REMOTE SENSING FOR NATURAL HAZARD STUDIES

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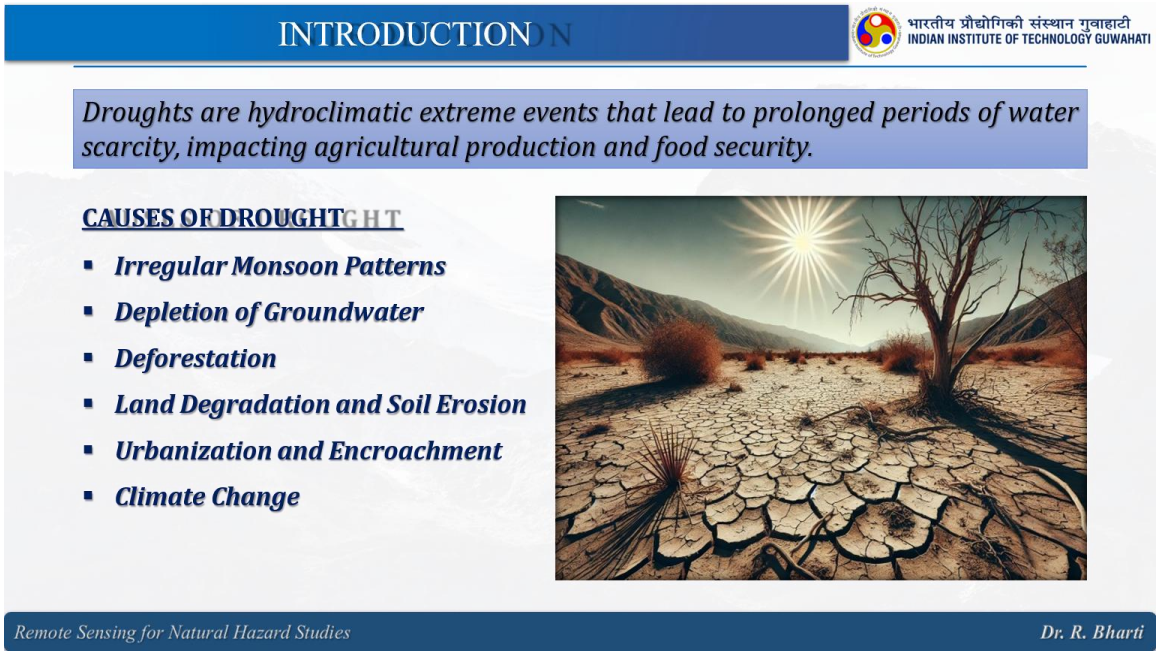
Lec 34a: Introduction to Drought - Part A

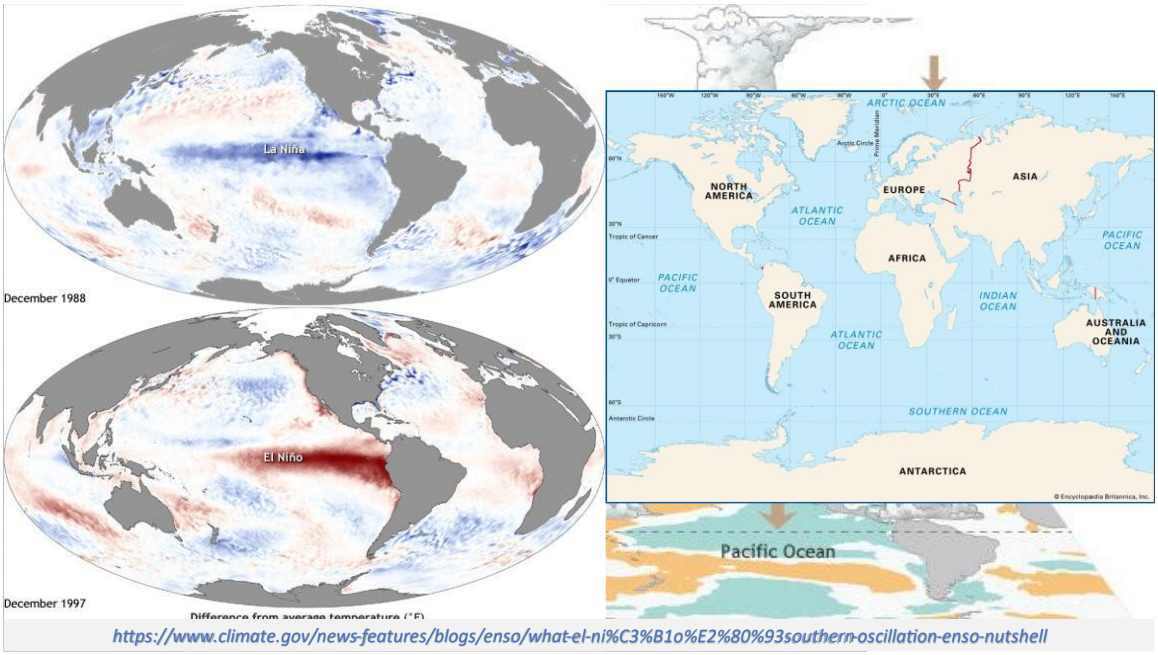
Hello everyone, welcome to Lecture 34. This is part of Module 10, and today we will talk about the drought. So, this is the first part of Lecture 34 that is on the introduction to drought. So, when we talk about this drought, immediately you will have this kind of picture in your mind. You will imagine a scenario where there is no water, and the surfaces with the cracks and all the vegetation or the plants are dry. So, that is true.

So, when we talk about drought, it is a prolonged period of abnormally low rainfall resulting in a shortage of water, and this water shortage can be atmospheric water, surface water, or groundwater. So, if you refer to any standard literature, this is the definition. So, droughts are hydroclimatic extreme events that lead to prolonged periods of water scarcity, impacting agricultural production and food security. Because ultimately, when there is a drought, it will affect agriculture, and once you have the agricultural impact, then you will have food insecurities.



So, the causes of the droughts can be due to an irregular monsoon pattern, depletion of

groundwater, or deforestation. Land degradation and soil erosion. Urbanization, encroachments, and climate change are the last ones. So, because of climate change or any of these reasons, there will be a shortage of water in a given area, and it can be atmospheric, surface, and groundwater. When we refer to India, it has a varied landscape, inconsistent rainfall, and intensified the severity and frequency of droughts, leading to significant scarcity in the 19th and 20th centuries.



https://www.climate.gov/news-features/blogs/enso/what-el-ni%C3%B1o%E2%80%93southern-oscillation-enso-nutshell

So, here you can see the southwest monsoon in 2020; this is from IMD. And here you can see how these waves come in, and the dates are also written here. So, the southwest monsoon, which accounts for 80 percent of India's annual rainfall, is the primary source of agricultural water and groundwater recharge. Because of the southwest monsoon, we will have precipitation, and 80% of this rainfall is due to the southwest monsoon. So, the weakening of the southwest monsoon is driven by Indian Ocean warming and the El Niño Southern Oscillation. So, we call it ENSO. It is a major contributor to drought in the country. So, here we will try to learn about El Niño; we will see what it is, how it is impacting India in particular, and how we are experiencing drought conditions in our country. So, we will focus on this El Niño-Southern Oscillation (ENSO). So, if you just refer to this map, it is used here to show the location. So, here is the Pacific Ocean. So, this is also the Pacific Ocean; it goes like this. So, the currents are generated here in the Pacific Ocean. and this will come to India. So, the Pacific Ocean has this warm current and the cold currents, which happen when we have El Niño.

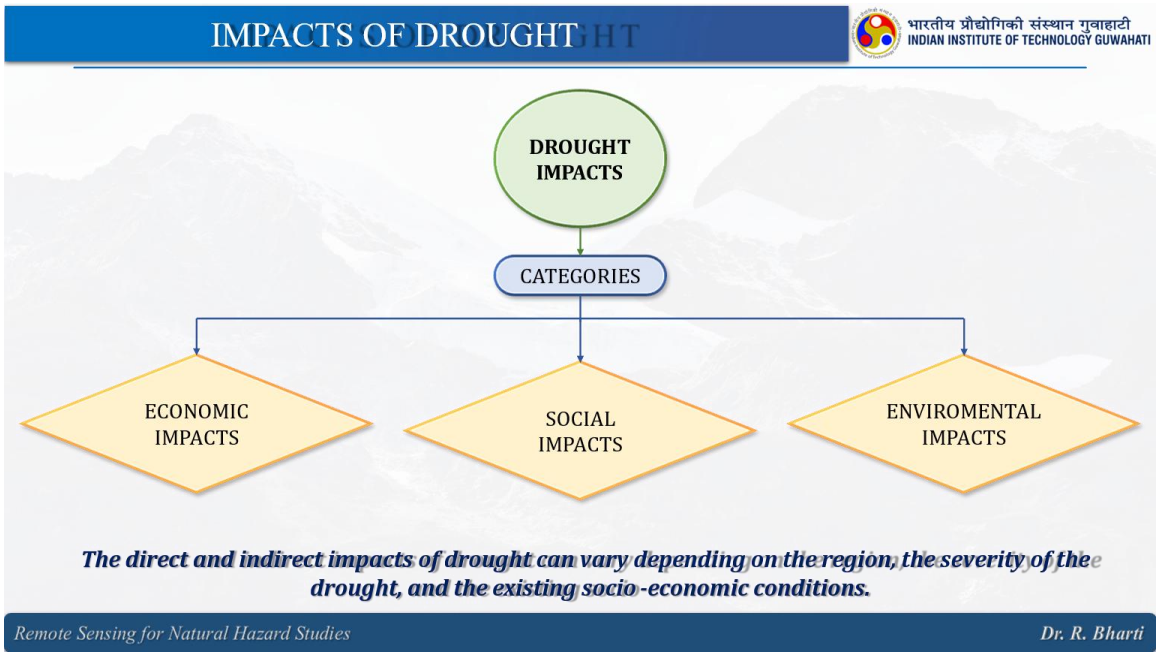
So, when we refer to El Niño, you see that the map is warmer than average. So, the Pacific Ocean is warmer than the average, and when we refer to the other phenomenon, which is La Niña, that is colder than the average. So, what happens? Remember this, La Nina is

hotter, La Nina is colder. Now we will refer again to our map. So, here is what is happening: if we refer to El Niño, the hotter currents are generated, which are coming here.

Now, when we have the hotter currents, particularly from May to June-July, India is hot; the temperature is higher here. So, what happens when the temperature is high in India is that the air will rise because of the heat. So, if you refer to the La Niña and El Niño effects. So, when we are referring to this El Niño, the hotter currents are generated, which are reaching this portion, and then we are referring to May-June. So, in May and June, the weather is hot.

So, the air will be lifted upwards. At the same time, the ocean is also hot. So, what will happen if there is no monsoon in this particular region? So, because of that, we will be facing drought conditions; there will be less rainfall if there is an El Niño. So, here you can see the difference from the average temperature. So, here it is hotter, and in La Niña, it is colder.

Now, what happens? The weather does not stop here. Now, after this El Niño, there will be La Niña; it follows El Niño. So, this La Niña will be next year, following this El Niño. So, at that time, this was hot, and this was cold. So, this difference is what will happen here: the air is hot, while the ocean is cold. So, what will happen is that the monsoon will be pushed very drastically to this region. So, at that time, we will have a flood situation. So, you need to understand El Niño and La Niña. So, in El Niño, you have this dry condition, in La Niña, you have wet conditions, and because of that, we generally experience drought and flood scenarios in our country.



I hope this concept is clear. India is highly vulnerable to drought, with approximately two-thirds of its area prone to such events. You can see that many news articles and many

standard literature papers have been published on this problem. As an agriculture-dominant country and home to a very large population, drought significantly impacts agricultural productivity, water resource management, and socio-economic well-being because everything is linked to water. We will see how it is. In recent decades, there has been a noticeable rise in the frequency, severity, and duration of droughts, a trend that is expected to worsen due to climate change. The increasing food demand from a growing population and urbanization, combined with unsustainable groundwater extraction, further amplifies the challenges posed by droughts. So, if we classify the impacts of drought, we have three categories. The first one is the economic impacts, then we have social impacts, and then environmental impacts. The direct and indirect impact of drought can vary depending on the reason, the severity of the drought, and the existing socio-economic conditions.

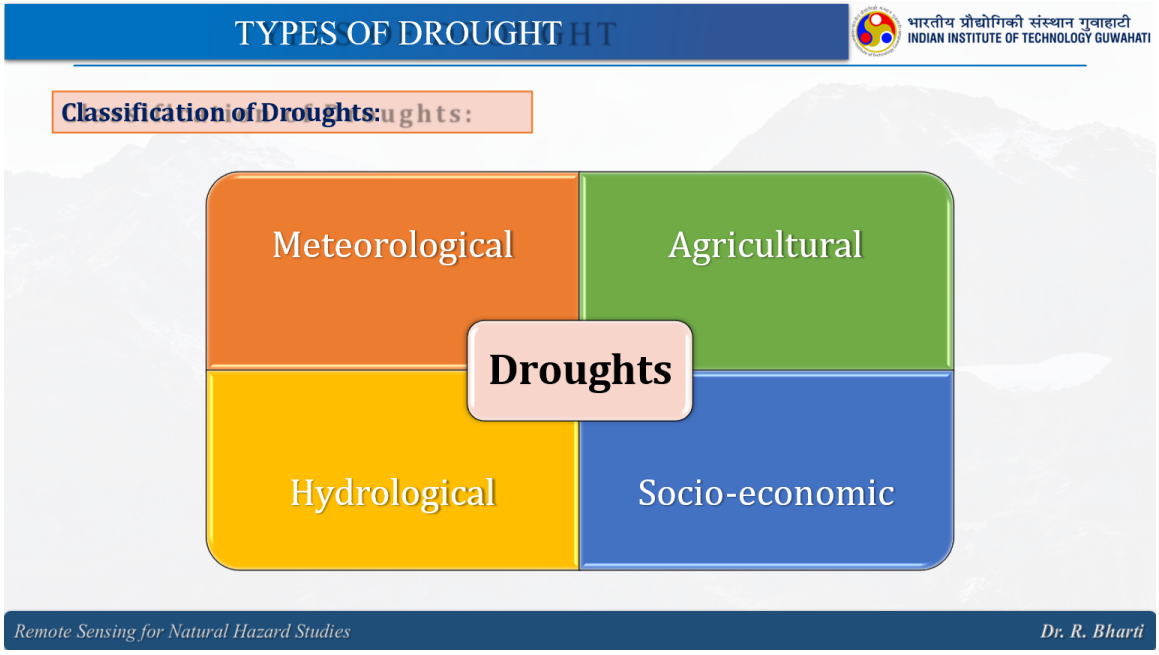
So, let us talk about the economic impact. Drought-induced economic losses include reduced production in agriculture, livestock, fisheries, timber, and the dairy sector. Because water is needed everywhere in day-to-day life, it is a must in many of our activities. Declines in agriculture-dependent industries increase unemployment, strain financial institutions, and raise water transport costs. Because of that, you will have a high cost for water.

The development of new water resources further adds to the economic burden. Distress sales of personal and agricultural assets lead to amplified obligations, severely affecting weaker population segments. So, those are the people in the poor sector or in the poor category that will be impacted majorly. Then let us see the social impact of the drought. Droughts disrupt social structures and relationships, particularly in rural communities.

The joint family system often disintegrates, and occupational diversification becomes a necessity. Social losses are evident in increased conflicts, weakened family solidarity, migration, and shifts in settlement patterns that can be seen easily. Resource depletion, such as scarce water, grass, and fodder, exacerbates tensions among agro-pasture groups. In some cases, entire villages have faced issues like blocked roads, buried homes, and silting of water ponds. So, this is a major problem in the rural sector.

Then let us see the environmental impacts. Increased fallow land and barren areas reduce crop intensity and lead to wind erosion and shifting sand dunes. Because the water is required to maintain the soil moisture properly, and the soil moisture is needed not only for agriculture but also to sustain the soil in its position. Soil erosion due to wind and water loss decreased groundwater levels and increased turbidity in rivers and lakes, affecting ecosystems and agriculture. We have already talked about it; now let us see the ecosystem and how it is impacting the ecosystem, because we all know that ponds, lakes, and rivers have aquatic life everywhere.

And once your source is less and the water availability is lower, then what happens is that slowly the ecosystem of that fluvial system will be disturbed. Reduced moisture in soil kills plant roots while wetlands dry up, affecting the riparian species. A dust storm, reduced precipitation, and dry air concentrate pollutants, causing respiratory ailments. Wildlife stress leads to disease and displacement, with some animals migrating to human settlements, where we can easily see that many times wildlife are reported in the settlements. So, those are the extreme scenarios.

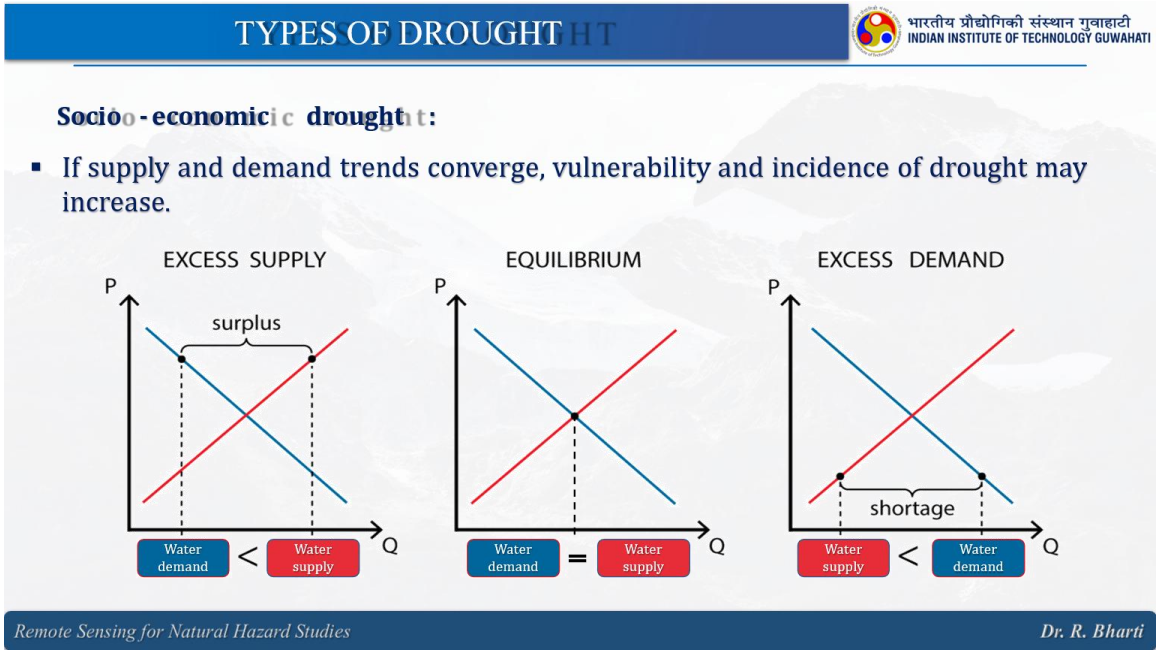


Now, let us see the classification of drought: what are the different types of droughts? So, we have a hydrological drought. Then, we have meteorological drought, then agricultural drought, and finally, we will also see socioeconomic drought because it starts with meteorological, then we have hydrological, then agricultural, and then socioeconomic. Let us see all of them one by one. When we talk about meteorological drought, this is the earliest stage and is primarily defined by a precipitation deficiency. It is the foundation upon which other types of droughts develop because that is the input.

If you remember the water balance equation, our input is precipitation. Just ignore the snowmelt. So, when we talk about this metallurgical drought, our precipitation is less in a given area, and subsequently, this will act as a foundation for other types of droughts. Then you have a hydrological drought. It occurs when meteorological drought leads to a deficit in water supply, affecting surface and subsurface water resources like rivers, lakes, and groundwater.

So, when we talk about hydrology, it is mainly because of the shortage of water in the surface and subsurface zones. Agricultural drought. So, you have seen the meteorological hydrology; now you can visualize how it will impact the agriculture sector. So, this type of

drought is characterized by soil moisture deficits, which lead to crop stress and impact agricultural production. It is closely linked to both meteorological and hydrological drought because some of the crops require good soil moisture during the initial phase.



Some of the crops require a high amount of water in their mature state. So, depending on the type of drought and what type of crop you have, we will experience agricultural drought. Then comes the socioeconomic drought. This is the broadest category and refers to the impacts of drought on society and the economy. It occurs when meteorological, hydrological, or agricultural droughts affect the supply and demand of economic goods and services in the given region.

So, when we talk about this meteorological drought, it is a complex phenomenon influenced by regional and temporal factors. Meteorological droughts are defined as a lack of precipitation over a region for a period of time, commonly analyzed using precipitation data. Drought is considered a precipitation deficit with respect to the average value of that region. Remember this: it is not related to the other area with respect to the average value of precipitation for the same area.

We try to analyze, and then we identify the drought. Several studies use monthly precipitation data to analyze droughts. Some approaches focus on drought duration and intensity in relation to cumulative precipitation shortages. Now, I have an example for you. Here you can see that these are 2 different areas: one is a desert, and the other has very good vegetation.

In both areas, if we have 50 centimeters of annual rainfall, will both be fine? No, for this desert, maybe this is good with respect to the average precipitation, and there is no drought condition. But for another reason, the average rainfall of that particular area, 50

centimeters, may be very, very low. So, this area will qualify for the criteria of drought; drought is reason specific. Level of precipitation. The duration of dryness must be compared with the regional normal.

This is what I explained in the previous slide. Considerable variation in atmospheric conditions leads to differences in precipitation deficiencies. Different time scales contribute to variability in meteorological drought occurrence. It is measured in terms of seasons, years, or decades of deficient precipitation. The duration of meteorological drought affects soil moisture and influences water supply in streams.

Shallow groundwater tables, small lakes, and reservoirs. Understanding drought through precipitation analysis helps with better water resource management. Because once we have the meteorological drought, that means rainfall is less; then comes the management of the water resources in that region, and for that, we need to understand the drought condition. Then comes the hydrological drought; it is generally defined on a watershed or river basin scale. It measures the effects of periods of deficient precipitation on surface and subsurface water supplies, such as streamflow, reservoirs, lakes, and groundwater levels.

So, here you can see that for a given catchment, you can perform the drought analysis. Although all droughts originate with a deficiency in precipitation, hydrological drought specifically refers to a water supply shortage caused by a rainfall deficit over a watershed or a river basin. While meteorological drought is characterized by reduced rainfall, agricultural drought affects soil moisture and crop growth. Hydrological drought is associated with long-term declines in surface and groundwater levels. Hydrological drought is specifically related to inadequate water for established water uses, including domestic, agricultural, and industrial purposes.

When precipitation remains below average for an extended period, the effects of hydrological droughts become evident in the declining levels of surface and subsurface water resources. This impact can vary significantly based on different water use patterns and regional characteristics because different areas have different demands; for example, if you refer to a rural sector, an urban sector, or an industrial sector, the water requirements are different. Factors influencing hydrological droughts include climatic patterns, land use, and human water consumption. Regression analysis has shown that the geological composition and the geology of that area play a significant role in determining the severity of the hydrological drought. The ability of soil and rock formations to store and release water affects how quickly a region experiences water shortages during prolonged dry spells.

So, depending on your geology, whether the rocks are permeable or impermeable, and what types of soil we have. And what is the status of the water resources? Whether we have sufficient water to continue for the next 6 months or 3 months to meet the demand of that

particular area, we will have different measures. Hydrological drought has serious implications for water resource management as it can lead to shortages in drinking water supplies, reduced agricultural productivity, and impacts on energy production. Since hydrological drought develops over time, this is not a one-day job. So, many times we do not get rainfall, but we never say that it is a drought condition because the next day or maybe in the next few days, rain will come.

So, long-term monitoring and planning are essential for mitigating their effects. Hydrological drought is often analyzed with stream flow data, as changes in stream flow levels provide measurable indications of prolonged dry periods. Understanding the geological and catchment characteristics is very important. It will help predict and manage hydrological drought more effectively. So, this groundwater drought occurs when it is reduced within the hydrological drought; here, we are specifically talking about the groundwater.
So, it occurs when reduced precipitation leads to a decline in groundwater discharge, followed by decreasing groundwater levels and discharge. These droughts typically develop over a month to years, making them long-term water scarcity issues. So, if it takes a long period of time to develop, it will similarly take time to overcome this particular problem. Groundwater drought is often defined by a drop in groundwater levels, but it can also be measured through changes in groundwater storage, recharge, and discharge. So, we can also monitor the storage, recharge, and discharge patterns of a particular area.

Negative impacts of groundwater depletion can be felt long before a total shortage affects water availability for various uses. Now comes the agricultural drought. So, here you can see these photographs that will help you understand what we mean by agricultural drought. So, it occurs when declining soil moisture leads to water stress in crops, affecting their growth and yield.

Its impact depends on the magnitude, duration, and timing of the drought, along with soil, plant, and animal responses to water stress, because this is a stress condition for plants as well. So, whether they will be able to manage with less water depends on the type of crop. Insufficient topsoil moisture at planting can hinder germination, resulting in low plant population and reduced yield. This is one of the examples. Drought in the later stages of crop development can destroy or severely deplete crop yield.

The impact of drought varies depending on the biological characteristics of crops, their growth stages, and soil properties. As I said, it depends on the type of soil, whether the soil is porous or permeable. So, how much moisture can they hold that will help the plant overcome this situation? Soil moisture decline is influenced by meteorological and hydrological drought factors as well as differences between actual and potential evapotranspiration. This evapotranspiration is also an input in the agricultural drought assessment.

Plant water demand is affected by weather conditions. Plant characteristics, the type of plant, the growth stage, whether it is in the initial stage, middle stage, or the mature state, and the soil properties. Several drought indices combining precipitation, temperature, and soil moisture have been developed to analyze agricultural drought. So, here you can see the socio-economic drought; this table gives you daily water consumption, and this is the time. Socioeconomic drought occurs when the water supply is insufficient to meet human and environmental needs. It emerged when meteorological, hydrological, and agricultural droughts impacted on the supply and demand for water.

So, here the situation will be like this. This can be linked to the failure of the water resource system to meet the growing water demand. Human and animal population, growth rate, water and fodder requirements, and severity of crop failure are important parameters to assess this socio-economic drought. Here, you can see some of the cases. So, when the water supply is greater than the water demand, we have surplus water, and this is an excess supply. When the water supply is equal to the water demand, it is in equilibrium.

When water demand is greater than water supply, this is the excess demand. So, this will be the vulnerable situation, and this is what we are talking about regarding the drought conditions. Drought management is a continuous cycle that affects phases involving monitoring and assessment to ensure a timely response. The drought management includes mitigation, preparedness, relief assistance, and reconstruction.

Each phase plays a crucial role in minimizing the impact of drought. In the mitigation phase, you have proactive measures, community development, contingency planning, capacity building, and infrastructure development that come under these proactive measures. Drought preparedness and mitigation can be accomplished through soil and water conservation and management. Conservation practices minimize the disruption of soil structure, composition, and natural biodiversity, thereby reducing erosion, soil degradation, surface runoff, and water pollution. This water pollution is also one of the major impacts of drought conditions.

It can be achieved through agronomic and engineering practices. So, we have some mitigation measures: crop rotation, contoured row cropping, terrace farming, tillage practices, erosion control structures, water retention and detention structures, and reclamation of salt-affected soil. You might be familiar with this crop rotation. So, we try to use different types of crops in a year so that the soil will become more fertile, and depending on the water availability, we will use the appropriate crop type. And here, contoured road cropping and tillage forming are examples of tillage practices. So, with this, I will end part 1 of lecture 34, and we will continue this in the next part.

Thank you.