Natural Resource Management (NRM)
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Lecture - 62
Information Communication Technologies (ICT) for Efficient Soil Management

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This lecture we will discuss about Information Communication Technology and its application for efficient soil management. Soil management, as you know, as you understand that one of the most critical aspect of food production, agricultural management, and food security per se. And soil is again one of the most important natural resources and we in this lecture would see that how information communication technology (ICT) can be utilized for efficient soil management.

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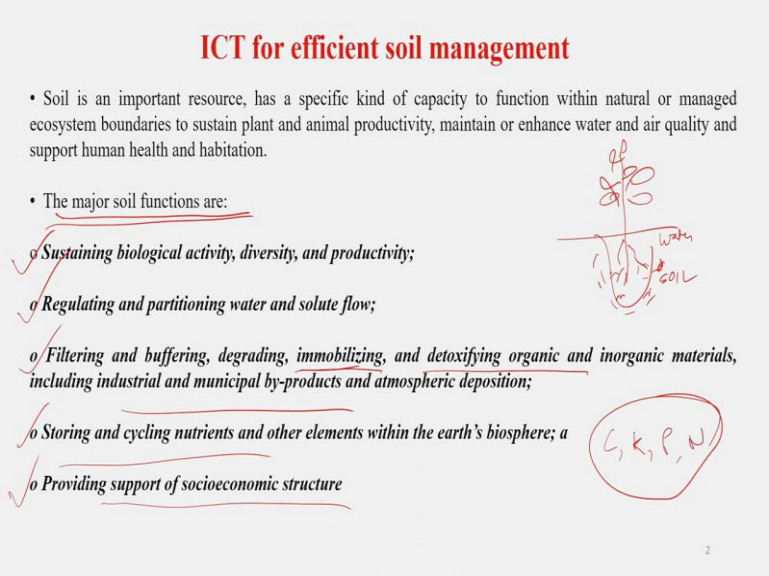

Now in the introductory lecture of ICT, we have already seen that ICT has different kinds of you know, beneficial uses in different aspects related to natural resource management. Now we all understand that soil as a natural resource has a specific kind of capacity and also function, and it provides basically all the nutrients that require for us, for any living organisms.

And the food that we are intaking that food you know, get all kinds of nutrients and energy basically from soil. So if soil is not maintained properly, certainly the entire nutrient ecosystem will be disturbed. So let us see that what are the major functions of soil, and then we will see how ICT actually can help in managing those aspects.

Now first- sustaining biological activity, diversity and productivity. Because in soil we have you know million-trillion of organisms residing there. Many of them are bacteria, fungus, actinomyces, etc. They not only actually maintain the ecological diversity, the soil ecological diversity, but also play a very important role in food production and productivity. These organisms in the soil also play a very important role in the nutrient cycling. You know that carbon cycling, phosphorus cycle, potassium cycle, so they play a very important role.

Next role that soil plays is regulating and partitioning of water and solute flow. Now we know that when in soil, when there is a plant, you know, so this plant gets all nutrients through its root from the soil.

Now to regulate this water and solute near the rhizospheric region, again that also being regulated by soil.

Next soil is a great buffer. So filtering and buffering, then degradation of certain unwanted element, compounds, chemicals, immobilizing some of the bad elements into the soil so that they are not becoming available to plants or organisms, detoxifying organic or inorganic material which are not beneficial for you know living organisms including us, industrial and also municipal by-products and various atmospheric deposition on the soil is also being filtered. So soil is a great buffer for our ecosystem.

Next, storing and cycling of nutrients. As I just mentioned, we have carbon cycle, we have potassium cycle, phosphorus cycle, nitrogen cycle; all these you know nutrient cycling are going on and soil play a major role in running this you know, nutrient cycling.

Soil also provides support for socio-economic structure. How? Through helping to maintain productions. Food production, crop, grain various kinds of plants on which the livelihood of many people are dependent.

So if soil quality goes wrong, then your entire production system will go wrong and then it will affect your livelihood. So the entire social, dynamic socio-economic structure might get affected. Now, these are the important aspects of soil.

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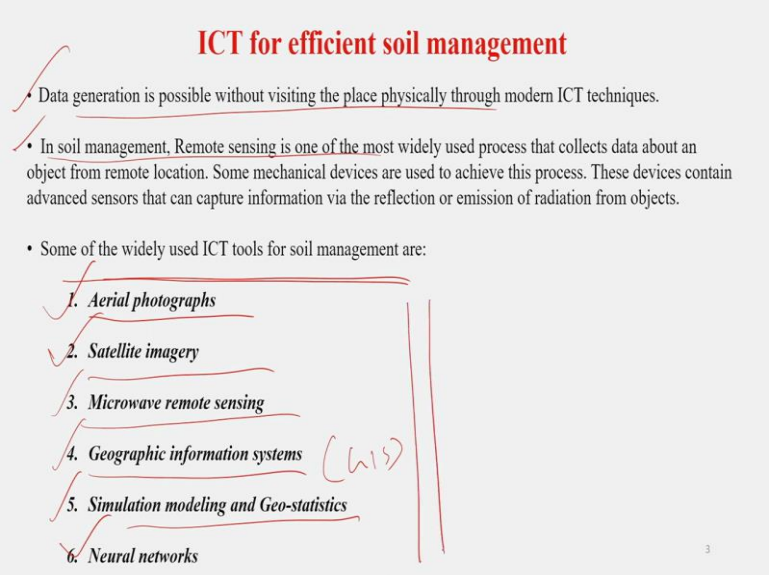

Now how ICT can help in maintaining or managing this important natural resource? We need lot of data and information. By now we know that for good management of any resources, good quality of information and data is of primary importance.

Now data integration is possible through ICT without visiting the field. We know that when we discussed about remote sensing, GIS technology. You need not to go to the field. You can actually do it sitting at your classroom or office. So that also comes under ICT.

Now in case of soil management we already in the remote sensing lecture we have seen that how remote sensing can help in managing soil and plant, and also water. So through this technology we can get data from various locations without visiting that particular site.

Now, let us see that what are the some important uses of ICT tool for soil management. Number one, aerial photographs that we talked you know in remote sensing lectures. So the aerial photograph is very important.

Satellite imagery, where we talked about various spectral images. Microwave remote sensing, we discussed about that. GIS we have also discussed about this aspect. Simulation modeling and geo statistics. We talked about simulation modeling aspect as well.

Neural networks also you know these days people are using for natural resource management including soil, water and all other important resources. So these are some of the widely used purposes of ICT tool.

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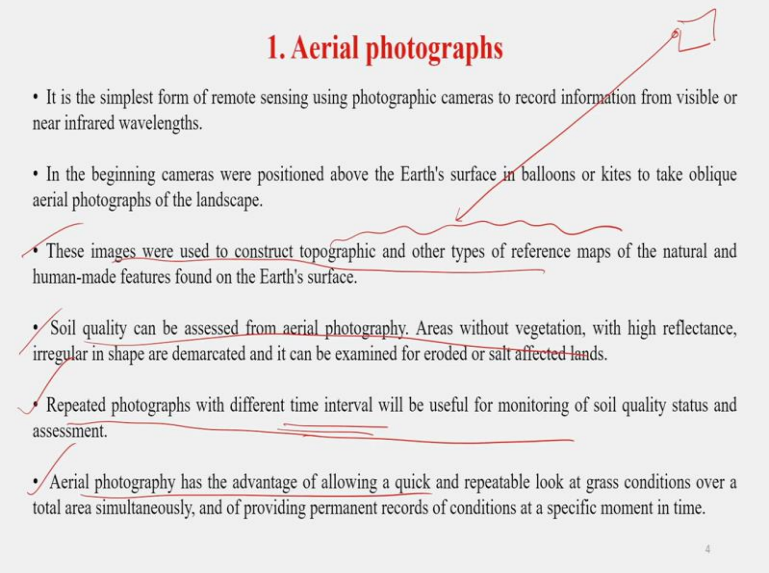

Now we will go with a few you know aspects of each one of these six uses of ICT tool just to give you an idea that how actually it is being used. The aerial photographs, we already discussed that it is one of the simplest form of remote sensing.

You take an aerial photograph of an area and then that information goes into the satellite and from satellite it comes into the hub, gets interpreted. So what actually is done is that the cameras for this kind of aerial photography or position above the earth surface in balloons or kites to take you know oblique aerial photographs of the landscapes.

So suppose your camera is somewhere here with aperture and it will take the surfaces here, it will take the picture in this way, and then it passes to the satellite and goes then finally to the hub. So these images actually were used to construct topographic or other types of reference maps of natural resources including soil.

Soil quality can also be assessed through aerial photography, especially areas without vegetation with high reflectance. We talked about this in remote sensing lecture. So even irregular shapes also can be identified, it can be examined. So all these information are useful for maintaining soil.

Repeated photographs with different time interval is very useful for monitoring soil quality and its assessment because of same location. If in different time interval you take picture, you can understand that how over a period of time the changes in the soil is taking place.

Also the aerial photography has advantage of allowing a quick and a repeatable look at grass conditions of any area and it also provides permanent records of conditions of a specific area

for a specific time. So though this technique of aerial photography is simple in nature but it is very handy when you try to assess the soil, soil quality, and the conditions of the soil.

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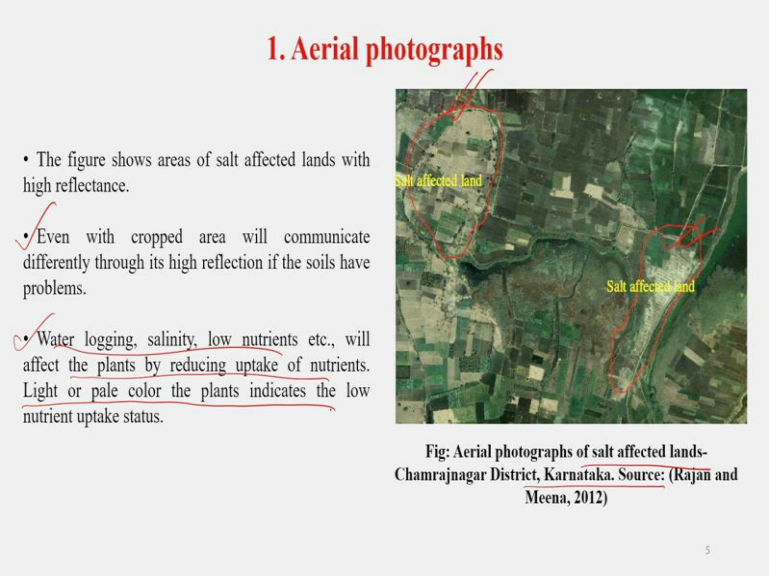

So this is one aerial photograph of salt affected lands in Karnataka. So as you see that this is the salt effected area. So the color is definitely is important to understand the area. So this picture shows the salt affected lands with high reflectance. So even the cropped area sometimes will communicate differently through its high reflection, if the soils have any problem.

Water logging, salinity, low nutrients, these are all soil related problem. This will definitely affect plants by reducing the uptake of nutrient from soil into the plant. And how you can get it? Through aerial photograph, you will find that light or pale color picture of plant and that will indicate low nutrient uptake status.

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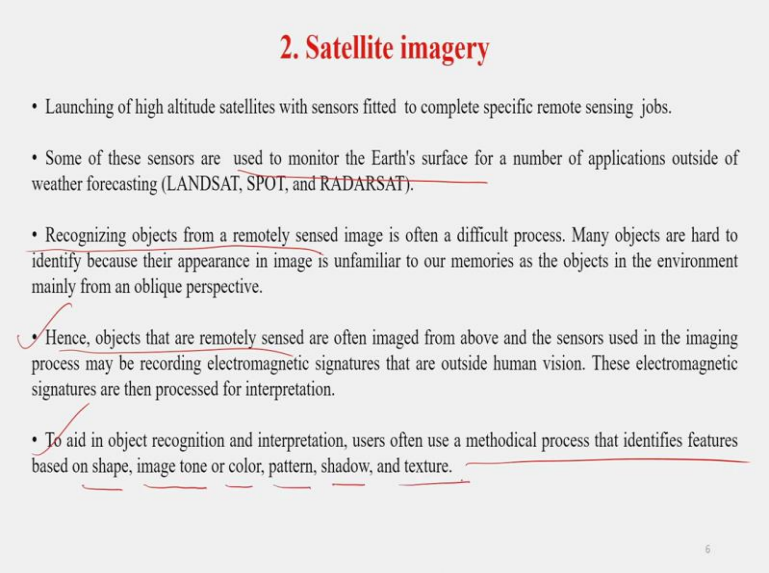

Second, satellite imagery. We talked about this in remote sensing in great detail but how for soil it helps. So satellite imagery, high altitude you know, satellites it helps to take pictures through sensors and some of these sensors are used to monitor you know the earth surface for a number of application apart from weather forecasting. Land use is one of them.

Then soil color will tell you the nutrient condition of that particular area. Recognizing objects from a remotely sensed image is often a very difficult process and it requires skilled manpower to understand that.

Many objects are very hard to identify. The reason is that they look in the image you know unfamiliar to our old memories or the objects that we actually see through our eyes in the environment. But when we see the same picture of that same area because of its you know capturing angle and other filtering process, these pictures may look a little different. So the interpretation of the picture satellite imagery has to be done by a skilled person.

Hence, objects which are remotely sensed are often you know, pictures taken from above and the sensors which are used in taking this imaging process may be recording electromagnetic signatures that are outside our vision. And these electromagnetic signatures are then processed for further interpretation,

So to help in object recognition, the object that in the photograph that satellite imagery that you find to help to recognize and interpret the users often use a methodical process which identifies the features based on shape, image tone, color, pattern, shadow, and texture.

So based on these properties, a skilled person, a trained person can actually tell you the ground reality. Now this also in remote sensing lecture we discussed but here I am giving an example of soil.

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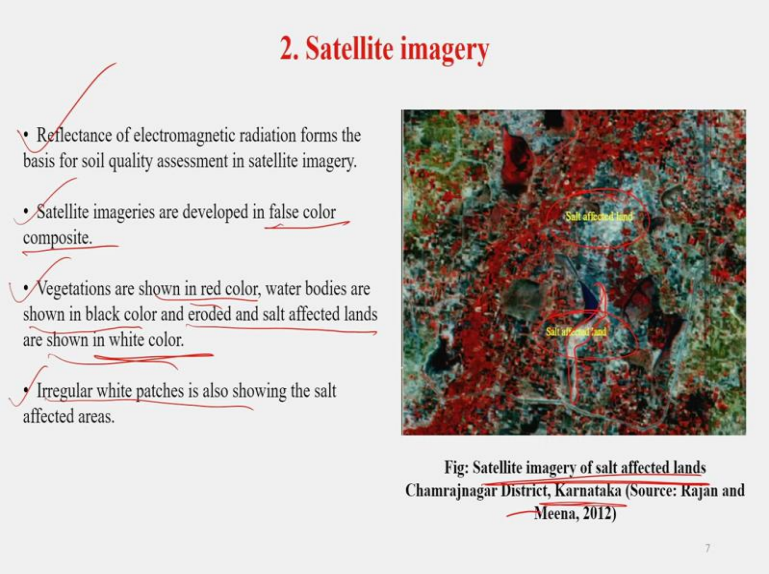

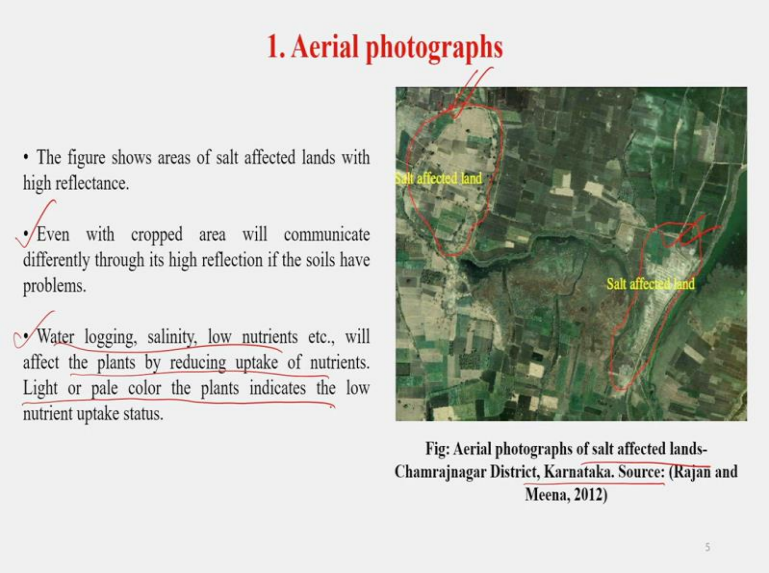

Now satellite imagery of salt affected land of the same area, the area that we just saw here. This is a simple aerial photograph and this is a remote sensing image. See the differences of salt area coming here. So the reflectance of electromagnetic radiation basically forms the basis for soil quality assessment in case of satellite imagery.

Now satellite imageries we know that they are developed in false color composite. That we discussed in remote sensing lecture. Now vegetation in case of remote sensing imagery, it

shows in red color; green vegetation in red color, water bodies shown in black color, eroded and salt-affected lands are shown in white color.

Now to understand these things, one also need to cross-check with the ground truth but an experience trained person with imagery processing knowledge can actually easily identify these properties.

Irregular white patches are also showing the salt affected areas as you see here. Now this need to be cross-checked also validated from with the ground truthing because sometime you may mix up with some other aspect or other object.

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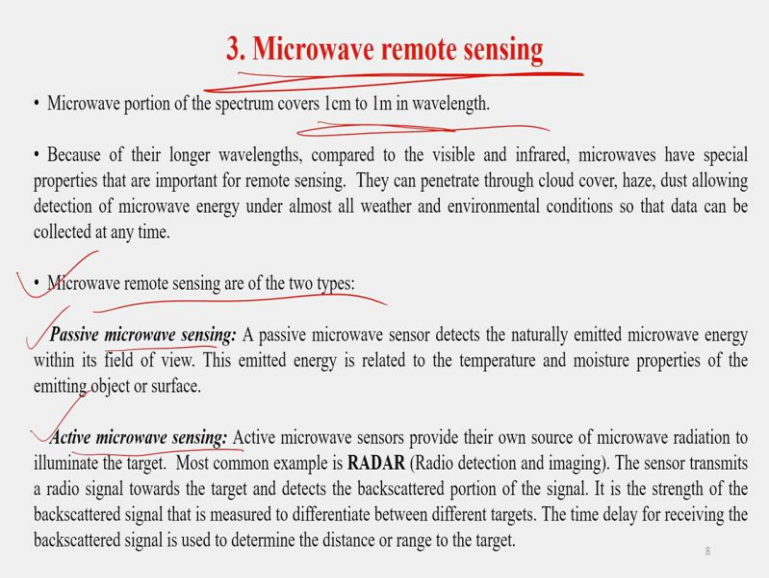

Microwave remote sensing. We discussed that in the remote sensing lecture but how is soil management it helps? So microwave portion of the spectrum covers you know 1 centimeter to 1 meter in wavelength and because of their long wavelength compared to visible and infrared, microwaves have special properties that are important for remote sensing.

The reason is that they can penetrate through cloud cover, haze, dust, and that is how they allow detecting the conditions of weather, environmental condition throughout the day. Now microwave remote sensing things are generally of two types. One is passive microwave sensing and another is active microwave sensing. So these things we have discussed already in remote sensing.

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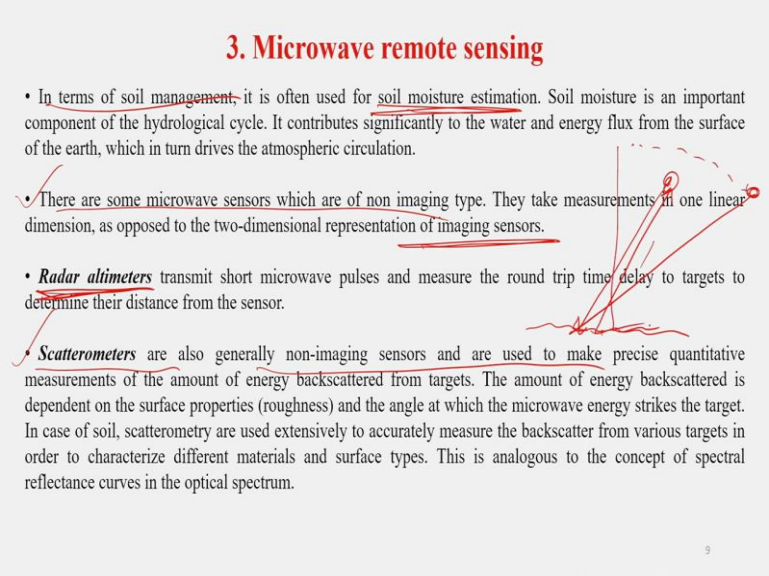

Now coming to the soil management aspect using microwave remote sensing. This is often used for estimating soil moisture which is a very important component of the hydrological cycle, and it contributes significantly to the water and energy flux from the surface of the earth, which in turn you know effect the entire atmospheric circulation and thus the climate of a region, of the country. So that is how soil moisture is critical. Microwave remote sensing help us to assess the soil moisture condition.

There are some microwave sensors which are of you know non-imaging type and what they do? They take the measurements in one linear dimension as opposed to the two-dimensional representation of imaging sensor.

Now we have another type of equipment- radar altimeters. Now these radar altimeters, they transmit short microwave pulses and measure the round trip time delay to target to determine their distance from the sensor.

So radar altimeters help us to understand the distance between the sensor and the target object on the ground because the satellite is moving continuously. So at what time and how far that particular satellite from the object is that radar altimeter can helps you to measure.

Now then we have scatterometers which are generally non-imaging sensors and are used to make precise quantitative measurements of the amount of energy that is back scattered from the targets.So you have here satellite and this is your earth surface. It comes here then it also goes back. This backscattered imagery or the signal, coming from the surface is actually measured by scatterometers.

The amount of energy that backscattered is also dependent on the surface property of the earth, and also the angle at which the microwave energy strikes. Suppose from here it is striking. After some time if it is from here, then it will be more, the angle will be less.

So as it move here, so angle will be much higher. So depending upon that angle of inclination also there can be change in the backscattered energy. So, scatterometers helps in measuring that.

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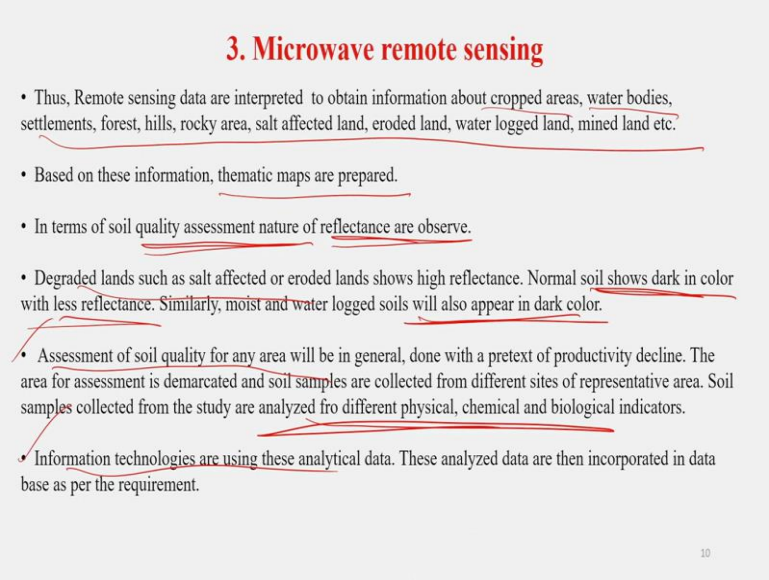

So remote sensing data are generally interpreted to obtain information about crop areas, water bodies, and all these things as mentioned here. Based on you know these information; thematic maps are prepared which we discussed in the remote sensing lecture if you recall.

In terms of soil quality assessment, nature of reflectance are normally what we do is that suppose in case of degraded lands such as you know salt affected or eroded lands, they show high reflectance and you get to see white patches as you saw in the remote sensing picture here.

So in this case what happened is that degraded lands, they show high reflectance, normal soil dark in color with less reflectance. Similarly, moisture or waterlogged soil will also appear in dark color. So from these color differences, one can identify the problem.

So assessment of soil quality for any area will be in general done with the pretext of productivity decline means ultimately it is linked with agricultural crop productivity. The area of assessment is demarcated and soil samples are collected from different sites wherever you have gone or you have marked your experimental site or your target area.

Soil samples will be collected from the study area, analyzed for different physical, chemical and biological indicators. Now that information you can actually put also when you prepare the GIS map. So you can also with the help of remote sensing and GIS, you can actually bring in much more information in the final outcome in the form of different map using different thematic layers.

So information technology or ICT often used these analytical data that just mentioned here and these data are then incorporated in database and then used for different purposes for managing soil.

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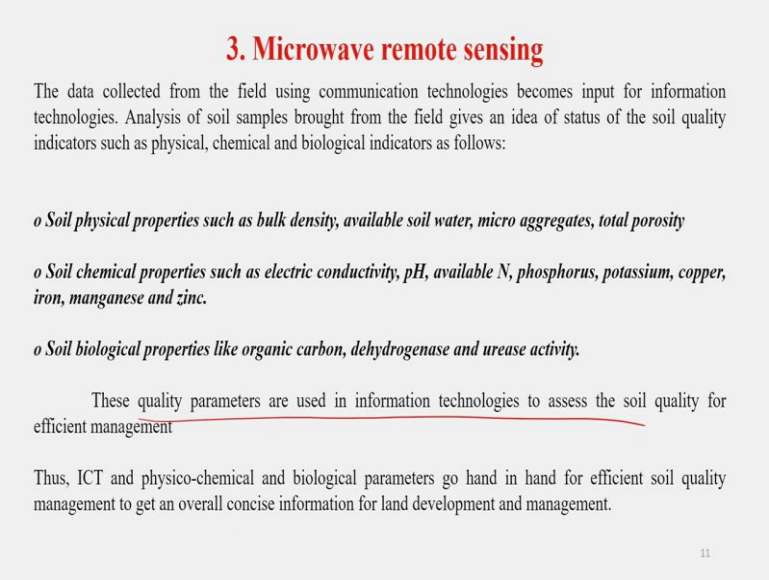

So again microwave remote sensing, it helps you know collecting various data information coming from the microwave imagery, analysis of soil samples from the field. This also gives an idea of the real status of the soil and then its different aspect of the soil.

Once those things are there, soil physical, biological and chemical properties, then you actually incorporate all those properties along with the imagery that you have already captured, and these quality parameters, you know, are often used by these ICT tools to assess the soil quality for efficient management.

And that is why ICT and physico-chemical biological parameters can go together hand in hand for efficient soil quality management and to get an overall idea about a particular location. So together remote sensing, microwave remote sensing, and the field-level sample collection, analysis of various properties can be very useful for efficient soil management.

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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.

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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

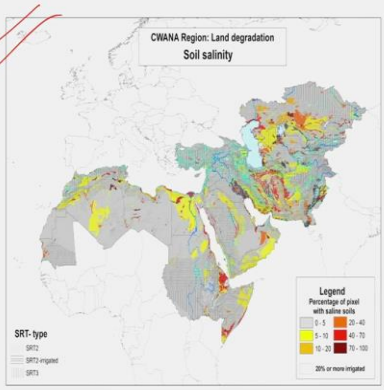

Fig: A typical GIS map showing Soil Salinity. (https://geoagro.icarda.org/en/cms/category/maps/13/regional/1/title/DESC)

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Next come, GIS. Again in remote sensing GIS, we talked in great detail about that. So straightaway, I would like to go that what are the different uses for soil management through GIS.

We know that GIS helps us in representing various information through various thematic layers. So you see that this is a map showing soil salinity and this provides comprehensive knowledge about the soil quality and different indicators that are used. And basically, it helps policy makers and the experts to understand that where, how much soil problems are existing, so that is how it helps in maintaining or managing soil.

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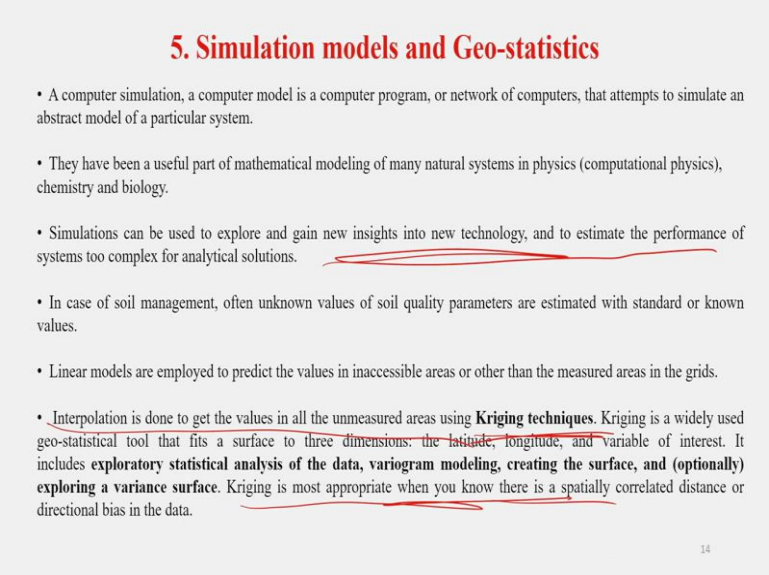

Simulation models and geo-statistics models we have discussed in great detail in previous lecture. Geo-statistics also, you know, often these days used within even GIS platform. Basically computer simulation, computer modeling, we use to understand various kind of phenomena, physical phenomena, chemical phenomena in the soil, and often we also use different kinds of mathematical modeling to understand various functions, phenomena happening in the soil.

Simulation also can be used to explore and gain new you know insight into a new technology and to estimate the performance of a very complex system. In case of soil management, what happened that there are many unknown properties or values of soil quality parameters which actually sometimes are estimated with standard or known values. So you have some standard or a particular property standard value and then you estimate your own sample.

Now interpolation technique is also used some time to get the values in all unmeasured areas and for that we use a technique called Kriging. This I also have discussed in the remote sensing GIS lecture. So I will not repeat it here.

But Kriging is most appropriate remember, when you know that there is an especially correlated distance or directional bias in the data. So that time actually Kriging can actually help you to understand the area much better.

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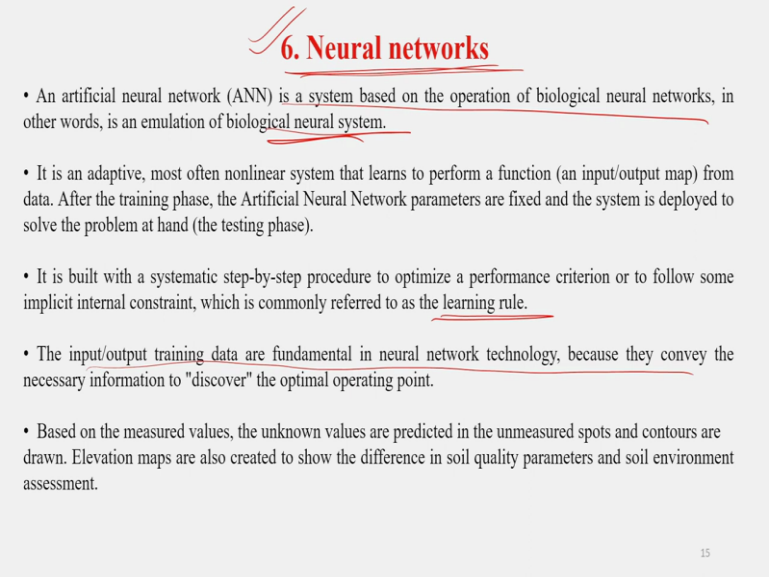

Neural networks, well these days there are different kinds of uses of neural network. An artificial neural network is a system on the operation of biological neural networks. In other words, you can say that it is an evolution of biological neural system and it works in almost in similar pattern.

So it is built basically with a systematic step-by-step procedure to optimize a performance criteria or to follow some internal constraint, you know, which is commonly we refer to as learning rule.

So in this case, the input-output training data are very much fundamental for neural network technology because these you know data convey the necessary information to discover the optimal operating point.

Because if you are going to use neural network for soil maintenance, soil management, you need to know you know the optimal operating point because that will actually help you to carry out a meaningful exercise.

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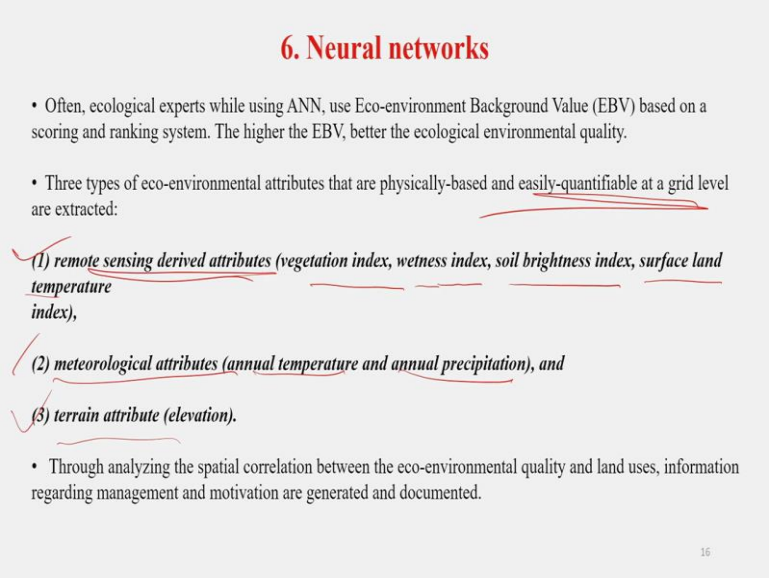

Now neural network are three types: eco-environmental attributes that are physically based and easily quantifiable at a grade level using ANN and these are remote sensing derived attributes which we earlier talked about- vegetation index, wetness index, soil brightness index, surface land temperature index.

Then metrological attributes- annual temperature, annual precipitation; and then we have terrain attribute means, the elevation, and the height. So this information also helps or we call it eco-environment background values. So this helps actually your neural network to work in much more meaningful manner.

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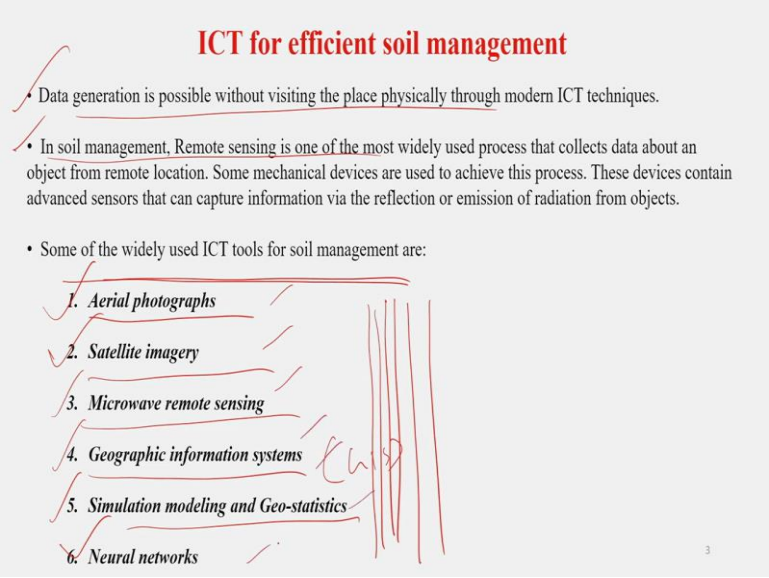

So with this actually we end this particular topic of utilizing of various kinds of ICT, you know, uses and in maintaining the soil in a effective manner. So six different widely used ICT tools that we have discussed in this lecture and individually we have seen that how they could be used for better management of soil as a natural resource.