Course Name: Watershed Hydrology

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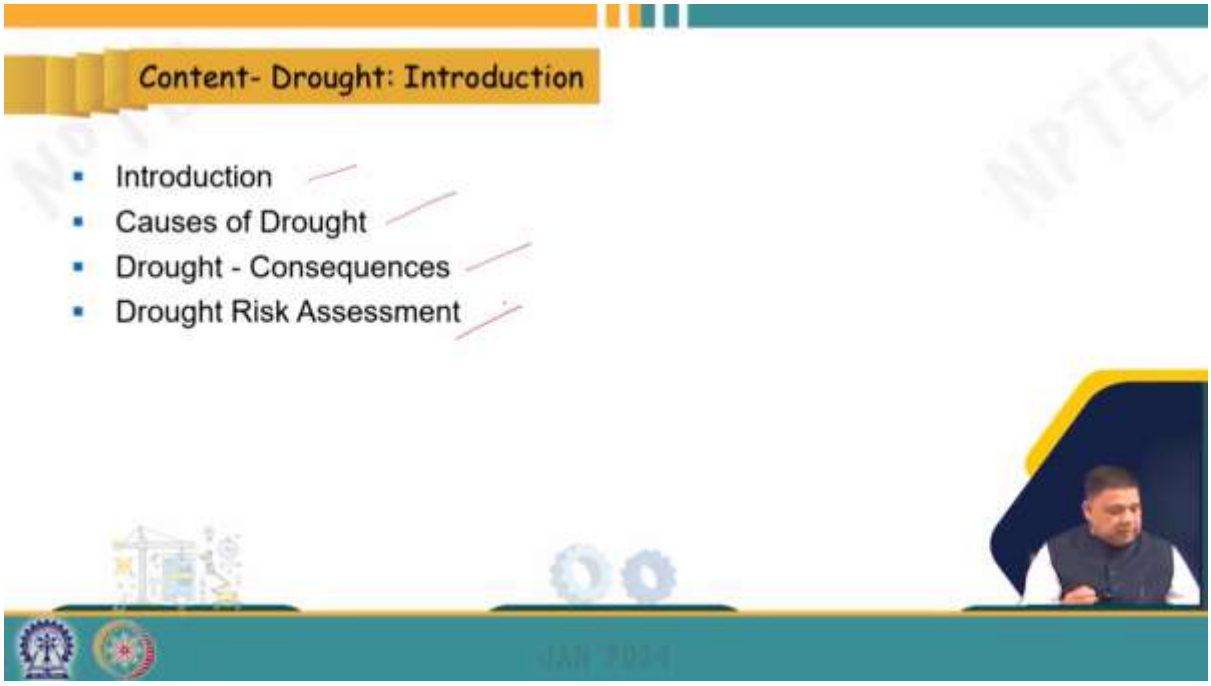
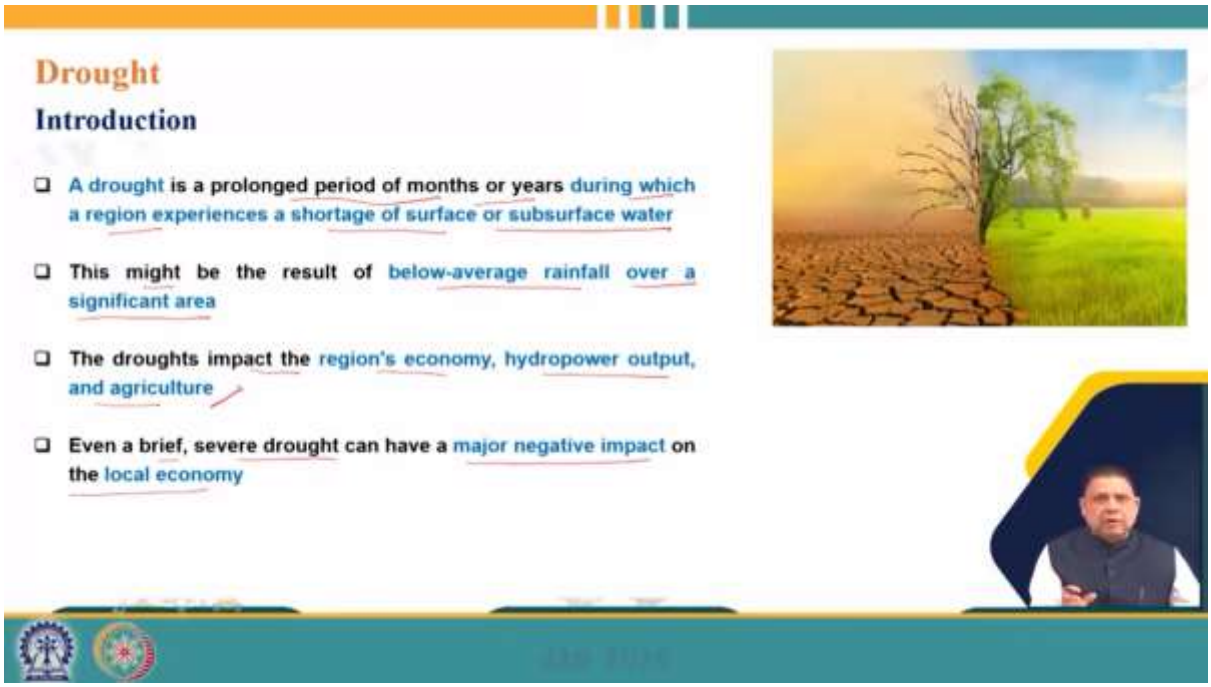
Week: 11

Lecture 51: Drought: Introduction

Hello friends, welcome back to this online certification course on watershed hydrology. I am Rajendra Singh, a professor in the Department of Agricultural Food Engineering at the Indian Institute of Technology Kharagpur. We are beginning with Module 11 today. This is Lecture Number 1, and the topic is drought and introduction.



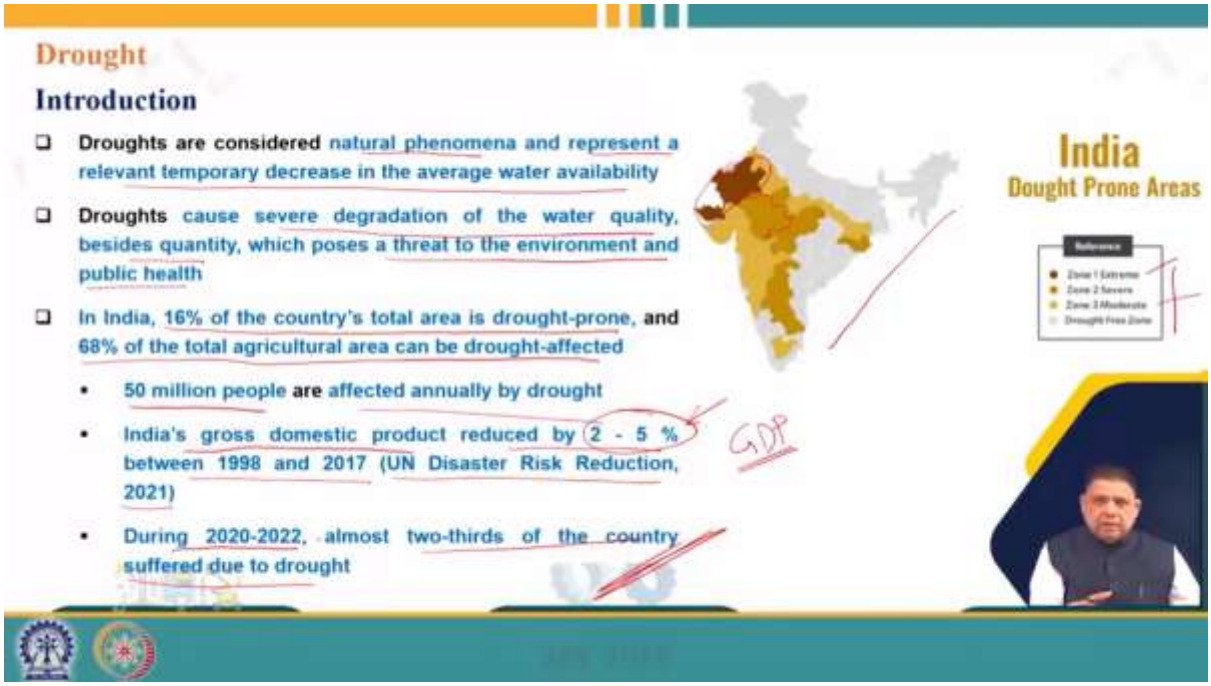
In this particular lecture, we will introduce drought, then we will talk about causes of drought, drought consequences, and we will also discuss drought risk assessment.



Drought is prolonged period of months or years during which a region experiences a shortage of surface or subsurface water result of below average rainfall over a significant area. So, that simply means whenever an area has below average rainfall - average when we say normal rainfall is, we talk about 30 years average. So, 30 years average rainfall. So, if a particular area receives below average rainfall in a significant larger area, then of course, there might be a shortage of surface or subsurface water, and of course, there will be a situation where there

is no water available and there will be a prolonged period of months or years of drought. The drought impacts the region's economy, hydropower output, and agriculture. Hydropower output and agriculture directly depend on water availability if water is not there, there cannot be any hydro output or agricultural productivity or efficiency will go down that will impact the region's economy.

So, regions economy, hydropower output, agriculture, and several other things are impacted by drought. Even a brief severe drought can have a major negative impact on the local economy. So, I mean even if it is a short period of drought, but that could affect especially agriculture, say it is an irreversible loss. If agriculture suffers, then even later on, if you put a lot of irrigation, a lot of water is available, then also that does not revive even a short period of drought will have a major negative impact on the economy of a particular region.



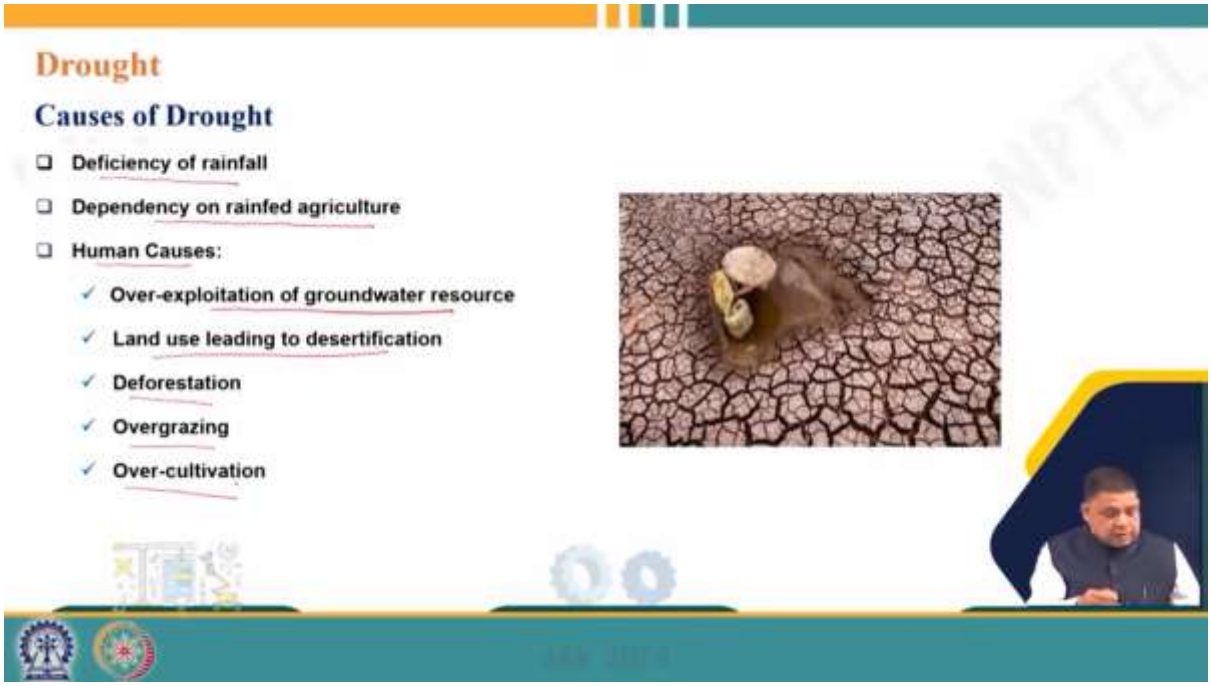
Now, droughts are basically considered natural phenomena and represent a relative temporary decrease in average water availability. So, this another way so natural phenomena so obviously, rainfall is a natural phenomenon. So, obviously, rainfall not occurring is also though abnormal, but a natural phenomenon and because of that there will be a shortage of water availability and that then drought. droughts cause severe degradation of water quality besides quantity which poses a threat to the environment in public health

So, we were discussing about the impacts of drought. So, one other impact is the water quality gets impacted and so will be the environment in public health of a particular region which is suffering through drought. So, drought not only impacts the economy, but also the environment and health sectors also get impacted. As far as India is concerned, 16 percent of the country's total area is drought-prone and 68 percent of the total agricultural area can be drought-affected.

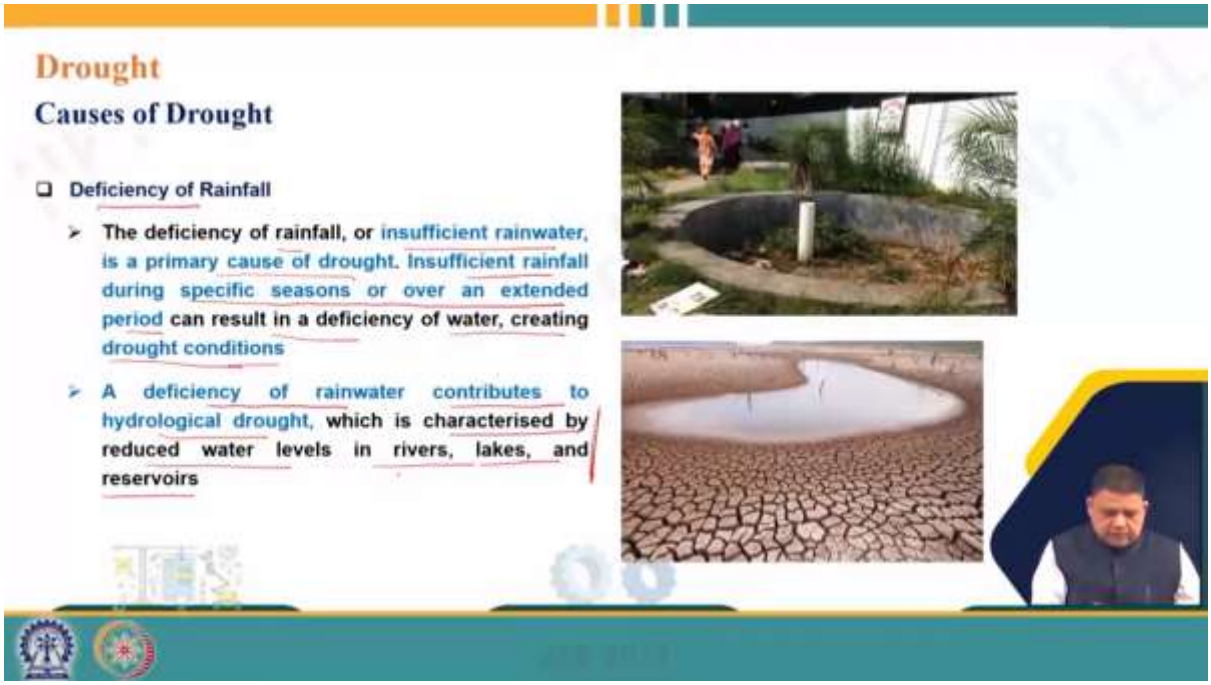
So, obviously, you can see this map of India where there are zone 1, zone 2, and zone 3 of drought. So, the brown colour is extreme drought-prone area, the darker yellowish shade is severe drought-prone area, and the light yellow is moderate drought-prone area. And then you have drought-free zone. So, almost 68 percent of the total area could be affected by different levels of drought, and 50 million people are affected annually by drought. So, it is an annual

phenomenon, and obviously, as a result, around 50 million people get affected every year because of the drought in various parts of drought-prone areas. India's gross domestic product reduced by 2 to 5 percent between 1998 and 2017 reported by UN disaster risk reduction in 2021

So, in this 2021 report, it says that over a 10-year period, 1998 to 2007, the gross domestic product (GDP) has been impacted by 2 to 5 percent. So, that means, you can see that drought could have a severe impact on the nation's growth and national economic growth; GDP could be affected as shown by this report. And during 2020 to 2022, almost two-thirds of the country suffered due to drought.



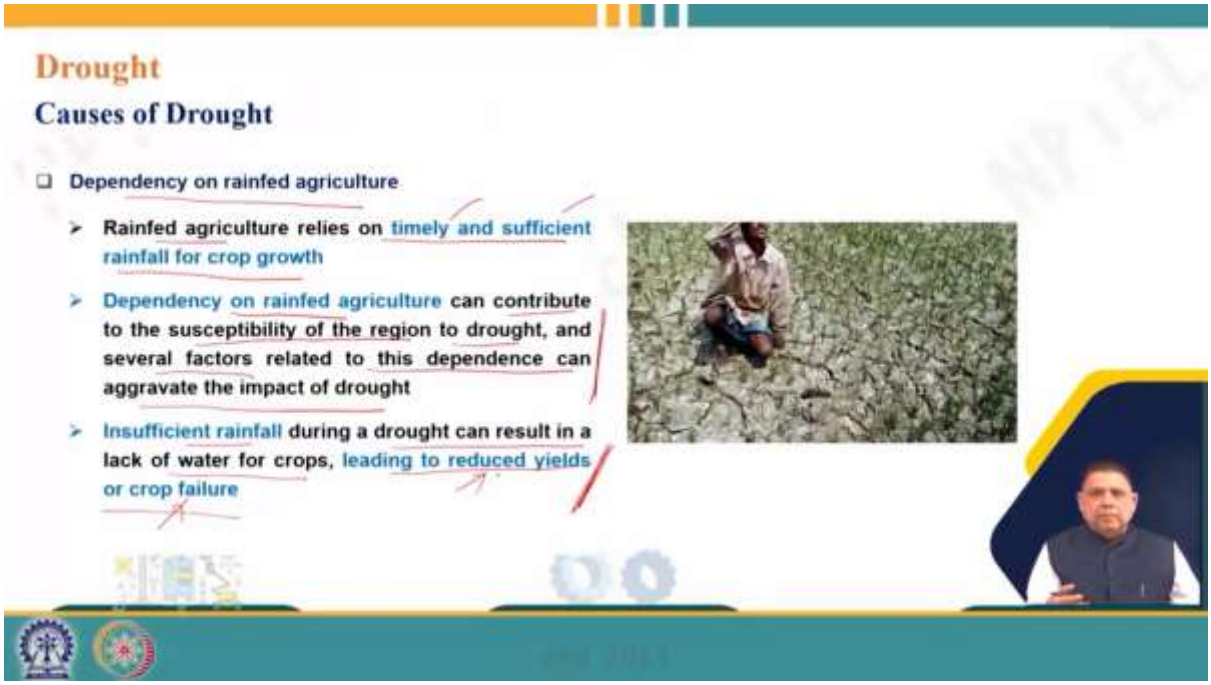
Coming to causes of drought, the causes of drought could be many, and of course, the foremost is deficiency of rainfall then dependency on rain-fed agriculture could be a major reason anthropogenic causes are caused by human beings that is overexploitation of groundwater resources, land use leading to desertification, deforestation, overgrazing, overcultivation.



and so on Coming to deficiency of rainfall, the deficiency of rainfall or insufficient rainwater is the primary cause of drought. Insufficient rainfall during specific seasons or over an extended period can result in a deficiency of water creating drought conditions.

So obviously, in India, as we know that most of the rainfall occurs during the monsoon period, four months of monsoon period that is June, July, August, and September, that is the period where we see most of our water. So, obviously, if there is insufficient rainfall or deficiency of rainfall monsoon rainfall in the country then obviously, the water that is available for surface sources or even supplementing the groundwater resources they will be deficient and of course, it will lead to drought condition. A deficiency of rainwater contributes to hydrological drought which is characterized by reduced water levels in the rivers, lakes, and reservoirs.

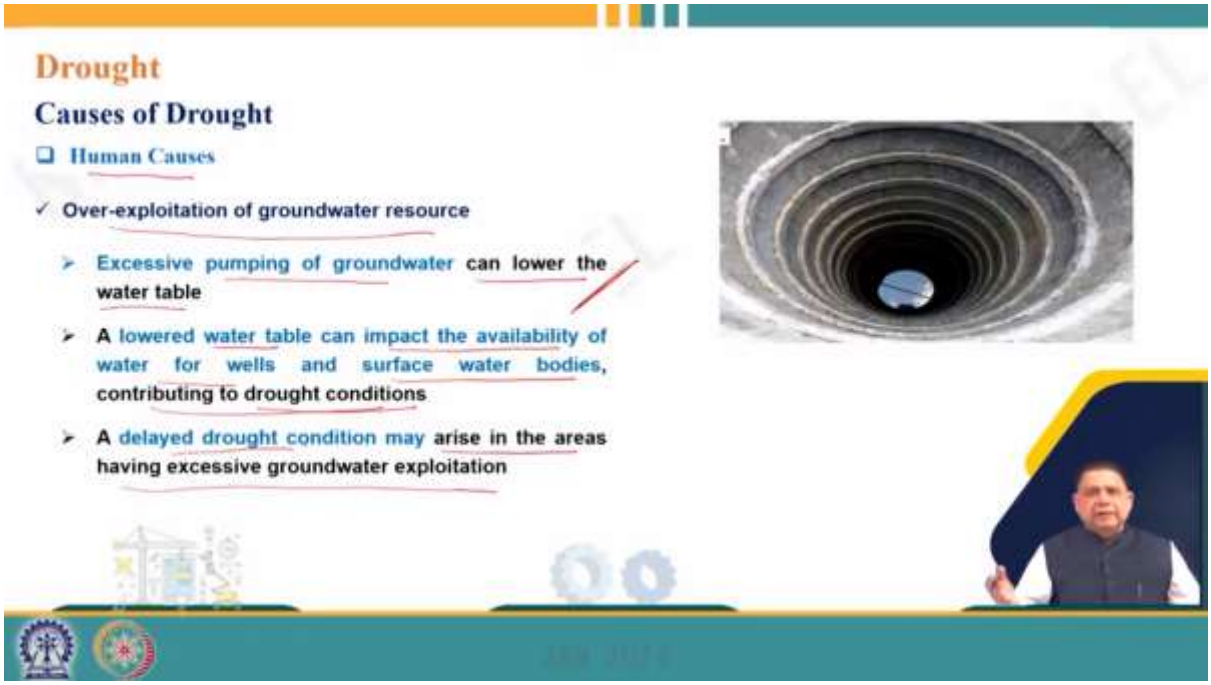
So obviously, if we have deficient rainfall then it results in hydrological drought which is basically defined by reduced water levels in rivers, lakes, and reservoirs. We know that through our knowledge of the hydrological cycle, we know that rainfall occurs, overland flow takes place, then obviously, the water reaches the rivers or other water bodies like lakes or reservoirs and of course, when there is insufficient rainfall there will be insufficient overland flow that means, the water will not the source of water to these rivers, lakes, and reservoirs will diminish and obviously, then water availability will go down and as a result, you can see that a reservoir we should have been fulfilled completely you can see that only a limited portion has water rest of the area is dry.



Dependency on rain-fed agriculture relies on timely and sufficient rainfall for crop growth Basically, rain-fed agriculture means that when rain supplies the irrigation, I mean there is no artificial irrigation facility in the area.

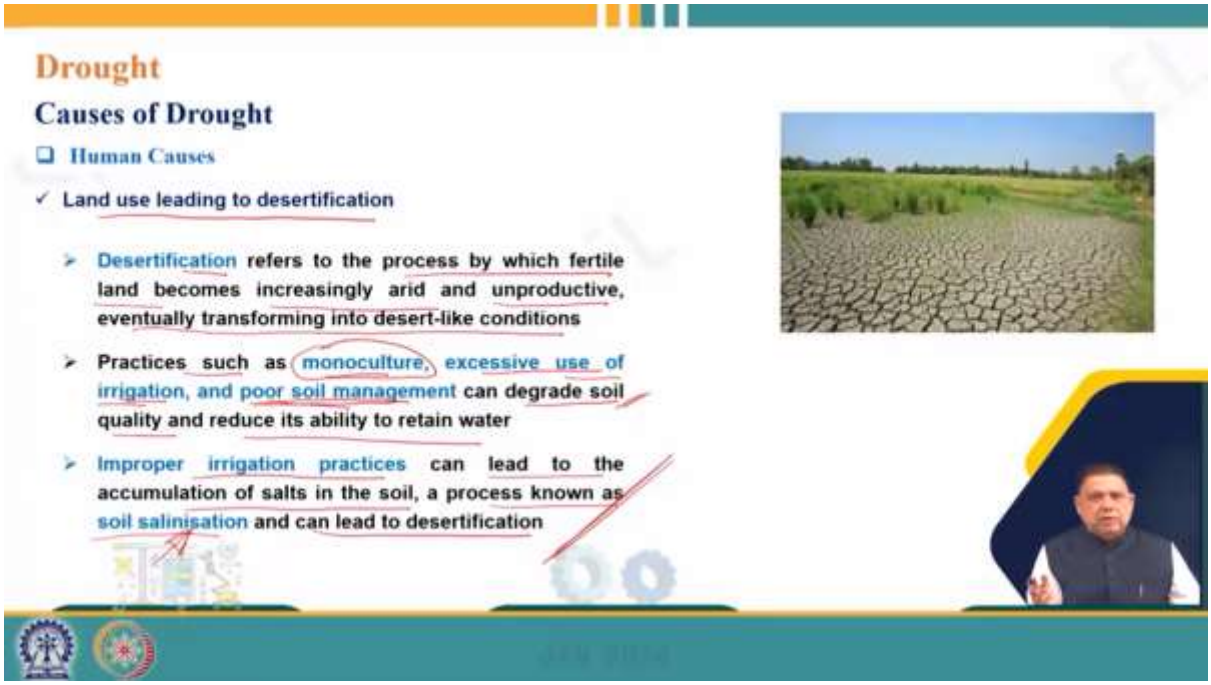
So, that is rain-fed agriculture. So, obviously, in that area, since rainfall is the only source of water supply to crops, if there is insufficient rainfall then obviously, the timely and sufficient supply to crop growth will not be there. A dependency on rain-fed agriculture can contribute to the susceptibility of the region to drought, and several factors related to this dependence can aggravate the impact of drought. So, obviously, any region which is rain-fed is always at the mercy of the rain god because if there is no rainfall there will be no irrigation or supply to crops, and that means there will be a drought-like situation and a drought situation impacts almost everything environment, health, economy everything is impacted in that particular area. So, any area which depends on rainfall is susceptible to drought. Rainfall during a drought can result in a lack of water for crops leading to reduced yields or crop failures.

So, that is what we have been discussing. So, obviously, when no irrigation water is there, then obviously, the yields will be impacted or there could be a crop failure, and as a result, the economy of the local people and as well as the region will be affected in a grave way.



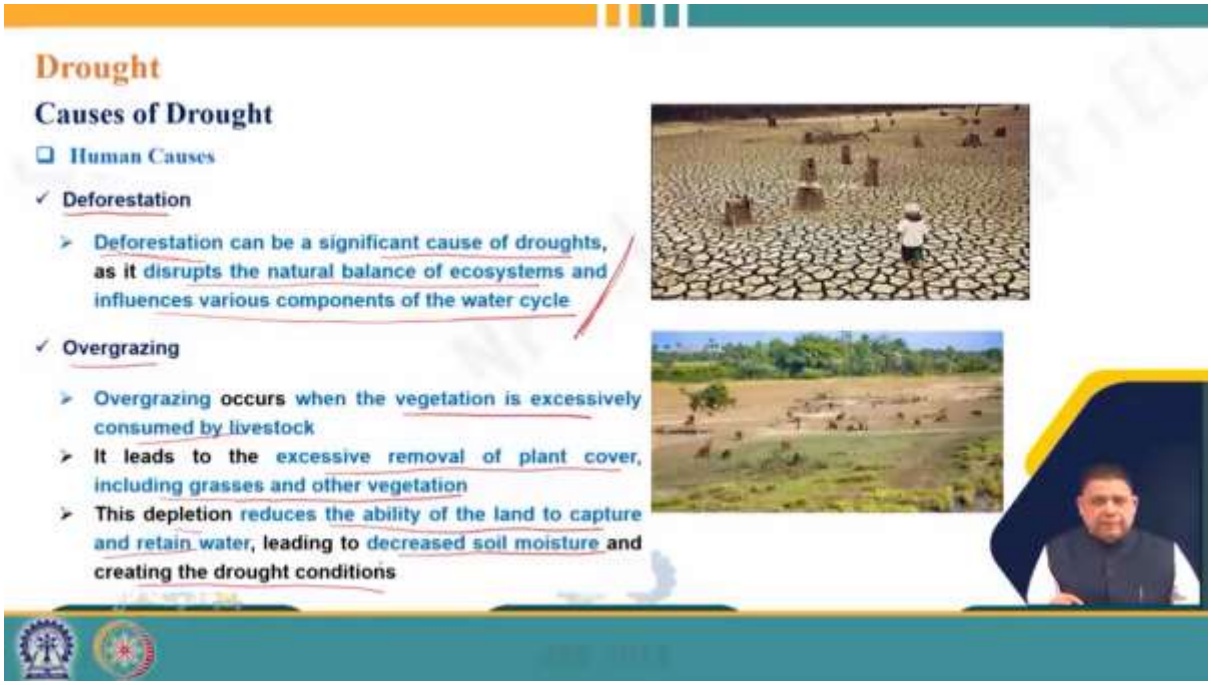
Then of course, there are human causes which we listed earlier like one of them is overexploitation of groundwater resources. So, excessive pumping of groundwater can lower the water table, that is a well-known factor, and a lower water table can impact the availability of water for wells and surface water bodies, contributing to drought conditions. A delayed drought condition may arise in the areas having excessive groundwater exploitation.

So, obviously, groundwater exploitation or excessive groundwater use by at least in India several places, it is a serious issue, and because of that, the water table goes down and states like Punjab and Haryana they are suffering in a great way because of the lowering of the groundwater table. Now, this lowering of groundwater table has several impacts related impacts like, for example, the water availability will be reduced because if you have to pump water from that lower portion, then obviously, the electricity consumption will be very high. So, it is a very costly affair to pump water from a very deep tube well and of course, once water is not available, then obviously, it will result in drought conditions. And of course, in areas which depend heavily on excessive groundwater exploitation, so obviously, immediately after monsoon, the groundwater levels will be higher, water will be readily available and then people will be over exploiting that. By as the season passes say dry season dry cropping season passes then obviously, there will be lesser and lesser water or lesser there will be lowering of groundwater table and as a result pumping will become difficult or uneconomical and that is why there will be a delayed drought condition there might be a delayed drought condition in those areas.



Then comes land use leading to desertification. Desertification refers to the process by which fertile land becomes increasingly arid and unproductive, eventually transforming into desert-like conditions. Practices such as monoculture, excessive use of irrigation, poor soil management can degrade soil quality and reduce the availability of retained water. So obviously, it is a long process. It does not happen in a season or so, but it is a long process. For example, monoculture if somebody is going for the same crop, then obviously, the nutrients are being taken by the crop roots from the same segment of soil layer every time, and as a result, the nutrient availability or the soil quality gets degraded, and obviously, it will impact the yield with time, and of course, then obviously, it might get converted into unproductive land. Similarly, if you have poor soil management or use excessive use of irrigation, then these also have their side impacts or effects. That is why we always talk when we talk about soil and water conservation in different lectures in different portions, we always talk about that you have to have crop rotation or like you go for leguminous crops in certain seasons.

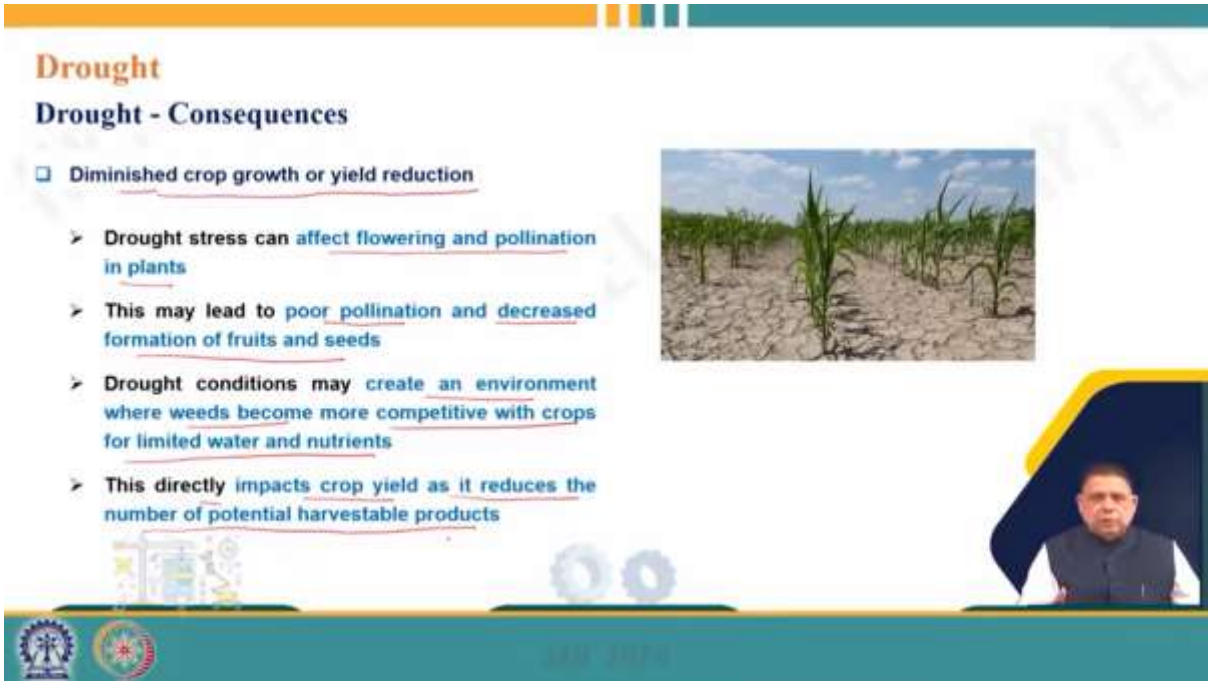
So, all those things are important, and if you do not do proper soil and water management, then obviously, you are at risk of converting your land into a desert. Improper irrigation practices can lead to the accumulation of salts in the soil, a process known as soil salinization, and can also lead to desertification. So, this is again related to irrigation. So, if you irrigate too much, the salts get accumulated in the soil column, and of course, the soil could get converted into saline in certain cases also gets alkaline, and then of course, in all cases, the crop growth gets affected, of course, desertification occurs as a result.



Then of course, deforestation is a major cause, it can be a significant cause for drought as it disrupts the natural balance of the ecosystem and influences various components of the hydrological cycle. So, we have already seen and we have discussed the role of especially we talked about watershed, the forested watersheds also, and we know that and also in various discussions of runoff also, we saw that forest land, they not only bring higher amount of water rainfall, but also, they retain a lot of huge amounts of rain rainfall in the catchment. And you remember we discussed that if we remove the forest, almost 20 to 40 percent of water rainfall will be available for runoff. So, that means, that is a forested watershed can retain 20 to 40 percent of water that means, there will be a recharge of the groundwater and availability of water for the soil and in the ground. And of course, if we go for deforestation, then obviously, the ecosystem will be impacted, the water cycle will get impacted, and obviously, there will be effects.

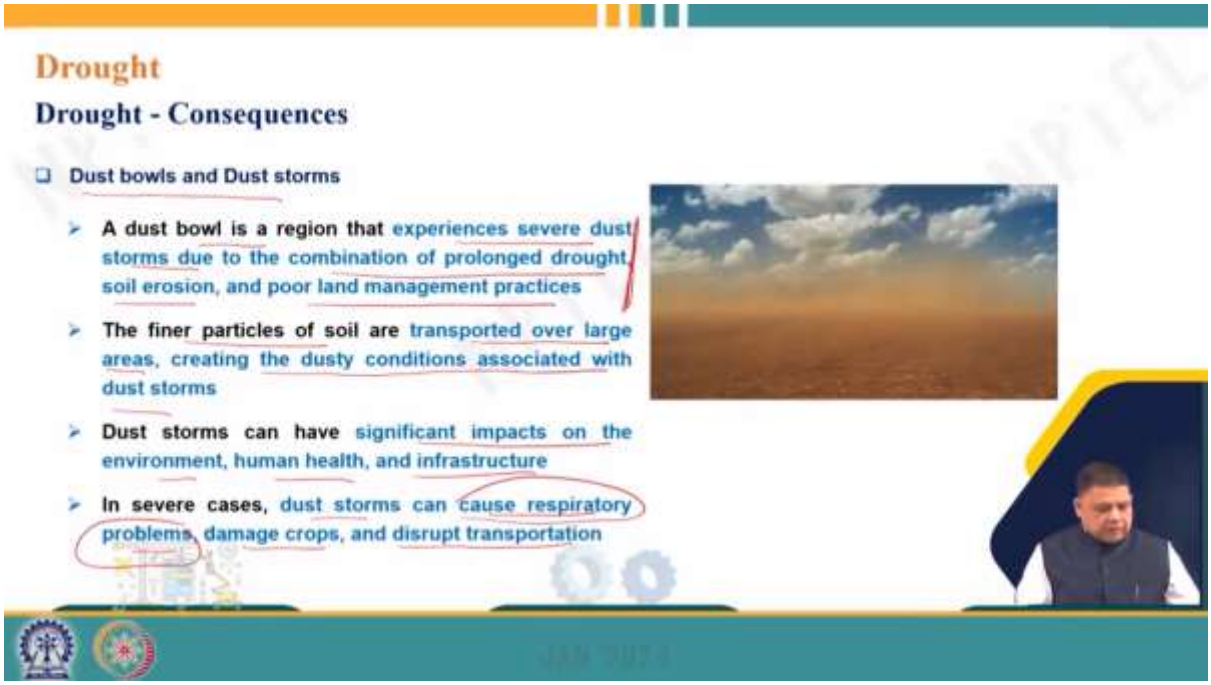
Then overgrazing is another cause of drought. When vegetation is excessively consumed by livestock, it leads to excessive removal of plant cover, including grasses and other vegetation. This depletion reduces the ability of the land to capture and retain rainwater, leading to decreased soil moisture and creating drought conditions. So, a very similar effect. If you allow overgrazing on your land, then obviously, it becomes almost barren land. So, obviously, there is no water conservation, but at the same time, there will be soil erosion and when there is no soil conservation, soil moisture will get reduced, and obviously, then the crop health will be impacted. So, that is a drought kind of situation that could be brought by overgrazing.

Then over cultivation, over cultivation, or excessive continuous agricultural activity on the same piece of land can contribute to the causes and aggravation of drought in several ways. So, obviously, I mean you play with the soil health actually if you go for over cultivation or excessive continuous agricultural activity, then soil health gets impacted and as a result, over a period of time, you will feel that the soil is not able to retain enough water and that means, a drought kind of situation is there. Over time, continuous cultivation without proper nutrient management can deplete soil fertility. Exhausted soils are less able to support healthy plant growth leading to reduced vegetation cover and further aggravating the impact of drought. So, obviously, as I already mentioned all these regions, the soil health is very important. Soil wealth get degraded that means, your agricultural economy will be impacted and obviously, because of the less retaining of the moisture, there will be a drought kind of situation or the irrigation requirement will go up. So, if you can supplement fine otherwise there will be a drought kind of situation.



Then we come to drought consequences and we the first and foremost already we have discussed a lot is diminished crop growth or yield reduction. So, drought stress can affect flowering and pollination plants which may lead to poor pollination and decreased formation of fruits and seeds. Drought condition may create an environment where weeds become more competitive with crops for limited water and nutrient and this directly impacts crop yield as it reduces the number of potential harvestable products.

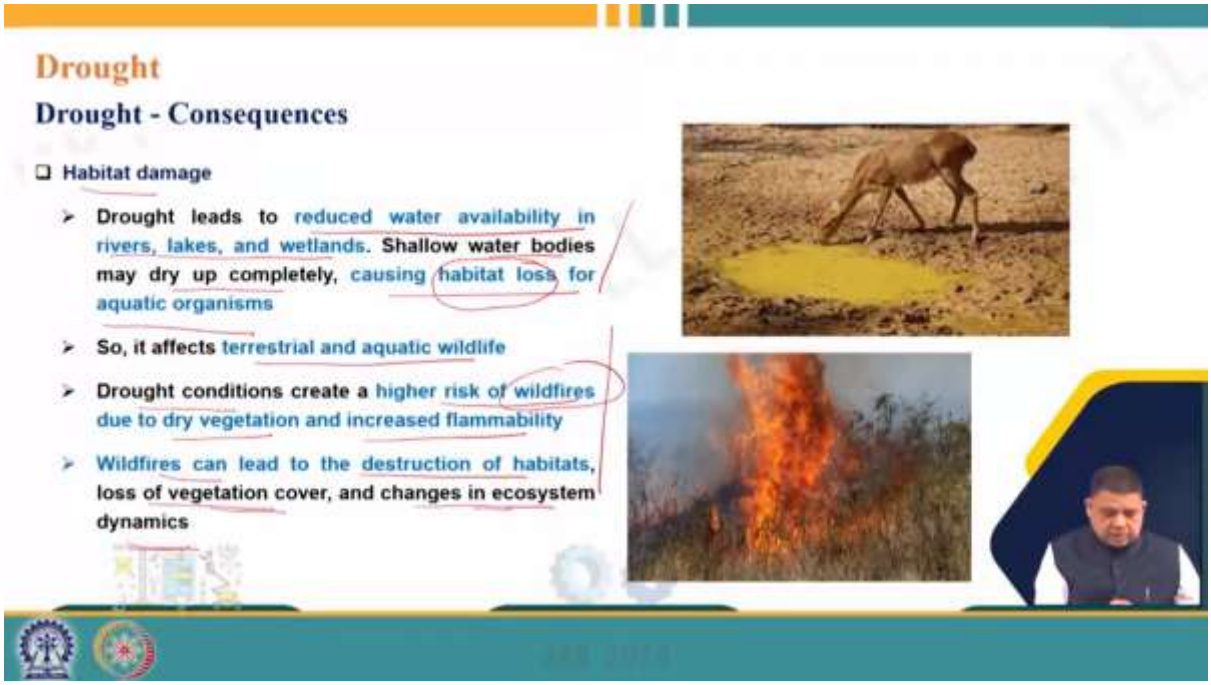
So, already we have discussed a lot that I mean if you do not manage your soil properly and then obviously, there will not be soil moisture and in case of reduced rainfall, the water will not be affected and that means, there will be decreased formation of fruits and seeds. Also, the weed growth will be too much it will be kind of a parasite to your primary crop and that means, it will be eating up the nutrients which whatever are available and that is your crop growth will be impacted. So, overall, the crop growth due to drought crop growth will be impacted and agricultural production will go down.



Then of course, there is a consequence is dust bowls and dust storms. A dust bowl is a region that experiences severe dust storms due to the combination of prolonged drought, soil erosion, and poor land management practices.

The finer particles of soil are transported over large areas creating the dusty condition associated with dust storms. Dust storms can have a significant impact on the environment, human health, and infrastructure and in several cases dust storms can cause respiratory problems, damage crops, and disrupt transportation. So, obviously, not only your own area if there is a drought kind of situation not only your lower area, but adjoining area could also be affected because the loose soil particles which are the final soil particles if there is wind, they can be taken far off and ultimately, they will be dumped and impacting the soil characteristics of a particular place. And of course, it is a dust storm the final soil particles they are a serious cause of respiratory issues which we are facing even in our towns because of the pollution. So, basically, it is a kind of pollution and we see in the town also this kind of an impact already.

Then there will be a famine the consequence is a finite situation when a large number of people have little or no food and many of them die. Famine is one of the most severe consequences of drought as it directly affects food production availability in excess leading to widespread hunger and malnutrition and it can disrupt educational systems as families prioritize immediate survival over schooling. So, obviously, famine of course, is an extreme impact of the drought when you do not have enough production or enough supply of food available for people and there is hunger all around. And of course, it will also lead to malnutrition and also impact the schooling of children especially children because when there is no food of course, there cannot be people cannot think of education or health or any other issues.

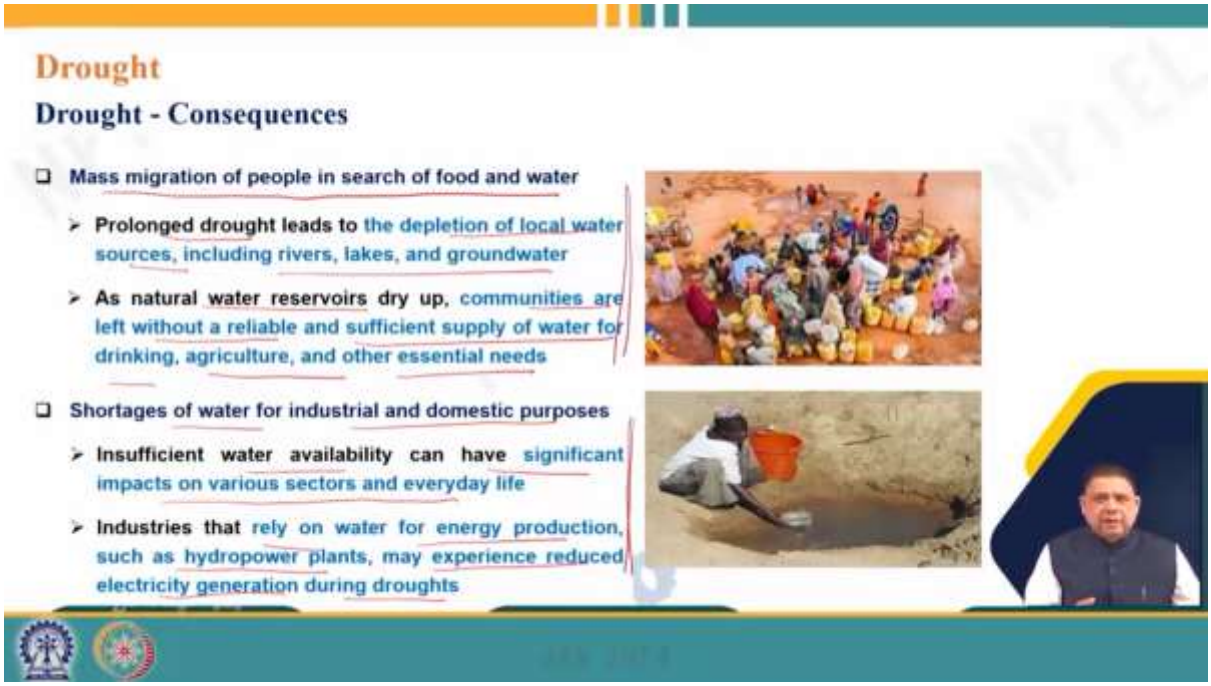


Then habitat damage drought leads to reduce water availability in rivers, lakes, and wetlands. Shallow water bodies may dry up completely causing habitat loss for aquatic organisms. So, it affects terrestrial and aquatic wildlife. Drought conditions create a higher risk of wildfires due to dry vegetation increase vulnerability. Wildfires can lead to the destruction of habitat loss of vegetation cover and change in ecosystem. So, there are two different impacts one is because of reduced water the shallow water bodies may dry up completely and as a result, there will be aquatic life will be impacted the habitat loss will be there.

The other is that because of the extreme dry conditions in the forest the wildfires the forest fires or wildfires are becoming quite common and as a result, if there are wildfires then obviously, the loss there will be destruction of habitats loss of vegetation cover and change in ecosystem dynamics everything will be happening.

Then hunger drought reduces the availability of water for both drinking and irrigation. Communities reliant on agriculture livestock are particularly affected insufficient for water for irrigation means fewer crops can be planted leading to reduce products food production and of course, when there is reduced food production there will be hunger all around. So, I mean it starts with hunger and then ultimately leads to pay mind kind of situation. Malnutrition, dehydration, and related diseases food scarcity during drought may force communities to rely on less nutritional diets it leading to weakening of the immune system and increasing susceptible to disease.

So, obviously, as you can see, drought does not impact health on a short-term basis; it might even impact on a long-term basis because if the body gets malnourished, the immune system may get damaged and obviously, that will have an impact over a longer period of time. This is a serious drought consequence.

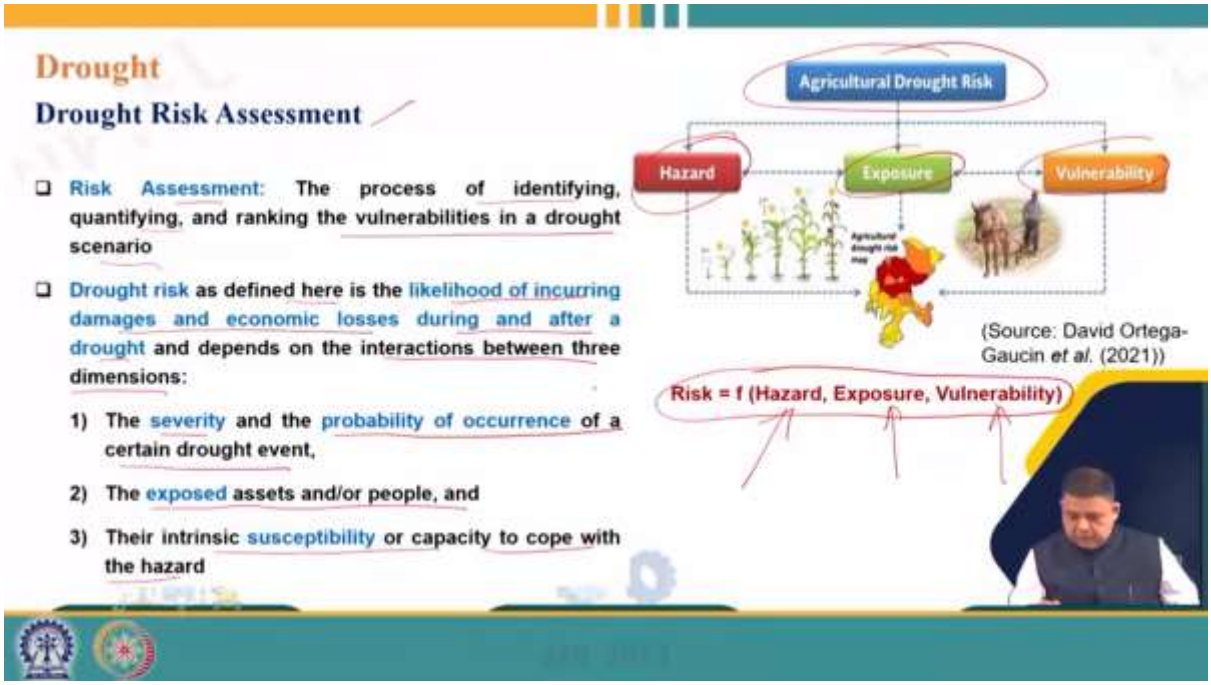


Then there are issues like mass migration of people in search of food and water. Prolonged drought in an area leads to depletion of local water sources, including rivers, lakes, and groundwater. As natural water surface reservoirs dry up, communities are left without a reliable and sufficient supply of water for drinking, agriculture, and essential needs. And of course, as a result, they will be forced to leave that particular area and move to places where water is available. So obviously, as you can guess, when there will be migration to areas where people are migrating, those areas will also be affected because of the drought in some other area.

Then there is a shortage of water for industrial and domestic purposes. Insufficient water availability can have significant impacts on various sectors and everyday life. The issues that rely on water for energy production, such as hydropower plants, may experience reduced electricity generation during drought. So obviously, even if there is insufficient water, then obviously, domestic water supply will be impacted and also the industrial water supply. So especially those industries which cite hydropower, which completely depends on water. So obviously, as you know that probably most of the hydropower units, especially on rivers, they most of them only work during the monsoon period, but if there is insufficient rainfall during

the monsoon period, then these cannot be operated even during the monsoon period. So, that is also a serious issue.

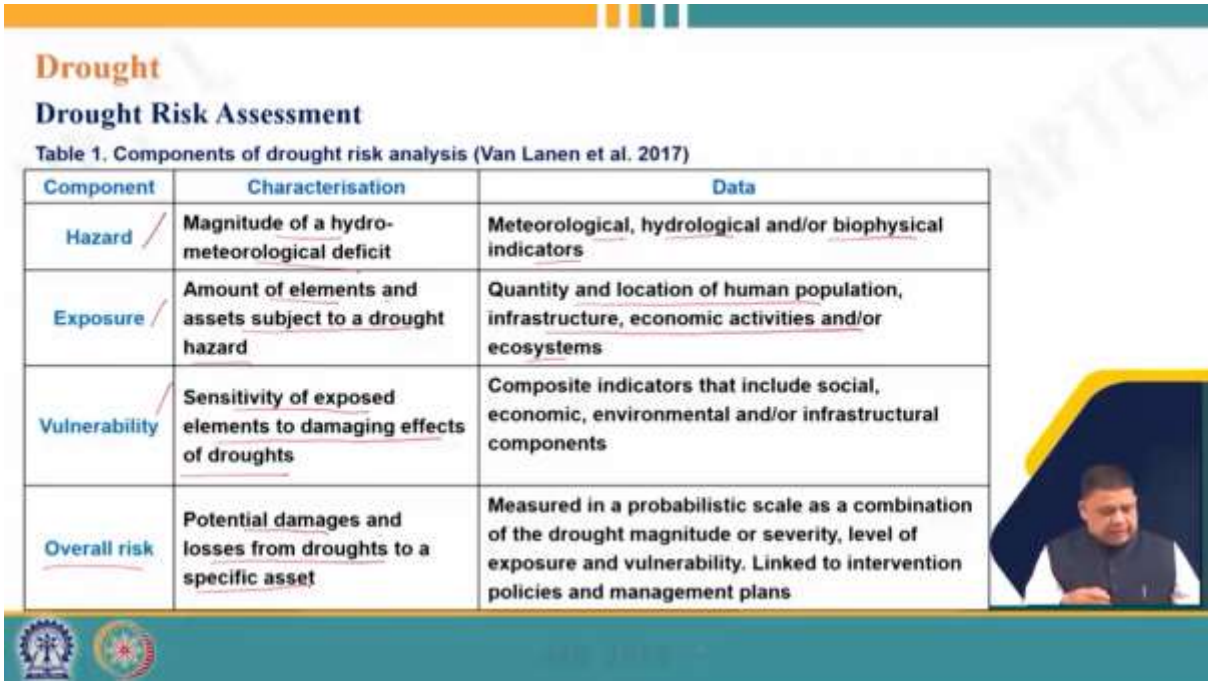
Then the flight over natural resources including water and food. So obviously, once there is a drought kind of situation, so obviously, there will be competition over natural resources particularly water and food leading to conflicts and disruptions among communities, regions, or even nations. Conflict between agriculture and urban demands urban centres may demand more water for domestic use, rely on water for irrigation the fight over natural resources during drought may intensify existing social and so obviously, all these things will be impacted once there is a supply.



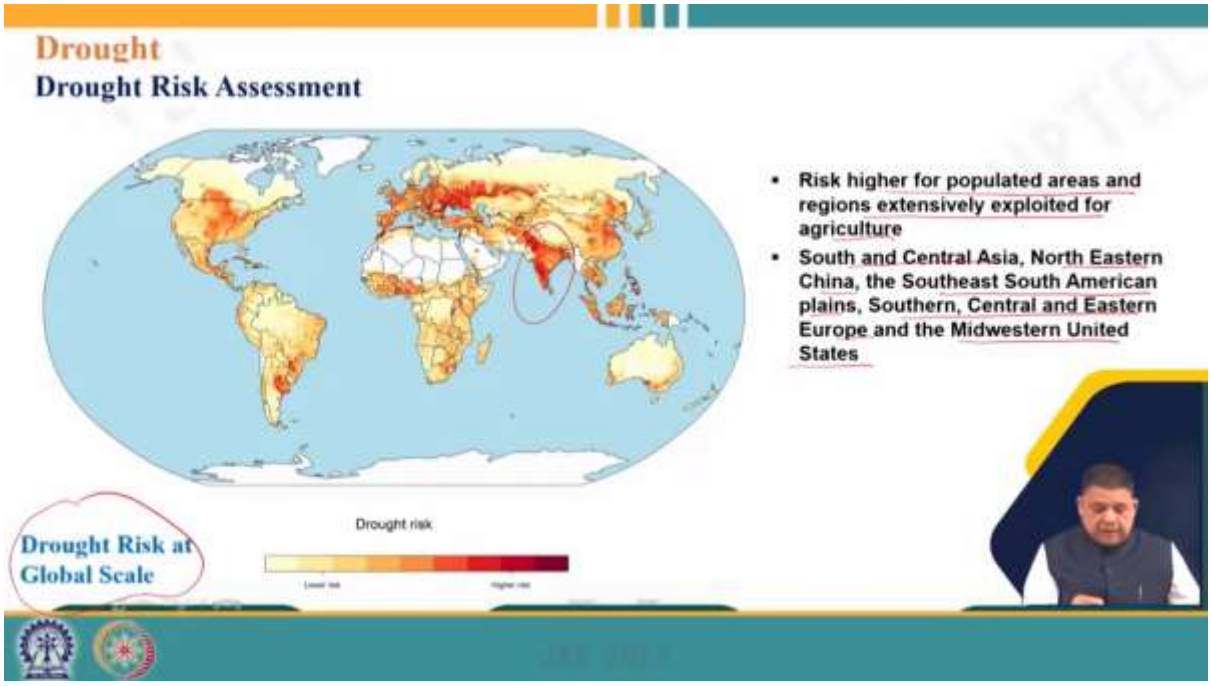
Then we come to the next part that is drought risk assessment. When we say risk assessment, it is the process of identifying, quantifying, and ranking the vulnerability in a drought scenario.

Drought risk is defined here as the likelihood of incurring damages and economic losses during and after a drought and depends on the interactions between three dimensions. There are three dimensions to drought: one is the severity and the probability of occurrence of a certain drought event. The exposed assets and people and their intrinsic susceptibility or capacity to cope with the hazard. So, there are three different dimensions are there severity and probability of occurrence, then there is exposure there is a susceptibility. Similarly, a similar thing is shown here in this picture that if you talk about agriculture drought risk there is hazard there is exposure there is vulnerability.

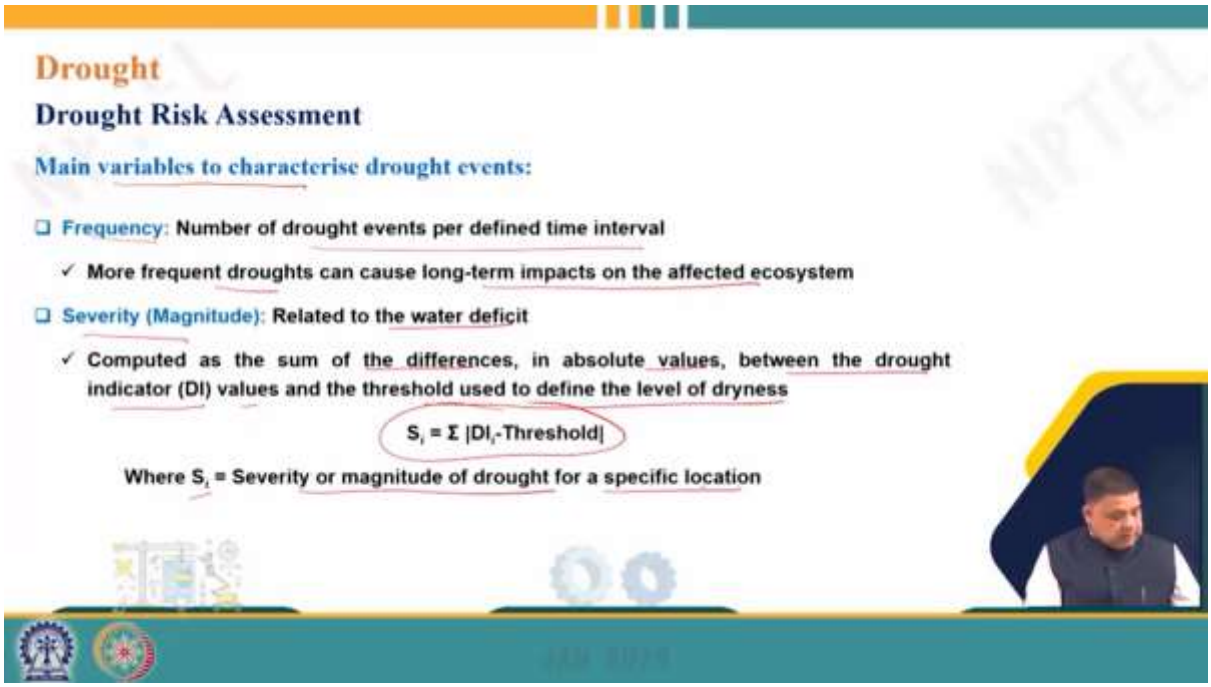
So, basically, risk has three components: hazard, exposure, and vulnerability if we talk about the assessment point of view. So, these are the three different components that we can find.



Now, if you talk about these components individually, then if you talk about their components I said hazard, exposure, vulnerability, and of course, there is overall risk and these each of them can be characterized in a different way like hazard is the magnitude of a hydrometeorological deficit, exposure is the amount of elements and assets subject to a drought hazard, vulnerability is the severity of exposed elements to damaging effects of droughts, and overall risk is the potential damages and losses from droughts to a specific asset. So, all these different characterizations are there and of course, all these will be can be analysed using different kind of data like for hazard you need meteorological, hydrological, and biophysical indicators, for exposure you need quality and location of human population infrastructure, and so on. So, different kinds of data will be needed for analysing these different components.

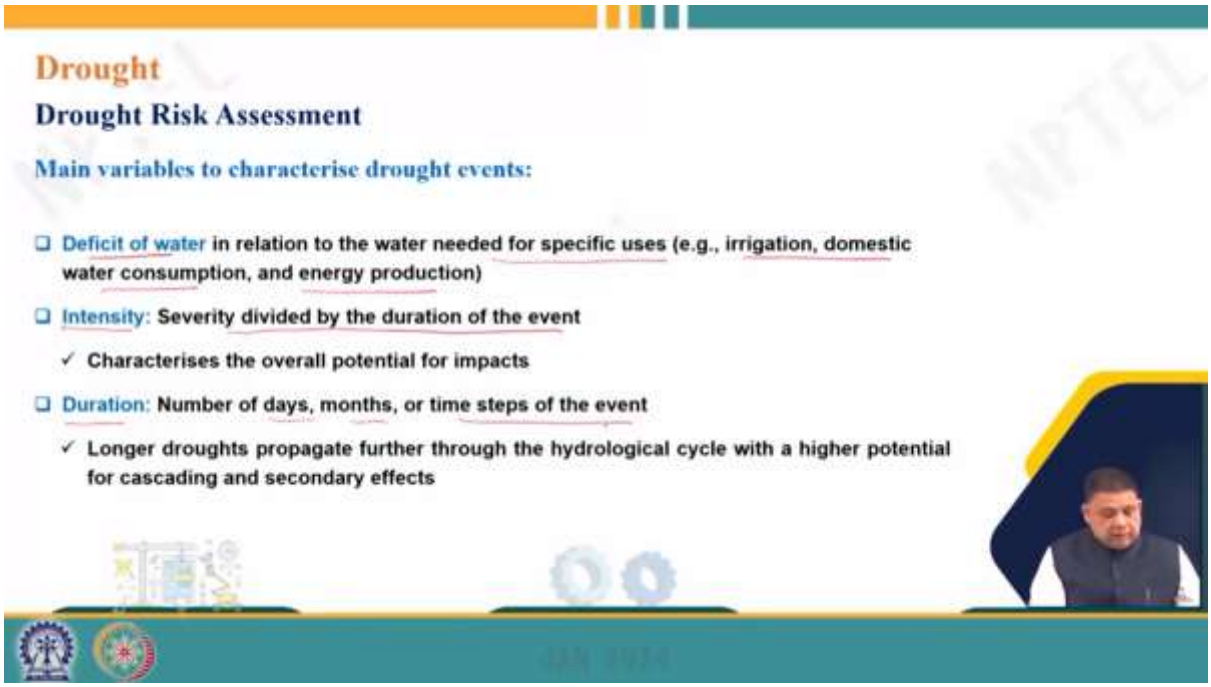


Then drought risk assessment if you talk about drought risk global scale then this is a map which shows the drought risk countries or regions and of course, this figure shows that the risks are higher for populated areas and regions extensively expected for agriculture south and central Asia, northeastern China, south-central South American plains, southern central eastern Europe, and Midwest United States and of course, as you can see that the India is there these are at higher risk.

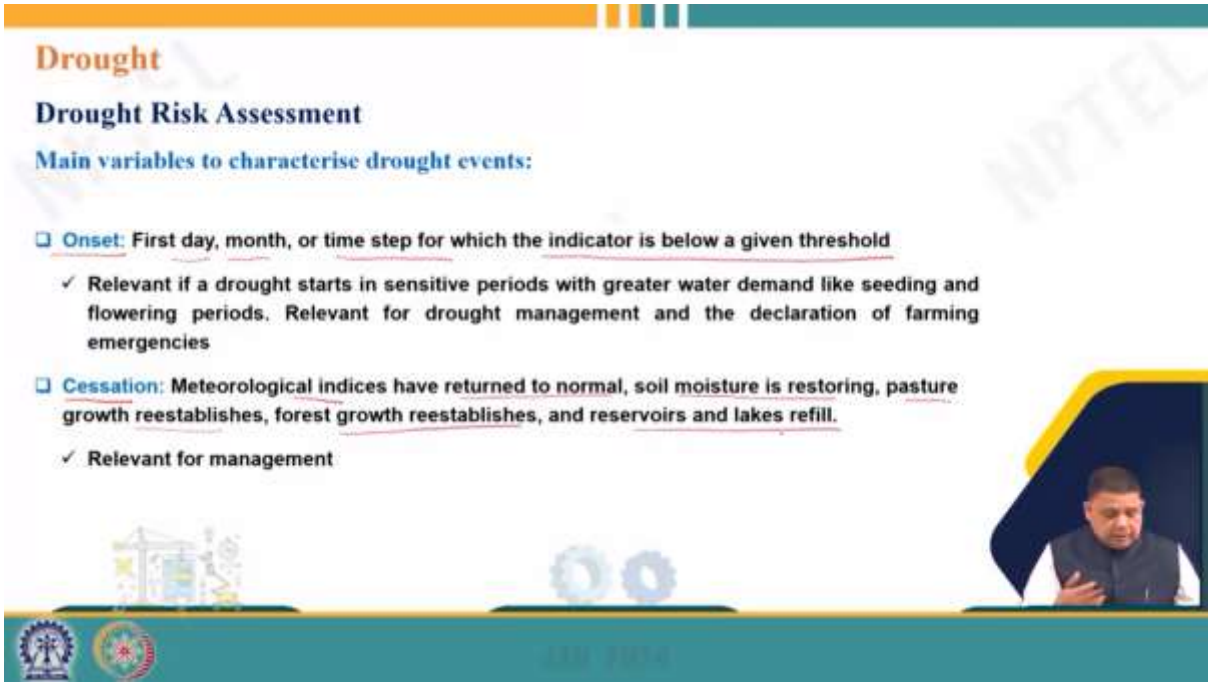


Then if you talk about the main variables for drought then of course, it is of course, frequency that is the number of drought events per defined time interval of course, more frequent droughts can cause long-term impacts on affected ecosystems then severity or magnitude which is related to water deficit and it is computed as a sum of differences in absolute values between

the drought indicator values and the threshold used to define the level of dryness. So, this is a kind of equation where S i is the severity or magnitude of drought for a specific location.

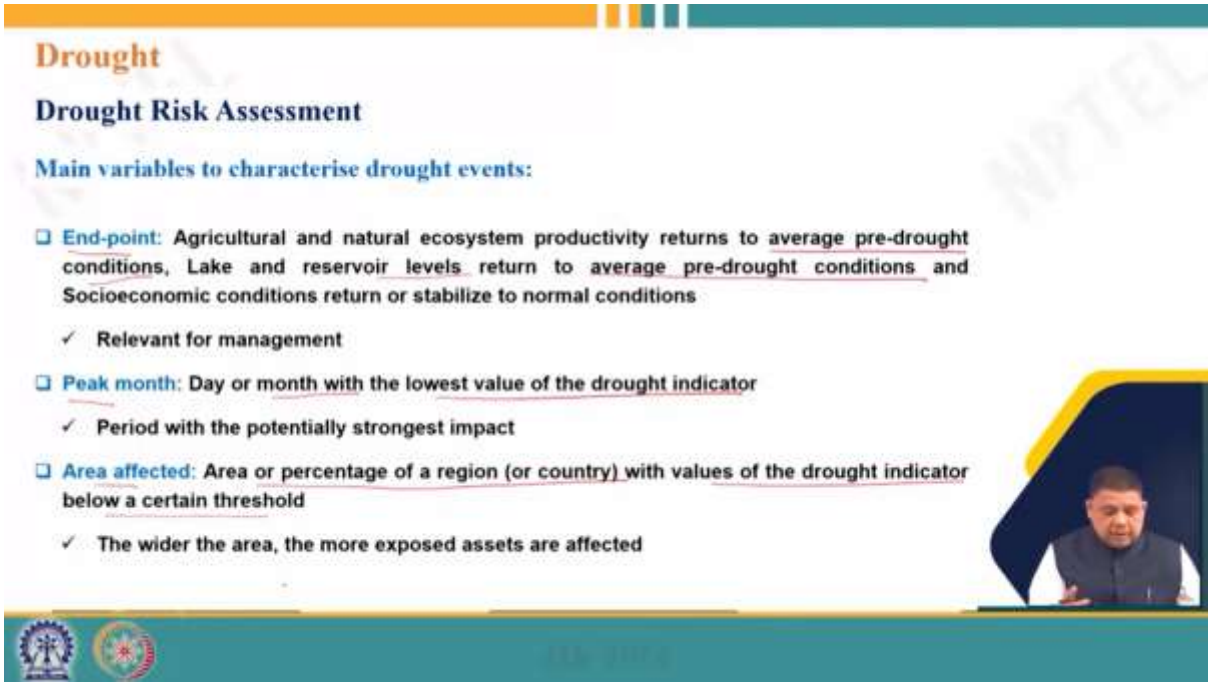


Then of course, variables are deficit of water how much deficit is there which is where needed for specific like irrigation, domestic water consumption, energy production, what is the intensity, severity divided by the duration of the event then duration of course, number of days, months, and time step of the event those all those issues.

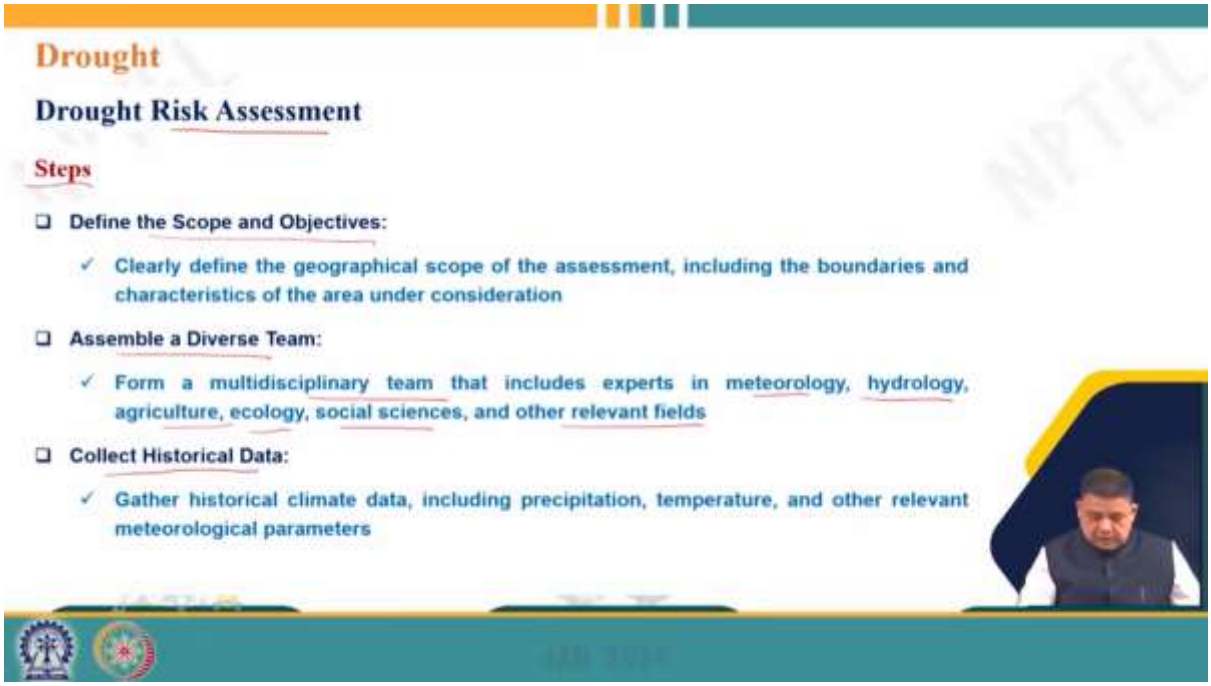


Then the main variable to characterize drought events also include onset that is the first day, month, or time step for which the indicator is below.

So, then when the basically a drought is set in a particular area and of course, cessation that is the end the meteorological indices have returned to normal soil moisture is storing pasture growth reestablishes, forest growth reestablishes, and reservoirs and lakes refills. So, when the what drought gets modelling finished actually the normal situations returns.

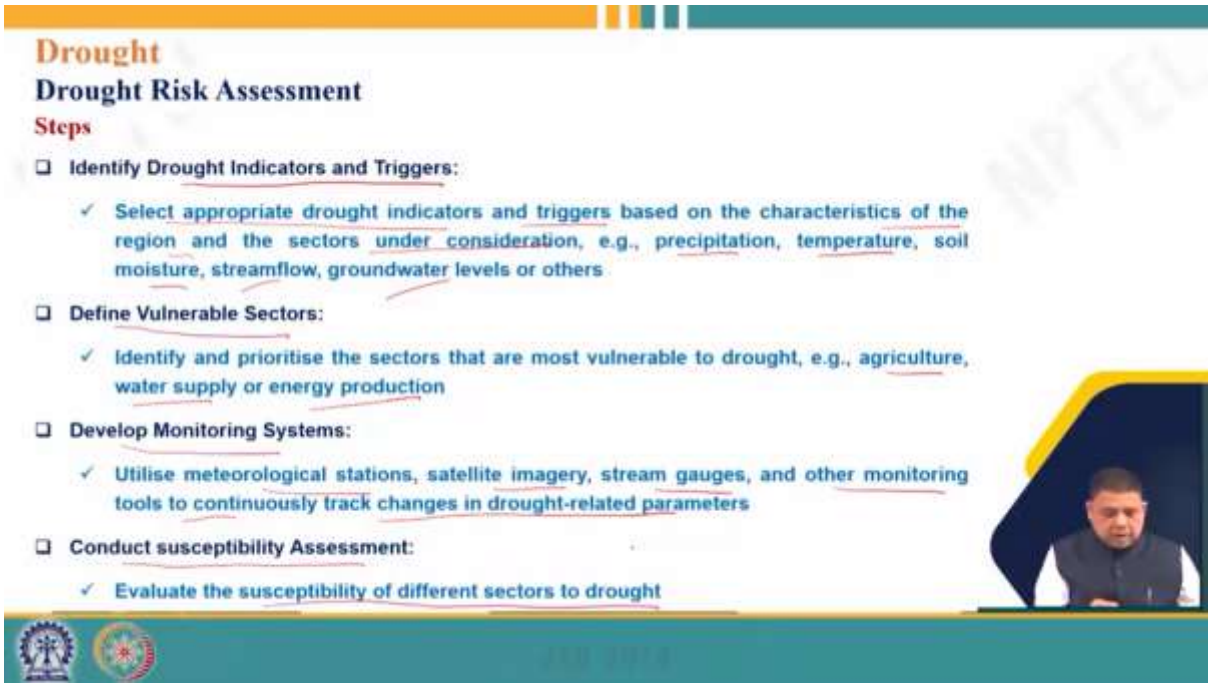


So, that is cessation then of course, endpoint that is agriculture and natural ecosystem productive returns to average pre-drought conditions that is the endpoint and of course, lake and water level reservoirs return to average pre-drought conditions. So, similar to cessation then peak month day or month with the lowest value of drought indicator area affected is the area or percentage of the region or the country with values of drought indicator below a certain modelling threshold that will be the total area that is impacted.

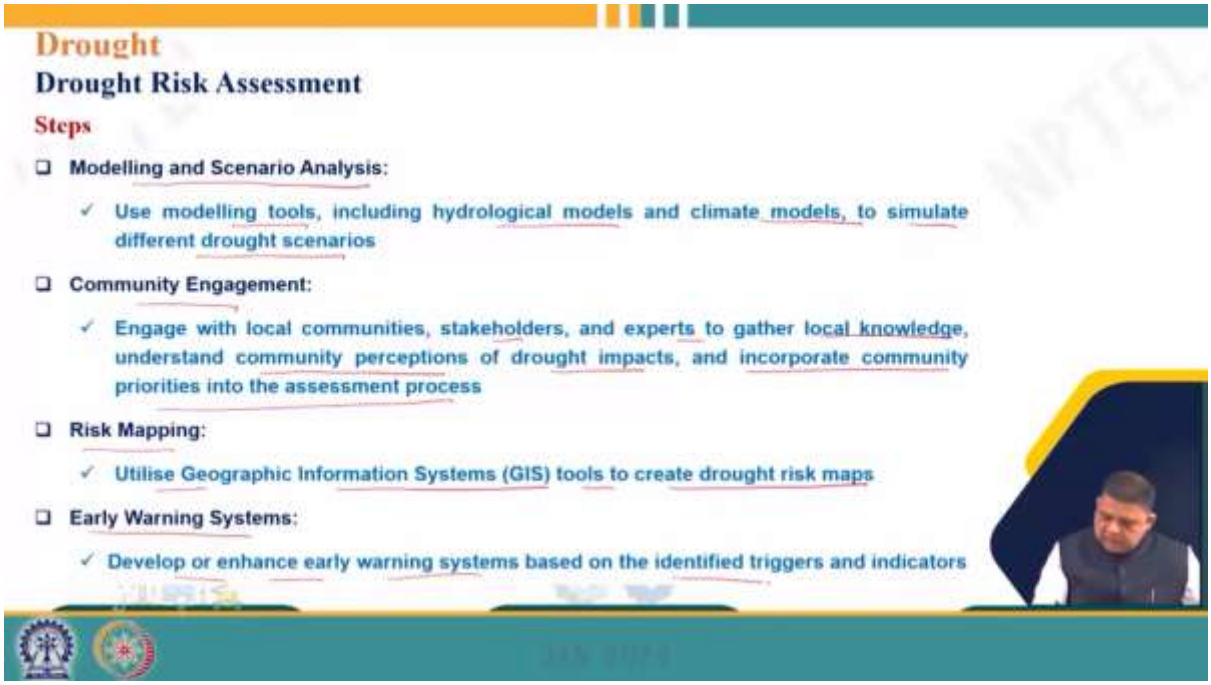


And so all those variables can be taken into account while defining drought and as far as risk assessment goes there are certain steps like we have to define the scope and objective, we have to assemble a diverse team because it has a multi-dimension.

So, we need a multi-disassembly team which includes meteorologist, hydrologist, agriculturalist, ecologist, social scientist and modelling people from other relevant fields. We need to collect historical data in a particular place what was the history behind modelling such events.



And then identify drought indicators and triggers like modelling approach we have to select appropriate drought indicators and triggers based on the characteristics of the region and modelling sectors under consideration. Then and these triggers could be precipitation, temperature, soil moisture, steam flow, groundwater level, or any other then we have to define the vulnerable sectors modelling. So, which sectors are affected it may be agriculture, it may be water supply, it may be energy production. We have to develop monitoring systems and we have to of course, utilize metallurgical stations, satellite imagery, stream gauges, other monitoring tools to continuously track changes. Then we have to conduct susceptible assessment that is susceptibility of different sectors to drought has to be modelling analysed.



Then finally, we have to may use modelling and scenario analysis that is may use modelling tools including hydrological models and climate models to simulate different drought scenarios. Modelling, we need to of course, engage community modelling stakeholders and experts to gather local knowledge understand community perceptions of drought impact and incorporate community priority into the assessment process. We have to have risk mapping that is utilize GIS kind of tools to create drought risk maps and of course, we have to develop an early warning system that is develop or enhance early warning systems based on identified triggers and indicators. So, with this, we come to the end of this lecture and where we have introduced drought or we have discussed the regions behind drought.

We have discussed the drought consequences and also, we have studied the drought risk assessment process. So, thank you very much please give your feedback and also those questions or doubts we shall be happy to answer on the forum. Thank you.


THANK YOU