**Course Name: Watershed Hydrology**

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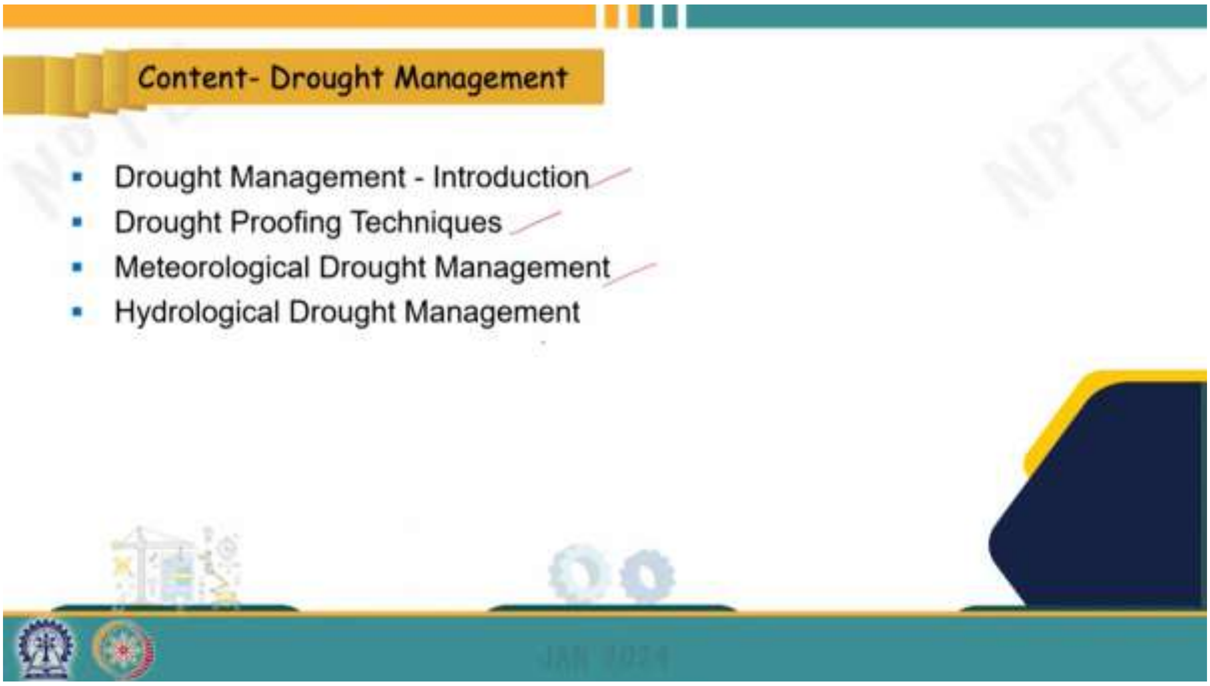
**Week: 11**

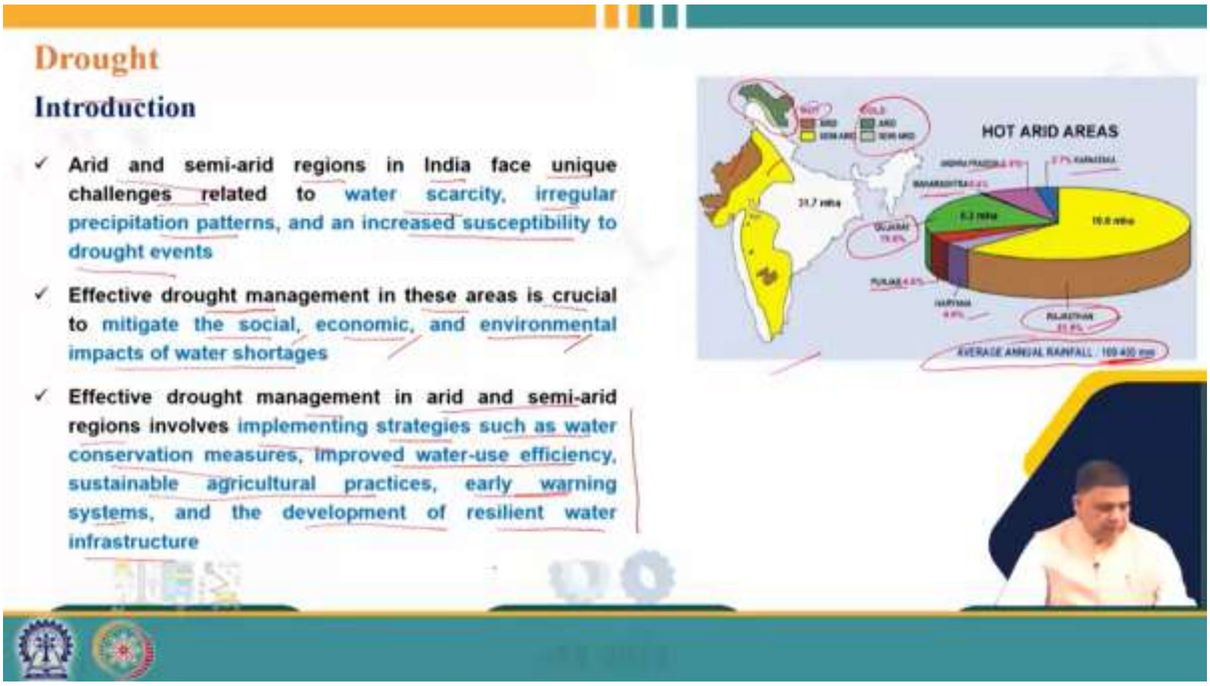
**Lecture 55: Drought Management**

Hello friends, welcome back to this online certification course on Watershed Hydrology. I am Rajendra Singh, a professor in the Department of Agricultural and Food Engineering at the Indian Institute of Technology Kharagpur. We are in Module 11, and this is the last lecture of the module, with the topic being Drought Management.

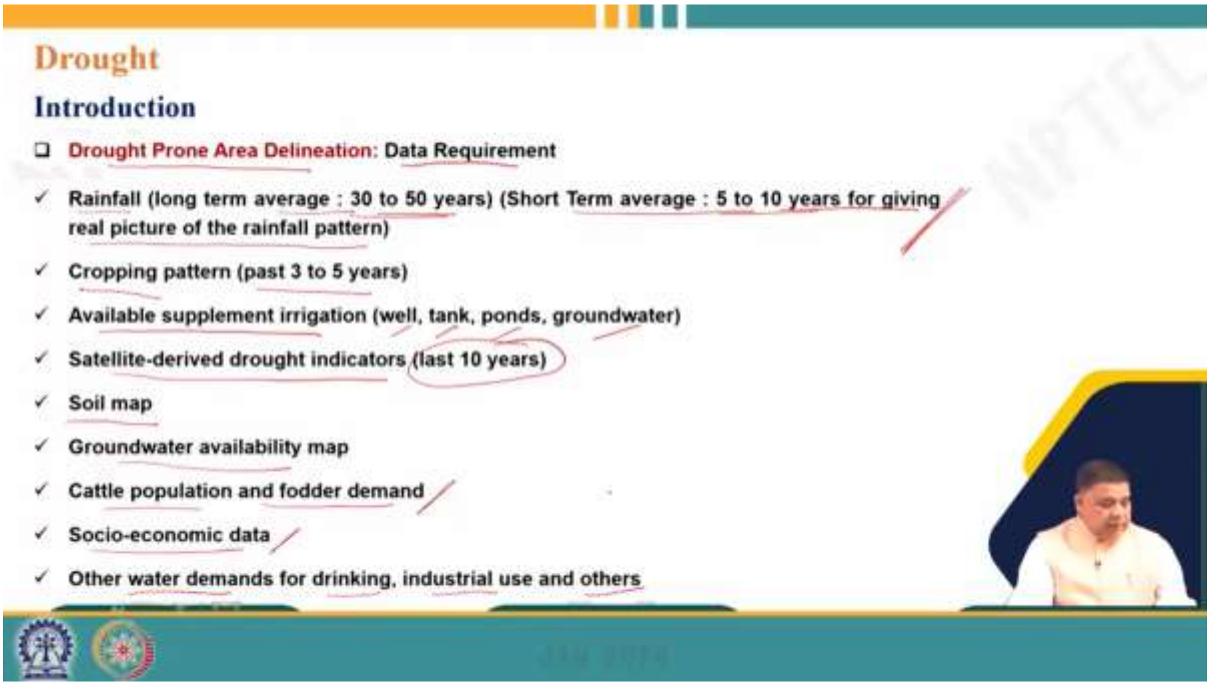

In this lecture, we will introduce drought management, discuss drought-proofing techniques, and then cover metallurgical drought management and hydrological drought management.




Now, coming back to drought, we have already discussed and introduced the concept of drought, its regions, and the consequences. However, as we know, arid and semi-arid regions in India face unique challenges related to water scarcity, irregular precipitation patterns, and increased susceptibility to drought events. So, of course, not only India but also the world's arid and semi-arid regions are major concerns regarding drought. If you look at this picture, it shows the arid and semi-arid regions in the country, with the average annual rainfall in these areas ranging from 100 to 450 millimetres. Just to give you an idea, the annual average rainfall of India is 1200 millimetres. Therefore, these areas receive one-third or even less than one-third of the average rainfall over the entire country. Additionally, you can see that the dark and light green colours represent cold semi-arid regions, mainly in the Himalayas. And then we have arid and semi-arid regions, hot arid and semi-arid regions. So, these are brown colours and yellow colours as you can see. And of course, also if you can see that Rajasthan is the state which has the most prominent arid and semi-arid areas; around 61.9 percent of the area is under arid or semi-arid region. Then Gujarat almost had 20 percent of it then Punjab, Haryana, Maharashtra, Andhra Pradesh, Karnataka. These are the states which have certain areas under hot arid and semi-arid regions and that means, which are susceptible to drought in any normal condition. So, effective drought management in these areas is crucial to mitigate the social, economic, and environmental impacts of water shortage. And we studied drought and types of drought in great detail. So, we saw that it first starts with the meteorological drought where the rainfall is in deficit. Then of course, it impacts the hydrological drought where the water storage is on the surface and the ground reduced. And of course, the soil moisture in the soil also gets reduced which causes agricultural drought. And then of course, after all these three, we have a social drought. So, obviously, the drought has all dimensions like social, economic, and environmental and if we have to manage these areas properly then we have to really look into various ways to mitigate these impacts. Now, effective drought management in area and semi-arid regions involves implementing strategies such as water conservation measures, improved water use efficiency, sustainable agricultural practices, early warning systems and the development of resilient water infrastructure. So, obviously, as you can see that the focus has to be on water conservation and water storage. I mean, these are the two things. And then of course, the efficient use of the water stored besides the early warning system which we have studied in earlier classes. So, all these, this could be used to really find out whether there is any early warning or any signs are dropped and if that is there, then proper care has to be taken. So, of course, the focus has to be on water conservation, water storage, and efficient use of water.

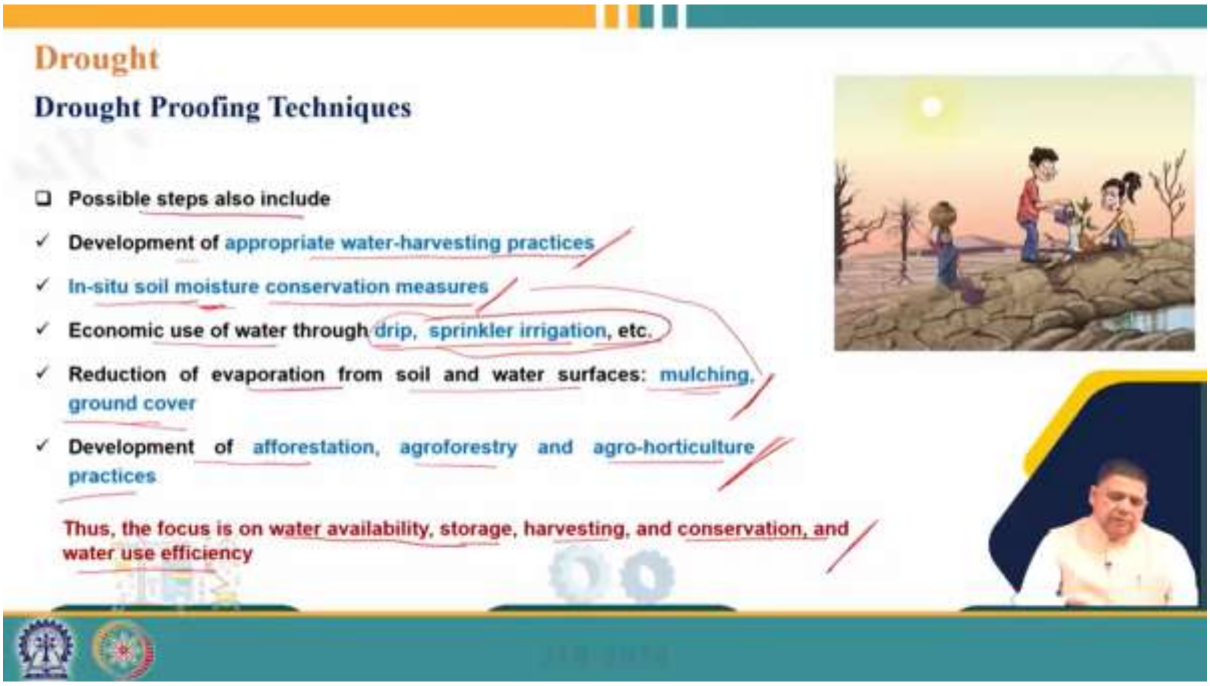



Now, of course, before any kind of management, we must identify the drought-prone areas and of course, that means we have to go for drought-prone area delineation. We already saw that we based on rainfall we have identified semi-arid and arid regions, but within those regions also we can have a much finer resolution delineation of the drought-prone areas. And of course, for that, we require a significant amount of data and of course, the most important data is rainfall, that is long-term average 30 to 50 years, short-term average 5 to 10 years for giving a real picture of the rainfall pattern. So, of course, you do not want the natural cyclic climate variability to get your decision effect impacted. So, that is why you want to have long-term data as well as short-term data. So, that you have a clear pattern of the rainfall variations in the area. Then you have to have cropping pattern over the past 3 to 5 years, you have to find out all sources of supplemental irrigation, maybe it is a well, tank, ponds, or groundwater. Then of course, you have to have satellite-derived drought indicators we have discussed so many, especially with reference to agricultural drought. And of course, this has to be the last 10 years' data because again you do not want to be impacted by a single year data. So, you have to have long-term analysis done. You have to have a soil map so that you have a clear idea about the soil water holding capacity, groundwater availability map so that you know how much water is available, how much recharge, discharge could take place in a given area. Then you have to have capital population and fodder demand. And this is important because I mean a significant amount of water is also needed not only for human consumption, but also for cattle and also for their feed production. Then of course, you have to have socio-economic data, that is how vulnerable the society is to drought. And then other water demands like drinking water, industrial use, and any other data. So, of course, all data related to water, agriculture, soil, cropping pattern, irrigation, rainfall has to be collected for the area in order to be able to delineate drought-prone areas.

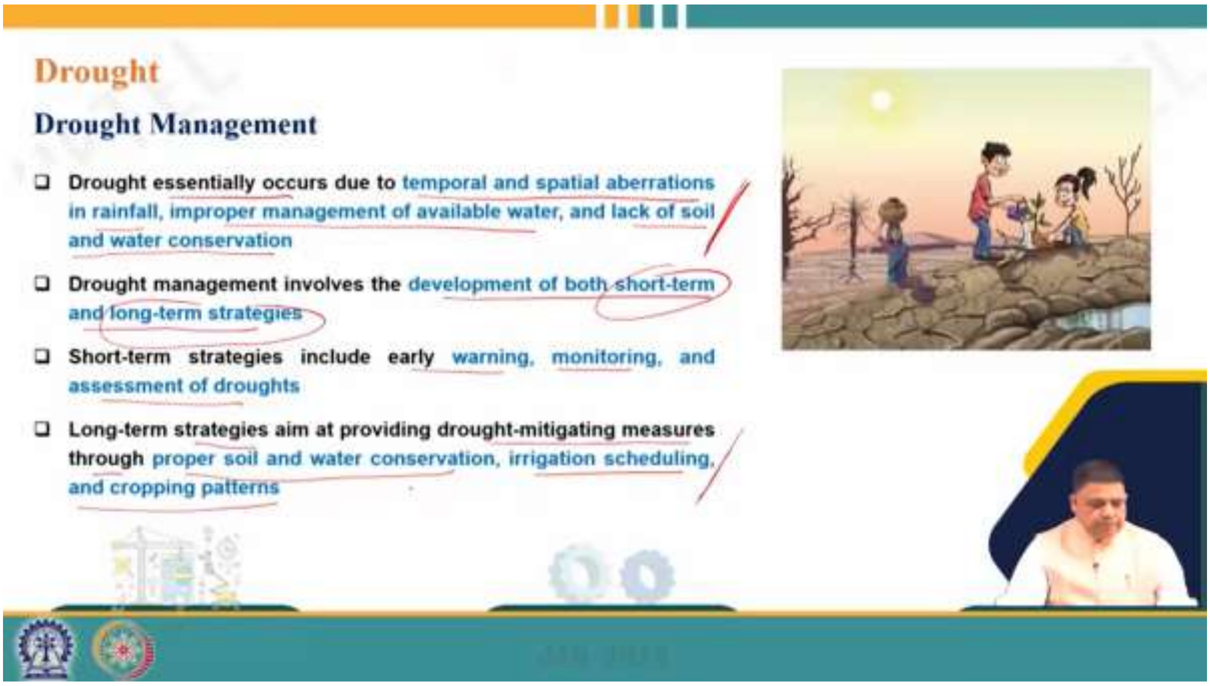



Then of course, we come to drought proofing and drought proofing techniques. So, basically, drought proofing focuses on immediate support for drought-affected areas and long-term resilience and preparedness measures. So, of course, anything we can do at a short-term level just to take care of immediate pain of people or immediate loss which people are suffering through. And then of course, you have to have long-term resilience and preparedness in order to be able to face drought in a proper way, that is drought-proofing. So, drought-proofing of a region calls for an integrated approach taking into account the multidimensional interlinkages between various natural resources, environment, and local socio-economic factors. So, of course, just now we discussed what data are required. So, that also gives you an idea about what kind of data should be there in order to make a decision about the drought-proofing also. And possible steps involved in drought-proofing and that could be taken are creation of water storage through appropriate water resources development, inter-basin transfer of surface water from surplus areas to drought-prone areas and development management of groundwater potential. So, again, as you see, the focus is on water, the water availability, water storage and of course, efficiency will also come when the water usage comes into the picture. So, all the focus has to be on water all the time.

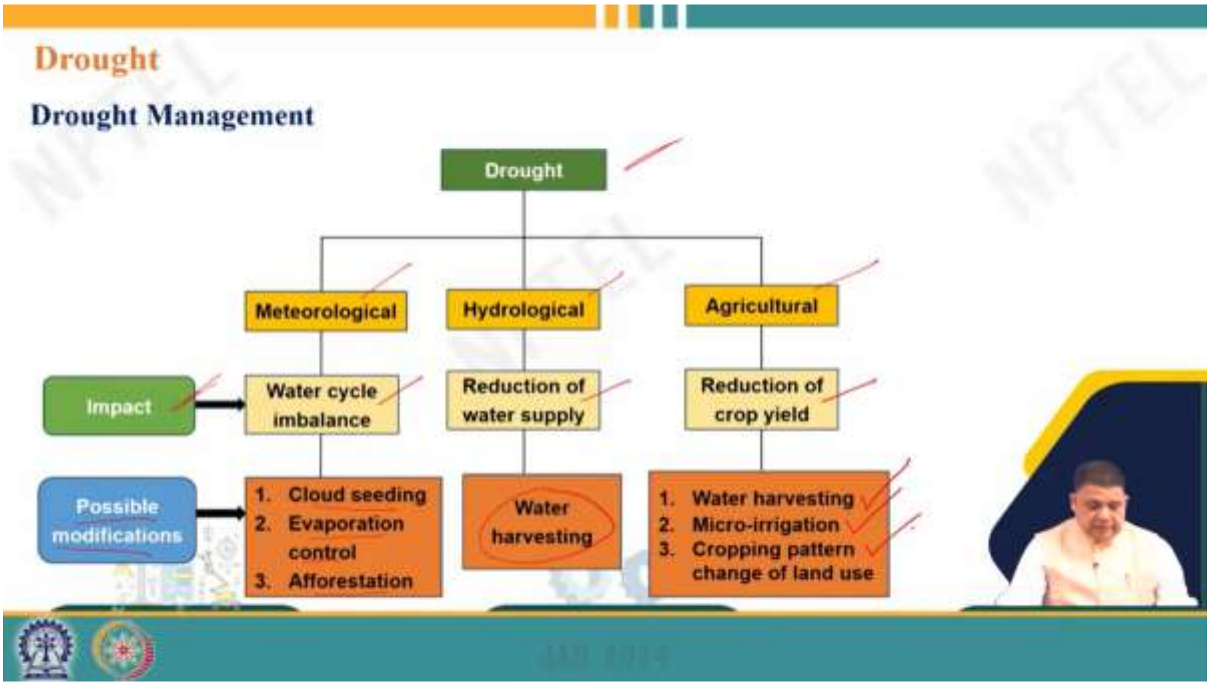

Then possible steps may also include development of appropriate water harvesting practices, that various kinds of water harvesting structures could be made. Then in suit to soil moisture conservation measures, that means, your soil should be able to retain as much soil moisture as possible. So, you all you would like to take all kinds of measures like crop cover and many methods we have discussed earlier. Then you have to have economic use of water through drip sprinkler irrigation. So, you want to use high-efficiency pressurized irrigation systems so that the efficiency of irrigation improves. We know that surface irrigation has typically efficiency of 40 to 45 percent where drip and sprinkler could have a higher 70 to 90 percent. So, obviously, you want to go for efficient utilization of water for irrigation because irrigation, of course, is the largest user of water resource in the country and around the world in fact. And reduction of evaporation from soil and water surfaces for mulching ground water. So, again, you want that most of the soil should be there. So, of course, you want that evaporation should be reduced, which is basically it is nothing also it will ah it means in suit to soil moisture conservation that means, mulching ground cover that cover crop etcetera we have to take care that is now I also mentioned. Then development of afforestation, agroforestry, and agro-horticultural practices. So, various kinds of agricultural agroforestry and agro-horticultural practices so that you can not only retain more and more water, but also the environment becomes better for encourage the rainfall in the area. Thus, the focus of drought-proofing has to be on water availability, water storage, water harvesting, conservation, and water use efficiency just as we discussed for drought management basically. So, drought-proofing takes care of all those things just as we discussed earlier.



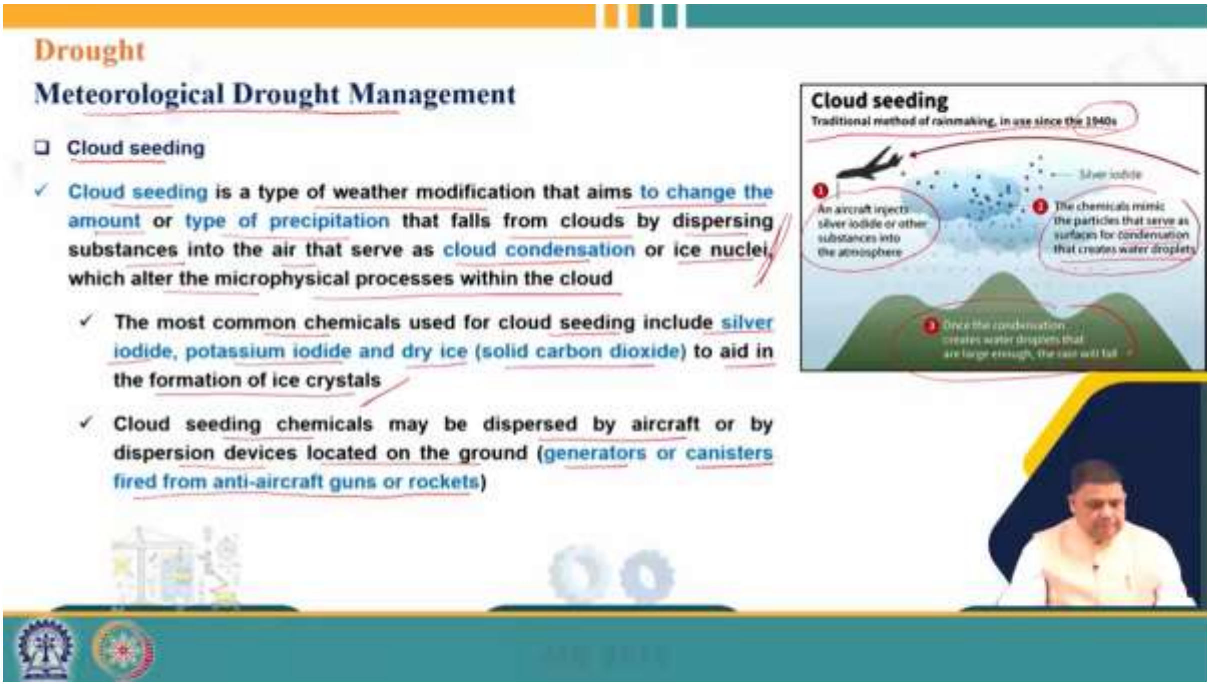

Then we come to drought management basically. A drought essentially occurs due to temporal and spatial aberration in rainfall, improper management of available water, and lack of soil and water conservation. So, it involves the development of both short-term and long-term studies. So, of course, we know that it is the water that is the lack of rainfall of course, then lack of water storage facilities and also inefficient use of water and lack of soil and water conservation measures. Now all these lead to drought and that is why you have to have both short-term as well as long-term strategy. Short-term strategy includes early warning, monitoring, and assessment of droughts whereas long-term strategy aims at providing drought mitigating measures through proper soil and water conservation, irrigation scheduling, and cropping patterns. So, obviously, early morning warning or monitoring or assessment gives you a fair idea of the onset of drought and then what measures should be taken and long term of course, you want to have more of soil and water conservation. That means, again focus will be on storage and conservation storage and efficient use of water.



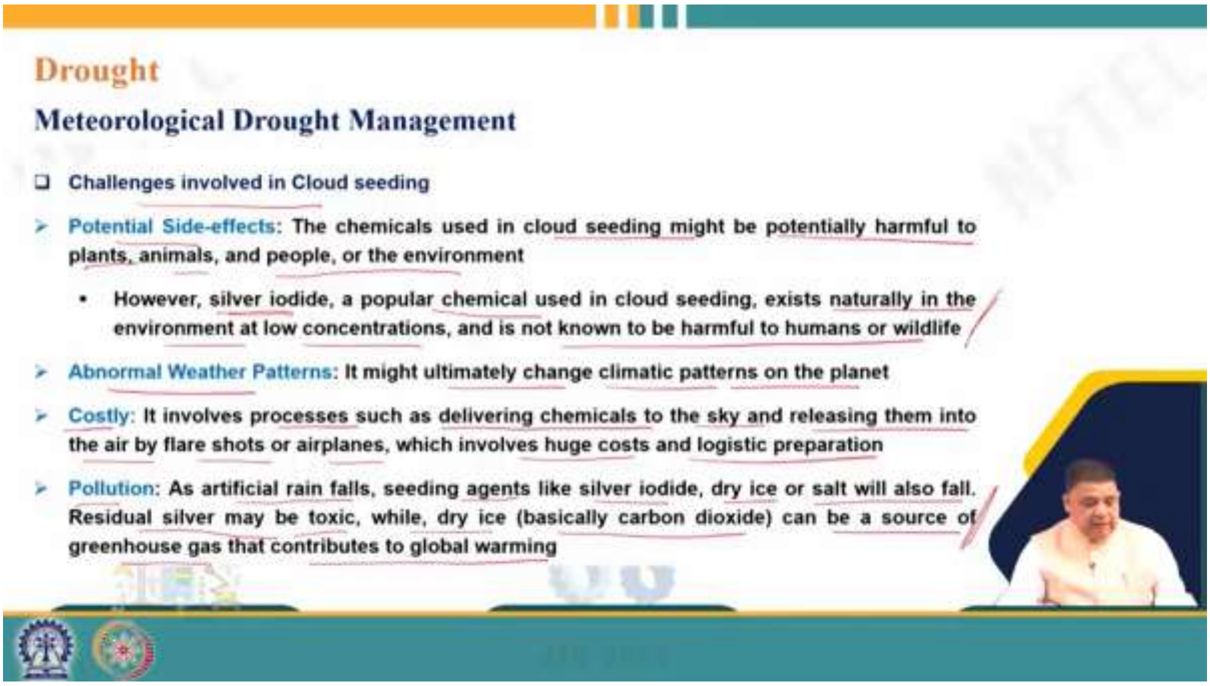

Then as we also know that drought we talked about metallurgical drought, hydrological drought, and agricultural drought in great detail and of course, we have also seen the impacts of each one of them. So, the impact of metallurgical drought is water cycle imbalance, hydrological is reduction of water supply that is you do not have enough water available in the areas in the storage structures and agricultural reduction of crop yield. So, these are the major impacts of each type of drought and then we talk about the possible modification. So, metallurgical drought which causes water cycle balance we can think about cloud seeding, evaporation control, and afforestation that is anything which can be done to enhance or availability of water or rainfall itself. Then under hydrological drought where we suffer through reduction of water supply, we will focus more on water harvesting and agriculture where the focus on reduction of crop yield will talk about rather we will go for water harvesting, we will adopt micro-irrigation and we will go for micro cropping pattern change land use change in the area in order to tackle agricultural drought. So, these are the possible modifications that can be thought of under drought management and we can take each one of them one by one.




So, of course, we will start with the metallurgical drought management. So, the first focus is on cloud seeding, that is one step, and cloud seeding is a type of weather modification that aims to change the amount or type of precipitation that falls from clouds by dispersing substances into the air that serve as cloud condensation or ice nuclei which alter the microphysical processes within the cloud. So, basically, you take an artificial route of cloud formation and condensation. So, that rainfall occurs in the area, the most common chemicals used for cloud seeding include silver iodide, potassium iodide, and dry ice, which is also referred to as solid carbon dioxide to aid in the formation of ice crystals. So, once ice crystals are formed, which we also call hydrometeors. The moisture through evaporation joins that and then condenses and then the rainfall occurs. So, that is why we want to focus on the formation of ice crystals. And the cloud seeding chemicals may be dispersed by aircraft, that is, you take at appropriate height and disperse that or by dispersant devices located on the ground, that is, through generators or canisters fired from anti-aircraft guns or rockets. So, you fire and so that again the same impact takes place. So, this is cloud seeding and as you can see, the traditional method of rainmaking, which has been attempted in various parts of the world right from the 1940s where you take in aircraft inject silver iodide or other substances into the atmosphere. The chemicals mimic the particles that serve as surfaces for condensation that creates water droplets and once the condensation creates water droplets that are large enough, the rain will fall. So, basically, you create the artificial environment for rainfall to occur. So, that is what we look for in cloud seeding.

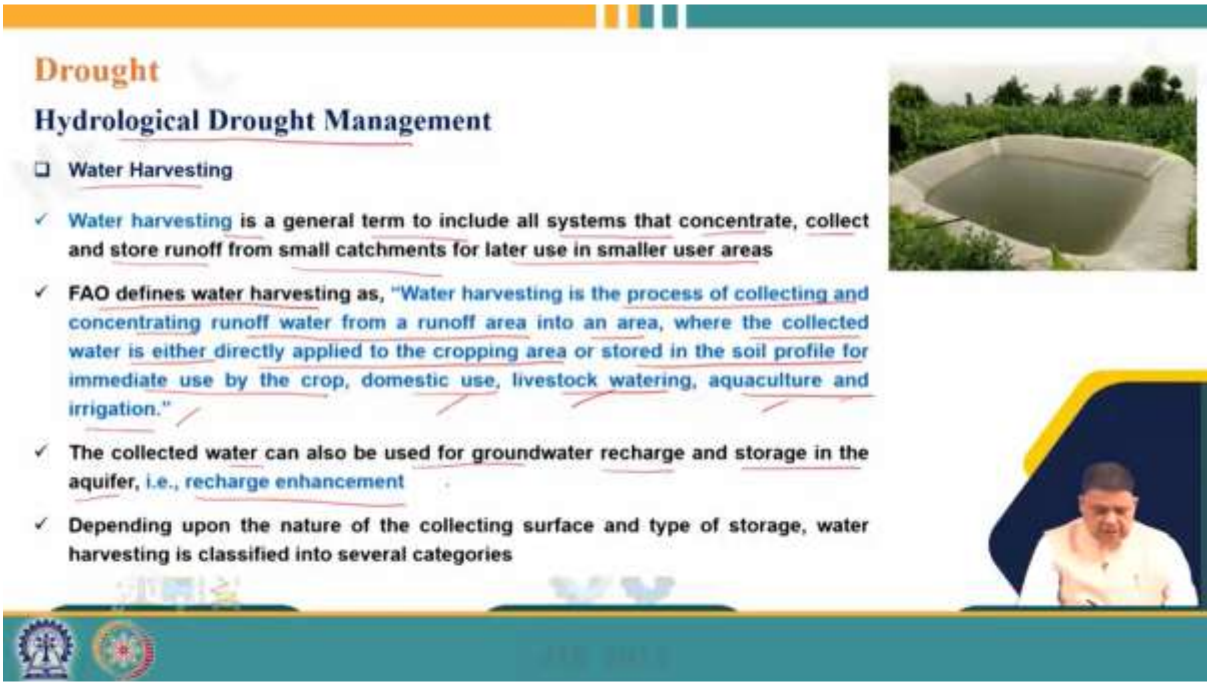



But there are certain challenges involved in cloud seeding like there are potential side effects, chemicals used in cloud seeding might be potentially harmful to plants, animals, and people or the environment. However, silver iodide, which is quite commonly used a popular chemical used in cloud seeding, exists naturally in the environment at low concentrations and is not known to be harmful to humans or wildlife. So that means, silver iodide could be used in low concentrations. Then abnormal weather patterns could be another challenge that it might ultimately change the climatic pattern of the planet or at least the area where this is being practiced, it is a costly affair. So, it involves processes such as delivering chemicals to the sky and releasing them into the air by flare shots or airplanes which involve huge cost and logistical precipitation. Then of course, pollution, that is, artificial rainfalls seeding agents like silver iodide dry ice or salt will also fall residual silver may be toxic while dry ice, basically carbon dioxide, can be a source of greenhouse gas that contributes to global warming. So, of course, there could be local pollution, but a long term impact, the greenhouse gas effect could also be there if you do it quite regularly.

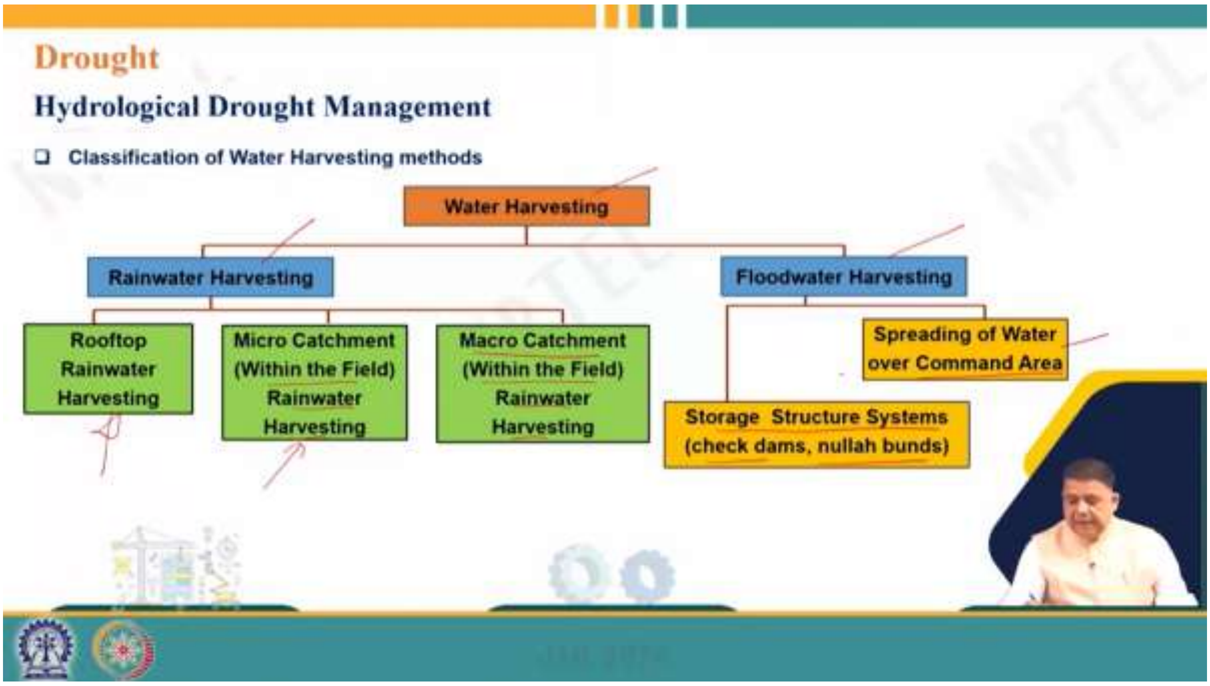



The next is evaporation control under metallurgical drought management. So, controlling evaporation is one approach to managing the impacts of metallurgical drought, which is characterized by a prolonged period of below-average precipitation. And evaporation control aims to reduce the loss of water from reservoirs, lakes, and other water bodies, helping to conserve water resources during dry periods. So, of course, it is a combination, you could say, a combination of both metallurgical and hydrological drought because whenever there is a metallurgical drought, that means, below-average precipitation will be there, then water bodies there will not be enough input to the water bodies. So, the focus has to be on conserving water, whatever water is available through evaporation control, and then there can be many ways like there could be floating covers or shades provided over the water surfaces, even chemicals are used. Cetyl alcohol is a chemical which is quite commonly used for controlling evaporation from water bodies. And of course, you could also have arrangements like windbreaks, basically which control the wind velocity and if the winds are less then obviously, the evaporation will be reduced as we have already studied. So, evaporation control could be one major.

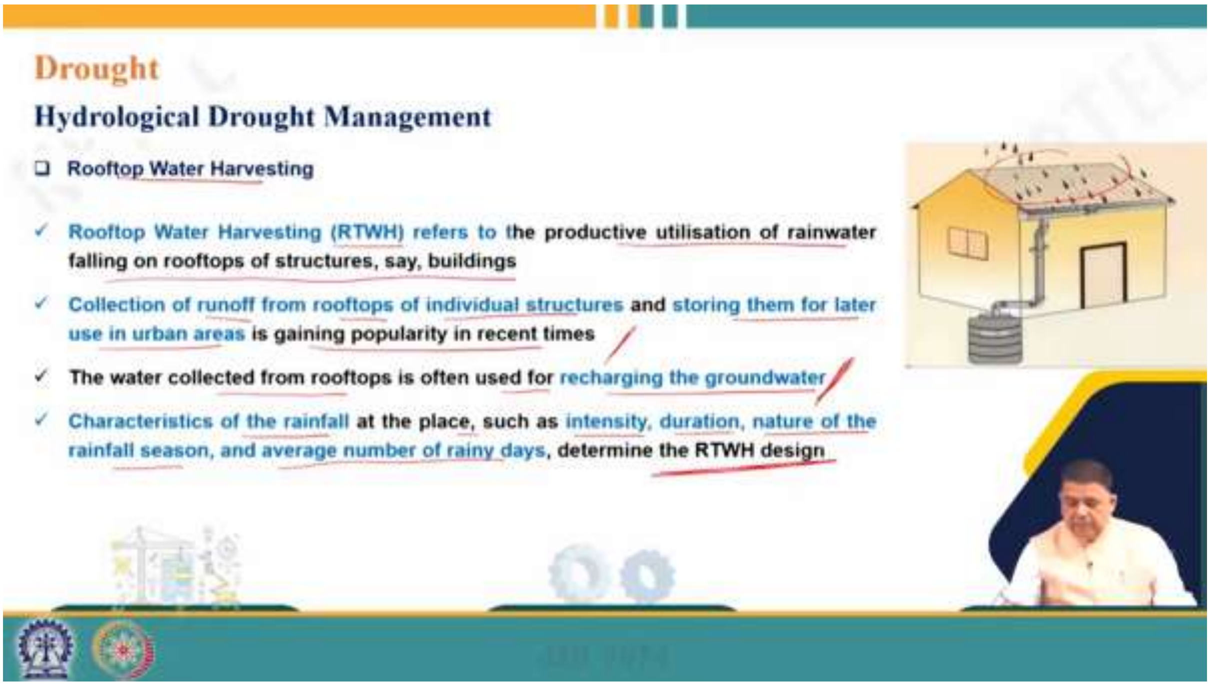

Then we go to hydrological drought management and of course, water harvesting is the most popular of hydrological drought management practices which is a general term to include all systems that concentrate, collect, and store runoff from small catchments for later use in small usual area. So, that means, you would like to store water whenever it is available that's safer in the monsoon season during the rainy season and then so that you can use it later on. FAO defines water harvesting as it is a process of collecting and concentrating runoff water from a runoff area into an area where the collected water is either directly applied to the cropping area or stored in soil profile for immediate use by the crops, domestic use, livestock watering, aquaculture, and irrigation. So, the same thing that when in the rainy season when there is a sufficient amount of rainfall there will be runoff. So, you store water, you store runoff water. So, that can be used immediately for crop growth, for irrigation or it can be used for domestic use, livestock watering, aquaculture, and irrigation purposes. The collected water can also be used for groundwater recharge and storage in the aquifer that is recharge enhancement. So, that is also one purpose. So, you allow groundwater recharge to take place from such water bodies and depending upon the nature of the collecting surface and type of storage, water harvesting is classified into several categories and these are shown here.




So, basically water harvesting could be broadly classified into rainwater harvesting and floodwater harvesting. So, if in rainwater harvesting we can have rooftop rainwater harvesting, we can have micro catchment that is within the field rainwater harvesting, we can have macro catchment that is within the field rainwater harvesting. Wherein on the flood watering side we can have storage structure systems like check dams and allowance and alternately we can also spread the water over the command area that could also be one way of floodwater harvesting and we will see these systems one by one.

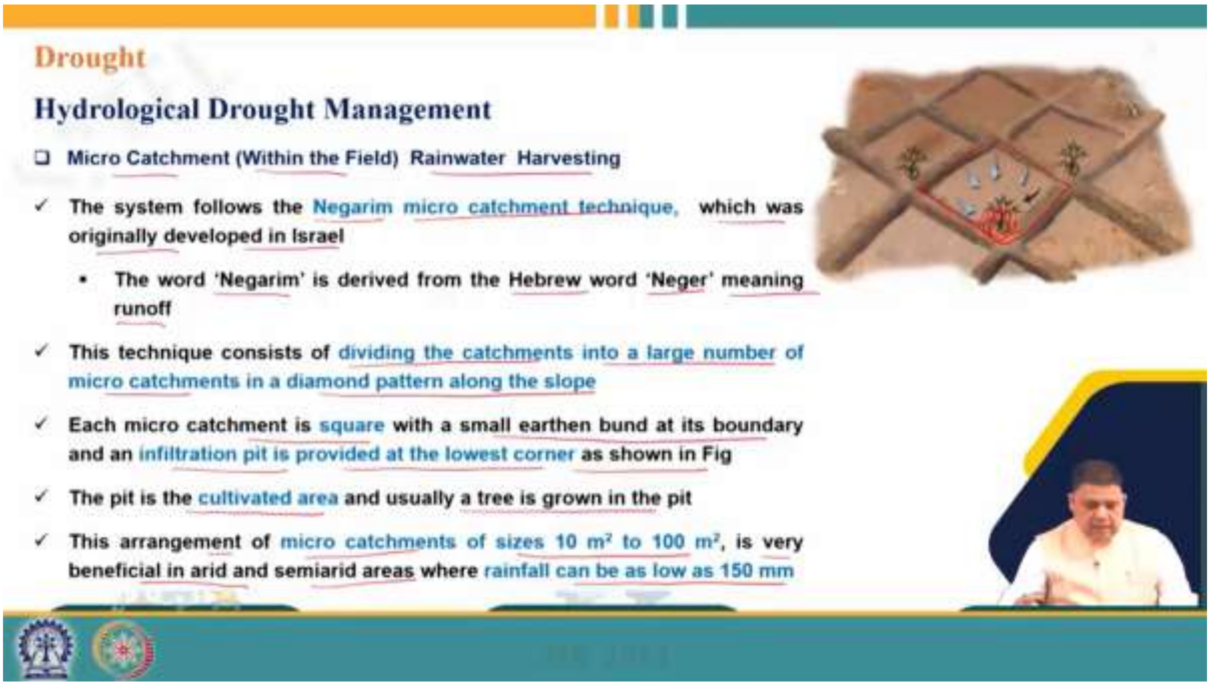



So, if we talk about the rooftop water harvesting or it is RTWH generally it is referred as it is the productive utilization of rainwater falling on rooftops of structures say buildings. So, obviously, whatever rooftop is there you collect that and either store it on the surface or use it for groundwater recharge. So, collecting runoff from rooftops of in joule structures and storing name for later use in urban areas is gaining popularity in recent time. Water collected from rooftops is often used for recharging the groundwater. So, obviously, as I said that you can all store it on the surface, but mostly it is preferred that the groundwater harvested water should be used for groundwater recharge. Characteristics of rainfall in a place such as intensity, duration, nature of rainfall season, and average number of rain days determine the RTWH design. So, obviously, you have to have a proper design in order to optimize the water usage.

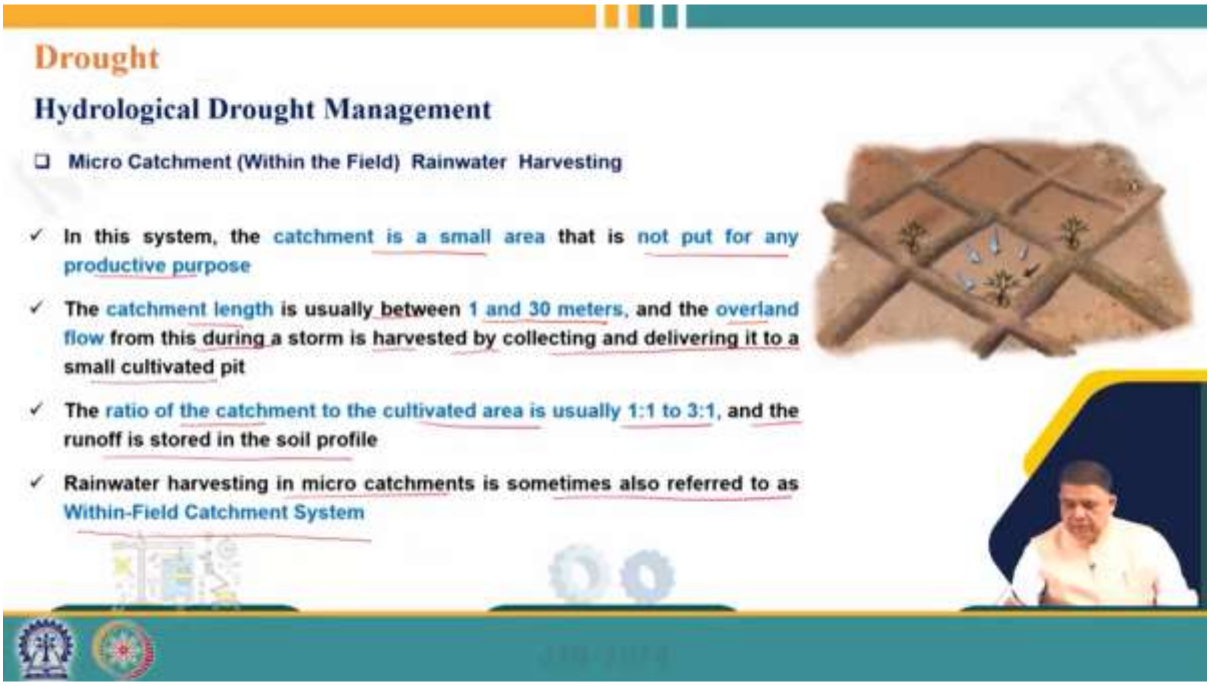



Then inadequacy of water availability and cost of supply has been many industries and large institutions in urban area situated in the area in the similar regions adopt RT WH system in a big way. So, it is gaining popularity and in fact, in India Tamil Nadu is a state which has made rooftop rainwater harvesting compulsory for all the houses across the state. So, any construction which takes place any building that is constructed there has to have a roof water harvesting facility. Factors like water quality and methods for efficient and economic collection and storage are some factors that have to be worked out in designing an efficient system to meet specific needs. And the cost of adequate size storage is a major constant in economical RT WH design. So, economics is a major factor because if you want to have stored on the surface then obviously, the storage structure and the space required could be quite large for any meaningful water storage.

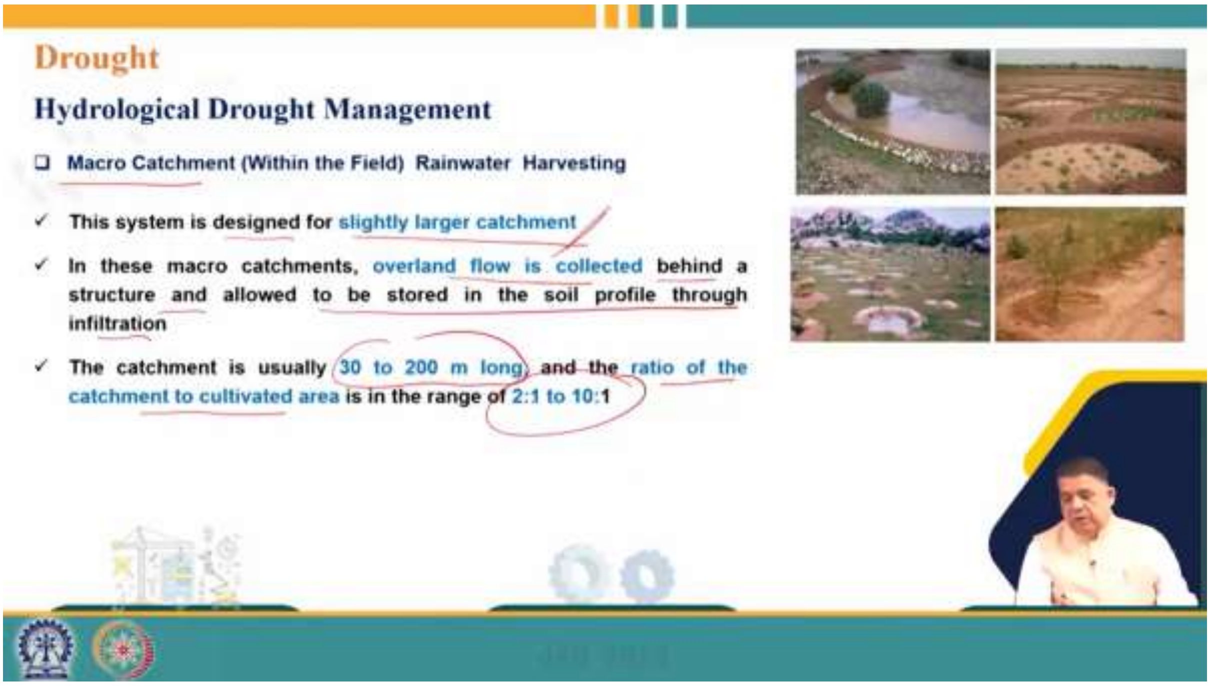

Then we go to micro catchment within the field rainwater harvesting. If the system follows the Negarim micro catchment technique which was originally developed in Israel. The word Negarim is derived from the Hebrew word “niger” which means runoff and this technique consists of dividing the catchment into a large number of micro catchments in a diamond pattern along the slope. So, along the slope you can see here the diamond pattern macro catchments have been developed. Each micro catchment is square with a smaller than one at its boundary and an infiltration pit provided at the lower corner. So, as you can see that it is a square there is a boundary and at the lower corner there is a pit and the pit is for the cultivated area and usually a tree is grown in the pit. So, as you can see a tree is grown here and this arrangement of micro catchments of sizes 10 square meters to 100 square meters is very beneficial in a semi-region where rainfall can be as low as 150 millimeters. So, as we saw that 100 to 450 millimetres we have a lot of area. So, there this system can be quite effectively used.




The catchment is a small area and is not put for any productive purpose. So, catchment is not used only the pit which is basically used for planting the crop. The catchment length is usually between 1 to 30 meters and overland flow from this during a storm is harvested by collecting delivery to a small cultivated pit. The ratio of catchment to the cultivated area is usually 1:1 to 3:1 and the runoff is stored in the soil profile. Then water harvesting micro catchment is sometimes also reported as a within-field catchment system. So, of course, as you can see that this negative system is a pretty popular way of doing it.

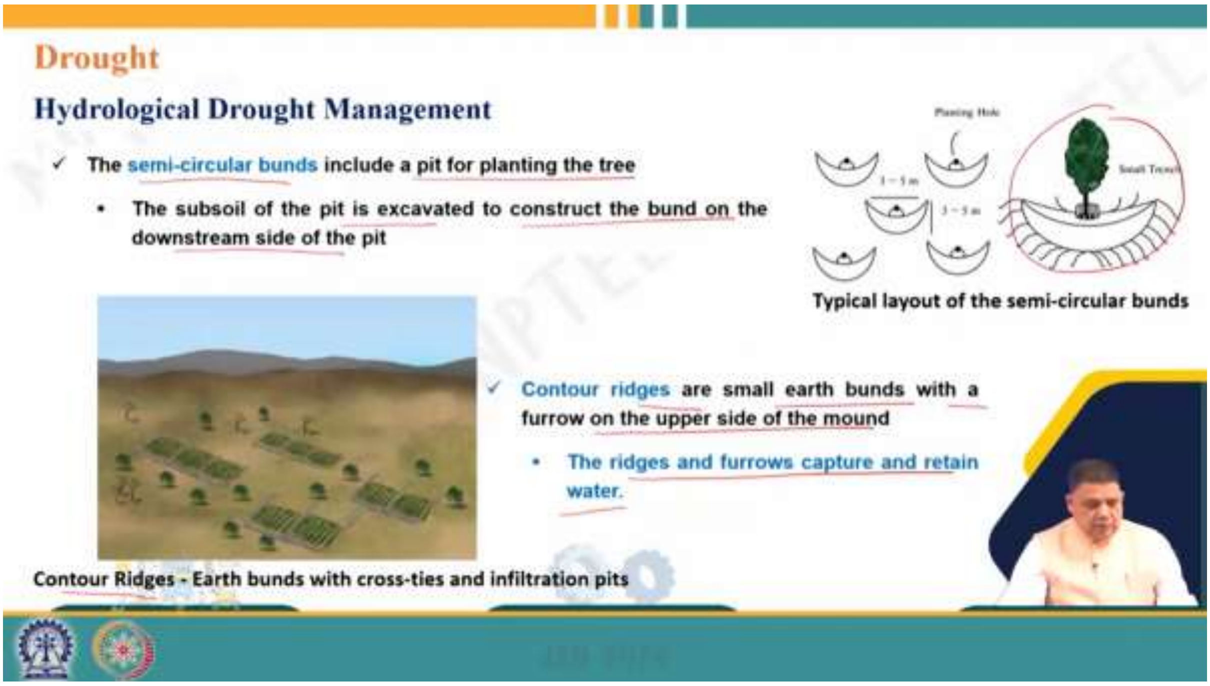



Then we go for macro catchment which is this system is designed for slightly larger catchment. So, that is why macro and overland flow is collected behind a structure and allowed to be stored in the soil profile through infiltration. Catchment is usually 30 to 200 meters long and the ratio of the catchment to cultivated area is 2:1 to 10:1. So, pretty large area is there as you can see the structures here.

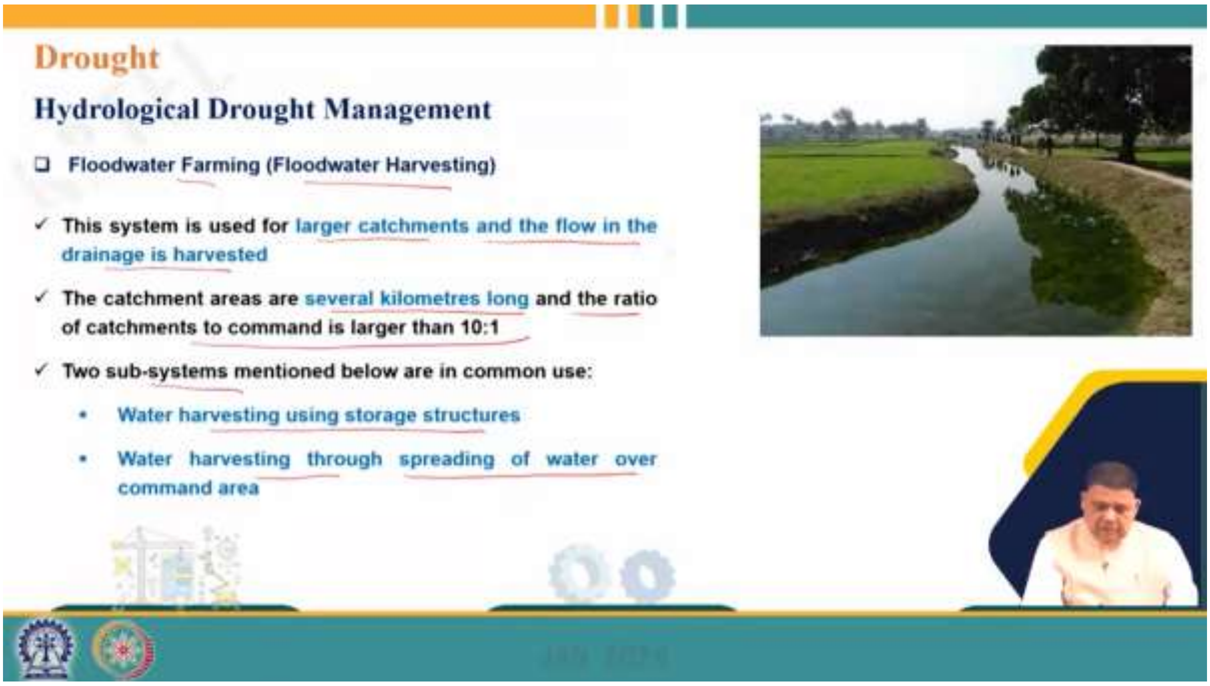



Typical arrangement may consist of one row or two staggered rows of trapezoidal bunds as you can see here they are bunds ah these are there. Then these capture runoff from macro catchment area. Then there could be contour bunds made of piled up stones ah which can be used for the system and infiltration behind the bund is used for growing crops. So, as you can see the water is getting stored which could be used for growing the crops.

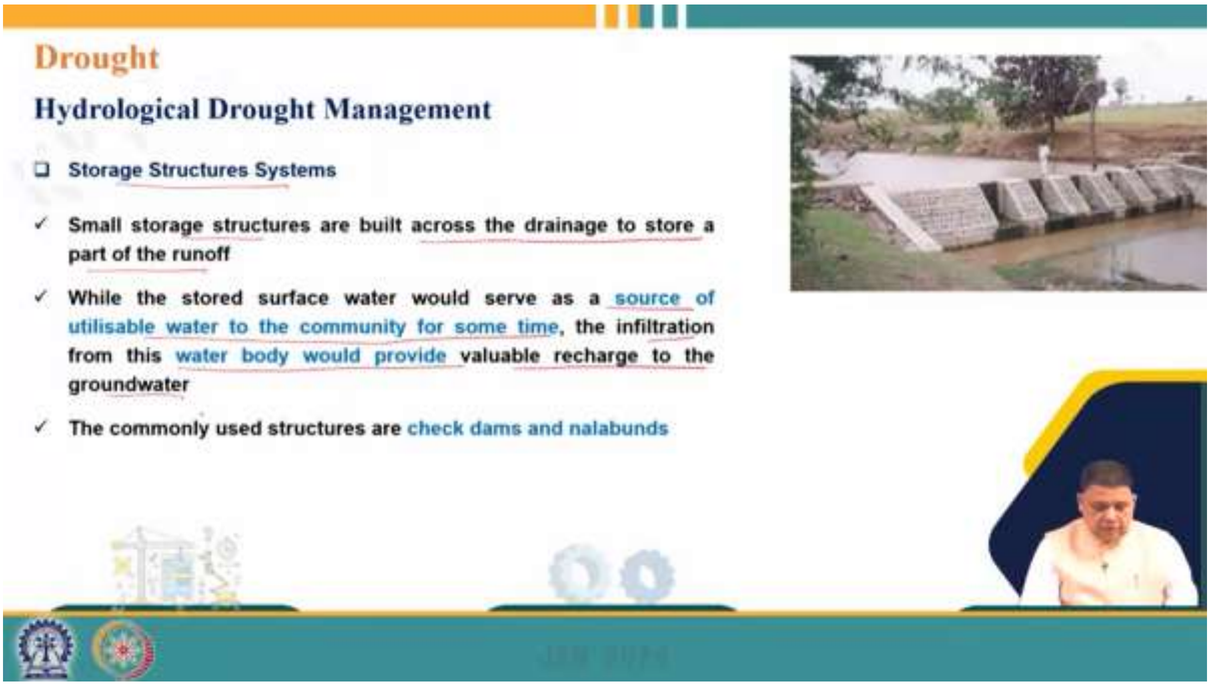
Then certain parts ah especially in ah Africa semi-circular bunds which includes a pit for planting the tree is very commonly used as you can see here they save this semi-circular bund. The subsoil of pit is excavated to construct the bund on the downstream side of the pit. So, same soil that is extracted that is used. Then contour ridges are smaller bunds with a furrow on the upper side of the mound and rigid furrow capture and retain water.So, this is contour rigid. So, basically contour various kinds of contours ah bunds are the embankment these can be used for ah making the water.



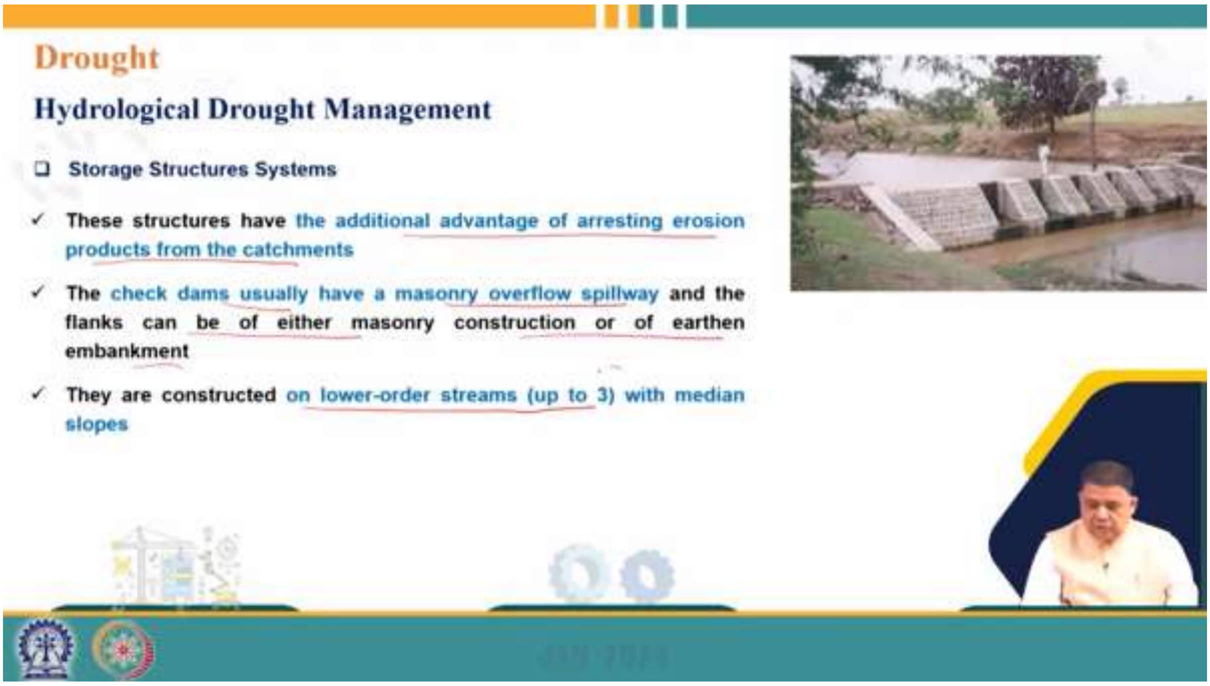

Then comes the flood water farming or flood water harvesting that is ah the second category and this system used for larger catchments and the flow in the drainage is harvested. The previous case was rainfall that we are bothering now it is the flow itself and the catchment area are several kilometres long and the ratio of two catchments to command could be larger than 10:1. And there are two subsystems ah which can be used that is water harvesting using storage structures and water harvesting through spreading of water over command area.



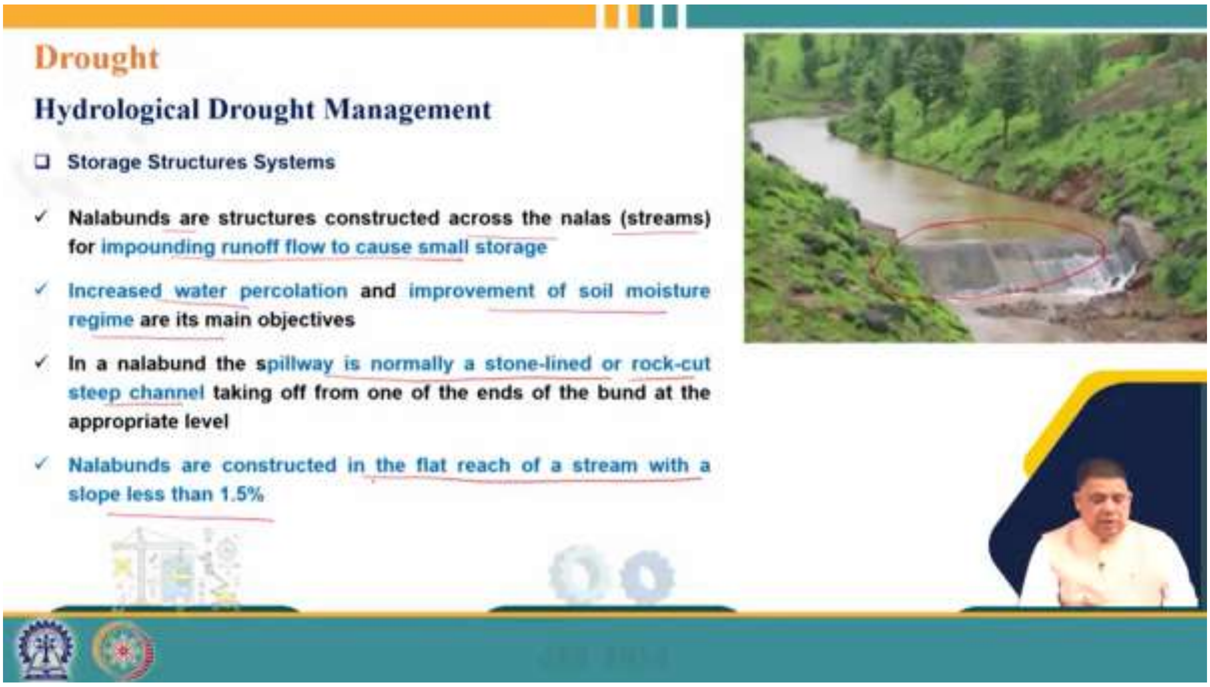

So, of course, storage structure systems are pretty called common small structures are built across the drainage to store a part of the runoff. While the stored water surface water could serve as a source of usable water to the community for some time then filtration from this water body would provide valuable recharge to the groundwater and ah typically, we use shake dams and ah Nala bunds.



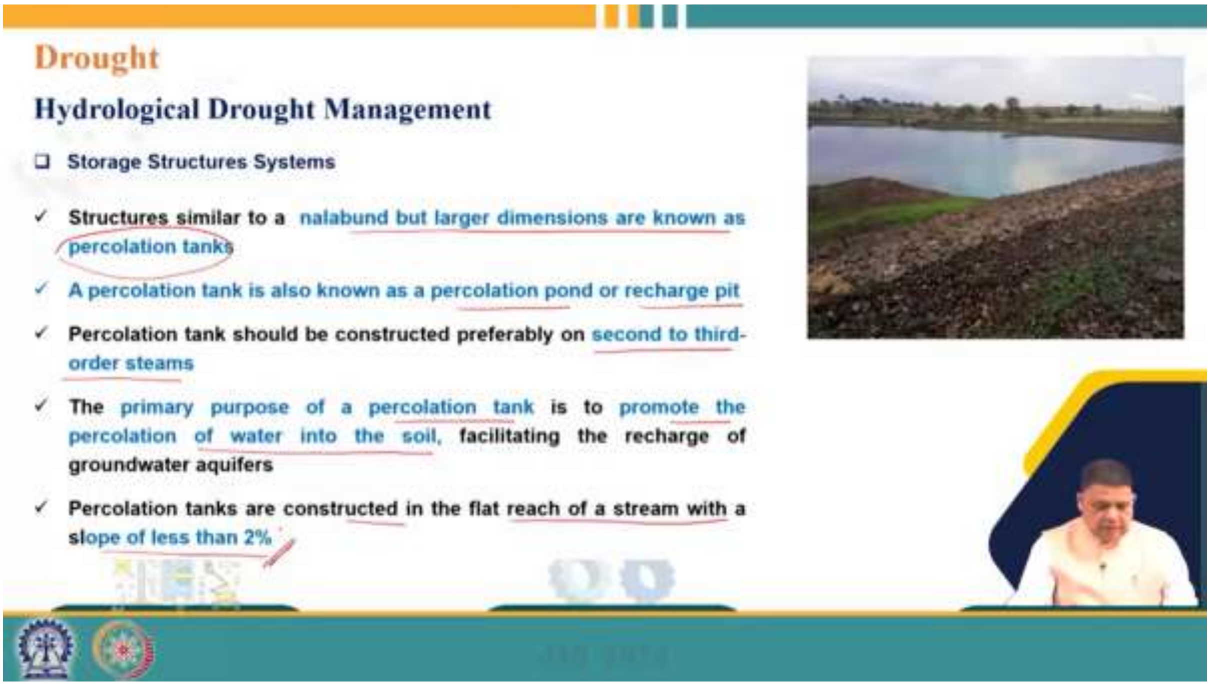

These structures have an additional advantage of resting erosion from the catchment. So, of course, these are also soil erosion structures. Check dams usually have a masonry overflow with spillway and the flanks can be of either masonry construction or then embankment. They are constructed on the lower side order stream that is up to the third order stream with median slopes.



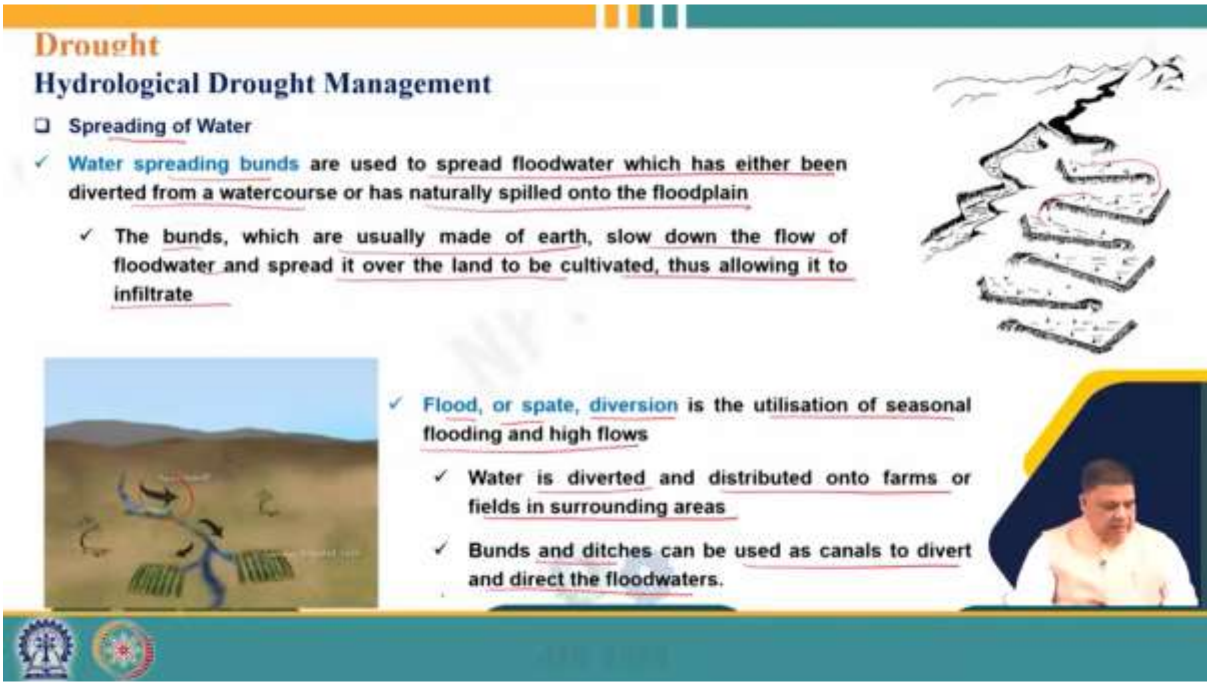

On the other hand, Nala bunds are structures constructed across the Nala's streams for impounding runoff flow to cause small storage. Increased water percolation and improvement ah of soil moisture regime are the main objectives. In this case, spillway is normally a stone-lined or rock-cut steep channel as you can see here and which takes up from one end of the bund and these are constructed in the flat reach of the stream with a slope less than 1.5 percent. So, these are smaller structure compared to ah the drop structures.




Then structures similar to Nala bund, but larger dimensions are can also be used which are referred to as percolation tanks. So, it has much larger water bodies which are also called percolation pond or recharge pit and they are constructed on second to third order streams. And the primary purpose of the percolation tank is to promote the percolation of water into the soil. So, obviously, water stands for a longer period of time and then it gets recharged into the groundwater. And these are constructed in flat reach of a stream with a slope of less than 2 percent. So, obviously, it has to be a pretty flat area ah where water can be stored and could be there for a long period of time.




Then lastly, we have spreading of water wetter water spreading bunds are used to spread flood water which has either been diverted from a watercourse or has naturally spilled into the flood pane. The bunds which are usually made of earth slow down the flow of flood water and spread it over the land to be cultivated thus allowing to infiltrate. So, obviously, as you can see that there is a zigzag kind of pattern is there. So, water is first getting stored here then comes here it is again stored here then flows here and so on. So, that means, you are allowing ah you are cutting down the velocity of flow and residence time you are increasing. So, that more and more water gets infiltrated into the soil. The second one is the flood or spade diversion is the utilization of seasonal flooding and high flows where water is diverted and distributed into farms or fields in the surrounding area. So, whenever you have a flood kind of situation then you basically you take the spade runoff and spread that over the larger area. Bunds and ditches can be used as canals to divert and direct the flood water. So, basically whatever bunds or can bunds or ditches be there they can be used for time being as a canal for spreading the water to a larger area. So, that water gets spread into a larger area and ah it resides there for more and more groundwater which has to take place. So, these are the thing.




So, with this ah we come to an end of this lecture. So, we have talked about ah drought management ah various ways of ah hydrological and meteorological drought management. Please give your feedback and raise questions or doubts we shall be happy to answer on the forum. Thank you very much.