Watershed Management

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Module No. # 09

Lecture No. # 35

Drought Assessment

Hello and welcome back to the video course on watershed management. Today, I will start a new module - module number nine. So, the topic is on drought management; some of the topics covered in this module include drought assessment and classification drought analysis techniques and drought mitigation planning.

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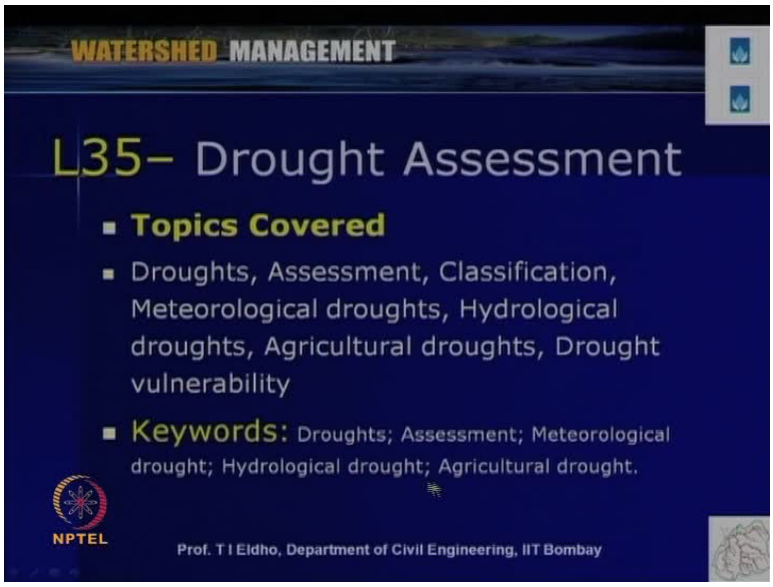

In this module lecture number thirty five today, we will discuss about droughts assessment. Some of the topics covered in today's lecture include droughts, assessment, classification, meteorological droughts, hydrological droughts, agricultural droughts, drought vulnerability.

Some other keywords for today's lecture: droughts, assessment, meteorological drought, hydrological drought and agricultural drought. So, as we were discussing about the

watershed management, it's one of the important resource is water so, it is mainly the management of water. So, as we discussed in the last module if plenty of water is available the rainfall exceeds certain limits and then, various drainage problem then there is a possibility of flooding; so that means plenty of water. Excess of water is needed; water needed so that is the flooding problem. The drought is opposite to the flooding; so, where we do not have sufficient water for long time? For many months or few years in time there is no sufficient rainfall; there is no sufficient water availability - either surface water or groundwater. So, that way when we discuss about the watershed managements, drought is one of the important aspect which we have to see all the aspects and then how we can reduce the vulnerability of droughts as far as when we discuss about the watershed management.

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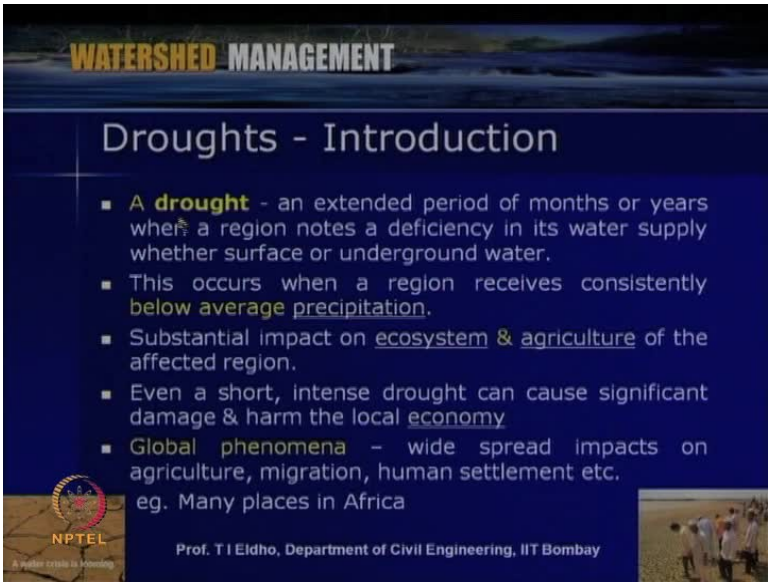

In this context today, let us discuss about the drought assessment; so as I mentioned the definition of a drought is a drought is an extended period of say is an extended period say may be for months or years when a region notes a deficiency in its water supply whether surface or ground water. So that way drought means, there is no sufficient water say whether surface water, groundwater it is not only for few months but say may be number of months or so for few years, there is no sufficient water is available either surface water or ground water. So, that way we can say that location where watershed is say amenable to drought. So, when there is no sufficient rainfall say for few seasons or few years or say even whenever sufficient rainfall is there, but say, for 2 - 3 months and then

say 7 - 8 months or 9 months, there is no rain at all and then there is no sufficient water available. So that way it can be short term drought or long term drought; this way droughts occurs when a region receives consistently below average precipitation. So, that way we can see that when rain is not at all taking place say to a normal condition or average condition so for say few seasons or few years.

So, that way we can say that consistently below average precipitation is the condition for a watershed. Then we can say that that watershed is amenable to amenable to droughts. So that way there is substantial say we when we look about to the drought situations so when we say looked at drought situation many countries or many locations we can see that there is substantial impact of drought on the ecosystem agriculture human being flora and fauna. So that way that affected region there is no sufficient water either in terms of surface water groundwater so that is a major issue so even a short intense drought can cause significant damage and harm the local economy.

As I mentioned, the drought can be for short term or for long term. Short term means even though there was a rainfall say to certain average condition but, that is for a short duration but say for example, two - three months of rainfall. But then, 9 or 10 months of there is no rainfall or there is no sufficient water is available due to various reasons. So then, we can see that that is so called short term duration, so that way, the total watershed will be affected in terms of economy and various other conditions so that way the availability of water is so important as far as watershed management is concerned. So we can see that this drought is a global phenomena so it is we can see it is not only in India or say in Asia but all the countries all the parts of the world or the earth is affected by drought so it is the drought is wide spread and it has impacts on agriculture. So, we can see that if say agriculture needs a sufficient say moisture or water, so that way when the availability of water is not say reduced.

Then, agriculture will be affected and then say when the agriculture say most of the rural economy is based upon the agriculture. So, when the agriculture is affected then the people will be migrating from say the concerned watershed to other places in search of job; so that the other impact will be migration and then human settlement will be say affected. So, if the drought is persisting for long time say many years like what we can see in many of the African countries like Sudan and Chad then, you can see that the human settlement itself will be affected. And then people will be migrating to other parts

of the world so that, we can see these kinds of problem drought say droughts can be short term drought or long term drought. So, long term drought is very detrimental so that the total the settlement or the people will be very much affected especially with a long term drought.

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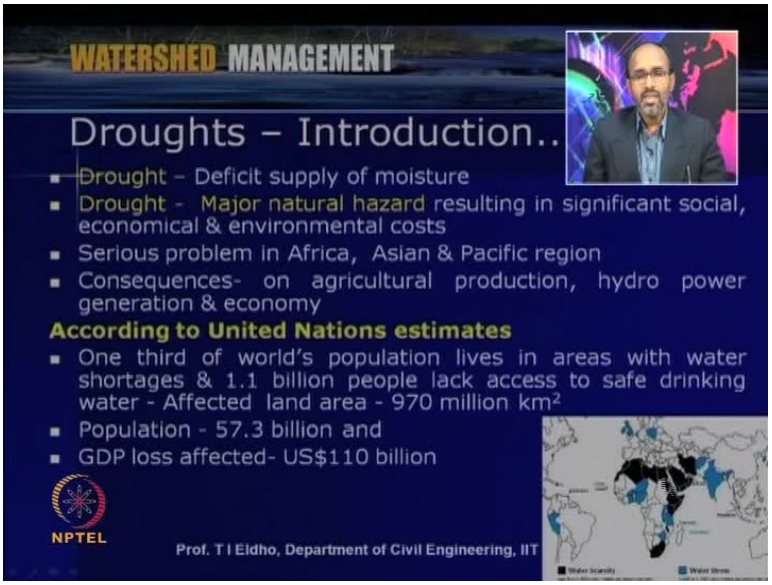

So, that way when we look into droughts so on a watershed scale we can see that say drought is say is we say that there is drought when deficit supply of moisture. So that way it is a major natural hazards and it results in a significance of social economical and environmental cost. So the cost will now not only in social terms economical terms but also environmental terms so that means ecosystem will be say very much affected so as we can see that this is a serious problem in many of the African countries we can see that this is a say world drought map. We can see that wherever this black area is there it is it is say the water scarcity is too much. So that we can see that these are all this; these countries are very much drought prone and long term effect is there as far as drought is concerned.

Then this blue region like India and other region is it is water stressed region. So, there is we can say that many locations will be having short term droughts. The consequences as I mentioned say, long term consequences like agricultural production would be affected. Then wherever, whichever countries where say mainly depend upon hydro power production. So, when water is not available due to the drought, hydro power generation

will be affected. Then total economy will be affected. So, that way the consequences are very detrimental in many of the areas either on a say watershed basis or river basins basis or state basis or even the country wise.

According to United Nations estimates, we can see that about one third of world's population lives in areas with water shortages. So, that means you can see that in many parts of India, then China, Africa, so many and south America, many locations, water-stressed, areas are there. And, even 1 point 1 billion people lacks access to safe drinking water and then say, almost about 900 and 70 million square kilometer area is say water stressed area. So, that way say, on an annual basis we can see that about 60 billon people are affected say annually due to the droughts and there is a gross domestic product loss of annually about 110 billion US dollars.

So, that way this drought is a major disaster; we can see that now many developed countries like United States and European countries have done many measures to combat with the droughts and developing countries like India, China and then many of south African many African countries are all now looking to various say interventions to deal with the short term droughts or long term droughts.

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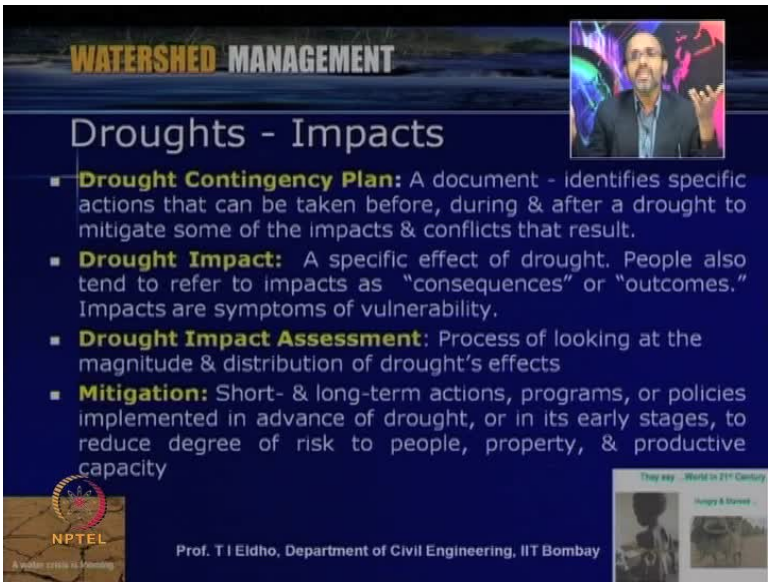

Now, let us see, what are the major impacts of these droughts. When we look into the impacts of droughts say, most of the time we… it is always better to critically analyze it

by preparing the contingency plans. So, we have to analyze what are the causes of droughts and then what kind of measures can be implemented so that, the effects of droughts impacts of droughts can be reduced. So that way, it is always better to prepare a drought contingency plan.

It is a document that identifies specific actions that can be taken say, before droughts, during the droughts and after a drought to mitigate some of the impacts and conflicts that results. So, we can see that as we discussed, impacts are there on the economy, then agriculture, then the total ecological system. So that way, when we prepare a contingency plan, we should have contingency plans to deal say, before the droughts situation can takes place or during the drought and after the drought. So, after the drought, what kinds of measures to regenerate back the system? That way we have to see.

So, as I mentioned, drought impacts say, drought impacts specific effect of drought; so there can be various types of impacts like a economical impact, environmental impact, the impact on the human settlement. So, people also tend to refer to impacts as consequences or outcomes. So that is say, when we say drought impact, it can be also sometimes we can call it drought consequences or the outcome of the droughts. Impacts are symptoms of vulnerability; as we discussed, we can identify the vulnerable areas due to the droughts and then based upon that we can have a drought impacts.

We can assess the drought impacts; so drought impact assessment is the process of looking at the magnitude and distribution of drought's effects. How much intensity, how much is the magnitude? Say, when we look into the drought and then what will be the effects of that magnitude? Say, it is whether it is a very strong type of drought or the moderate or the say what type of drought; accordingly we can see that the impacts and then it is effects can be also analyzed.

Then the next question is how? What are the mitigation plans when we look into drought mitigation? We can have short and long term actions programs or policies that can be implemented in advance of drought or in it is early stages to reduce degree of risk to people, property and productive capacity. So, with various climate conditions we can predict in advance whether the possibility of drought is there or even some areas are always drought-prone areas say and that kind of areas we can take earlier measures to

combat these kinds of droughts. Then, say for example, wherever say arid or semi-arid regions we can implement say schemes like water harvesting schemes or total watershed management plans. So that say that itself is serve as a mitigation plans and then so that we can try to protect the people property and then the productive capacity of that particular watershed so that way on a watershed basis we can think about the drought assessment drought impacts and then drought mitigations plans.

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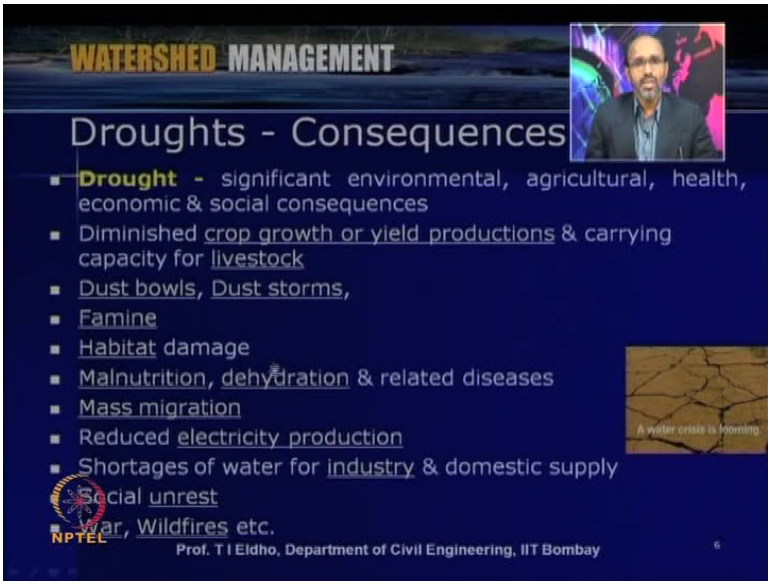

Now, let us look into in details what are the consequences of droughts so here I have listed various consequences so as I mentioned earlier there are significant consequences on environment so environmental consequences; consequences on agriculture then a health and economic consequences and social consequences. So that way we can classify the drought consequences into environmental agricultural health economic and social consequences so say some of the important consequences I have listed here.

So say for example agriculture is concerned so consequences like say when the water availability is reduced so the crops production the crops yield will be reduced or even the crops itself will be affected so that say there is possibility of famine. So diminished crop growth so when the water stress takes place due to the less availability of water so diminished crop growth or yield productions and then carrying capacity of the livestock like either say flora and fauna the carrying capacity will be reduced. Then environment is concerned say some portion of the region become say dust bowls so the sands storms

will be taking place so like a dust storms can takes place then due to the agricultural problems related problems so there can be famines or there is when the production is reduced and then famine possibilities are there and then say if one area becomes say drought prone then habitat damage will takes place since water availability will be reduced and then there will be related issues.

Then as far as the health of the people is concerned malnutrition since due to lack of availability of food and water of a good quality water then dehydration and related diseases so especially in African regions many countries like a chad then say Ethiopia and all these regions we can see these kinds of issues health related issues like malnutrition dehydration and related diseases.

Then the people migrated from one country to another country or one area to another area so mass migration will be the outcome of this and then say the areas wherever the electricity production is power production is from hydroelectric power plants there is possibility of reduced electricity production since sufficient water will not be available Then shortage of water for industry so industrial say yield will be reduced industrial output will be reduced and then even there will not be water for sufficient water for domestic supply and then all these related issues can create social unrest between the communities.

Then even there can be wars between the countries or between the states or between the regions and then also when the temperature rises I mean there is no sufficient rainfall for say many seasons or many years there is possibility of existing forest will be affected due to wild fires. So that way we can see the consequences are too much as far as droughts are concerned and it is too intense and then when we discuss about the watershed management plans especially we have to assess whether the concerned watershed is drought prone and then we have to see that what kind of measures can be adopted to reduce the droughts problem or to mitigate the drought related problems.

So now let us look into some of the issues like the risk and vulnerability related to the droughts so when we discuss about the risk and vulnerability so risk is the potential adverse effects like a product of both the frequency and severity of the hazard and corresponding vulnerability.

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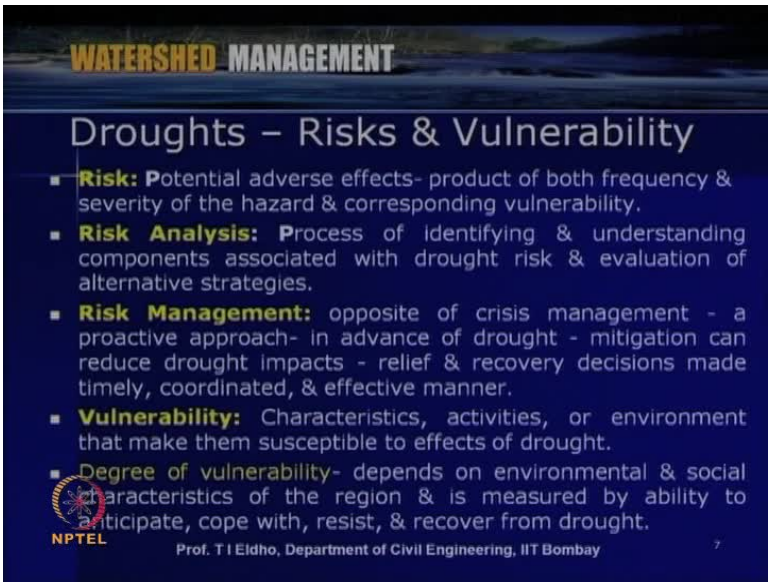

So this is the definition of risk so in say the area is concerned we have to go for risk analysis so based upon the potential adverse effects and then risk analysis the process of identifying and understanding the components associated with a drought risk and evaluation of alternative strategies. So we can assess the what will be the risk related to the droughts say for the particular area or particular watershed and then we can look into alternative strategies based upon the vulnerability analysis or risk analysis. So then the term like risk management so risk management is opposite of crisis management a proactive approach actually we are looking for risk management so crisis management is once the situation become worst or the things happen then we have to see how to deal that is crisis management.

But a risk management if this particular area is say prone to risk so then we can have advance measures like in advance of drought mitigation can reduce drought impacts and then we can have relief and recovery decisions made timely in a coordinated and effective manner. So that way we can go for risk management and then when we look into vulnerability so vulnerability indicates the characteristics activities or environment that makes them susceptible to effects of drought.

So when we say about the drought vulnerability means so these are the characteristics or activities that make them susceptible to effects of drought so we can say calculate the degree of vulnerability so for the particular area depending upon various conditions so

this degree of vulnerability depends on environmental and social characteristics of the region and is measured by ability to anticipate cope up with resist and recover from drought.

So when we discuss about the degree of vulnerability we have to see that with respect to the environmental related issues or social characteristics of that particular region particular location we have to see that how we can say anticipate the issues and then how we can cope up with this the drought situations or how we can resist with respect to the situation arised from the droughts or we can once the drought occurs then how we can recover from the droughts. So these kinds of questions to be answered so this is possible through risk analysis and vulnerability analysis related to the droughts now let us look briefly into say the how the which are the locations mainly drought prone or drought generally occurs so as I mentioned droughts can be either short term or long term.

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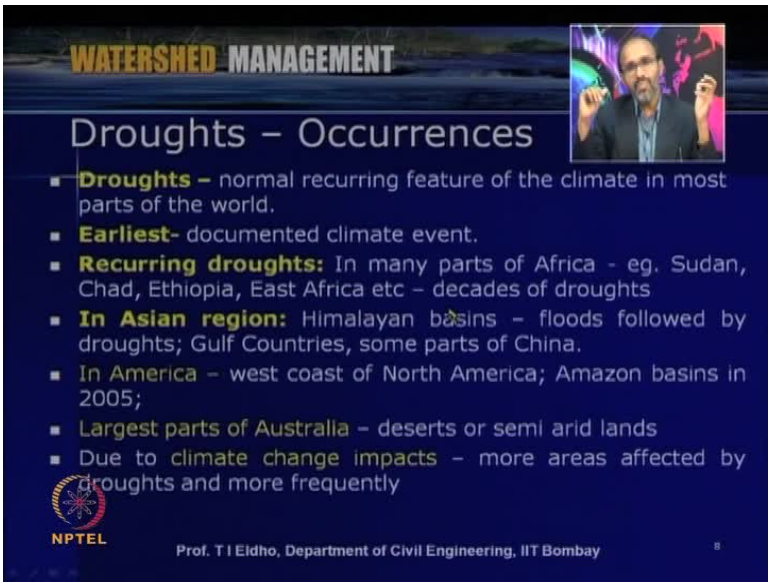

So the droughts when we look into the say the drought situation in at various parts of the world so droughts normal say it is recurring feature of the climate in most parts of the world so especially in many of the African countries.

So this droughts say the occurs say it is normally it is a recovering feature and then so this is actually the drought is actually one of the earliest documented climate event

So we can see that in many of the epics textbooks or the bible or the hindu textbooks or all these say epics textbooks we can see that this droughts have been mentioned and then say the recurring droughts as I mentioned we can see many parts of Africa like countries like a Sudan, Chad, Ethiopia, East Africa etcetera. There are many countries where say year after year the droughts are there so decades of droughts in some of the locations some of the countries.

In especially in Asian countries like a Himalayan basins say in a monsoon season say three 4 months there will be severe floods and that will be followed by drought conditions since immediately the once the say rainfall occurs all the water will be drain say due to the topographical nature of the region and then next few months there is say possibility of droughts.

So these droughts are actually short term droughts but in a country like India Rajasthan where arid regions or semi-arid regions we can see that this this areas are very much drought prone since generally in this region say the available rainfall is very less even some regions just 20 centimeter average annual rainfall in in states like a Rajasthan. Then a Gulf countries some parts of China and then America say especially west coast of USA and then amazon basins say for example there were some drought in 2005 and then say largest part of Australia these are these areas arid or semi-arid region.

So where the normally the rainfall conditions are less and then say the below average rainfall takes place for a number of years then this area become very much drought prone and then related issues will be there. Then as far as now we can see that in the last few years we are discussing about the climate change and it is effects so we can see that due to the climate change impacts say more areas will be affected by droughts and then the droughts become frequent frequently droughts may takes place.

So the climate changing impact assessment shows that whenever say due to the climate change say the possibilities are that rain the short the rainfall may increase many location but the rainfall will be short term and then due to the increasing in as a evaporation and various climate conditions the frequency of droughts will be increase so these are some of the recent assessment which we can see in the literature.

So now let us look into various causes of droughts so we were discussing about the consequence of droughts occurrence of droughts now let us looking to what are the important causes of droughts.

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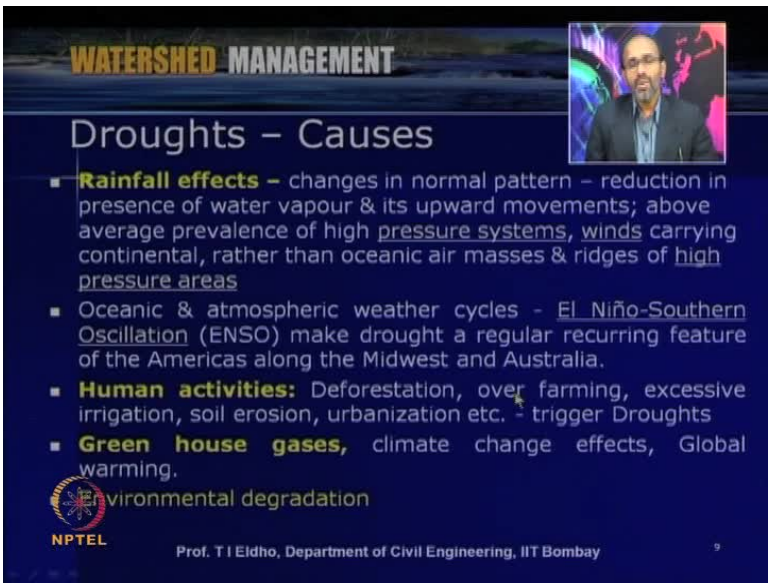

So as I mentioned earlier say the mainly the important causes that the below average rainfall in the region so main impact is the main cause is the rainfall effects so which so this rainfall say wherever average annual possible rainfall conditions are not taking place say 25 percent less or 50 percent less like that.

So that locations become drought prone depending upon the other conditions also rainfall effects can be changes in normal pattern so the just like reduction in presence of water vapour and it is upward movements so say sufficient water vapour should be there and that should be upward movement should be there that way only rainfall takes place and if it does not takes place then rainfall will be effected.

Above average prevalence of high pressure systems then winds carrying continental rather than oceanic air masses so oceanic air masses means there will be say more vapour in the air masses but if it is coming from say continental then there will be less say the vapour so that way the possibility rainfall will be reduced.

Then ridges of high pressure areas so that way the main cause is say less rainfall taking place so that way this have some of the causes of this the rainfall effects then conditions

like a oceanic and atmospheric weather cycles. So like say El Nino Southern oscillation ENSO or El Nino that kind of phenomena like a make drought a regular recurring features of the various continents like Americas along the Midwest and Australia.

So this can be also not only the rainfall effects but rainfall is the main cause but the rainfall will be reduced or the monsoon will be effected due to oceanic and atmospheric weather cycles. Then also like a other than the natural causes like a human activities also can cause this type of drought situations so human activities like a deforestation over farming excessive irrigation soil erosion then urbanization etcetera trigger droughts.

So that is we have large number of examples so this kinds of problems like a say for example in India some Gujarat Kutch region and Rajasthan regions say wherever say like a deforestation over farming all those things taking place say on a long period then we can see that the adverse effects takes place and that one of the effect is the possibility of droughts. Then say as we already discussed climate change effects like a greenhouse gases increasing greenhouse gases then climate change effects and global warming are also the causes of droughts.

So generally we can say that the all the effects will be the environmental degradation so this environmental degradation leads to the short term or long term droughts when we critical analyze the drought situation in many of the locations all over the world. So now say with this backgrounds now let us looking into the classification of droughts so we can classify the droughts into 4 categories depending upon the nature or the what is the after effects of the of the drought.

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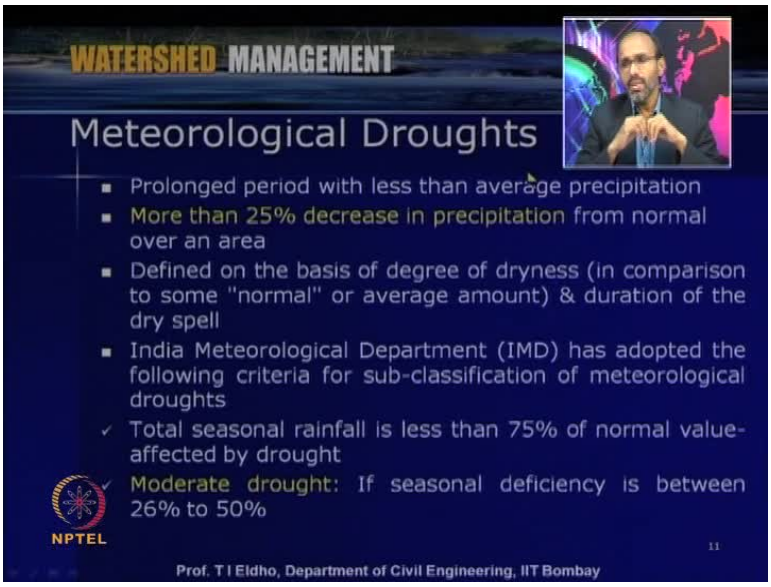

So we can classify the droughts into meteorological droughts hydrological droughts agricultural droughts and socio-economic droughts so meteorological drought actually defined by climatic variables say like a precipitation humidity evaporation and the duration of the dry period so this is actually meteorological drought is defined by this climatic variables.

Then hydrological drought means it is associated with effects on surface or subsurface water supplies so like a stream flow reservoir lake rivers and groundwater so even though rainfall takes place due to various reasons if the availability of surface water and groundwater is reduced then there is possibility of hydrological droughts.

Then the third category is agricultural drought so this impacts of meteorological drought to agricultural like a focusing on precipitation shortages then differences between actual and potential evapotranspiration soil water deficits crop failure etcetera so this is the actually the outcome with respect to the meteorological drought.

Then socio-economic droughts actually this occurs when the demand for an economic good exceeds supply as a result of a weather related shortfall in water supply so when water is not available so the impacts related to social or economical say related issues so that generally we call it as socio economic droughts. So, now let us, looking to all these classifications into details so first one is the meteorological droughts so meteorological

droughts so as we discussed say whenever prolonged period with a less than average precipitation takes place then we can say that meteorological droughts takes place.

So this we can classify into 3 categories say when the average the rainfall in a particular location is say 25 percent decrease is there with respect to the normal that is one category so that is maybe we can say mild type drought or say when the rainfall is or precipitation is in a say 50 percent decrease with respect to normal.

Then, we can say moderate and when the rainfall is say to 75 percent decrease with respect to the normal condition then we will say severe drought conditions so that way so we can defined the drought situation on the basis of degree of dryness so in comparison to some normal or average amount and duration of the dry spell.

Accordingly, we can classify the meteorological droughts so based on the degree of dryness say for example say according to norms of Indian meteorological department IMD so they adopted the following criteria for sub-classification of meteorological droughts. So like a total season rainfall is a less than 75 percent of normal value affected by droughts then moderated drought is if season deficiency is between 26 to 50 percent then say the third category is say like say compare to this say earlier first one is 75 percent then 26 to 50 percent and then less than 26 but up to 25 percent.

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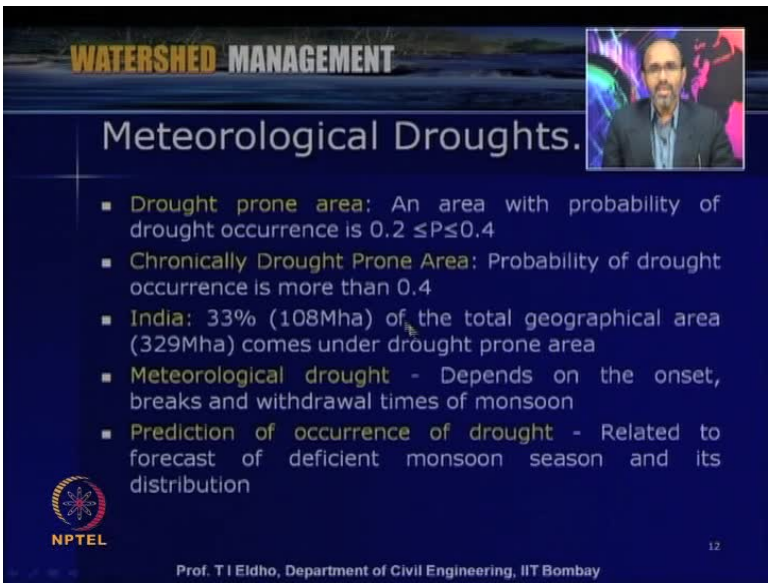

So that way mild moderate or severe drought conditions so that way we can classify so this a meteorological droughts when we look say the we can also see with respect to the probability of drought occurrence so if you defined probability of drought occurrence say if it is say in a particular area and if the area is said to be drought prone if it the probabilities between point 2 to point 4.

We say that that area is chronically drought prone area when the probability exceeds point 4 and say 4 for example say 4 depending upon this whether it is simply drought prone area or chronically drought prone area we can classify the area and then see with respect to various conditions or with respect to the probability of the drought occurrence.

So say for example in India about 33 percent or one third of the total geographical area comes under drought prone area so say some areas like a Rajasthan say Gujarat Kutch region these regions are chronic drought prone area and some areas are say depending upon the weather conditions or various conditions say some part of Maharashtra, Bihar or Madhya Pradesh are say simply drought prone area. Then, this meteorological drought depends on the onset breaks and withdrawal times of monsoon say for example we consider the monsoon condition in a country like India so this meteorological drought we will say that say what time the monsoon starts the onset of monsoon and whether the monsoon is continuously proceeding to the various locations of the country or whether it breaks or say what time it will be withdrawing the withdrawal times of the monsoon.

Accordingly, we can say that whether meteorological drought takes place or not so actually Indian meteorological department generally predicts the rainfall conditions say one month before the monsoon and then that they assess the drought situation with respect to various data at various location of the country.

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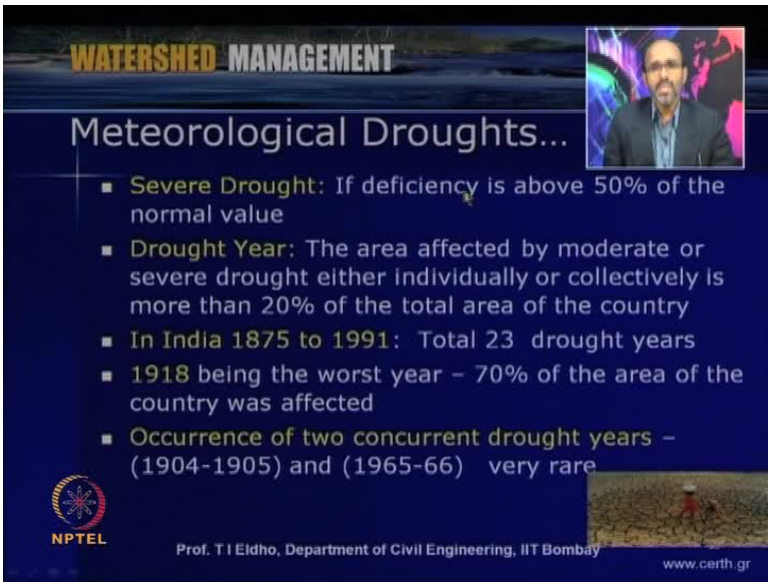

So then prediction of occurrence of drought is related to forecast of deficient monsoon season and it is distribution so in India this is done by indian meteorological department so then say as I mentioned the meteorological drought when we consider say severe drought if deficiency is above 50 percent of the normal value. Then say we say that a drought year is there when the area affected by moderate or severe drought either individually or collectively is more than 20 percent of the total area of the country.

So say a county like India when we say that is a drought year say for example 2000 2 3 or 2009 say some of the drought years. So we say that more than 20 percent of the total areas of the countries affected by moderate or severe droughts say if we looking to the literature we can see that is say for example India if we consider the data for between 1875 to 1991. About totally 23 drought years were there and say for example 1918 being the worst year of the drought say 70 percent of the area of the country was affected in 1918.

Then say this drought when we when it occurs say 2 concurrent or consecutive years drought years then it is becoming a severe problem so say for example in India 1904 and 1905 2 years were drought period and then 1965 and 66 were drought years. Actually, even though this occurs rarely but if it happens then the condition becomes very bad as far as the economical situation and various other conditions as far as the drought backs are concerned.

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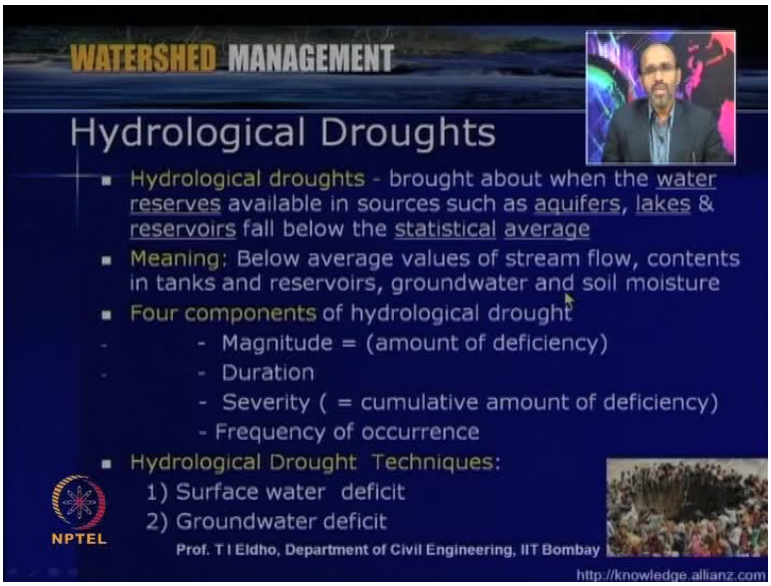

Now, next category is the hydrological droughts so hydrological droughts actually brought about when the water resource available in sources such as aquifers lakes and reservoirs fall below the statistical average so we can have a statistical average like if you consider reservoir groundwater aquifer systems like that. So we say that there is a hydrological droughts when the water levels in this storage systems goes fall below the statistical average so this can be due to various reasons as I mentioned say in Kokand region in Maharashtra so even though severe heavy rainfall takes place during the monsoon season. But immediately after the rainfall this all the water will be drained due to the topography of the region so then there is say hydrological drought will be there next say 6 months like that.

So this hydrological drought means below average values of stream flow then contents in tanks ponds and reservoirs groundwater and soil moistures so all these will be less than the average values or minimal say mean values. So that way when we look into hydrological droughts we can say 4 components of hydrological droughts we can see there are 4 components of hydrological droughts like a what is the magnitude so say how much is the deficiency with respect to the statistical average in the reservoirs or other storage systems.

Then how much duration whether it is say 6 months 3 months like that and then what is the severity say like cumulative amount of deficiency how much is the deficiency taking

place. So and then what is the frequency of occurrence so whether it occurs say every year or once in 10 years like that so that way we can say ascertain the hydrological droughts.

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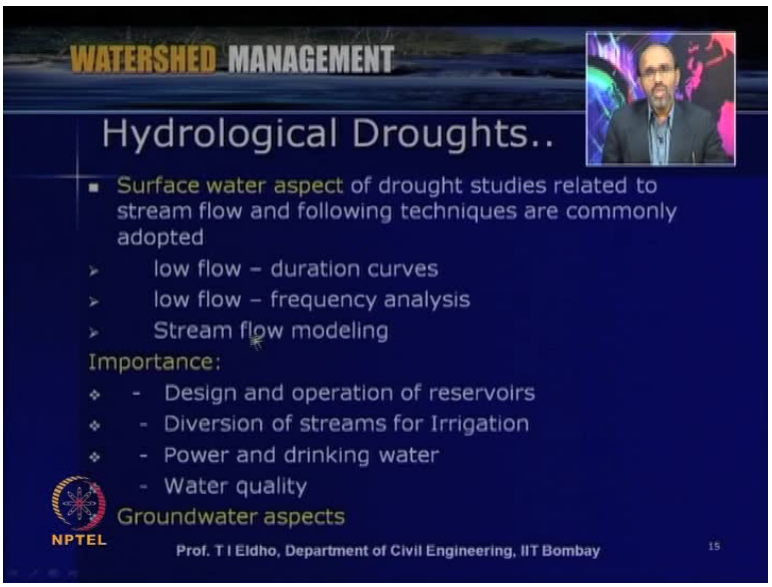

These hydrological droughts that way we can classify into surface water deficit and groundwater deficit so surface water aspects when we look into with respect to hydrological droughts.

So the surface water aspect of drought studies related to stream flow and following techniques are commonly adopted like say whether the through the river or to the reservoir or in the pond what is the level of water so like a low flow duration curves or low flow frequency analysis or stream flow modeling so all these indicates the surface water aspects. So the importance of this surface water assessment or aspect is say when we look into design and operation of reservoirs we have to see in the possibility of this type of hydrological droughts. Then diversion of streams for irrigation say when we are diverting the water from one river basin to another river basin or one watershed to another watershed we have to see.

Then power whether the electric power is produced from hydropower then we have to see it is related issues and then availability of drinking water and then water quality so

when the level in the rivers or the water level goes down or the reservoir levels goes down then we can see water quality will be affected.

So all these issues we have to see with respect to the surface water aspects and with respect to the groundwater aspects we have to see the quantity the water level going down in the aquifer system so that the wells become dry and then also the quality of the water will be also affected with respect to the groundwater aspects so these are the issues related to the hydrological droughts.

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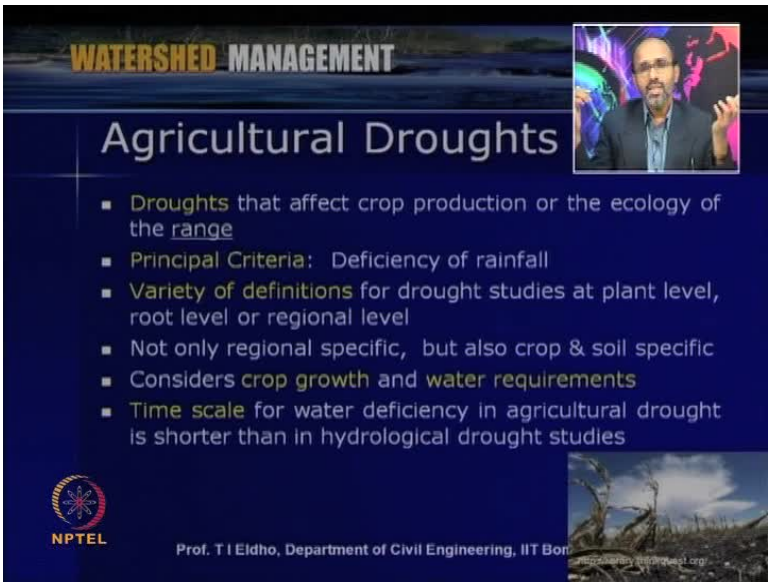

Now, the third classification in the agricultural droughts so droughts that affects crop production or the ecology of the of the range so that is so called agricultural droughts so the principal criteria is the deficiency of rainfall or deficiency of the soil moisture so that the crops cannot grow properly and then yield will be reduced or the crop will be died.

So variety of definitions for drought studies at plant level we can put like a root level or region level or the with respect to soil moisture condition level or the evaporation level like that. So not only regional specific but also crop and soil specific and this considers a crop growth and water requirement so say for example in India when we look into the Kharif crop or the Rabi crop say Kharif crop is due to the monsoon time and Rabi is after the monsoon time.

So now especially the Rabi season say the crops may be depends upon the soil moisture available and then if there is no irrigation then we have to see say how much water is available and then with respect to the soil moisture available how the crop growth is affected. So this is with respect to timescale for water efficiency in agricultural drought so this maybe for shorter period compare to the hydrological or a meteorological drought studies.

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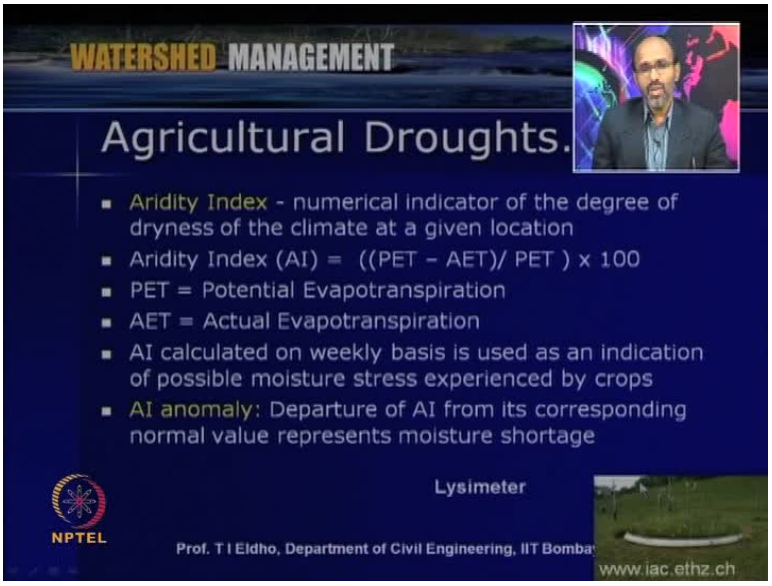

So when we look into the agricultural droughts we can derive an index called a aridity index so actually this aridity index is a numerical indicator of the degree of dryness of the climate at a given location. So the aridity index indicates how severe is the agricultural drought so there are number of definitions available for aridity index one of the commonly used definition is say aridity index is equal to potential evapotranspiration minus actual evapotranspiration divided by potential evapotranspiration multiplied by 100.

So the aridity index we can calculate either on a weekly basis or say once in 2 weeks like that and it is an indication of possible moisture stress experienced by the crops so we have to calculate the potential evapotranspiration by Equipment's like a Lysimeter in particular region and then based upon that these calculations we can find the aridity index.

So aridity index anomaly actually it shows the departure of aridity index from it is corresponding normal value represents the moisture shortage so the when the moisture shortage is taking place then the crop will be affected crop will be water stress and then the crop yield will be affected.

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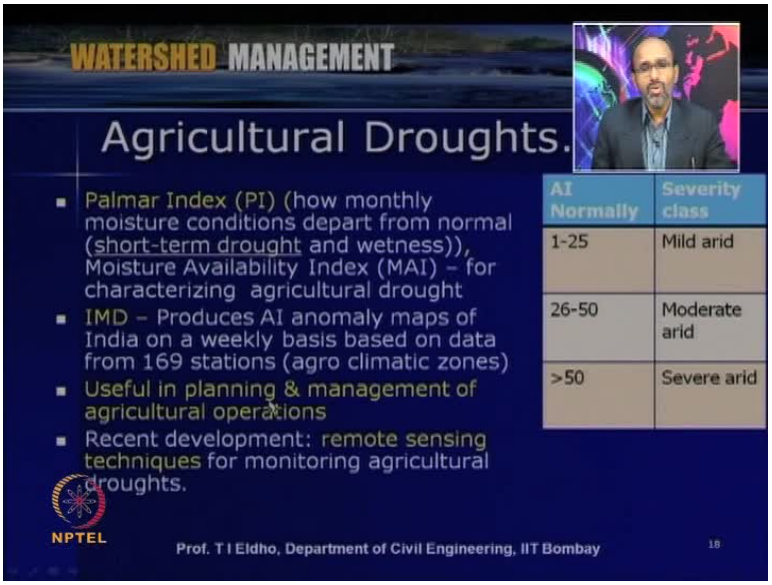

So accordingly this aridity index say with respect to the aridity index we can say that when it is varying from 1 to 25 we can say it is mild arid then a 26 to 50 we can say it is moderate arid and then when it is greater than fifty we can say it is a severe arid .

So and then some other indexes like a palmar index say which shows monthly moisture conditions how it is departing from normal or conditions it is a actually short term drought and wetness and then moisture availability index so these are all use to identify whether the particular area is say that area agriculture drought is there. Then accordingly say whether it is short term or long term we have to go for various mitigation measures say for example Indian meteorological department IMD produces aridity index anomaly maps of India on a weekly basis based on data from 169 stations spread over the country.

So say this stations are in various agro climatic zones and then this aridity index will give an indication say how the crops will be affected whether the crops are water stressed and then whether a corresponding agricultural droughts possibilities are there are not.

So that way this aridity index are useful in planning and management of agricultural operations and recently now we can use remote sensing techniques also to identify whether there is a agricultural droughts or whether the area is arid say through the when the with remotely sensed data we can say it can be either microwave or specific type of say remote sensing data so that shows the soil moisture variation in the soil so this can be used for monitoring the agricultural droughts so this is about the agricultural droughts.

So now let us look into the socio-economic droughts actually socio-economic drought is a not a real classification drought but what will be impacts with respect to the either meteorological drought or the hydrological droughts or the agricultural droughts.

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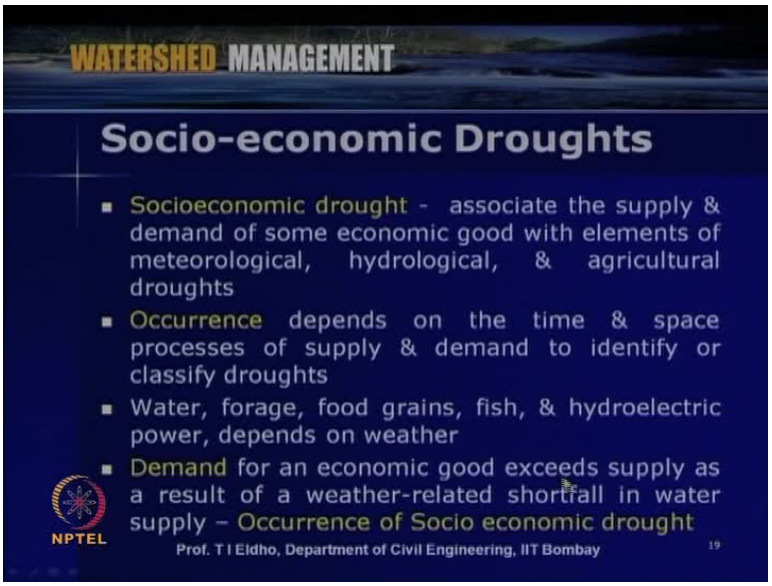

So what will be the effect on the so what will be the social effects or the economical effects so that is we are trying to indicate by socio-economic droughts socio-economic drought are associated so it is associated with the supply and demand of some economic goods with elements of meteorological hydrological and agricultural droughts.

So with respect to the this meteorological hydrological or agricultural droughts we are coming with the conditions of socio-economic droughts so the socio-economic droughts occur say occurrence depends on the time and space a process of supply and demand to identify or the classify or classify the droughts.

So what time the droughts takes place or how much time into takes place and what location so accordingly this socio-economic droughts and occurrence will be there so water forage food grains fish and hydroelectric power so all these say depends upon weather and then correspondingly the variations say this the economical say the activities will be depending upon that.

So that way when the water availabilities say reduced due to the droughts so then economical impacts will be there so then corresponding economical drought and then corresponding social effects will be there that is the social economic droughts.

So the demand for an economic good exceeds supply as a result of a weather related shortfall in water supply then we say that there is a occurrence of socio-economic drought. So that way say the we have to assess with respect to the drought situation how the economical impacts will be there and then what are the social impacts and then corresponding consequences we have to analyze and then we have to see the remediation or mitigation measures.

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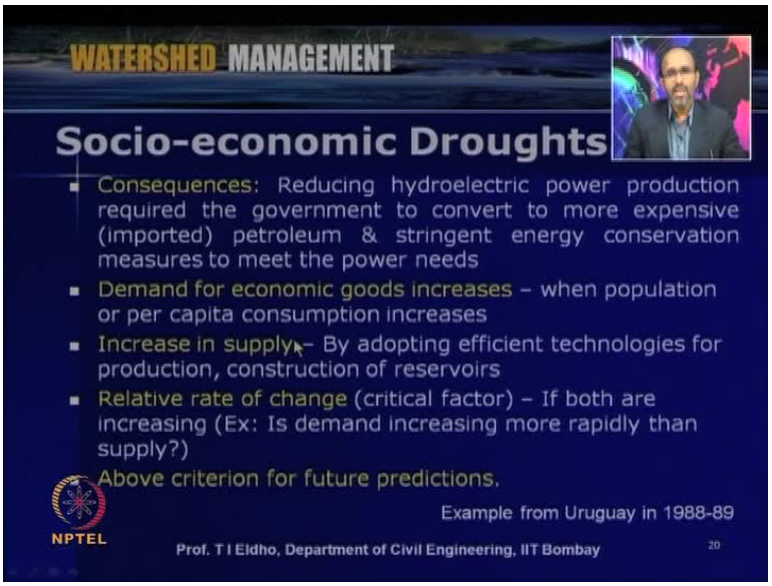

So that way when we look into the socio-economic droughts the consequences are reducing hydroelectric power production required the government to convert to more expensive imported petroleum and stringent energy conservation measures to meet the

power needs say for examples if it is the area the location in the power production is through hydroelectric power plants.

Then demand for economic goods increases when population or per capita consumption increases say that can be another consequence then increase in supply by adopting efficient technologies for production construction or construction of reservoirs we can reduce the impacts. Then relative rate of change like a critical factor if both are increasing say is demand increasing more rapidly than supply then we can see the relative rate of change how it is taking place.

Then above criterion for future predictions are depending upon the consequences or the demand for economic goods so accordingly say we can assess the socio-economical impacts and corresponding socio-economic droughts situation for the particular watershed or particular region. So now say we have seen the classifications with respect to the droughts now let us look what are the impacts and then the vulnerabilities so we will be discussed this aspect earlier also we defined the risk and vulnerability.

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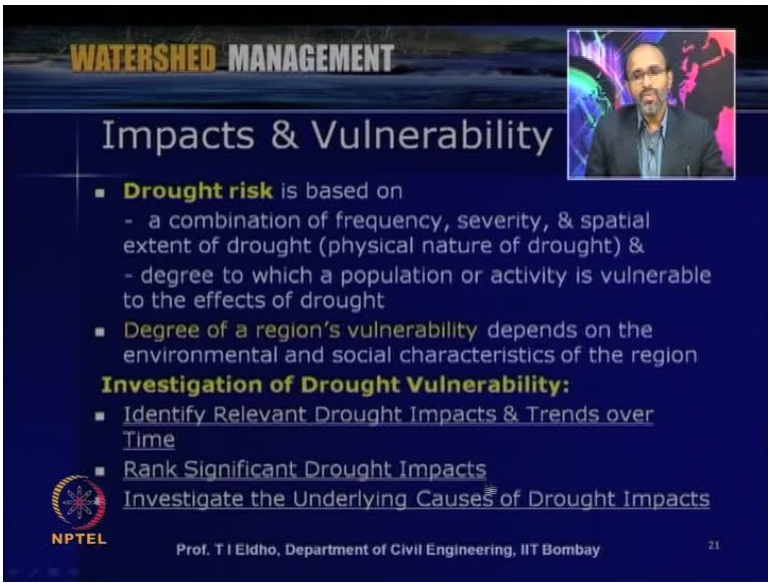

So the drought risk is based on a combination of frequency severity and spatial extent of drought so as a physical nature of drought and degree of to which a population and activities vulnerable to the effects of droughts

So as we discussed so this is a combination of say frequency severity and spatial extent then degree of regions vulnerability depends on the environmental and social characteristics of the region

So what are the environmental effects say what are the social effects so accordingly we have to define the degree of the degree of vulnerability of that particular region so we have to investigate the drought vulnerability

So first we can identify the relevant drought impacts and the trends over time and then we can rank significant drought impacts with respect to the conditions and then we can investigate the underlying causes of drought impacts

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So that way we can have we can investigate the drought situation and then we can come up with say vulnerabilities and then even we can produce vulnerability maps so when we discuss the drought vulnerability so the we have to identify the relevant drought impacts and trends so like impacts are often symptoms of other underlying problems like vulnerabilities

So for example drought impact reporter developed by united states of America so this drought impact reporter shows how the system whether particular area is vulnerable or not

Then we can have a ranking so ranking drought impacts so like a ranking based upon the cost areal extent trends over time public opinion fairness and ability of affected area to recover

Say accordingly to various parameters we can produce a ranking and this ranking ensure equitable policy formulation so like you have say economical helps or a economical say particular funding for particular region. So we can have these kinds of ranking and the so that we can have equitable policy formulation that helps say for public and community advisory committees and groups of relevant scientists and policy makers.

So these kinds of ranking of drought impact is very important say for example drought impact ranking matrix we can have illustrate or community level business or individual scale and the from that we can easily identify what will be the possibility of the particular area affected to be affected by the drought and what is the rank.

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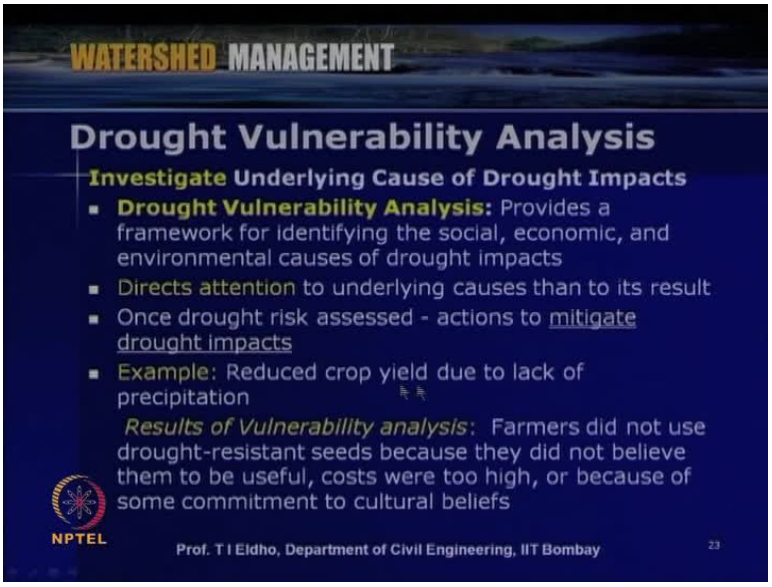

So then accordingly the various mitigation measures or economical measures we can go for so when we discuss about drought vulnerability analysis so we have to investigate the underlying causes of drought impacts as we already discuss.

So drought vulnerability analysis provides a framework for identifying the social economic and environmental causes of drought impacts so this all these issues we have to discussed earlier so then we may have to some directs attention to underlying causes

than to its results. So, what are the causes? According to the causes say, we have to go for the mitigations or the remediation. So, first we have to identify the causes then only to the results so that, causes say for example, if we can go for say water conservation or rainwater harvesting or build a dam so what kind of direct attention is needed.

Once drought risk assess is assessed, action to mitigate the drought impacts. We can look say for example, reduced a crop yield due to lack of precipitation. So then, the results of vulnerability analysis the farmers did not use drought resistance seeds because they did not believe them to be useful or costs were too high or because of some commitment to cultural beliefs. So we have to say, what I am saying, we have to identify the causes and then we have to see the what is all vulnerability as far as the drought is concerned and then we have to come up with the mitigation measures.

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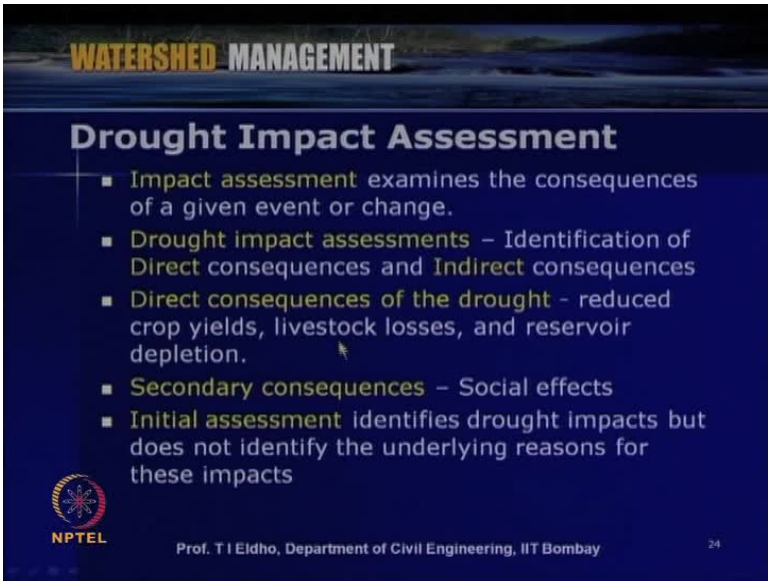

So, that way the drought impact assessment is very important; based upon this drought impact assessment only we can generate the vulnerability maps. The impact assessment examines the consequences of a given event or change. So, drought impact assessments actually are useful identification of direct consequences and indirect consequences as far as the drought is concerned. there are certain direct consequences like directly the water will… availability will be reduced and then agricultural will be, yield will be reduced and then, indirect consequences will be the total ecological system will be affected; so the flora and fauna will be affected like that.

Direct consequences of the drought like reduced crop yield, livestock losses and a reservoir depletion, these are some of the direct consequences and then secondary consequences or the indirect consequences; then corresponding social effects. So, the people will be affected the society will be affected. Then the initial assessment; identify the drought impacts but, does not identify the underlying reasons for these impacts. So, we can have initial assessment as far as the drought situation is concerned and then we can go for a final assessment based upon the initial assessment by critically studying various aspects, so that the drought impact can be properly assessed.

So when we look into the drought impacts, so we have already discussed there are mainly 3 common types of impacts. Like a first one is the economic impacts, second one is social impacts, third one is the environmental impacts.

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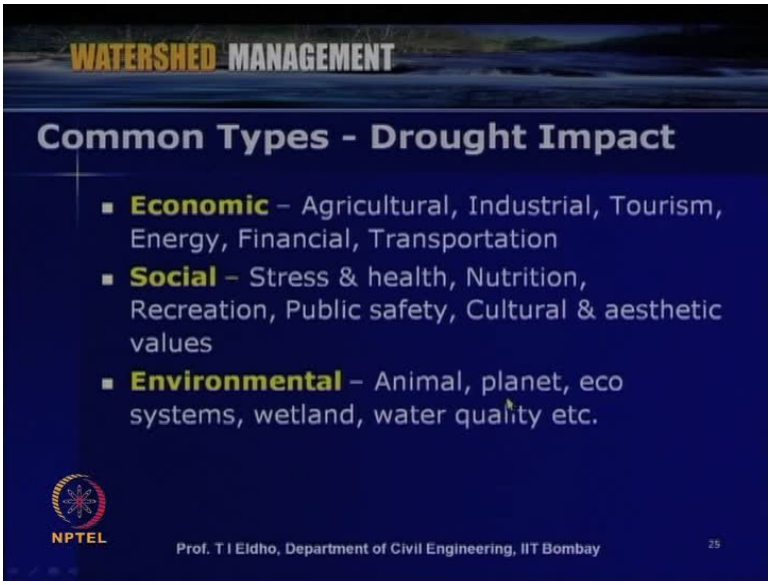

So the economic impacts as we discussed can be agricultural, industrial, tourism related energy related financial or transportation related. So, these are some of the important economical impacts. Then social impacts like the social stress or the health of the people are effected then malnutrition. Then, there is no facility for recreation; then public safety is affected; then the cultural and aesthetic values are affected. So, these are some of the social impacts of the droughts. Then we when we look into environmental impacts like flora and fauna are affected the planet; the area is affected, eco-system is affected when,

if the wetland is effected then surface water and groundwater qualities are affected. So, like that so the number of environmental impact impacts will be there.

So say, when we look into the drought assessment we can produce say various tables in tabular forms various parameters and then we can come up with a checklist whether the with respect to various condition; whether it is there are historical situation is there or current, how it is or there is potential drought.

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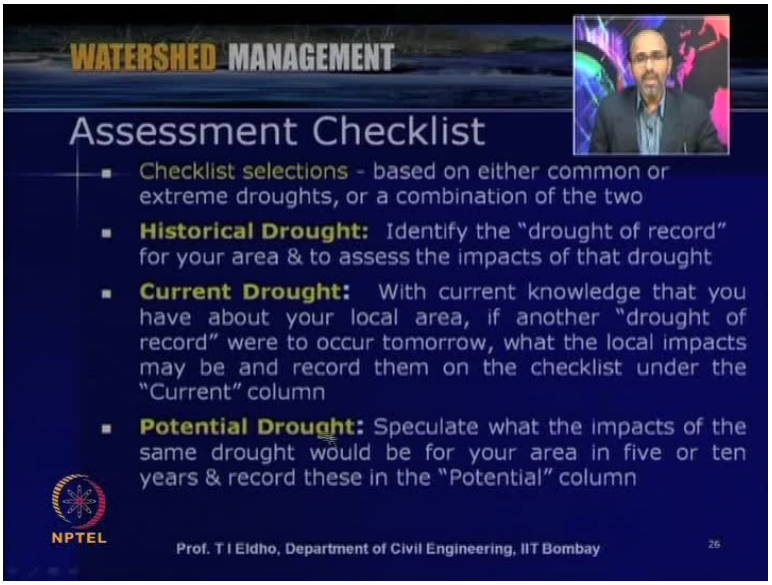

So that way say a checklist selection can be based upon either a common or extreme droughts or combination of the 2 and then, historical droughts that identify the drought of record for the area and to assess the impacts of that droughts. Then current drought like a… with a current knowledge that you have about your local area, if another drought of record were to occur tomorrow or what the local impacts may be and then record them on the checklist under the current column. Then, potential droughts like that is speculated; what the impacts of the same droughts would be for the area in 5 or 10 year time and then record this in the potential column. So, that way we can come up with a checklist with respect to the drought when we look into the drought impact assessment.

Then with respect to the conditions like a severe moderate or low impacts or we can put with a historical drought situation, current drought situation or the area is potential drought situation.

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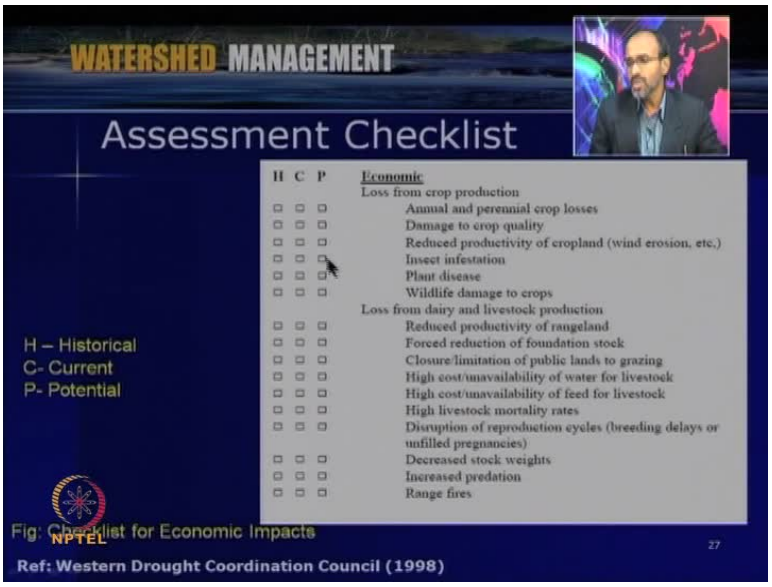

Fig: Checklist for Economic Impacts

So that way say for example, here these checklists are taken from western drought coordination council of United States. Here, they have put economic assessment; so the checklists for economic impacts like a loss from crop production, various columns are there; loss from dairy and livestock production. So the columns are given like, what is the historical situation? What is the current situation? Then, what is the potential drought situation? So, we can keep, we can give ranks for the each of these and then see whether the area is say historically drought prone area or current drought is there or the area is potentially drought prone.

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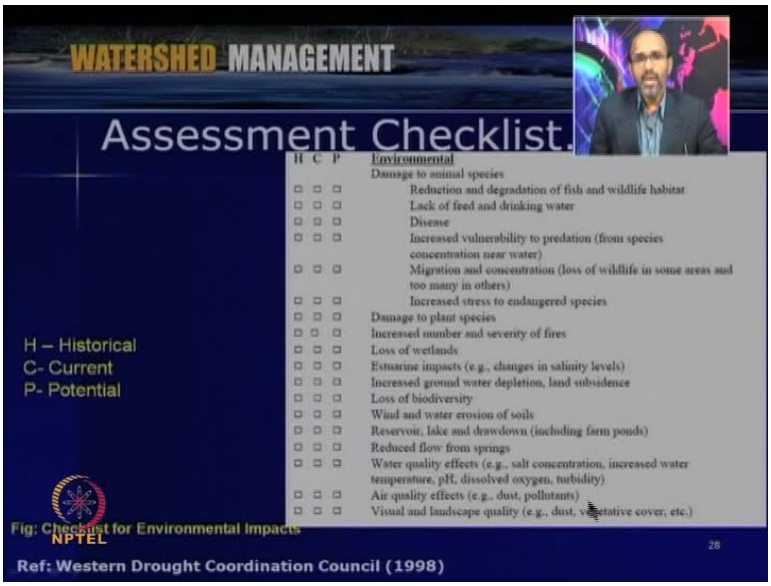

Fig: Checklist for Environmental Impacts

Then say with respect to the environmental impacts, this also taken from western drought, coordination council website. So, their environmental related issues like damage to animals species, then damage to planet species, loss of wetlands wind and water erosion of soils, so like that. Here again we can have the checklist like a historical situation current and potential; so that way we can put the tick mark or checklist and then we can come up whether the area is how much drought prone and we can have the drought assessment.

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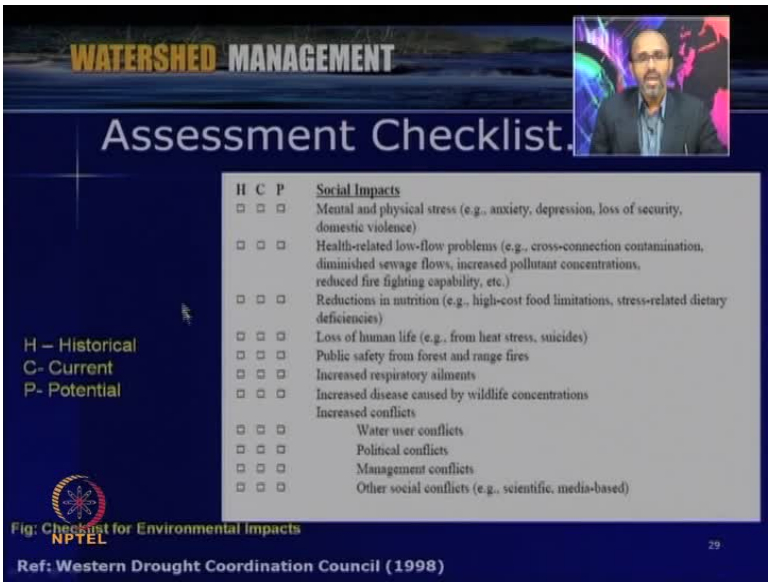

Fig: Checklist for Environmental Impacts

Then if you consider, the social impacts are concerned, then social impacts like a mental and physical stress, then health related low flow problems, reductions in nutrition, then loss of human life, then public safety from forest and range fires, like that. So, this is a checklist for social impacts and whether it, with respect to historical or current or potential, what are the possibilities? So, this checklist shows how the system will be behaving.

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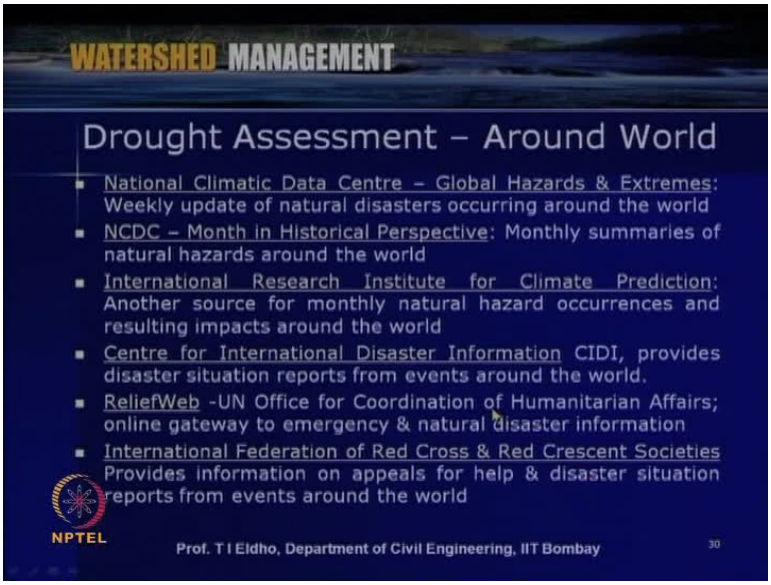

So, that way we can have the checklist and then we can assess the drought and as far as drought assessment is concerned say, around the world various agencies assess the drought situations; not only drought, other natural hazards like earthquake, tsunami and other flooding, etcetera all these disasters.

But drought is also one of the disasters which various agencies are monitoring like a National Climatic Data Center then, say (NCDC) then, International Research Institute for Climate Prediction, then Center for International Disaster Information, then Reliefweb United Nations office for coordination of humanitarian affairs, International Federation of Red Cross and Red Crescent societies. So, all these agencies with respect to various parameters, with respect to various checklists, they assess various the various locations whether it is drought prone or how much severity can be there with respect to drought. So, all these situations there will be assessed and then it will be put there in their website.

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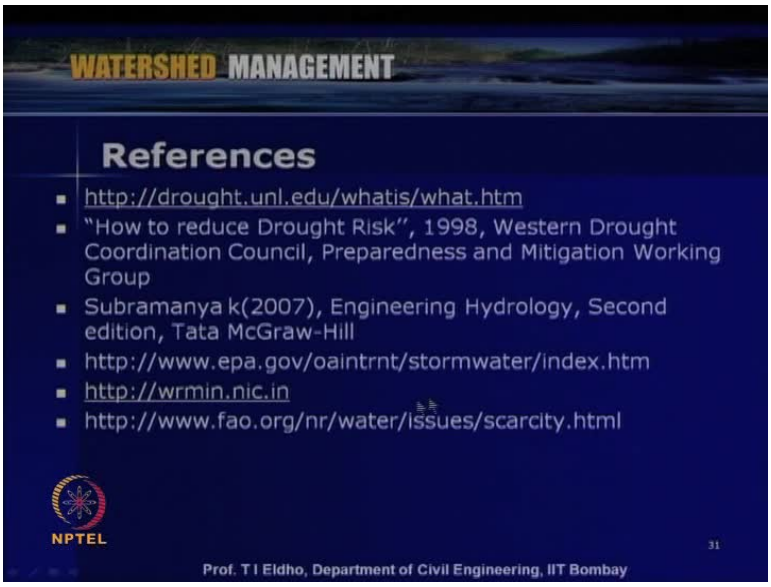

From that - their websites we can identify particular region or particular area is drought prone and related drought assessment can be done. So, maybe we are discussing today the drought assessment and related issues some of the important reference used for today's lecture are listed here.

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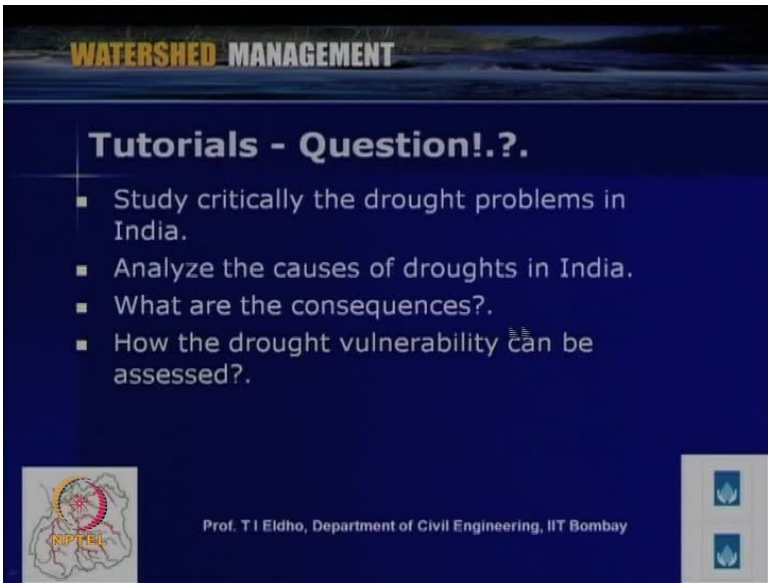

Then, before closing down, few questions like total questions like - study critically the drought problems in India; analyze the causes of droughts in India; then, what are the consequences of these droughts? How the drought vulnerability can be assessed?

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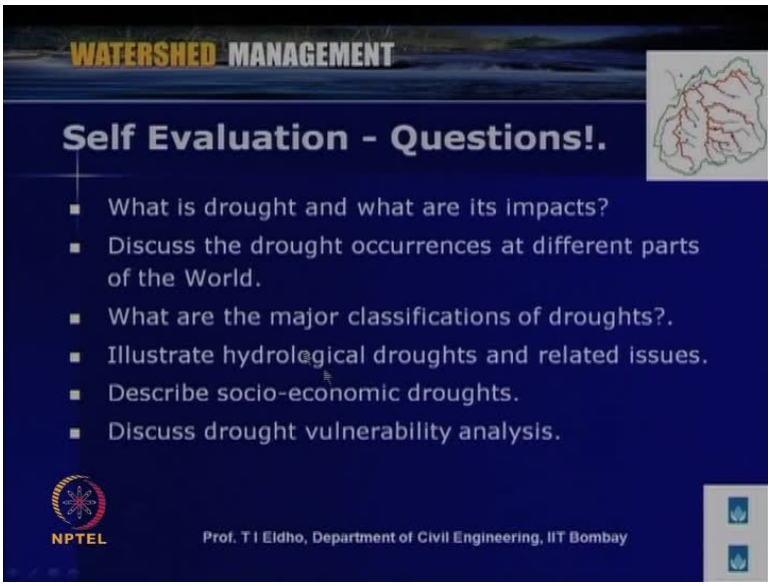

These details you can get through, from various websites of ministry of water resource, environmental ministry, agricultural ministry, like that.

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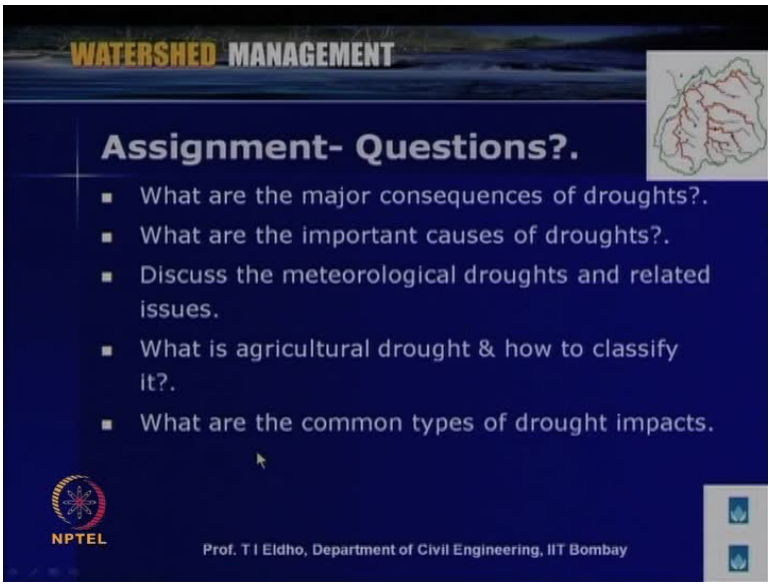

Then say few questions for self-evaluation: what is drought and what are it is impacts? Discuss the drought occurrence at different parts of world. What are the major classifications of droughts? Illustrate hydrological droughts and related issues. Describe socio-economic droughts discuss drought vulnerability analysis.

Then few assignment questions: what are the major consequences of droughts? What are the important causes of droughts? Discuss the meteorological drought and related issues. What is agricultural drought and how to classify it? What are the common types of drought impacts? So, say today we were discussing about the droughts, its consequences and then the classification of droughts and then how we can do the drought assessment.