Remote Sensing: Principles and Applications

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Lecture No -30
Spectral Properties of Few Common Earth Features in the Visible, NIR and SWIR Bands – Part 4

Hello everyone, welcome to the next lecture in the topic of spectral reflectance curve of few commonly occurring Earth's surface features. Till last lecture we discussed in detail about the spectral reflectance curve of vegetation, the factors that influence it, red edge and also what other factors may influence the final reflectance that we obtain from a remote sensing sensor. In this lecture, we are going to start with the spectral reflectance curve of soil, which is another one of the most abundantly occurring features on the Earth's surface.

The spectral reflectance of soil is a very simple curve. It is not as complex or it will not have any kind of a complex dips and peaks as it of vegetation. An example is given in this particular slide.

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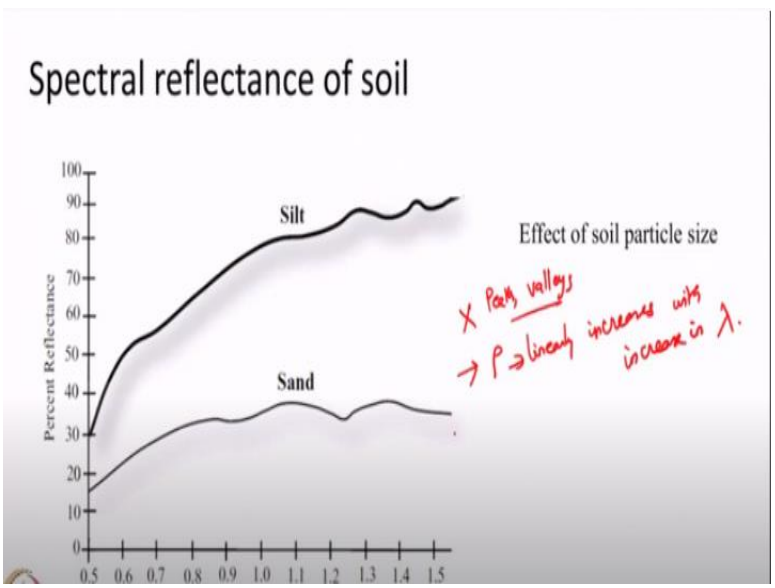

So, if you look here, in general, the reflectance curve of soil may not have lot of peaks and valleys that we observed in the reflectance curve of vegetation. These characteristic features will be absent. Also one more thing, we may notice that the reflectance in general linearly increases with increase in wavelength. That is as the wavelength increases the reflectance increases.

There may be some ups and downs but not as sharp as vegetation and also high dips may not be there. It is gradually increasing curve. So, this is how the reflectance curve of soil will look. So, what are the different factors that may affect the spectral reflectance curve of soil?

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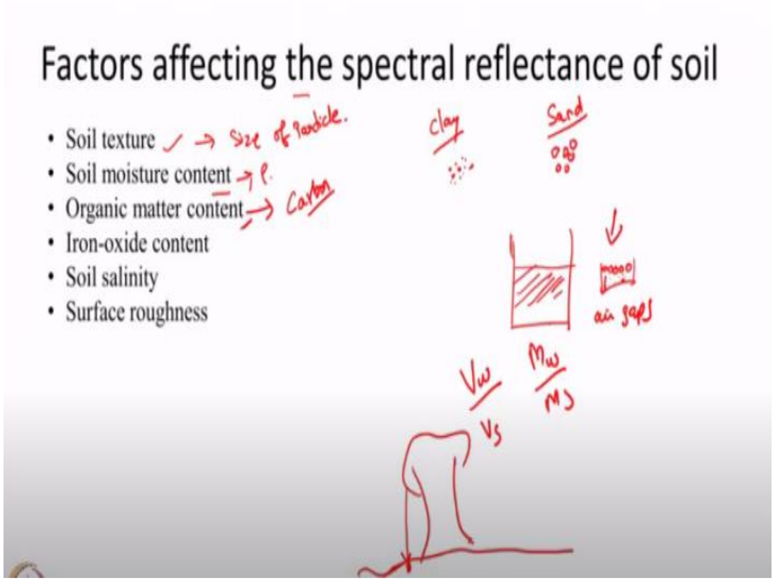

The major factors that affect the spectral reflectance curves of soil is the soil texture. So, soil texture generally means the size of particle in soil. Some soils may have very tiny particles say for example, if you take clay, clay may be made up of lot of tiny soil particles that are closely packed together. On the other hand, if you take sand in beaches, it may have slightly larger particles with larger air gaps in between them. So, how the soil texture is, whether it is rough or smooth, whether it has large grain particles or whether it has small grain particles or so on. It will affect the reflectance.

The next important property of the soil that will affect the reflectance is the moisture content. Let us say this is a small vessel in which we filled soil to some extent. So, whatever be the soil is, there will always be a mix of soil particles plus some air gaps. So, whenever we pour water over this or whenever it rains then naturally the air gaps between the soil particles will be filled with water. So, essentially we will be able to measure how much is the amount of water present within a given amount of soil. Be it volume of water to the volume of soil or mass of water to the mass of soil, we will be able to measure how much water is present within the soil column. That amount of moisture content will increase or will normally decrease the reflectance.

Then organic matter content, that is, substances that are rich in carbon. Say for example, this may be a land surface where a tree is standing. The leaves from the tree may fall down, decay, decompose and mix with the soil. There may be a lot of tiny organisms present in the soil which may die and decompose. Most of the naturally occurring substances are organic in nature. So, all these organic substances may finally fall on the soil, mixed with it or decompose. So, the amount of organic content present within a soil is going to affect this reflectance.

The next property which may affect the soil reflectance is the amount of iron oxide, that is presence of iron materials or ferrous materials. Some soils we may see having bright red in color, some soils may be black in color. So, the red soils typically have high content in iron oxide or any other iron content. So, those will affect the reflectance of soil.

Then soil salinity. Soil salinity is saltiness of the soil, that is, some examples we might have heard, when people do irrigation it is very normal to use groundwater for irrigation. We also know that groundwater is present underneath the ground which may have lot of dissolved minerals within it. Because under the ground we have a lot of minerals present in rocks, soils and everything. So, when water is there some of the minerals present in underground may get dissolved in the water. When we pump it, it may come to the land. We pour that water or we use that water for watering our crops. Similarly farmers may add some fertilizers, some pesticides etc, which may again contain certain minerals. So, they will slowly start settling down on the soil. Then the soil salinity or the presence of salts in the soil will begin to increase. So, this soil salinity also may increase or decrease the reflectance.

And finally the surface roughness. Let us say there is a smooth soil surface, like a barren land without any human activity. On the other hand a normal farmland, at the beginning of cropping season the farmer would have tilled or ploughed the land surface. When that happens and if you look at the land, the land will clearly have a lot of small ridges and valleys because of the ploughing effect which increases the surface roughness of the soil. So, all these factors both the physical and chemical, physical means soil particle size, surface, roughness, etcetera, chemical means presence of soil organic content, presence of salt in the soil etcetera, all these things will contribute to the reflectance of the soil that we observe either in laboratory or from remote sensing measurements.

So, now we will see the effect of each factor one by one. First, we will start with the soil particle size. In general, the reflectance of the soil will increase when the particle size decreases. For example we have two reflectance curves plotted, one for sand another one for silt. Sand has larger particle sizes. Silt has a much smaller particle size. So, when we plot this, soils with finer or smaller particle size will have a higher reflectance than soils with larger particle size. This is when done in proper laboratory conditions, where everything is finely powdered to its natural state observed under strict lab conditions.

In reality, in ground, when we observe sandy soil and clayey soil, clayey soil has very fine tiny soil particles. So, if we observe these two what will be our inference? Our normal observation is sand will look brighter to our eyes than fine textured clayey soil. But in the lab we are getting the opposite thing. This is because in reality such fine textured soil such as clay or silt, which has the capacity to hold lot of water will be forming aggregates. Aggregates means say for example, if you take clayey soil and if you pour water over it and leave for some time, they may come closer and form small tiny ball like structure. So, they may form larger soil aggregates, which will finally increase their net effective particle size. All these things may happen with soils having very fine particle size nature, example clay and silt. That is why in reality we may observe the contrary of what is observed in lab. So, in lab, under controlled conditions when everything is finely powdered to its natural state, the fine textured soils will have higher reflectance than coarse grained soils.

But in real life fine textured soil such as clay or silt may club together or may come together to form larger aggregates due to presence of water. They will form larger aggregates which will reduce their overall reflectance. So, in reality fine texture clayey soils may appear much darker to our eyes when compared to the sandy soils or soils with coarse grain texture. This we should always keep in mind. Our lab obtained curve may not be really valid in field especially in case of these fine textured and coarse grained soils.

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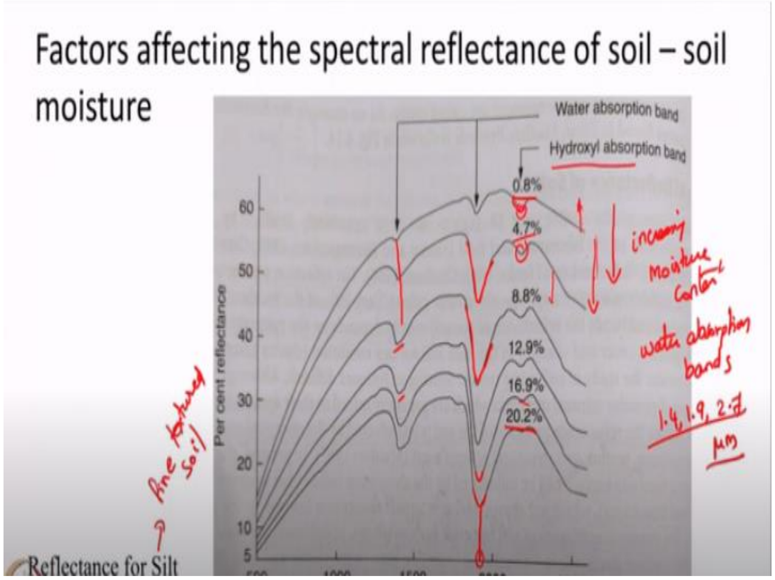

The next most important property that we are going to discuss is presence of soil moisture. So, as moisture content in the soil increases the reflectance will decrease. Example is given here in this slide. This is reflectance of silt loam. It is a type of soil. This is a fine textured soil. So, for such fine textured soil, so this is in the order of increasing moisture content. So, the amount of moisture content is given here; 0.8% is moisture, 4.7 moisture, 20.2% moisture and so on.

As moisture content increases, the reflectance increases. The entire curve actually goes below. These curves they are not intersecting, they are just falling one below the other. So, overall in all the wavelengths the reflectance will go down as the moisture content increases. In addition to this, in earlier classes we have come across characteristic water absorption bands. So, either even in vegetation or even in atmosphere we have discussed that 1.4, 1.9 and 2.7 micrometers these wavelengths are essentially water absorption bands.

So, as the moisture content in the soil increases at these particular wavelengths, the reflectance will go down sharply. This is much clearly seen in this 1.9 micrometer range. Around this 1.9 micrometer range, as the moisture content increases, the dip or the absorption feature becomes very deep with increasing moisture content. So, this figure or this water absorption will be prominently seen when the moisture content increases.

In addition to this for fine textured soil such as clay or silt, it may contain hydroxyl ions which may cause a characteristic absorption around 2.2 micrometers. That is given here around 2.2 micrometers we are having what is known as hydroxyl absorption band. As the moisture content changes, the hydroxyl absorption band also changes. So, here the hydroxyl absorption band is kind of doing the reverse of this water absorption bands.

As the moisture content is increasing, the hydroxyl absorption band is becoming more narrow and narrow. And the absorption band is becoming quite sharp as the moisture content decreases. But this hydroxyl absorption band normally will not be present in sandy soils. It is a characteristic of fine grained soils such as clay or silt. But here the major take-home message from this particular slide is, as the moisture content increases the overall reflectance of the soil goes down in almost the entire portion of electromagnetic spectrum starting from visible to SWIR.

In addition to this increasing moisture content may lead to a prominent water absorption band. Those bands may become prominently visible or clearly visible in the wavelengths of 1.4, 1.9 and 2.7 micrometers. But as I said when we discussed about vegetation this characteristic water absorption bands 1.4, 1.9, 2.7 are also characteristic water vapour absorption bands that are present in the atmosphere.

So, normally these bands we cannot use for understanding the amount of water present in Earth's surface features. Because if we put anyone band in say around 1.4 or 1.9 micrometers, they will be absorbed in the atmosphere itself. We would not be getting any signal from the land be it vegetation present or be it soil present. So, normally for water, what we will do? We will use the EMR band slightly adjacent to this.

We may use 1.5 to 1.6 or we may use 2.1 to 2.3. Such bands we will use for monitoring vegetation. Same concept applies for soil also. Even for soil using these exact bands around 1.4 or 1.9, we may not be able to use it for understanding or characterizing the soil moisture content because of the presence of atmosphere and water vapour absorption in atmosphere.

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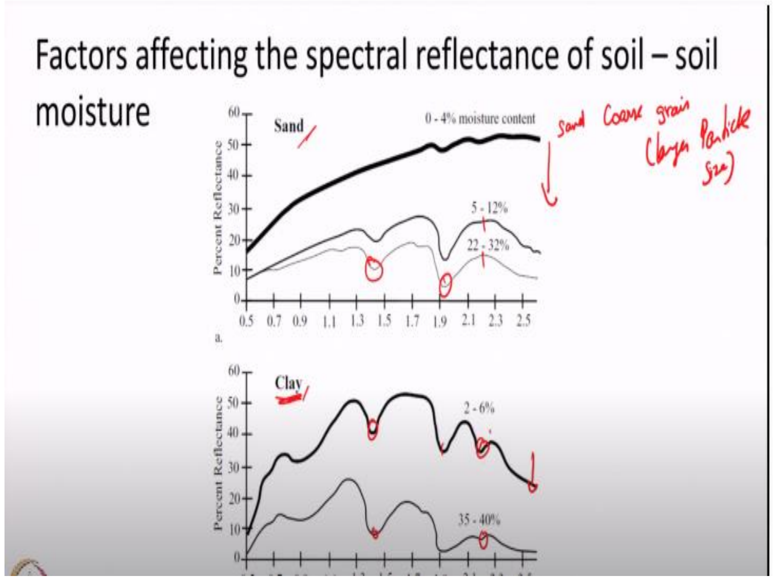

So, this slide again tells us the spectral reflectance of soil with increase in moisture content. Sand is a coarse grained soil and it has larger particle size. For such larger particle size soil, the hydroxyl absorption brand around 2.2 micrometers is not there as I said. So, it is a characteristic of only fine grained soils like clay. But what you can notice is whatever be the soil texture, be it coarse textured sand or fine textured clay, the overall reflectance decreases as the moisture content increases plus the water absorption bands become very prominent. So, here for clay also the same results hold good. The reflectance decreases as the water absorption bands become more prominent and also hydroxyl bands we are able to observe only in fine textured soil such as clay or silt.

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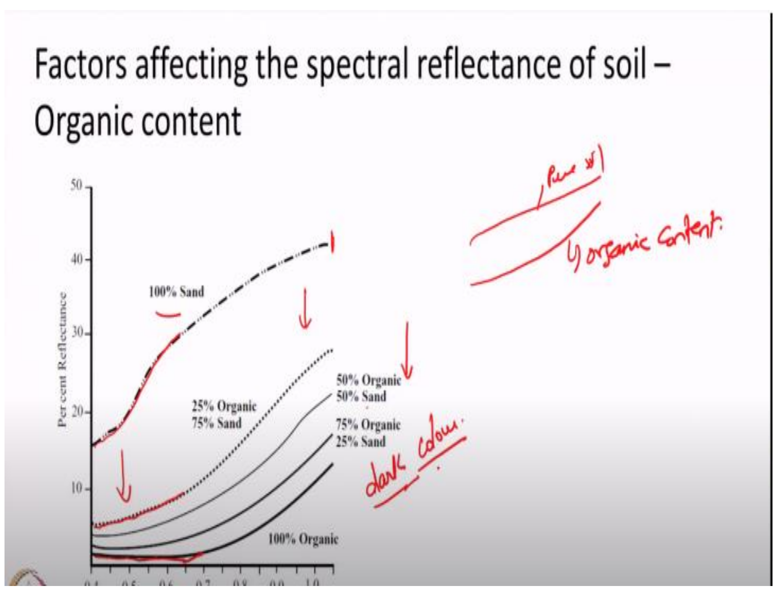

The next property what we are going to discuss is soil organic content. As I said before organic content comes because of the mixture of large amount of living organisms or other organic manure that may be supplied to the soil. So, leaves may fall, organisms may die and decay or the farmers may apply manure like cow dung to the soil. All these things will change the organic content present within the soil.

In general, if you look at organic matter whatever be the source, after decay and decomposition when they mix properly with soil, they will in general have a very dark color. So, that will be the effect of organic material in soil. So, when organic material thoroughly mixes with soil, and when everything becomes like one single mass, the soil will become much darker in color.

So, we may observe dark brown soils, dark blackish soils whenever organic content increases. So, in general, the presence of organic content in the soil will decrease its reflectance. That is given here in the slide. So, this is pure sand 100% sand and we start beginning to add organic material to it. So, each curve represents different proportion of mixture of organic material and sand.

So, as you can see the organic content increases, the reflectance decreases. We have seen that the curve for pure sand will look something like this. It will be kind of increasing like this. But as the organic content increases the reflectance in visible portion dramatically decreases and the curve becomes almost inverted. Instead of being something like this, the curve becomes something like this.

So, the curve is slightly having a different shape. This is for pure soil. This is for soil mixture with organic content. So, here you can see the curve has become tilted in a different direction. So, this is because of presence of organic material. And organic material as I said, to our eyes it appears really dark because it absorbs a large fraction of visible wavelength. So, that is why its reflectance is extremely low in the visible wavelength from 0.4 to 0.7 micrometers.

And that is why when the organic content increases the visible reflectance will go down drastically. The reflectance in all bands goes down or decreases but it affects this much, more clear in the visible portion. In this visible portion it decreases drastically which gives a characteristic dark color to the soil that is filled with organic material. So, some organic soils may be brown, some organic soils may be dark. It depends on the climate in which it is present and depending on the material with which it is mixed everything. But in general if the soil is pure in a region, it will have a higher reflectance when compared with the same soil after getting mixed with organic material. So, the next important property we are going to see is the presence of iron oxide. So, iron oxide whenever it is present, it gives soil a characteristic red color. So, soil rich in iron material will have a characteristic red color.

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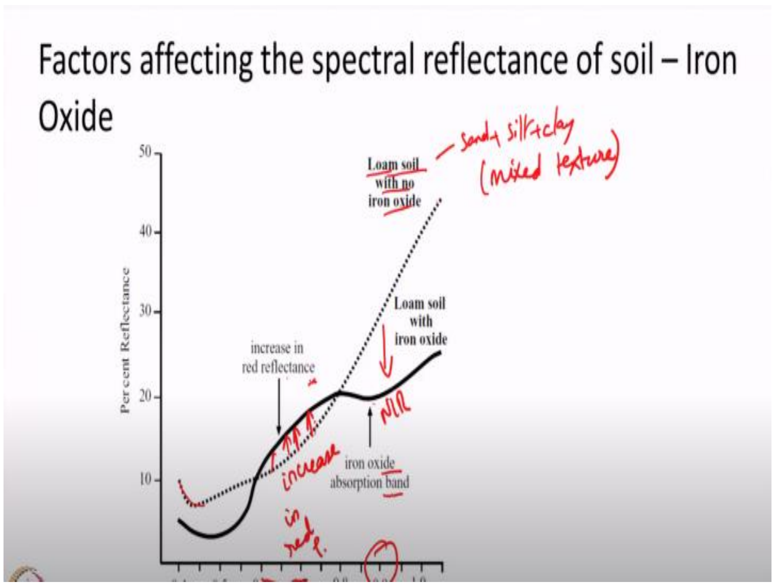

So, that is what we are going to see in this slide. Say this is loamy soil, loam is another type of soil which is a mix of sand, silt and clay at different proportions. So, it will be having a mixed texture. So, this is the general loam without any iron oxide. This curve is kind of increasing naturally. But when iron oxide is added a characteristic increase in the red band will come.

So, around this 0.6 to 0.7 micrometers increase in red reflectance is observed. And there will be an iron oxide absorption band in the NIR region around this, 0.9 micrometers. So, this one gives a characteristic red color. This increase in red reflectance is what gives a characteristic red color to the soil that has abundance of iron oxide plus the reflectance in NIR portion also goes down because of the presence of iron oxide absorption bands. So, this is a general property of soil which contains iron oxide. So, the next property what we are going to see is the soil salinity. In general soil salinity means addition of salt to the soil which will increase the soil reflectance. So, that is given here in this slide.

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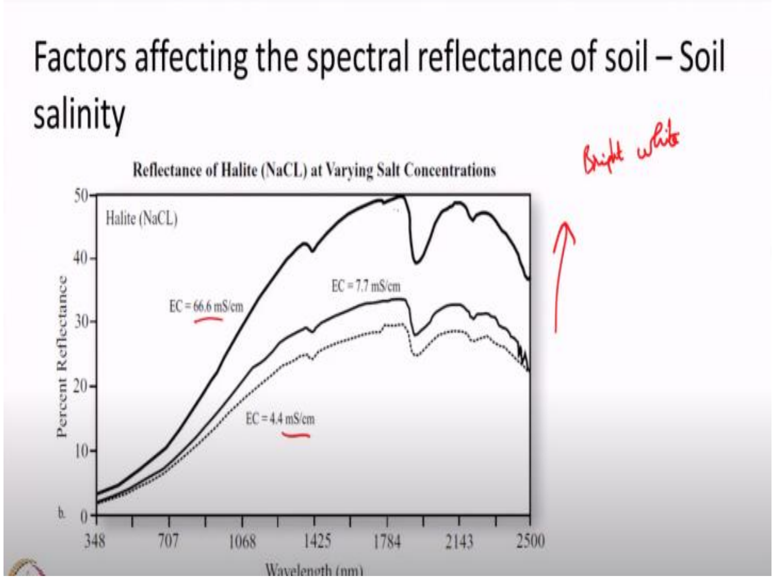

So, increase in soil salinity generally increases the soil reflectance. So, maybe soils that are highly saline sometimes may appear bright white in color. Normally people use satellite images to observe the saline nature of soils over certain regions. It is one of the important applications of remote sensing. So, soils with very high salt content will generally have very bright reflectance. It may appear even white in remote sensing images. When we combine certain bands together and see them it may appear white because of the increased reflectance due to increase in soil salt content. So, the presence of salt in the soil will in general increase the soil reflectance.

Then one more property that we have discussed is soil roughness. So, soil roughness is whether a soil surface is kind of really smooth without any tillage or something or when it is ploughed or when it is being disturbed by some animals, which will increase the surface roughness. When such thing happens normally when the surface roughness of the soil changes, the soil particles may come together and form large clumps. Farmers may plough the land, may supply some moisture to it, all these things may happen which will make the soil to form clusters. When such clusters forms due to the change in surface roughness then the reflectance may go down. That is what we have seen, large grained soil may have a lower reflectance. So, when the soil roughness changes then effectively the reflectance also will change. But especially the soil roughness is not a uniform property. Several other factors such as moisture, organic content, everything will influence. But roughness is also one of the important things which we should remember when we observe the soil reflectance. So, this brings us to the end of spectral reflectance of soil. Actually the spectral reflectance nature of soil is quite a very simple topic because as I said even the reflectance curve do not have a large number of characteristic dips and peaks which needs detailed explanation.

Whatever be the factor whether it is moisture or salinity or soil particle size, whatever be the factor most likely it increases the soil reflectance overall in all the wavelengths. And the presences of absorption bands are very minimal in the soil reflectance curve. That is why it is normally very easy to understand the different properties that affect the spectral reflectance nature of soil. But one thing we should always remember is that a soil reflectance curve obtained in laboratory may behave completely different when we compare this with a reflectance curve obtained from field measurements because in field a lot more factors influence soil's reflectance. So, remote sensing of soils is being carried out very frequently. We always have to observe caution, that is we should not simply match the curve obtained from the lab with what is being obtained in field.

We should take into account all these factors in reality, what was the soil particle size that was used in the lab that will cause a change? What is the amount of moisture content in the field when compared to the moisture content used in lab. So, all these factors we have to keep in mind when we match the spectral reflectance curve obtained in laboratory with the spectral reflectance curve obtained from field measurements. So, remote sensing of soils is not a straightforward task. In addition to all these, presence of vegetation or some other structure over the soil may prevent us from observing the soil itself. When a tree is present over a soil and if our goal is to get information about the soil itself, we may not be able to get it. We may be getting the signal only from the vegetation which we do not want at this stage.

So, a lot of other features present over the soil may contaminate the signal or may cause its own signal rather than giving us the spectral reflectance of soil. So, we should always have all these points in the mind when we do remote sensing of soils. With this we end this lecture and also the topic of spectral reflectance of soil.

Thank you very much.