

ENVIRONMENTAL GEOSCIENCES

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Lecture-47

Impact of Soil Erosion

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the Module nine. In the Module nine, we have to discuss about the process of soil formation, impact of soil erosion, physical and chemical properties of soils. Till now, we have discussed two lectures. Today, we will discuss the lecture three, that is, Impact of Soil Erosion.

In this lecture, the important concepts will be covered like introduction to soil erosion, causes of soil erosion, factors affecting soil erosion, types of soil erosion by water, effects of soil erosion by water, techniques for control of water erosion, soil erosion by wind, control of soil erosion by wind, effect of soil erosion, soil erosion by sun, soil conservation. Now introduction to soil erosion. Soil erosion is the removal of topsoil by natural agents like sun, water, wind etc. which is called natural or geological erosion and by man which is termed as artificial erosion. The natural erosion is a very slow process. Soil erosion that is the removal of soil by water and wind is the most common and extensive.

This erosion, also known as natural or geographical erosion, ranges from very little in undisturbed lands to extensive in steep arid lands. Natural or geological erosion takes place as a result of the action of water, wind, gravity and glaciers. This type of erosion takes place at such a slow rate that the loss of soil is compensated by the formation of new soil under natural weathering conditions. Artificial or accelerated erosion is caused by the human activities such as cutting forests, termed as deforestation, cultivating lands, constructing roads, building dams, etc. This type of erosion is increasing with increasing population.

In accelerated erosion, the removal of soil takes place at a much faster rate than that of the soil formation. Erosion extensively takes place in poorly aggregated soils containing low humus content and a high percentage of silt and very fine sand. The process of soil

erosion increases when the soil remains bare or without vegetation. Now, the causes of soil erosion. The main causes of soil erosion are unprotected topsoil which can be washed by the rain into streams, then into the rivers and finally into the sea.

It can be carried out by dust, storms to other places. The farmers loosen the topsoil for removing weeds and preparing seed beds and then leave it for a long time. The topsoil is therefore exposed to the action of wind which may cause erosion. Overgrazing by cattle causes removal of vegetation and hence exposes the soil to erosion. Forest fire destroy forests and expose the topsoil.

Man causes soil erosion in his venture of expansion of urban areas when he removes vegetation from a vast area for building roads, buildings, dams, bridges, etc and exposes the naked soil to wind and water, the two main agencies of soil erosion. The most important and chief agents of soil erosion are generally water and wind. Causes of soil erosion by water, Soil erosion by water starts when raindrops strike bare soil beds, resulting in the finer particles moving with the flowing water as suspended sediments. The soil along with water moves downhill, scouring channels along the way. Each subsequent rain erodes further amount of soil until erosion transforms the area into barren soil.

Water erosion is due to the dispersive action and transporting power of water as it descends in the rain and leaves the land in the form of runoff. Water erosion is also caused by the people who remove protective plant covers by tillage operation, burning crop residues, overgrazing, overcutting forests, etc., inducing loss of soil. Rainwater absorbs a significant amount of CO_2 to form H_2CO_3 . While passing through air, H_2CO_3 can dissolve hard rocks such as those of limestone rocks forming underground caves. Action of frost in soil erosion is important in cold countries.

When rain falls, part of it gets sink into the ground and fills up the cracks in the rocks. At night when it becomes very cold, water present in the cracks changes into ice and undergoes expansion. The expanded water makes the cracks in the rocks to widen. This process continues for many days and even for months till the cracks become very large and a day will come when the rock will break up into pieces. The blocks and stones thus formed by the action of frost are angular and sharpest.

Sea is a powerful agent in wearing away the land. During a storm, when each wave containing small stones and sand hurls a great mass of water against the shore and washes away the soft parts. Sea cuts the soft rocks rapidly while the harder parts are left as

headlands, capes and islands. Gradually the hard rocks are broken into pebbles and then into the sand. Now factors affecting soil erosion. The major climatic factors which influence runoff as well as erosion are rainfall, temperature and wind.

Wind also influences the angle and impact of raindrops. The amount, intensity, frequency and duration of rainfall have definite effects on the amount and rate of runoff. Heavy rainfall may cause heavy erosion if the intensity of rainfall is high. Frequent rains maintains a high moisture content of the soil and a low intake capacity and this increases runoff and erosion. The intensity and length of slopes are the most important components of topography that affect the soil erosion.

Sloping lands experience increasingly greater problems of soil erosion. Rate of runoff water increases as the land slope increases. For example, if the land slope is increased four times, the rate of water flowing over it approximately doubles and erosion and cutting capacity is increased approximately by four times. A good vegetation cover like thick growth or a dense forest may nullify the effects of climate, topography and soil on erosion. The vegetation increases soil aeration which provides a better environment for the activity of beneficial bacteria.

A compact soil is responsible for low infiltration and high runoff. A coarse sandy soil has a very high rate of water infiltration and permits very little runoff. A fine textured clay and clay loam soils containing high amount of micropores result in low rate of infiltration and hence accelerate soil erosion through surface runoff. The factors affecting soil erosion are rainfall, slope of the land, vegetation, tillage, nature of soil, and organic matter. Now rainfall.

Precipitation is the most forceful factor causing soil erosion. Raindrop impact exerts three important influences. First, it detaches soil. Second, its beating tends to destroy granulation. Third, its splash under certain conditions affects an appreciable transformation of soil.

Soil granules are loosened, detached and separated into fine particles by the action of dashing and heavy rain. Dispersed soil particles are removed by runoff that causes erosion. The erosion depends on amount, duration, intensity and frequency of the rainfall. The chances of erosion are greater where rainfall is not only heavy but concentrated in short areas rather than light showers distributed over a long area. You can see in the figure also about rainfall, then detachment, then transportation, then translocation, and then deposition.

In latter cases, there is a time available for rainwater to infiltrate in the soil. In former case, infiltration is less and runoff is high, which is responsible for the removal of soil. Second factor is the slope of the land. Slope accelerates soil erosion because it increases the rate of moving water. The amount of soil erosion depends on steepness, length and the shape of the slope.

Steepness of the slope is most influential and in general the greater the slope the greater the amount of erosion. Third is the vegetation. The type of vegetative cover and its condition help in controlling water erosion. Vegetative cover protects the soil from the beating and dispersive action of the raindrops by forming a canopy over the soil surface. Vegetation provides a mechanical obstruction to flowing water as well as the soil carrying capacity of flowing water.

The roots help in building better structures that is sphere like structures which increase rainfall infiltration and reduce surface runoff. Roots also help in opening the soil and consequently aid in increasing water absorption in reducing surface runoff. Vegetation increases the storage capacity of the soil for rainfall by the transpiration of large amounts of moisture from the soil. Next is the tillage. The infiltration as well as permeability of the soil are improved by the practice of proper tillage and thereby reduces erosion.

Soil erosion by running water is possible only when there is excess water over the surface for the free runoff. High infiltration and permeability result in rapid water absorption by the soil and hence little runoff. Then the next factor is the nature of the soil. Soil erosion depends on the nature of the soil, particularly on its texture, structure, organic matter, amount, and kinds of salt present, presence of hard pan in the soil and subsoil, and presence of high water table. In sandy and other coarse-textured soils, high infiltration and permeability result in rapid water absorption, and hence in, little erosion.

Permeability in heavy soil is much low as compared to light soils, and hence more erosion. In fine textured soil such as in clay loams, the structure is an important factor in determining soil erodibility. A soil with a granular structure in which the fine particles are arranged in clusters or aggregates absorbs water readily and so it is resistant to erosion. Next factor is the organic matter. It helps in the formation of better and more stable aggregates and keeps the permeability of the soil high.

When the organic matter decreases as a result of growing cultivated crops, soil erosion increases. The presence of a high water table checks the infiltration and permeability and thereby resulting in more flow of water on the surface. Now types of soil erosion by

water. There are seven types of soil erosion by water. Raindrop splash erosion, sheet erosion, rill erosion, gully erosion, stream erosion, stream channel erosion, slip erosion and seashore erosion.

Raindrop splash erosion, the first type, it is caused from soil splash brought about by the impact of falling raindrops. There are four important factors that determine the rate of raindrop erosion. The first is the climate, mostly rainfall and erosion. Second is the soil, its rate, inherent resistance to dispersion and its rate of infiltration. Third, topography, particularly steepness and length of slope and fourth is the vegetative cover.

Second is the sheet erosion, the removal of a fairly uniform layer of surface soil by the action of rainfall and runoff water. The movement of soil by splash erosion is primarily caused by sheet erosion. Sheet erosion is common on land having a gentle or mild slope. It results in the uniform skimming off the cream of the topsoil with every hard rain. In this erosion, shallow soils suffer greater reduction in productivity than deep soils.

Now, rill erosion. This type of erosion is the removal of surface soil by running water with the formation of narrow shallow channels that can be levelled or smoothed out completely by normal cultivation. Rill erosion is more apparent than sheet erosion. Rills develop when there is the concentration of runoff water and if neglected, they grow into larger gullies. Rill erosion is more serious in soils having a loose shallow topsoil.

It is a transition stage between sheet and gully erosion. Gully erosion, it is the removal of soil by running water, with the formation of channels that can be smoothed out completely by normal agricultural operation or cultivation. Gully erosion is an advanced stage of rill erosion. Unattended rills get deepened and widened every year and begin to attain the form of gullies increasing their width, depth and length. Stream channel erosion.

This type of erosion is the scouring of material from the water channel and the cutting of banks by flowing or running water. This type of erosion occurs at the lower end of the stream tributaries and to streams that have almost continuous flow and relatively flat gradients. Scouring is influenced by the velocity and direction of flow, depth and width of the channel and soil texture. Slip erosion, landslide causes slip erosion and big masses of soil and rock bodies slip down damaging the field. The effects of slip erosion are localised.

And then the seashore erosion. This erosion is caused by the shrinking action of strong waves. Now, effects of soil erosion by water. Water erosion causes various damages to

the land. Some of the adverse effects of the soil erosion by water are, first is the loss of top fertile soil.

The surface soil lost as runoff consists of fertile soils and fresh or active organic matter. The eroded soil deposited in a river bed or reservoir is not only unavailable for agriculture purposes, but it is harmful too. Silting of lakes and reservoirs, soil erosion from the catchment areas of reservoirs results in the deposition of soil. This reduces their storage capacity and minimizes their useful life. Silting of drainage and water channels, deposition of silt in drainage ditches in natural streams and rivers reduces their depth and capacity to handle runoff and at the same time the demand on these outlets increases. Consequently, overflows and flooding of downstream areas increase and this causes damage to agricultural crops and disaster to man-made structure.

You can see in the figure of the silting of the dam also. Now next is the decrease in water table. The amount of water available for entering the soil decreases because of the increase in runoff. This reduces the supply of water to replenish the groundwater in wells. This results in reducing the water table and decrease in the yield of the well.

Next is the accumulation of sand and other of unproductive coarse soil materials on other productive lands. In the plains, the fertile lands have been made unproductive because of the deposition or accumulation of coarser soil material brought down from the hills by streams and rivers. Fragmentation of land, Water erosion, especially the gully erosion, may divide lands into several valleys and ridges. As a result, fields become smaller as well as numerous. Consequently, crop rows are shortened movement of one field to another obstructed and land value get decreased.

Now techniques for control of water erosion. The main objectives in controlling soil surface runoff erosion by water are to reduce surface runoff, to put mechanical obstruction in the way of flowing water, to reduce dispersion of soil particles. Soil erosion caused by water can be reduced by reducing either soil detachment or soil sediment transport or both. Controlling Soil Detachment, Soil detachment can be controlled by cropping and other vegetative cover practices which are capable of covering the soil as much as possible. As raindrop falls on the vegetation then water gently slides off to be absorbed in the soil. Stubble mulches help to control soil erosion through the prevention of direct fall of raindrop on the surface.

Using deep or subsurface tillage leave much of the crop residue standing on the surface of the soil. This is called stubble mulch farming which is very effective in controlling soil

erosion. Now controlling soil sediment transport. It is hindered slowly by slowing the rate of eroding water, decreasing the steepness of the slope and by erecting barriers like brushes, dams, terraces, control cultivation and contour strip cropping. Terracing is used for intensively used eroding cropland.

There are two methods for the control or management of land eroded by water, biological methods and mechanical methods. Biological methods are subdivided into agronomical methods and agrostological methods. Agronomical methods. Growing cover crops. Sod-like crops such as grass, berseem, groundnut, etc. offer excellent soil protection against erosion by water. These crops are effective because they provide a cushion against the raindrops. The denser the vegetation the more effective is the cushioning effect.

Close growing crops are also helpful in controlling erosion by providing root channels through which water moves downwards more freely. Besides, plant root also help in making a suitable as well as desirable soil structure. Vegetation also encourages the growth of earthworms and other desirable forms of life. These in turn help to keep the soil open and receptive to raindrops. Strip cropping, these type of cropping consists in growing erosion permitting crops such as jawar, maize, bajra etc. in alternate strips with erosion checking close growing crops such as grasses pulses etc. The erosion checking strips check and arrest the flowing water and soil. Contour strip cropping is the growing of erosion permitting and erosion resisting crops alternately in strips across the slope and on the contour.

Next is the crop rotation. Growing two or more different crops in sequence in a field for maintaining the soil fertility. Continuous growing of clean cultivated crops such as tobacco causes more erosion. A good rotation should include densely planted small grams, spreading legume which may check the soil erosion. Mulching, Mulching of different kinds minimize evaporation and increase absorption of moisture.

Stubble mulching is based on stirring the soil with the implements which leave considerable part of vegetative material i.e. crop residue of vegetative litter on the hand as a surface protection against erosion. This also conserves moisture and favours infiltration and reduces evaporation. Agrostological methods. Dense canopy and profuse root system of grasses tightly bind the soil against erosion. Grasses increase water infiltration and improves physical condition of soil.

Grasses are grown on land which are otherwise not suitable for cultivation. Mechanical methods. It construed various engineering techniques and structures. These practices

reduce runoff velocity, impound water for a longer time and provide more absorption opportunities. Water erosion is generally checked by mechanical practices such as contoured tillage on hilly lands and slopes all tillage operation and the sowing of crop should be done at right angles to the slope of the land.

On long slopes, the field may be laid out in narrow across the slope. In contour tillage, each furrow which lies intercepts the flowing water and holds it. As a result, the water is soaked in the soil. Contour bunding, the slope of the land is broken up into smaller, more level compartments by constructing earthen embankments of suitable size on contours. Each bund holds the rainwater within each compartment.

Farmers in the plains could raise level bunds around their fields for holding the rainwater and conserving the soil. Third is terracing. On steeper slopes, terraces or flat platforms are constructed in steps like series across the slope. Outlet channel. For the safe removal of excess runoff water, it is necessary to provide suitable outlet structure at proper places in order to avoid harmful effects of water logging, eroding, gullying or damage to other conservation structure.

Grass waterways and diversion ditches are some of the important arrangements. Basin listing, scoping out small basins at regular intervals on slopes, checks runoff. Pan breaking and subsoiling. Pan breaking and subsoiling permit infiltration and percolation. This increases the water shortage capacity of the soil and thus decreases runoff as well as erosion.

Now soil erosion by wind. Wind causes soil erosion in two ways. Strong wind blows loose and coarse soil particles and dust for long distances. In some countries, all the soil is blown by this way and so no cultivation is possible in such areas. In dry countries and seashores, strong wind is seen to eat up a cliff or a hard rock.

When strong wind armed with millions of sharp particles of sand blows against a cliff or a hard rock, it gradually eats it up. The action is strongest near the ground so that the rock is undercut and eventually falls over. Soil erosion by wind has caused an accumulation of eroded particles in loess, a type of soil which makes up some of the world's most fertile and productive regions. Soil conditions conducive to wind erosion are most commonly found in arid and semi-arid regions where rainfall is not sufficient and there is no vegetative cover on land. Changes in soil texture is the most serious damage caused by the soil erosion by wind.

Because the finer soil particles are moved away by the wind, wind erosion gradually removes silt, clay and organic matter from the topsoil leaving the coarser soil material. The loss of soil by wind movement involves two processes i.e. detachment and transportation. The abrasive action of wind causes some detachment of tiny soil grains from the granules of which they are apart. When the wind is laden with soil particles, its abrasive action is greatly increased.

The impact of these rapidly moving grain dislodged other particles from soil granules or soil clods as well as form aggregates. The transportation of the particles once they are dislodged takes place in three ways, saltation, suspension and soil creep. Saltation it is a process of soil movement in a series of bounces or jumps. Soil particles of medium size that is zero point zero five to zero point five mm generally move in this process. Saltation movement is caused by the pressure of the wind on the soil particle and collision of a particle with other particles.

The height of the jumps depends on various factors like size and density of soil particles, roughness of the surface of the soil and velocity of wind. Suspension, it is the floating of small size particles less than zero point zero one mm in the air stream. The movement of such fine particles in suspension is usually started by the impact of particles in saltation. Once these fine particles are picked up by the particles in saltation and enter the turbulent air layers, they can be lifted upward in the air by eddy currents and are carried over very long distances before being redeposited elsewhere. Final suspended particles move parallel to the ground surface and upward.

Dust particles will fall on the surface only when the wind subsidies or the rain washes them down. Soil creep, it is the rolling or sliding of the large soil particles along the ground surface. The soil creep is also encouraged by saltation. They are too heavy to be lifted by wind and are moved primarily by the impact of particles in saltation rather than direct impact of the wind. The bouncing particles carried by saltation strike the large aggregates and speed up their movement along the surface.

The coarse particles tend to move closer to the ground than the finer ones. Wind erodes the soil in three steps. Initiation of movement, transport in the air or along the surface and deposition of the soil in a new site. Each step is influenced by the condition of air, ground surface and the soil. After such movement started, the soil particles are carried by the wind by saltation, suspension and soil creep.

The minimum wind velocity needed to initiate the movement of soil particles is called threshold velocity. Control of soil erosion by wind. Conservation of moisture. If soil is kept moist, there is little danger of its erosion by wind. This can be done by ploughing of the lands during rains, levelling, bunding and terracing of the land and water harvesting practices.

By vegetative cover, a vegetative cover prevents soil blowing to a great extent by providing a mechanical obstruction to erosive winds by reducing their velocity and soil carrying capacity. The roots also help in binding the soil particles together. Next is the mulching stubble. Mulch has proved to be very effective in controlling the wind erosion. Rough surface, wind is more effective on smooth surface than on rough surface.

Surface roughness reduces wind velocity liable to lead heavy wind erosion. Opening ridges and furrows at right angles to the prevailing wind is desirable to a certain extent. Organic matter, the stability of the soil structure is maintained and even increased by the presence of organic matter. The latter improves water holding capacity of the soil and also the fertility of the soil. Using green manure crops is desirable for this purpose.

Crop residues should also be left on the soil in spite of using them as a fuel. Regular grazing, overgrazing is most important factor responsible for soil erosion by winds. There should therefore be grazing regulations to restrict the use of grazing lands. Strip cropping. This practice is effective in controlling soil erosion by wind.

Wind strip cropping is essentially suitable for the land which is susceptible to wind erosion. Windbreak and shelterbelt. Trees and shrubs commonly planted in rows at right angles to the prevailing winds are called shelterbelts. A shelterbelt for controlling wind erosion may be made by planting three rows of trees and shrubs. The control row must contain long trees that is babul, shisham, eucalyptus, neem etc. and two outside rows should contain smaller dense shrubs.

Now soil erosion by sun. In hot countries the surface of the rocks become very hot during day because of intense heat and sun. The rocks of earth crust consist of different minerals which expand at different rates because of heat and sun. One mineral expanding more quickly than other causes the rock to burst. This gives rise to cracks in rocks.

During night the rocks get very cold and thus contract. This process is repeated day after day so the cracks increases in size and gradually the rock breaks up into small pieces. The

action of sun is called insolation and is important in hot dry countries. Soil conservation. Conservation of water and conservation of soil are closely related.

Water is lost from the soil in surface runoff, percolation, transpiration, evaporation. Out of these sources by which the water is lost, surface runoff is usually the largest and most damaging as it causes soil erosion. The main factors in conserving moisture and storage capacity of soil and reducing runoff and evaporation. Untamed water is the main cause of soil erosion. Conservation of soil is a problem of national concern because it affects the equally rural as well as urban population.

The goal of soil conservation is to increase the productivity of the soil. There are two types of techniques which are used in conserving the soil. Techniques which restore the fertility lost in growing crops and techniques which prevent soil erosion. The fertility of soil can be maintained by making use of the following two important practices. Rotation of crop.

This technique is beneficial because most of the crops use up the essential elements in the soil. Only a few leguminous plants such as peas, beans, pulses etc. replenish the soil with nitrogen. Application of fertilizers this practice provides the elements required to balance for the nourishment of the plant. Now let us summarize the lecture. We have discussed about the soil erosion. It is the process of soil removal by natural forces like wind water or human activities. Then we have discussed the types of soil erosion by water water erosion, includes splash erosion, sheet erosion, rill erosion, gully erosion each progressively causing more severe land degradation. Thirdly, we have discussed about the techniques for control of water erosion. Controlling water erosion involves methods like contour ploughing, terracing, afforestation, mulching and building check dams to slow water runoff.

Then soil erosion by wind. Wind erosion occurs in dry, sandy or loose soils where strong winds blow away topsoil reducing soil fertility and causing dust storms. Control of soil erosion by wind. Wind erosion can be controlled using windbreaks, cover crops, conservation tillage and maintaining soil moisture through proper irrigation. Then soil erosion by sun.

Extreme heat and prolonged exposure to the sun can dry out and weaken soil structure, making it more prone to erosion by wind and water. And soil conservation. Soil conservation practices include crop rotation, contour farming, agroforestry, and soil cover management to protect soil from erosion and degradation. Thank you very much to all.