

Watershed Management
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Module No. # 09
Lecture No. # 37
Drought Mitigation

Welcome back to the video course on watershed management in module number nine on drought and management lecture number thirty seven. Today, we will discuss about drought mitigation so some of the important topics covered in today's lecture include drought mitigation and management drought, warning and monitoring mitigation and planning. So, keywords for today's lecture: drought mitigation management and planning.

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As we were discussing earlier, drought is a major issue in many parts of the world and especially in watershed management. If you manage the watershed area with respect to water land vegetation, we can reduce the effects of drought. So, related to the drought in the last 2 lectures we were discussing about the various aspects of droughts; then how to analyze the droughts and then various related issues consequences; all those things we were discussing in the last lecture.

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The slide is titled "WATERSHED MANAGEMENT" in yellow text at the top. Below the title, the word "Introduction" is written in white. The main content consists of two bullet points in white text, followed by a section header "Components of a drought mitigation plan" in yellow. Under this section, there are six sub-points, each preceded by a right-pointing arrow. At the bottom left, there is a small NPTEL logo. At the bottom center, the text "Prof. T I Eldho, Department of Civil Engineering, IIT Bombay" is displayed in white. The background of the slide is a dark blue gradient with a faint image of a landscape.

- Mitigating drought: Taking actions in advance of drought to reduce its long-term risk
- Involve a wide range of tools: policies, activities, plans, and programs

Components of a drought mitigation plan

- Prediction
- Monitoring
- Impact assessment
- Early-warning systems
- Action plans to deal with severity
- Relief & responses

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In today's lecture we will be discussing mainly on the drought mitigation aspects. So, once if we cannot stop the drought but we can do many things to prevent the effects of drought; or we can reduce the effects of droughts. So, in that sense mitigating drought means taking actions in advance of drought to reduce its long term risk. So, we are doing many things which will reduce the effects of the drought; this involves a wide range of tools, policies, activities, plans and programs.

So, a government level - central government or state governments or various district level, we can have many plans, policies, activities and programs so that the drought mitigation effectively can be implemented or the effects of droughts can be reduced to certain extent. So, that way when we look into drought mitigation the important components of a drought mitigation plan include prediction; we have to predict whether there is any possibility of drought for this particular or few months ahead. We have to predict then, we have to monitor. So, then we have to monitor the area on watershed basis or a district basis or the area basis.

We have to monitor the various hydrological parameters and the water level in the reservoirs; then the agricultural aspects, all those things we have to monitor and then see how the drought, whether it will be severe drought or moderate drought like that. Then, we have to study the impact. We have to do an impact assessment; so that way we have to see that with respect to the severity of the drought what will be happening? Whether there will be drought? Agriculture crops will be destroyed or not; whether the sufficient water will be available to

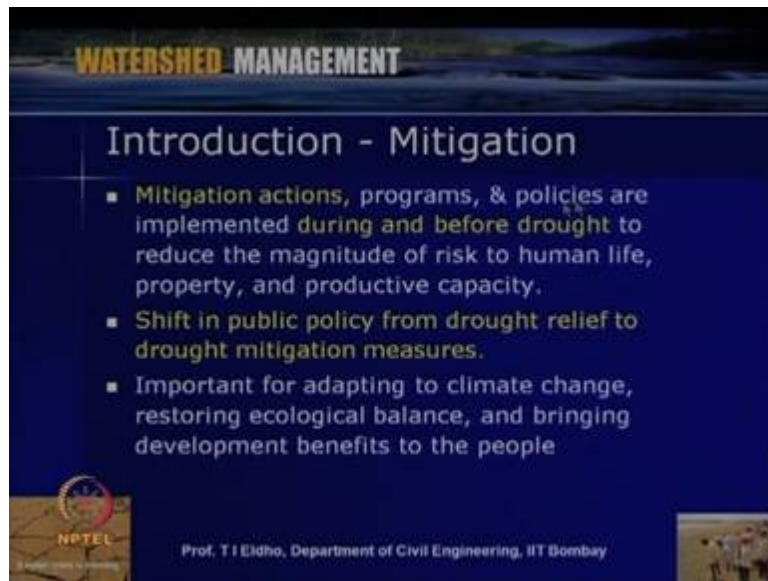
the people or not. So, these kinds of impact assessments we have to do when we discuss about the drought mitigation and then in that sense we can have by using now the modern tools like a remote sensing GIS; then hydrological modeling then climate hydrological modeling, etcetera, we can have now early warning systems.

So, in many countries like United States they have developed early warning system - drought warning system so that, from that we can predict whether there is any possibility of droughts and then accordingly we can go for mitigation plans. Then we have to come up with action plans to deal with a severity. Once the drought comes to the area, depending upon the severity whether it is mild moderate or severe, what kind of action plans? Since, we have to help the community, we have to help the people, there may be famine, may be there may be water shortage may be there; so many issues will be there.

So, how we can help the community? How we can do various things so that the severity will be reduced? So, that is the next step; action plans to deal with the severity. Then comes the relief and responses. So, relief and responses means once the routers already set on the area or that particular area then say, people or the system needs various relief measures like there may be shortage of food, there may be shortage of water, then the crop may get destroyed; so various issues will be there. So, **the as an** especially the government missionary either the federal system or the state government or the district administration, they have to give relief to the people through various means in terms of food products or money, monetary wise or whatever way it is possible.

So, that way most of the time the system needs immediate responses and reliefs so that way the important components of a drought mitigation plans include prediction monitoring impact assessment early warning systems action plans to deal with a severity and relief and responses.

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Now, within this context let us look into what kind of action plans are possible or as far as mitigation is concerned. So, mitigation plans and programs and policies are implemented say, during and before drought to reduce the magnitude of risk to human life, property and productive capacity. So, that way we can see that say, once drought warning system predicts there is a possibility of drought, so before the drought started we can do many measures so that like, related to agriculture management or water management or the ecological management we can do many things. And, then during the drought also the system the government or the disaster management bodies they can do many things so that to reduce the magnitude of risk to human life property and the flora and fauna of that particular area.

So, nowadays instead of now just giving relief to the people now we are looking for mitigation measures in advance so that the shift is the public policy. So, we have to frame the policy in such a way that the drought relief to instead of earlier times if we have giving once the drought is set we are giving relief during the droughts situation; but now we are looking for mitigation measures. I mean, before the drought set in or during the drought various mitigation measures.

So, that way it is important for adopting so that we know. We are all hearing about the climate change effects so we have to see whether the effect of climate the climate change effects will be having the problems like drought kind situation. So, it is important for adopting to climate change then restoring ecological balances and bringing development benefits to the people.

So, that way we have to put the mitigation plans as far the drought management is concerned. Now, let us look say as far drought mitigations are concerned, what are the important strategies possible. Let us look into various issues related to the drought mitigation strategies.

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The slide is titled "WATERSHED MANAGEMENT" at the top. Below that, the main heading is "Drought Mitigation - Strategies". The content includes a bullet point about alternative cropping strategies, soil and water conservation, and water harvesting techniques. It then lists three main objectives for combating drought: (a) developing national strategies for drought preparedness, (b) strengthening early-warning information flow, and (c) developing and integrating drought-relief schemes. The slide also features the NPTEL logo and the name of the professor, T. I. Eldho, from the Department of Civil Engineering at IIT Bombay.

WATERSHED MANAGEMENT

Drought Mitigation - Strategies

- Alternative cropping strategies, soil and water conservation and promotion of water harvesting techniques – examples for emergency drought relief.

Main objectives, to combat drought are:

- (a) To develop national strategies for drought preparedness in both the short and long-term, aimed at reducing the vulnerability of production systems to drought
- (b) To strengthen the flow of early-warning information to decision makers and land users to enable nations to implement strategies for drought intervention
- (c) To develop & integrate drought-relief schemes and means of coping with environmental refugees into national and regional development planning

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So, like there can be alternative cropping strategies; if a particular area is always vulnerable to drought. Then, instead of high water intensive crops, we can go for low water intensive crops. So, like that alternating cropping strategies we can go soil and water conservation; we can do soil conservation so that sufficient moisture will be maintained in the soil. Then, water conservation and water harvesting so reduction of usage of water and then various measures like water harvesting promotion of water harvesting techniques. These are all examples for as far as the mitigation strategies concerned and then we can go for emergency drought relief plans.

In all these when we talk about the drought mitigation strategies, the main objectives generally are to combat drought to develop a national strategy for drought preparedness in both the short term and long term; aimed at reducing the vulnerability of production systems to drought is concerned, there can be a short term effect and long term effect. So, we have to come up with a say when we are developing a drought mitigation strategy, we have to come up with a strategy or we have to come up with a preparedness in both the long term and short term strategies to reduce the vulnerability far as crop product reduction crop or the availability of water, all those issues are concerned.

Then second one to strengthen the flow of early warning information to decision makers and land users to enable the nations to implement strategies for drought interventions. If we can come up with early warning systems in few months in advance so then the decision makers or the policy makers, they can come up with a certain decisions that will be very useful say in terms of availability of food water or any other measures are concerned and then also the owners of the land especially, wherever agricultural say they can go for appropriate interventions such that the crops can be saved.

So, that way the land users if they can get appropriate warning systems they can strengthen the drought related issues then third issues is to develop and integrate drought relief schemes and means to of coping with an environmental refugees into national and regional development plan.

So, when we are going for development plans either national basis or a regional basis so if the some areas are especially drought prone and then if there is a we can give advance warning that there is a possibility of drought then we can look into we can integrate the drought relief schemes within the existing schemes so that we can deal with the drought very effectively

So, that way when we look into drought mitigation strategies we have to look at all these aspects in a comprehensive way and then come up with appropriate strategies suitable for that particular area depending upon the various parameters like geographical or meteorological and agricultural related parameters

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Now, let us look when we look into drought mitigation then what kind of commitments we have to do improve the system we have to reduce the severity of the drought so in this slide we can see some of the important points are mentioned like improve land and water management. So, as far drought is concerned mainly it is mainly lack of available water so the water availability is reduced or whether is no available water and then the land is affected so that way we have to improve the land and water management so that is one of the most important aspects.

So, when we look into watershed management it is always since watershed is hydrologic unit scientifically based on hydrologic unit. So, it is always better to go for watershed based scheme that will be more effective. As we were discussing in many of the earlier lectures and then another aspect is the soil management, in most of the drought prone area the crops or the vegetation is not getting sufficient soil moisture. That way, if we can do some soil management with respect to moisture availability then we can effectively deal with the drought and then promote agricultural management and provide trainings. As I mentioned say, if we can shift to the crops which does not need much water so that way agriculture water management can be effectively done and that can be the formals can be given appropriate training so that they can go for more scientific based irrigation schemes or crop rotation or the appropriate crop management.

So, that way we can promote agricultural management and provide appropriate trainings. Then develop strategies for drought preparedness so we can in advance as drought mitigation plans we can develop appropriate strategies depending upon the various issues for that particular area like the socio cultural or the geographical or the meteorological parameters by considering this parameters we can prepare the appropriate strategies for the drought preparedness. And then in all the cases we need wherever the area is drought affected we need large amount of financing so that way how the central government or state government or district administration can mobilize the finance or we some other time we have to help the farmers to deal such issues so how to mobilize the finance so that can be another commitment.

Then most of the time we can see that the drought prone areas the deforestation has been taken place. Most of the area or the vegetation cover will be much thin in those areas so we can look whether the possibility of afforestation or reforestation depending upon the areas how we can improve the existing forest or how we can reforest or we can put different types of plans which are suitable for that particular environment and then go for reforestation.

Then we have to also look into minimum necessities of the communities so in a drought prone area mainly the people will be affected with lack of water food and other basic amenities so we have to see when we are look into drought mitigation we have to see how we can provide these kinds of basic amenities.

Then another issues social issues related to the due to as the for especially the agriculture sector they will not be any jobs or the crops we have already destroyed due to the drought effects so that way people may the labors may be migrating from one location to another location so these kinds of social issues also we have to see when we prepare appropriate drought mitigation commitment plans.

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The slide is titled "WATERSHED MANAGEMENT" at the top. Below it, the main heading is "Drought Monitoring & Early Warning". The slide contains a bulleted list of points:

- Drought - Typically a slow-onset phenomenon
- Often possible to provide early warning of an emerging drought
- Early warning allows for a shift from reactive to proactive hazard management

Below the list, the text reads "Drought monitoring techniques across the world". This is followed by two more bullet points:

- **China** - Standardized Precipitation Index to monitor drought occurrence
- **United States** - Multiple climate indices and indicators

At the bottom left is the NPTEL logo. At the bottom center, it says "Prof. T. I. Eldho, Department of Civil Engineering, IIT Bombay".

So, now within this context as we can see that a drought monitoring and early warning is the very important aspect to deal to have appropriate drought mitigation plans so that way drought monitoring and early warning system is very important. Most of the time drought is concerned it the onset of drought will be very slow process so typically a slow onset phenomenon is generally as for the drought is concerned.

So, often possible to provide early warning of an emerging drought that is possible by considering various hydrological meteorological and other parameters early warning allows for a shift from reactive to proactive hazard management as far as that particular area is concerned.

So, if we look into a various countries then drought monitoring techniques across the world we can see that a various countries use various norms as far the drought monitoring or early warning is concerned for example, China considered standardized precipitation index as we discussed in our earlier lecture so they characterized standardized precipitation index to monitor drought occurrence whether there is any possibility or drought or some particular area is unable to drought.

Then if United States America is concerned instead of choosing so one particular drought index they use multiple climate indices and indicators so based upon various indicators they have developed advanced level early warning or monitoring tools so that by considering all

these parameters or all these indices were some of the indices which we have discussed in one of our earlier lecture also.

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So, they use this or various indices to come up with for early warning far as drought is concerned then countries like a Australia is concerned they tries to quantifies in terms of precipitation percentiles so that is what they use as far the early warning is concerned.

And then a African countries as per the f a o food and agriculture organizations and other United Nations organizations they use system called famine early warning system FEWS net so this is has been developed under the umbrella of United Nations development schemes and f a o.

Since in Africa, many countries are in many countries drought is a common phenomenon so that way this system has been found to be very effective then in Asian countries like Afghanistan Pakistan and western parts of India so we have got early warning scheme called south Asia drought monitor schemes.

So, this SADM this is based on remote sensing data drought related indices some of the indices like a standard precipitation index and then so these also seems to be found to be very effective and then early warning systems like few net is mainly focused on Africa where majority of food security warning systems operate but it also covers parts of central Asia central America and the Caribbean. So, that way based upon the various available drought

indices and then advance tools like a remote sensing and then other hydrological modeling tools various warning systems have been developed and are in effective use in many countries.

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WATERSHED MANAGEMENT

Drought Mitigation & Preparedness Measures

Mitigation Measures & Preparedness:

- **Structural/physical** (e.g., appropriate crops, sand dams, engineering projects)
- **Non-structural** (e.g., policies, awareness etc..)
- **Preparedness:** Defined as pre-disaster activities that are undertaken within the context of disaster risk management and are based on sound risk analysis

Examples:

- **Water scarcity during the dry season (problem) ?- the groundwater dam (Solution)!**

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So, now coming back to again to drought mitigation and preparedness measures so as far as preparedness is concerned when we deal with drought mitigation which can be either structural measures or the non-structural measures so this structural measures or a physical measures or actually we are directly implementing in the field as a development of a structure or an engineering project like appropriate crops sand dams engineering projects, etcetera.

So, to deal with as said to prepare as far as drought is concerned we can go for these kinds of structural or physical measures then non-structural measures actually it is mainly to deal with the government policies awareness warnings etcetera. So, that is we are not implementing directly in the field but the policy or strategies will be developed in awareness will be developed between the communities so that this will be very effectively implemented. Then as far as mitigation and preparedness is concerned it is defined as pre-disaster activities that are undertaken within the context of disaster risk management and are based on sound risk analysis

So, when we are preparing the drought mitigation plan strategies or the preparedness we have to make it appropriate in an appropriate way such a way that should be based upon the risk assessment or risk analysis for example, water scarcity during the dry season so we have to

analyze what are the problems and then whether it is the lack of rain or the whether it is the soil nature or the drainage systems or whatever it is

So, and accordingly we can identify solutions like a for example, some region we can have instead of surface water dams we can have groundwater dams so where we can have appropriate structure that we will stop the easy flow of the groundwater so that sufficient moisture will be there and water even groundwater will be available.

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WATERSHED MANAGEMENT

Drought Mitigation & Preparedness Measures

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Examples:

- **Water scarcity during the dry season (problem) ?- the groundwater dam (Solution)!**

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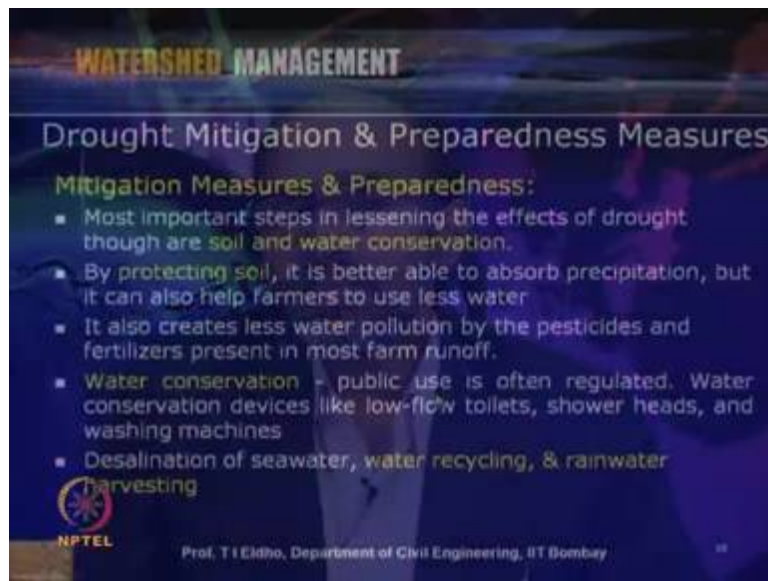
So, that way we can go for preparedness as far the particular system is concerned and then most important steps in in lessening the effects of drought through as we discussed are mainly the soil conservation and water conservation so soil is concerned against soil erosion or to keep the soil moisture as far the drought is concerned and then water conservation is considered to reduce less to reduce the usage of water in an effective way so that with a less water we can have better agricultural production.

So, water conservation and then by protecting soil it is better able to absorb rainfall or precipitation but it can also help farmers to use a less water so if more soil moisture is available then farmers have to use only less water so that way water conservation is also possible and then, it also creates less water pollution by the pesticides and fertilizers present in most farm runoff so that is another indirect benefit so through soil and water conservation if you can reduce the usage of water then the water pollution problems due to the usage of fertilizers a pesticides and others we can reduce so as far as water conservation is concerned

we are looking for reduction in usage of water so like a public use is often regulated so that the usage of water is reduced.

Then water conservational devices like a low-flow toilets as far domestic usage is concerned shower heads and then washing machines so for that particular area particular communities are concerned water conservation is possible.

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And then wherever if the sufficient water is not available through rainfall then if the if the seawater if the sea is near by a coastal regions we can look into desalination of seawater as many of the gulf countries are doing and then another important aspect is like a water recycling so that we recycle the water and then reuse for various purposes actually the next module is module is on water recycling and reuse so there will be discussing more aspects. Then, rainwater harvesting so like that depending upon the area depending upon the various conditions depending upon the geographical areas or the socio economical aspects we can have various measures as far as the drought mitigation is concerned.

So, that way now when we look into drought mitigation so we have to see the how we can protect the ecological systems so the area from the water stress or as far as the total area is concerned say whether we can manage appropriate way.

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WATERSHED MANAGEMENT

Drought Mitigation & Protection

Mitigation Measures & Protection:

- **Dams** - many dams & their associated reservoirs supply additional water in times of drought.
- **Cloud seeding** - an artificial technique to induce rainfall.
- **Desalination** of sea water for irrigation or consumption.
- **Drought monitoring** - Continuous observation of rainfall levels & comparisons with usage levels- help prevent man-made drought.
- Eg: Analysis of water usage in **Yemen** - revealed that their **groundwater table** - at grave risk by over-use for **Khat** crop.
- **Monitoring of moisture levels** - help predict increased risk for wildfires, using such metrics as **Palmer Drought Index**.

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So, that way when we look into drought mitigation we have to look into the protections like a dams we can have many dams and there are associated reservoirs supply additional water in times of drought so in drought prone area we can look the possibility of having more dams so that we can store more water then we can also get rainfall artificially through cloud seeding so it is an artificial technique to induce rainfall so that way another option then desalination of seawater for irrigation or consumption as we discussed.

Then drought monitoring so we have to monitor continuously as far as the rainfall levels and then comparison with a usage level and then whether there is with over use or with misuse whether there is any possibility of manmade drought like that for example, in a gulf country like a Yemen they are using groundwater for agricultural purposes or due to the over use it has been observed that the groundwater tables are going drastically down.

Since due to over use for the khat crop so that way we have to do appropriate a interventions so that it to protect the available groundwater resources and then effectively utilize it then we have to go for monitoring of moisture levels like to help predict increased risk for wildfires using such metrics as palmer drought index what we discuss in the last lecture.

So, that way we have to see the monitoring of moisture levels then another important aspect is the land use as far as the drought mitigation and protection is concerned so as I mentioned earlier as far agriculture is concerned, instead of going for especially the drought prone area instead of going for the high water intensive crops.

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WATERSHED MANAGEMENT

Drought Mitigation & Protection

Mitigation measures & Protection:

- **Land use** - planned **crop rotation** - minimize **erosion** & allow farmers to plant less water-dependent crops in drier years.
- **Outdoor water-use restriction** - Regulate use of sprinklers, hoses or buckets on outdoor plants, filling pools, & other water-intensive home maintenance tasks.
- **Rainwater harvesting** - Collection & storage of rainwater from roofs or other suitable catchments.
- **Recycled water** - wastewater (sewage) treated & purified for reuse.
- **Transvasement** - Building canals or redirecting rivers as massive attempts at **irrigation** in drought-prone areas.

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So, we can go for low water intensive crops and then we can go for crop rotations and then we can minimize the erosion and allow farmers to plant less water-dependent crops in drier year or the drought years.

Then also we can go for outdoor water-use restriction like regulate use of sprinklers hoses or a buckets on outdoor plants when filling pools and other water intensive home maintenance tasks so this way we can concern the water then as we discuss the rainwater harvesting is one of the most important aspects as far as the mitigation measures and protection is concerned so rainwater harvesting is collection and storage of rainwater from roofs or other suitable catchment so that to that can be either directly utilized or we can recharge back to the aquifer systems.

And then recycle water like waste water sewage treated and purified for reuse either for domestic purposes or the gardening or the agricultural purposes and then also we can look to the possibility of transvasement like building canals or redirecting rivers as massive attempts at irrigation in drought prone area. So, you can see that in a state like Gujarat so we can see that with respect to river canal system now Gujarat state is taking the water from the Narmada river or the its canal systems to be drought prone area so Kutch and other areas.

So, that the to these kinds of by building canals and water transfer so we can mitigate the drought or the we can reduce the effect of droughts in an effective way so then as I mentioned in a drought prone area if the rainfall is less so then we can go instead of and especially we

can see that as a consequence of drought prone drought or the most of the areas the evaporation will be much more. So, that way if we store the water in surface reservoirs then what happens more water will be loss through evaporation so that way now we can even go for dams called ground water dams.

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WATERSHED MANAGEMENT

Drought Mitigation & Preparedness Measures

- **Examples:**
- **Groundwater dams-** Store water underground, rather than on the surface
- Ex: "Mother's Water Cellar" project launched in August 2000 by China Women Development Foundation -Now, provides readily accessible potable water for about one million people in rural China
- **Percolation tanks-** for Groundwater Recharge

Survival of about 15 million farmers living in the semi-arid basaltic plateau in Western India

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ground water dams say we can store water underground rather than on the surface so for example, in china under the scheme called mother's water cellar the project launched in August 2000 by China women development foundation.

Now, many areas drought prone areas they are providing water through these schemes so this provides readily accessible potable water for about 1 million people in rural China by developing this so called ground water dams so that way that kind of changes are possible. Then also we can go for percolation tanks so percolation tanks actually we can use for temporary storage of water and that also act as ground water recharge to the aquifer systems so that way the water will be available so this percolation tanks have been used effectively in many parts of western India like in Maharashtra Gujarat and Rajasthan so this has been the source of water for 15 million farmers in a semi-arid basaltic plateau in in western India.

So, that way as far as mitigation preparedness is concerned we can go for groundwater dam's percolation tanks and many other schemes depending upon the geographical conditions and the area these ground water dams are concerned. So, actually this is a structural measure; you can see that this is how a ground water dam is constructed. So, this is the structure we are

building so this is the ground surface and this is the riverbed level so we are constructing below the ground like this and these are the structures that intercept or obstruct natural flow of groundwater and store water underground.

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WATERSHED MANAGEMENT

Drought Mitigation – Groundwater Dams

- **Groundwater dams** - structures that intercept or obstruct natural flow of groundwater & store water underground
- Basic principle : instead of storing the water in surface reservoirs, water is stored in underground - less contamination
- No problem of submergence of land

Sub-surface dam:

- Intercepts or obstructs the flow of an aquifer
- Reduces variation of level of groundwater table upstream of the dam.
- It is built entirely under the ground



http://www.rainwaterharvesting.org/rural/Contemporary_more.htm

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So, the basic principle is instead of storing the water in surface reservoirs water stored in underground so there is no possibility of contamination and then we can reduce the evaporation problems and then there is no problem of submergence of land so this is one of the structural measures which has been found to be very effective. So, this ground water dams can be like a subsurface dams so this is a subsurface dam so this here we intercepts or obstruct the flow of an aquifer and then reduces the variations of levels of groundwater table upstream of the dam and it is built entirely under the ground as shown here.

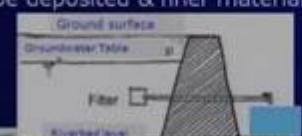
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WATERSHED MANAGEMENT

Drought Mitigation – Groundwater Dams

Sand storage dam:

- Constructed above ground
- Sand & soil particles transported during periods of high flow are allowed to deposit behind the dam
- Water is stored in these soil deposits (figure)
- Sand storage dam - constructed in layers to allow sand to be deposited & finer material be washed downstream



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Then also we can have sand storage dam if this is the ground surface and this is riverbed then it can be just like this so this is constructed above the ground then sand and soil particles are transported during periods of high flow and are deposited here and are allow to deposit behind the dam water is stored in this soil deposit as shown in this figure and so this is actually sand storage dam constructed layers to allow sand to be deposited and finer material be washed downstream so this is become a good storage as far as the water is concerned in that particular area for the drought season.

So, that way we can have a various schemes structural measures of course watershed various measures which we are discussed obviously will help and then some measures like groundwater dams or percolation tanks so these are all some of the structural measures as far as the drought mitigation is concerned.

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WATERSHED MANAGEMENT

Technology for Drought Reduction

Field agricultural technology:

- Straw or plastic film mulch, conservation tillage and rainwater harvesting
- water saving technology such as hole irrigation, surge flow irrigation, micro-irrigation and drip-irrigation

Water-saving technology of chemistry

- Drought-resistant and water save technologies
- For preserving soil moisture and reducing crop transpiration

Water storage cellar, sea water desalination, wastewater treatment

- Water cellar - digging cellar to collect rainwater

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Then some of the other say technology for drought reduction or drought mitigation include like a field agricultural technology like a straw or plastic film mulch and conservation tillage and rainwater harvesting then water saving technology such as hole irrigation then the surge flow irrigation micro irrigation drip irrigation.

So, here all what we are trying to do is we are going for effective water management so that we are trying to use less water for agricultural purposes so that way this field agricultural technologies helps very much to deal with the drought so that we can reduce the effects of droughts. Then water-saving technology say like drought-resistant and water save technologies we can even have the crops which you can say resist to the drought to certain extent and save the water.

Then for preserving soil moisture and reducing crop transfer transpiration we can use certain chemicals and mix with the soil and then that way we can save the water and then water storage cellar sea water desalination then waste water treatment or water recycling and water reuse so all these including the rainwater harvesting and storing in the water cellar so these are some of the techniques technologies which we can use for drought reduction and that way we can mitigate the drought.

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WATERSHED MANAGEMENT

Technology for Drought Reduction

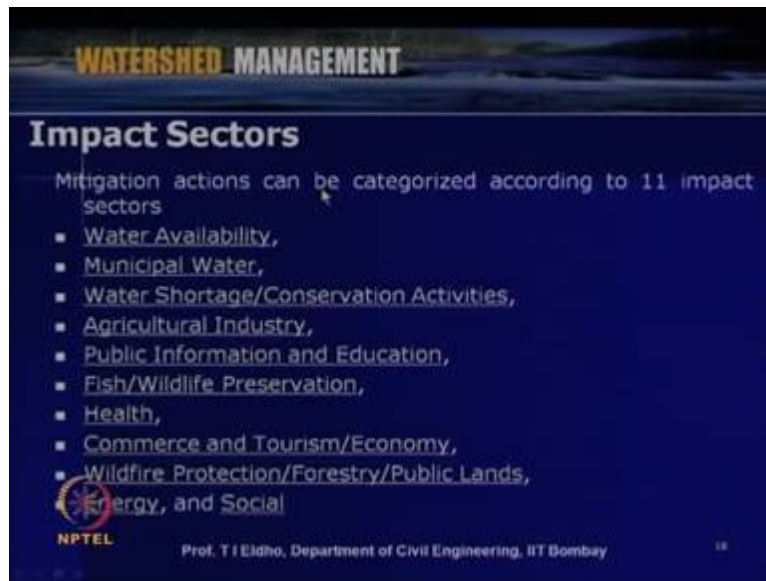
- Development of drought plans or reporter on drought impact
- Ex: "Drought monitoring index on the national and global basis"
- Implemented by Beijing Climate Centre (BCC), China Meteorological Administration (CMA)
- Several routine products for China and the globe are produced on a daily basis from real-time station-based and satellite-derived data
- Available for free downloading from the web page of BCC

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Now, some of the other techniques or technology for drought reduction includes the development of drought plans or the report on drought impact. This is high end technologies like software based technologies; so we can based upon the various indices which we discuss in the last lecture. We can have drought monitoring index on the national and global basis. Then, this can be effectively used depending upon the index we can come up with the reduction measures. So, for example, in China they have implemented a Beijing climate - Beijing climate center is implemented. China meteorological administration, they have come up with several routine products for China and the globe are produced on a daily basis from real time station based and satellite derived data. So, they come up with the monitoring then warning and then this Beijing climate center they come up with various measures as far as drought reduction is concerned and this they are giving not only for China but on global base also.

So, that way the modern technologies also we can utilize effectively for drought reduction now we were discussing about the drought mitigation aspects and we can see that say as far as drought is concerned the its consequences we have already discuss but let us look what are the important sectors which will be affected by the drought or the impact sectors where we have to looking to the mitigation actions so when we look into mitigation actions if we can classify the impact sectors then accordingly we can go for the drought mitigation.

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So, we can classify into eleven impacts sectors as far the drought mitigation is concerned some of the important impact sectors are mentioned here in this slide first aspect is water availability. So, we have to see how effectively we can utilize say the various schemes so that water availability can be improved for that particular area then the municipal water say how we can effectively conserve or how we can effectively improve the system when water shortage or conservation activities so as we already discussed whether we can go for water conservation or water recycling or reuse.

Then agricultural and industries are concerned how effectively we can use deal with a demand management then another important aspect is public information and education so if the people are knowing how to reduce the water usage or how to deal with the droughts so public information and education will help to the reduce the effect of drought or drought mitigation.

So, the particular area is concerned how to deal with the fish or wildlife preservation is concerned so what kind of impacts will be there and then corresponding what kind of mitigation action can be taken then health issues say in the drought prone area so there will be the water stress or the people may use the polluter water all those issues will come.

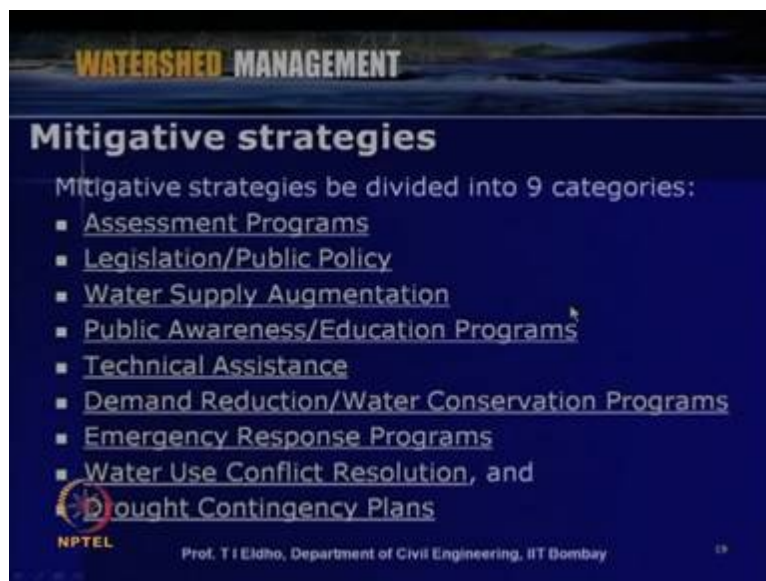
So, health sector is concerned say how we can we can go for the mitigation actions and then commerce and tourism or economy so if the particular area is drought prone or the drought is

occurring for few years then the its tourism potential will be reduced its economy will be started so that way we have to see the impacts.

Then wildfire protection forestry and public lands so we can see that in many of the drought prone areas wild fire is a major problem so how we can protect the vegetation from the fires and how we can manage the forest and the public lands and then how we can meet with the energy requirements for the people.

And then how we can deal with the various social issues so like that when we look into drought mitigations so what kind of action can be taken with respect to this 11 impact sectors. So, these are some of the important impact sectors where we have to see the drought mitigation plans then as far as mitigative strategies or drought mitigation is concerned we can classify or we can divide into 9 categories

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So, like so these categories are listed here first one is assessment programs so as I mentioned we have to assess whether the drought is going to then what will be the its effects so that way assessment programs.

Second one is legislation and public policy so for the drought prone area to how to deal with the droughts what kind of measures so the state or central governments can come up with a legislation and then there can be public policy documents so which can be effectively utilize

so like for example, government of India has made national disaster management and action plans according they have come with a drought and mitigation plans.

So, that way that kind of plans which is available now as a document so that will help to have a say public policy with respect to the drought situation then how we can augment the water supply then public awareness and educational programs so this is very important in the public should know whether there is any possibility of drought and how to deal with this droughts and then technical assistance what kind of technical assistance can be given to the people with respect to for example, land management water management or crop management like that.

Then demand reduction and water conservation programs so how to reduce the water demand and then what kind of conservation programs water conservation programs can be implemented then what kind of emergency response programs are possible then water use conflict of resolution say especially when the availability of water is reduced there will be number of conflicts between the communities.

So, how to deal with these kinds of conflicts so water use conflicts and then drought contingency plans how to come up with contingency plans which will be which we have to deal.

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WATERSHED MANAGEMENT

Legislation/Public Policy

Specific actions taken by Government:

- Prepare position papers for legislature on public policy issues
- Examined statutes governing water rights for possible modification during water shortages
- Pass legislation to protect in-stream flows
- Pass legislation providing guaranteed low-interest loans to farmers
- Impose limits on urban development

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So, now as far as legislation and public policy is concerned, so the concerned government can come up with the specific actions plans like a we can prepare position papers for legislature or public policy issues then we can examine statutes governing water rights for possible modification during water shortages.

Then we can pass legislation to protect in stream flows then we can pass a legislation providing guaranteed low-interest loans to the farmers then we can go for impose we can impose limits on urban development. So, like this various legislative measures or public policies are possible as far as the drought impacts or the various governments can come up with a various measures now let us look into what are the important challenges when we deal with the drought monitoring is concerned.

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WATERSHED MANAGEMENT

Challenges of Drought Monitoring

- Meteorological and hydrological data networks are often inadequate in terms of the density of stations
- Data quality is also a problem because of missing data or an inadequate length of record
- High cost of data limits their application in drought monitoring, preparedness, mitigation and response
- Information delivered through early warning systems is often too technical and detailed, limiting its use by decision makers
- Forecasts are often unreliable on the seasonal timescale and lack specificity, reducing their usefulness for agriculture and other sectors
- Drought indices are sometimes inadequate for detecting the early onset and end of drought

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So, here some of the important aspects as the challenges of drought monitoring is concerned here I have listed like a meteorological and hydrological aspects. So, as we have seen drought is concerned it can be meteorological drought or hydrological drought mainly so with respect to data networks the data availability will be inadequate so we have to have more stations or the density of stations can be improved so that we get better data and then we can go for better warning systems or better predictions.

Then data quality is also a problem because of missing data or an inadequate length of record so this is we have to continuously check the data quality whether it is a good data or whether in missing data like that.

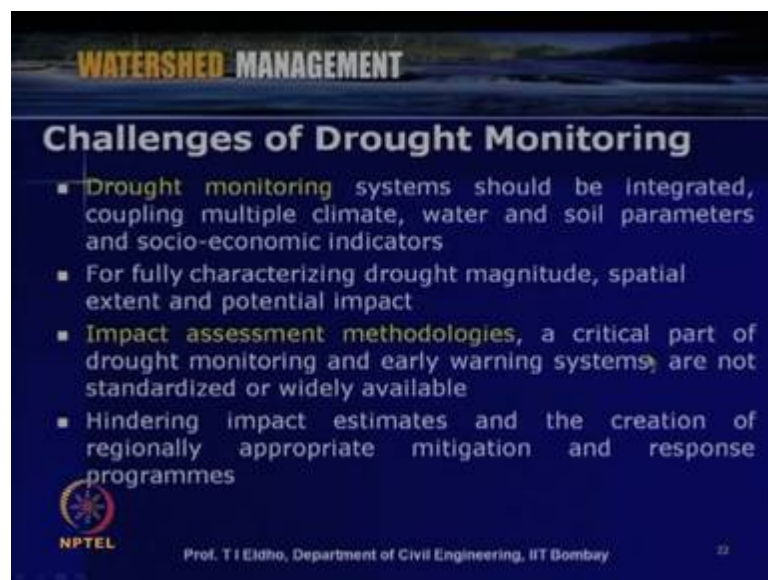
Then high cost of data limits their application in drought so say the data should be available cheaply so that the various agencies can come with various monitoring schemes then say monitoring or for drought monitoring drought preparedness mitigations and responses then information delivered through early warning systems is often too technical and detail so that limits its use by decision makers so we have to come up with ah plans which are simple and which are quite informative and then which can be easily implemented in the field. Then we can look into various forecasts forecasts are often unreliable on the seasonal time scales and lack specificity then reducing their usefulness for agriculture and other sectors.

Then as we discussed the possibility of droughts drought indices we can have appropriate drought indices so this so if the drought indices are not made appropriately then may be

inadequate for detecting the early on set and end of drought. So, that way we have to see that for particular area say particular types of suitable drought indices we have to come up and may be not only one index but may be more indices may help to come up with appropriate say drought monitoring systems so that way we have to plan or we have to deal with the drought monitoring.

So, these are some of the challenges as far as the drought monitoring is concerned like a meteorological hydrological data availability then high cost of data then the information passage then forecast and then the appropriate drought index so which we have to deal so that way so these are some of the challenges as far as the drought monitoring is concerned.

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The slide is titled "WATERSHED MANAGEMENT" at the top. Below that, the main heading is "Challenges of Drought Monitoring". The slide contains a bulleted list of four challenges:

- Drought monitoring systems should be integrated, coupling multiple climate, water and soil parameters and socio-economic indicators
- For fully characterizing drought magnitude, spatial extent and potential impact
- Impact assessment methodologies, a critical part of drought monitoring and early warning systems, are not standardized or widely available
- Hindering impact estimates and the creation of regionally appropriate mitigation and response programmes

At the bottom left is the NPTEL logo. At the bottom center, it says "Prof. T I Eldho, Department of Civil Engineering, IIT Bombay". At the bottom right is the number "22".

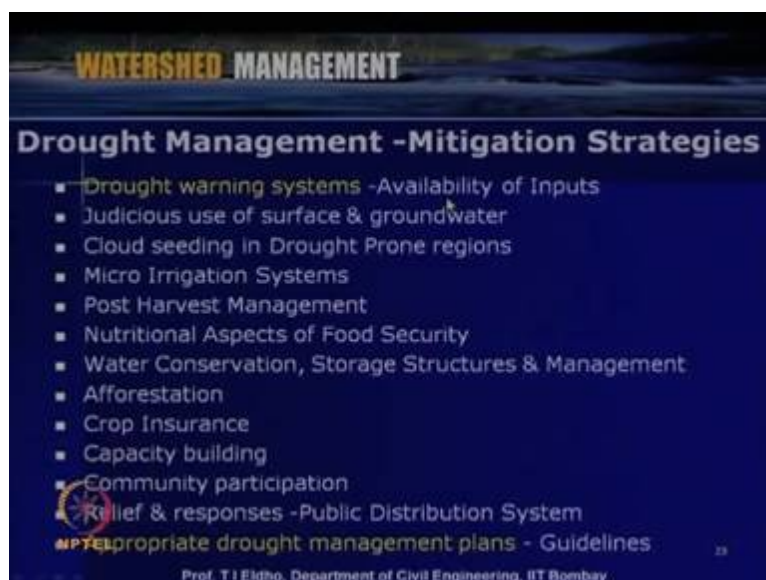
Then say drought monitoring system when we deal with drought warning and monitoring so we should have we have to say integrate this drought monitoring systems so that a say with respect to climate water and soil parameters and socio economic indicators so whatever the drought index we are using or the drought monitoring schemes or systems we are using. So, we may have to integrate with respect to the climate predictions or the water availability or soil parameters or socio economical indicators so for fully characterizing the drought magnitude spatial extent and potential impact so we may have to integrate with respect to various systems.

Then, we have to go for impact assessment methodologies so the generally most of the drought monitoring critical part of drought monitoring is and early warning systems so we

have to standardized it or this things may not be widely available so we have to make the monitoring and early warning system widely available and we have should have a standardized systems so that the people can effectively get the warnings or we can monitor the drought appropriately. Then, hindering impact estimates and the creation of regionally appropriate mitigation and response programs we can generate as far as the drought impact assessment or the drought mitigation is concerned so these are some of the other challenges as far as the drought monitoring and then impact assessment methodologies are concerned.

Now, within this context let us look to the when we deal with a drought management say what are the major issues we may have to deal as far as the mitigation strategies are concerned so some of the important points I have listed here.

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So, like I said, it is always as we have already seen, it is always better to have an appropriate drought monitoring and warning systems. So, the effectiveness of the warning systems or monitoring depends upon various input data like hydrological or meteorological or other parameters.

So, that way this is one of the important aspects as far as the mitigation strategy is concerned and then judicious use of surface and groundwater so for a particular area especially drought prone area what are available water surface or groundwater we have to see that so this available water is judiciously used so that we can meet the demand in such a way that the drought, its severity can be, drought severity can be reduced and in a drought prone area, we

can go for artificial rainfall like a through cloud seeding we can induce more clouds to rain so that we can have more ah precipitation. Then, instead of flooding and other kinds of irrigation systems we can go for micro irrigation systems then we can after the harvesting of that particular area of soil management is concerned we can go for post-harvest management so that soil can maintain the moisture.

Then the nutritional aspects of food security say as far as the people or the communities are concerned we have to see the nutritional aspects are maintain as far as there food securities concerned then like a water conservation storage structures management so like a the structural measures what we can adopt as far as the mitigation strategy is concerned.

Then as we have seen afforestation so the deforestation is a major issue related to drought so how we can improve the forest cover so that is another management issue then the drought prone areas most of the farmers are affected due to the crop laws due to the onset of the drought. So, whether the government or whether various insurance companies can provide appropriate crop insurance and then how we can build a capacity of the communities of the people so that capacity building and community participation can be effectively utilized as far as the drought management is concerned. Then, relief responses say relief and responses so once the drought is set in so say how we can give relief to the people through either monetary or food or the various measures how we can implement as far as the drought prone area is concerned. So, how the system is responding to the systems so this way we can see that public distribution system can be maintained in those areas so that people get sufficient food and other supplies.

So, that way the concerned state or central or district administration they can have an appropriate guidelines so that will be very useful to deal with appropriate ah so for appropriate drought management plans so in an we have to develop appropriate drought management plans or guidelines by considering the various issues various aspects as far as the drought mitigation is concerned.

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WATERSHED MANAGEMENT

Case Study: Drought Analysis in Rajasthan

- **Ref:** State Level Analysis of Drought Policies and Impacts in Rajasthan, India, M.S. Rathore, IWMI, 2005, Working Paper 93
- Rajasthan- one of the largest State of India- area of 342,000 km² (10%) & population of 56.5 million (5%) & only 1% of India's water resources – economically backward.
- Climate - varies from arid to sub-humid; average rainfall - 574 mm -varies significantly- western Rajasthan, average annual rainfall less than 100 mm
- In Rajasthan, about 50 drought years since 1901
- Detailed analysis- in 9 out of 102 years were none of the districts in the State affected by droughts.
- Every year some part(s) of Rajasthan- affected by drought
- State considers drought as a transient phenomenon
- plan shortterm relief measures – not solution.

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So, before closing today's lecture let us have a brief discussion about a case study so this is about the drought analysis in Rajasthan so the case study data are taken from the technical report by M S Rathore and I tell there are state level analysis of drought policies and impacts in Rajasthan IWMA 2005 working paper 93 so Rajasthan is one of the largest states of India and then the area is about three lack forty two thousand per kilometer about 10 percent of the total area of India and population is about 56 point 5 million or the about 5 percent of the total population of India.

But as far as water is concerned, it is an arid and semi-arid region only 1 percent of the India's water resources is available in Rajasthan state and then this is an economically backward state so as far as climate of this state is concerned the it is mainly arid to sub-humid area and the average rainfall is about 574 millimeter and this also drastically varies from one location to another location so in western Rajasthan it is a less than 100 mm and other areas slightly more so that way the rainfall is distributed the average rainfall.

Then the Rajasthan about 50 drought years are identified in the last century so and detailed further analysis showed that in 9 out of 112 by 2 years were none of the districts in the state affected by drought so only 9 years out of the 112 by 2 years there was no doubt. But, all the other years in one or another area there were droughts. So, that way we can say that every year some parts of Rajasthan is affected by drought and state considers drought as a transient phenomenon even though most of these areas are drought prone. But, the state administration

is considering still the drought or transient phenomenon; but, that is not the case. This analysis shows that all the years most of the years there are some or the other area is drought prone.

So, that way the state government presently has only short time plans or relief measures; but that is not the solution. We have to look for long term plans and what are the causes and how we the system can be improved.

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The slide is titled "WATERSHED MANAGEMENT" and "Drought Analysis in Rajasthan". It contains the following text:

- **Ref:** State Level Analysis of Drought Policies and Impacts in Rajasthan, India, M.S. Rathore, IWMI, 2005, Working Paper 93
- **Drought Index (DI) = (P - X) / SD**, P- annual precipitation, X- long term mean and SD- standard deviation
- **DI - classified into four:** DI ≤ -0.1 light drought, DI ≤ -0.2 moderate drought, DI ≤ -0.5 severe drought, DI ≤ -0.8 very severe drought.
- **48 out of 102 years** were drought years - chance of occurrence of a meteorological drought in the state is 47%
- **Vulnerability to drought:** both low-income and middle-income households are vulnerable to droughts; **Indicators:** forced migration, borrowings, food shortage, change of occupation, forced unemployment, falling health conditions etc.

The slide also features the NPTEL logo and the text "Prof. T I Eldho, Department of Civil Engineering, IIT Bombay" at the bottom.

According to this the reference paper by Rathore, the drought index they have calculated by using this formula p minus by where is the annual precipitation is the long term mean and is the standard deviation so accordingly this drought index they have derived and classified into 4 when is less than or equal to minus 0 point 1. Then, they call it as light drought and when drought index is less than or equal to minus 0 point 2 they call it as moderate drought and when it is less than are equal to 0 minus 0 point 5 severe drought and when is less than or equal to minus 0 point 8 very severe drought.

So, that way they have defined the drought situation in Rajasthan by analyzing 100 years of data for the last century so that way they identify than 48 out of 100 by 12 and 2 years were drought years in Rajasthan and chance of occurrence of meteorological drought in the state is about 47 percent.

But of course, as we discuss due to the geographical and various other parameters so the pattern is varying from one location to another location that the Rajasthan's vulnerability to drought both low-income and middle-income households, are most vulnerable and the indicators are like a forced migration, borrowings from the various agencies, food shortage, change of occupation, forced unemployment, then failing health conditions etcetera. So, these are some of the vulnerability analysis done by the, presented in this paper by mister Rathore.

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WATERSHED MANAGEMENT

Drought Analysis in Rajasthan

■ **Ref:** State Level Analysis of Drought Policies and Impacts
India, M.S. Rathore, IWMI, 2005, Working Paper 93

Frequency and intensity of droughts in Districts of Rajasthan during 1901-2002

Region	Number of years with droughts of different intensity				% of all drought years in the period
	Very Severe	Severe	Moderate	Light	
Western Region	12	12	11	11	45.0
NE Region	12	8	11	16	46.0
Southern Region	10	12	9	12	42.1
All Rajasthan	10	10	15	13	47.0

Drought perceptions & implications:
 Perceived as creeping phenomenon- onset & end difficult to identify.
 Viewed as a transient phenomenon.
 Direct impacts- withering crops, dry watering points, reduced forage for livestock etc., are obvious.

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So, we will the frequency and intensity of drought in districts of various districts have been done for 1991 to 2000 on a region basis. A number of years with a drought of different intensities like a western region very severe was about 12 years severe was and moderate was 11 and light. So, that way the percent of all drought years in the period is about 45 north eastern region about 12 very severe is 8 and moderate is 11 light droughts 16 so 46 percent and southern region about 10 very severe and years 12 moderate 9 light 12 and so that way 42.1.

So, that way all Rajasthan it was identified that for this period of analysis 10 years were very severe and then years about 10 and then moderate 15 and light 13. So, that way 47 percent they have analyzed. So, this drought perceptions and perceptions and implications as for this Rajasthan is concerned it is perceived as creeping phenomenon onset and difficult to identify viewed as transient phenomenon and direct impacts like a withering of crops dry watering points reduced forage for livestock etcetera so these are all obvious in the Rajasthan area.

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WATERSHED MANAGEMENT

Drought Impacts in Rajasthan

Ref: State Level Analysis of Drought Policies and Impacts in Rajasthan, India, M.S. Rathore, IWMI, 2005, Working Paper 93

Annual statistics of drought impacts in Rajasthan

Finance Year	District affected (%)	Human affected (%)	Livestock Population affected (%)	Foodgrain Production Index
1970-71	36.92	1.35	2.28	140.24
1971-72	50	17.3	8.79	100.52
1972-73	100	32.77	47.37	81.84
1984-85	77.78	27.38	26.74	125.58
1985-86	76.3	70.44	61.4	125.88
1986-87	100	82.54	65.96	107.76
1987-88	100	92.27	74.88	76.23
1993-96	93.55	62.47	39.09	151.81
1996-97	67.74	14.37	15.2	203.44
1997-98	75	11.27	NA	222.67
1998-99	62.5	48.83	54.42	205.23

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Then, drought impacts are concerned, annual statistics of drought impacts in Rajasthan; it has been presented here. For some of the years we can see that a district affected the percentage wise, humans affected percentage wise then, livestock population affected percentage wise, food grain production index.

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WATERSHED MANAGEMENT

Drought Impacts in Rajasthan

Ref: State Level Analysis of Drought Policies and Impacts in Rajasthan, India, M.S. Rathore, IWMI, 2005, Working Paper 93

Impact of drought in Rajasthan

Item	1988	1998	1999	2000	2001	2002
Villages affected	36,252	20,069	23,406	30,583	7,964	40,490
Population affected (million)	31,737	21,507	26,179	33,041	6,97	44.8
Cattle affected (million)	37.23	28,578	34.56	39,969	6,973	45.2
Crop damage						
Area (million ha)	7,436	6,496	7,818	8,947	2,653	11.7
Value (million US \$)	539.1	496.4	740.6	763.4	272.2	959.5
Rainfall deficiency	-45%	-3%	-16%	-29%	-5%	-64%

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So, that way we can see that this is phenomenon is it varying with respect to years varying with respect to space then the impact of drought in Rajasthan is concerned for example, year wise 81,98, 99, 2000 like that. So, with respect to rainfall deficiency then crop damage

population is affected. So, all these are listed here; as given by this paper. So, we can see the impacts of drought so for example, in 2002 about 40,490 villages were affected due to the droughts in Rajasthan.

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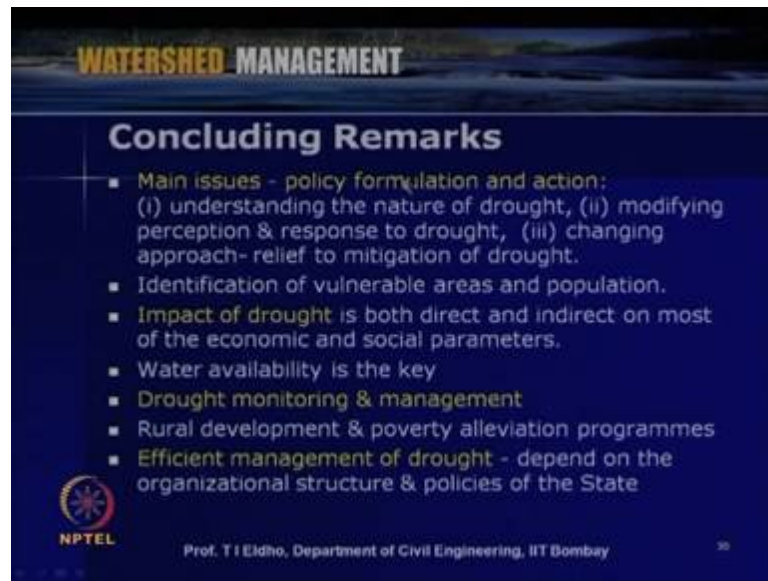


As far as the drought management is concerned, the state government has instituted drought management plans task force and committee's drought monitoring and early warnings have been now installed with the help of Indian meteorological department, weather watch group based on rainfall data, water levels in reservoirs and crop prospects.

Then, drought mitigation programs like rural development programs infrastructure programs watershed development schemes like a national watershed development program then integrated watershed development program like that. Then, drought prone area development program then desert development program then employment generation program rural poverty alleviation program so like that a number of schemes have been developed by the state governments with the assistants of central government.

So, they of course, these schemes are found to be very effective in many areas but still now, as these are all some of the short term measures we can. But, the state is not thinking in terms of long term measures which are very essential for these kinds of... since the drought is recurring and about 47 percent possibilities there in any of the area of Rajasthan as far as drought is concerned; so that way they have to go for long term measures.

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WATERSHED MANAGEMENT

Concluding Remarks

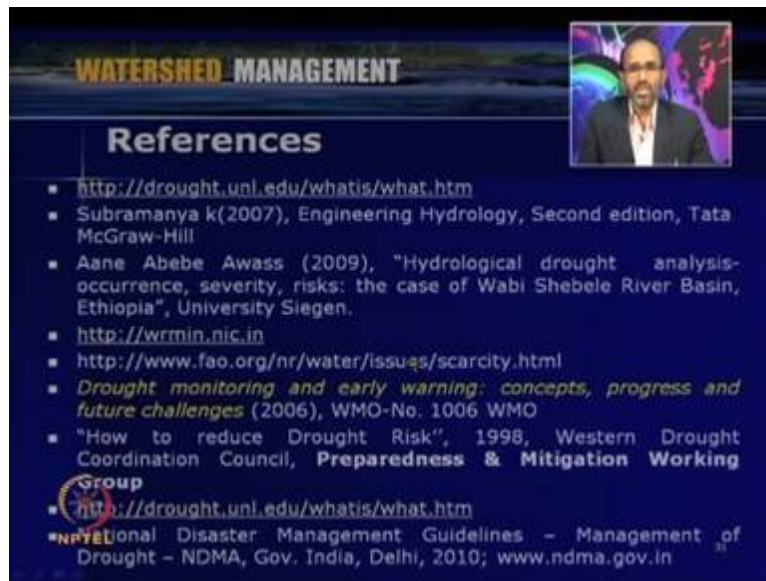
- **Main issues - policy formulation and action:**
 - (i) understanding the nature of drought, (ii) modifying perception & response to drought, (iii) changing approach- relief to mitigation of drought.
- Identification of vulnerable areas and population.
- **Impact of drought** is both direct and indirect on most of the economic and social parameters.
- Water availability is the key
- **Drought monitoring & management**
- Rural development & poverty alleviation programmes
- **Efficient management of drought** - depend on the organizational structure & policies of the State

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So, to conclude this case study - the main issues - we have to see the policy formulation and action like understanding the nature of drought. Then, modifying perception response to drought and changing approach relief to mitigation of drought. Then, identification of vulnerable areas and population then impact of drought is both direct and indirect on most of the economic and social parameters, as we already seen and then water availability is the key issue in many of the areas. Then, drought monitoring and management we have to, we should have effective management plans. Then, rural development and poverty alleviation programs are very essential which we have to not only in short term basis but long term basis then efficient management of drought depends on the organizational structure and policies of the of the state.

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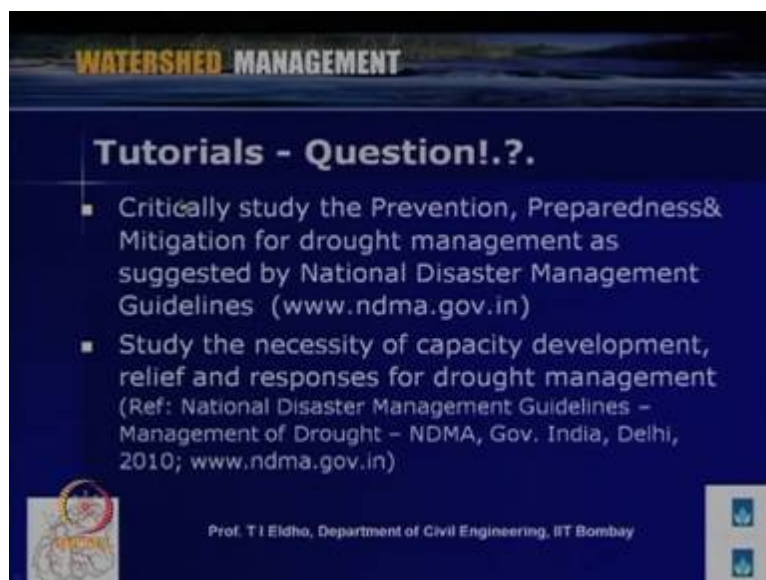
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References

- <http://drought.unl.edu/whatis/what.htm>
- Subramanya k(2007), Engineering Hydrology, Second edition, Tata McGraw-Hill
- Aane Abebe Awass (2009), "Hydrological drought analysis-occurrence, severity, risks: the case of Wabi Shebele River Basin, Ethiopia", University Siegen.
- <http://wrmin.nic.in>
- <http://www.fao.org/nr/water/issues/scarcity.html>
- *Drought monitoring and early warning: concepts, progress and future challenges* (2006), WMO-No. 1006 WMO
- "How to reduce Drought Risk", 1998, Western Drought Coordination Council, **Preparedness & Mitigation Working Group**
- <http://drought.unl.edu/whatis/what.htm>
- **NDMA** National Disaster Management Guidelines – Management of Drought – NDMA, Gov. India, Delhi, 2010; www.ndma.gov.in

So, that way we were discussing about the drought mitigation and short term plans and long term plans and what are the strategies which are possible as far the drought mitigation is concerned.

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WATERSHED MANAGEMENT

Tutorials - Question!?.

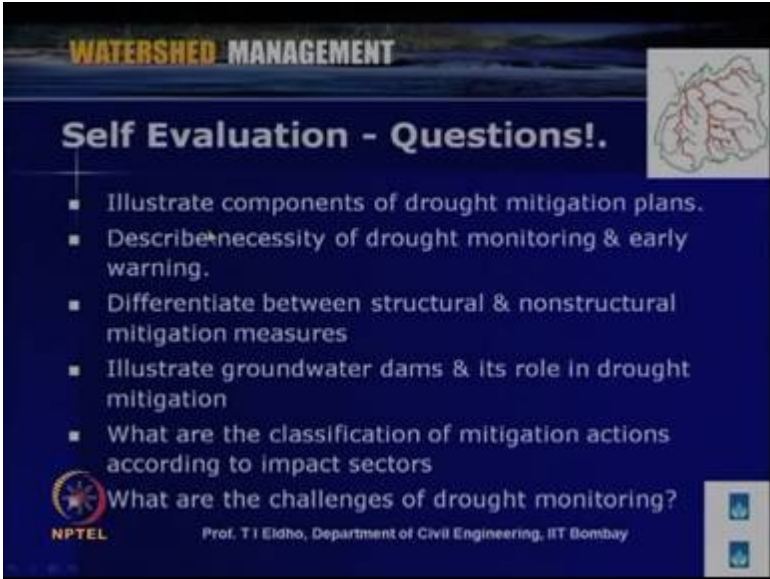
- Critically study the Prevention, Preparedness & Mitigation for drought management as suggested by National Disaster Management Guidelines (www.ndma.gov.in)
- Study the necessity of capacity development, relief and responses for drought management (Ref: National Disaster Management Guidelines – Management of Drought – NDMA, Gov. India, Delhi, 2010; www.ndma.gov.in)

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So, some of the important references used for today's lecture are listed here; then, 5 questions before closing the lecture. so tutorial questions critically study the prevention F preparedness and mitigation for drought management as suggested by national disaster management guidelines this details are available in this website. Study the necessity of capacity

development relief and responses for drought management. You can do this based upon this report. Then few self-evaluation assignment questions: illustrate components of drought mitigation plans. Describe necessity of drought monitoring and early warning. Differentiate between structural and nonstructural mitigation measures illustrate groundwater dams and its role in drought mitigation. What are the classification of mitigation actions according to impact sectors?

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The slide features a dark blue background with a light blue header area. The title 'WATERSHED MANAGEMENT' is in white. Below it, 'Self Evaluation - Questions!' is written in a larger white font. A small diagram of a watershed is in the top right. The main content is a bulleted list of five questions in white text. At the bottom left is the NPTEL logo, and at the bottom center is the text 'Prof. T I Eldho, Department of Civil Engineering, IIT Bombay'. There are two small icons in the bottom right corner.

WATERSHED MANAGEMENT

Self Evaluation - Questions!

- Illustrate components of drought mitigation plans.
- Describe necessity of drought monitoring & early warning.
- Differentiate between structural & nonstructural mitigation measures
- Illustrate groundwater dams & its role in drought mitigation
- What are the classification of mitigation actions according to impact sectors

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What are the challenges of drought monitoring? Then, few assignment questions: what are the important drought mitigations strategies? Compare various monitoring and early warning systems used in drought in different countries. Discuss drought mitigation and protection discuss technology for drought reductions. What are the categories of mitigation strategies comment on drought management and mitigation measures?

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WATERSHED MANAGEMENT

Assignment- Questions?.

- What are the important drought mitigation strategies?
- Compare various monitoring & early warning systems used in different countries.
- Discuss drought mitigation & protection.
- Discuss technology for drought reductions.
- What are the categories of mitigation strategies.
- Comment on drought management & mitigation measures.

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So, all these questions you can answer by going through this today's lecture and then going through various references given. In this module number 9, we were discussing about the drought management. We have seen the problems of droughts, drought consequences and then we have seen how to analyze the droughts by using various indices. Today's lecture we were discussing about drought mitigations strategies and various plans. So, with this module on drought management is over; we will go to the next module in the next lecture; thank you.