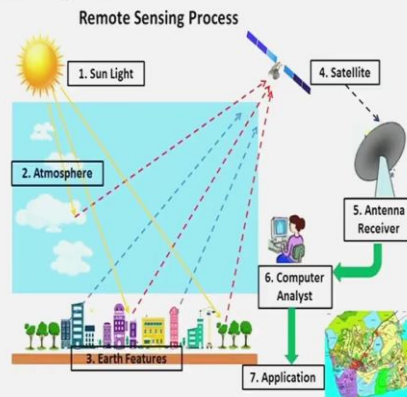
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Remote sensing and GIS application in agriculture and NRM

12

Remote sensing

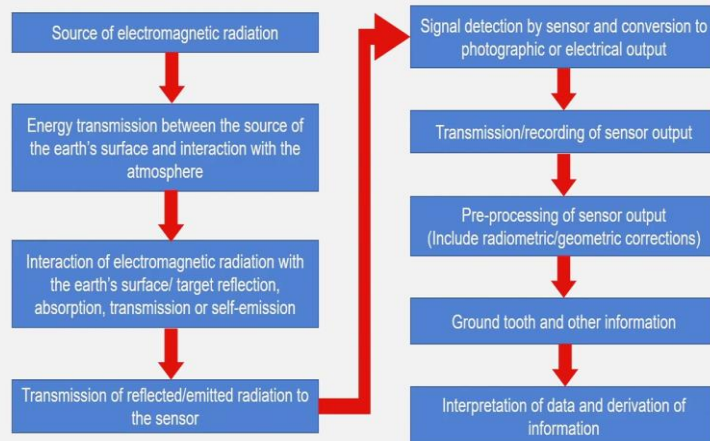
RS is Art, science, and technology for acquiring reliable information for any object, area or phenomenon earth surface without having any physical contact with the object, area or phenomenon under investigation.



At the previous lecture within the precision farming and modeling, we discussed remote sensing and GIS just touched upon that. But later then we discussed in very great detail about these tools and techniques.

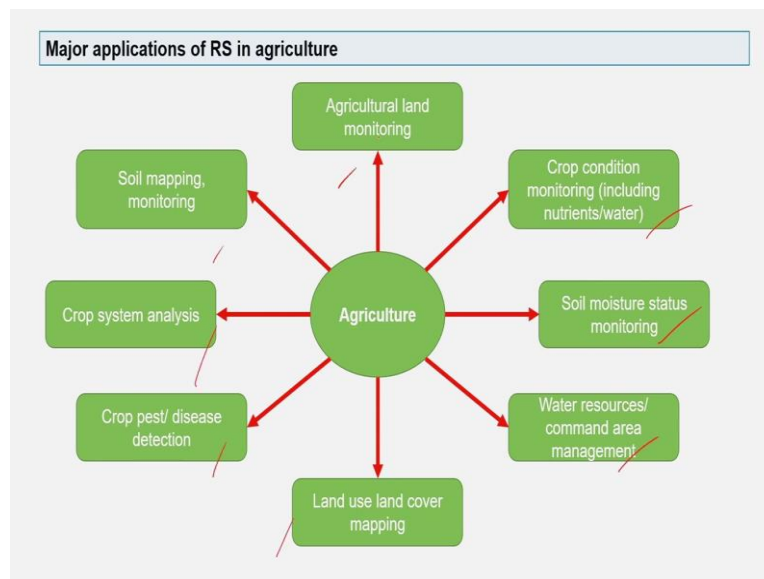
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Remote sensing (Key steps involved)



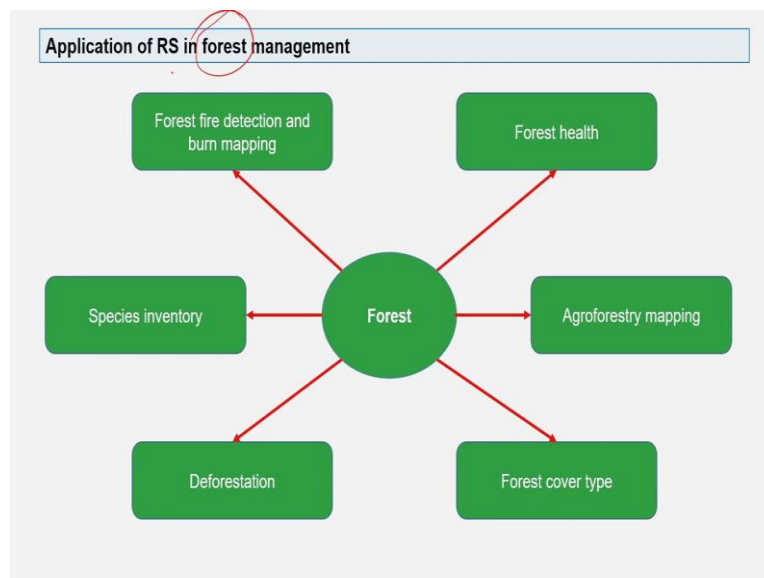
Different kind of remote sensing processes, we have discussed, what are the different steps are involved into it, that also we have detailed discussion taking place.

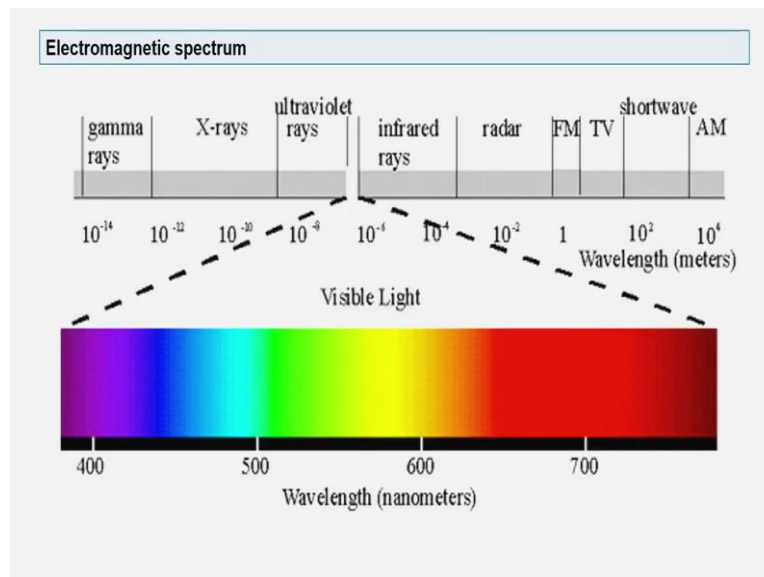
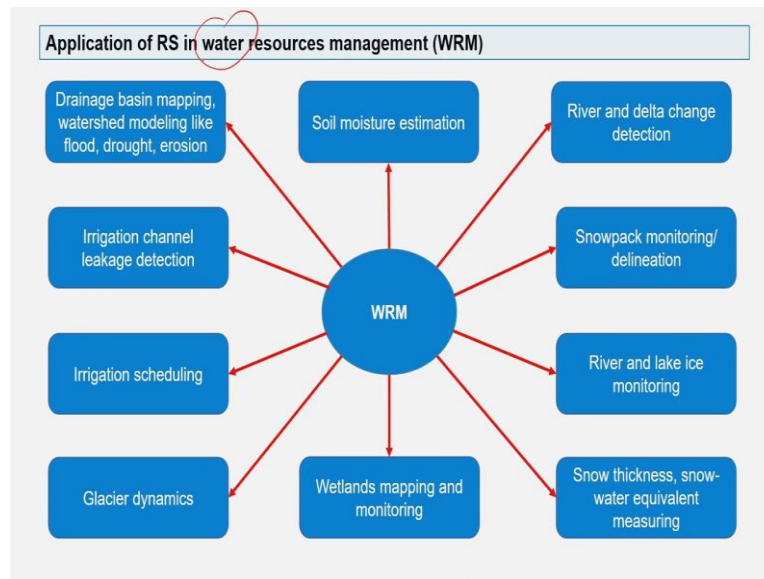
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How in agriculture, remote sensing can play a role, various aspect of agriculture that we also discussed.

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Application of remote sensing for another natural resource that is forest, how it can be applied, that also we have discussed. Then water. So, each one of these we have discussed with the examples.

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Sensors

- ❑ Devices that gather electromagnetic energy and convert it to signal for obtaining information in a suitable form about the targets under the investigation
- ❑ Remote sensors are classified as passive or active depending on the light source.
- ❑ Passive sensors measure the amount of solar energy reflected from the objects. Because of this reliability on sunlight, data can only be recorded when the sun is illuminating the target area and cloud cover is minimal. These restrictions often constrain data collection to around noon to maximize available sunlight. Passive sensors are those mounted on satellites or airplanes. Example: LANDSAT, LISS, QuickBird.
- ❑ Active sensors use their own modulated light at defined or fixed wavelengths. The sensor illuminates the object and uses photodiodes to measure the portion of the light that is reflected. Active sensors include those mounted on satellites or ground vehicles. Example: RADARSAT, LIDAR.
- ❑ Advantage of active sensors over passive sensors is their ability to obtain measurements at any time, regardless of the time of day or season, while removing the effects of sun angle and cloud cover.

Hyperspectral and multispectral remote sensing

❖ Hyperspectral RS

- ❑ Also called imaging spectroscopy.
- ❑ Used to detect and identify minerals, terrestrial vegetation, and man-made materials and backgrounds.
- ❑ Information is collected and processed from across the electromagnetic spectrum.
- ❑ The goal is to obtain the spectrum for each pixel in the image of a scene
- ❑ Data sets are generally composed of about 100 to 200 spectral bands (**continuous**) of relatively narrow bandwidths (5-10 nm).
- ❑ The ample spectral information provided by hyperspectral data is able to identify and distinguish spectrally similar materials.
- ❑ Hyperspectral data allows for the identification of many materials, even if they are mixed.
- ❑ Can provide several pieces of information about crop biophysical properties and can accurately estimate the yield data.
- ❑ Cost and complexity are major disadvantages.
- ❑ Fast computers, sensitive detectors, and large data storage capacities are needed for analyzing hyperspectral data

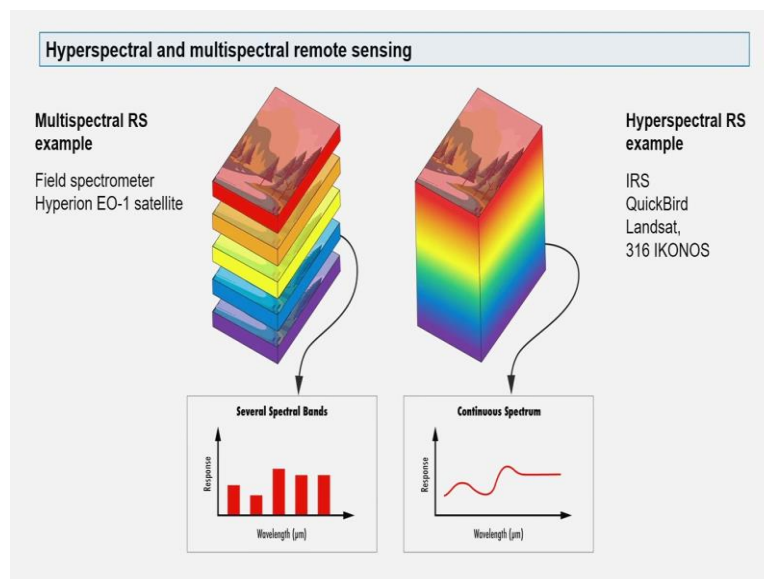
Hyperspectral and multispectral remote sensing

❖ Multispectral RS

- ❑ Multispectral RS involves the acquisition of visible, near-infrared (NIR), and short-wave infrared (SWIR) images in several broad (**discrete**) wavelength bands.
- ❑ Useful to discriminate land surface features and landscape patterns and detect the existence of various materials.
- ❑ Different materials reflect and absorb differently at different wavelengths.
- ❑ Poorer resolution than Hyperspectral sensors
- ❑ Multi spectral satellites and sensors are greater in number than multispectral satellites.
- ❑ Poorer resolution than hyperspectral sensors.
- ❑ Sensors are less costly than hyperspectral sensors.

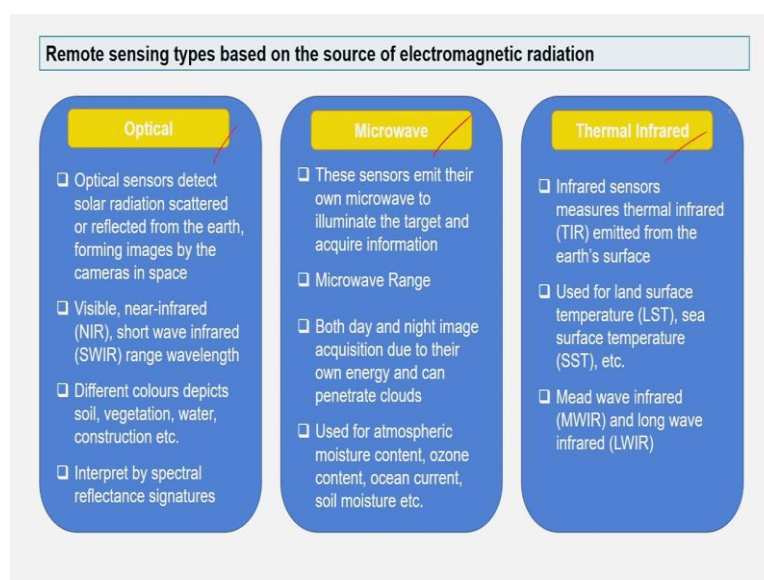
Then we came into the sensors part of remote sensing, which is one of the most important aspect of remote sensing exercise. So, we discussed with various example and how different kinds of spectral images it differently provide different kind of informations and data. Hyperspectral, multispectral, how they are different from each other, in which country which condition for which kind of resources, what kind of spectral imagery is useful, we discussed all these things in great detail.

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And then how technically actually this spectral imagery process work that also we have discussed.

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And then how remote sensing depends on different sorts of electromagnetic radiation and on that basis, how they are different from each other and every one of them can be actually used for different purposes.

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Spectral reflectance

Reflected radiation (R_λ)

Incident radiation (I_λ)

Absorbed radiation (A_λ)

Transmitted radiation (T_λ)

$$R_\lambda = I_\lambda - (A_\lambda + T_\lambda)$$

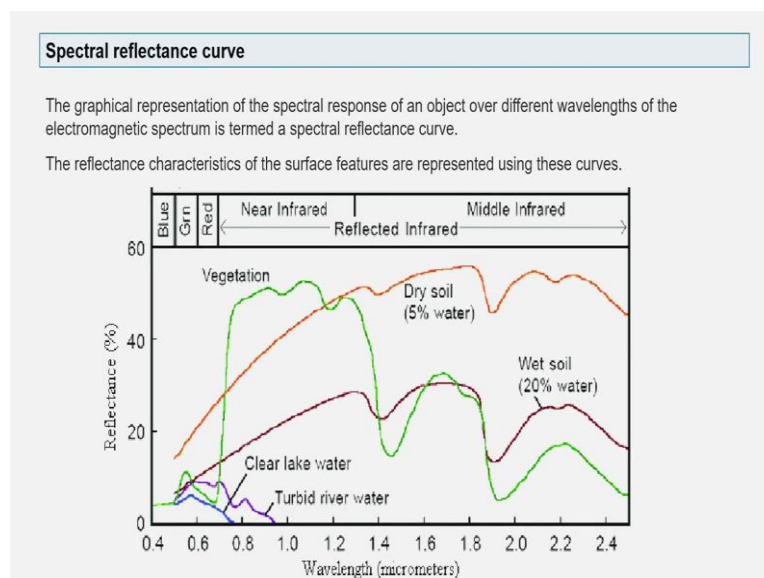
$$\frac{R_\lambda}{I_\lambda} = 1 - \left(\frac{A_\lambda}{I_\lambda} + \frac{T_\lambda}{I_\lambda} \right)$$

$$\rho_\lambda = 1 - (a_\lambda + \tau_\lambda)$$

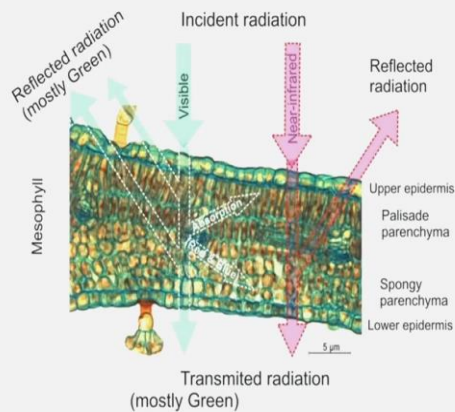
Reflectance = 1 - (Absorbance + Transmittance)

□ **Spectral Reflectance**

The reflectance characteristics of earth surface features expressed as the ratio of energy reflected by the surface to the energy incident on the surface, measured as a function of wavelength is called spectral reflectance.



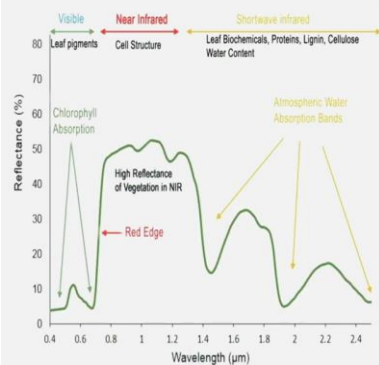
Spectral reflectance curve for vegetations



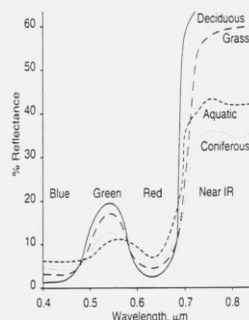
□ Healthy leaves absorb 70–90% of incident visible radiation, particularly in the blue and red wavelengths (centered on 450 nm and 670 nm respectively), and reflect most of the green light (centered on 533 nm) which is why leaves appear green to the human eye.

□ Green light is reflected back by the chlorophyll pigment within the chloroplasts in the palisade cells. Blue and red light are absorbed and used in photosynthesis by the chlorophyll pigment in the palisade cells.

Spectral reflectance curve for vegetations



□ Plant stress considerably changes the spectral properties of vegetation, as the chlorophyll pigment rapidly decays and loses its absorption properties, increasing reflectance in the green to reddish part of the visible region (from around 530 nm to 670 nm) of the electromagnetic spectrum.



Spectral reflectance also we have discussed in great detail. How spectral reflectance curve help us to understand different data that are being generated through the spectral images, spectral reflectance curve also how it helps in understanding different condition on the ground on that surface, vegetation. Vegetation's types, its conditions like is moisture content, even in vegetation. So, these all those things, how actually it can be carried out, we have discussed in these remote sensing and GIS classes.

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Spectral reflectance curve for soils

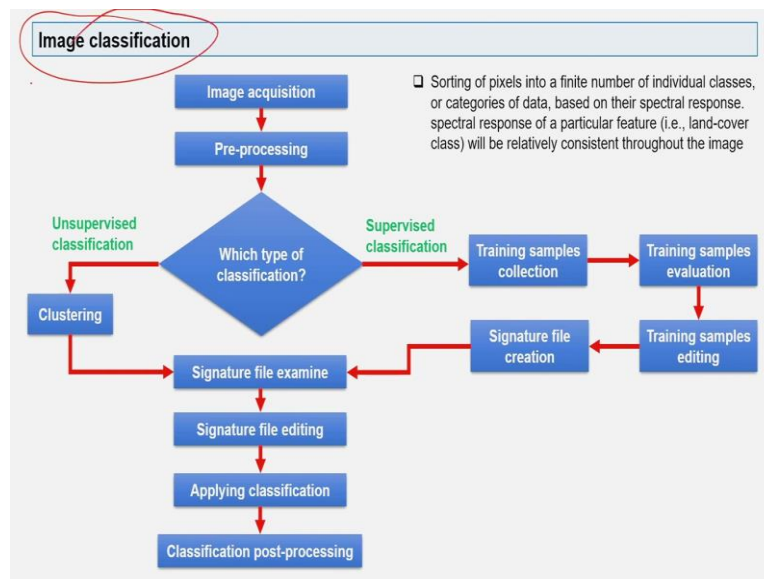
- ❑ Factors affecting soil reflectance are namely moisture content, soil texture, surface roughness, presence of iron oxide, organic matter content, etc.
- ❑ The presence of moisture in soil decreases its reflectance. This effect is maximum in the water absorption bands at 1.4, 1.9, and 2.1 μm . On the other hand, similar absorption characteristics are displayed by the clay soils. Clay soils have hydroxyl ion absorption bands at 1.4 and 2.2 μm .
- ❑ Soil moisture content is highly related to the soil texture. Coarse, sandy soils are usually well-drained, resulting in low moisture content and relatively high reflectance. Whereas, poorly drained fine-textured soils generally have lower reflectance. In the absence of water, however, the soil itself exhibits the reverse tendency i.e., coarse-textured soils appear darker than fine-textured soils. Spectral reflectance decrease due to moisture content in soils in all the spectral bands because of the darker appearance of soils at moist conditions.
- ❑ Presence of iron oxide in the soil also significantly decreases reflectance, at least in the visible region of wavelengths
- ❑ The spectral reflectance of red soils was higher, in-situ as well as under laboratory conditions, as compared to black soils, which is attributed to variation in soil color, organic matter, and clay content of soils. Soil reflectance depends upon the decomposition of organic matter. Increase of soil organic matter reduces reflectance.

Spectral reflectance curve for water

- ❑ Water provides a semi-transparent medium for electromagnetic radiation. Thus the electromagnetic radiations get reflected, transmitted, or absorbed in water.
- ❑ The spectral responses vary with the wavelength of the radiation and the physicochemical characteristics of the water
- ❑ In the solid phase (ice or snow) water gives a better reflection at all visible wavelengths. On the other hand, reflection in the visible region is poor in the case of water in the liquid stage. This difference in reflectance is due to the difference in the atomic bond in the liquid and solid states.
- ❑ In the visible region between 0.4 μm and 0.7 μm , around 0.6 μm of water in the liquid form shows high reflectance. Wavelengths beyond 0.7 μm are completely absorbed (i.e. no curve formed beyond 0.7 μm). Thus clear water appears in a darker tone in the NIR image.
- ❑ Due to the absorption property of reflected infrared wavelengths, locating and delineating water bodies with remote sensing data is done more easily in these wavelengths

So, a great deal of discussion taking place on spectral reflectance on vegetation, then on soils, how it works for water, because as I said that the three major resources that are directly linked with human life and society is soil, water, air and then your vegetation or plant. So, these all resources can be actually monitored very successfully through remote sensing and GIS.

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We talked about another important aspect about image classifications. And I understand that probably, you have gone through these classes and lectures carefully. Having said that, once again, I remind you that remote sensing GIS is a subject which requires a completely specialized training. In this course, under natural resource management, it was my attempt to introduce these particular tools and techniques to you, because it is a tool which is very effectively used for natural resource management.

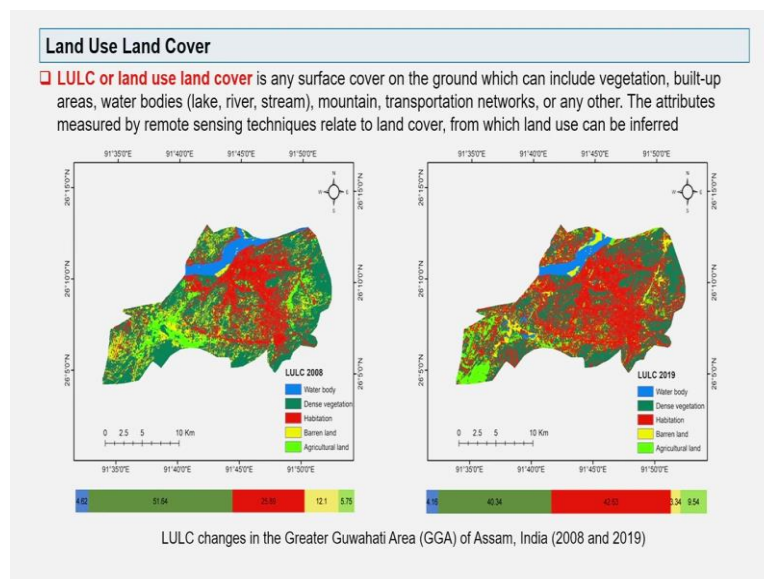
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Supervised and unsupervised classification	
Unsupervised classification	Supervised classification
<ul style="list-style-type: none"> □ An unsupervised classification can be performed without any ground reference information. □ Unsupervised classification identifies groups of pixels that exhibit a similar spectral response. These spectral classes are then assigned "meaning" by the analyst (e.g., assigned to land use land cover classes) □ This was evaluated, while the ground reference data was being collected. □ Increasing the number of classes defined in the unsupervised classification decrease the number of signatures that have to be forced into an individual category as the spectral range for each class increases. □ Unique spectral classes are produced 	<ul style="list-style-type: none"> □ Each supervised classification used the ground reference image pixels representing regions of known, homogenous surface composition (training areas or training data) to classify unknown pixels of the different classes □ Training samples are key because they will determine which class each pixel inherits in the overall image. For different open field classes, higher resolution imagery was used for training. Training areas are reusable (assuming they do not change; e.g. roads) □ Generates informational classes representing features on the ground □ Supervised classification can be much more accurate than unsupervised classification, but depends heavily on the training sites, the skill of the individual processing the image, and the spectral distinctness of the classes

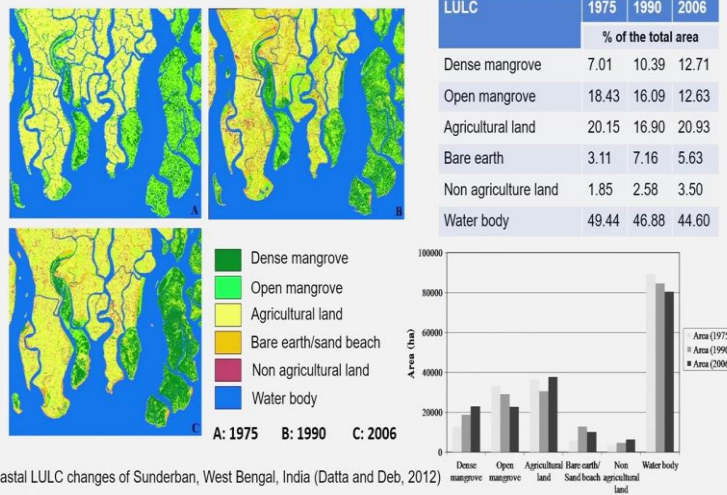
Unsupervised classification	Supervised classification
<ul style="list-style-type: none"> ❑ Spectral classes do not represent features on the ground ❑ Does not consider spatial relationships in the data ❑ Spectral properties vary over time, across images ❑ Can be very time-consuming to interpret spectral classes ❑ No prior knowledge of the image area is required ❑ Human error is minimized as the process is done by the computer automatically. Thus it is relatively quick and easy to perform ❑ Most of analyst's work comes after the classification process in this classification 	<ul style="list-style-type: none"> ❑ Information classes may not match spectral classes. (e.g., a supervised classification of "forest" may mask the unique spectral properties of pine and oak stands that comprise that forest) ❑ Confusion occurs during classification between the mixed class and the softwood and hardwood classes as almost all references have some degree of mixed wood. Some of the open areas (fields and shrub areas) carry the same spectral response as hardwood, decreasing accuracy. ❑ Difficulty and cost of selecting training sites. Training areas may not encompass unique spectral classes ❑ Most of the analyst's work comes before the classification process in this classification

We talked about then supervised, unsupervised classifications and how actually, it differs from each other.

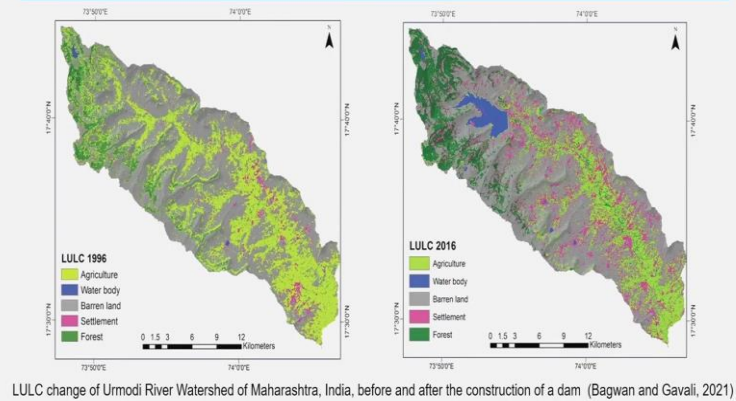
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Land Use Land Cover

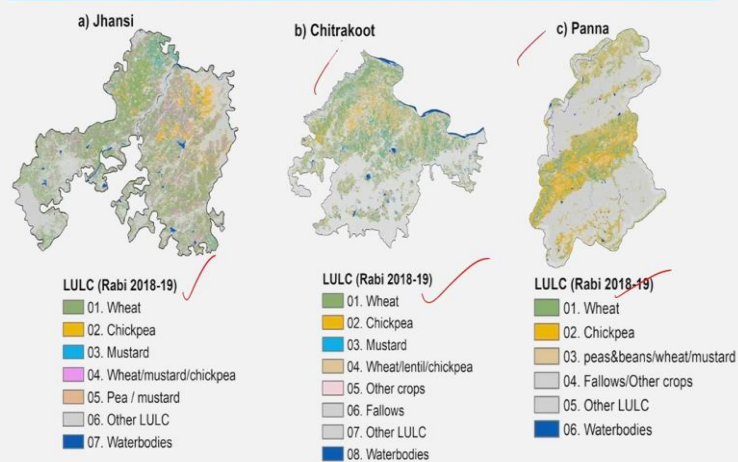


Land Use Land Cover




LULC	Year	Agriculture	Waterbody	Barren land	Settlement	Forest
Proportion area (%)	1996	32.58	0.16	53.77	4.88	8.62
	2016	16.31	2.88	57.05	11.35	12.41

Land Use Land Cover and Crop type



Land Use Land Cover and Crop type (Continue)			
LULC and crop type	Jhansi (area ha)	Chitrakoot (area ha)	Panna (area ha)
Wheat	180306	49145	117001
Chickpea	37992	16150	80772
Mustard	18412	14543	
Wheat/lentil/chickpea		42265	
Wheat/mustard/chickpea	38442		
Peas & beans/lentil/wheat/mustard			28758
Peas/mustard	5751		
Other crops		6326	
Fallow/mixed crops		17528	
Fallow/other crops			68304
Other classes	220559	152314	410824
Water bodies	5728	10095	
Water bodies /wetlands/fallow			5542

 No direct information was given about LULC and crop area

Then one by one example, I have given that how land use land cover can be studied and the changes over time and then what kind of conditions actually remote sensing data gives you better informations and how season wise the pictures, quality also changes. We have given real examples of different places of our country with some crop data.

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Vegetation indices
<ul style="list-style-type: none"> ❑ A vegetation index is a single number that quantifies vegetation biomass and plant vigor for each pixel in a remote sensing image ❑ Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation ❑ VIs gives reliable spatial and temporal inter-comparisons of terrestrial photosynthetic activity and canopy structural variations ❑ Mathematically VI compares the number of absorbed lights of different wavelengths (Example: visible red light and the reflected near-infrared light) ❑ Vegetation indices are designed to maximize sensitivity to the vegetation characteristics while minimizing confounding factors such as soil background reflectance, directional, or atmospheric effects ❑ Measurements of vegetation attributes include leaf area index (LAI), percent green cover, chlorophyll content, green biomass, and absorbed photosynthetically active radiation (APAR).

Vegetation indices		
VI types	Mathematical expressions	
Ratio Vegetation Index (RVI)	$RVI = \frac{\rho_{NIR}}{\rho_R}$	NIR = Near Infrared R = Red
Difference Vegetation Index (DVI)	$DVI = \rho_{NIR} - \rho_R$	
Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}$	$0 \leq NDVI \leq 1$
Soil Adjusted Vegetation Index (SAVI)	$SAVI = \left[\frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R + L} \right] (1 + L)$	$L = 0.5$ L = correction factor for soil brightness L = 0, very high vegetation cover L = 1, very low vegetation cover
Enhanced Vegetation Index (EVI)	$EVI = \frac{G(\rho_{NIR} - \rho_R)}{\rho_{NIR} + C_1\rho_R - C_2\rho_B + L}$	B = Blue $C_1 = 6, C_2 = 7.5, L = 1, G = 2.5$ $-1 \leq EVI \leq 1$ For health vegetation (practically) $0.2 \leq EVI \leq 0.8$

And then explain to you that how it works.

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Vegetation indices
<ul style="list-style-type: none"> ❑ A vegetation index is a single number that quantifies vegetation biomass and plant vigor for each pixel in a remote sensing image ❑ Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation ❑ VIs gives reliable spatial and temporal inter-comparisons of terrestrial photosynthetic activity and canopy structural variations ❑ Mathematically VI compares the number of absorbed lights of different wavelengths (Example: visible red light and the reflected near-infrared light) ❑ Vegetation indices are designed to maximize sensitivity to the vegetation characteristics while minimizing confounding factors such as soil background reflectance, directional, or atmospheric effects ❑ Measurements of vegetation attributes include leaf area index (LAI), percent green cover, chlorophyll content, green biomass, and absorbed photosynthetically active radiation (APAR).

Vegetation Indices types	Mathematical expressions	
Optimized Soil Adjusted Vegetation Index (OSAVI)	$OSAVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R + L}$	L = 0.16
Transformed Vegetation Index (TVI)	$TVI = \sqrt{\left(\frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}\right) + 0.5}$ $TVI = \sqrt{NDVI + 0.5}$	
Vegetation condition index (VCI)	$VCI = \left(\frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right) \times 100$	$NDVI_j$ = NDVI for j th month or week $NDVI_{min}$ = long-term (e.g., 30 years) minimum NDVI for j th month or week; $NDVI_{max}$ = long-term (e.g., 30 years) maximum NDVI for j th month or week; VCI = 0: poor vegetation VCI = 50%: Fair vegetation VCI = 100%: Optimal vegetation
Modified Soil Adjusted Vegetation Index (MSAVI)	$MSAVI = \frac{2\rho_{NIR} + 1 - \sqrt{(2\rho_{NIR} + 1)^2 - 8(\rho_{NIR} - \rho_R)}}{2}$	
Normalized Difference Moisture index (NDWI)	$NDMI = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}}$	SWIR = Short Wave Infrared $-1 \leq NDMI \leq 1$

Vegetation indices		
Vegetation Indices types	Mathematical expressions	
Normalized Difference Water index (NDWI)	$NDWI = \frac{\rho_G - \rho_{NIR}}{\rho_G + \rho_{NIR}}$	$-1 \leq NDWI \leq 1$ G = Green Water surface $0.2 \leq NDWI \leq 1$ Flooding, humidity $0 \leq NDWI \leq 0.2$ Moderate drought, non-aqueous surfaces $-0.3 \leq NDWI \leq 0$ Drought, non-aqueous surfaces $-1 \leq NDWI \leq -0.3$
Global Environmental Monitoring Index (GEMI)	$GEMI = \eta(1 - 0.25\eta) - \left(\frac{\rho_R - 0.125}{1 - \rho_R}\right)$ $\eta = \frac{[2(\rho_{NIR}^2 - \rho_R^2) + 1.5\rho_{NIR} + 0.5\rho_R]}{\rho_{NIR} + \rho_R + 0.5}$	
Normalized Difference Red Edge Index (NDRE)	$NDRE = \frac{\rho_{NIR} - \rho_{RE}}{\rho_{NIR} + \rho_{RE}}$	Bare soil or a developing crop $-1 \leq NDRE \leq 0.2$ Unhealthy plant or immature crop $0.2 \leq NDRE \leq 0.6$ healthy, mature, ripening crops $0.6 \leq NDRE \leq 1$ RE = Red edge light (715 to 720 nm)

We talked about vegetation index, because NDVI, EVI these are the index which actually helps in understanding the vegetation or the crop cover in a better way.

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Vegetation indices

- ❑ Enhanced Vegetation Index (EVI) is similar to NDVI and can be used to quantify vegetation greenness. However, EVI corrects for some atmospheric conditions and canopy background noise and is more sensitive in areas with dense vegetation.
- ❑ **NDVI** is chlorophyll sensitive, whereas the **EVI** is more responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy, and canopy architecture.
- ❑ This **EVI** has improved sensitivity to high biomass regions with improved vegetation monitoring. The atmospheric effect is minimized in **EVI**.
- ❑ **Transformed Vegetation Index (TVI)** is commonly used to monitor vegetation cover. **TVI** is aimed at eliminating negative values and transforming NDVI histograms into a normal distribution. **TVI** cannot be calculated when **NDVI** < -0.5
- ❑ **Normalized Difference Moisture Index (NDMI)** is used to determine vegetation water content
- ❑ **Normalized Difference Water Index (NDWI)** is strongly related to the plant water content. It is therefore a very good measurement for plant water stress. NDWI is used to highlight open water features in a satellite image, allowing a water body to "stand out" against the soil and vegetation. High values of **NDWI** correspond to high vegetation water content and to high vegetation fraction cover. The NDWI index also used for assessing the risk of fire based on moisture presence in vegetation cover
- ❑ **NDMI** general value ranges from 0.685 to - 0.154 whereas for the same condition **NDWI** value ranges from 0.146 to - 0.444 (Taloor et al., 2021).

RS in agriculture

- ❑ RS provides several types of spatial information that include soil, Land Use Land Cover (LULC), vegetation indices (VI), soil moisture, a fraction of absorbed photosynthetically active radiation (FAPAR), crop biophysical condition data like leaf area index (LAI), crop height, canopy cover, stem width, above-ground biomass, crop biochemical parameters like leaf color, chlorophyll content, etc. which are crucial for crop model performance for computing evapotranspiration, biomass yield.
- ❑ RS can also represent the missing data and describe crop conditions throughout various crop growth stages
- ❑ RS can minimize the unpredictability of spatial information associated with the crop models
- ❑ The RS application in agriculture began with the large area crop inventory experiment (LACIE) using LANDSAT data to estimate wheat production
- ❑ Unmanned aerial vehicle (UAV) system has become a modern technology for crop water status detection, plant density estimation, crop biophysical parameter estimation, and several other applications
- ❑ UAVs can provide very high-resolution images
- ❑ Limitations of UAV are, such as small area coverage and insufficient flight time

So, after vegetation index, then, we just discussed about the role of remote sensing in general in agriculture.

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Satellite-based estimation of evapotranspiration

❖ Surface Energy Balance Algorithm for Land (SEBAL)

Based on the surface energy balance

The model computes a complete radiation and energy balance along with the resistances for momentum, heat, and water vapor transport for each pixel.

$$\lambda ET = R_n - G - H$$

λET = Evapotranspiration that is derived in terms of instantaneous latent heat flux

R_n = Net radiation (W/m^2)

G = Soil heat flux (W/m^2)

H = sensible heat flux (W/m^2)

Net radiation is computed from the land surface radiation balance as

$$R_n = (1 - \alpha)R_{Sin} + R_{Lin} - R_{Lout} - (1 - \epsilon_0)R_{Lin}$$

Satellite-based estimation of evapotranspiration (SEBAL)

R_{Sin} = Incoming short-wave solar radiation (W/m^2)

α = Surface albedo

R_{Lin} = Incoming long-wave solar radiation (W/m^2)

R_{Lout} = Outgoing long-wave solar radiation (W/m^2)

ϵ_0 = Land surface emissivity

G is empirically related to NDVI as

$$\frac{G}{R_n} = \frac{T_s}{\alpha} (0.0038\alpha + 0.0074\alpha^2)(1 - 0.98NDVI^4)$$

T_s = Surface temperature (K)

The expression for sensible heat flux is given as

$$H = \rho C_p \frac{dT}{r_{ah}}$$

ρ = Air density (Kg/m^3)

C_p = Specific heat capacity of air (≈ 1004 J/kg/K)

dT = Near-surface temperature difference (K)

r_{ah} = Aerodynamic resistance to heat transport (s/m)

Satellite-based estimation of evapotranspiration (SEBAL)

In the SEBAL model, T_s and dT are related linearly as

$$dT = aT_s + b$$

a, b are calibration parameters

Calibrated on the basis of the knowledge of two boundary conditions identified within the image itself where the dT values can be back-calculated using a known H at the two pixels

a and b require a choice of the two pixels, representing the extreme conditions of temperature and humidity, called the hot pixels and cold pixels

The cold pixel is a well-irrigated crop surface with full cover and the surface temperature T_s close to the air temperature T_a

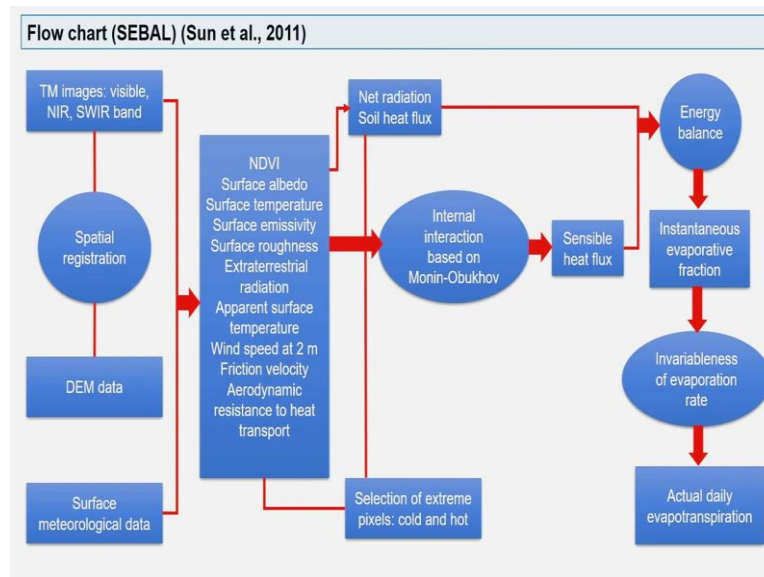
The hot pixel is a dry bare agricultural field where λET is assumed to be 0

The two pixels tie the calculations for all other pixels between these two points.

An iterative way started from neutral stability assumptions is conducted for the sensible heat flux estimation using atmospheric stability corrections

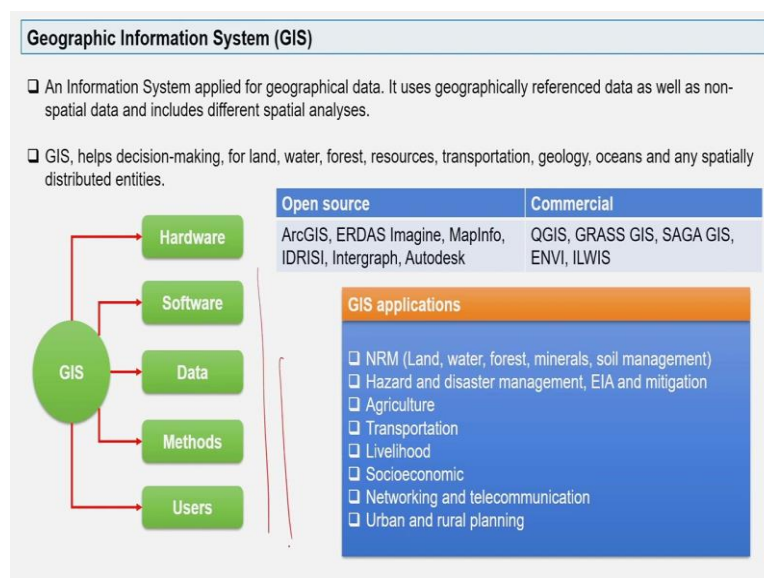
Satellite based different kind of data generation and what are the different processes that are being followed.

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SEBAL is one of the process that I have discussed in great detail, especially from the point of view of satellites role in helping us to monitor the natural resources.

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GIS

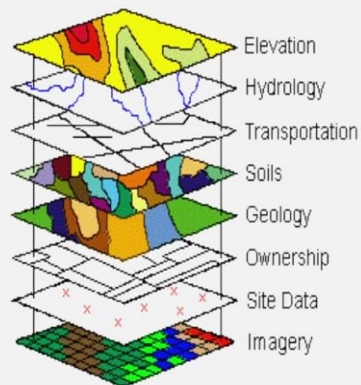
GIS data types

- ❖ Vector: point, line or, polygon
- ❖ Raster: data that are described by a cell grid, one value per cell
- ❖ Attribute: Data that are non-spatial characteristics that are connected by tables to points, lines, "events" on lines, and polygons (and in some cases GRID cells)

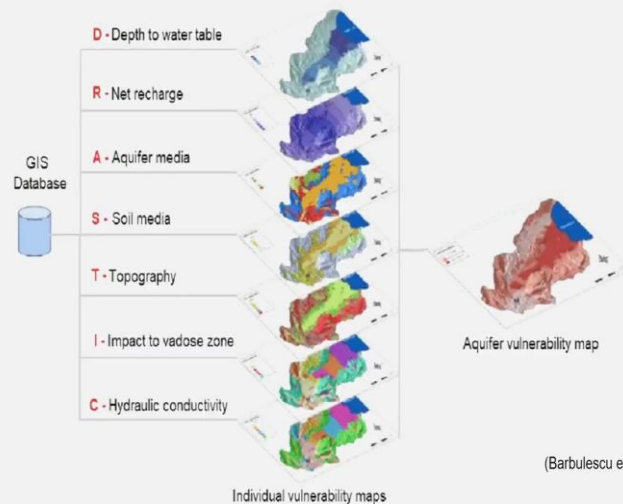
GIS interpolations

- ☐ Nearest neighbor
- ☐ Inverse Distance Weight (IDW)
- ☐ Kriging
- ☐ Spline
- ☐ Bilinear interpolation

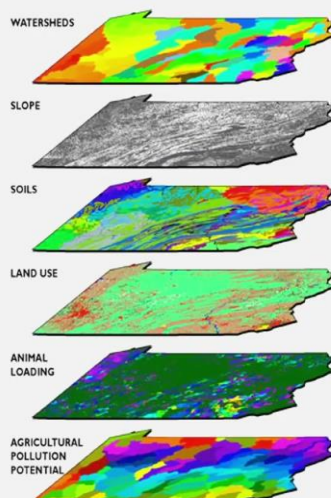
GIS Data Layers



GIS map layers for aquifer vulnerability



GIS map layers for agricultural pollution potential



Then we discussed the geographic information system GIS. Many of you might be using it already or some of you might hope to use it in future, so, GIS again is another important tool that you can actually utilize for various purposes. We discussed about GIS very fundamental way, its applications, its principles goals, how it works, and certain basic inner mechanism of GIS data with some real case studies or example. So, after remote sensing, we discussed another important topic that was climate change and vulnerability.

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Climate change, vulnerability, adaptation in NRM

How can we leave this topic when you talk about natural resource management and here we talked about the vulnerability and adaptation in natural resource management?

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Climate change

Drivers of climate change

- ☒ Natural drivers
- ☒ Anthropogenic drivers

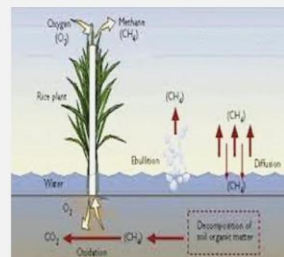
- ☐ Changes in the atmospheric abundance of greenhouse gases, aerosols, changes in solar radiation, land use land cover aerosols, solar radiation, surface albedo, and land surface temperature change the energy balance of the climate system.
- ☐ The changes are often known as radiative forcing which acts as an indicator to depict the impact of natural and anthropogenic factors impact on climate change.
- ☐ Radiative forcing is the change in net irradiance at the atmospheric boundary between the troposphere and the stratosphere.
- ☐ Natural drivers like greenhouse gas emissions like methane, Nitrous oxide, etc. Release of Sulphur dioxide, water vapor, dust, ash, etc. from the volcanic eruption
- ☐ Anthropogenic or Human causes are caused due to human activities and cause being man-made pollution.

If you recall that we started with the basic fundamental thing of the drivers, which actually change the climate. So, we talked about natural and anthropogenic driver, two drivers and how they actually impact our climate and how they change it.

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Climate change

- ❑ A huge part of this pollution caused by the burning of fossil fuels and the production of which is greenhouse gas like CO_2 and traps heat within the atmosphere of the Earth contributing to global warming
- ❑ Agricultural practices and conversion of dense vegetative lands to agricultural lands also contribute emission of greenhouse gases in the atmosphere
- ❑ Climate changes cause an increment of sea surface temperature (SST), different SST indices like El Niño, La Niña, Indian Ocean Dipole (IOD), etc. events. Frequency increment of drought, flood conditions, sea level rise, changes in soil moisture, river discharge characteristics, etc.



Climate variability

- ❑ Climate variability is used to denote deviations over a given period of time when compared to long-term statistics for the same calendar period. Climate variability is defined as the variation in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events.
- ❑ Climate variability is measured by these deviations, which are known as anomalies
- ❑ Variability may be due to natural internal processes within the climate system which are called internal variability.
- ❑ Variability may occur due to variations in natural or anthropogenic external factors that are called external variability

❑ Adaptive Capacity

The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.

❑ Exposure

The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.

❑ Hazard

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate related physical events such as droughts, floods, hurricanes, etc.

❑ Impact

Effects on natural and human systems. It generally refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. They are also referred to as consequences and outcomes.

And what are the different phenomenon that takes place due to climate change. And what is climate variability, we also discussed the differences between climate and weather, which often actually we tend to get confused, sometimes we take simple weather changes as climate changes, we discussed about that in great detail if you recall.

Then one by one, we talked about various terminologies that are being used in the field of vulnerability and adaptation in the field of climate change. So, we discussed about adaptive capacity, exposure, hazard, impact, which whenever you talk about the impact of climate change or natural resource management, these are the aspects will come into picture.

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❑ Risk

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

❑ Sensitivity

Degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct or indirect. An example of a direct effect is crop yield variation due to climate change whereas an indirect effect example is, damage due to an increase of coastal flood frequency

❑ Vulnerability

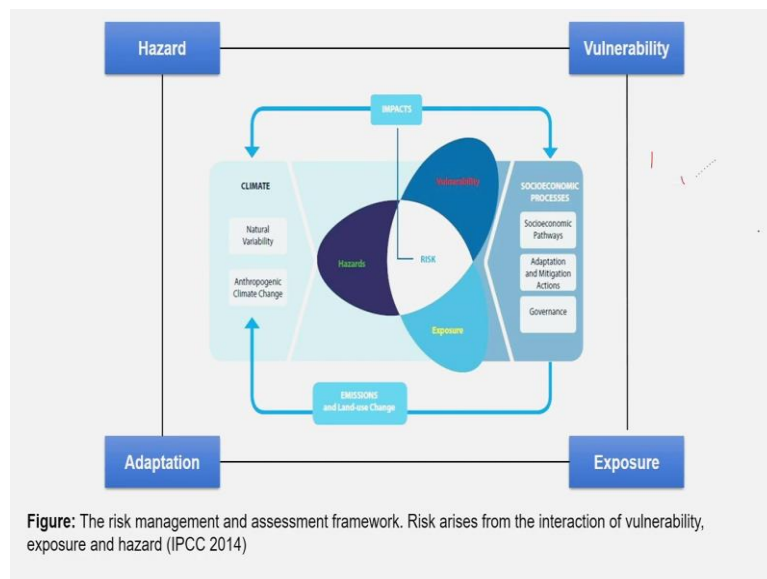
The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

❑ Vulnerability Index

A metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability.

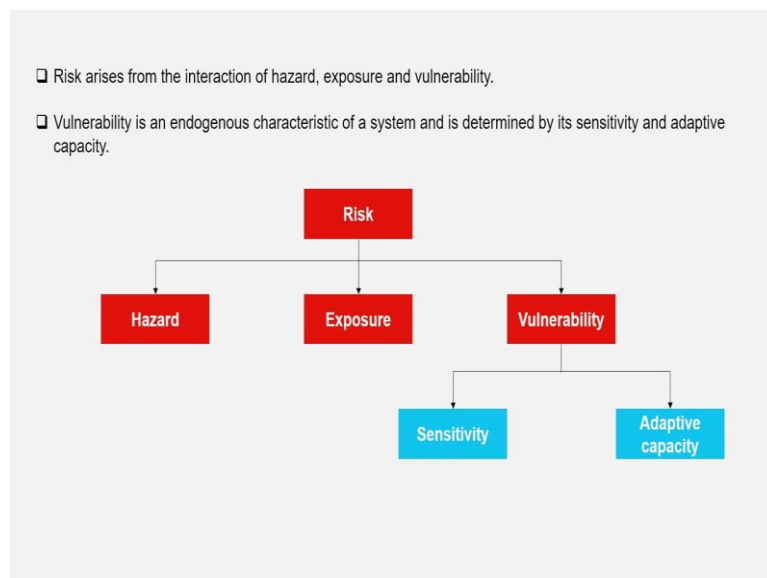
So, then we also discussed about risk, sensitivity, vulnerability, vulnerability index.

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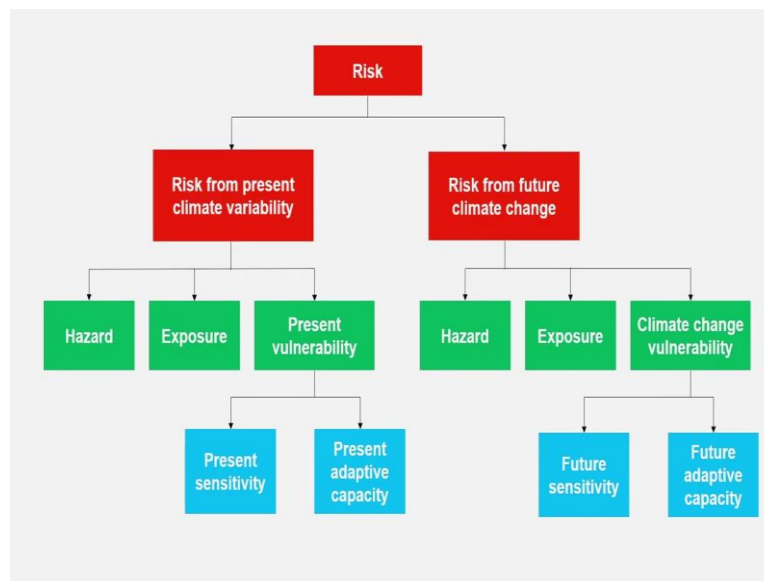
Then we went into the model, the risk management and assessment framework as given by Intergovernmental Panel on Climate Change IPCC discussed in great detail these all aspects.

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And then next we went into the risk and relation between risk hazard vulnerability and exposure.

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Vulnerability, sensitivity, adaptation

$$V = f(S, AC)c$$

V = Vulnerability, S = Sensitivity, AC = Adaptive capacity

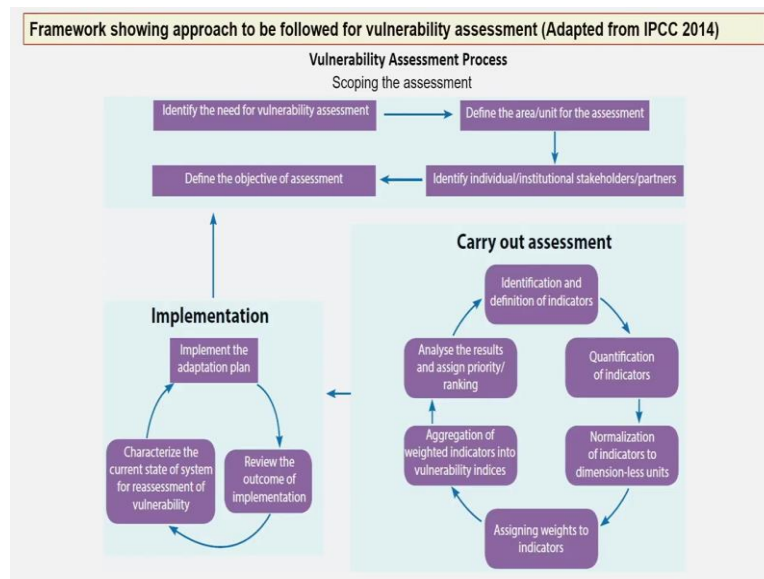
$$\text{As } V \propto S \text{ and } V \propto \frac{1}{AC} \text{ hence } V = f\left(S, \frac{1}{AC}\right)$$

$$V = f(S, H, p_H)$$

H = Hazard, p_H = Probability of occurrence of hazard

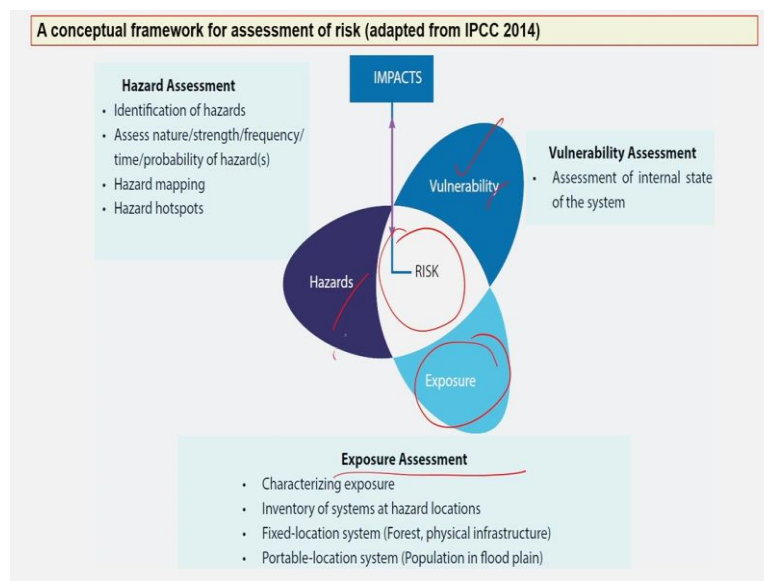
And after that, then we looked at that how risk from present climate variability and risk from future climate changes they work. So, in both the cases the vulnerability analysis to know the indicators of vulnerability is important, which actually we discussed it in a great detail about vulnerability sensitivity analysis adaptations.

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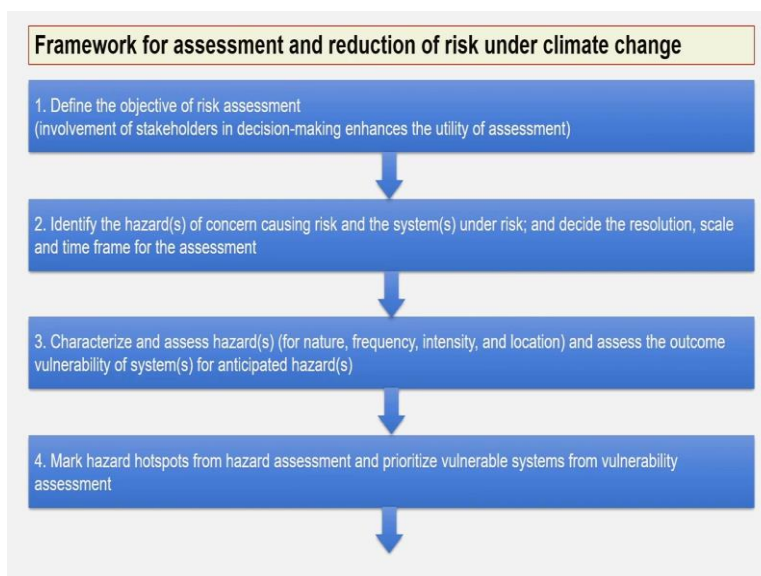
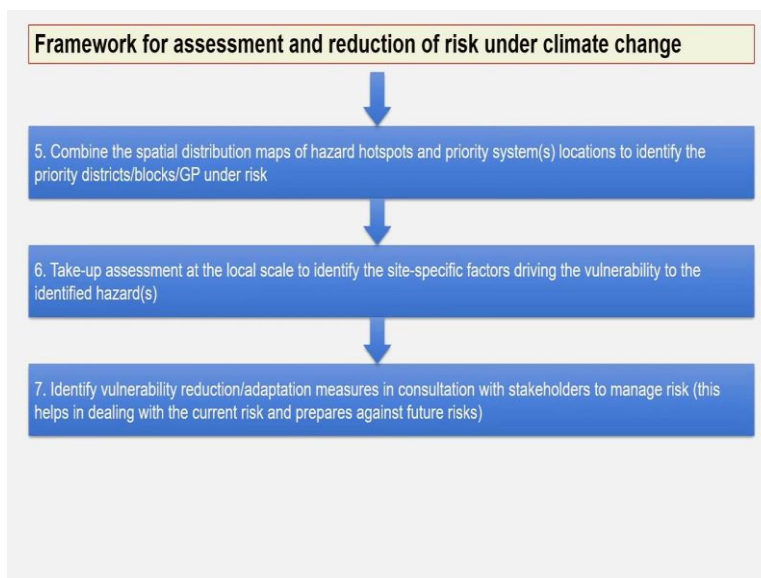
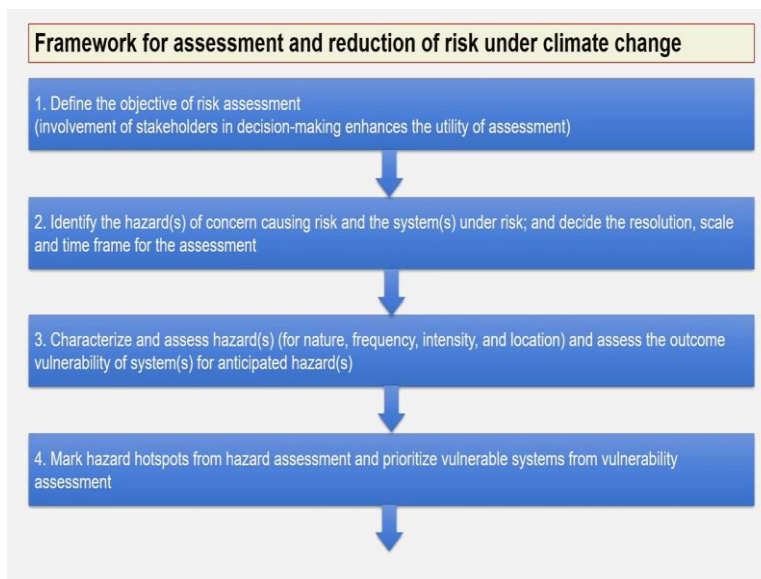
So, again, there is a vulnerability ability assessment process that we have discussed the given already well given framework by IPPC.

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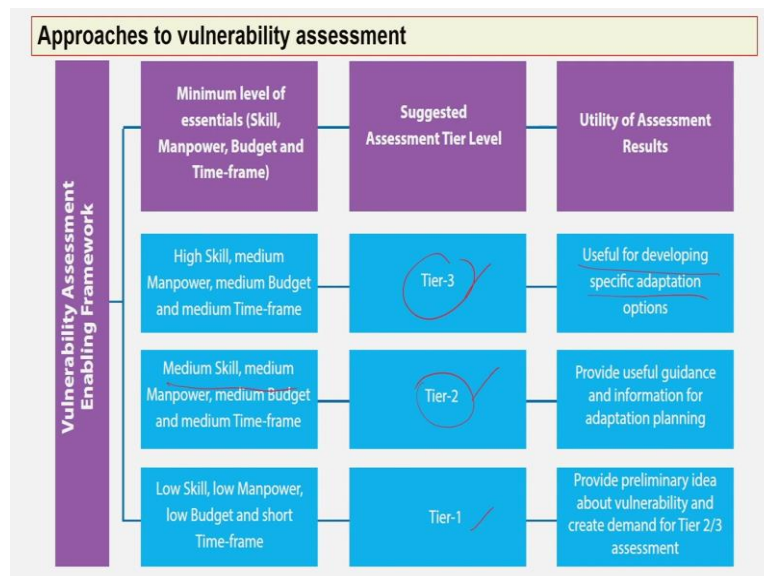
So, we discussed about these processes and the conceptual framework for assessment of risk again given by ITPC how you actually assess hazard, vulnerability and exposure and because risk is a product of vulnerability hazard and exposure. So, it works almost together and to understand risk, we need to understand this vulnerability hazard exposure and we have discussed that in great detail.

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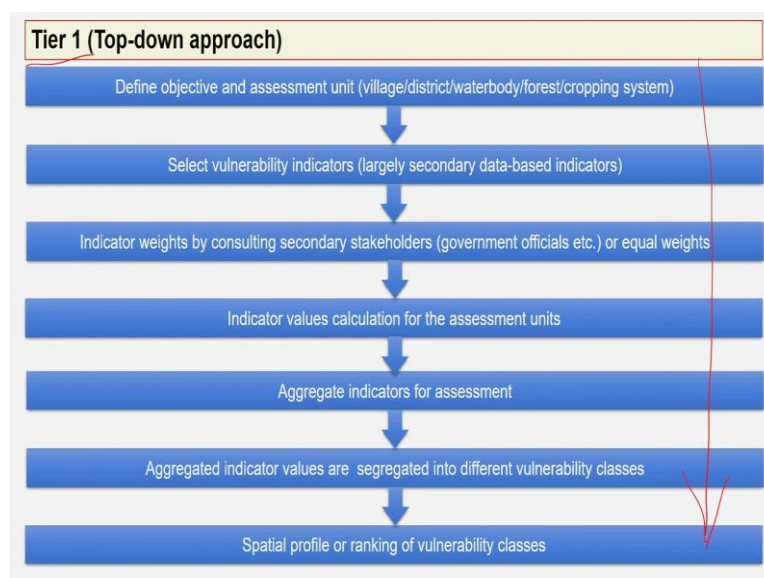
We have discussed the different reduction of risk under climate change, how we can do it.

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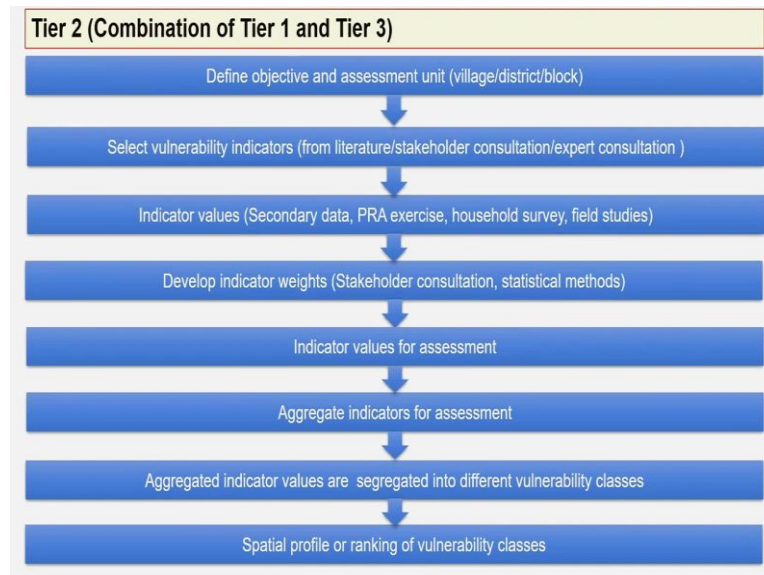
Then we also discussed about the vulnerability assessment approaches, various approaches. Again, we discussed about three different tiers if you remember. So, the tier 1 is the very basic tier which even unskilled manpower can do it. In tier 2, is medium skill manpower, and also you need medium budget. Tier 3 is the topmost level of vulnerability assessment, where you need some good high skilled technical expertise and because it also provides very specific adaptation options which finally policymakers can work on that and implement.

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We have also discussed these things tier wise, tier 1, tier 2 how actually you can step wise follow it and get the vulnerability classes.

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Comparison between different approaches			
	Tier 1	Tier 2	Tier 3
Indicator data	Secondary data	Both primary and secondary	Majorly primary with GIS, model data
Data sources	Government sources including reports, maps, past assessments, databases and non government sources data	Tier 1 + field, PRA exercise, household survey	Tier2 + data from national and international organization, satellite data, climate model data
Application	Provides preliminary assessment of vulnerability to assist in identifying the most vulnerable systems and may lead to carrying out tiers 2 and 3 assessments	Rigorous assessment providing useful system details for initiating measures for vulnerability and risk reduction	Very rigorous assessment informing about the sources of risk/vulnerability and useful for initiating action on the ground level, developing anticipatory strategies and initiating long term policy changes for risk/ vulnerability reduction
Data type	Secondary	Primary + 2ndary	Primary (largely) + GIS, climate data

Comparison between different approaches			
	Tier 1	Tier 2	Tier 3
Advantage	Easy and relatively quick implementation Lesser expertization requirement Low-level investment requirement	Stakeholder involvement improves the acceptability and the credibility of the assessment outcomes Useful for adaptation planning and for creating demand for adaptation action	Useful for developing a site-specific adaptation strategy Stakeholder participation and GIS and other modern techniques like modeling increase the accuracy and robustness of the results
Limitations	Provides only preliminary information about the vulnerabilities of the system Results are less accurate Methodologies are not less elaborate and robust	Requires medium to a high level of expertise More elaborate than tier 1 but more time and resource consuming than tier 1	Time, resource consuming and data-intensive Requirement of high level and knowledge, skill, and expertise

So, tier 1 and tier 3, when you combine, you basically get the tier 2, which is medium, scale medium outcome. So, that one process which I think most of the time people prefers to follow. So, we discussed about these tiers in great detail.

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Why to assess vulnerability
<input type="checkbox"/> Identify the most vulnerable regions or sectors or communities/systems <input type="checkbox"/> Raise awareness regarding the vulnerability of communities/systems <input type="checkbox"/> Identify drivers/sources of vulnerability for the development of targeted adaptation strategies and allocation of adaptation funds <input type="checkbox"/> Assist in developing and implementing adaptation practices and strategies
Why assess vulnerability to climate change
<input type="checkbox"/> To create awareness and demand for resilience-building anticipatory measures in anticipation of an uncertain climate change in the future. <input type="checkbox"/> To identify the most vulnerable mountain systems/communities/regions to projected climate change. <input type="checkbox"/> To assist in developing climate change adaptation practices and programs. <input type="checkbox"/> To assist in developing programs to enhance long-term resilience to climate change.

Different vulnerability assessment		
Indicators	Application	Applicants
Biophysical (Ex: natural resources)	Impact study of natural resource degradation on vulnerability Identification of the biophysical factors contributing to vulnerability Prioritize natural resources to be considered in adaptation planning	Watershed managers, Forest department, agriculture department, world bank, multilateral funding agencies
Socio-economic (Ex: different communities)	Identification of the contribution of social and economic factors to vulnerability Target adaptation interventions on social and institutional factors	Local communities, NGOs, community, government, and non-government organizations
Integrated (Ex: watershed (above 2))	Prioritizing socioeconomic and biophysical factors causing vulnerability Designing technological, institutional, social and economic interventions to reduce vulnerability and adaptation strategies in production systems	Watershed managers, Agriculture forest, fisheries, water resources, animal husbandry department, World Bank, and multilateral funding agencies

Different vulnerability assessment		
Indicators	Application	Applicants
Hazard specific	Enables Identification of drivers that contribute majorly to vulnerability to droughts floods landslides etc. Identifying the most vulnerable exposure units to climatic hazards Focusing on the high damage-causing events and regions for vulnerability and risk reduction programs	Disaster management, development, and planning department Organizations associated to draughts, floods, landslides, earthquake etc.
Quantity of indicators		
<input type="checkbox"/> If indicators are too less then data gathering is easy and rapid assessment is possible but the disadvantage is that many drivers might not be covered, indicators might be general and drivers might not be easily recognized.		
<input type="checkbox"/> If indicators are too many then in-depth and huge information can be gathered as well as drivers can be recognized easily. But time-consuming, difficult in data collection as well as depend on stakeholder consultation.		

Then we discussed about the indicators that how vulnerability can be assessed through different indicators. Now, the indicators and its applications and who applied that also we have discussed quality of indicators have also been discussed.

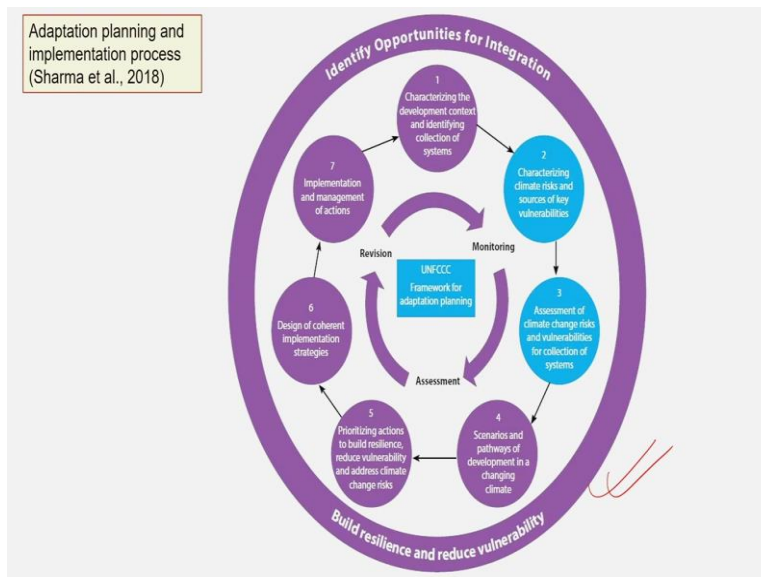
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Indicator categories for vulnerability	
Indicators	Examples
Physical	Slope, elevation, soil physical, hydraulic property, drainage density
Chemical	Soil, water, air quality
Biological	Crop types, forest types, Invasive species
Economical	Landholding capacity, occupation, diversified income sources
Social	Gender, caste, marginality, inaccessibility
Institutional	Presence of community-based organizations, banks, insurance, watershed management programs, social security, awareness program, etc.

Then categories of indicators for vulnerability assessment also we have discussed. Various categories and the examples of vulnerability from which sector which indicator you should use that also have discussed.

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Example (Biological indicator): Crop type, yield
<ul style="list-style-type: none">❑ Crop yield unit generally ton/ha, kg/ha, etc. or local units❑ Number of different crops planted in a single cropping season for the crop diversity❑ Data can be obtained by field observations or household surveys. Questions can be like land holding capacity, irrigation, annual income, crop yield, and crop type cultivated can be asked in the household survey.❑ Field observations need to be done during the cropping season and household surveys at the end of the cropping season❑ Sample selection may be done based on land holding (may be in a stratified way)
Example (Physical indicator): Groundwater level (GWL)
<ul style="list-style-type: none">❑ Measured by generally m bgl (i.e. below ground level)❑ Secondary data of GWL data collecting organizations, soil data, hydrogeologic data, rainfall data, household data (no of bore wells, well depth, etc.) for different agencies.❑ Field observations by vertical electrical survey❑ Getting subsurface data in field measurement needs expertization and many subsurface hydrogeologic properties disturb electrical signals thus inaccuracy in readings. The household survey can give only very general information which might not be useful.



We have discussed each one of those indicator with real example. Then, we discussed about the adaptation planning and implementation process once you understand the indicator, through indicator you identify the vulnerability of a particular sector of a people or location, then you come out with some adaptation planning and this is a adaptation process which even FCC has given a framework and a lot of exercise studies has been gone behind it, and then this kind of framework has come into picture. So, this helps us in planning, proper adaptation.

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Climate change : Flood and Drought

Floods

- ❑ Excess water that covers land which is in normally dry condition
- ❑ Riverine floods occur when the water level rises above its natural river banks
- ❑ This type of flood may be caused by runoff generated due to snowmelt in combination with prolonged and heavy rainfall
- ❑ Much longer duration than a flash flood. Take much time to reach its peak and also return back to normal condition
- ❑ Flash floods may occur due to short-duration heavy rainfall, cloud bursts, dam break, or an excessive amount of water spilling from reservoirs
- ❑ Flash flood causes severe damage and death due to its sudden arrival
- ❑ Commonly severity and hazard of a flood depend on the velocity of flood water, flood water level, duration of the flood, rate of floodwater level rise, flood frequency, and seasonality of the flood
- ❑ Flood cause death of plants, and animals, people, remove top soil which is rich in nutrients, damages buildings, and structures
- ❑ In countries having high monsoonal rainfall flood occurs during heavy rainfall whereas in high latitude countries flood occurs during the spring season as a result of snowmelt. In urban areas due to poor drainage floodwater may last for a longer duration

Draughts

- ❑ Deficiency of water either temporary or permanently
- ❑ Draught is classified as a meteorological drought, hydrological drought, agricultural drought, socioeconomic drought
- ❑ Rain water deficiency, overexploitation of groundwater, desertification of land, deforestation, excessive dependency on rainfed agriculture, sea surface temperature indices like El Nino, etc. are some major causes of drought
- ❑ Draught causes severe damage to crops and humans, and animals, particularly if drought happens in crop-growing seasons
- ❑ Usually arid regions suffer long-term drought while humid regions experience short-term drought
- ❑ Drought reduces water in water resources, drops the topsoil and soil becomes unfavorable for crop growth
- ❑ Draught may also occur if there is little precipitation as well as soil moisture removal at an accelerated rate due to high evapotranspiration
- ❑ Draught vulnerability of a region may be computed by several drought indices

And to do that, if you take one example of floods, then we discussed that how in case of flood, you can actually carry out adaptive exercise, how people adaptation can be built or resilience can be built.

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Meteorological droughts indices

Percent of normal

- ❑ Also called Percent Departure from Normal (PDN)
- ❑ Simple method for drought detection which is calculated by dividing actual precipitation by normal precipitation and multiplying it by 100% for each location
- ❑ Percent of Normal is effective in a single region or season.
- ❑ Popular in India. IMD declares meteorological drought on a weekly/monthly basis based on rainfall departure from its long-term averages.
- ❑ PDN is unable to determine the frequency of the departures from normal or compare with different locations.

PDN (%)	Drought severity type
> 0	No drought
0 to -25	Mild drought
-26 to -50	Moderate drought
< -50	Severe drought

Meteorological droughts indices

Decile

- ❑ Developed to use instead of percent of normal.
- ❑ Monthly precipitation totals from a long-term record (~30 years) are used for deciles
- ❑ Deciles are calculated from the number of occurrences distributed from 1 to 10 or in %
- ❑ The lowest value indicates conditions drier than normal and the higher value indicates conditions wetter than normal.
- ❑ Widely used in Australia
- ❑ Requires a long-term climatic record for accuracy

Decile (%)	Drought severity type
0 to 20	Much below normal
20 to 40	Below normal
40 to 60	Near normal
60 to 80	Above normal
80 to 100	Much above normal

Meteorological droughts indices

Palmer Drought Severity Index (PDSI)

- ❑ Uses historical data on precipitation, temperature & soil available water content (AWC), and computes the rainfall pattern abnormality as a drought indicator.
- ❑ Soil moisture data is calibrated to the homogeneous climate zone. Thus it may lag in the detection of drought over several months because the data depend on soil moisture and soil properties which have been simplified to one value for each climate division.
- ❑ PDSI also used as an indices for **agricultural drought**
- ❑ PDSI is commonly used in USA and it is not popular in India

PDSI	Drought severity type
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
< -4.00	Extreme drought

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-3.00 to -3.99	Severe drought
< -4.00	Extreme drought

Hydrological droughts indices

Hydrological drought is measured by its magnitude (i.e. amount of water deficiency), Duration, severity (i.e. cumulative amount of deficiency), and frequency of occurrence. This type of drought can be measured by water deficit by means of hydrological modeling, frequency analysis of low water flow, flow duration curve etc.

Surface Water Supply Index (SWSI)

- ❑ Used for frequency analysis to normalize long-term data
- ❑ Monthly time step
- ❑ Includes precipitation, snowpack, stream flow, and reservoir level
- ❑ Very useful for indicating snowpack conditions in mountainous regions to measure the water supplies
- ❑ SWSI for different basins can not be compared with each other

$$SWSI = \frac{1}{12} [w_S P_S + w_R P_R + w_Q P_Q + w_{RS} P_{RS} - 50]$$

Suffix S, R, Q and RS are four water balance components namely snow, rain, streamflow, and reservoir storage, respectively

SWSI	Drought severity type
-4.2 to -3.0	Extremely dry
-2.9 to -2.0	Moderately dry
-1.9 to -1.0	Slightly dry
-0.9 to 1.0	Near normal
1.1 to 2.0	Slightly wet
2.1 to 3.0	Moderately wet
3.1 to 4.2	Extremely wet

P_i = probability (%) of non-exceedance for each of the four water balance components.
 w_i = weights for four water balance components
 $w_S + w_R + w_Q + w_{RS} = 1$

So, to understand this flood or drought situation, there are various kinds of indices which help us to understand the severity of drought or flood that also we have discussed. We discussed about meteorological drought indices. And then we talked about various methods of calculating or analyzing meteorological drought.

After meteorological drought we discussed about agricultural drought; how agricultural or hydrological drought, how hydrological drought is different from meteorological drought, different indices for hydrological drought, we have discussed and how they can be calculated that also we have discussed and which value means, what? Level of severity of drought that also has been discussed.

(Refer Slide Time: 43:01)

Hydrological droughts indices

Standardized runoff Index (SRI)

- ❑ SRI incorporates hydrologic processes that determine seasonal lags in the influence of climate on streamflow
- ❑ By calculating the cumulative probability of runoff data for a given period, the corresponding SRI value can be obtained through the normalization of probabilities of different distributions
- ❑ The determination procedure of SRI is similar to standardized precipitation index (SPI) but instead of rainfall time series data (which is used in SPI) runoff time series data is used here in the case of SRI

SRI	Drought severity type
< -2.0	Extreme drought
-2.0 to -1.5	Moderate drought
-1.5 to -1.0	Mild drought
-1.0 to 1.0	Near normal
1.0 to 1.5	Slightly wet
1.5 to 2.0	Moderate wet
> 2.0	Extreme wet

Agricultural droughts indices

Aridity Index (AI)

- ❑ Ratio of annual precipitation (P) and annual potential evapotranspiration (PET), expressed in %
- ❑ Simple water balance calculation
- ❑ Similar to the SWSI
- ❑ Does not properly account for rainfall-runoff before the stored moisture is estimated
- ❑ Crop-water requirements are not considered.

Thornthwaite formula for Aridity Index

$$AI = \frac{PET - P}{PET} \times 100$$

AI	Drought severity type
≤ 25%	Mild drought
26% – 50%	Moderate drought
> 50%	Severe drought

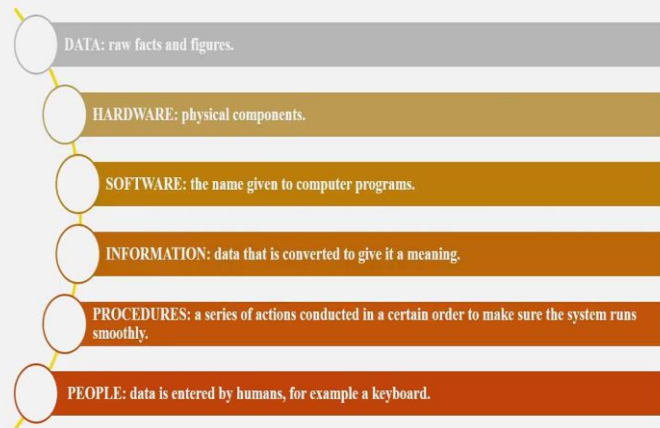
So, after meteorological drought indices then hydrological drought indices and then finally, we discussed about agricultural drought indices. So, these three actually looks at drought in a different way and they are level of severity analysis also differs from each other. Well, then after these vulnerability indicators and its adaptation analysis, finally, then we have gone into in role of ICT. So, in role of ICT, we discussed about how information communication technology can be used for natural resource management.

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Information Communication Technologies (ICT) for Natural Resource management

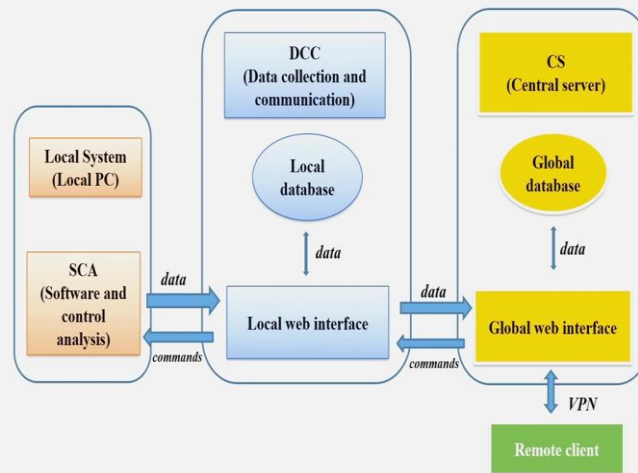
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Components of ICT



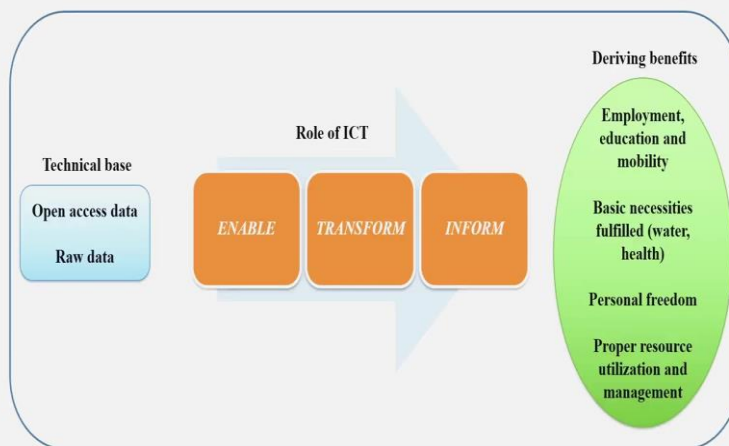
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Data flow in ICT



4

Data flow in ICT: a sustainable framework



5

ICT and Environment

ICT has both positive and negative impacts on the environment

Positive impacts can come from: □

- *Dematerialization and online delivery;* □
- *A reduction in the need for travel;* □
- *A host of modeling, monitoring and management applications; and*
- *Greater energy efficiency in production and use, and recycling.*

Negative impacts can come from: □

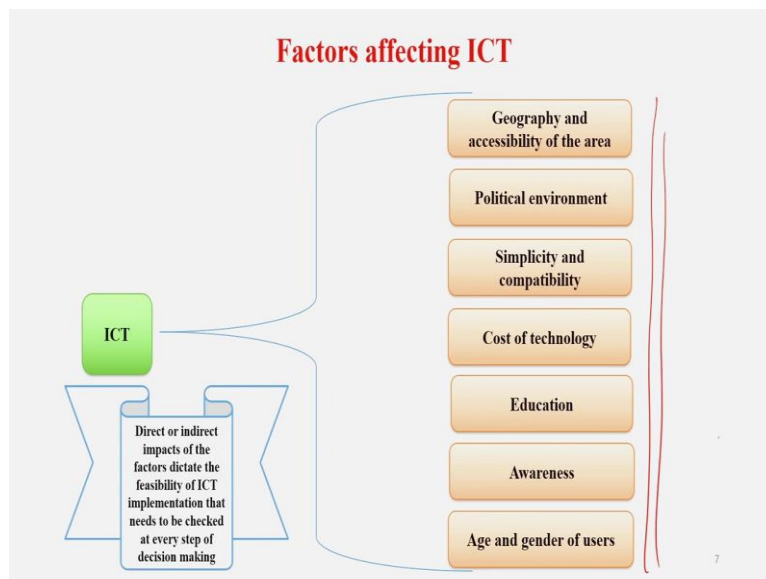
- *The production and distribution of ICT equipment;* □
- *Energy consumption in use (directly and for cooling);* □
- *Short product life-cycles and e-waste; and*
- *Potentially exploitative applications.*

5

We talked about various components of ICT, how data actually flows within an ICT system, how ICT can help in developing sustainable framework, relationship between ICT and environment also has been discussed.

(Refer Slide Time: 44:09)

Factors affecting ICT



7

ICT in Natural resources management

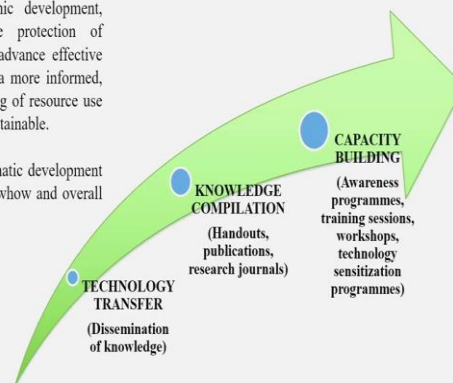
- The natural resources of most developing countries are under increasing stress, and many nations are increasingly concerned about achieving environmental sustainability through efficient use of land and water resources.
- As population is escalating very fast, there is need to take stronger step by national government to monitor their natural resources and take immediate steps to maintain these resources when being overused.
- Efficient use of information and communication technologies (ICTs) is crucial for inclusive growth of agricultural sector as India. The importance of ICTs lies less in technology itself than in its ability to create greater access to information and communication in underserved populations.
- To better understand trends and causal relationships, it is necessary to combine data from different sources. Doing this requires the development of standards and protocols for describing phenomena, as well as quality control to ensure that the knowledge that results is based on facts.
- ICT can have significant affects where time lags are a barrier to achieving goals. For example, early responses to emergencies such as forest fires or pest/disease/invasive species outbreaks are much more cost effective and more likely to be successful than late responses. It can also make a difference when markets are involved

8

ICT in Natural resources management

Technology transfer is an important tool for achieving global goals for economic development, biodiversity conservation, and the protection of ecosystem services. It can help to advance effective governance and rule of law through a more informed, mobilized public and better monitoring of resource use to ensure that it is lawful as well as sustainable.

Its significance in ICT lies in a schematic development of knowledge building, technical knowhow and overall sustainable management



9

ICT in Natural resources management

The ICT based tools are applied for processing, exchanging and managing data, information and knowledge management, and also having great ability to;

- ☐ *Record text, drawings, photographs, audio, video, process descriptions, and other information in digital formats,*
- ☐ *Produce exact duplicates of such information at significantly lower cost,*
- ☐ *Transfer information and knowledge rapidly over large distances through communications networks.*
- ☐ *Develop standardized algorithms to large quantities of information relatively rapidly.*
- ☐ *Achieve greater interactivity in communicating, evaluating, producing and sharing useful information and knowledge.*

10

ICT in Natural resources management

The management of natural resources with ICT is the most trending topic in environmental economics and management.

All natural resources, their utilization and management can be optimized with smart use of ICTs.

In terms of NRM, following are major aspects in which the use of ICT is considered:

1. *ICT for soil management* ✓
2. *ICT for water management* ✓
3. *ICT in agriculture* ✓
4. *ICT for disaster management* ✓

11

Various factors affecting information communication technology, role of ICT and natural resource management, how actually ICT can be utilized for resource management, for soil for water for agriculture for disaster management. So, after this fundamental aspect, then we discussed each sector like soil, then water. So, how ICT actually different sector wise or different types of natural resource wise can be utilized.

(Refer Slide Time: 44:44)

1. Aerial photographs

- It is the simplest form of remote sensing using photographic cameras to record information from visible or near infrared wavelengths.
- In the beginning cameras were positioned above the Earth's surface in balloons or kites to take oblique aerial photographs of the landscape.
- These images were used to construct topographic and other types of reference maps of the natural and human-made features found on the Earth's surface.
- Soil quality can be assessed from aerial photography. Areas without vegetation, with high reflectance, irregular in shape are demarcated and it can be examined for eroded or salt affected lands.
- Repeated photographs with different time interval will be useful for monitoring of soil quality status and assessment.
- Aerial photography has the advantage of allowing a quick and repeatable look at grass conditions over a total area simultaneously, and of providing permanent records of conditions at a specific moment in time.

4

1. Aerial photographs

- The figure shows areas of salt affected lands with high reflectance.
- Even with cropped area will communicate differently through its high reflection if the soils have problems.
- Water logging, salinity, low nutrients etc., will affect the plants by reducing uptake of nutrients. Light or pale color the plants indicates the low nutrient uptake status.



Fig: Aerial photographs of salt affected lands- Chamrajnagar District, Karnataka. Source: (Rajan and Meena, 2012)

5

2. Satellite imagery

- Launching of high altitude satellites with sensors fitted to complete specific remote sensing jobs.
- Some of these sensors are used to monitor the Earth's surface for a number of applications outside of weather forecasting (LANDSAT, SPOT, and RADARSAT).
- Recognizing objects from a remotely sensed image is often a difficult process. Many objects are hard to identify because their appearance in image is unfamiliar to our memories as the objects in the environment mainly from an oblique perspective.
- Hence, objects that are remotely sensed are often imaged from above and the sensors used in the imaging process may be recording electromagnetic signatures that are outside human vision. These electromagnetic signatures are then processed for interpretation.
- To aid in object recognition and interpretation, users often use a methodical process that identifies features based on shape, image tone or color, pattern, shadow, and texture.

6

2. Satellite imagery

- Reflectance of electromagnetic radiation forms the basis for soil quality assessment in satellite imagery.
- Satellite imageries are developed in false color composite.
- Vegetations are shown in red color, water bodies are shown in black color and eroded and salt affected lands are shown in white color.
- Irregular white patches is also showing the salt affected areas.



Fig: Satellite imagery of salt affected lands Chamrajnagar District, Karnataka (Source: Rajan and Meena, 2012)

7

3. Microwave remote sensing

- Microwave portion of the spectrum covers 1cm to 1m in wavelength.
- Because of their longer wavelengths, compared to the visible and infrared, microwaves have special properties that are important for remote sensing. They can penetrate through cloud cover, haze, dust allowing detection of microwave energy under almost all weather and environmental conditions so that data can be collected at any time.
- Microwave remote sensing are of the two types:

Passive microwave sensing: A passive microwave sensor detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature and moisture properties of the emitting object or surface.

Active microwave sensing: Active microwave sensors provide their own source of microwave radiation to illuminate the target. Most common example is **RADAR** (Radio detection and imaging). The sensor transmits a radio signal towards the target and detects the backscattered portion of the signal. It is the strength of the backscattered signal that is measured to differentiate between different targets. The time delay for receiving the backscattered signal is used to determine the distance or range to the target.

8

3. Microwave remote sensing

- In terms of soil management, it is often used for soil moisture estimation. Soil moisture is an important component of the hydrological cycle. It contributes significantly to the water and energy flux from the surface of the earth, which in turn drives the atmospheric circulation.
- There are some microwave sensors which are of non imaging type. They take measurements in one linear dimension, as opposed to the two-dimensional representation of imaging sensors.
- **Radar altimeters** transmit short microwave pulses and measure the round trip time delay to targets to determine their distance from the sensor.
- **Scatterometers** are also generally non-imaging sensors and are used to make precise quantitative measurements of the amount of energy backscattered from targets. The amount of energy backscattered is dependent on the surface properties (roughness) and the angle at which the microwave energy strikes the target. In case of soil, scatterometry are used extensively to accurately measure the backscatter from various targets in order to characterize different materials and surface types. This is analogous to the concept of spectral reflectance curves in the optical spectrum.

9

3. Microwave remote sensing

- Thus, Remote sensing data are interpreted to obtain information about cropped areas, water bodies, settlements, forest, hills, rocky area, salt affected land, eroded land, water logged land, mined land etc.
- Based on these information, thematic maps are prepared.
- In terms of soil quality assessment nature of reflectance are observe.
- Degraded lands such as salt affected or eroded lands shows high reflectance. Normal soil shows dark in color with less reflectance. Similarly, moist and water logged soils will also appear in dark color.
- Assessment of soil quality for any area will be in general, done with a pretext of productivity decline. The area for assessment is demarcated and soil samples are collected from different sites of representative area. Soil samples collected from the study are analyzed fro different physical, chemical and biological indicators.
- Information technologies are using these analytical data. These analyzed data are then incorporated in data base as per the requirement.

10

3. Microwave remote sensing

The data collected from the field using communication technologies becomes input for information technologies. Analysis of soil samples brought from the field gives an idea of status of the soil quality indicators such as physical, chemical and biological indicators as follows:

o Soil physical properties such as bulk density, available soil water, micro aggregates, total porosity

o Soil chemical properties such as electric conductivity, pH, available N, phosphorus, potassium, copper, iron, manganese and zinc.

o Soil biological properties like organic carbon, dehydrogenase and urease activity.

These quality parameters are used in information technologies to assess the soil quality for efficient management

Thus, ICT and physico-chemical and biological parameters go hand in hand for efficient soil quality management to get an overall concise information for land development and management.

11

4. Geographic Information System (GIS)

- A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data.

- GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry.

- GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making.

- These systems combine computer cartography with database management software (DBMS).

- GIS is used to:

- a) measure natural and human phenomena and processes from a spatial perspective;*
- b) store these measurements in digital form used a computer database and digital maps;*
- c) analysis of these collected measurements.*

12

4. Geographic Information System (GIS)

- GIS digitally creates and "manipulates" spatial areas.
- Soil quality of a region is visualized with geo-referencing using GIS techniques.
- A comprehensive knowledge is acquired when all the soil quality indicators are put together.
- The land is categorized based on the soil quality and management strategies are planned accordingly

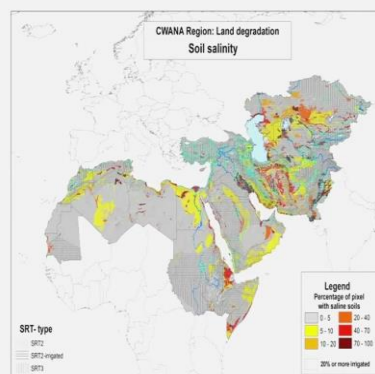


Fig: A typical GIS map showing Soil Salinity.
(<https://geoagro.icarda.org/en/cms/category/maps/13/regional/1/title/DESC>)

13

5. Simulation models and Geo-statistics

- A computer simulation, a computer model is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system.
- They have been a useful part of mathematical modeling of many natural systems in physics (computational physics), chemistry and biology.
- Simulations can be used to explore and gain new insights into new technology, and to estimate the performance of systems too complex for analytical solutions.
- In case of soil management, often unknown values of soil quality parameters are estimated with standard or known values.
- Linear models are employed to predict the values in inaccessible areas or other than the measured areas in the grids.
- Interpolation is done to get the values in all the unmeasured areas using **Kriging techniques**. Kriging is a widely used geo-statistical tool that fits a surface to three dimensions: the latitude, longitude, and variable of interest. It includes **exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface**. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data.

14

6. Neural networks

- An artificial neural network (ANN) is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system.
- It is an adaptive, most often nonlinear system that learns to perform a function (an input/output map) from data. After the training phase, the Artificial Neural Network parameters are fixed and the system is deployed to solve the problem at hand (the testing phase).
- It is built with a systematic step-by-step procedure to optimize a performance criterion or to follow some implicit internal constraint, which is commonly referred to as the learning rule.
- The input/output training data are fundamental in neural network technology, because they convey the necessary information to "discover" the optimal operating point.
- Based on the measured values, the unknown values are predicted in the unmeasured spots and contours are drawn. Elevation maps are also created to show the difference in soil quality parameters and soil environment assessment.

15

6. Neural networks

- Often, ecological experts while using ANN, use Eco-environment Background Value (EBV) based on a scoring and ranking system. The higher the EBV, better the ecological environmental quality.
- Three types of eco-environmental attributes that are physically-based and easily-quantifiable at a grid level are extracted:
 - (1) *remote sensing derived attributes (vegetation index, wetness index, soil brightness index, surface land temperature index),*
 - (2) *meteorological attributes (annual temperature and annual precipitation), and*
 - (3) *terrain attribute (elevation).*
- Through analyzing the spatial correlation between the eco-environmental quality and land uses, information regarding management and motivation are generated and documented.

16

So, for soil also we have if you recall that different kinds of satellite imagery microwave sensing how differently for different kinds of soil problem, it can be utilized. We have discussed for soil and then we have discussed also for water.

(Refer Slide Time: 45:11)

ICT for efficient water management

- The water management is the activity of planning, developing, distributing, managing, and optimum use of water resources under defined water policies and regulations. It may include management of water resources, irrigation methods and water table.
- Water scarcity affects more than 40% of the global population. Water-related disasters account for 70% of all deaths related to natural disasters.
- ICT is relevant to protecting water quantity, water quality, enabling water predictions, water management, and aquatic biodiversity. ICT can help in assessing water supply adequacy, modelling different supply and technology alternatives and factor in different usage technologies.
- This includes the development of dynamic Geographic Information Systems (GIS) for identifying water availability, storage, transmission and distribution, monitoring of water quality, optimization of the allocation between different water uses (e.g. treated drinking water, agriculture etc) and water use management at a societal level including distribution systems (loss reduction) and utilization efficiency.
- The strategic incorporation of different ICT tools in the water management sector mitigates some of the existing and future water issues. ICTs act as a tool, an agent of change, and an alternative method.

2


ICT for efficient water management

- ICTs provides a unique opportunity for stakeholders involved in water management process, and helps them to obtain information about a number of physical and environmental factors.
- They also provide benefits in water management process such as:
 - *real-time monitoring and control at wide scale;*
 - *integrated management and decision support based on data collection and aggregation;*
 - *empowering user with real time information to create awareness and stimulate behavioral change;*
 - *water smart meters and ICT tools to support leak detection and*
 - *automated meter reading through communication networks.*

4

ICT for efficient water management

The water management sector has emerged number of challenges before policy makers, technocrats, extension professionals, water users, farmers and other stakeholders:

1. *Water availability*
 2. *River pollution*
 3. *Water conflicts*
 4. *Groundwater pollution*
 5. *Crumbling inadequate infrastructures*
 6. *Inadequate storage capacity*
 7. *Aquifer depletion*
 8. *Poor water use efficiency*
 9. *Ever growing water demand*
- 

3

ICT for efficient water management

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 - *water smart meters and ICT tools to support leak detection and*
 - *automated meter reading through communication networks.*

4

So, and on that actually the last topic that we discussed in this MOOC course was the ICT for efficient water management and we looked at the various aspects associated with water management and how information communication technology basically can help to manage water, looking at all these various aspects; water availability, river pollution, water conflicts, groundwater pollution, so, various important aspects associated with water management can also be studied with the help of ICT that we have discussed.

(Refer Slide Time: 45:53)

ICT application in different water management areas

1. Mapping of Water Resources and Weather Forecasting

- Remote sensing from satellites
- In-situ terrestrial sensing systems
- Geographical Information Systems
- Sensor networks and Internet

2. Asset Management for the Water Distribution Network

- Buried asset identification and electronic tagging
- Smart pipes
- Just in time repairs/Real time risk assessment

Contd.. 5

Application of ICT for different water management areas also we have discussed.

(Refer Slide Time: 46:01)

1. Decision Support System (DSS)

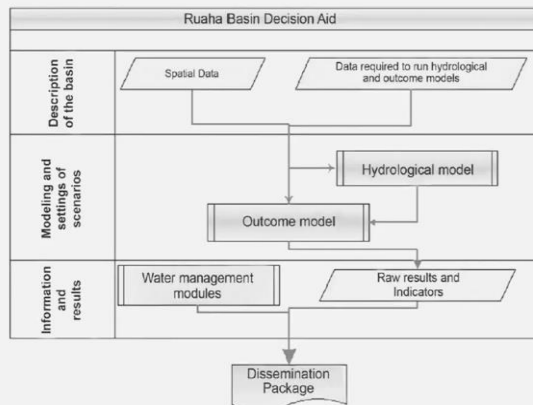
- The complexity of water resources management and the difficulties of making decisions about the allocation of water resources are crucial. In such situations, decision support systems (DSS) are intended to assist to make strategic and rational decisions.
- Decision Support Systems is a specific class of computerized information systems that supports organizational decision-making activities. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents and personal knowledge, to identify and solve problems and make decisions.
- A DSS helps structural decision-making processes and support the analysis of complex situations.
- Decision support systems bring together data and knowledge from different areas and sources to provide users with information beyond the usual reports and summaries. This is intended to help policy makers take informed decisions.
- A decision support system is an informational application as opposed to an operational application. Informational applications provide users with relevant information based on a variety of data sources to support better-informed decision-making. Operational applications, by contrast, record the details of business transactions, including the data required for the decision-support needs of a business.

7

And then we talked about that how DSS which is an important part of ICT decision support system, how it helps in water management.

(Refer Slide Time: 46:11)

1. Decision Support System (DSS)



A case study based in Tanzania showing the process of DSS In action.

8

2. Geographic Information System (GIS) in Watershed Management

- Geographic Information Systems (GIS) in watershed programs play critical roles in all aspects of watershed management, right from assessing watershed conditions, modeling impacts of human activities on water management and to visualize the impacts of alternative management scenarios.
- GIS application in watershed management has changed from operational support (e.g., inventory management and descriptive mapping) to prescriptive modeling and tactical or strategic decision support system.
- Henceforth researchers, resource planners and policy makers have to be realizing the power of GIS and its unique ability to enhance watershed management.
- A GIS based model of the terrain with all relevant spatial data related to natural resources, infrastructure and administrative boundaries attached with relevant attribute data will enable the planners, stake holders and funding agencies to develop the watershed keeping in mind to fulfill the stake holders need in the backdrop of natural resources potential as well as limitations.

9

2. Geographic Information System (GIS) in Watershed Management

• Watershed Restoration and Analysis of Alternative Management Strategies:

Watershed restoration studies generally involve evaluation of various management alternatives. In this view, GIS provides the perfect environment to accomplish that efficiently and accurately. It also provide a platform for collaboration among researchers, watershed stakeholders, and policy makers, significantly improving consensus building and offering the opportunity for collaborative work on interdisciplinary environmental issue.

• Watershed Policy Analysis and Decision Support:

Policy planning and management are based on a generic problem-solving process which begins with problem definition and description, involves various forms of analysis which might include simulation and modeling, moves to prediction and thence to prescription or design which often involves the evaluation of alternative solutions to the problem. GIS can assist the decision maker in dealing with complex management and planning problems within a watershed, providing geo-processing functions and flexible problem solving environments to support the decision research process.

11

3. Meters and sensors

Meters and sensors are currently being intensively applied to regulate different activities of water distribution systems. The major aim of water utilities is to convey water from one place to another without any losses, saving water and avoiding any damages caused by leaking water. Some of the different types of meters and sensors that have been developed for effective and sustainable water resource management are:

1. *Pressure management sensors*
2. *Flow sensors*
3. *Energy consumption sensors*
4. *Supervisory Control and Data Acquisition (SCADA)*
5. *Water quality sensors*
6. *Water consumption meter*

12

We talked about the framework of a standard DSS, GIS and its role in water management meters and sensors.

(Refer Slide Time: 46:23)

SCADA technology

SCADA systems perform main functions like the acquisition of data through the sensors, the transmission of the acquired data between a number of remote sites, the data presentation through the central host computer and the control of the data at the operator terminal or workstations. They can be incorporated into a system of hardware and software to improve the safety and efficiency of the operation of these large processes.

These systems usually consist of the following subsystems:

- Remote terminal units (RTUs) or programmable logic controllers (PLCs) which interface with the sensors in the process;
- A communication infrastructure connecting the remote terminal units with the supervisory system or central host computer;
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the process, sometimes called a SCADA centre, master station, master terminal unit, or MTU;
- A communication system to support the use of operator workstations;
- Standard human machine interface (HMI) software or man machine interface (MMI) software system, which is used to provide the central host and operation terminal application of SCADA, support the communication system and monitor and control remotely located field data interfaces devices.

13

4. Hydraulic models

- Hydrological models help water resource professionals, companies, and universities, local, regional, and governmental authorities, meteorological agencies, and other water sectors to effectively manage, predict, and make proper decisions on the available water resource.
- Hydraulic model based simulation and optimization of water distribution network (WDN) is a research trend where decision support system component incorporates simulation models with a network of sensors and forecasting models for practical management of the water distribution system.
- it is constantly updating itself due to new simulation and optimization linkage approach developed based on the innovative use of traditional and global simulation and optimization algorithms.
- Different companies provide models, simulation and optimization products to the water network managers to design, optimization of energy and costs, lowering the water loss, and effective controlling strategies.

14

5. Water supply, Irrigation design and management

- Utilizing different ICT tools to synchronize water supply with demand, regulate pump operations to save energy, manage the withdrawal of water from different sources and reservoirs, and control the purification processes in sewage recovery structures is one of the major water management goal.
- The different ICT tools applied in development activities helps to improve the network and hydraulic design of irrigation systems. Different elementary software applications were developed to calculate the water head losses during flowing water in pipes.
- New and advanced software applications simulate the water flow in a complicated loop of water network and facilitate optimization of pressure flow in irrigation systems. Designing of irrigation networks requires comprehensive software development using topography, aerial photography, and GIS data. This helps to facilitate computerized designs of irrigation network systems for a better water resource management.
- ICT tools help to facilitate computerized irrigation water budgeting system based on soil type and its water retention capacity, climatic condition, crop water requirements, soil moisture, and the plant water potential measurements. The designed water budget helps to programme solid scheduling of irrigation schemes.
- In addition, more advanced software also facilitates optimization of water distribution under the existing topography and the pressure regimes.

15

6. Urban water management

The very wide water domain and its stakeholder involvements cover an enormous number of all business domains and activities in the urban sector. Therefore, the development of ICTs focuses on five major areas that connect directly to the urban water supply and management activities:

1. *Real time monitoring*
2. *Water efficiency*
3. *Energy efficiency*
4. *Asset management and field work management*
5. *Cities of tomorrow*

16

For again, leakage study, monitoring, water management, hydraulic models, how it helps for predicting the water conditions, availability in certain area, water supply, irrigation, design management through ICT can be done very effectively, urban water management.

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ICT application in water management: future aspects

There is ample potential for effective use of ICT in water management. However, much still remains to be done. Knowledge transfer should be two way considering the subject matter experts as well as the communities involved with the aim of building on their knowledge and capitalize it.

Thus information technology, jointly with communication sciences, can play a big role in blending different perspectives. Several future trends of great importance have emerged as:

1. *Strong 'Network of Information System' for water and soil management at National, State and District Level*
2. *Pluralistic partnership between public, private, non-government organizations and water users and conservation association*
3. *Capacity building of different stakeholders in the areas of ICTs*
4. *Designing of different ICT based modules decision support system/expert system for water application methods, water conservation, water harvesting system etc.*
5. *Enhancing water use efficiency by using ICTs at field situation.*
6. *Pilot program for 'ICT enabled Soil and Water Management System' and its up scaling*
7. *Converging of media and tools for communication*
8. *Increased web based storage of relevant information;*
9. *Increased custom made, quality management information services etc.*

17

So, overall ICT is role in water management is great. Infact, even the future planning exercise for water management also can be carried out utilizing ICT, we discussed about that. And that actually bring us the end of the all the topics or modules that we wanted to discuss about.

And that is how we come to the end of this MOOC course on natural resource management. And I hope that all of you have enjoyed this course. And I wish all of you all the best for the upcoming final test. So, I wish you all the best. Thank you very much for your interest in this MOOC course on Natural Resource Management.