Soil and Water Conservation Engineering
Prof. Rajendra Singh
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 04
Soil Erosion - Mechanics

Hello friends welcome back to this NPTEL online certification course and title Soil and Water Conservation Engineering and I am Rajendra Singh, professor in Agricultural and Food Engineering Department, IIT Kharagpur and we are in lecture 4 of week 1.

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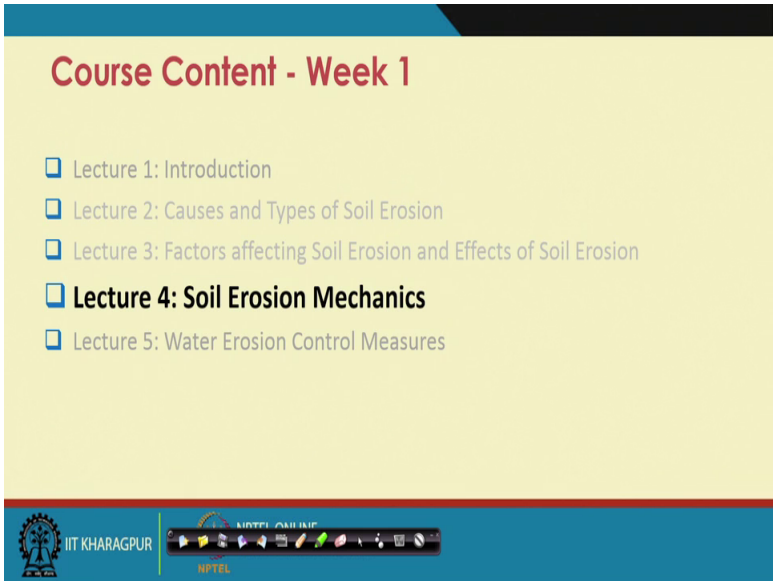

The topic today is the Soil Erosion Mechanics. Just to remind you, the course content of this week in first lecture, we introduced what is soil in water conservation. In lecture 2, we talked about the causes and types of soil erosion. In lecture 3, we discuss the factors affecting soil erosion and effects of soil erosion and today's lecture will be devoted to soil erosion mechanics. And in the last lecture of the week that is week lecture number 5, we will discuss the water control erosion measures.

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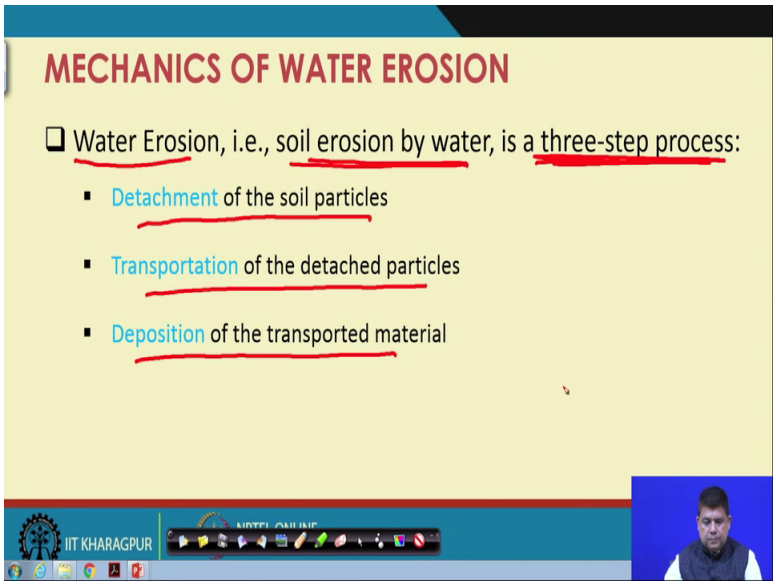

So, let us start with soil erosion mechanics. We know that water erosion; there are two major agents of soil erosion; water and wind and the soil erosion by water, soil erosion by water that is referred to as water erosion. We have been seeing this in previous classes also.

Now, there are three processes involved or three-steps, it is a three-step process or three processes involved in the soil erosion by water. And the processes are detachment of soil particles that process number one, then transportation of the detached soil particles that is process number two and deposition of the transported material that is process number three. So, soil erosion by water which is referred to as water erosion is a three step process; detachment, transportation and deposition.

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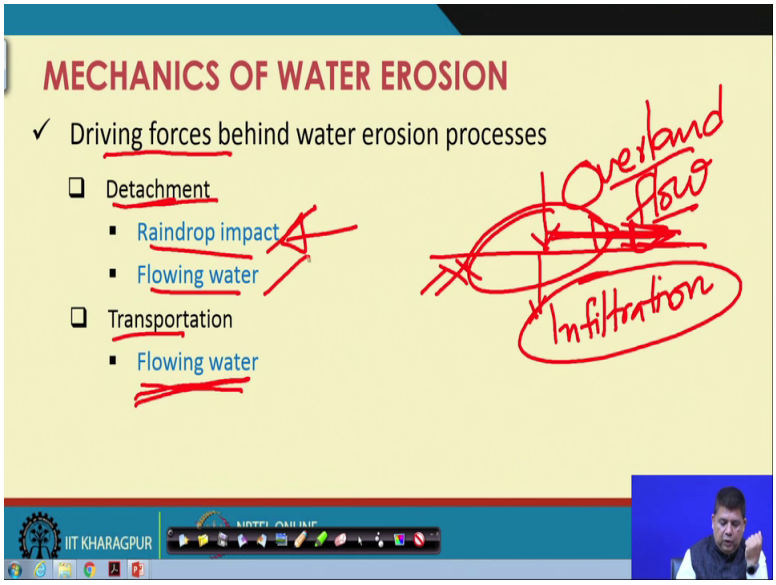

So, we start with the detachment or if we continue with our discussion, then the driving forces behind water erosion process are detachment of course, and then is transportation that is there are two major process detachment and transport. And the driving forces of detachment are raindrop impact and flowing water and for transportation, it is flowing water.

So, remember we discussed right from lecture 1, when lecture 1 when we started classifying soil erosion, then we started with the classification of water erosion and the first was raindrop impact erosion and we said that that is the first level where erosion starts. And that is a when the raindrops again I repeat when the rain drop hits the soil surface because of their velocity or because of their kinetic energy, they had the soil surface head and thus they break the soil aggregates. And once this soil aggregates are broken, the soil particles are because of the impact the soil particles get splashed all around.

And this during this is fresh process, the I mean that is nothing, but detachment of the soil particles, detachment of the soil particles takes place. And simultaneously another phenomena is occurring when the rainfall is occurring; simultaneously another phenomena is occurring that is the rainfall you know that when on a soil surface, if you see the soil surface and when the rainfall occurs then obviously first process that starts is infiltration.

Infiltration so that means, soil the rainfall will first satisfy the infiltration requirement of the soil and once the infiltration capacity of the soil is satisfied, then what ever rainfall occurs that will fall that will flow horizontally and that is referred to as we refer to that is overland flow or runoff generation. And this flowing water whatever details soil particles available here, the supreme water will carry that away.

So, and also during the process during the flow process, this soil particle whatever this flowing water because of its kinetic energy; it will also detach soil particle from the soil aggregates. And of course, as we already mentioned the flowing water will transport whatever loose materials or detach soil particles are available. So, that is how there are two major driving forces of detachment behind detachment transportation or raindrop impact and flowing water.

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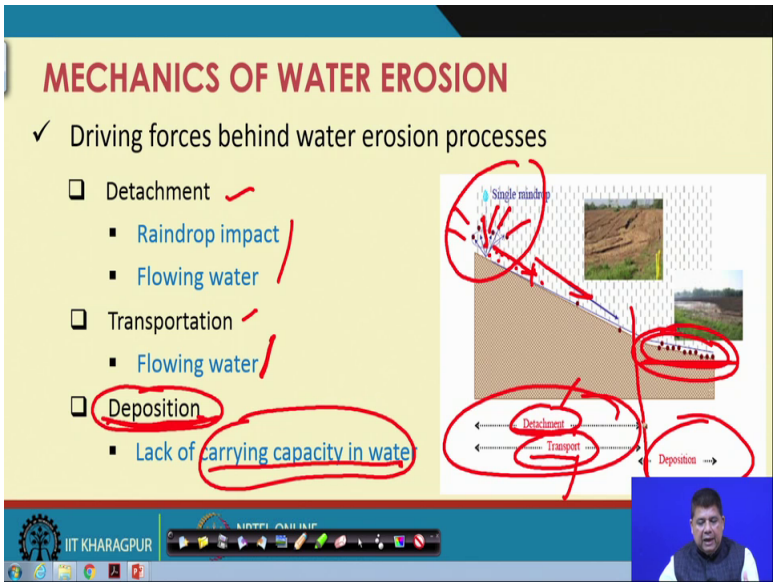

And the third process which is will takes place is deposition that is, when there is a the carrying capacity of the flowing water reduces then; obviously, it cannot for the transport the soil particles and thus the soil particles get deposition. So, that is the third phenomena. So, detachment and transportation, the raindrop impact and flowing water are responsible and when the carrying capacity of the flowing water reduces to a large extent such that it cannot for the carry the detached soil particles, then the soil particles get deposited.

If you look at a slope once again and if you just imagine that a single raindrop is heating the soil surface and because of this heat here as you can see that soil particles are getting splashed everywhere and in the process; obviously, there will be loose soil particles available on the surface all around.

Once the infiltration capacity is satisfied then; obviously, the overland flow process will take place and then the overland flow process will take place and that will take the detached soil particles further away. At the same time because this flowing water has a high velocity because of this slope. So, it will further detach the soil particles so; that means, as you can see that the detachment and transportation are occurring up to this point simultaneously, because it is not only the raindrop impact, but also the flowing water detaches the soil particles and the flowing water transports soil particles so; that means, simultaneously detachment and transportation phenomena are occurring.

But we when we reach the belly bottom where the slope is drastically reduced then; obviously, because the flow velocity reduces then the carrying capacity of the flowing water will be less and because of that soil particles that are being transported from upstream, they will get deposited here. So, that is where deposition is taking place. So, this is the entire mechanics of water erosion.

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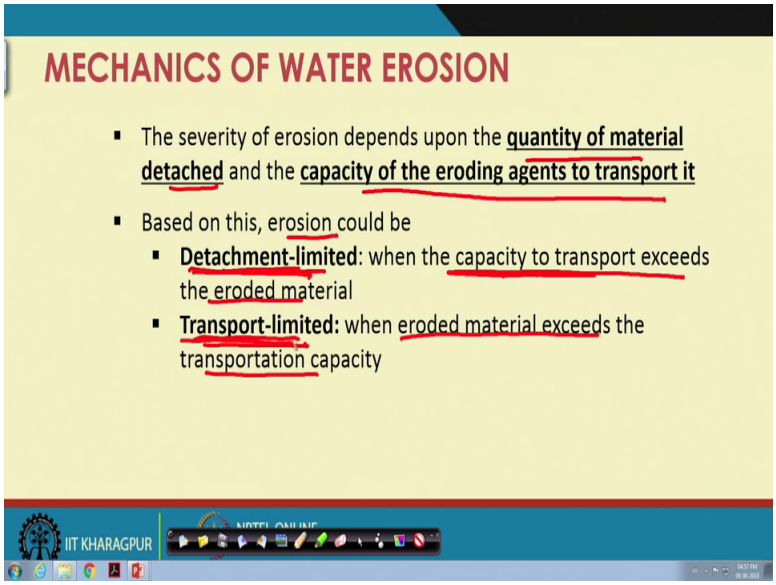

The severity of erosion depends on the quantity of material detached and the capacity of eroding agents to transport it quite obvious because these are the two processes involved.

So, based on this erosion could be detachment limited or transport limited. When the capacity of the transport exceeds the eroded material, then the detached is referred to as detachment limited is that means there are not enough details soil particles for what are the flowing water to transport along with it.

On the other hand, when eroded material exceeds the transportation capacity of the flowing water, then it is referred to as transport limited. So that means, the severity of erosion depends on quantity of material that is detached and capacity of eroding agents to transport it and based on whether the transport capacity is more or the eroded material more, it could be detachment limited or transport limited.

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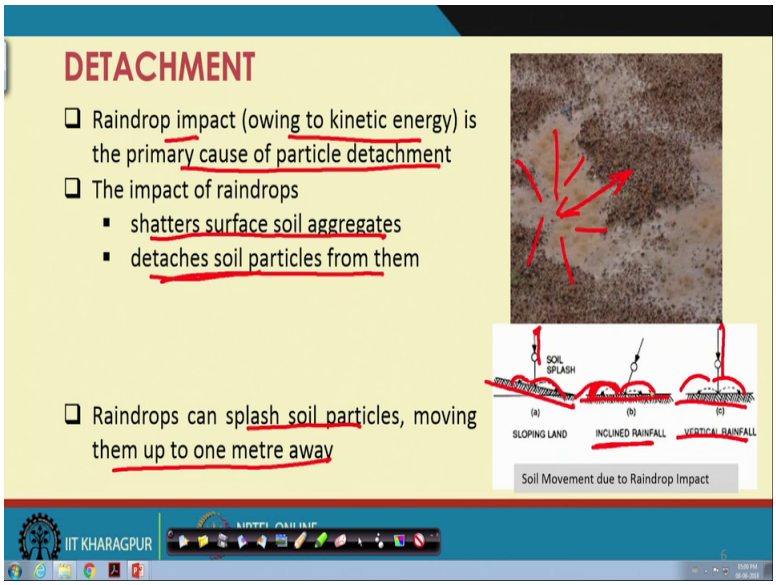

Now, coming to detachment process; several times we have seen this, but once again let us repeat this that raindrop impact going to kinetic energy is a primary cause of particle detachment. So, that is the major reason of course, we saw that it is the flowing water that also detaches soil particles, but it is a raindrop impact does the primary cause. And the impact of raindrops this shatters the surface soil aggregates that is the first phenomena that occurs and; obviously, one soil aggregates are detached, then shattered than the soil particles get detached from them.

And as you can see that here and surface changes here as you can see here, it is much more soil is there, but here you can see most of soil has been shattered or a soil aggregates has been shattered and probably splashed all around.

And raindrop can splash soil particles moving them up to one meter away that depends on the kinetic energy and is already we saw the slope wind and sloping land could also have impact on it. So, the ideal case is that when is there is vertical rainfall and vertical rainfall falling on horizontal surface, vertical rainfall horizontal surface then; obviously, you can see that this splash is uniform all around. But there can be two more cases that rainfall is vertical, but land is sloping. In that case on the down sleep, there will be much more splash is compared to upside.

Similarly the surface could be horizontal, but the rainfall itself could be inclined because the wind impact which already saw in a precious class. So, because of wind impact if rainfall impacts the soil surface at an angle then of depending upon on which side angle is being formed because of the velocity component the splash will be more on one side and lesser on the other side, that will depend on what is the wind velocity and what angle raindrop is heating the soil surface.

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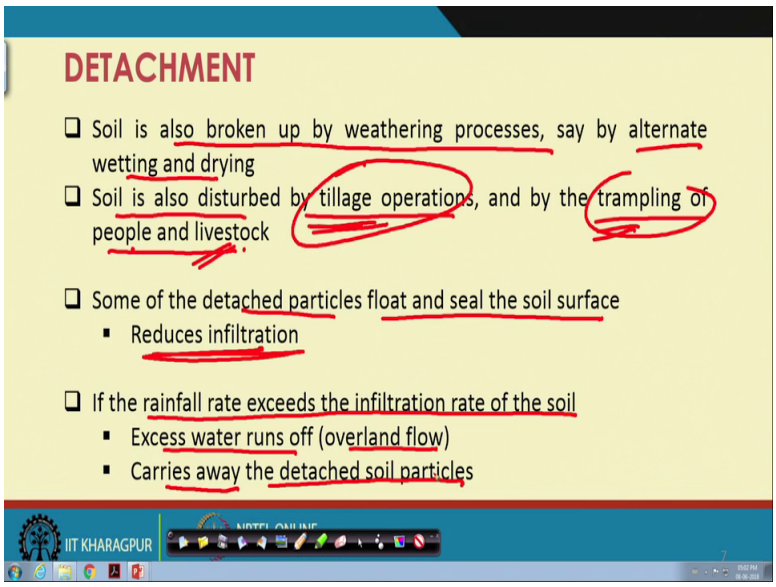

And this detachment and not only happens because of the raindrop impact wet, but also the soils could be broken by weathering process by alternate wetting and drying. So, if the soil is such that there is a rainfall the alternate wetting and drying is there, then natural weathering phenomena will take place and soil particles gets broken. And of course, if it is a tillage operations we take or there is a trampling of by people and livestock that also soil gets disturb.

Yesterday we saw that how human impact soil erosion and we saw the primary implements when we use the following etcetera, then will keep a lot of loose soil particles on the soil surface; making the area prone to soil erosion. Similarly if you see you might have seen the sidewalks on the bare soil; that means, if it is a grass area, but continuously people move or animals move or livestock move, then you see that the soil automatically a particular passage becomes bare and that is because of the because of trembling by people or by livestock soil gets detached or gets eroded.

And of course, during this detachment process already we have discussed that some of the detached particles, they will seal the soil surface and reduce the infiltration. And if when the inflation rate exceeds the infiltration, rate of the soil excess water will runoff in the form of overland flow and; obviously, this water will carry away the detached soil particles that is what happens in the case of sheet erosion.

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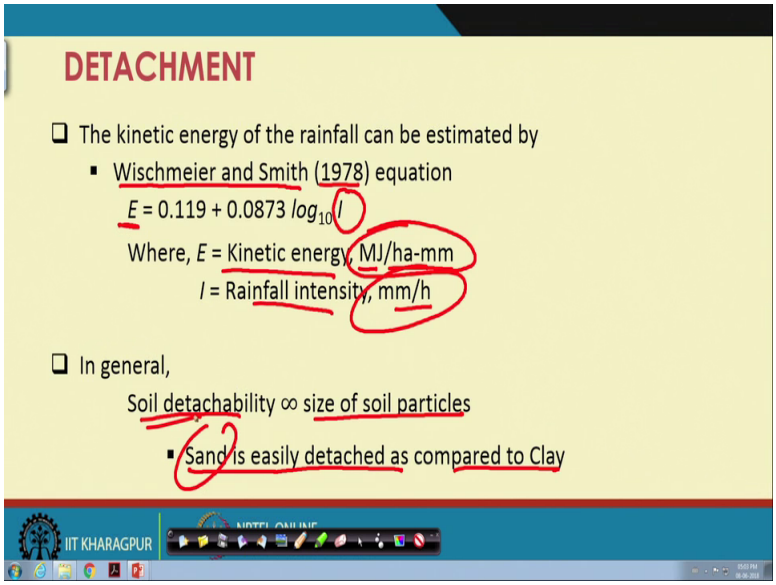

And in case of detachment, the kinetic energy of the rainfall can be estimated by a formula given by Wischmeier and Smith in 1978. And as per this equation E which is the kinetic energy in million joules per hectare millimeter that is related to rainfall intensity I in millimeter per hour by this equation; that is E equals to 0.119 plus 0.0873 log base 10 I. And as it is an empirical formulae, then; obviously, if you want to use this you have to remember that E will always be a kinetic energy, always be in million joules per hectare millimeter and rainfall intensity has to be used in millimeter per hour.

We have also seen that in general soil detachability is directly proportional soil particles; that simply means that sand is easily detached as compared to clay because sand is larger in size. So, it can be easily detached.

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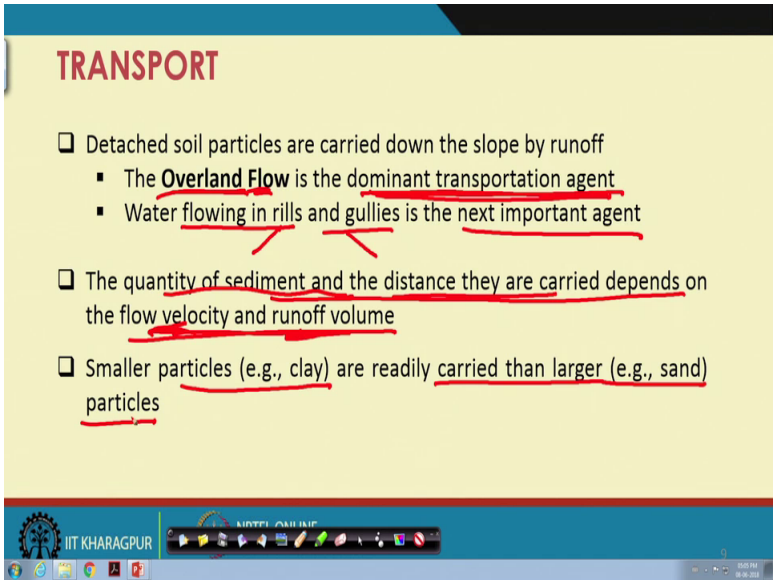

Coming to transport, the detached soil particles are carried down the slope by runoff and overland flow is the dominant transportation agent. We saw that in one of the earliest slide we saw that both raindrop impact as well as overland flow can cause detachment. But just previous slide in while talking detachment we saw, it is the raindrop impact which is the primary force behind detachment. Similarly we can say it is the overland flow which is the dominant transportation agent.

So, once the detached soil particles are lying on the soil surface, the overland flow takes these slides of these soil particles away. And water flowing in rills and gullies is the next important agent. We also saw that rills, what are the rills and what are the gullies while classifying the water erosion that is rill erosion is a form where we have a finger like structures and water will have a tendency to flow through this rills and cause erosion. Similarly gullies are much larger in size. We also saw that they could be u shaped or v shaped in previous class and; obviously, water flowing in this gullies is also will cause will transport soil particles.

The quantity of sediment and the distance they are carried depends on the flow velocity and runoff volume; that means, the carrying capacity of this of the flowing water; either

if it is a velocity of flow has to be very high or the quantity total quantity of water has to be too high for the erogic capacity of the flowing water to be high. And if that happen, that is either flow velocity is high or runoff volume is high or id both are high, then; obviously, the sediment will get transmit transported at much larger quantity and they will be carried away to a far of places.

And a smaller particles that is clay are readily carried is compared to large particles or sand particles. So, once again detachment it is a sand which is easily that is which is larger in part size where is clay which is smaller in size that is easily transported

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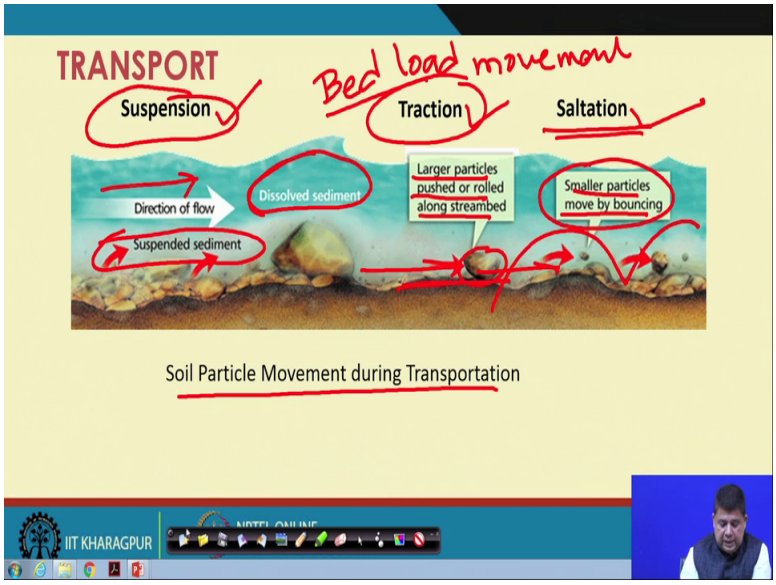

Now, if we look at the soil movement or soil particles movement during transportation, then this is how I mean this is a water body and this is the direction of flow already shown. Then obviously, on top of the surface there will be some dissolve sediment particles that will be floating. And of course, some particles will be suspended. So, a major phenomena that occurs is suspension. Then the smaller soil particles, they move by bouncing that is the they bounce and then again they are taken away in the in the water and then again fallback.

So, this that happens with the smaller particles and that particles is referred to as Saltation. And if it is the largest soil particles, they are basically pushed or rolled along the stream bed as you can see here, a very large particles that is being rolled along the stream bed and that is referred to as traction and sometimes it is also referred to as bed

load movement. So, the in the soil water erosion process the soil particles transport takes place in three different forms; suspension, saltation and traction or bed load movement; these are the three processes involved.

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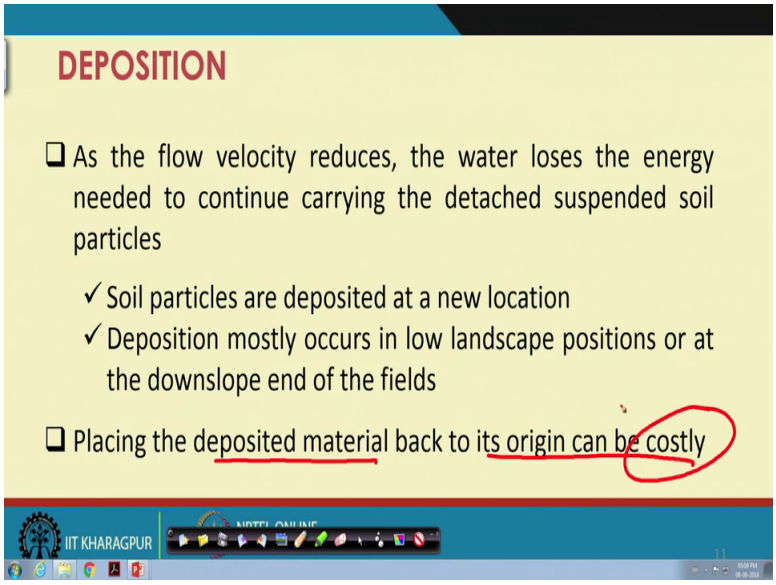

If we come to deposition, then basically deposition occurs is the flow velocity reduces the water loses the energy needed to continue carrying the detached suspended soil particles and soil particles are deposited at a new location. So; obviously, wherever this flowing water loses its capacity to transport soil particles further they are; obviously, whatever soil particle that they are been transported. They will get deposited. And deposited deposition mostly occurs in low landscape positions or at the downslope end of the fields which is quite obvious because if we talking about just now we saw the hill slope example, we saw that something like this is there.

So, here the transfer the detachment and transportation rockery, but once this horizontal surface came because the flow velocity gets reduced here. So, most of the deposition will occur at this point that is at low landscape position or downstream end. And of course, placing the deposited material back to its origin can be very costly affair. So obviously, we know that soil is getting attached, it is episteme place. It is being transported and getting deposited somewhere else. Now, if you want to take this soil back to its original position, then it will be a very very expensive phenomena and of course, probably it will

not be cost effective; that is what it is saying that a placing the depositor material back to origin can be very costly phenomena.

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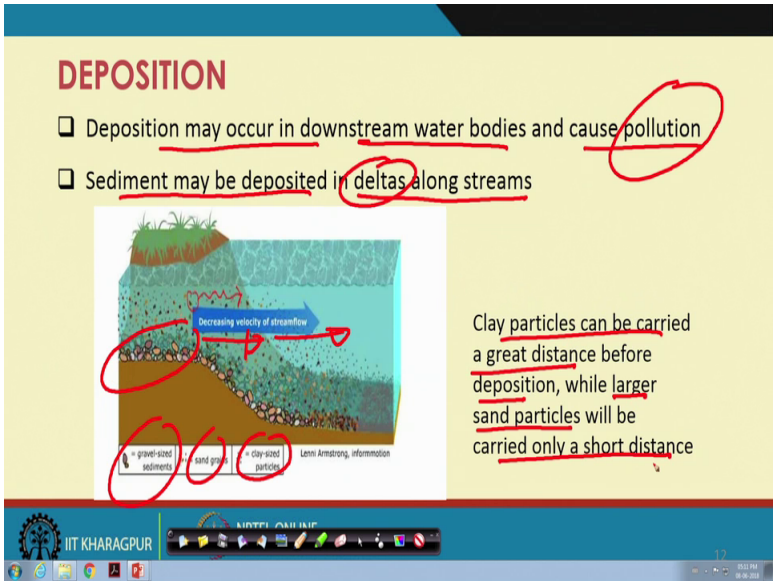

And continuing with deposition, deposition could occur of course, we saw in the downstream places, but if the flow continues then the deposition may also occur in downstream water bodies and cause pollution. So, if deposit if the transporter soil particles reach a stream or river then; obviously, it they because lot of loose particles and sand and soil particles are being carried so; obviously, the river water will get polluted.

And, but there is a plus side also like we know that sediment can also be deposited in delta along streams, again where the river joins the sea and because it loses its velocity. So, most of the soil particles they get deposited farming deltas, but we also know that these deltas are very productive there because they are they are built from the productive soil; the top soil which has been carried during the erosion process. So, their deltas are very productive. So, that could be called as a one plus of the entire erosion process.

And obviously, if you look at the flow then; obviously, the gravel sized sediments will be first deposited, sand grains will be taken little far of is compared to the gravel sized particles and clay sized particles which are much final, they will be carried further down. So, clay particles can be carried a great distance before the position while large larger sand particles will be carried only a shorter distance which is quite obvious because yes

we the flow get reduced or the velocity reduces first the larger part will get deposited and slowly and the light lighter particles will get deposited.

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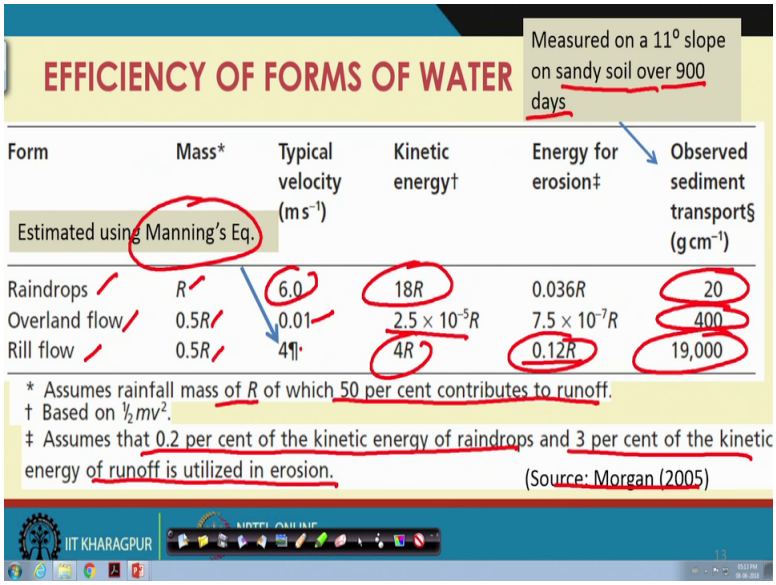

Now, this is a efficiency of the form of water erosion. This is data provided by Morgan in 2005, 2005 year and here it says three different forms it talks; raindrops, overland flow and rill flow and it resumes the mass of raindrops is R and assumes that rainfall mass of R which 50 percent contributes to runoff. That means, overland flow will be 0.5 R and rill flow point R the typical velocity is 6 in case of rain drops, 0.01 in case overland flow and 4 in case of rill flow which has been estimated using Manning's equation based of lot of experimental data.

So, if you look at the kinetic energy the raindrop, kinetic energy will be 18 hour very high, rill flow will be next and overland flow will be much lower as compared to rain drop of kinetic energy. And as a result if you look at the observed sediment energy for erosion; obviously, which we will be higher here and that is it assumes 0.2 percent of the kinetic energy of raindrops and 3 percent of the kinetic energy of runoff is utilized in erosion. Because of that the rill flow will have much much higher energy of erosion as a result the observed sediment transport in gram per centimeter is much higher in the rill erosion followed by overland flow and lastly by raindrops; that is the data based on the experiments conducted in sandy soil over 900 days.

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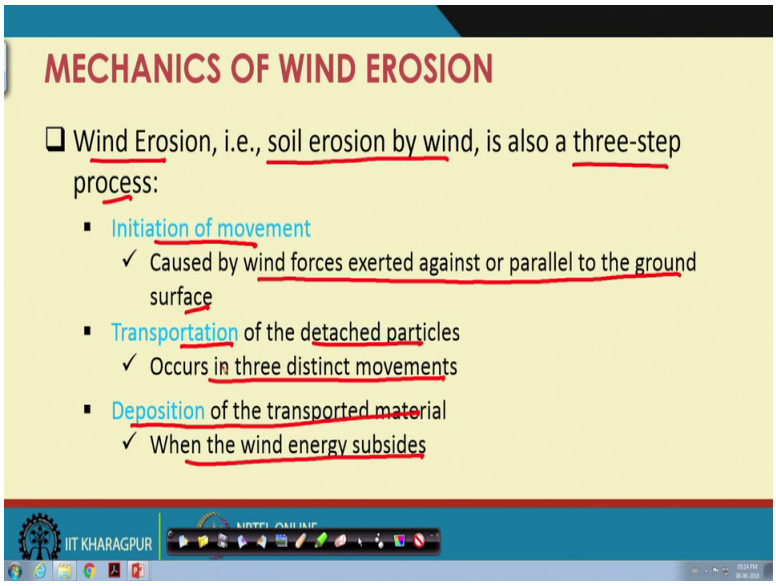

Now, coming to, up till now we have been discussing about one of the erosion agents water, but we have we have already seen that water and wind the two major erosion agents. So, now we come to wind erosion and soil erosion by wind is referred to as wind erosion which is also a three step process. In this case the process are initiation of movement which is called by wind forces exerted against or parallel to the ground surface. Then we have transportation of the detached particles which occurs in three distinct movements here also and finally, the deposition of the transported materials when the wind energy subsides.

So, in this case also there are three processes. There we called detachment transportation and deposition in case of water erosion. Here we are calling initiation of movement transportation and deposition that is the only chain. So, level one only has a name change.

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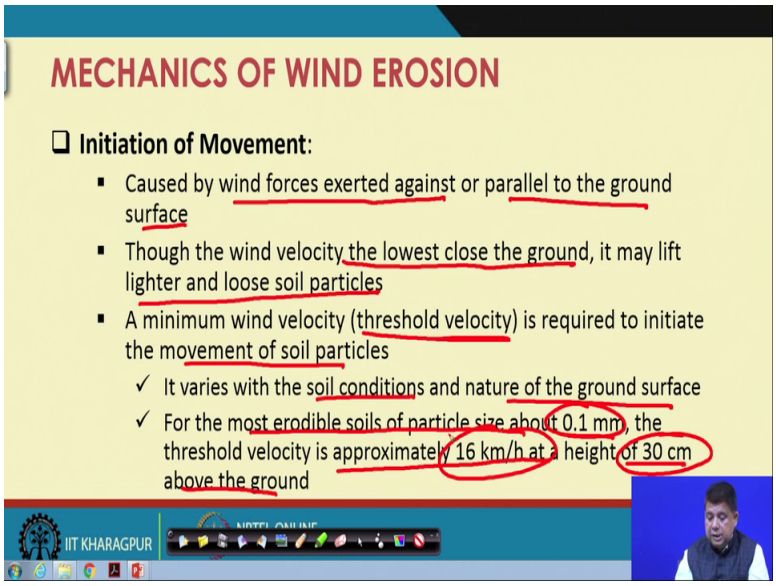

And if we talk about the initiation of movement, it is caused by wind forces exerted against or parallel to the ground surface; very similar to very similar to the raindrops, if the angle such that wind hits the soil surface an angle then; obviously, it causes any initiation movement or if it is a parallel to the ground surface, then also as we saw that even the light wind can roll the soil particles. The rolling of soil particles on initiation movement takes place. Through the wind velocity is the lowest close to the ground, it may lift lighter and loose soil particles. I mean even when it is very low velocity, then also the lighter and loose soil particles can be moved or initiation movement it can take place.

And the minimum wind velocity which is required to initiate the movement of soil particles which is referred to as threshold velocity that varies with soil conditions and nature of ground surface. And the for most erodible soils of particles size 0.1 mm, the threshold velocity is approximately 16 kilometer per hour at a height of 30 centimeter above the ground. So, thus the typical value of the threshold velocity for soil particles of around 0.1 mm and it measure the wind velocity when measured at thirty centimeter above the ground, then that is all threshold velocity is 16 kilometer per hour.

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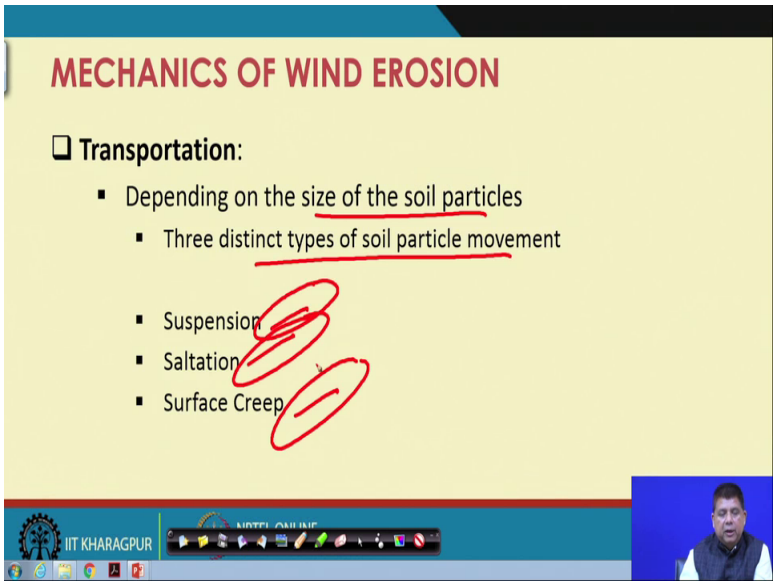

Then we come to the second phenomena, that is process that is deposition and here also like in the case of water erosion, depending upon the size of the soil particles, they are three distinct types of soil particle movements; suspension, saltation and surface creep. So here you remember in case of water also be called suspension, we call saltation and, but then that case we called traction or bed load movement, but in this case we call that surface creep. So that is the only one name change in one of the phenomena.

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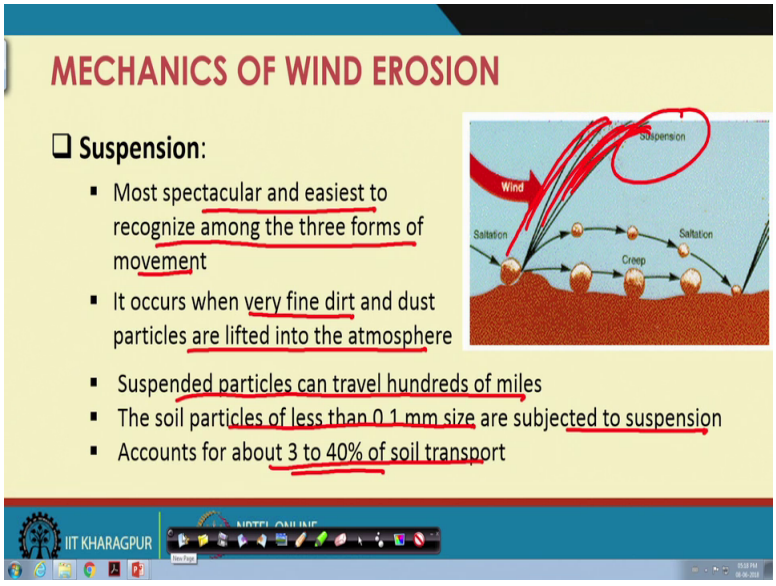

And if we come to define each one of them, then suspension is the most spectacular and easiest to recognize among the three forms of movement. It occurs when very fine dirt and dust particles are lifted into atmosphere and that is here that is the lighter particles are they can into atmosphere and I mean most of the dust is storm, when we talk about and suspended particle we see; that means, the lighter soil particles which are taken to suspension that is more clearly visible to us and that is the dust storm when we talk about.

And suspended particles can travel hundreds of miles depending upon the well velocity and the size of the soil particles, they can be taken far off from place where the initiation has started. And soil particles of less than 0.1 mm size are subjected to suspension that is much lighter side or smallest side particles and it accounts for three to forty percent of the soil transport. So, suspension accounts for 3 to 40 percent of the soil transport as for as wind erosion is concerned.

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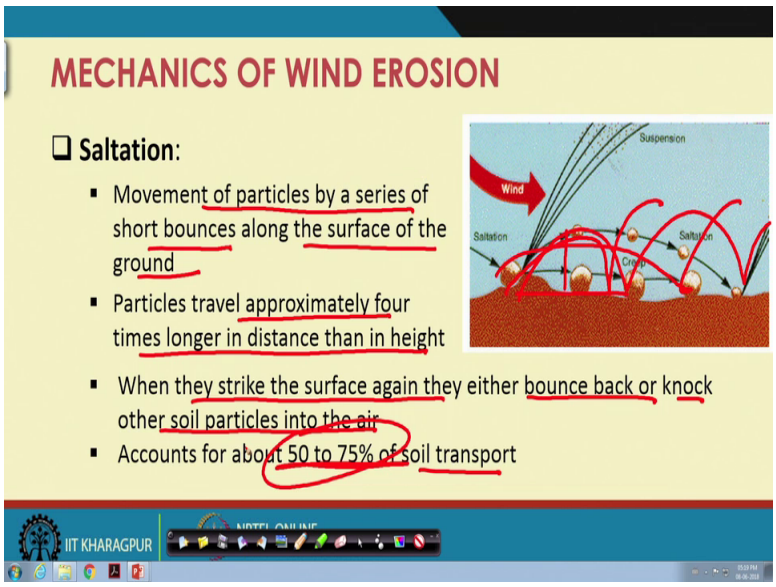

Then next process is saltation, similar to saltation there it is the movement of particles by a series of short bounces along the surface of the ground. So, the soil particles will something move something like that; particles travel approximately four times longer than distance then in height. So, this is four times higher than the height the travel. And when they strike the surface again, they either bounce back or knock other soil particles in to the air. So, both phenomena could happen that they fall and the bounce back or they

fall on soil particles and then make that particular soil particle to bounce. And obviously, it accounts of a maximum of soil transport under wind erosion that is around 50 to 75 percent of the soil transport in the wind erosion and take place due to saltation.

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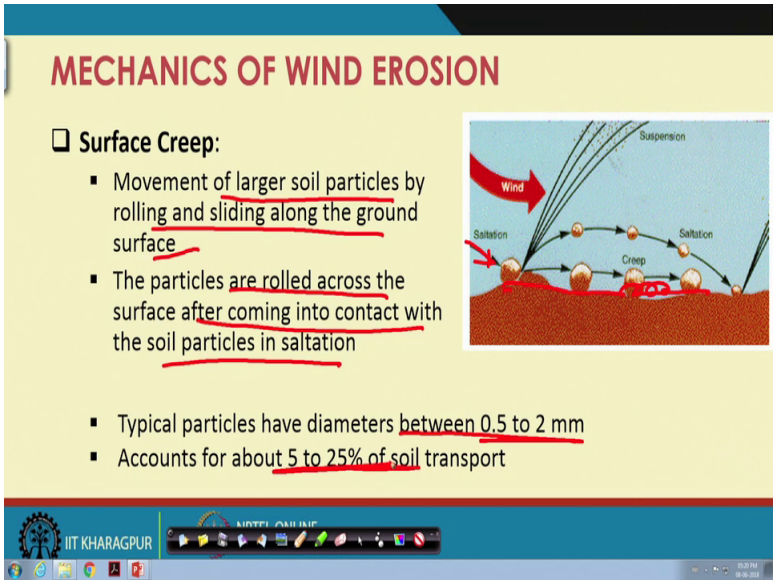

And then we come to the last process movement process that is referred to a surface creep and it is the movement of larger soil particles by rolling and sliding along the ground surface. So, this is here they either role or this slide along this further. The particles are rolled across the surface after coming into contact with the soil particles in saltation. So, they can roll because of the kinetic energy transferred by water or even the saltatation soil particles can heat and make the roll around. And the typical particles that have diameters between 0.5 to 2 mm, they are subject to surface creep and accounts for about on 5 to 20 percent of 25 percent of soil particles.

So, with this we close this chapter where we have seen the soil or water and wind erosion mechanics. Just to repeat quickly that detachment transport and deposition these are the three process involved in the water erosion where is initiative movement transport and deposition are the three processes involved, in case of wind erosion. We will continue further and see what can be done further to control this erosion.

Thank you very much.