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 it the rest of the module and I will go 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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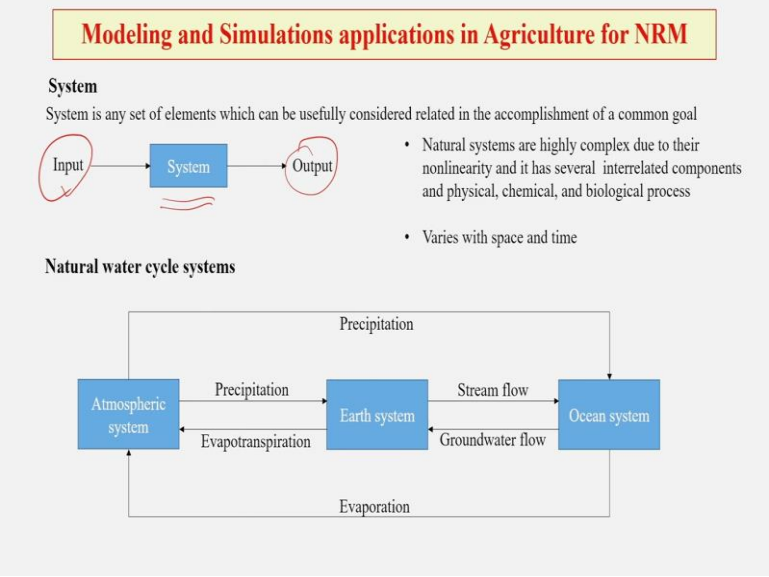

So, let us start with the one of the most interesting topics that we have discussed previously and that is modeling and simulation application in agriculture for NRM. What we discussed in this topic? We discussed various aspects of modeling simulation, the power of computations, how we can actually mimic 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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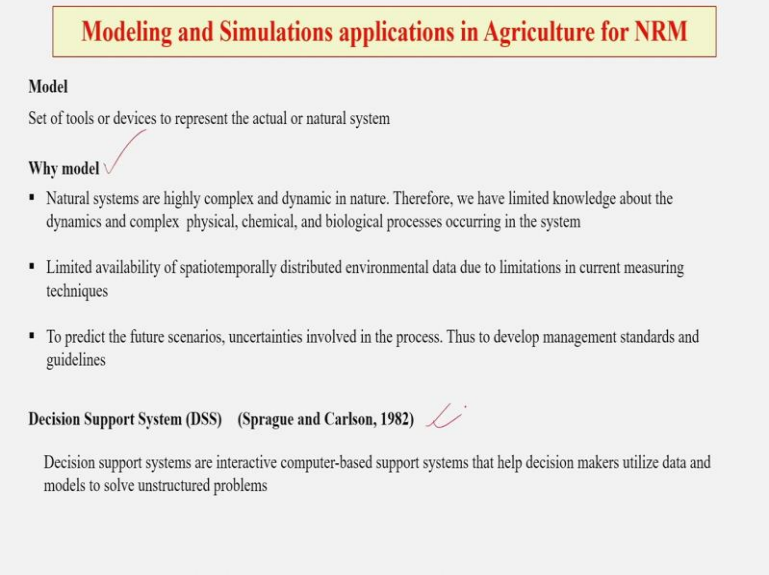

So, these are all the things that we have discussed in this modeling simulation lecture. We also discussed what is model, why we need model. Then we discussed about decision support systems, use of model.

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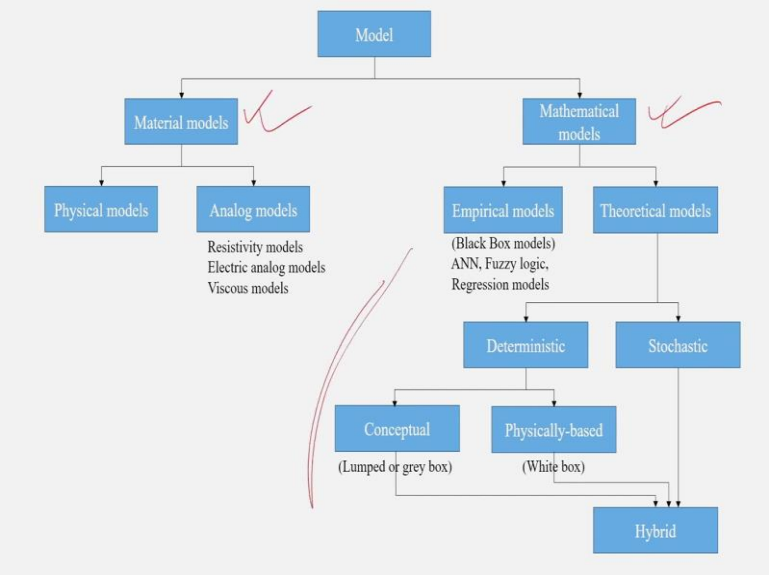

Then model framework actually, what kind of models that are available in public domain. We discussed about material models, mathematical models, and various type of mathematical models.

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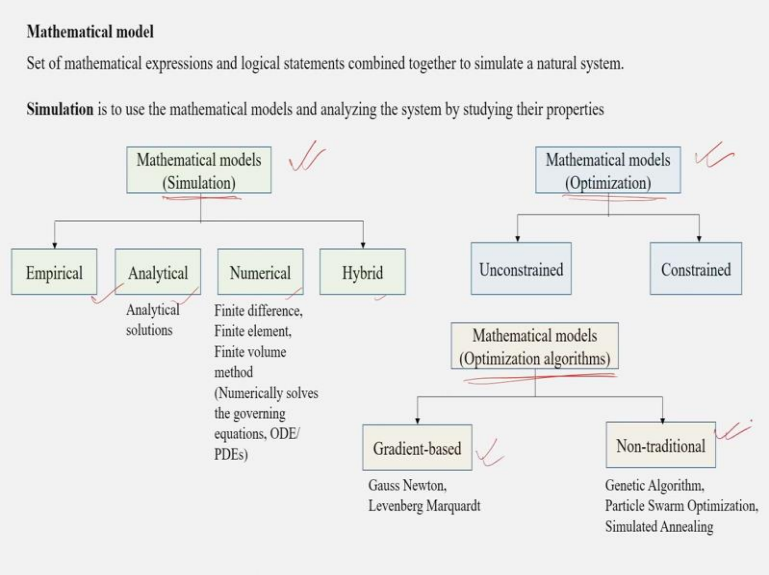

Then we one by one also went through a various model like mathematical model we first discussed. If you recall that we discussed with the different example, how mathematical models can be used for simulation and also for optimization.

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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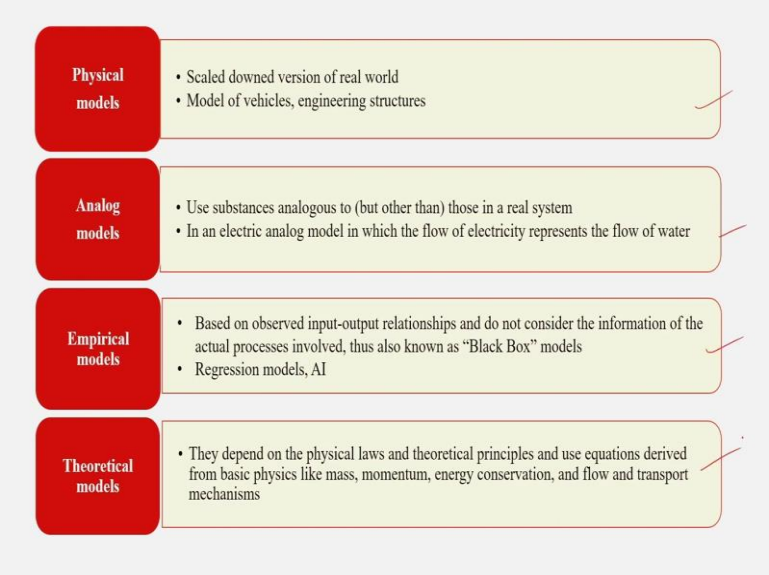

So, these we all have discussed then we went into the various kinds of nano models, physical models, analog models, empirical models, theoretical models, and how they actually function, what kind of data they require. All those things, also we have discussed.

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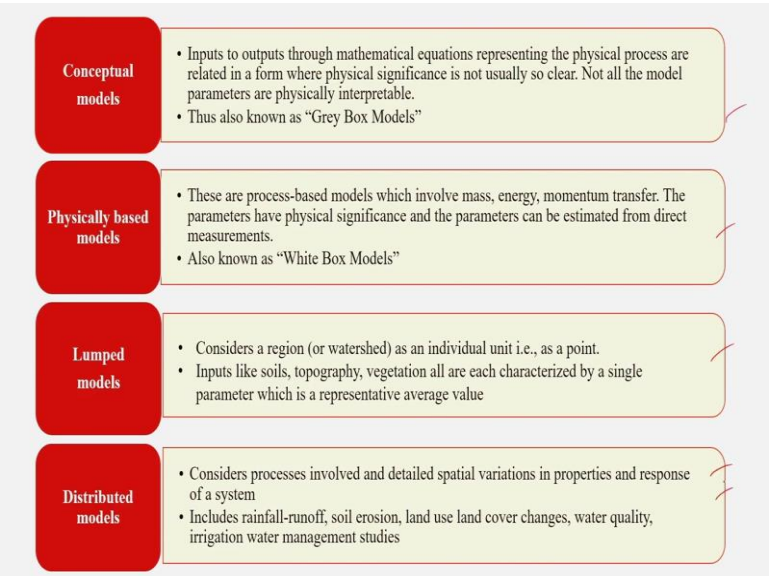

And all these slides are already shared with you in the MOOC portal, and I hope that you have critically gone through this. So, each one of these models have been discussed with a lot of details.

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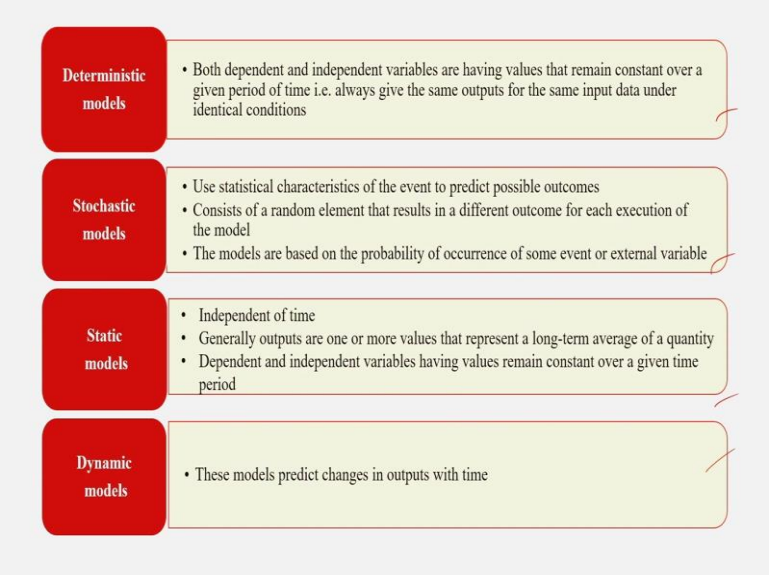

Then deterministic model, stochastic, static and dynamic model this also we have discussed that in what condition which model can be used, what are the requirements for various models.

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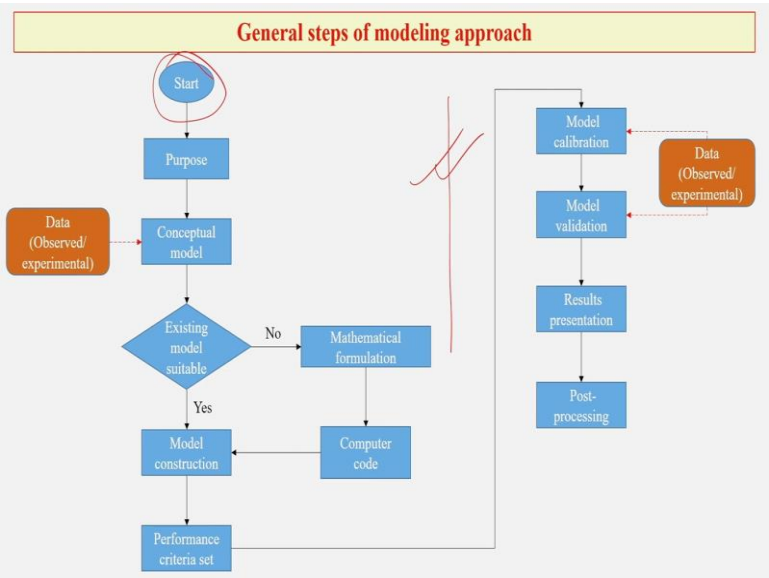

Then, we discussed about general steps of modeling approach. So, the framework, how actually you start with your basic conceptual model and then data, how you integrate it, how the different criteria that you test and then you calibrate, validate and finally, you come out with the result which you present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

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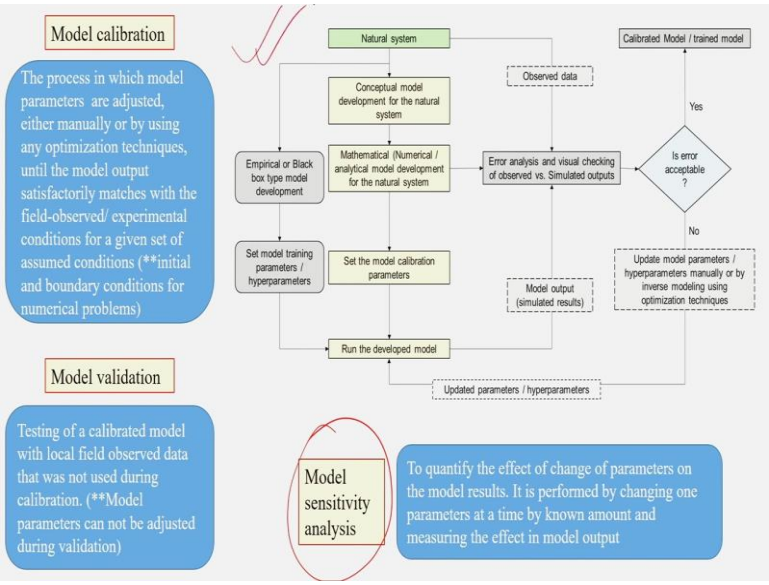

So, calibration and validation, we already discussed and mentioned that these are the two very important exercise or aspect of modeling exercises. Then we talked about that how sensitivity analysis can be carried out in detail, we discussed also with example, that how actually, this kind of modeling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

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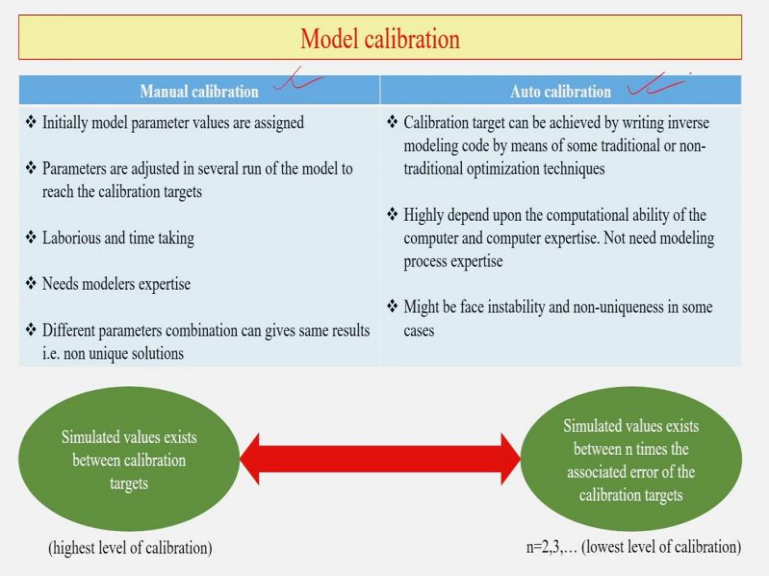

Model calibration again, better the model calibration better would be your predicted outcome. So, we also discussed about manual calibration as well as auto calibration, how they are different from each other, what are the benefits of each one of these.

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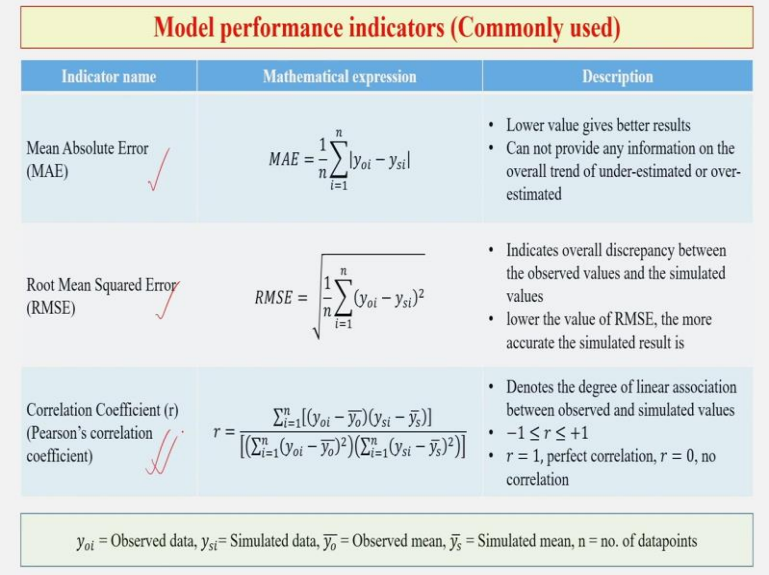

Then we also discussed about performance indicators. And we discussed about few very commonly used performance indicators, which many of you might have done already in your graduate, postgraduate or PhDs.

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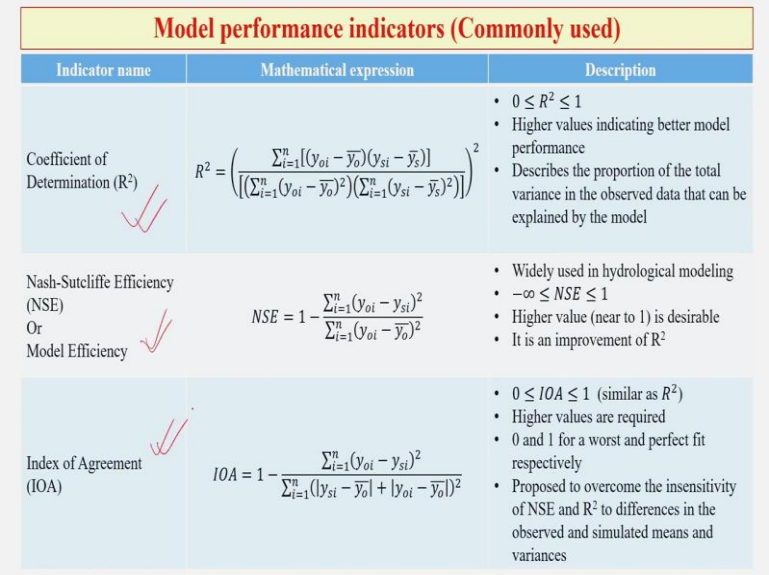

So, these things are actually carried out or analyzed to understand that how your model is actually performing.

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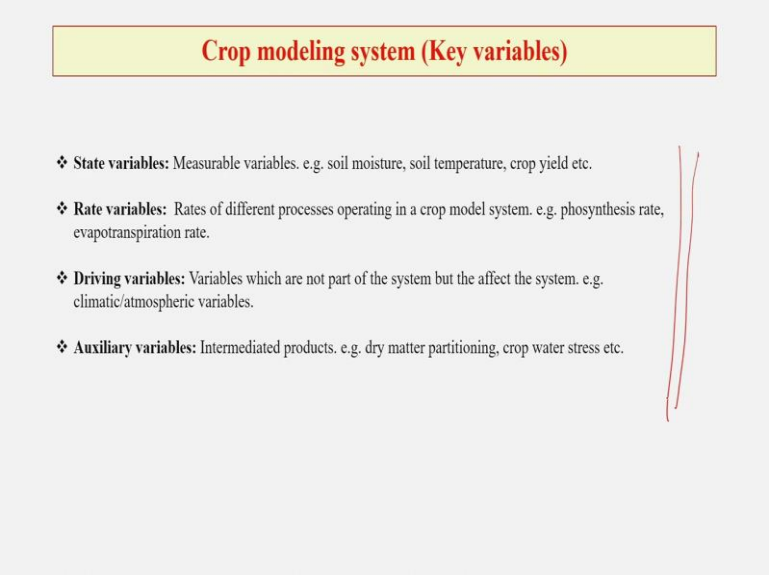

So, after model, indicate testing performance indicator, then we went into crop modeling system. One of the most important term modeling system, which actually talks about the yield means, under different kinds of conditions, how the crop yield will vary, and as that the crop yield is directly related 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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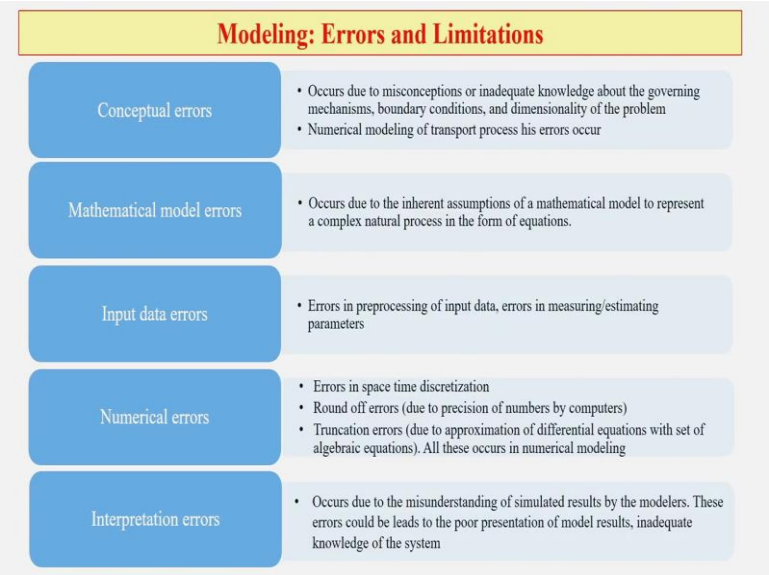

Then we went into different aspects of crop modeling and how actually we can minimize the errors.

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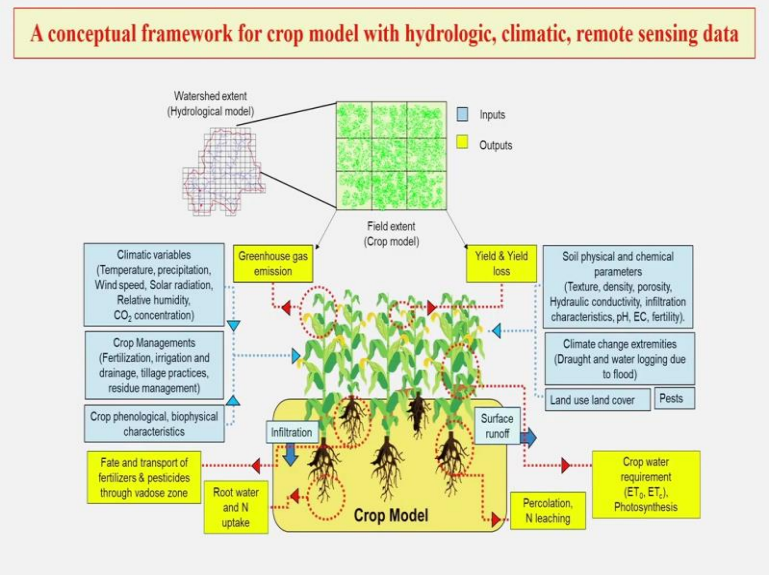

Then, we discussed about the conceptual framework for crop model with hydrologic, climatic and remote sensing data. So, this as you see here, this is one of the work that from our lab, we have carried out this conceptual framework and this has also a very recently has been published in the Journal of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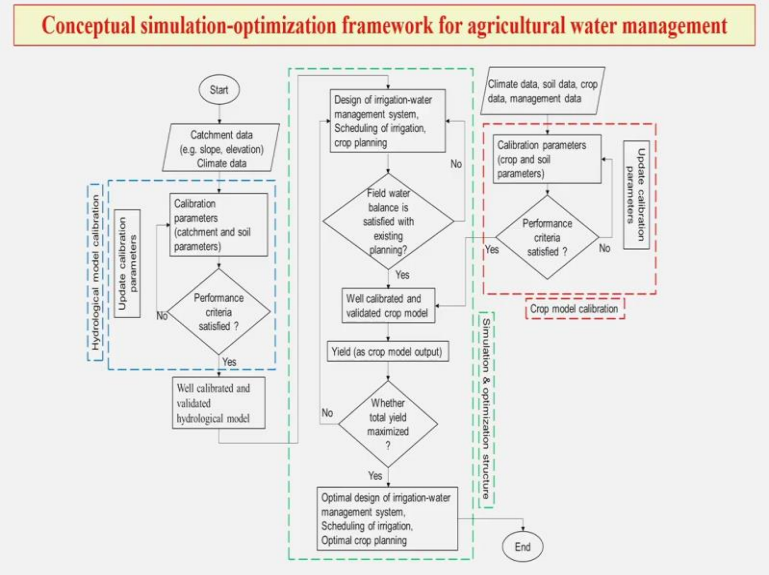

And along with that, when you bring in artificial intelligence and machine learning, then the power of your modeling systems become much higher. So, we also discussed about the conceptual simulation optimization framework for water management.

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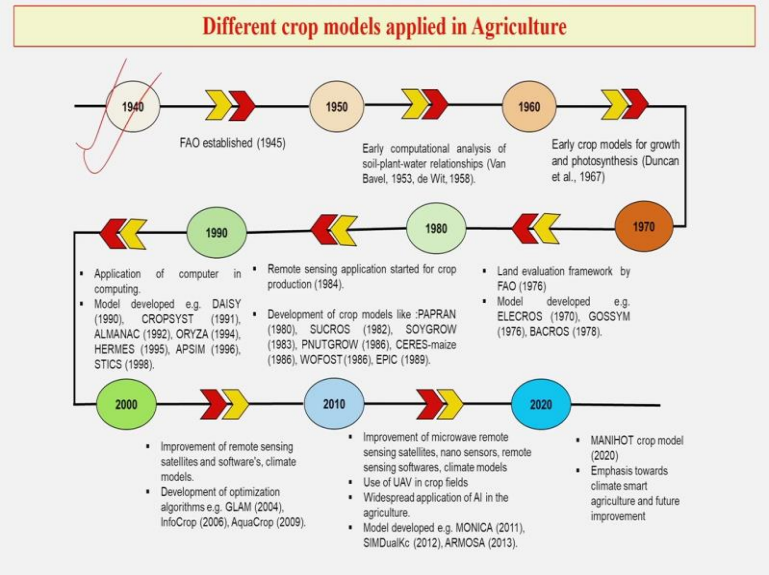

We also shared with you that how the crop models over the last few decades actually has evolved. So, we started from the very beginning of the crop modeling days and till very recently, its development.

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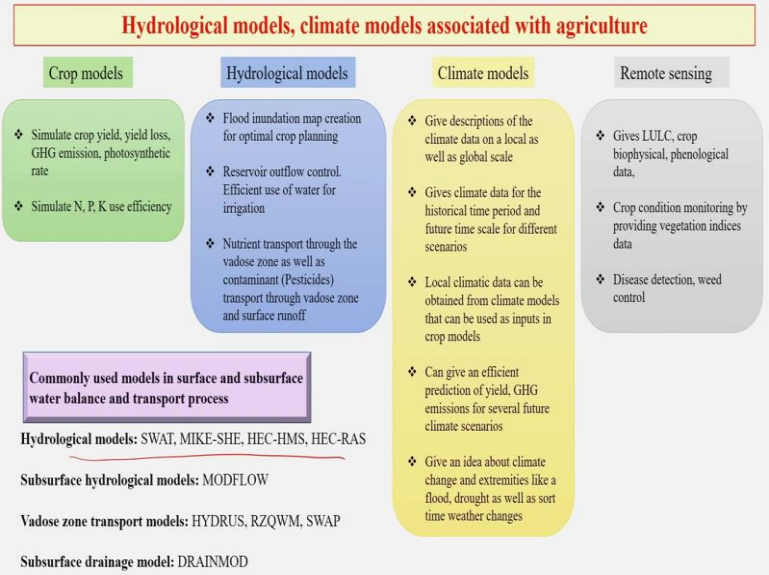

Then, we discussed about hydrological model, climate model and how they are linked with agricultural productions and how these different models can actually utilize the one of the most important resource which is water in the best possible manner to give better outcome which is food production or agricultural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

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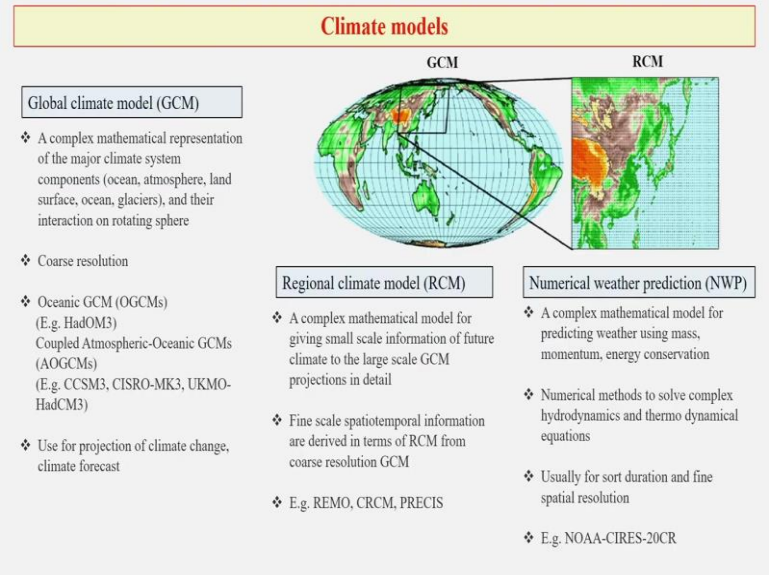

Then we talked about GCM and RCMs, how they work.

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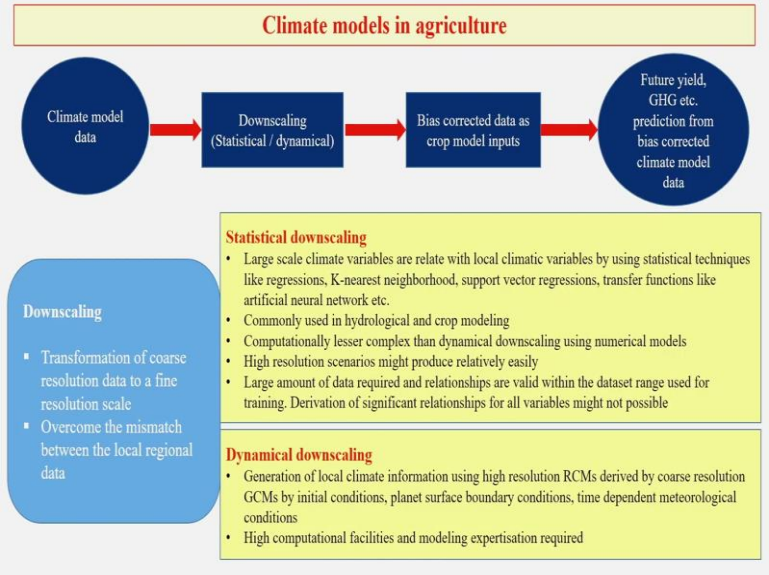

And then how we can actually apply different kind of climate models outcome into agriculture system.

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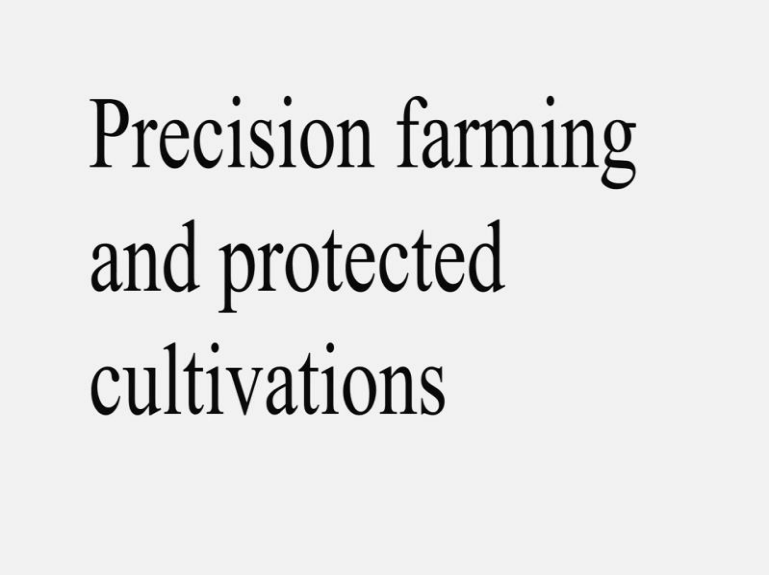

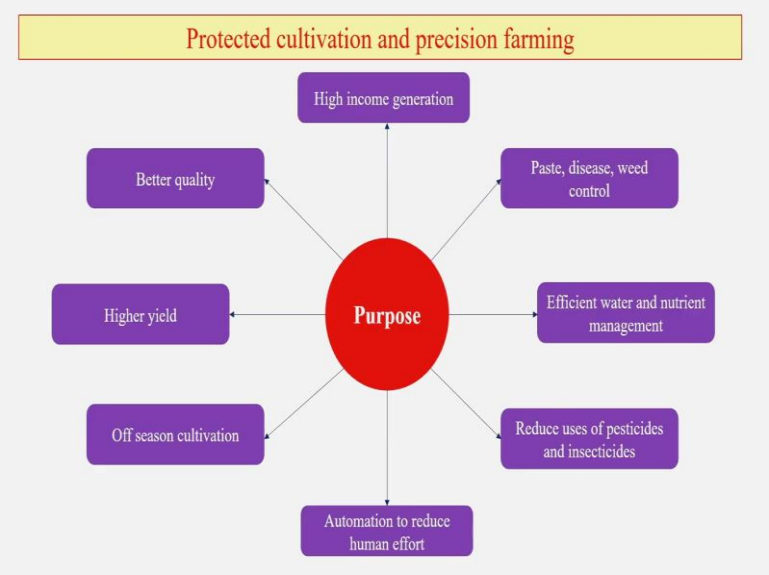

We also then discussed about about precision farming and protected cultivations which are very, very becoming popular in developed country as well as in our countries. So, we discussed about the various purposes of this kind of farming system.

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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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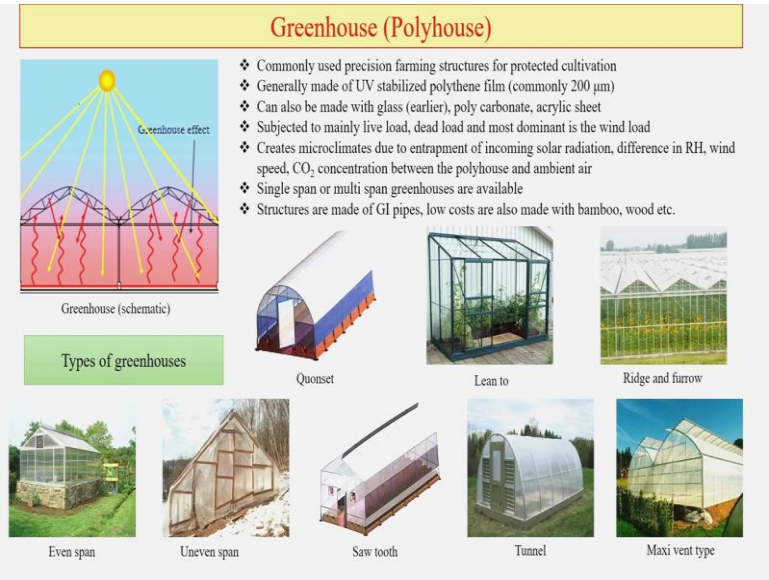

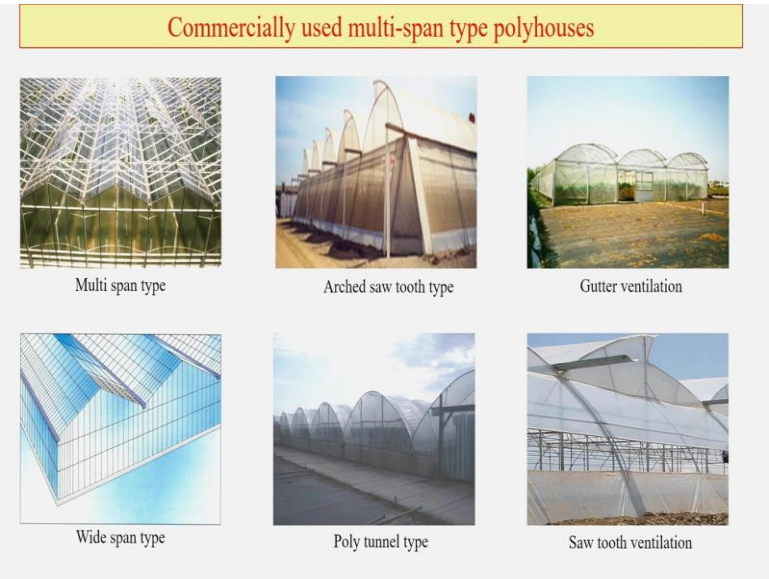

There are also some of the precision farming system which we have also discussed with the designs and engineering aspect.

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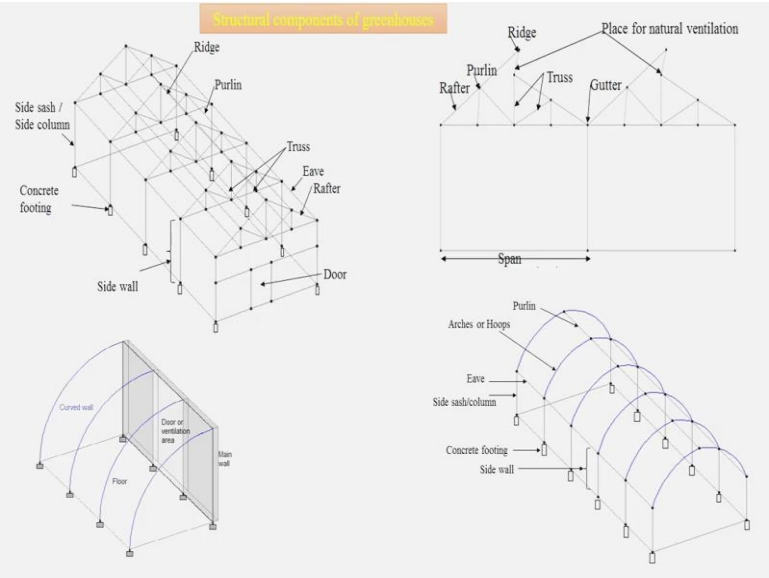

So, structural components of various greenhouses also, we have discussed.

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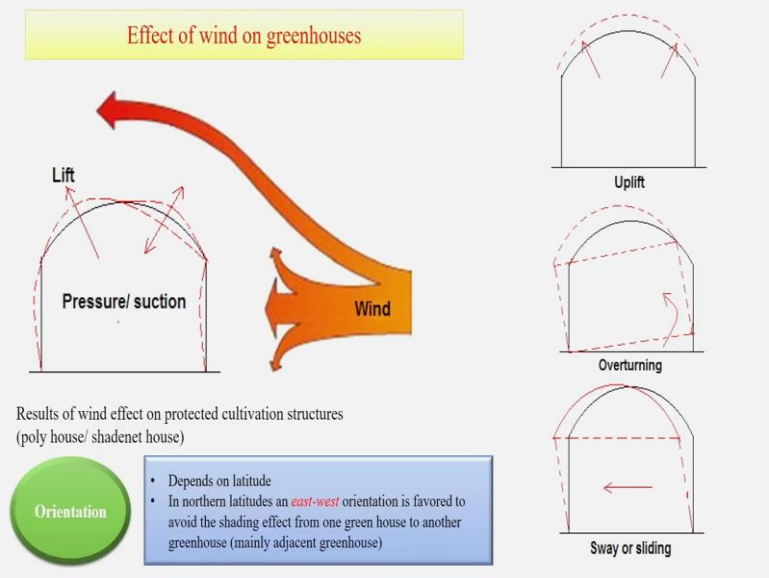

We discussed how wind can affect these structures and how you should modify the structures and made it such a way that your greenhouse will remain relatively stable.

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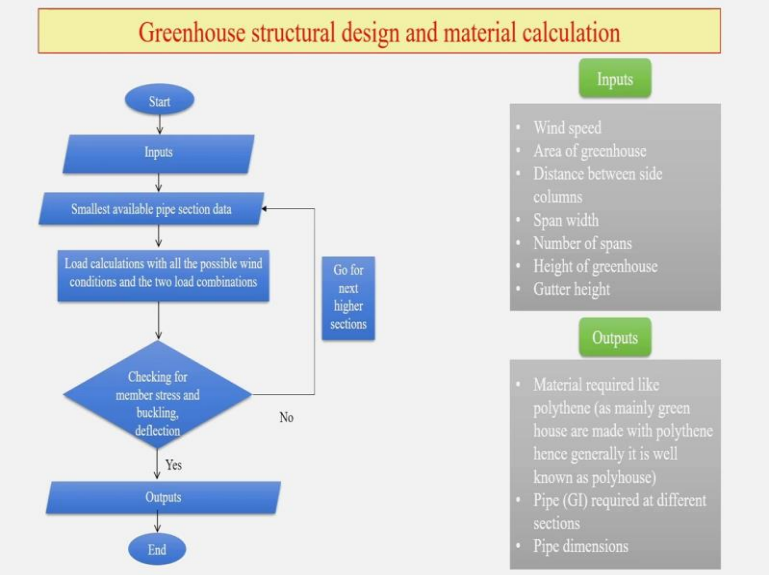

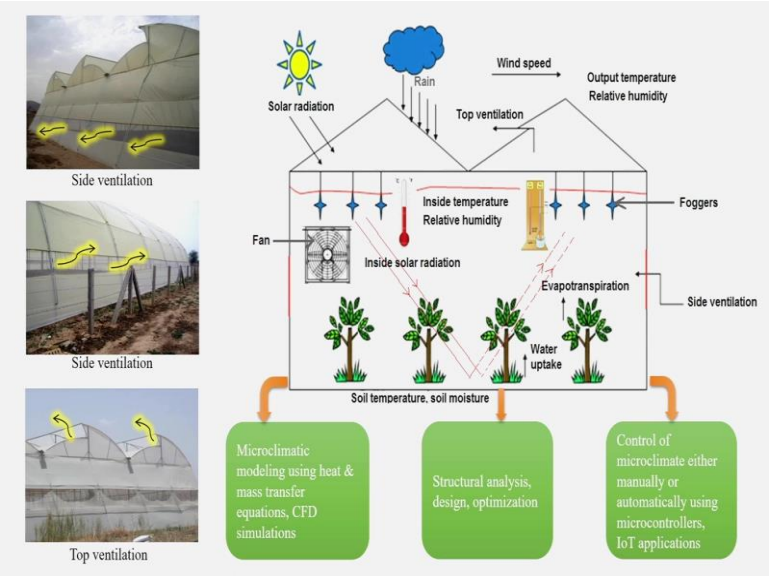

Then, we talked about various kinds of calculation of greenhouse efficiency and ventilation of air, maintaining humidity etc. So, these are the things also we have discussed.

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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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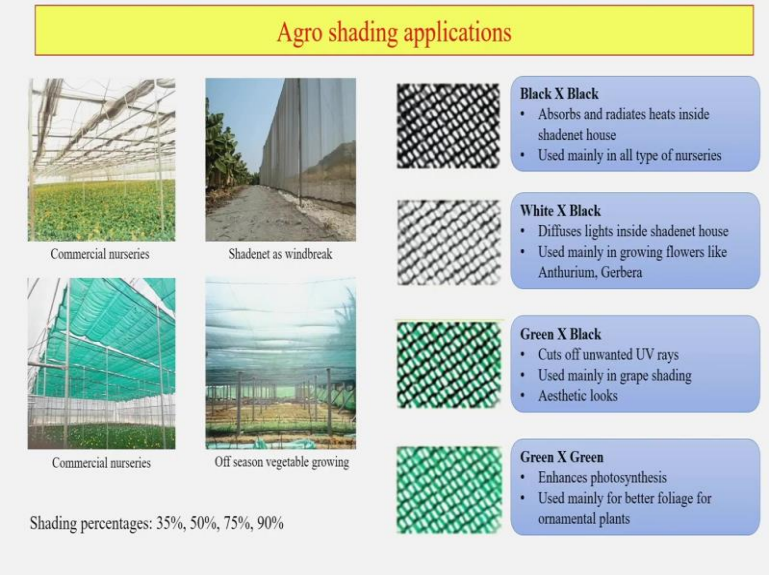

Agro shading applications also we have discussed and how different type of materials is actually used for this kind of agro shading.

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

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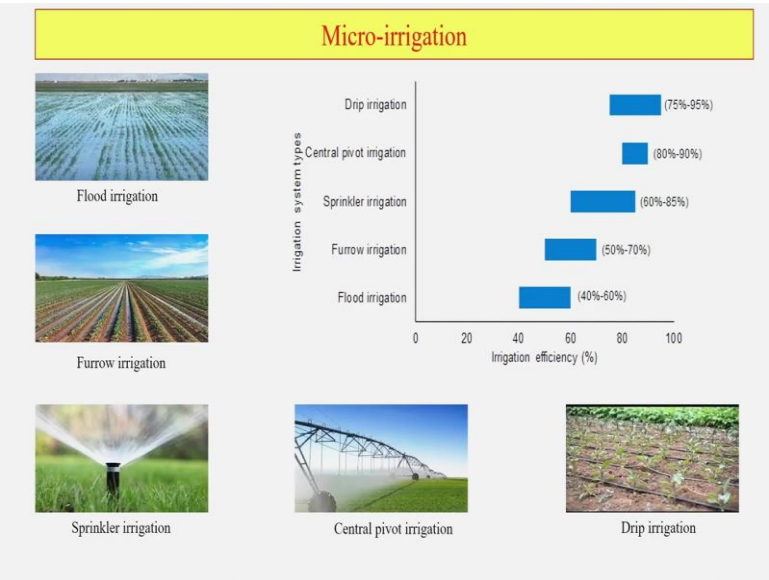
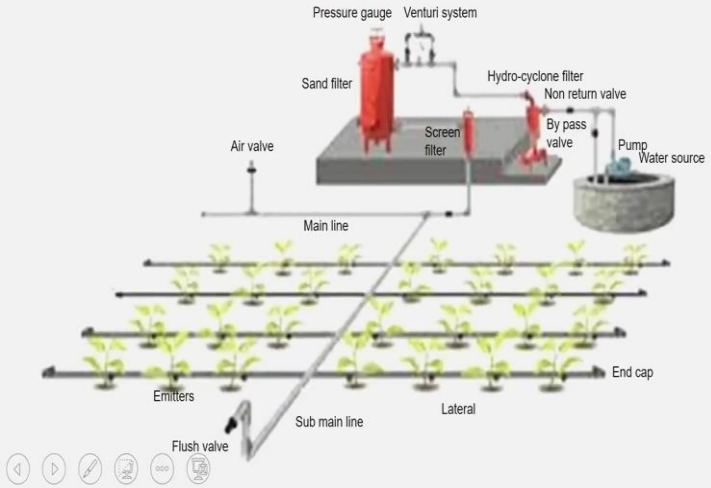


Drip system layout



On line emitters

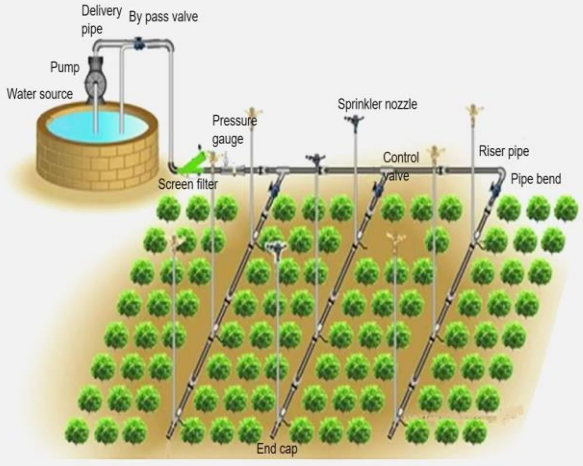
Bubblers

In line emitters

Low cost drip emitters using waste plastic bottles

Micro sprinklers

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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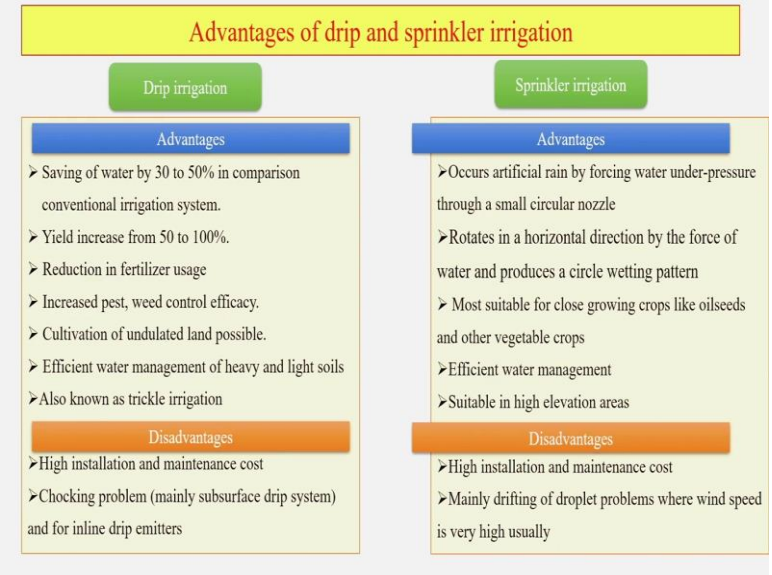

Advantage of drip irrigation and also sprinkler irrigation which are which one having better uses in which conditions there are disadvantages as well as advantages.

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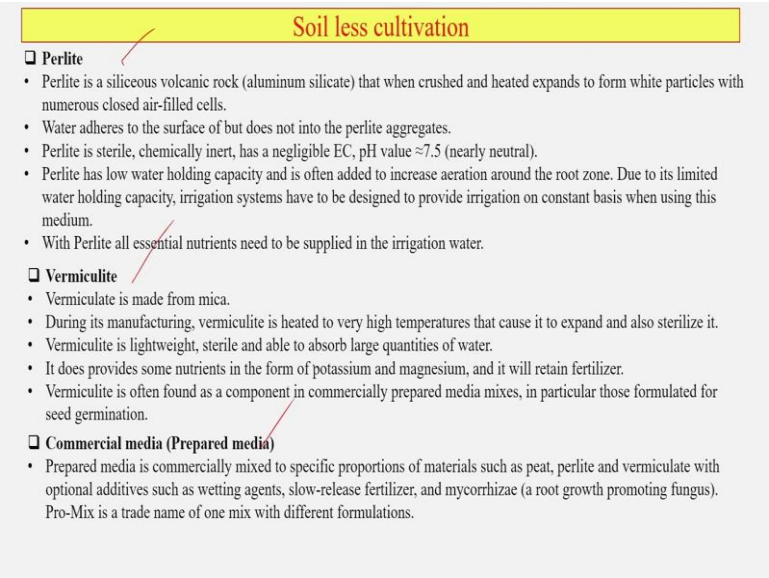

We also talked about soil less cultivation, which is becoming very popular these days, because soil also at some places especially, if you thinking about the urban areas, almost 35 to 40 percent of the urban areas are available on the building itself. So, different kind of thoughts are going on how these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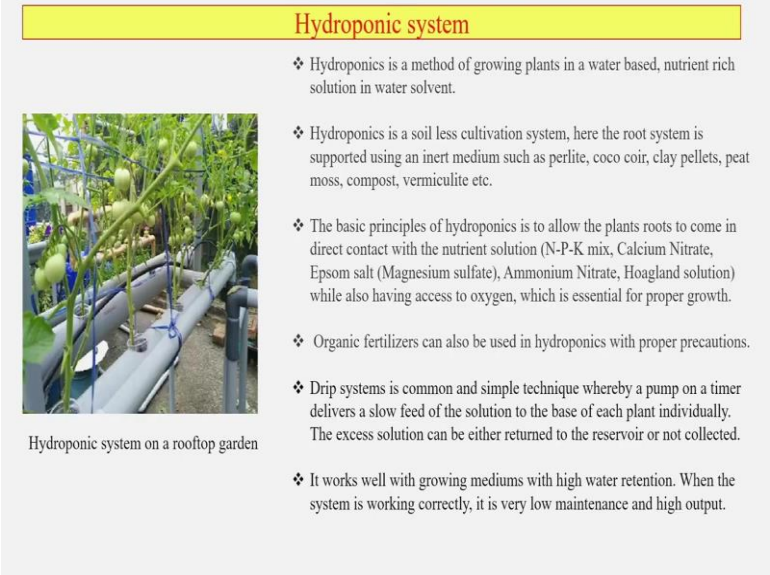

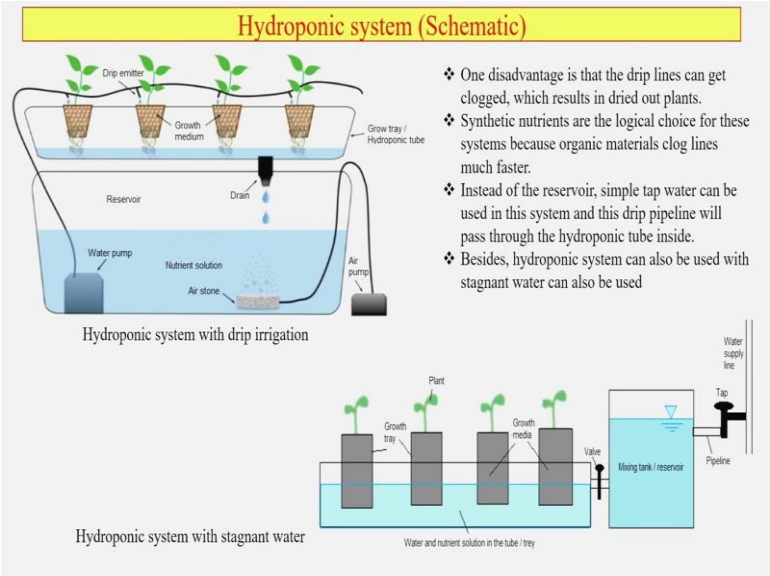

We also talked about hydroponic system and how it works, what are the different kinds of benefits limitations, how it should be built. So, a lot of I think topics and aspects has been discussed under this precision farming.

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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 form 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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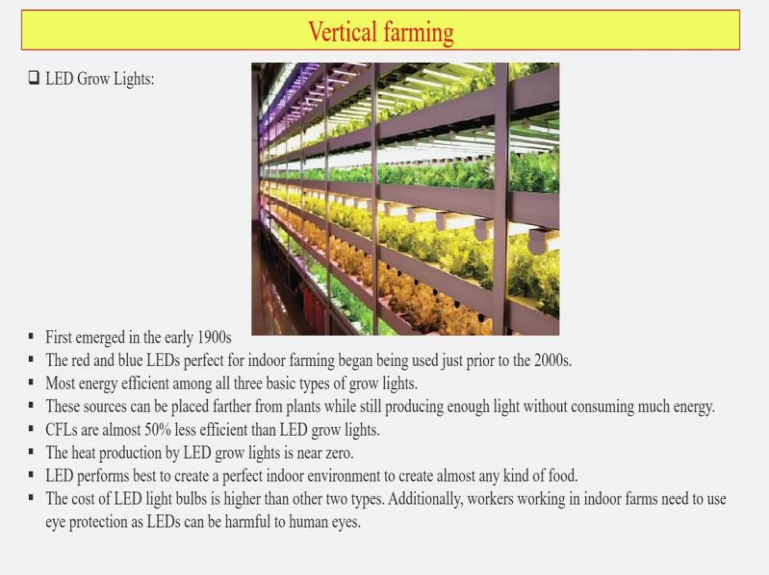

How it should be planned, what kind of plant.

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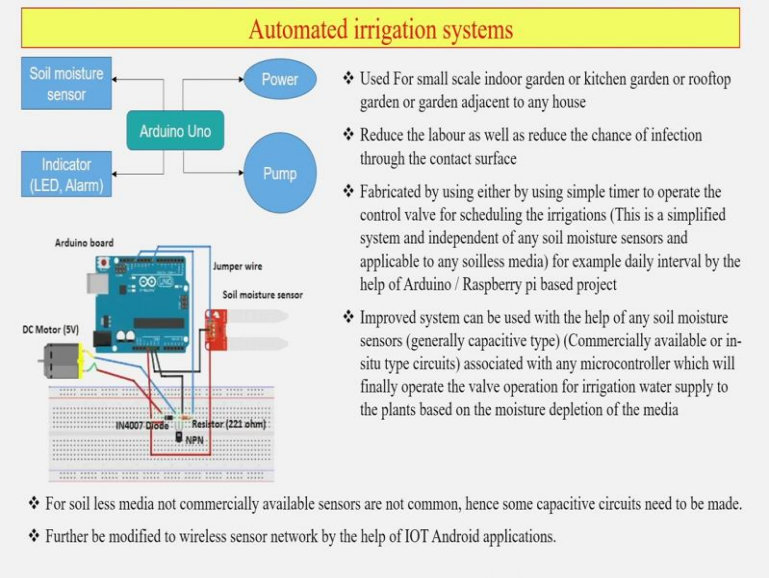

We then talked about automatic irrigation systems, because water resource has become a very scarce commodity at many places of the world. So, the option that left with us is that how we can actually maximize the utility of each drop of water. So, the concept of proper drop also has been discussed. We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

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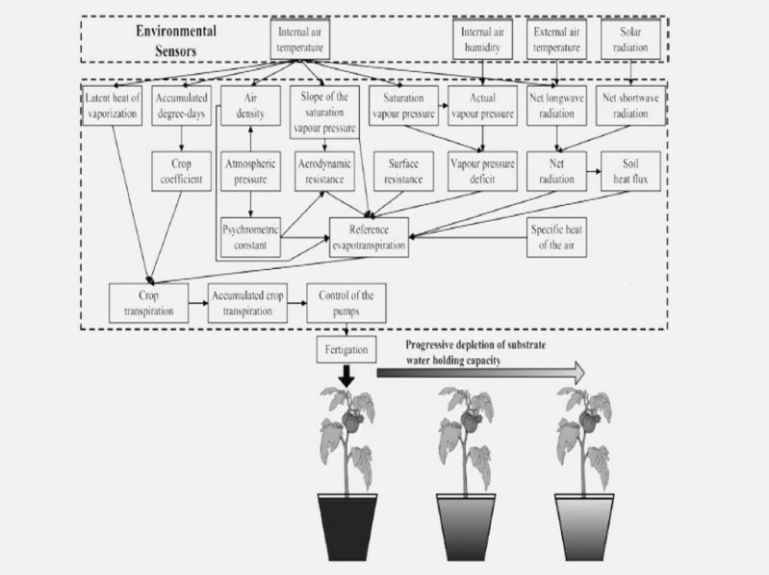

Different kind of sensors, how it can be used.

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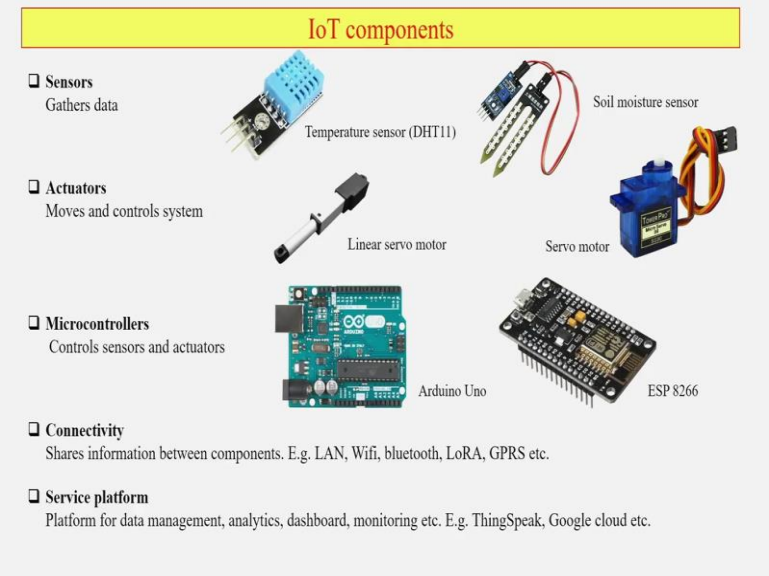

Then, we talked about IoT components, which are the components how it can be used for water management.

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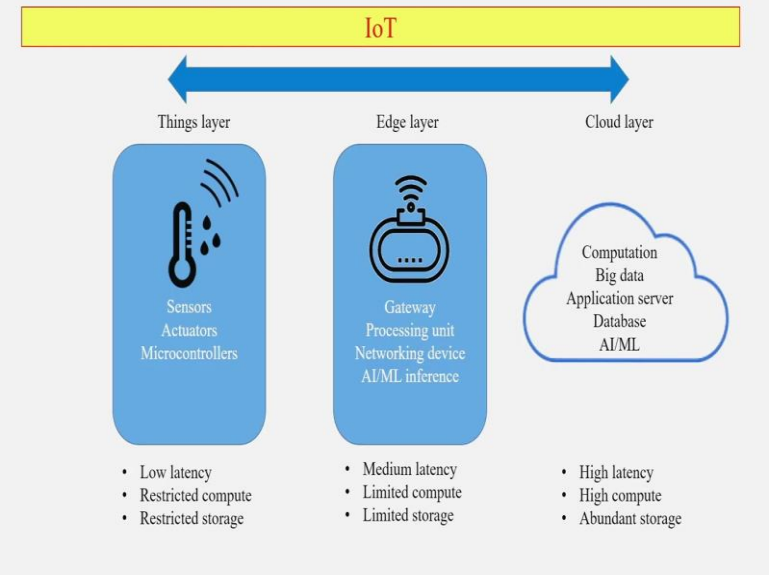

In fact, if you recall that in the lectures, we also discussed about that how IoT can be utilized for different kind of land preparations and various other farming practices.

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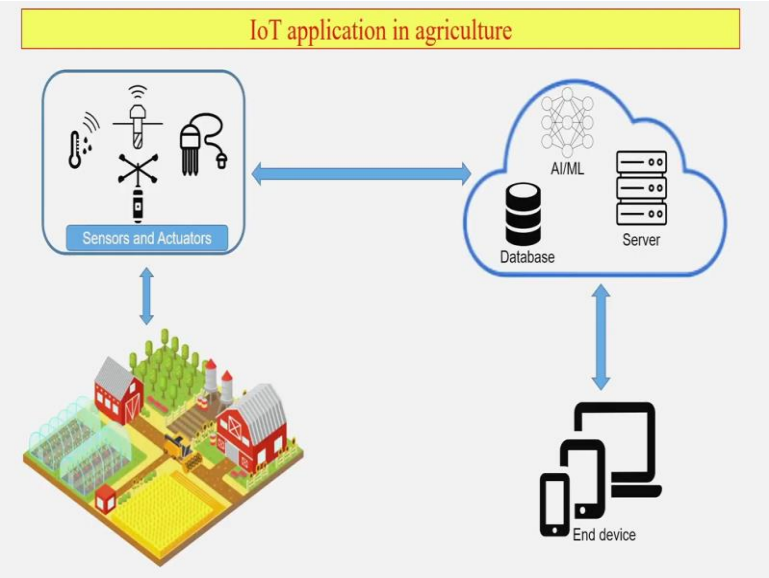

So, each application in agriculture is quite huge. And again, we have also discussed this particular aspect in great detail in some other forum.

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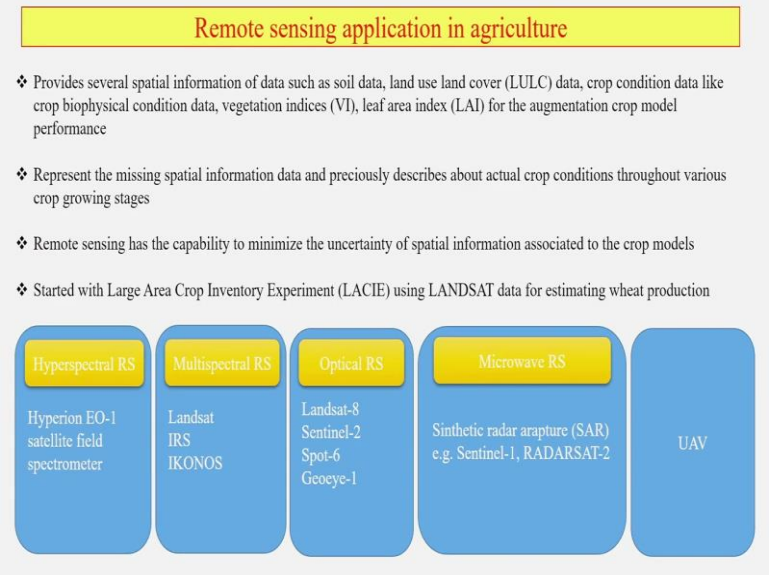

So, application of remote sensing in agriculture is a very well talked subject. And if you recall that we handled this particular topic in a separate lecture also discussing about various aspects of remote sensing and its application.

(Refer Slide Time: 16:56)

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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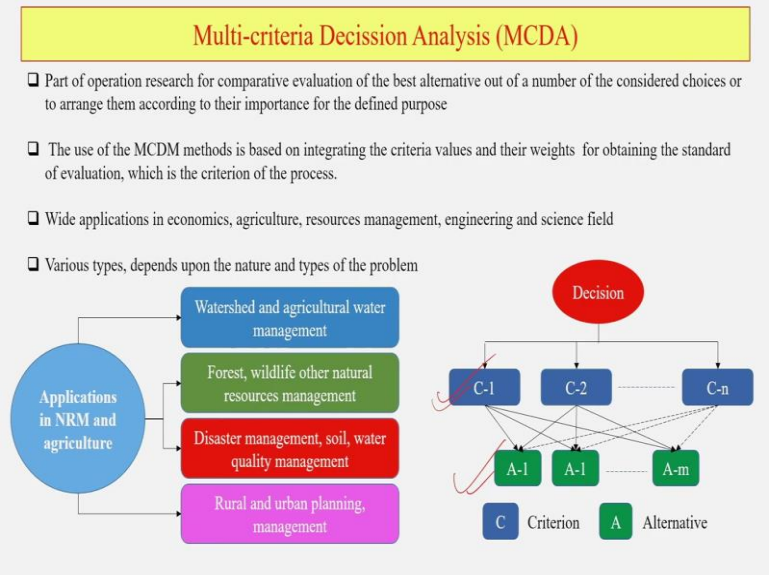

We talked about that how criteria versus alternatives you can choose the best alternatives for whatever particular criteria.

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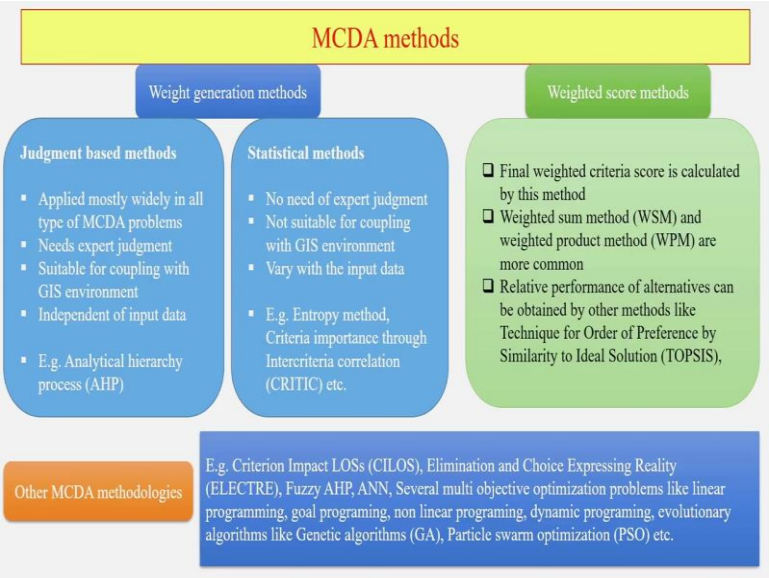

And there are various MCDA methods, we discussed about those things in great detail.

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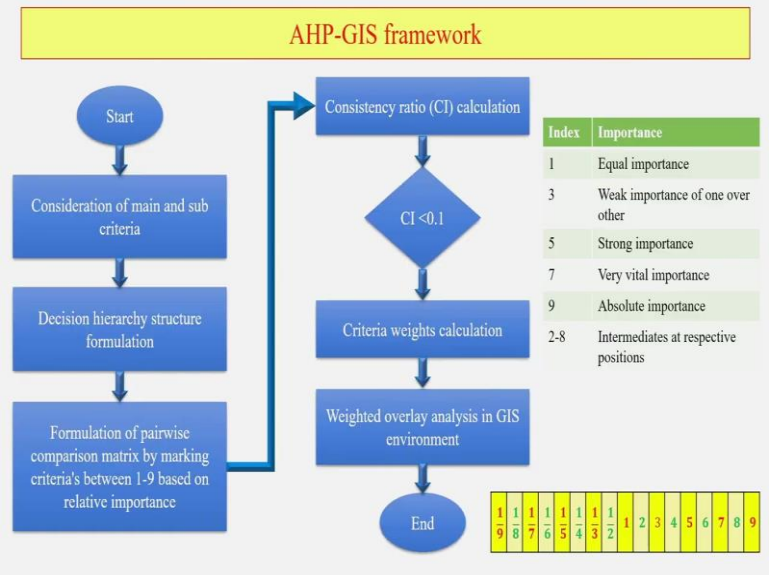

And then one by one every MCDA method, we discussed like analytical hierarchy process AHP, how it works.

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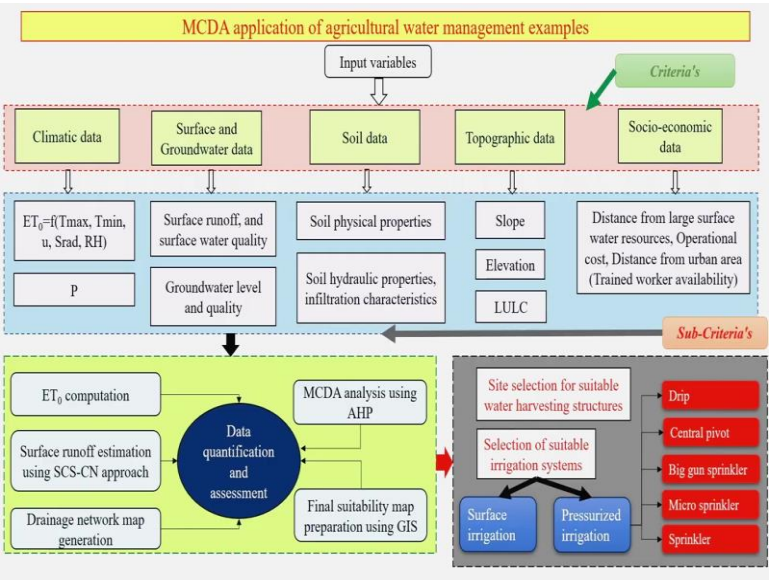

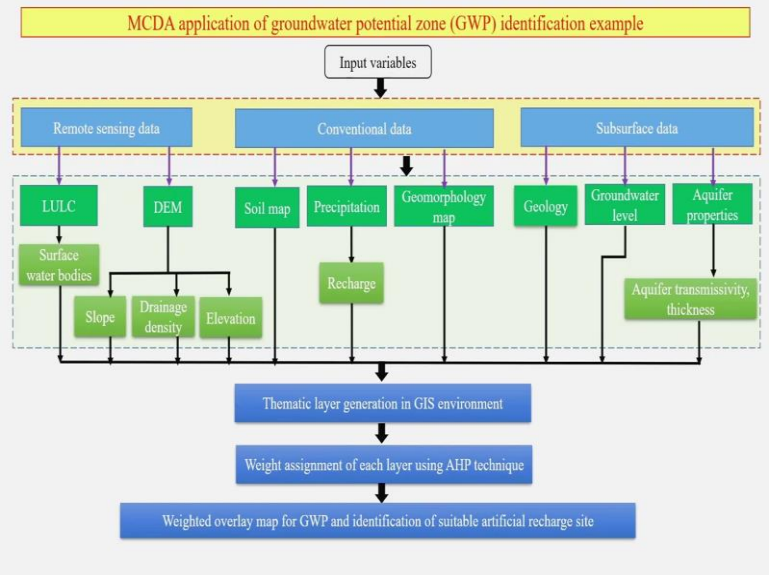

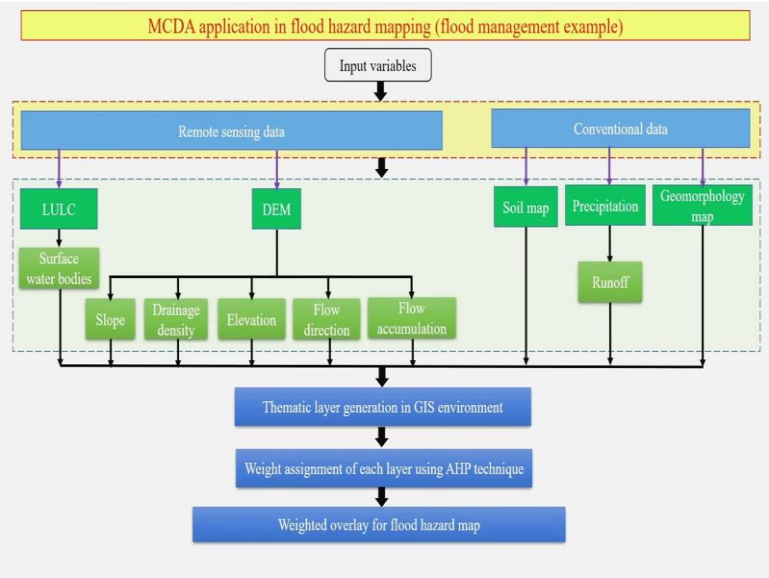

Then, we talked about how it can be used for potential water management, groundwater management, flood hazard mapping also.

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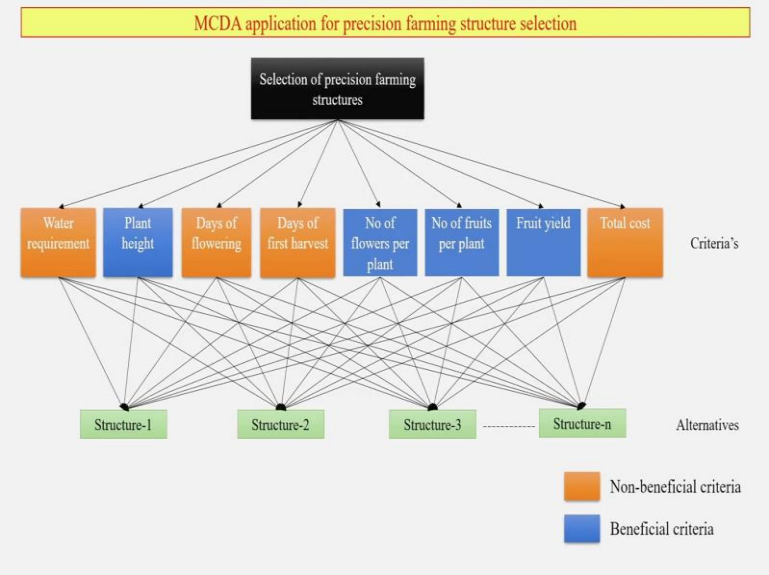

Then application of MCDA in precision farming structure selection is also in very high demand, where you can actually identify or find out the optimum solution for your purpose.

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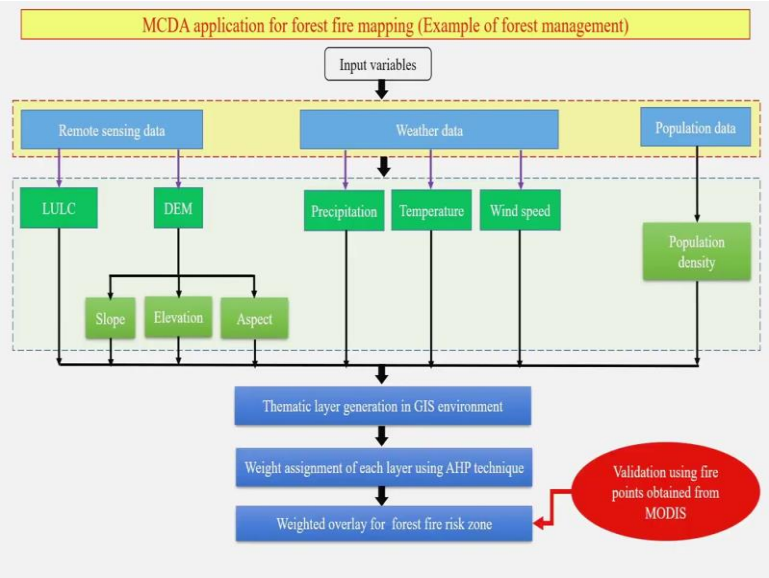


Forest fire mapping even that also we discussed how MCDA can help, I hope that all of you have gone through these slides very carefully, you need to give some time and that is the precise reason that today's this revision exercise I am carrying out for the benefit of all of you.

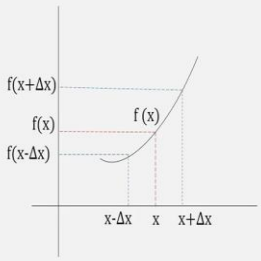
So, this was the part under precision farming and MCDA; introduction of various modeling system how it works.

(Refer Slide Time: 18:47)

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/s^2 (Constant) and V = 5m/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	$\frac{\partial H_f}{\partial K_e}$	$L\frac{V^2}{2g}$	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.

(Refer Slide Time: 19:15)

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 $x_1, x_2, \ldots\ldots, x_n$ and individual uncertainties of each are given as $u_{x_1}, u_{x_2}, \ldots\ldots, u_{x_n}$ then overall uncertainties in the model U_F is expressed as

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

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

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

Model uncertainty analysis also, we have discussed.

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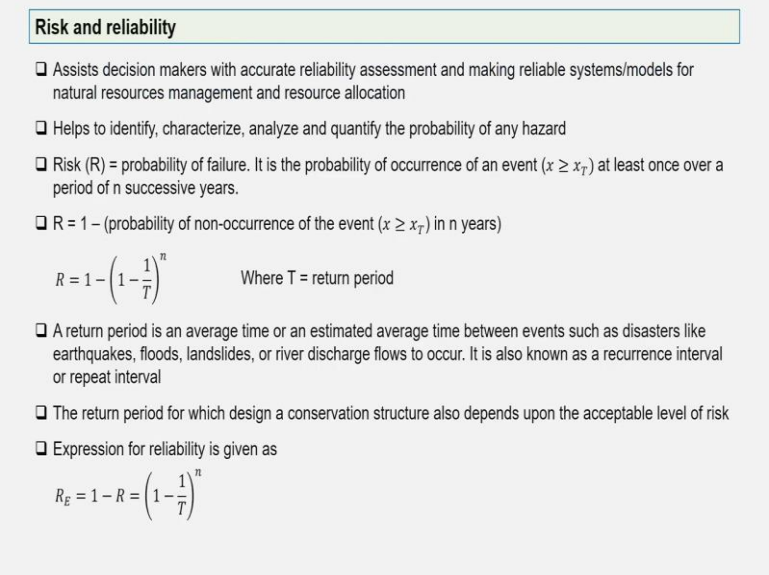

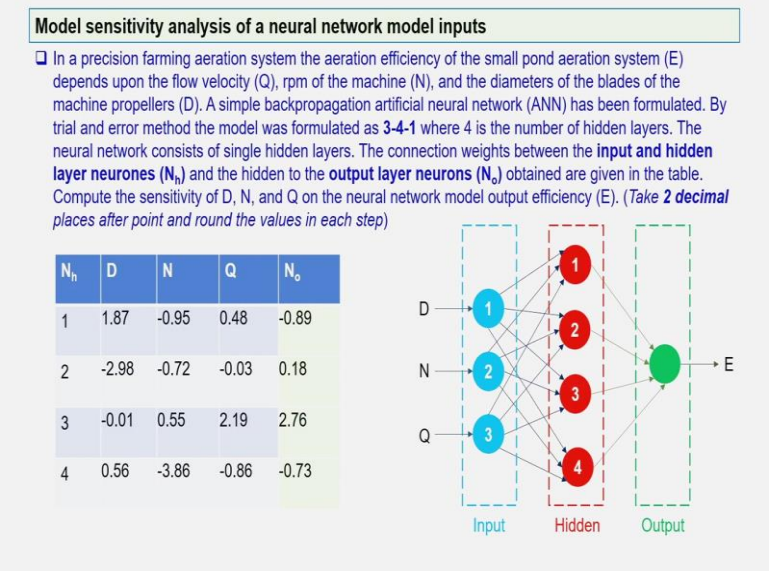

Risk and reliability, how you can actually measure that. Model sensitivity analysis utilizing neural network, what are the inputs, what are the outputs these all we have discussed in the previous lectures. Then we go next topic after the sensitivity analysis one that is your MCDM part one.

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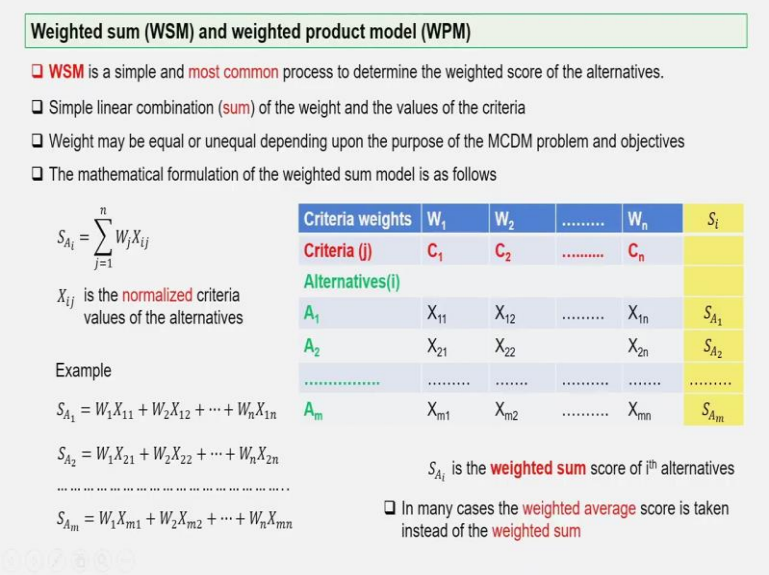

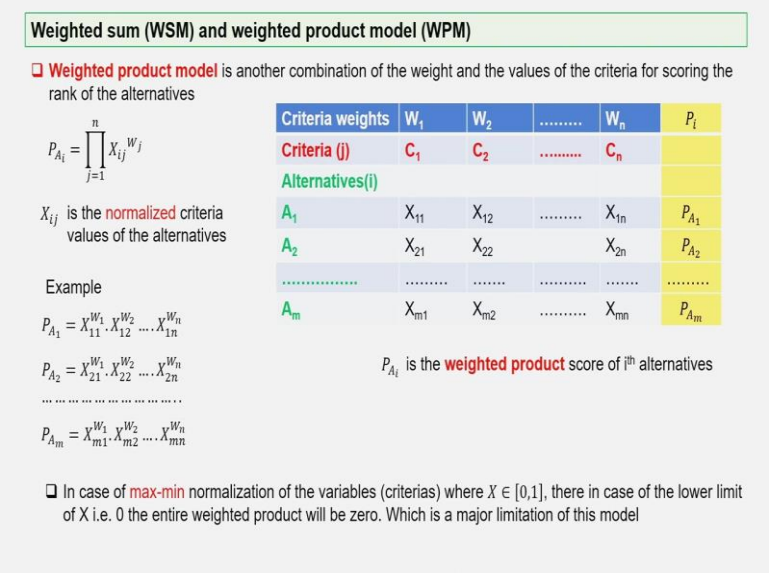

Here, if you recall that we have discussed in various aspects of MCDA with a real example, and how different methods of MCDA calculate the weightage and on that basis how we actually carry out the ranking and then you choose the top most the best one as your option. So, we discussed about WSM, weighted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

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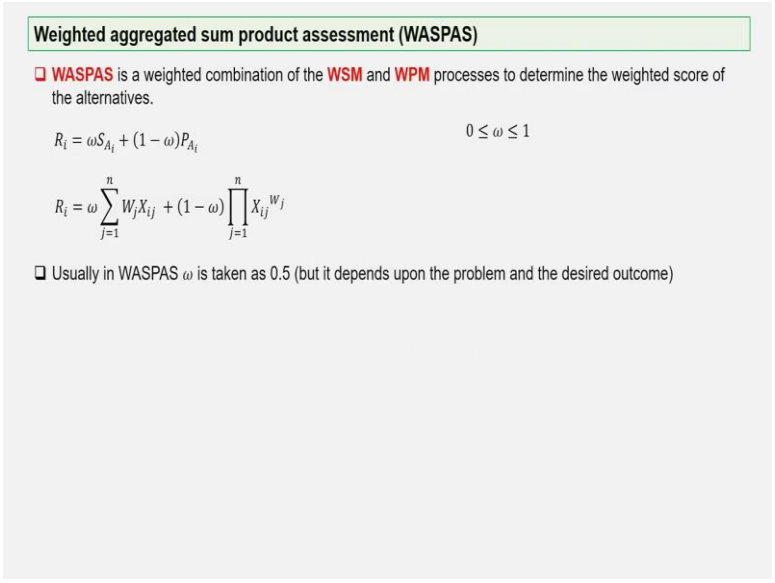

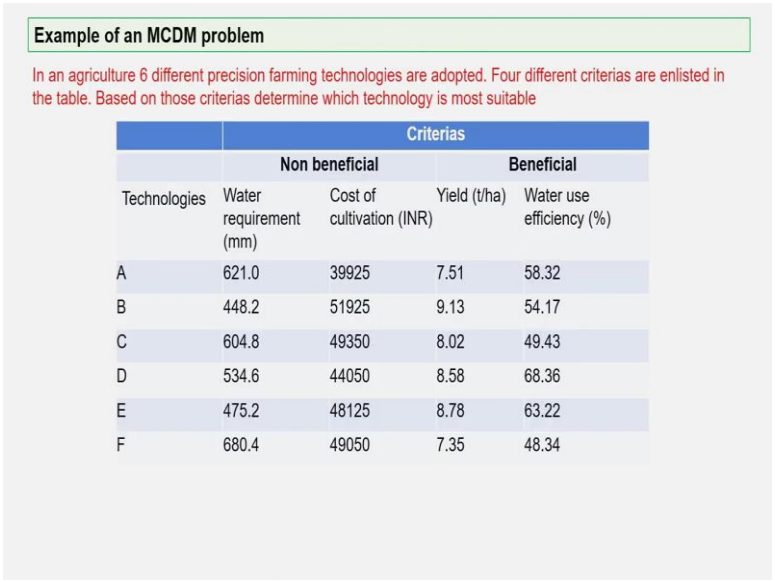

Then we discussed about WASPAS and each one we have discussed if you recall with appropriate example.

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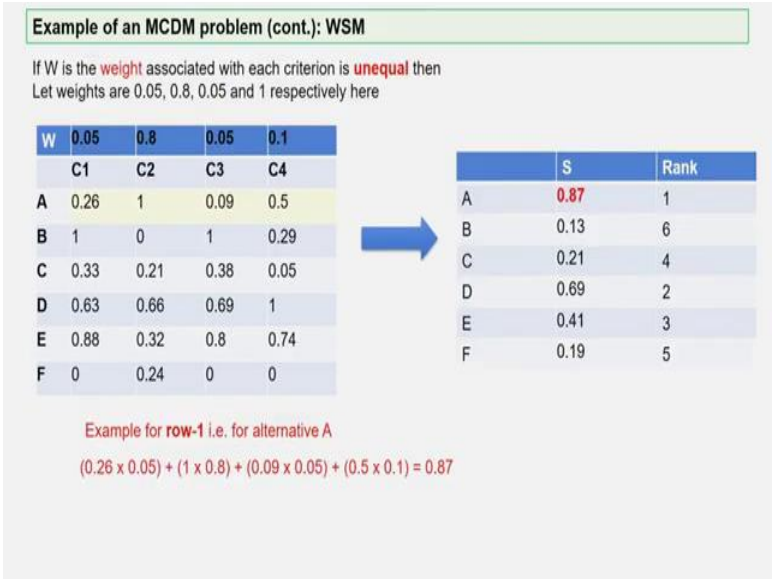

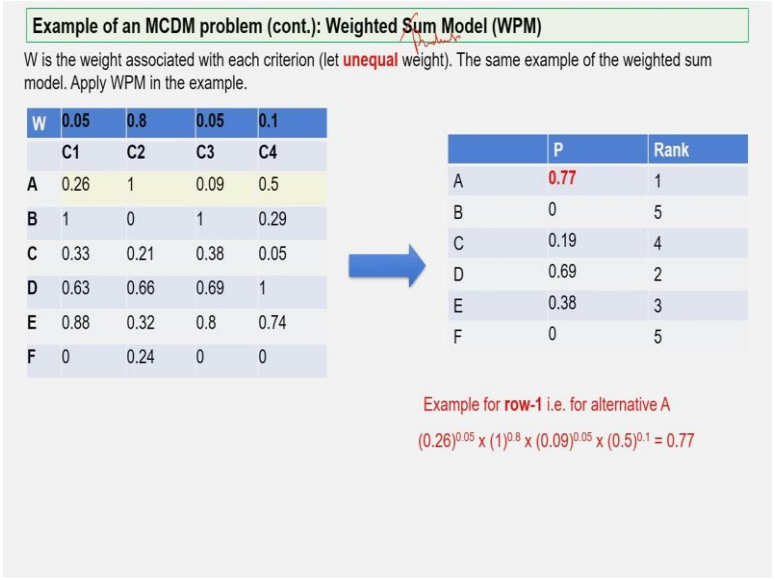

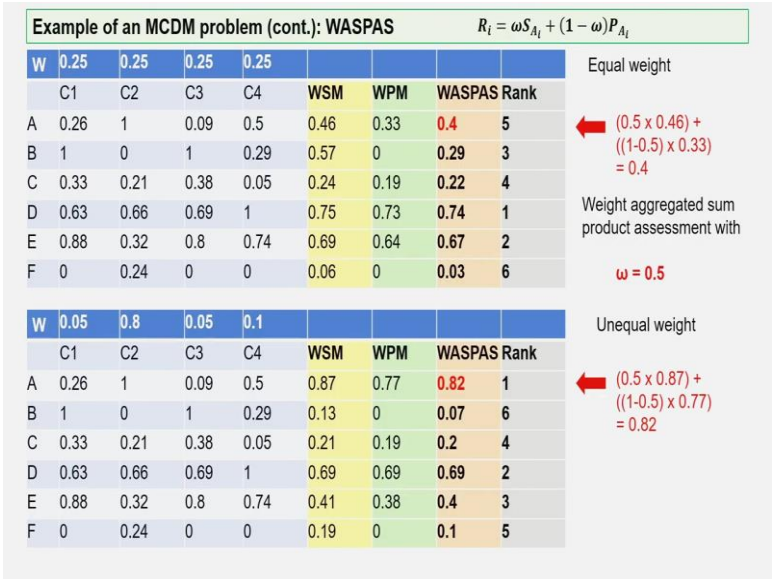

Then we discussed about also WSM weighted sum model, then weighted product model. So, weighted product model is actually you multiply; weighted sum model you add. So, these are the aspects that we discussed under MCDM, part one and then in the lecture MCDA part 2.

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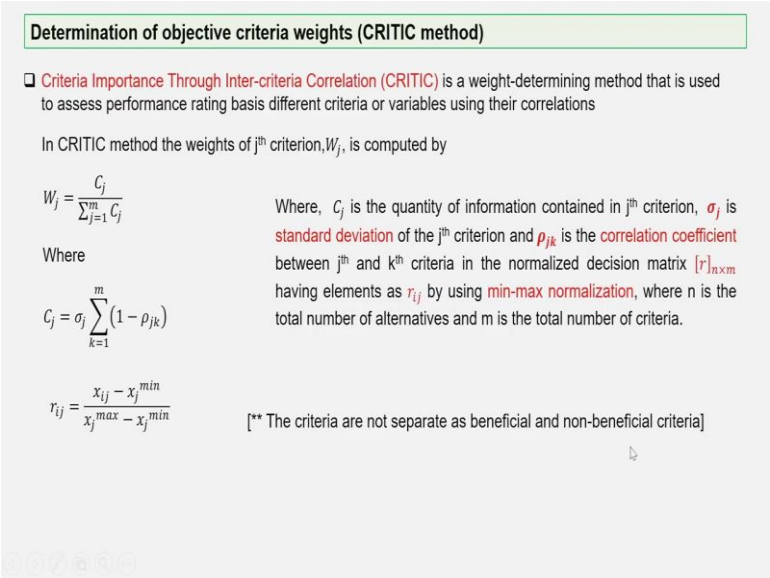

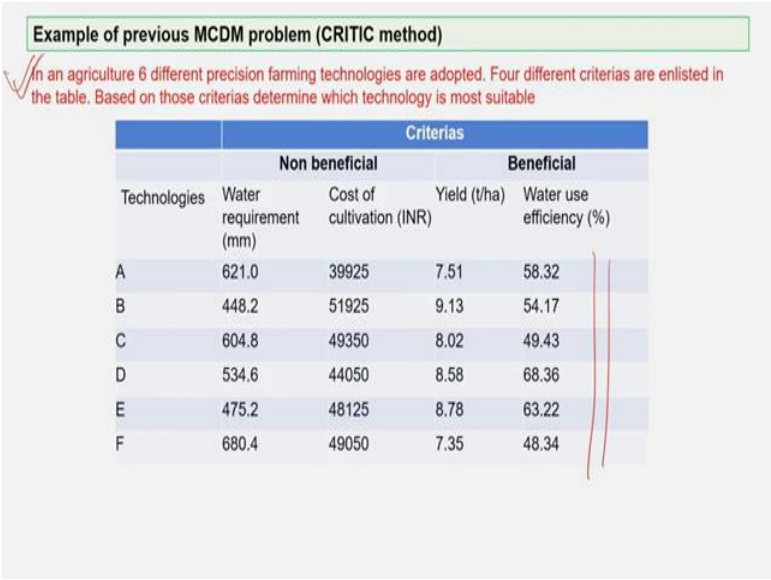

	Criterias			
	Non beneficial		Beneficial	
Technologies	Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

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.

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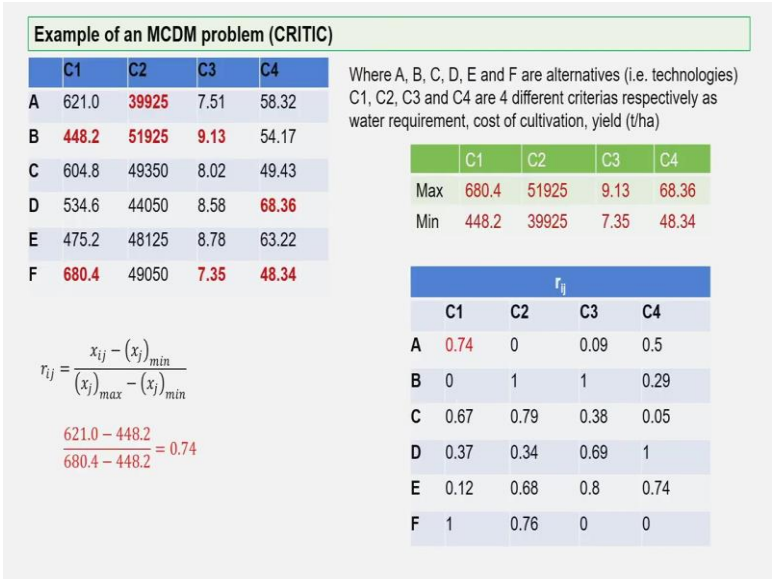
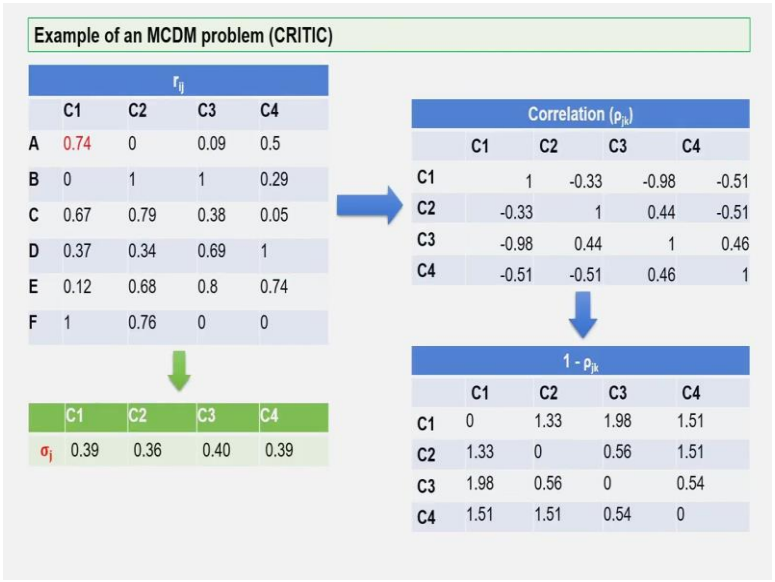


	C1	C2	C3	C4
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

	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



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)

- Commonly used weight determining method that measures value dispersion in decision-making
- Higher dispersion degree means greater weight and more information by the criteria

The entropy E_j for j=1, 2, ..., m for each criterion is calculated by

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}.\ln p_{ij}$$

Where, $0 \le E_j \le 1$; p_{ij} is the normalized value of j^{th} criterion for the i^{th} alternative which is given by sum-reciprocal normalization.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$$

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

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

$$d_j = 1 - E_j$$

After critic methods then entropy method.

(Refer Slide Time: 21:17)

Determination of objective criteria weights (Entropy method)

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

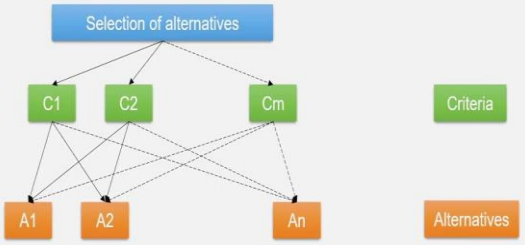
$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

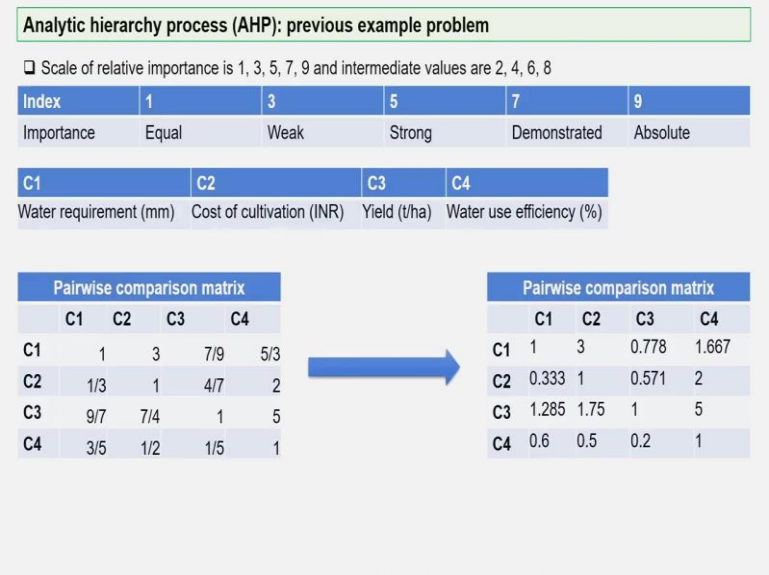
Example of previous MCDM problem (Entropy method)

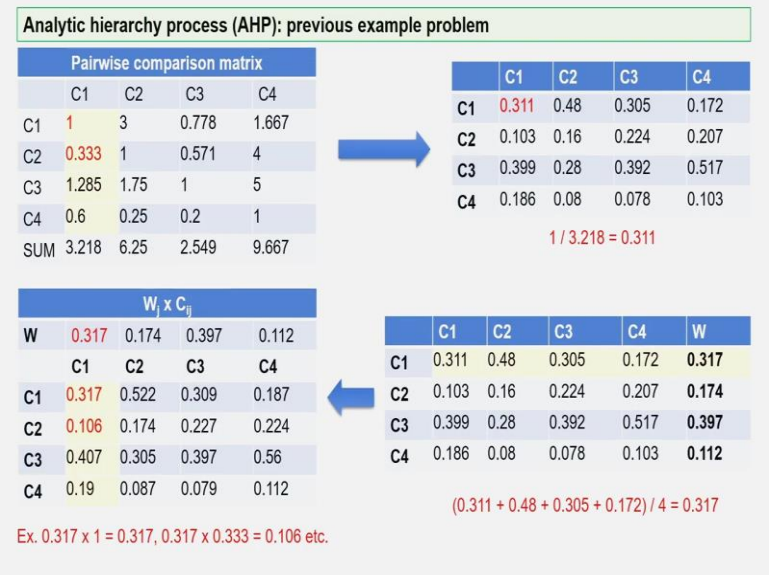
	Criterias			
	Non beneficial		Beneficial	
Technologies	Water requirement (mm)	Cost of cultivation (INR)	Yield (t/ha)	Water use efficiency (%)
A	621.0	39925	7.51	58.32
B	448.2	51925	9.13	54.17
C	604.8	49350	8.02	49.43
D	534.6	44050	8.58	68.36
E	475.2	48125	8.78	63.22
F	680.4	49050	7.35	48.34

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







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

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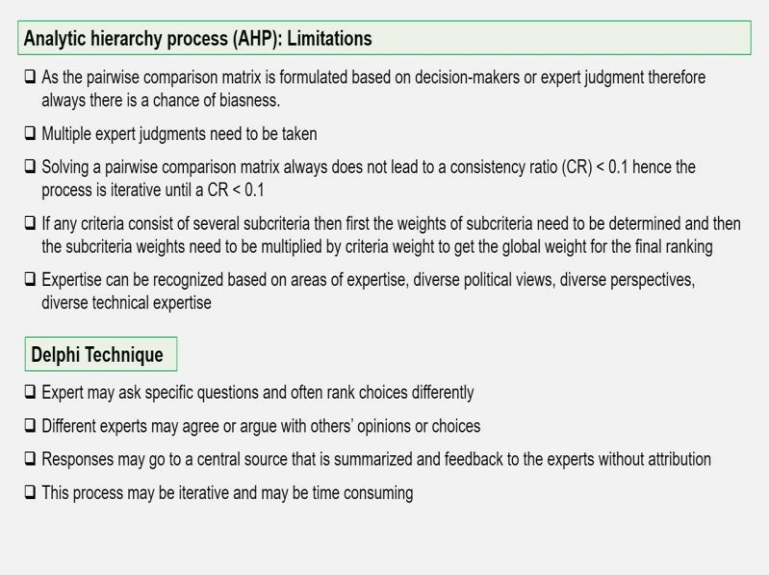

Then we talked about the limitation of AHP, though AHP is very popular. Then Delphi technique, Delphi technique is again one of the very important tools or techniques for data collections.

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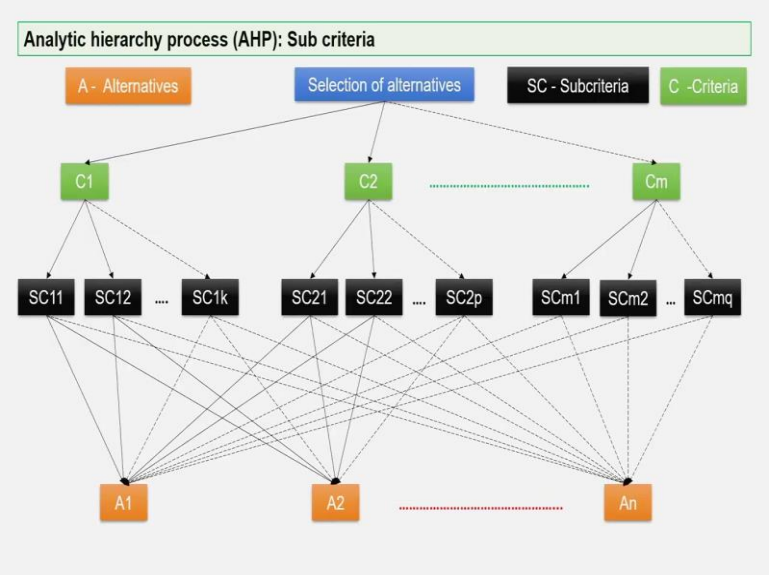


Analytic hierarchy process (AHP): Sub criteria

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

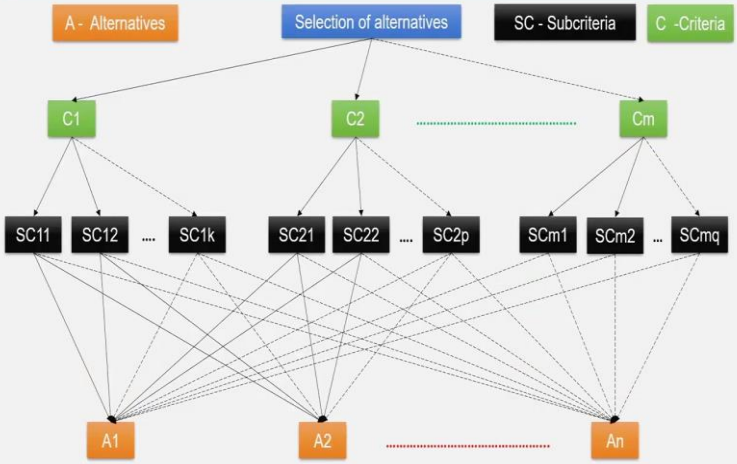
	SC11	SC12		SC1k
SC11				
SC12				
.....				
SC1n				
W_{SC1}	W_{SC11}	W_{SC12}	.....	W_{SC1k}

	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}

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

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

	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}

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

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.

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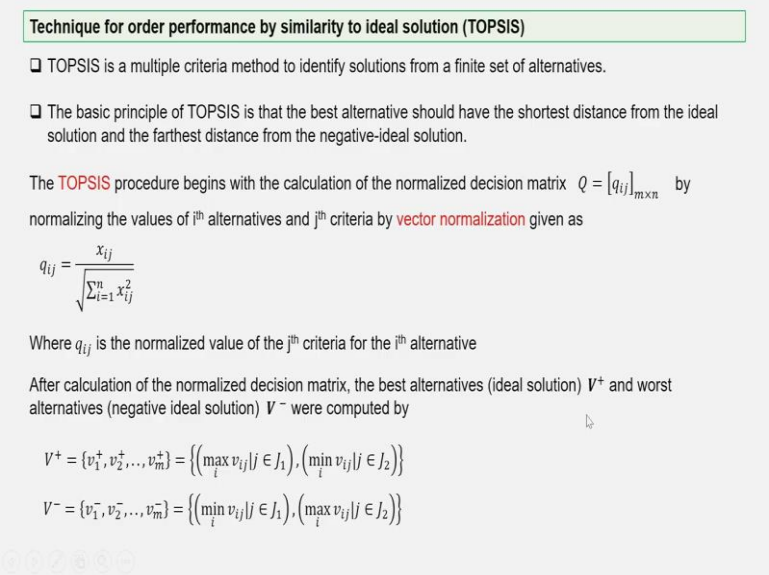

And then we went finally, the last part of MCDM that was to talk about few other methods like TOPSIS, how TOPSIS actually can be be calculated and ranking can be made.

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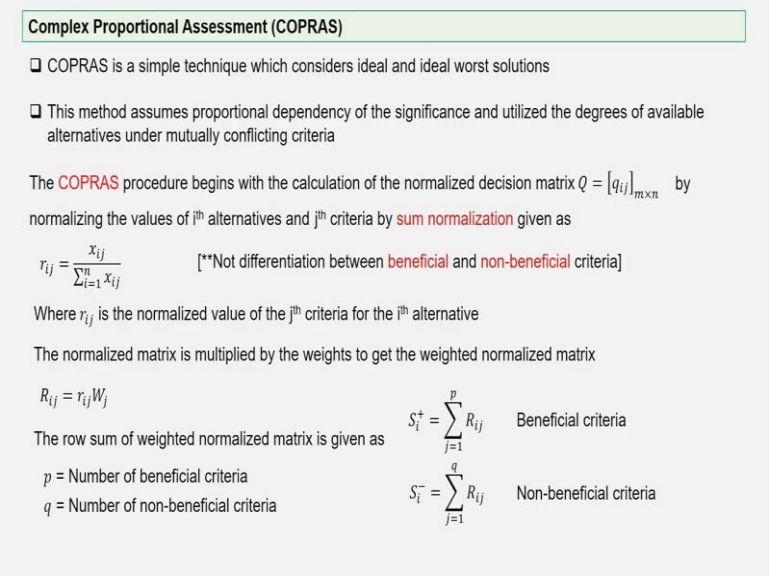

Then COPRAS we also discussed with same example, like others.

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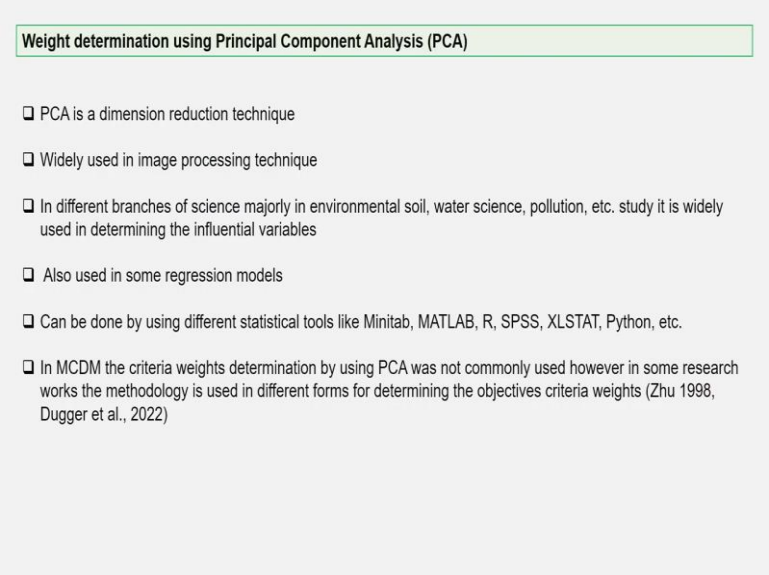

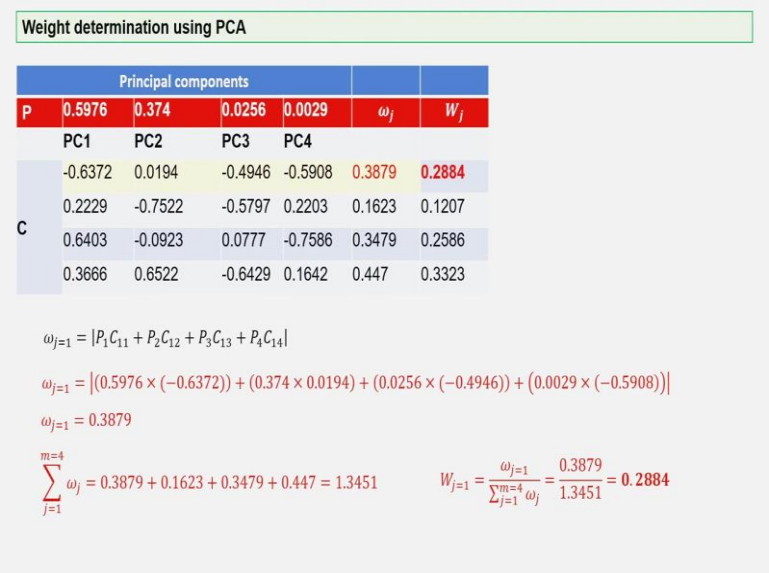

Then principal component analysis many of you might be already using it. So, how principal PCA can be also used for better ranking. So, in a sense that we discussed the MCDA, which is a very important tools or techniques for ranking, finding ranking of your alternatives, so, that you can take a decision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

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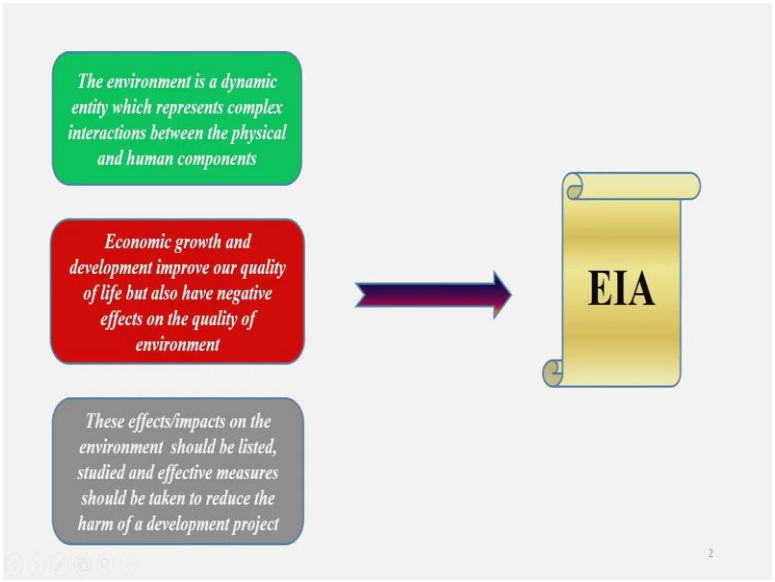


Then, if you recall that we have discussed in great detail about environment impact assessment. Because this is one technique, which helps you to understand the environment better and environment has direct link with natural resources.

(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.

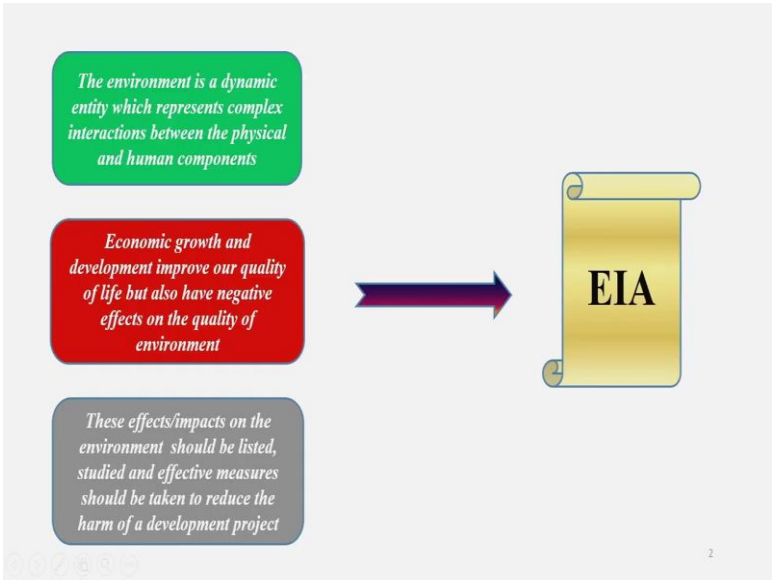
The purpose of the assessment is to ensure that decision makers consider the environmental impacts when deciding whether or not to proceed with a project.

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.

Contd.. 5

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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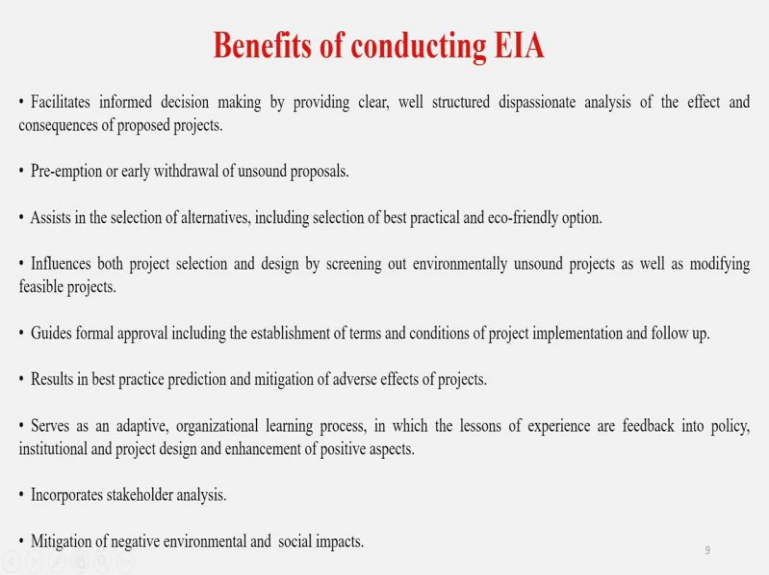

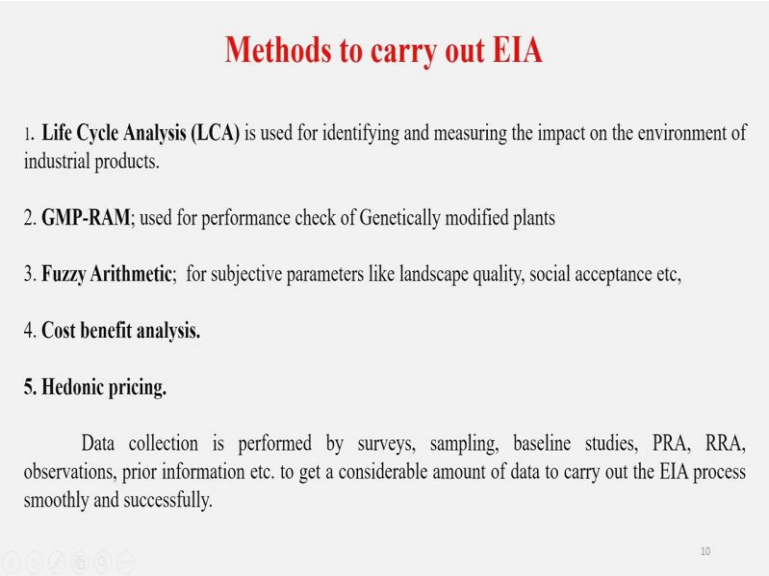

Then we went into benefits of conducting EIA then the methods. So, we took actually quite significant amount of time to discuss about the methods of EIA.

(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.

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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 likew: 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, pathogenicty 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 × Magnitude) to generate a matrix which will give the general impact value.

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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)

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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:

Biotechnology Range × Extent = Significance Index$_{Gen}$

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

Σ (Total Weight of Field A; B; C; D; E) / Number of Fields Analyzed = Magnitude Index (General Impact Index)

Σ (Total Weight of Field F;G; H; I; J; K; L) / Number of Fields Analyzed = Magnitude Index (Technological Impact Index)

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.

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.

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 $index_{tech}$

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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

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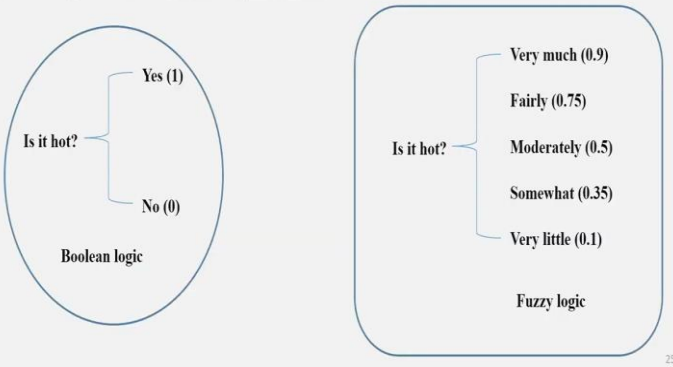
And there we discussed various methods like LCA and then GMP-RAM method, each one of them we have discussed if you recall with certain example.

(Refer Slide Time: 23:54)

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.



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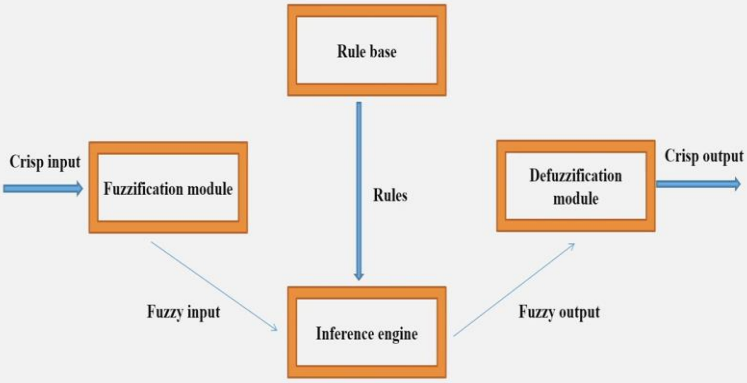
3. Fuzzy logic process

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.



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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

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And then fuzzy arithmetic process, fuzzy logic process.

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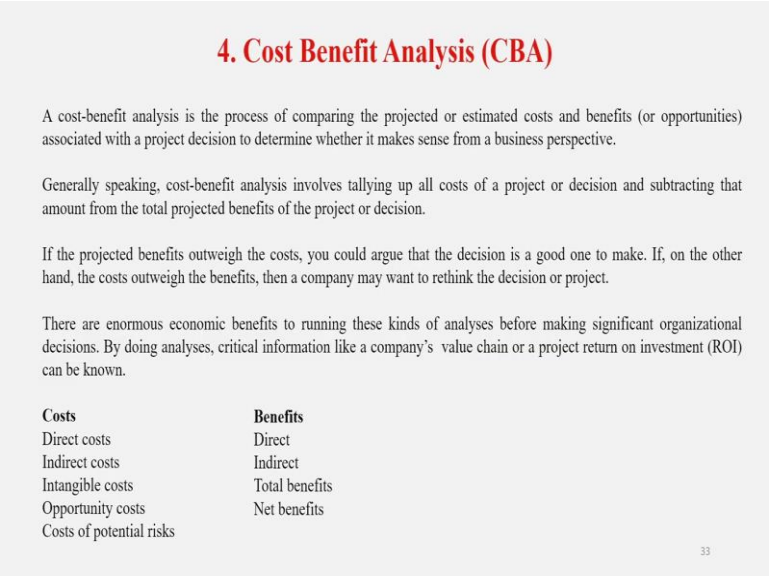

CBA, another very important aspect that we have discussed. So, please go through it with little bit of care because these aspects would be vvery helpful when you actually work in the field, whether into academics or in professions.

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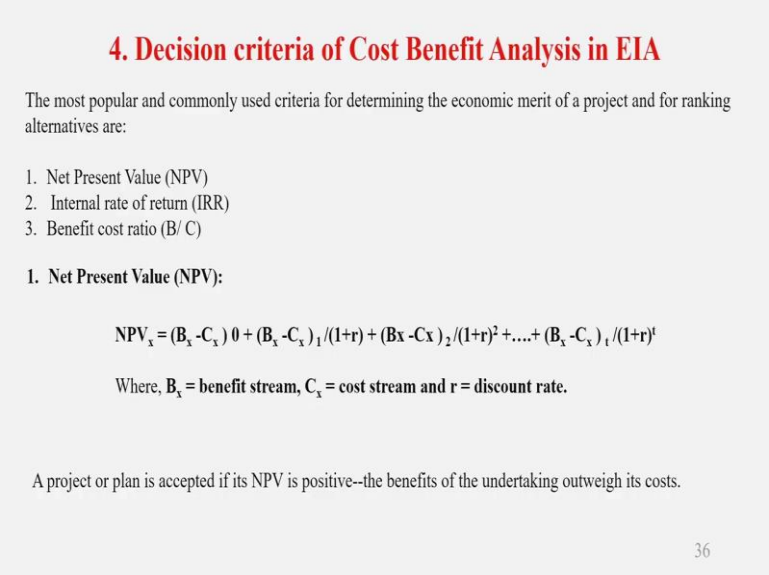

4. Decision criteria of Cost Benefit Analysis in EIA

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.

$$NPV_x = (B_x - C_x)\,0 + (B_x - C_x)_1/(1+r) + (Bx - Cx)_2/(1+r)^2 + \ldots + (B_x - C_x)_t/(1+r)^t = 0$$

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.

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So, CBA also we have discussed with some example.

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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.

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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.

5. Hedonic regression analysis

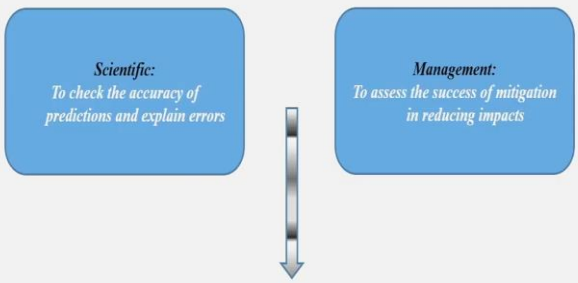
The hedonic regression function illustrates the relationship between the price of the asset (being the dependent variable) and the components/characteristics of the asset (being the independent or explanatory variables) as:

$$pi = j\,(ci)$$

Where:
p is the price of a variety *i* of a good
ci 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.

EIA considerations..



Sustainable Development

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.

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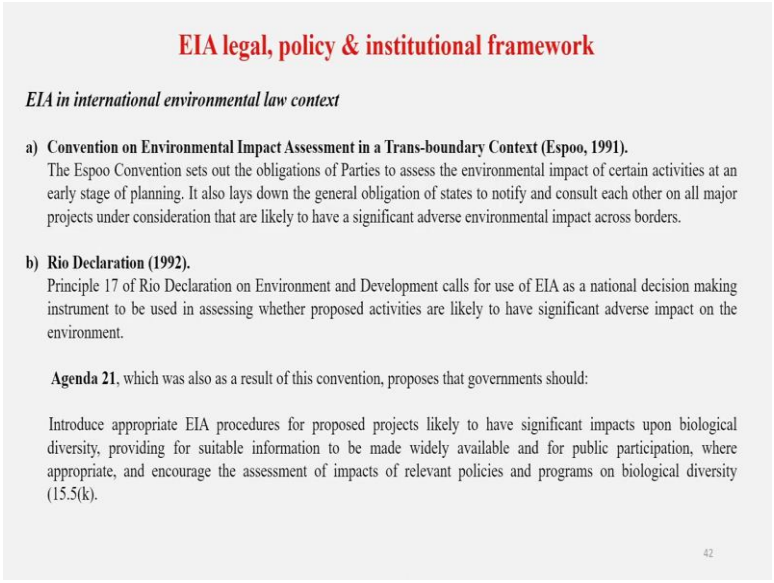

Legal and institutional framework, how EIA plays an important role into that because environment ultimately goes into some legal system. We have environmental law also. We discussed about also different rules, laws and tribunals.

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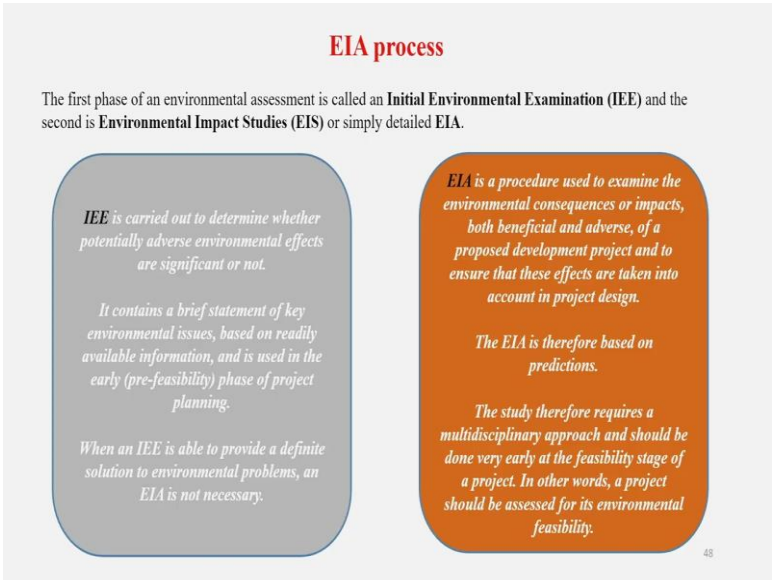

And how the process of EIA actually is carried out.

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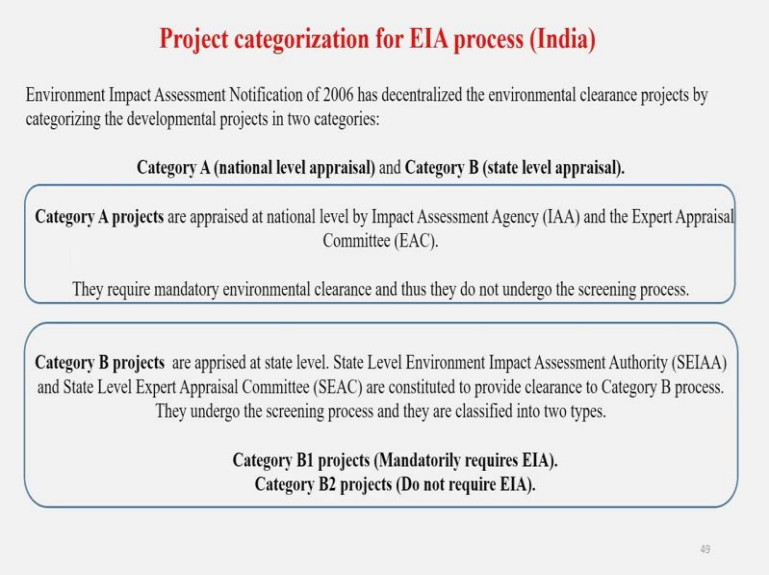

So, in India, we have given some example to you and explain that how EIA process takes place in our country.

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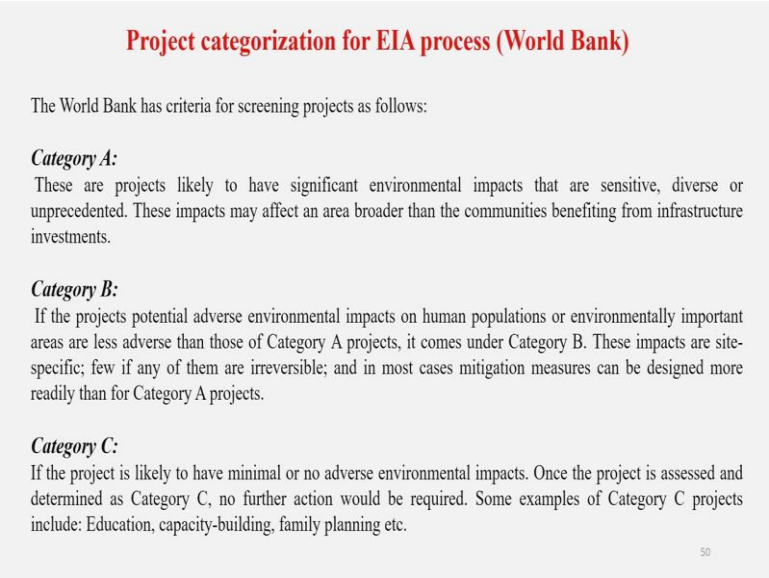

How World bank actually, which is a very active organization across the world, and especially in developing country, how they look at EIA exercise.

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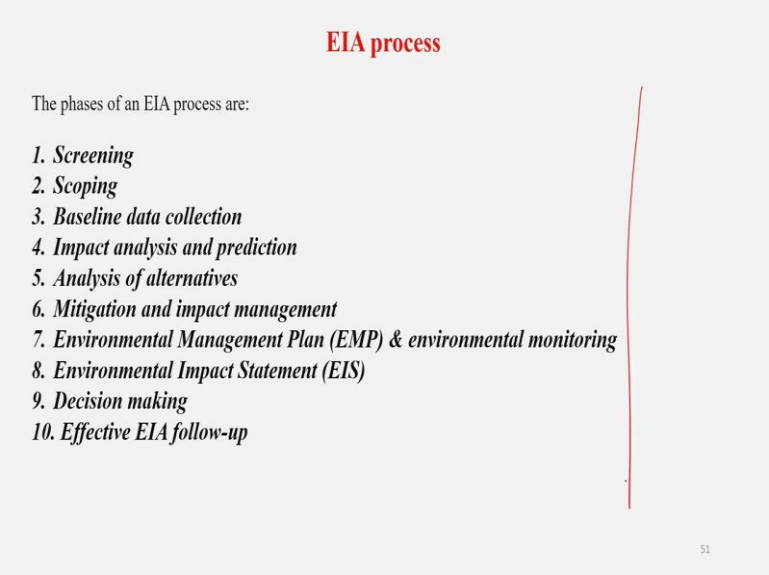

EIA process we discussed about all the different processes of EIA.

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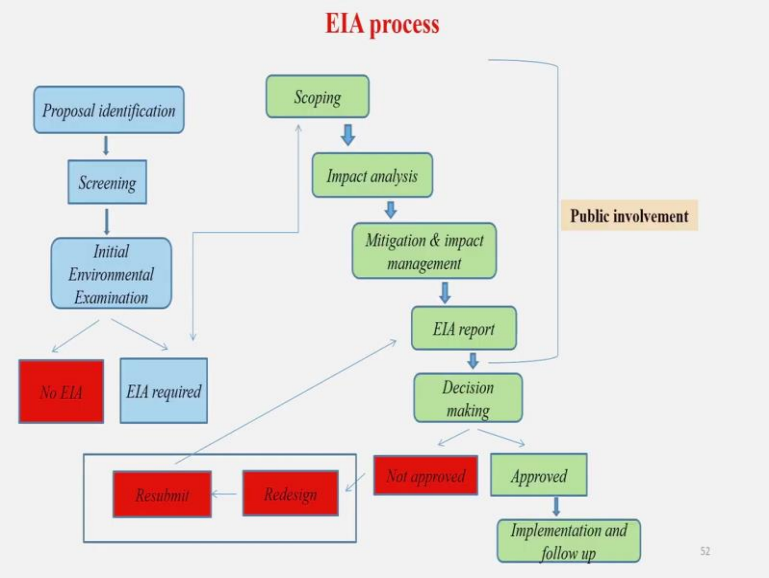

1. Screening

• 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.

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

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..

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.*

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.

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.

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.

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.*

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.

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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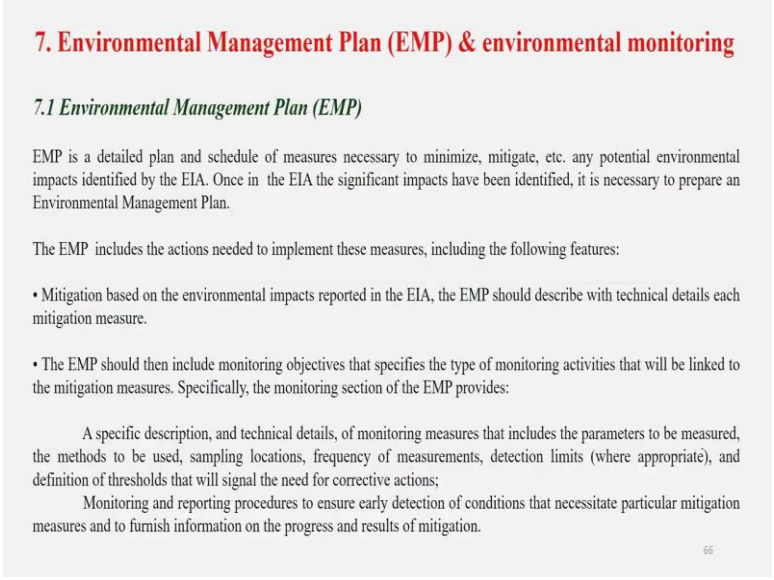

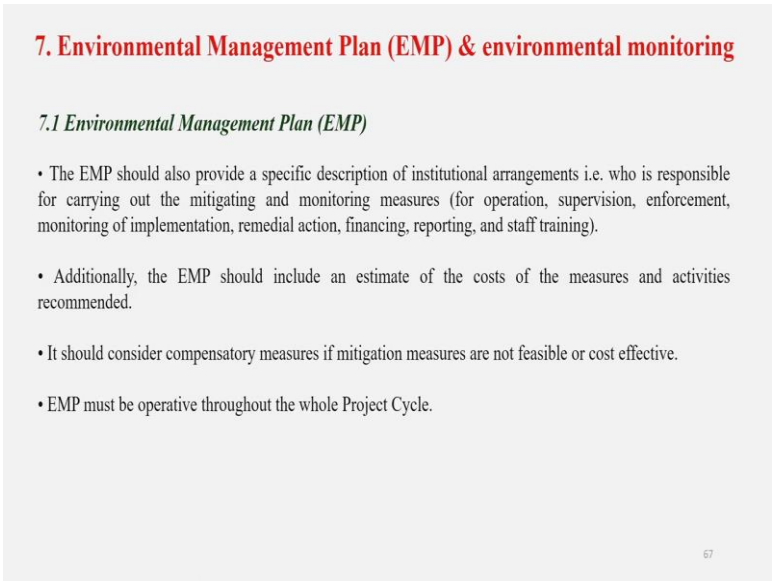

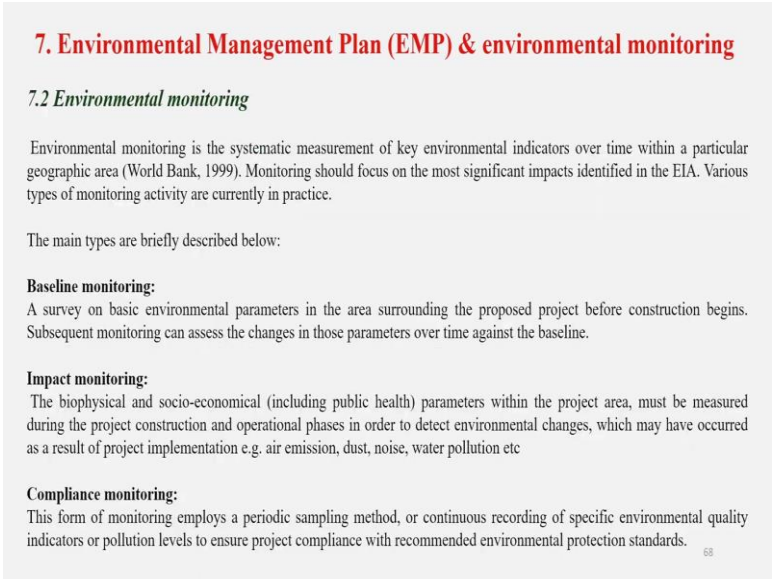

7. Environmental Management Plan (EMP) & environmental monitoring

7.2 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.

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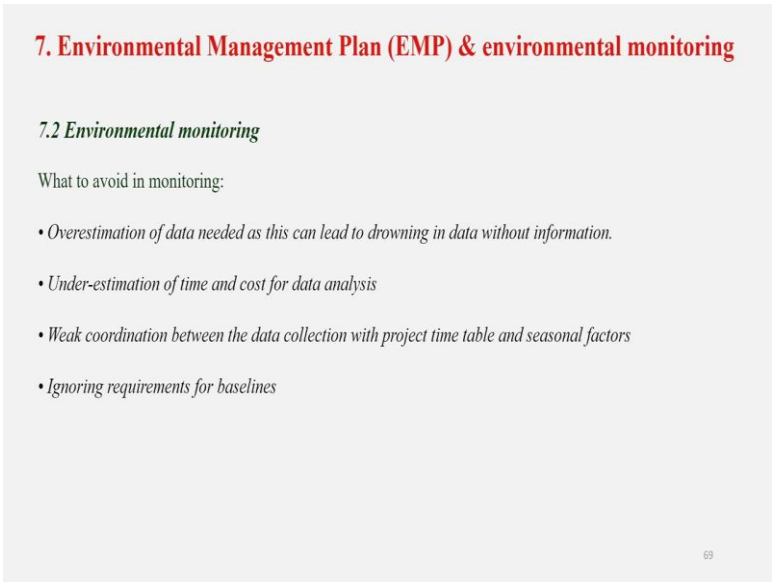

7. Environmental Management Plan (EMP) & environmental monitoring

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*

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

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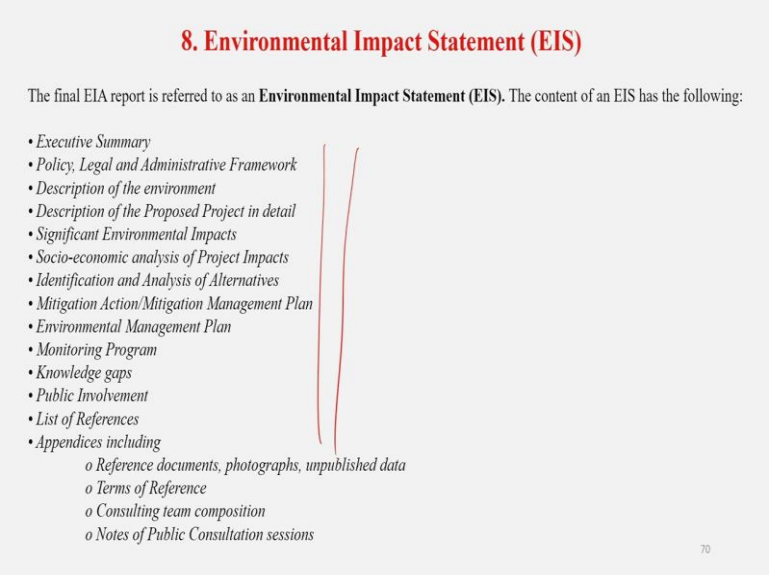

Then EIS, Environmental Impact Statement, which is very important. And these basically decide the fate of the natural resources and its utilizations.

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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.

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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.

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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.

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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.

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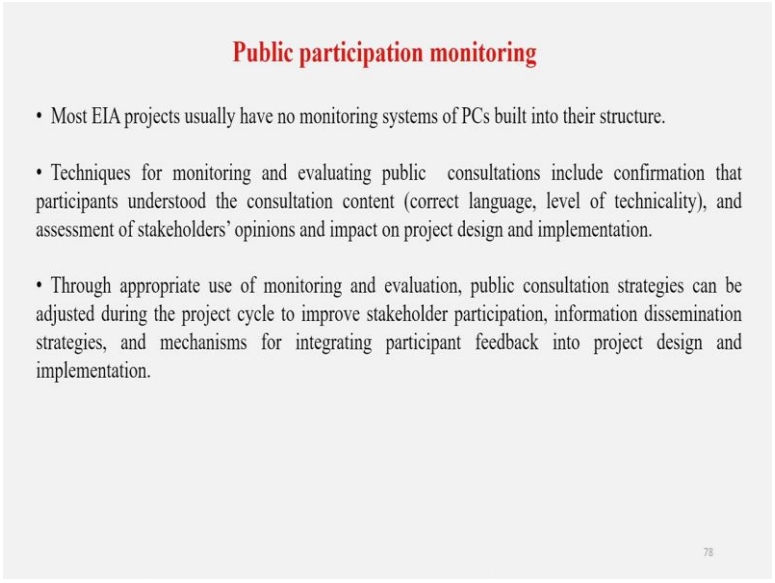

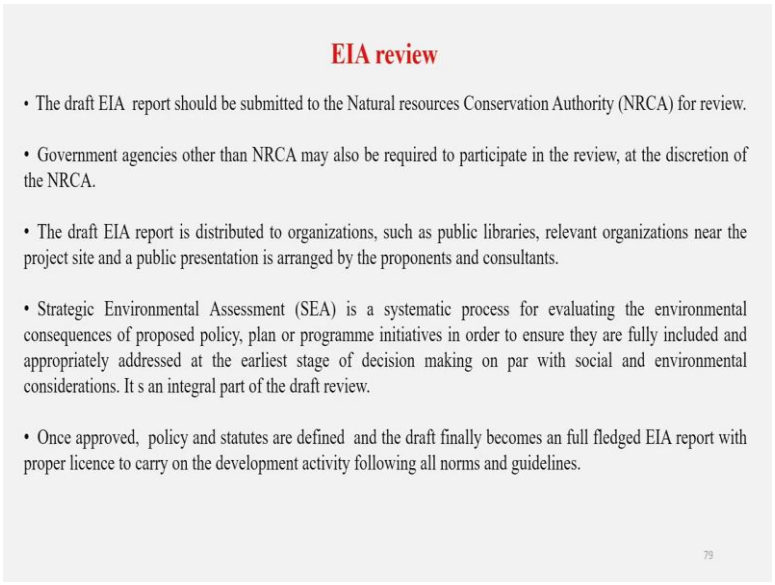

And I if you recall, that we have discussed again this aspect in great detail, how public participation in project cycle even development process itself is important because the input from the public is critical for a good EIA. If you recall that we also discussed a few examples about that.

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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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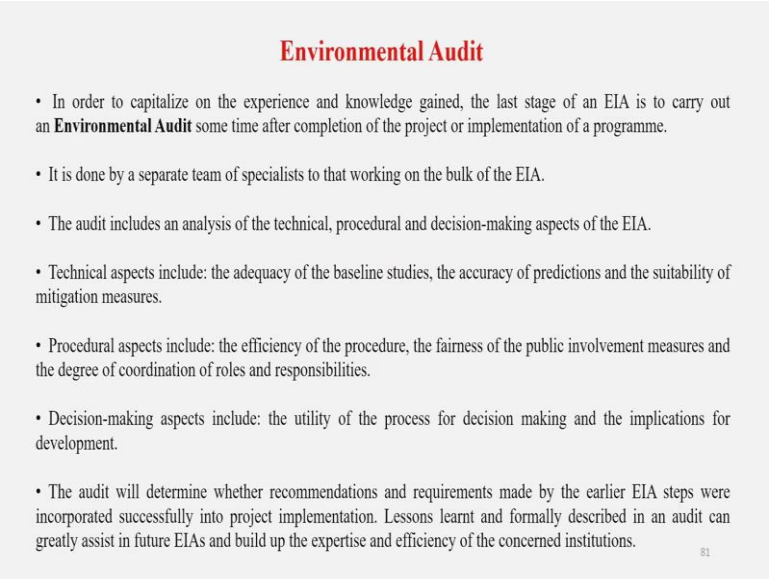


Environmental Audit

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.

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*

Types of Environmental Audit

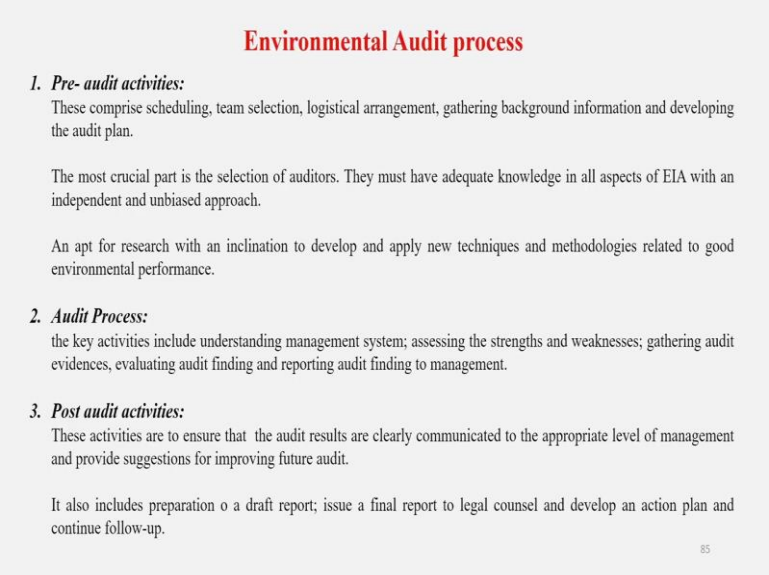
Compliance audits

Liability audits

Programme audits

Single issue audits

Risk definition or hazard identification audits



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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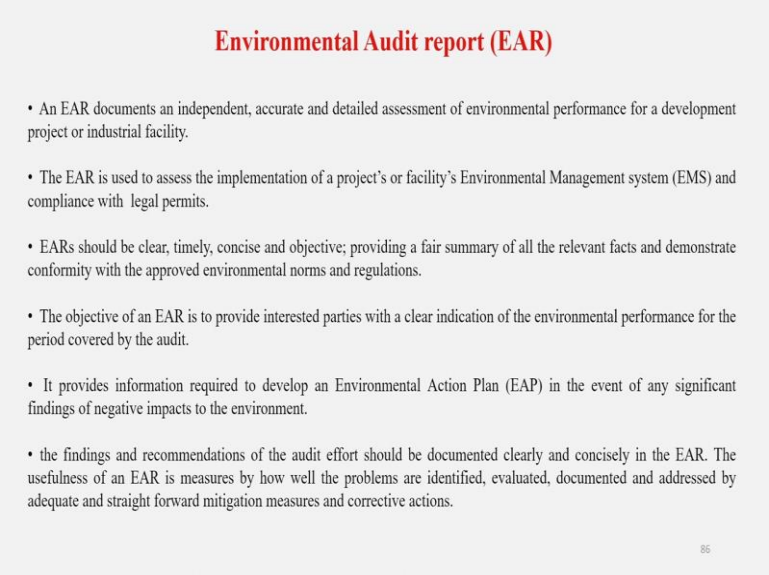

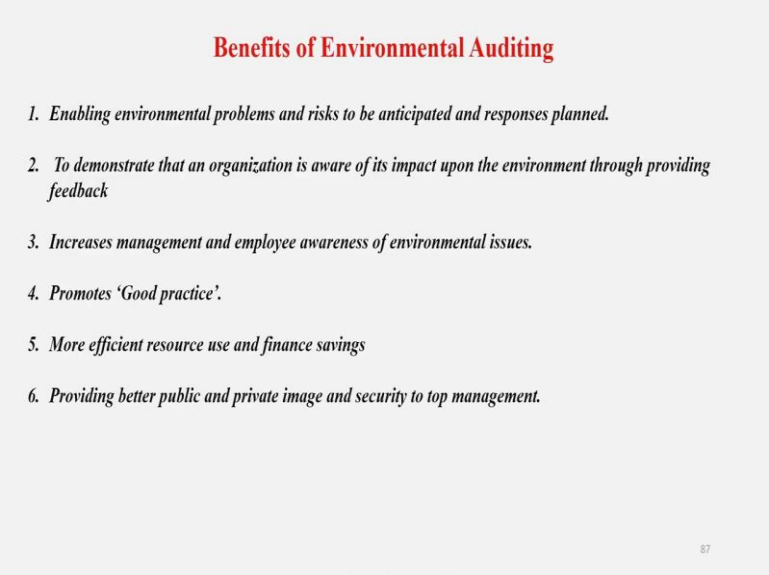

Then, we came into environmental audit report, EAR, another very important aspect. And if you recall that in the lecture schedule, we have actually discussed these sections in detail and with more time. So, I will again, request all of you to consider to go through this with a little bit of time and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

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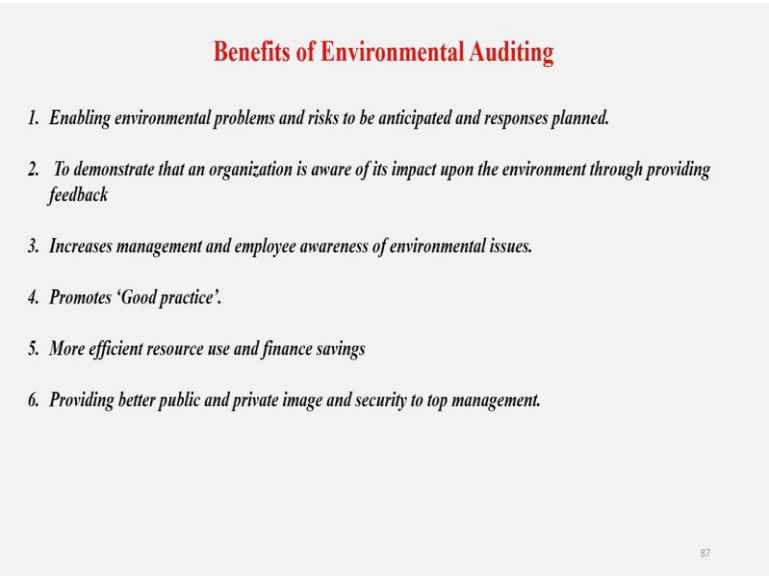


EIA related studies

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.

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.

Shortcomings of EIA Process

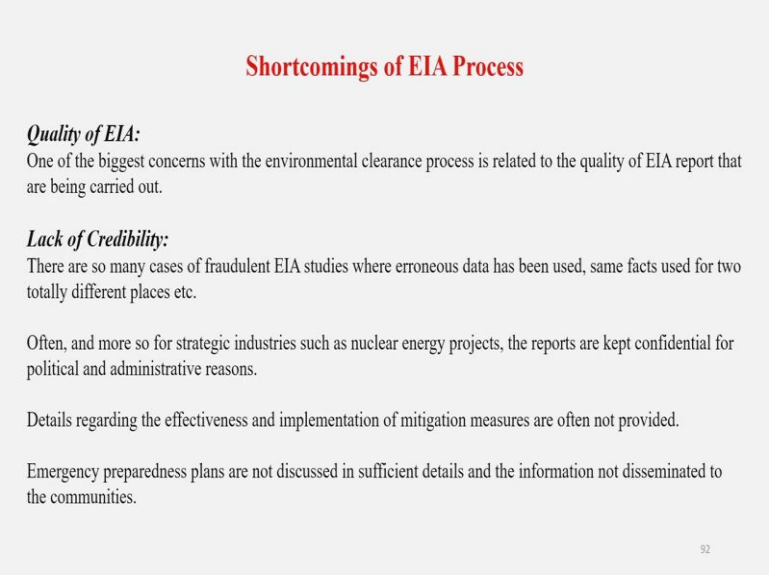
Applicability:
There are several projects with significant environmental impacts that are exempted from the notification either because they are not listed in schedule I, or their investments are less than what is provided for in the notification.

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.



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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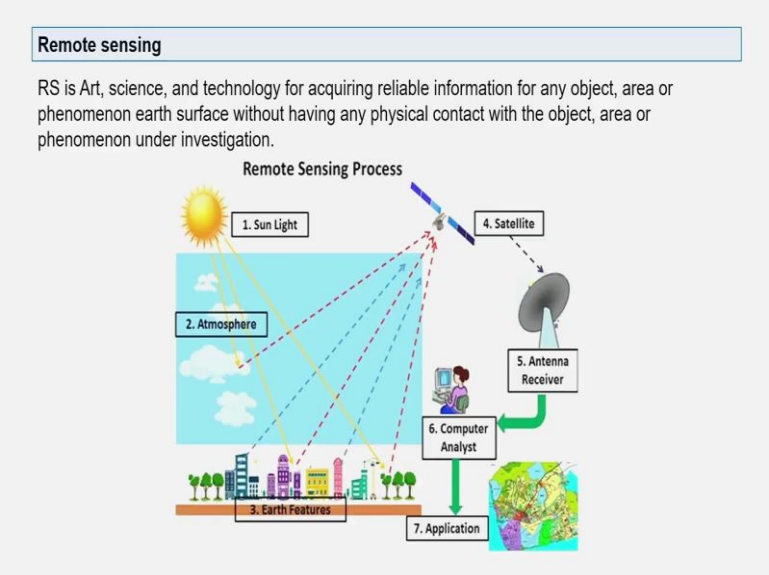

At the previous lecture within the precision farming and modeling, we discussed remote sensing and GIS just touched upon that. But later then we discussed in very great detail about these tools and techniques.

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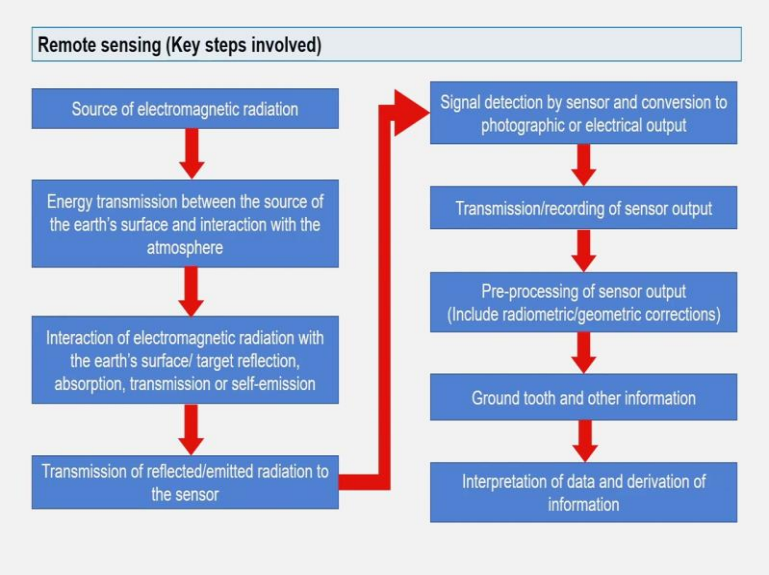

Different kind of remote sensing processes, we have discussed, what are the different steps are involved into it, that also we have detailed discussion taking place.

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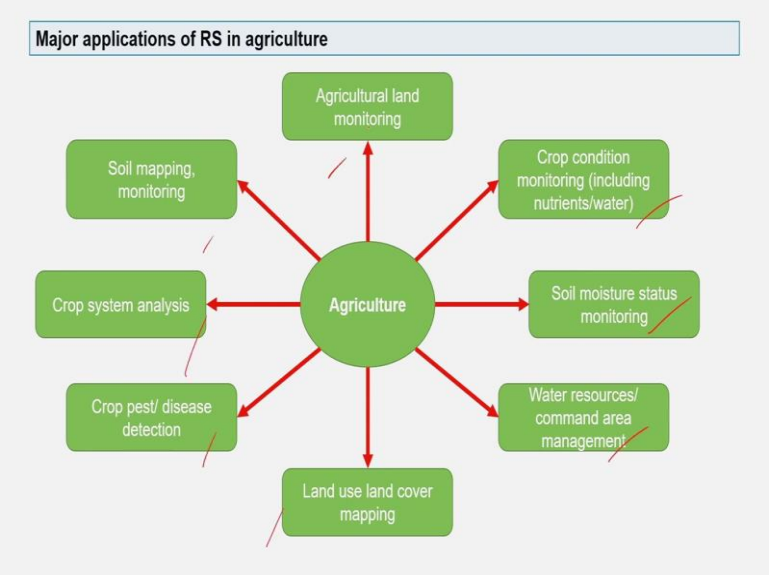

How in agriculture, remote sensing can play a role, various aspect of agriculture that we also discussed.

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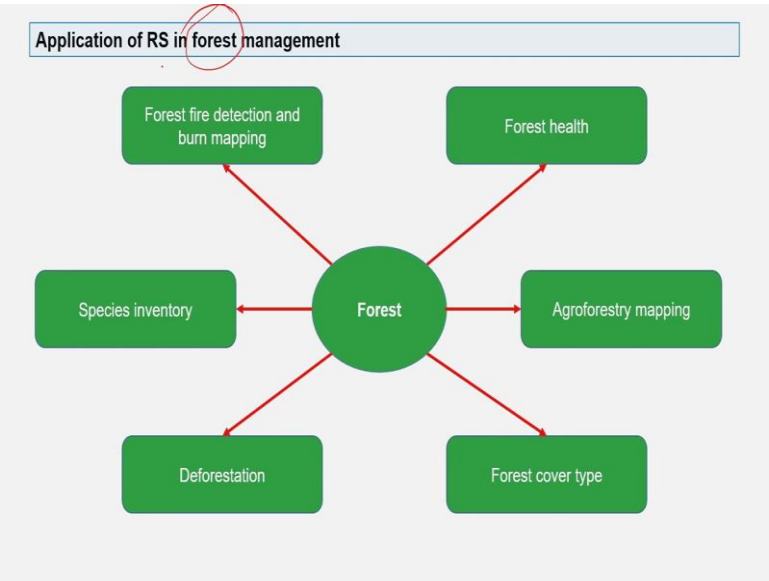

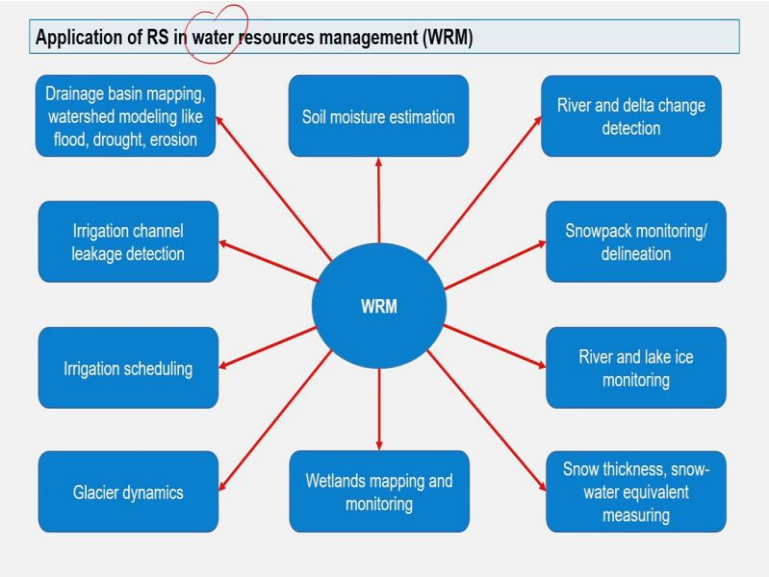

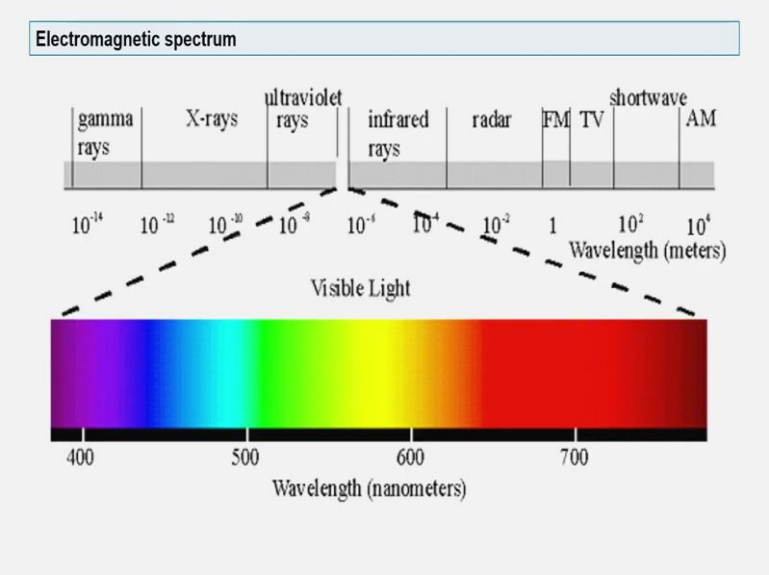

Application of remote sensing for another natural resource that is forest, how it can be applied, that also we have discussed. Then water. So, each one of these we have discussed with the examples.

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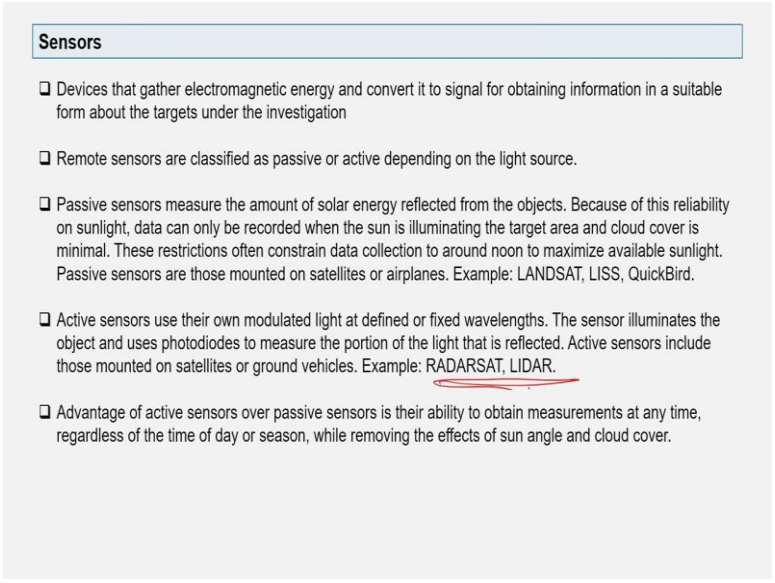

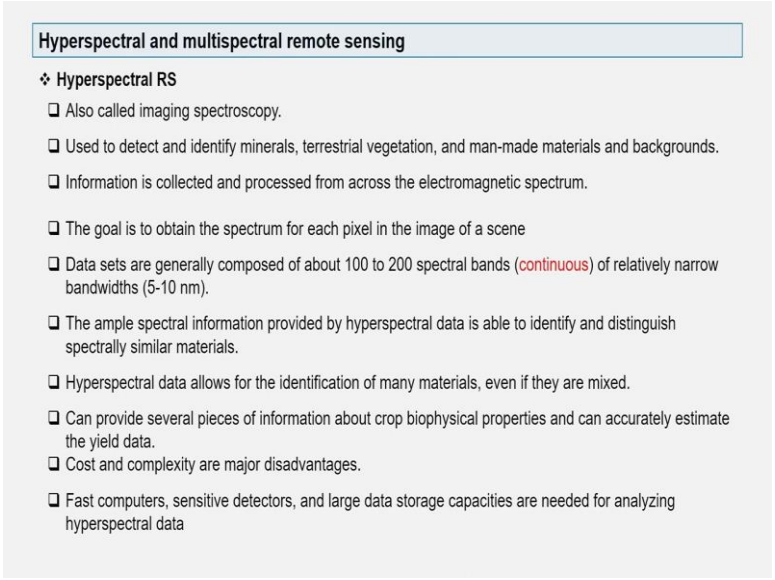

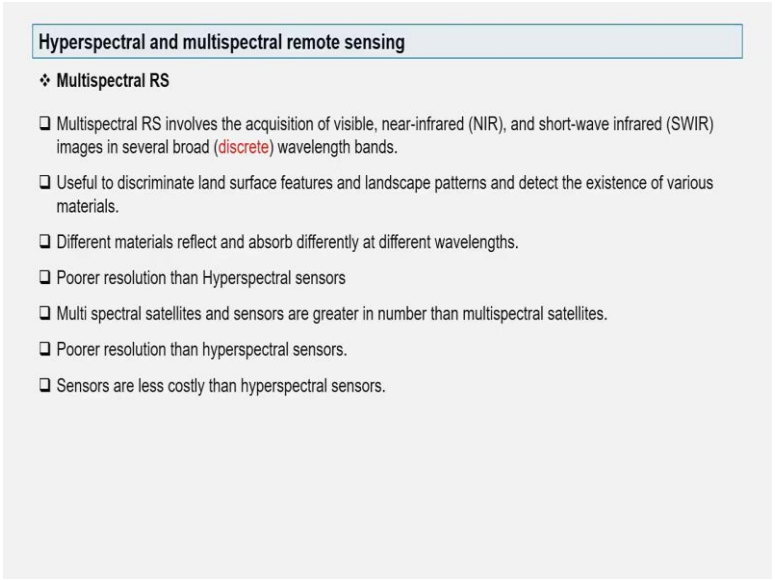

Then we came into the sensors part of remote sensing, which is one of the most important aspect of remote sensing exercise. So, we discussed with various example and how different kinds of spectral images it differently provide different kind of informations and data. Hyperspectral, multispectral, how 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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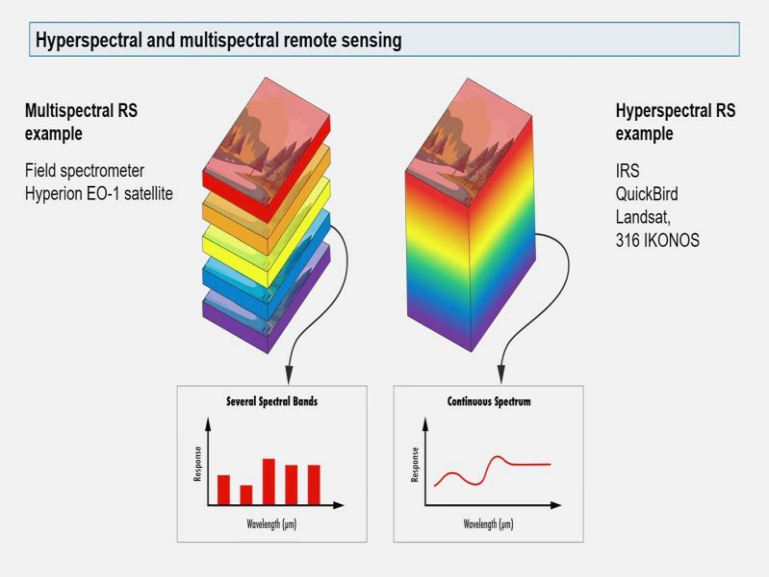

And then how technically actually this spectral imagery process work that also we have discussed.

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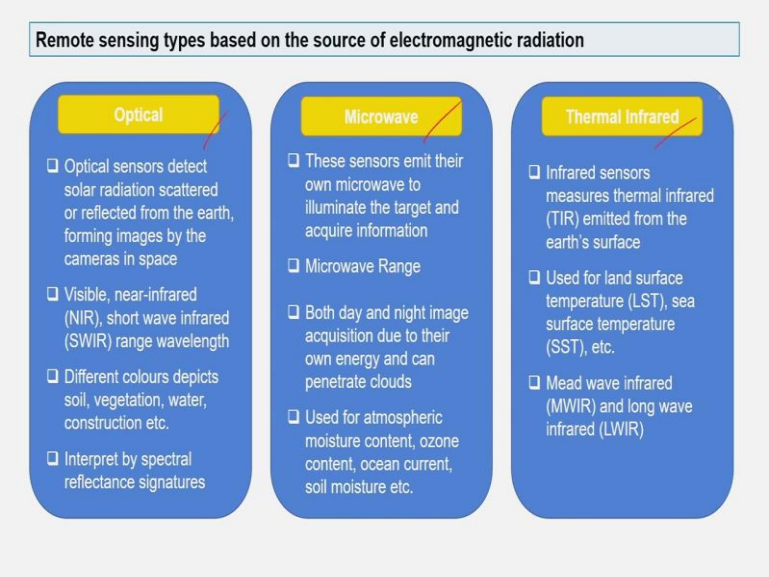

And then how remote sensing depends on different sorts of electromagnetic radiation and on that basis, how they are different from each other and every one of them can be actually used for different purposes.

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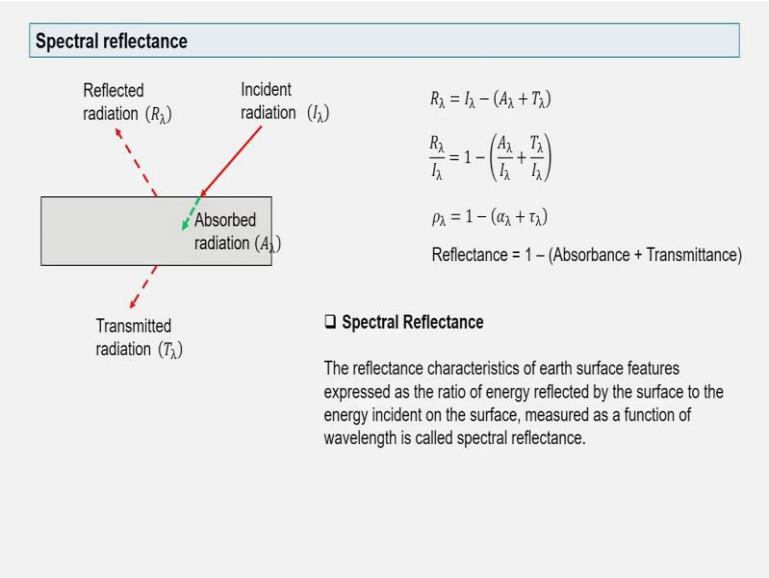

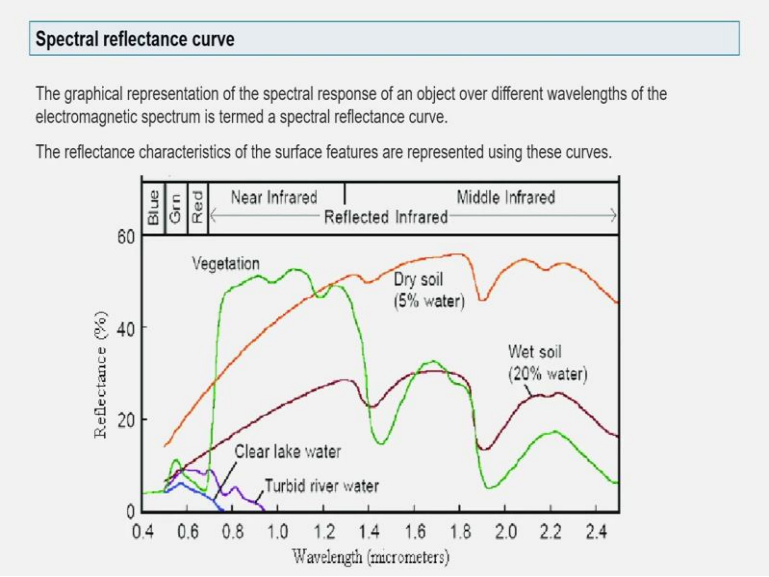

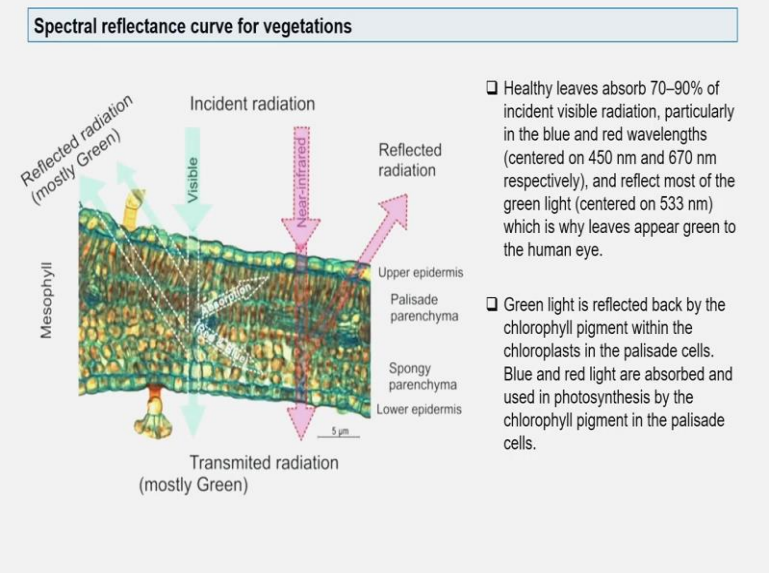

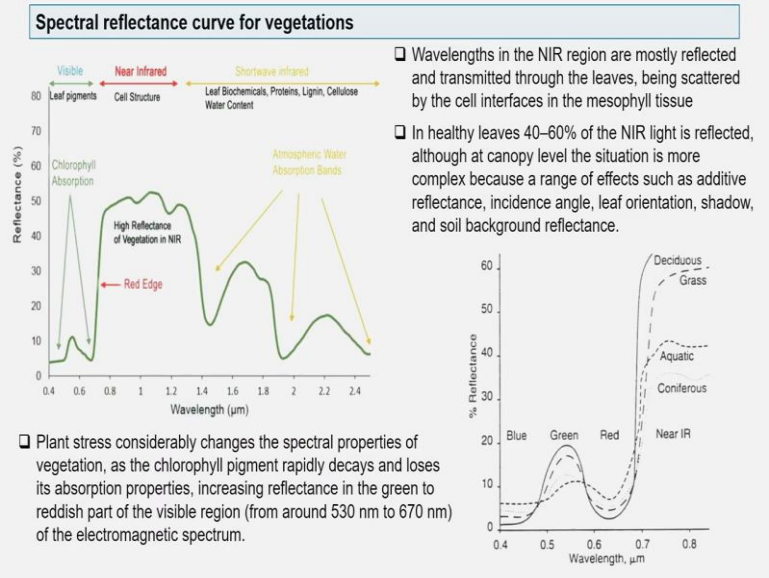

Spectral reflectance also we have discussed in great detail. How spectral reflectance curve help us to understand different data that are being generated through the spectral images, spectral reflectance curve also how it helps in understanding different condition on the ground on that surface, vegetation. 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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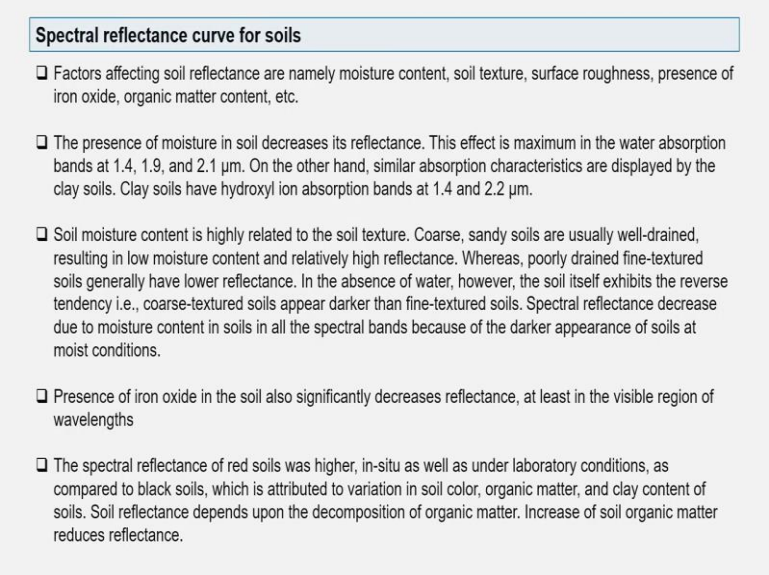

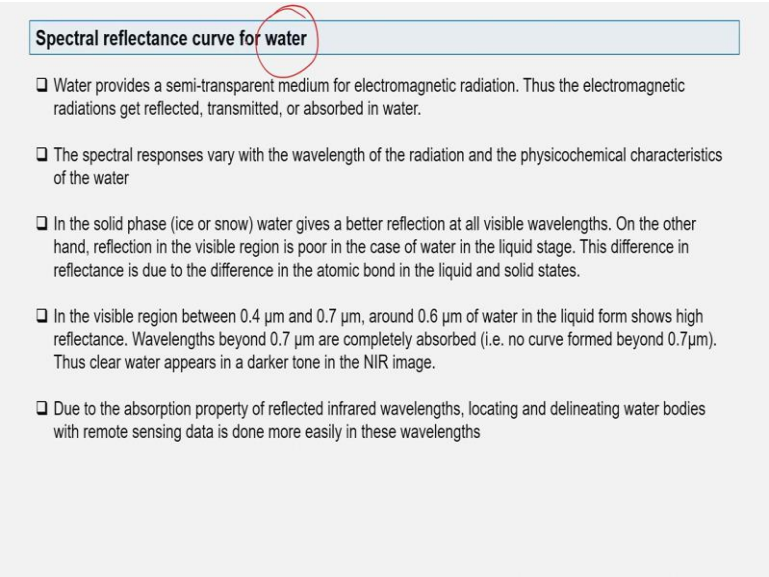

So, a great deal of discussion taking place on spectral reflectance on vegetation, then on soils, how it works for water, because as I said that the three major resources that are directly linked with human life and society is soil, water, air and then your vegetation or plant. So, these all resources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

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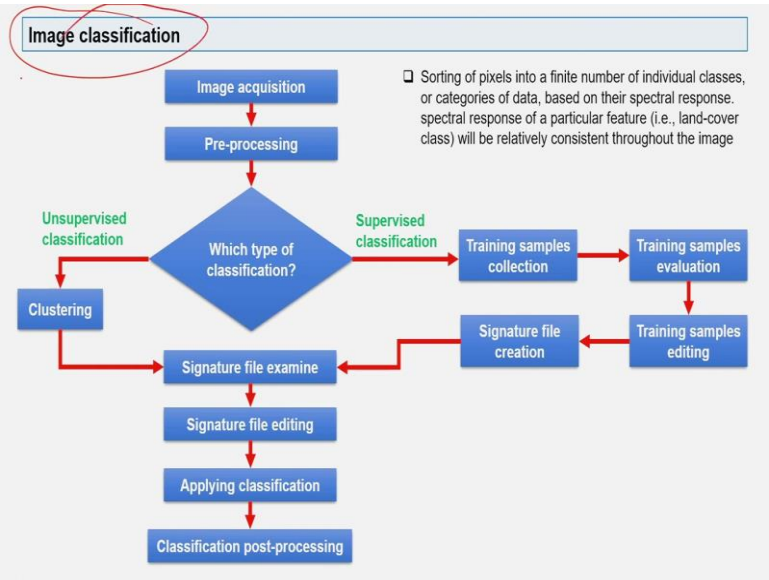

We talked about another important aspect about image classifications. And I understand that probably, you have gone through these classes and lectures carefully. Having said that, once again, I remind you that remote sensing GIS is a subject which requires a completely specialized training. In this course, 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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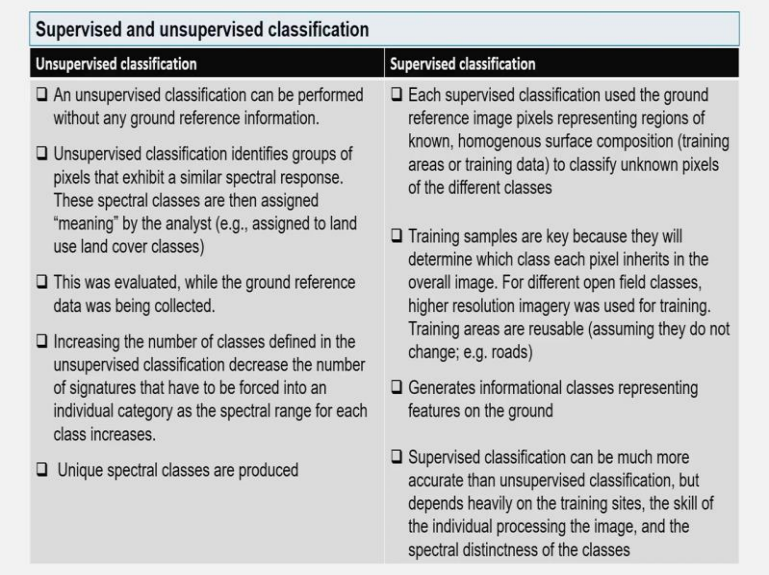


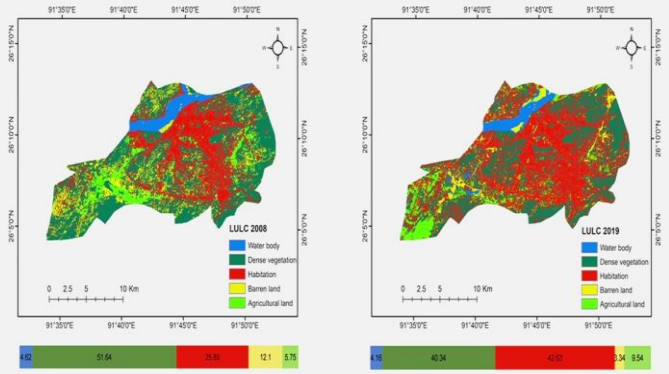
Unsupervised classification	Supervised classification
❑ Spectral classes do not represent features on the ground	❑ Information classes may not match spectral classes. (e.g., a supervised classification of "forest" may mask the unique spectral properties of pine and oak stands that comprise that forest)
❑ Does not consider spatial relationships in the data	❑ 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.
❑ Spectral properties vary over time, across images	❑ Difficulty and cost of selecting training sites. Training areas may not encompass unique spectral classes
❑ Can be very time-consuming to interpret spectral classes	❑ Most of the analyst's work comes before the classification process in this classification
❑ 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	

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

(Refer Slide Time: 33:26)

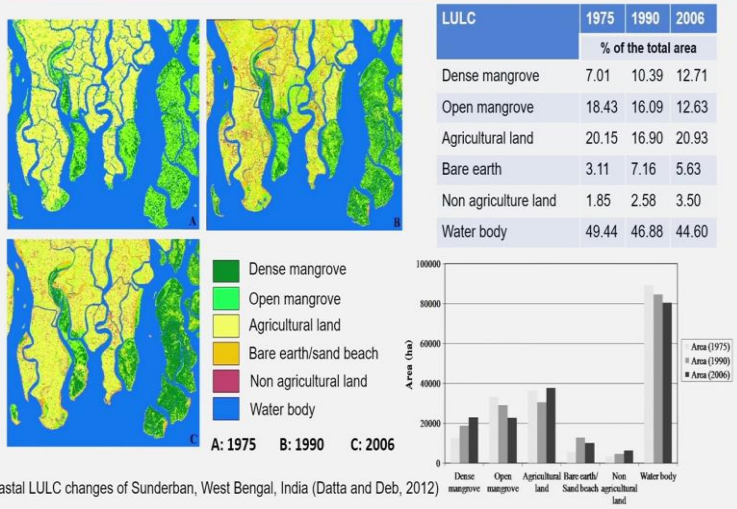
Land Use Land Cover

❑ **LULC or land use land cover** is any surface cover on the ground which can include vegetation, built-up areas, water bodies (lake, river, stream), mountain, transportation networks, or any other. The attributes measured by remote sensing techniques relate to land cover, from which land use can be inferred



LULC changes in the Greater Guwahati Area (GGA) of Assam, India (2008 and 2019)

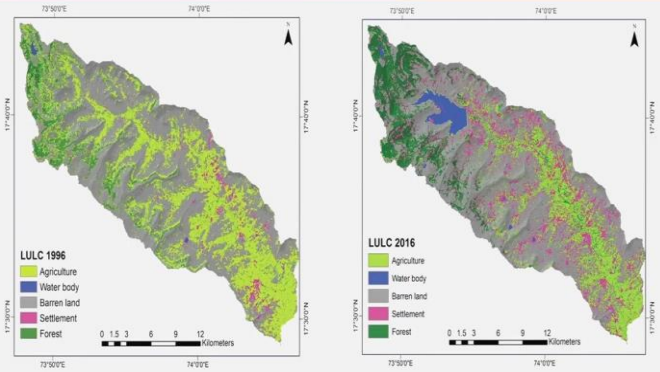
Land Use Land Cover



LULC	1975	1990	2006
	% of the total area		
Dense mangrove	7.01	10.39	12.71
Open mangrove	18.43	16.09	12.63
Agricultural land	20.15	16.90	20.93
Bare earth	3.11	7.16	5.63
Non agriculture land	1.85	2.58	3.50
Water body	49.44	46.88	44.60

Coastal LULC changes of Sunderban, West Bengal, India (Datta and Deb, 2012)

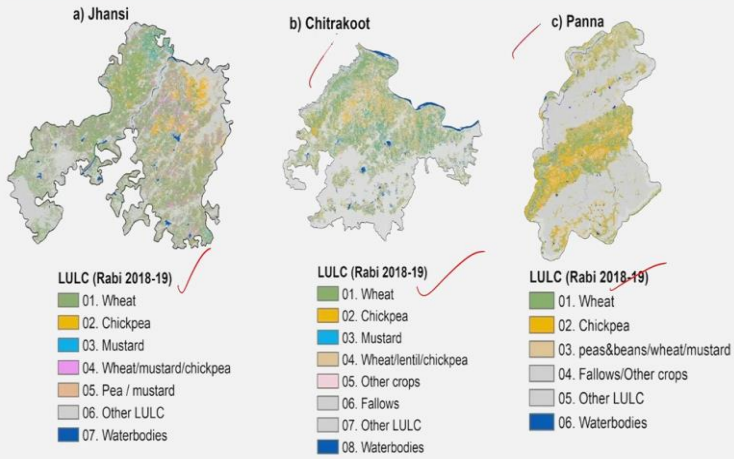
Land Use Land Cover



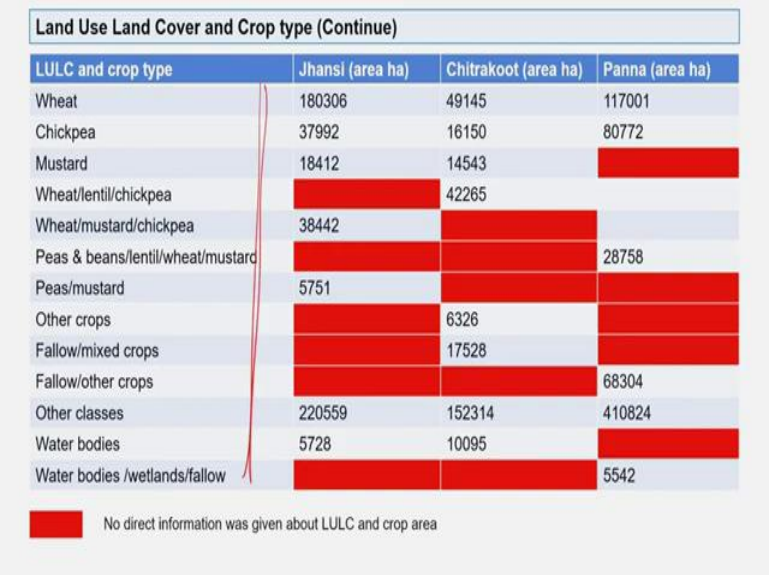
LULC change of Urmodi River Watershed of Maharashtra, India, before and after the construction of a dam (Bagwan and Gavali, 2021)

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



Crop type identification and spatial mapping (Gumma et al., 2022)



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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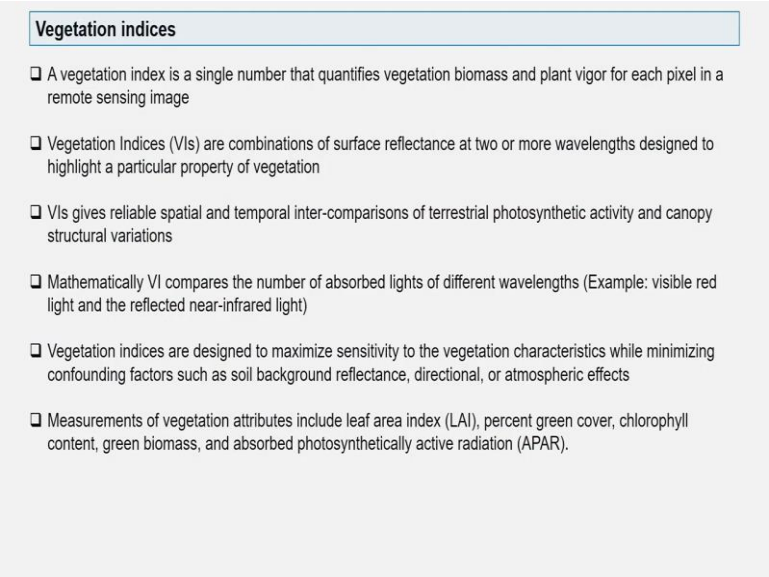

Vegetation indices

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

- 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 jth month or week $NDVI_{min}$= long-term (e.g., 30 years) minimum NDVI for jth month or week; $NDVI_{max}$= long-term (e.g., 30 years) maximum NDVI for jth month or week; VCI = 0: poor vegetation VCI = 50%: Fair vegetation VCI = 100%: Optimal vegetation
Modified Soil Adjusted Vegetation Index (MSAVI)	$MSAVI = \frac{\left[2\rho_{NIR} + 1 - \sqrt{(2\rho_{NIR} + 1)^2 - 8(\rho_{NIR} - \rho_R)}\right]}{2}$	
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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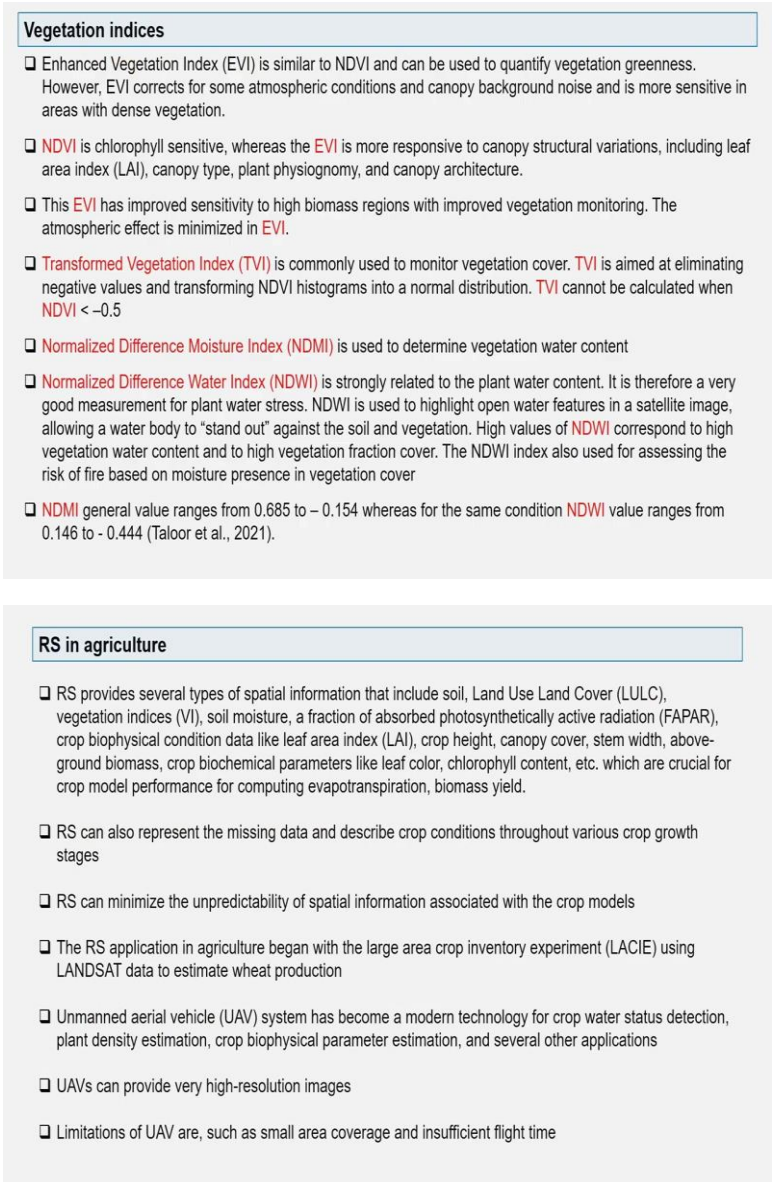

So, after vegetation index, then, we just discussed about the role of remote sensing in general in agriculture.

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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

$R_n = (1 - \alpha)R_{Sin} + R_{Lin} - R_{Lout} - (1 - \varepsilon_0)R_{Lin}$

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_{Lin} = 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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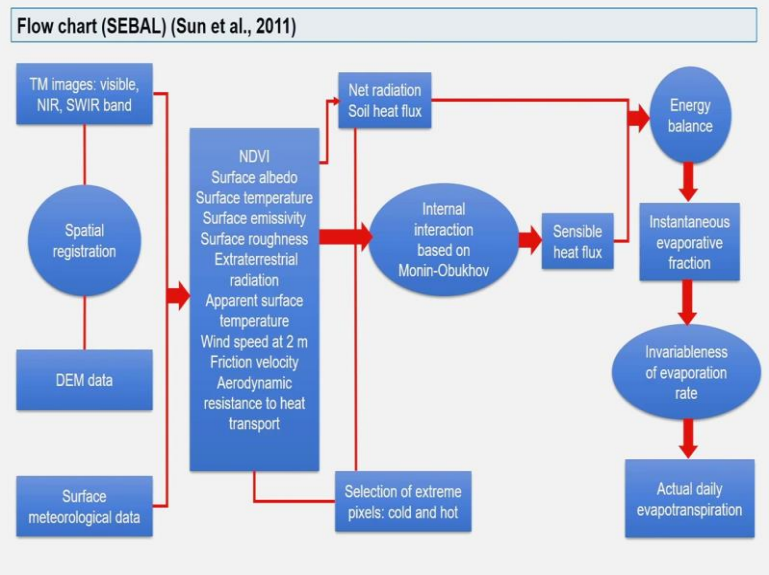

SEBAL is one of the process that I have discussed in great detail, especially from the point of view of satellites role in helping us to monitor the natural resources.

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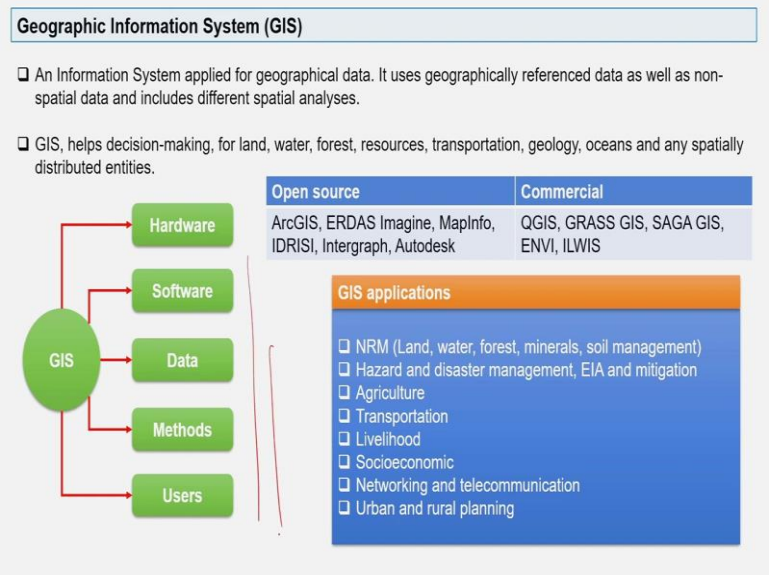
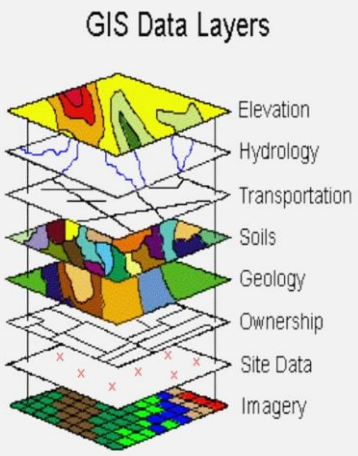


GIS

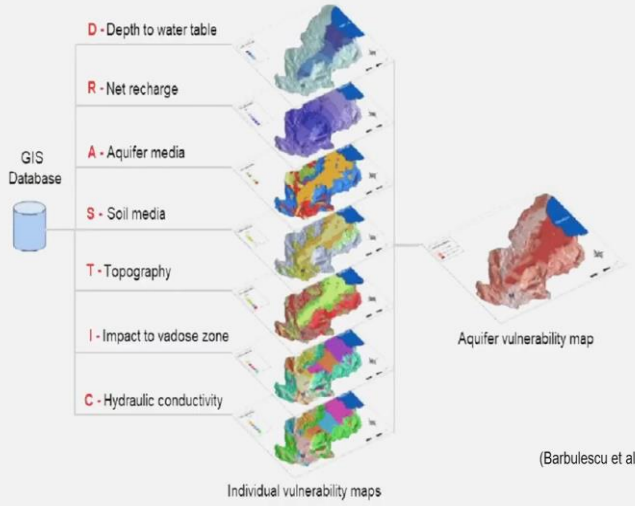
- GIS data types
  - Vector: point, line or, polygon
  - Raster: data that are described by a cell grid, one value per cell
  - Attribute: Data that are non-spatial characteristics that are connected by tables to points, lines, "events" on lines, and polygons (and in some cases GRID cells)



GIS interpolations

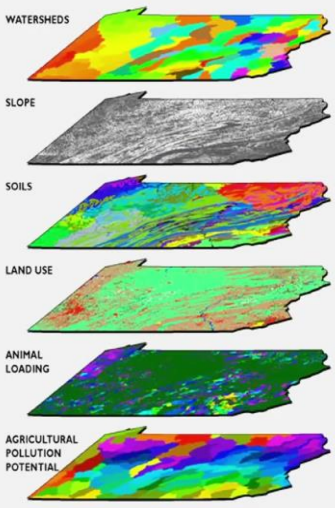
- Nearest neighbor
- Inverse Distance Weight (IDW)
- Kriging
- Spline
- Bilinear interpolation

GIS map layers for aquifer vulnerability



(Barbulescu et al., 2020)

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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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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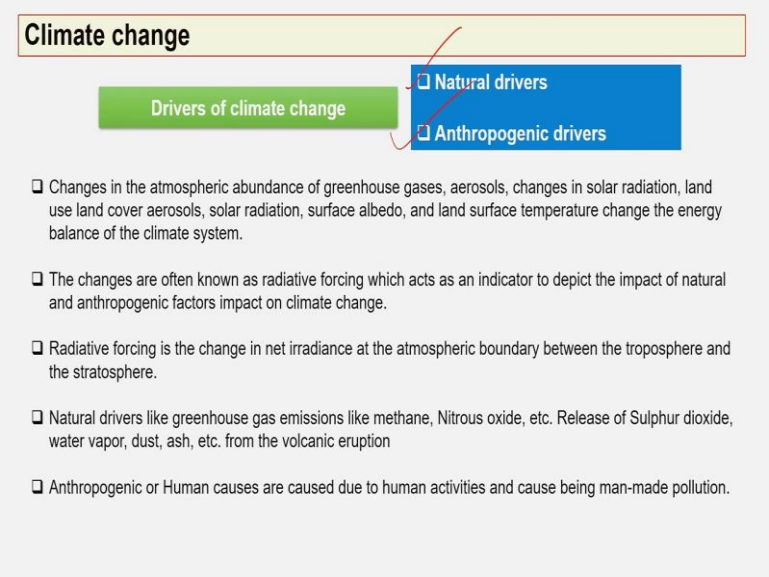

If you recall that we started with the basic fundamental thing of the drivers, which actually change the climate. So, we talked about natural and anthropogenic driver, two drivers and how they actually impact our climate and how they change it.

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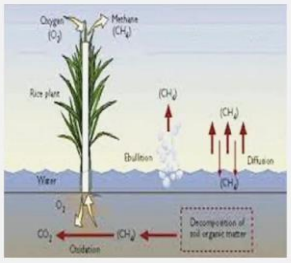
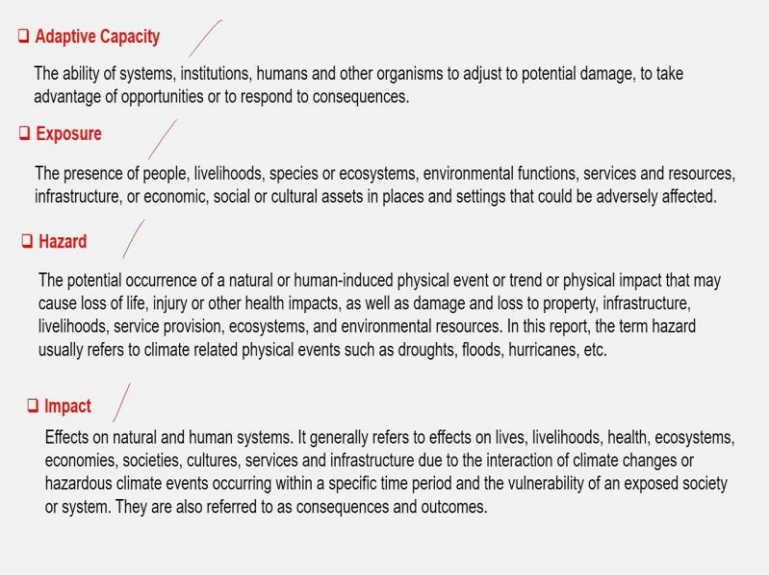
Climate change

- 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 Nina, 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



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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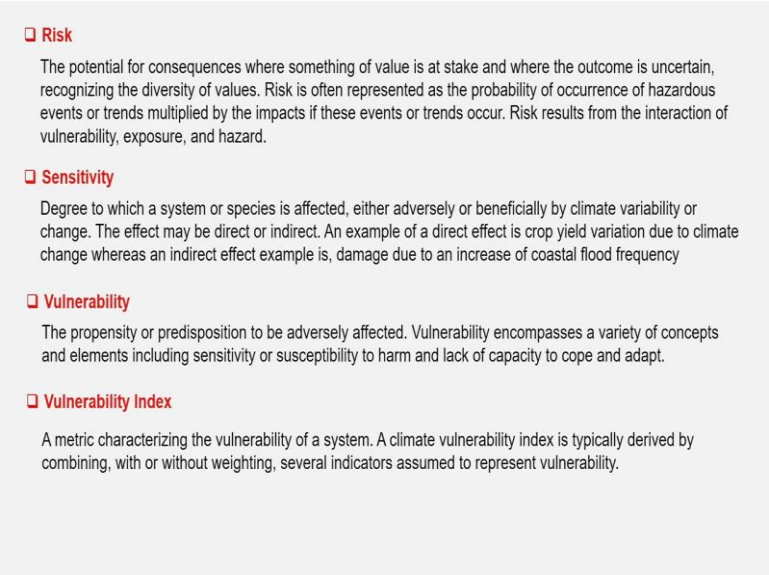

So, then we also discussed about risk, sensitivity, vulnerability, vulnerability index.

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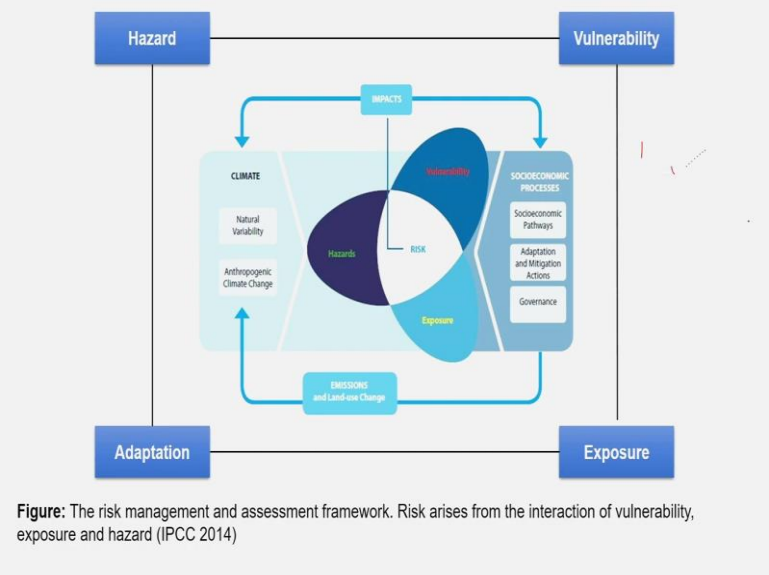

Figure: The risk management and assessment framework. Risk arises from the interaction of vulnerability, exposure and hazard (IPCC 2014)

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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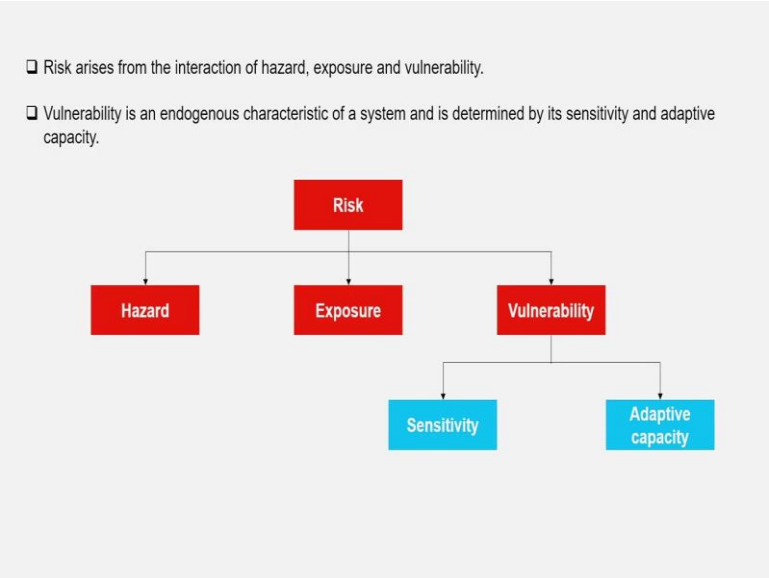

And then next we went into the risk and relation between risk hazard vulnerability and exposure.

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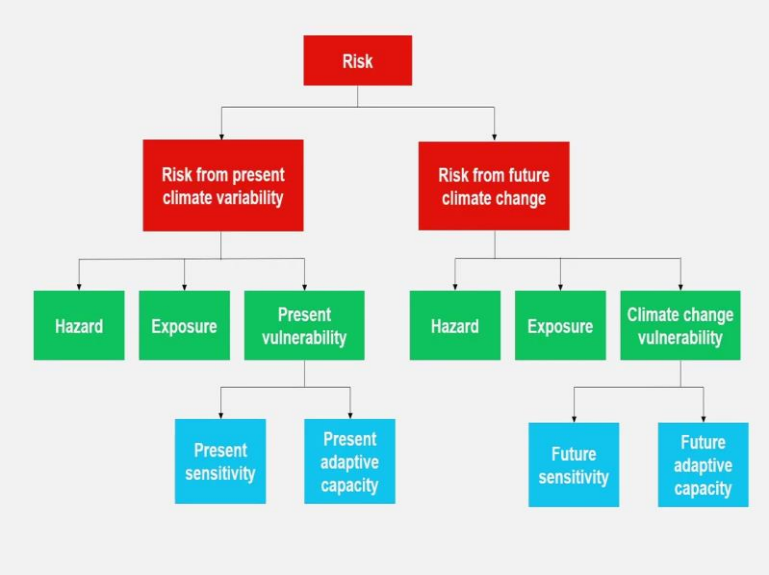

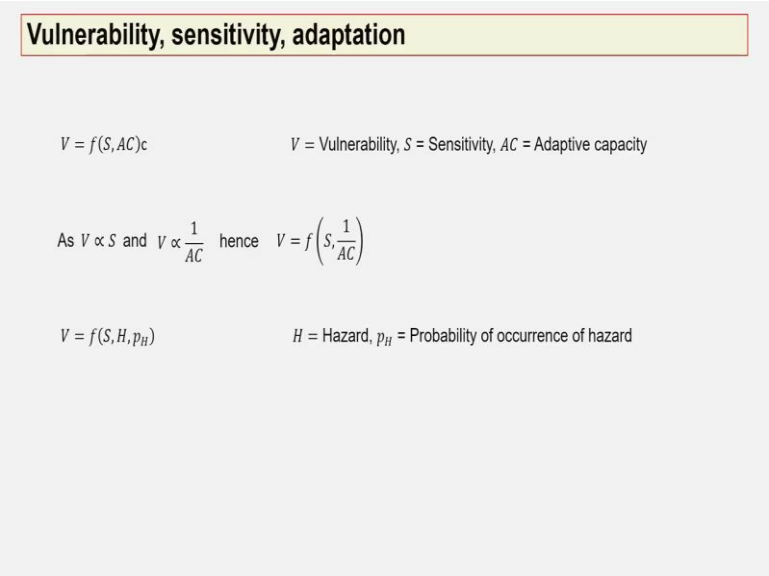

And after that, then we looked at that how risk from present climate variability and risk from future climate changes they work. So, in both the cases the vulnerability analysis to know the indicators of vulnerability is important, which actually we discussed it in a great detail about vulnerability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

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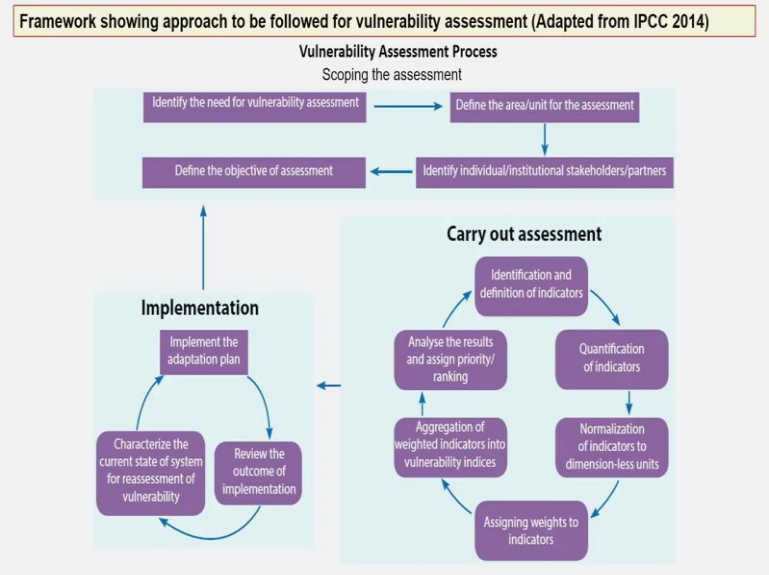

So, again, there is a vulnerability ability assessment process that we have discussed the given already well given framework by IPPC.

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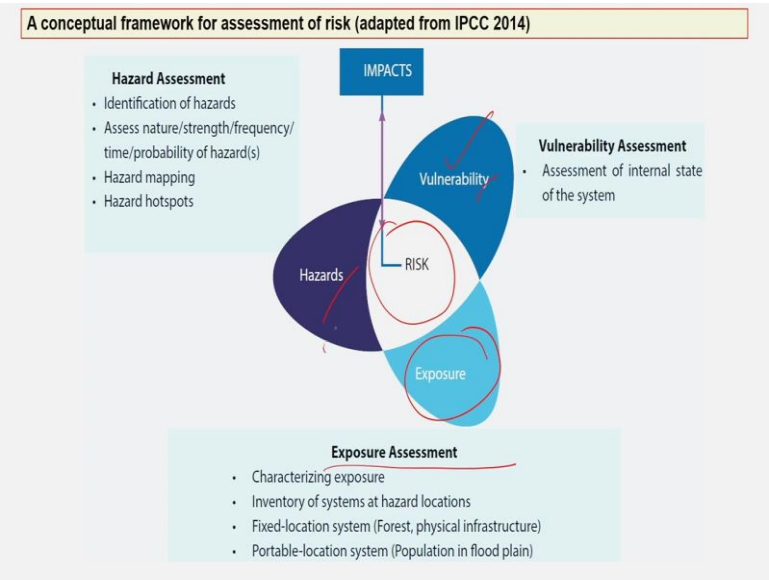

So, we discussed about these processes and the conceptual framework for assessment of risk again given by ITPC how you actually assess hazard, vulnerability and exposure and because risk is a product of vulnerability hazard and exposure. So, it works almost together and to understand risk, we need to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

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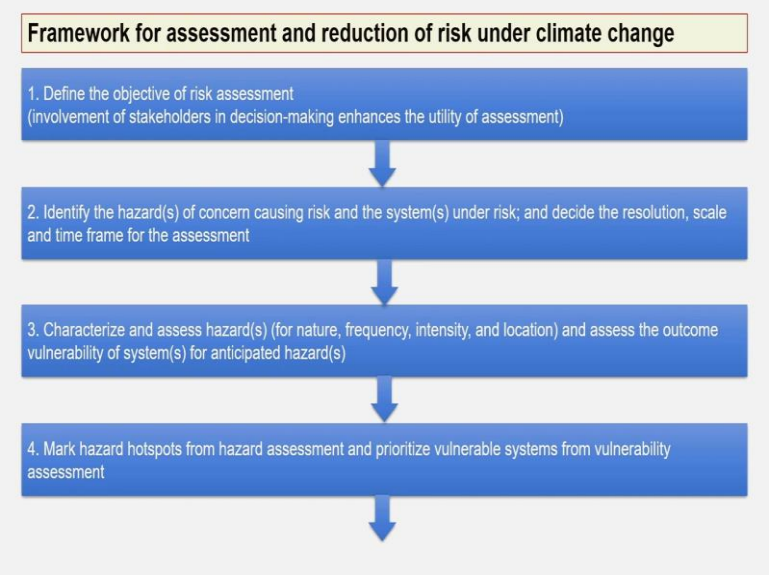

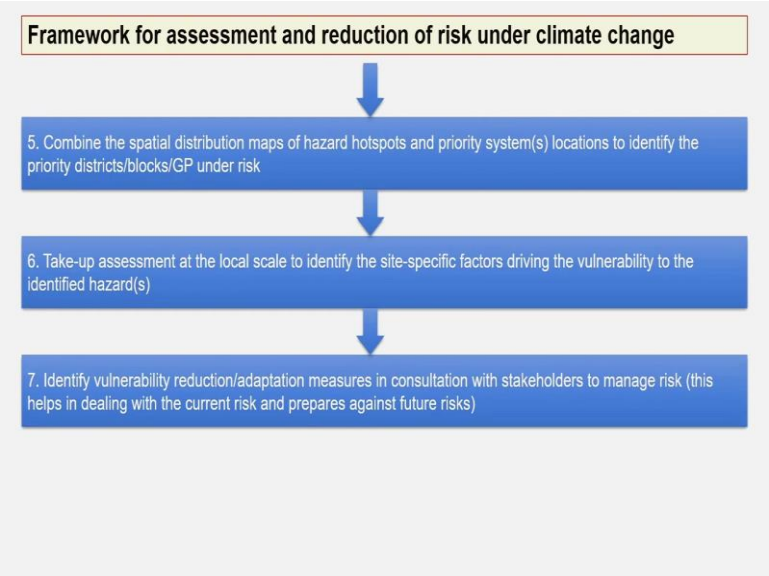

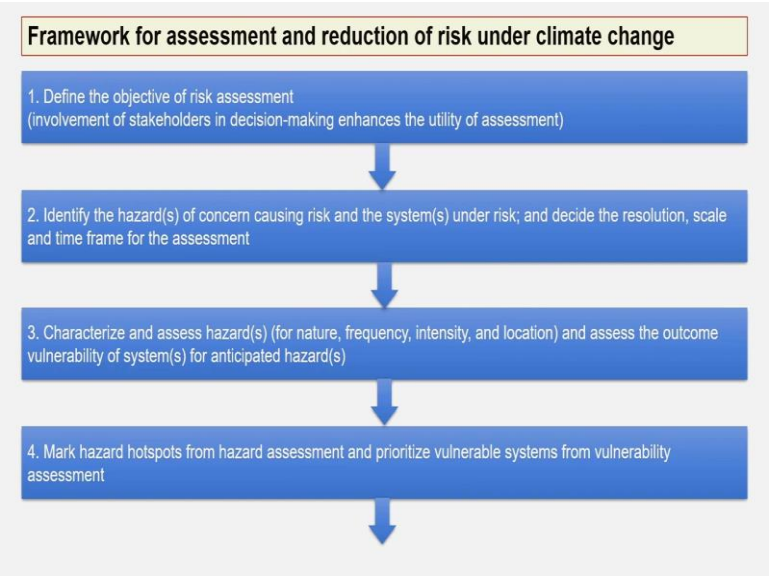

We have discussed the different reduction of risk under climate change, how we can do it.

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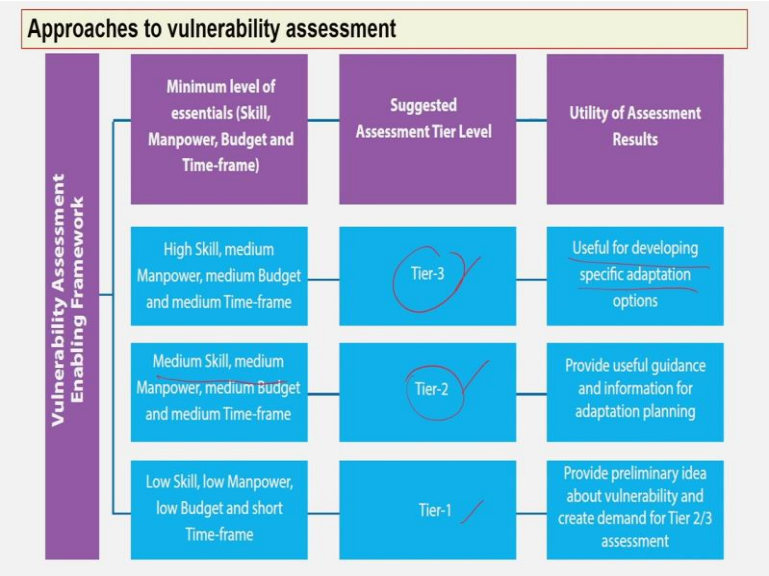

Then we also discussed about the vulnerability assessment approaches, various approaches. Again, we discussed about three different tiers if you remember. So, the tier 1 is the very basic tier which even unskilled manpower can do it. In tier 2, is medium skill manpower, and also you need medium budget. 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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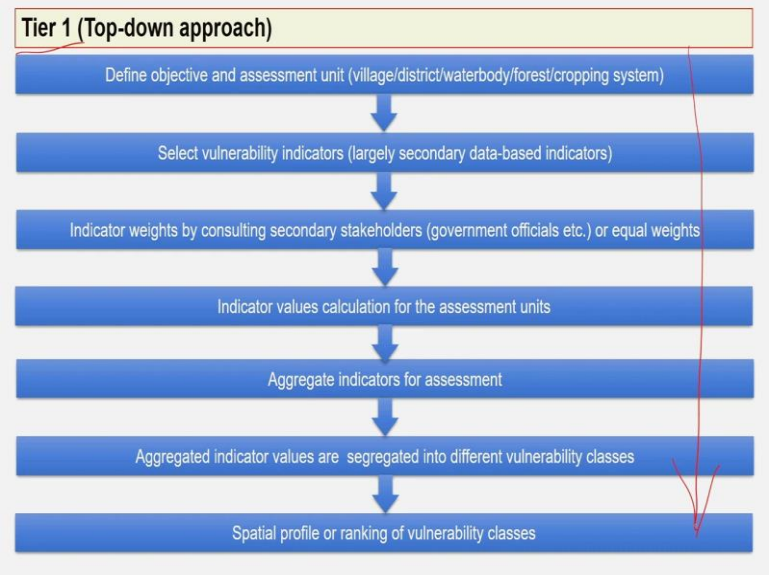

We have also discussed these things tier wise, tier 1, tier 2 how actually you can step wise follow it and get the vulnerability classes.

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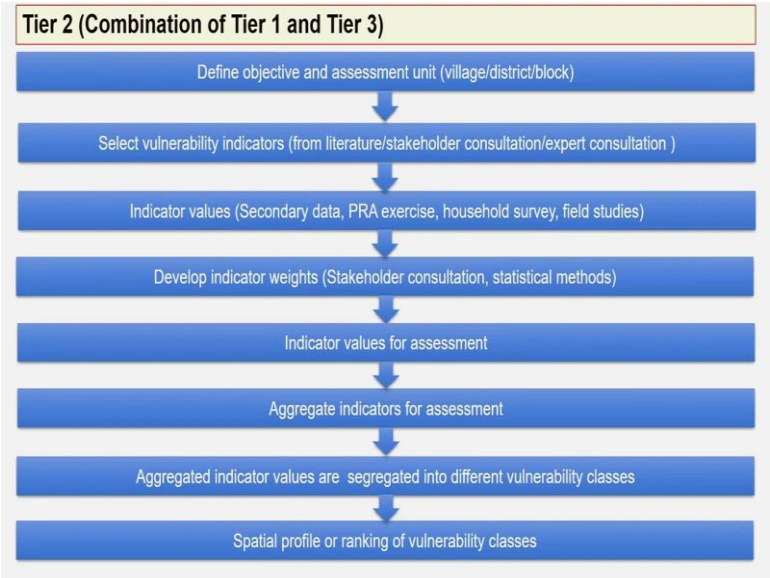
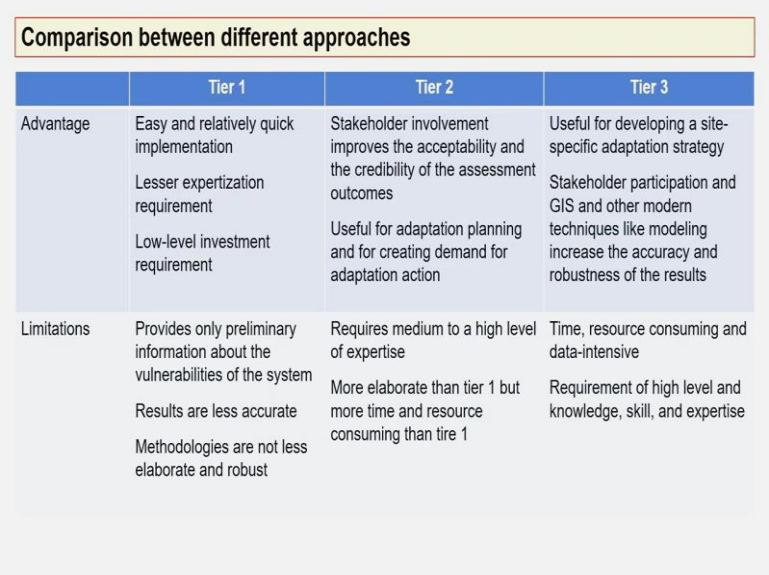


Comparison between different approaches

	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



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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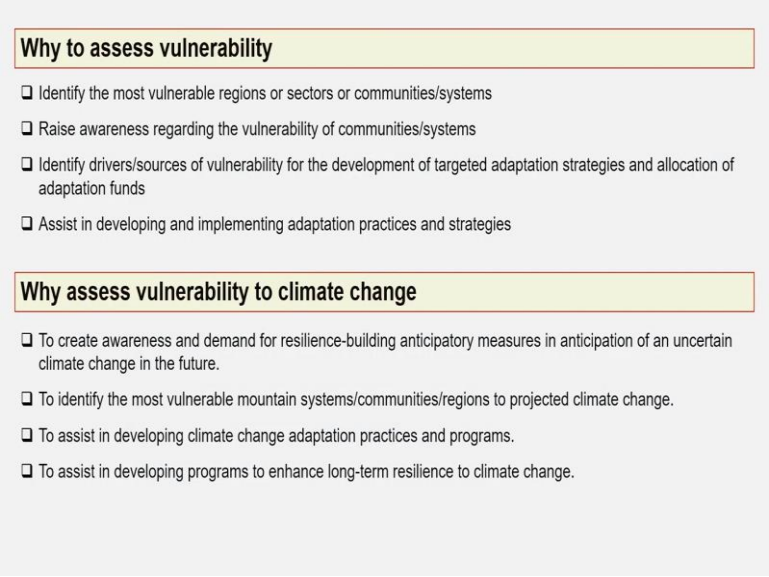
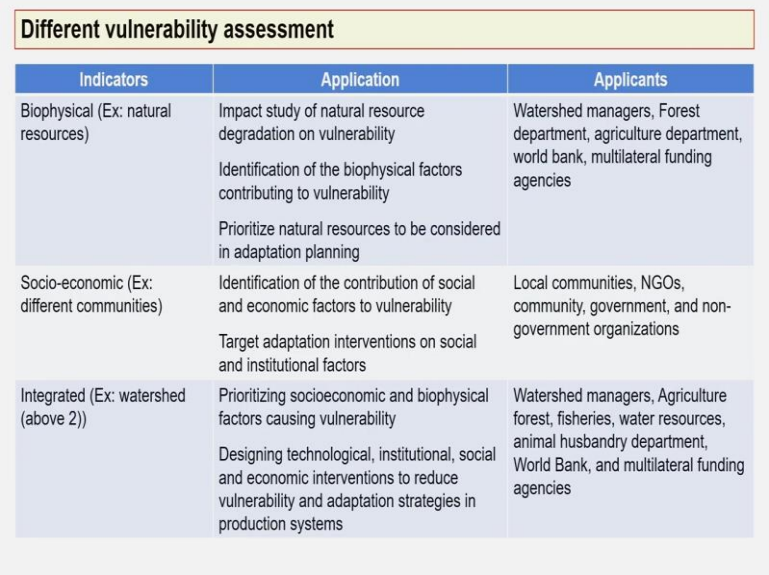
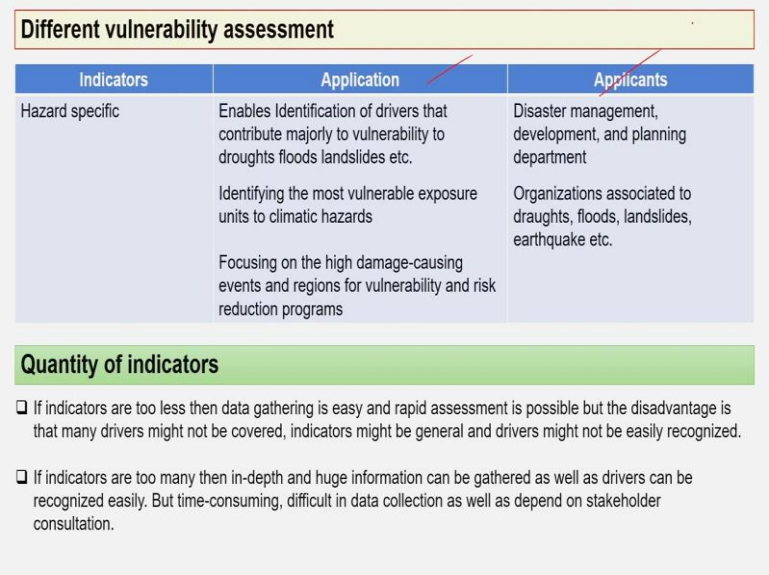




Different vulnerability assessment

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

- 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.
- 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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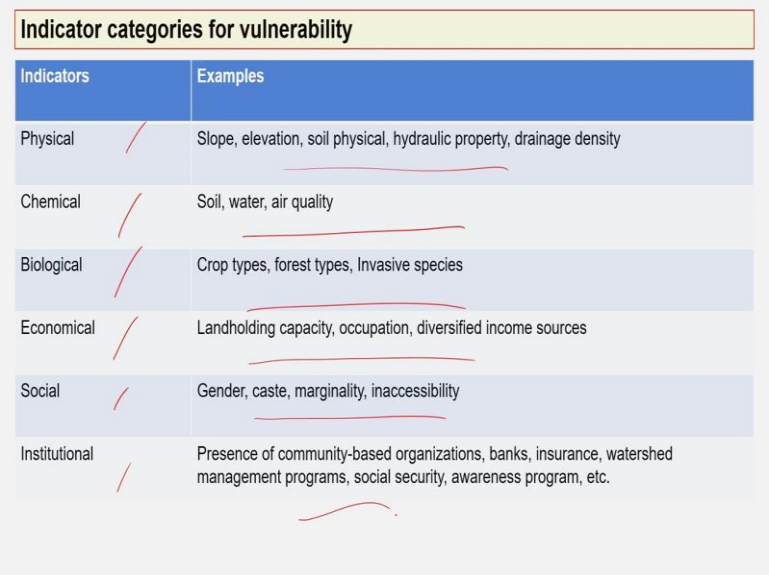

Then categories of indicators for vulnerability assessment also we have discussed. Various categories and the examples of vulnerability from which sector which indicator you should use that also have discussed.

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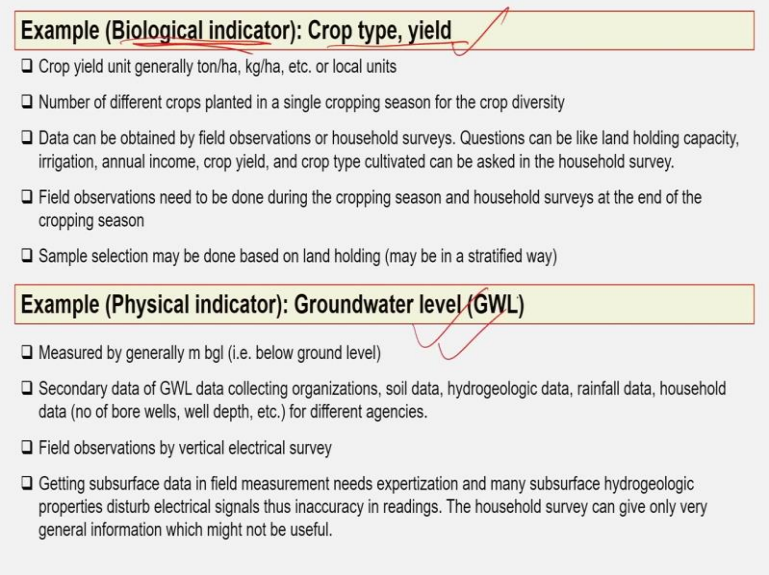

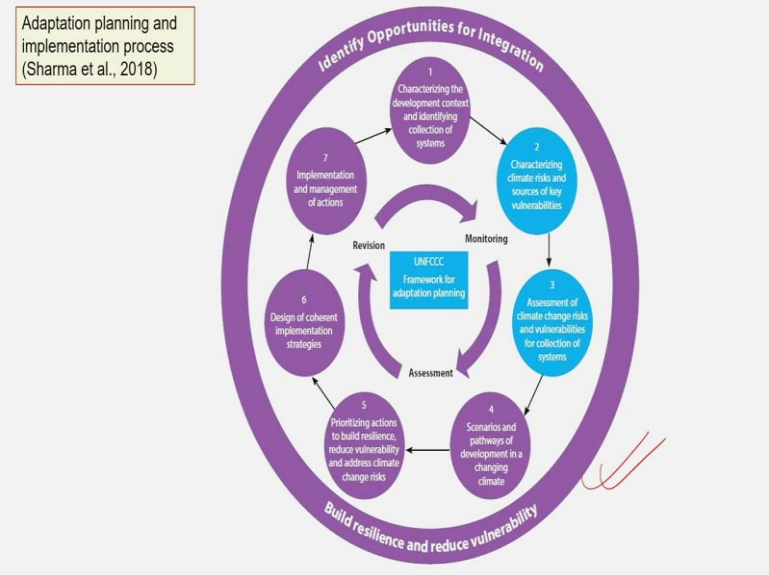

We have discussed each one of those indicator with real example. Then, we discussed about the adaptation planning and implementation process once you understand the indicator, through indicator you identify the vulnerability of a particular sector of a people or location, then you come out with some 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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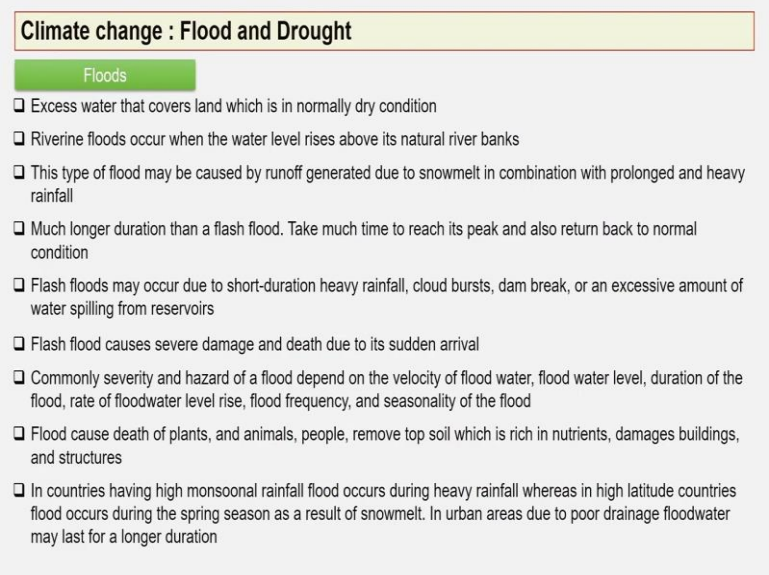

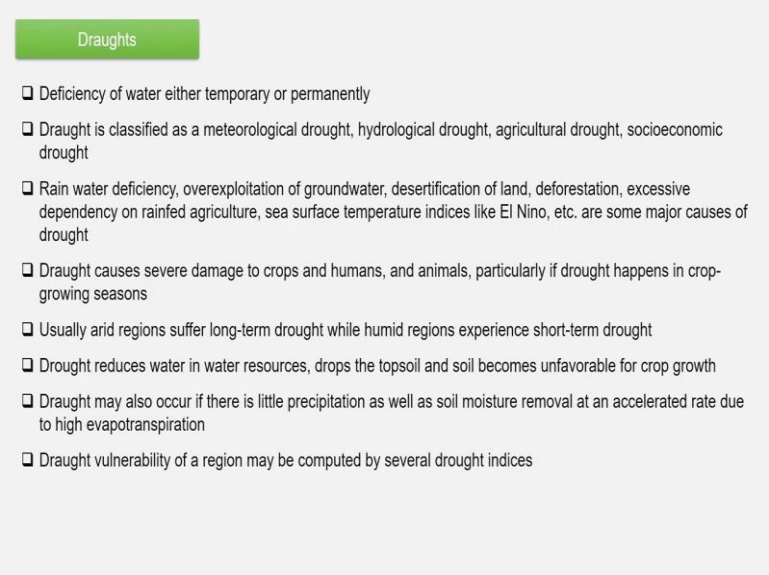

And to do that, if you take one example of floods, then we discussed that how in case of flood, you can actually carry out adaptive exercise, how people adaptation can be built or resilience can be built.

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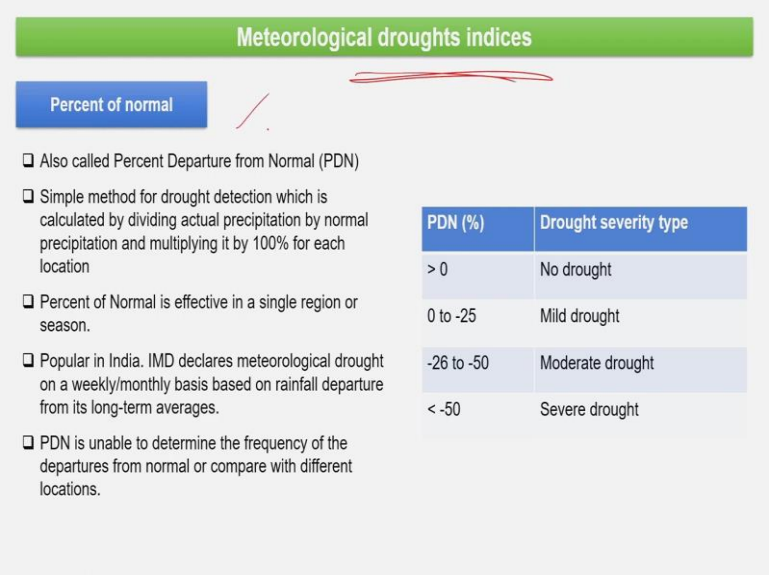

Meteorological droughts indices

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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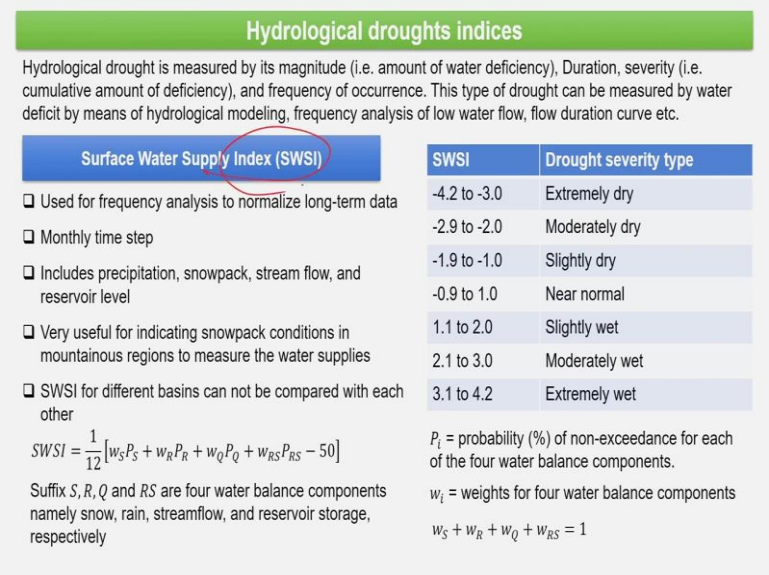

So, to understand this flood or drought situation, there are various kinds of indices which help us to understand the severity of drought or flood that also we have discussed. We discussed about meteorological drought indices. And then we talked about various methods of calculating or analyzing meteorological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

After meteorological doubt 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.

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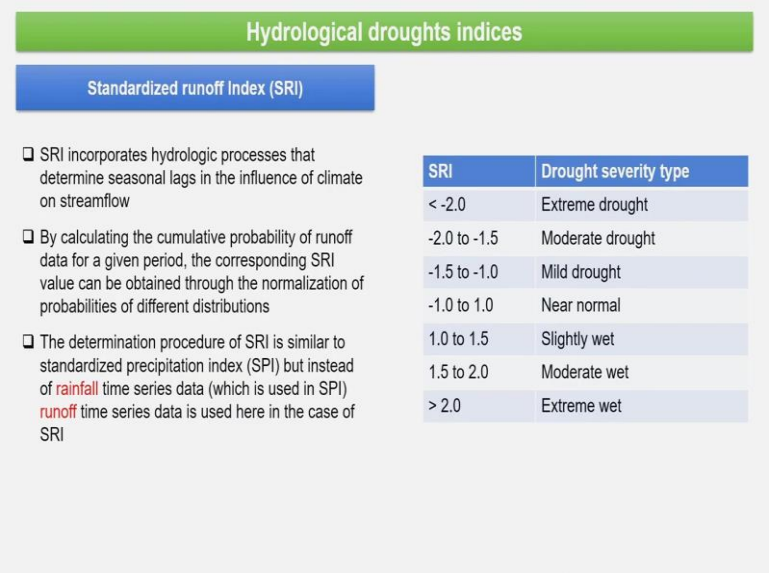

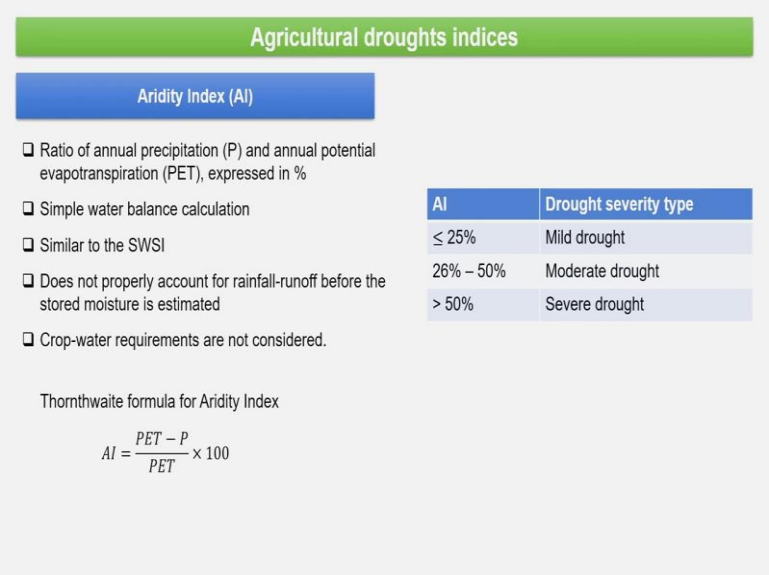

So, after meteorological drought indices then hydrological drought indices and then finally, we discussed about agricultural drought indices. So, these three actually looks at drought in a different way and they are level of severity analysis also differs from each other. Well, then after these vulnerability 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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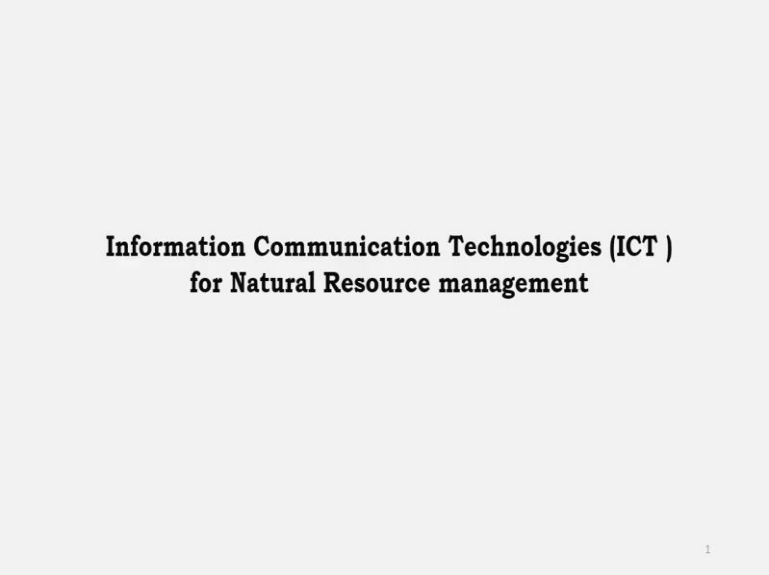
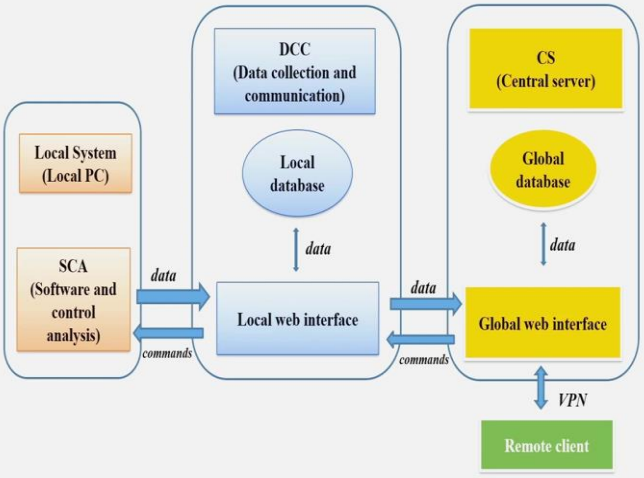


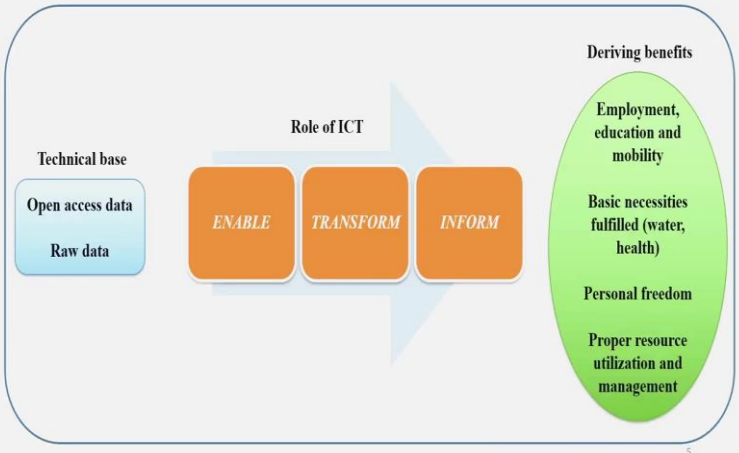
Components of ICT

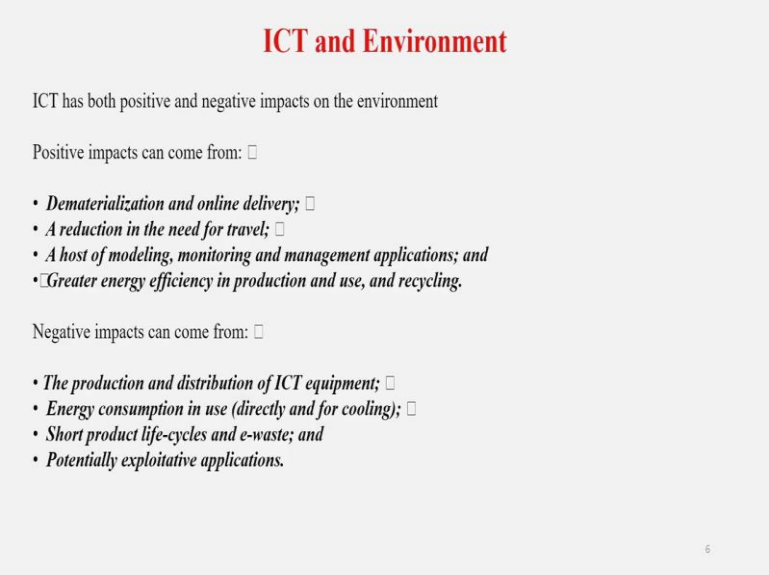
- DATA: raw facts and figures.
- HARDWARE: physical components.
- SOFTWARE: the name given to computer programs.
- INFORMATION: data that is converted to give it a meaning.
- PROCEDURES: a series of actions conducted in a certain order to make sure the system runs smoothly.
- PEOPLE: data is entered by humans, for example a keyboard.

Data flow in ICT



Data flow in ICT: a sustainable framework





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.

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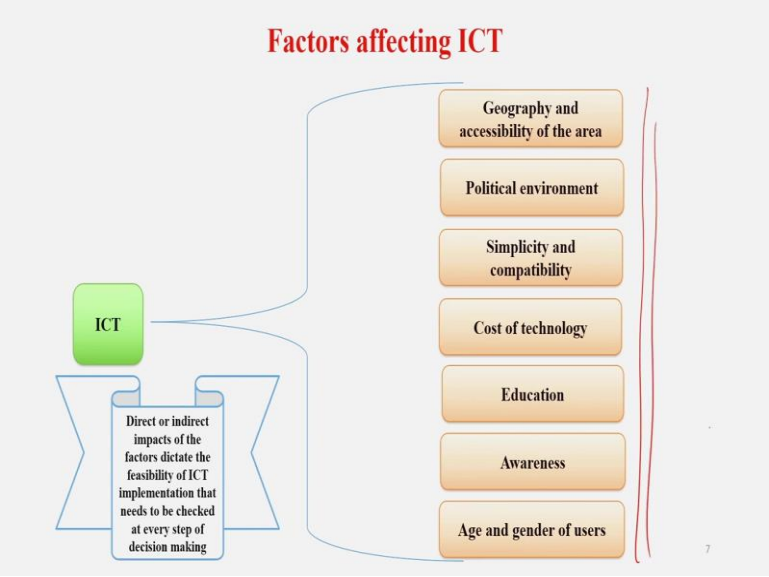


ICT in Natural resources management

• 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.

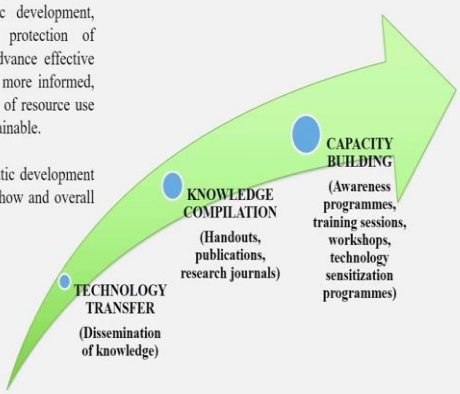
• To better understand trends and causal relationships, it is necessary to combine data from different sources. Doing this requires the development of standards and protocols for describing phenomena, as well as quality control to ensure that the knowledge that results is based on facts.

• 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

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.

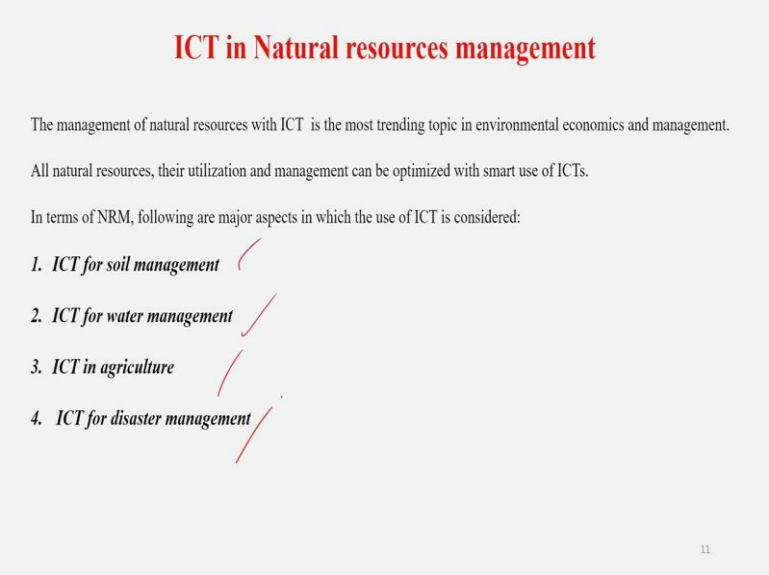
Its significance in ICT lies in a schematic development of knowledge building, technical knowhow and overall sustainable management



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.***



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.

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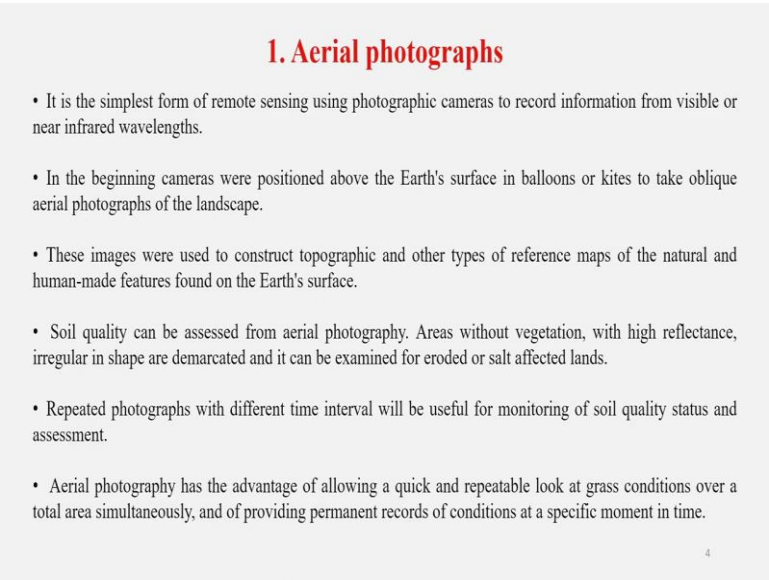

1. Aerial photographs

• 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)

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.

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.

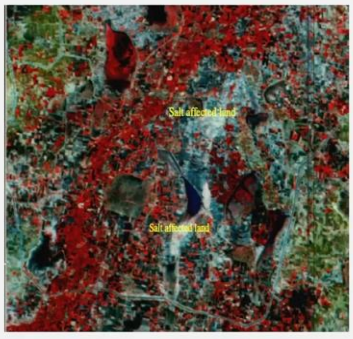

Fig: Satellite imagery of salt affected lands Chamrajnagar District, Karnataka (Source: Rajan and Meena, 2012)

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.

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.

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.

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.

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) analyis of these collected measurements.

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

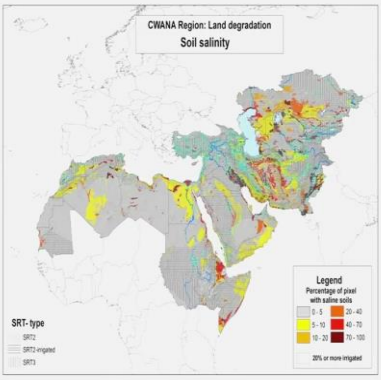

Fig: A typical GIS map showing Soil Salinity. (https://geoagro.icarda.org/en/cms/category/maps/13/regional/1/title/DESC)

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.

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.

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.

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.

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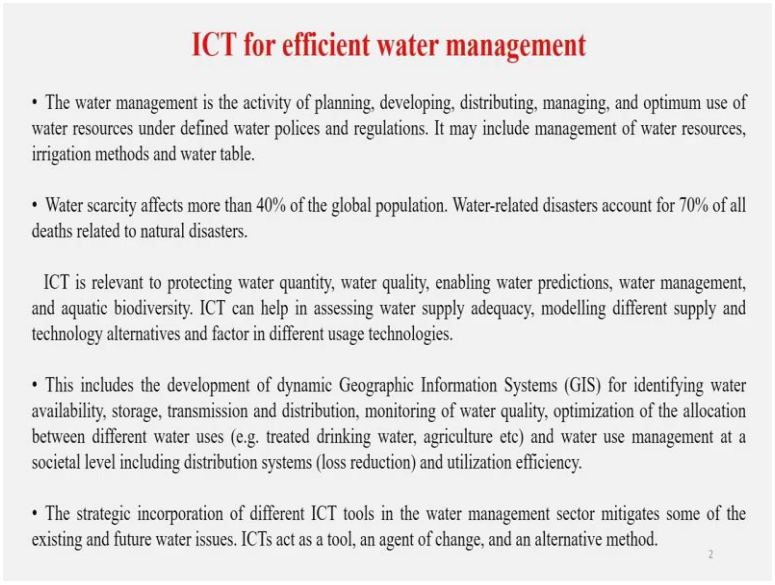

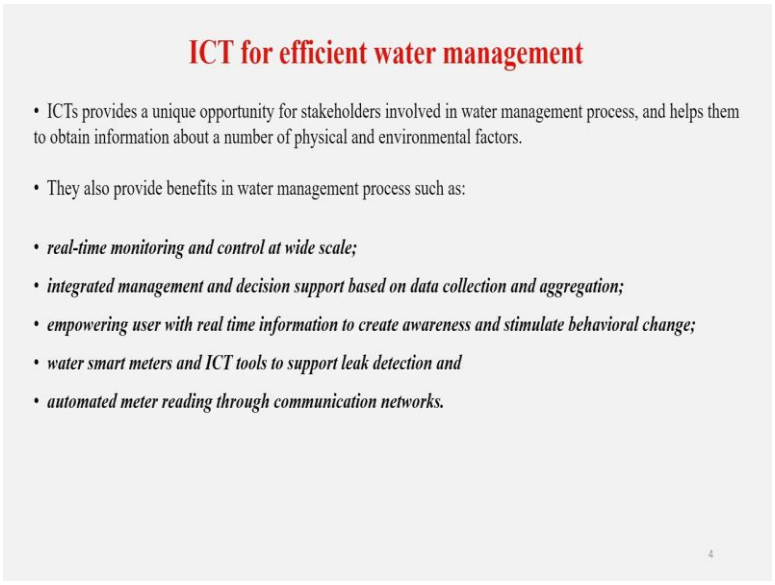

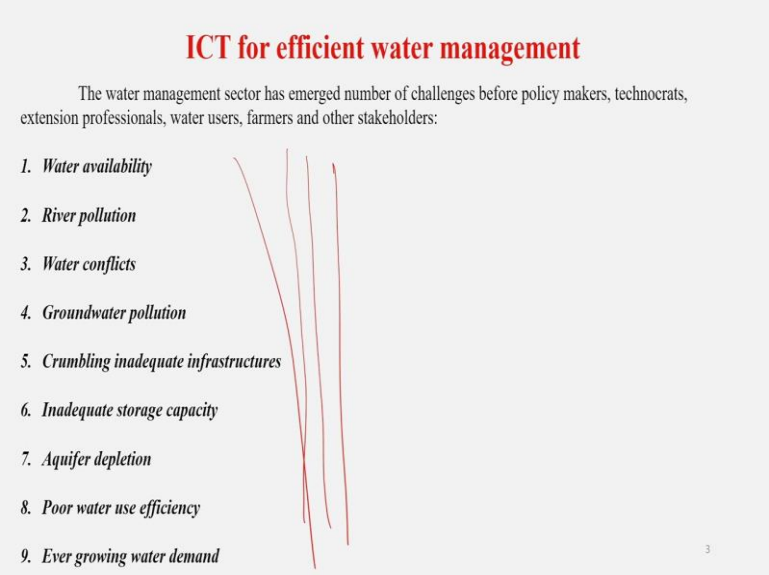

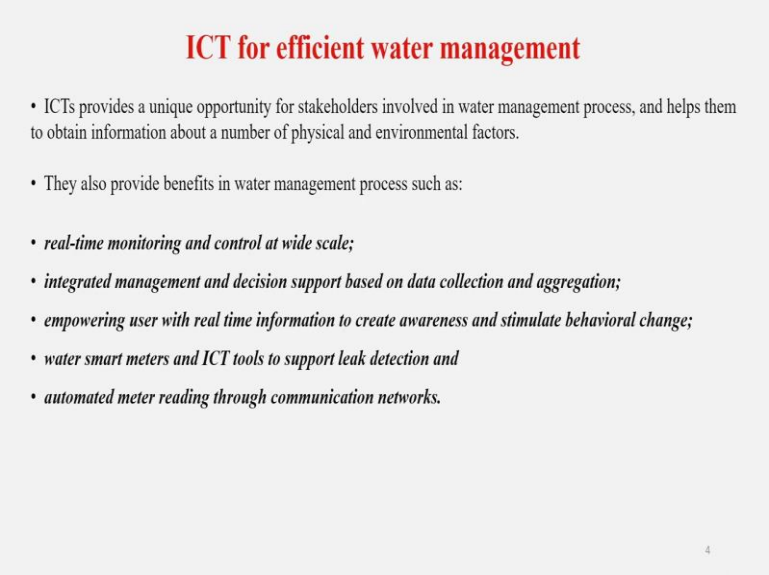

So, and on that actually the last topic that we discussed in this MOOC course was the ICT for efficient water management and we looked at the various aspects associated with water management and how information communication technology basically can help to manage water, looking at all these various 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.

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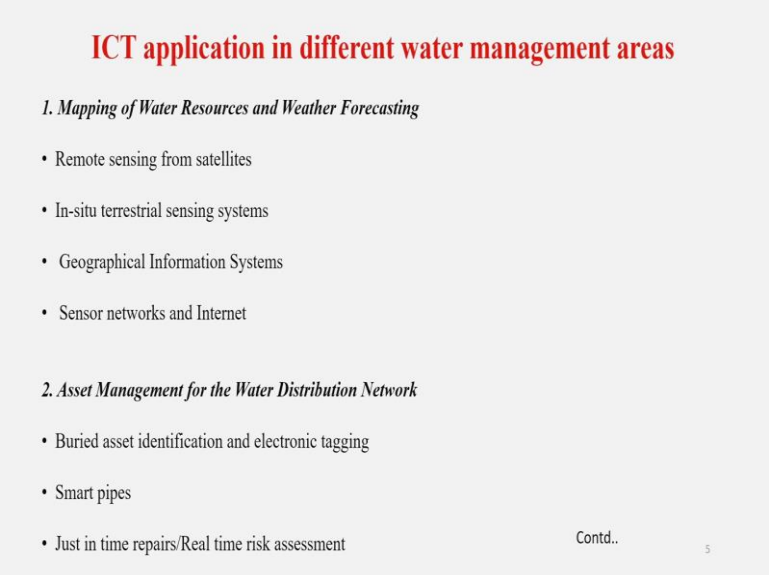

Application of ICT for different water management areas also we have discussed.

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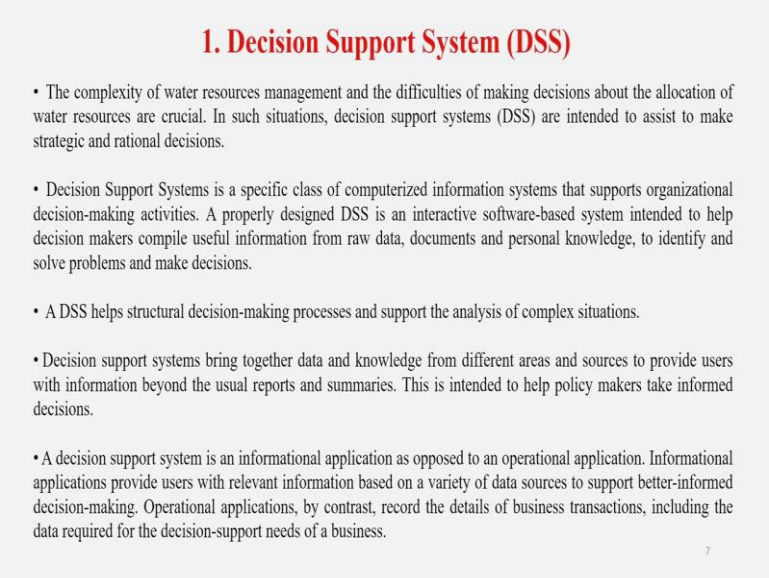

And then we talked about that how DSS which is an important part of ICT decision support system, how it helps in water management.

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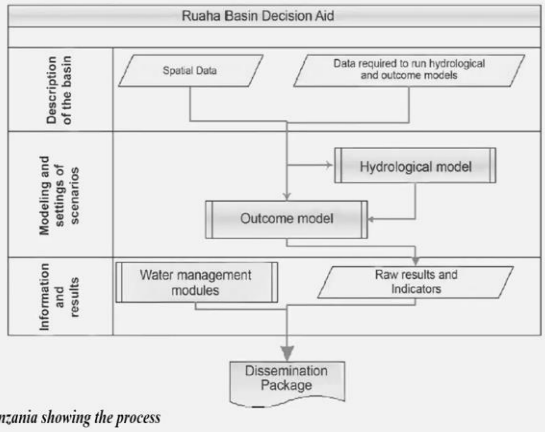
1. Decision Support System (DSS)



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

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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.

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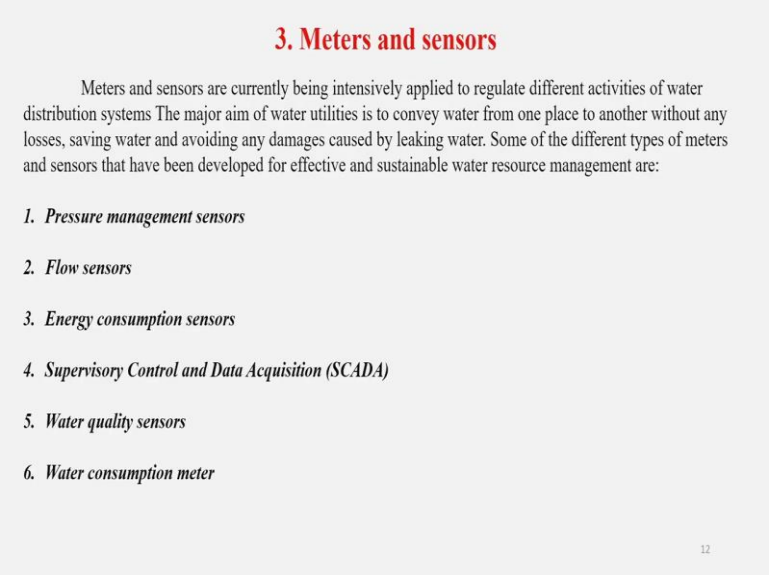

We talked about the framework of a standard DSS, GIS and its role in water management meters and sensors.

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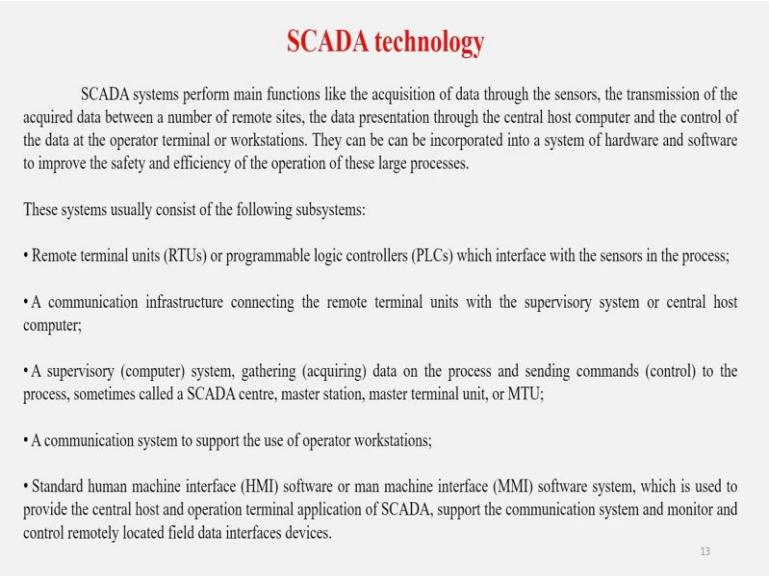

4. Hydraulic models

• 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.

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.

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***

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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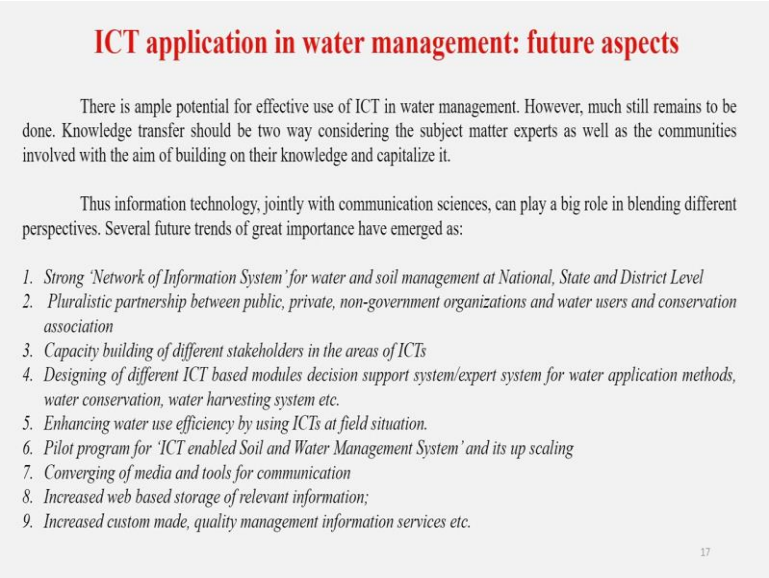

So, overall ICT is role in water management is great. Infact, even the future planning exercise for water management also can be carried out utilizing ICT, we discussed about that. And that actually bring us the end of the all the topics or modules that we wanted to discuss about.

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.