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Soil Erosion and its Types

Introduction

Soil erosion is the process by which soil is removed from the Earth's surface by exogenetic processes such as wind or water flow, and then transported and deposited in other locations. In general, soil erosion implies the physical removal of topsoil by various agents, including rain, water flowing over and through the soil profile, wind, glaciers or gravitational pull. Land and water are the most precious natural resources that support and sustain the anthropogenic activities. In India particularly, about 65% of the population depend on agriculture, the only sector which generates half of the employment and maintain ecological balance.

Soil erosion in India is amongst the leading areas of concern as it affects cultivation and farming in the country in adverse and unfavourable ways. Soil erosion leads to deprivation of physical characteristics of soils and damages plant and crops. In India almost 130 million hectares of land, i.e., 45 % of total geographical surface area, is affected by serious soil erosion through gorge and gully, shifting cultivation, cultivated wastelands, sandy areas, deserts and water logging. Soil erosion by rain and transportation of soil particles through rivulets that takes place in hilly areas causes severe landslides and floods. The anthropogenic activities including cutting trees for agricultural implements, firewood and timber; grazing by a large number of livestock over and above the carrying capacity of grass lands, traditional agricultural practices, construction of roads, indiscriminate quarrying and other activities, have all led to the opening of top surfaces to extreme soil erosion. In Indian condition, the control of soil erosion is a challenging task in the sense that the onset of monsoon often

coincides with the kharif sowing and transplanting. In this stage of kharif crop when canopy cover is minimal, major part of the land is exposed to the rainfall let the land prone to soil erosion. It is prudent to check soil erosion from agricultural lands since it affects majority of people.

Principles of Soil Erosion

Causes of Soil Erosion

No single unique cause can be held responsible for soil erosion or assumed as the main cause for this problem. There are many underlying factors responsible for this process, some induced by nature and others by human being. The main causes of soil erosion can be enumerated as:

Destruction of Natural Protective Cover by

- Indiscriminate cutting of trees,
- Overgrazing of the vegetative cover and
- Forest fires.

Improper Use of the Land

- Keeping the land barren subjecting it to the action of rain and wind,
- Growing of crops that accelerate soil erosion,
- Removal of organic matter and plant nutrients by injudicious cropping patterns,
- Cultivation along the land slope, and
- Faulty methods of irrigation.

Types of Soil Erosion:

According to Origin: Soil erosion can broadly be categorized into two types i.e. geologic erosion and accelerated erosion.

Geological Erosion: Under natural undisturbed conditions an equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative covers like trees and forests retard the transportation of soil material and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover. This erosion, called geologic erosion, is a slow process and is compensated by the formation of soil under the natural weathering process. Its effect are not of much consequence so far as agricultural lands are concerned.

Accelerated Erosion: When land is put under cultivation, the natural balance existing between the soil, its vegetation cover and climate is disturbed. Under such condition, the removal of surface soil due to natural agencies takes places at faster rate than it can be built by the soil formation process. Erosion occurring under these condition is referred to as accelerated erosion. Its rates are higher than geological erosion. Accelerated erosion depletes soil fertility in agricultural land.

According to Erosion Agents: Soil erosion is broadly categorized into different types depending on the agent which triggers the erosion activity. Mentioned below are the four main types of soil erosion.

(1) Water Erosion: Water erosion is seen in many parts of the world. In fact, running water is the most common agent of soil erosion. This includes rivers which erode the river basin, rainwater which erodes various landforms, and the sea waves which erode the coastal areas. Water erodes and transports soil particles from higher altitude and deposits them in low lying areas. Water erosion may further be classified, based on different actions of water responsible for erosion, as : (i) raindrop erosion, (ii) sheet erosion, (iii) rill erosion, (iv) gully erosion, (v) stream bank erosion, and (vi) slip erosion.

(2) Wind Erosion: Wind erosion is most often witnessed in dry areas wherein strong winds brush against various landforms, cutting through them and loosening the soil particles, which are lifted and transported towards the direction in which the wind blows. The best example of wind erosion are sand dunes and mushroom rocks structures, typically found in deserts.

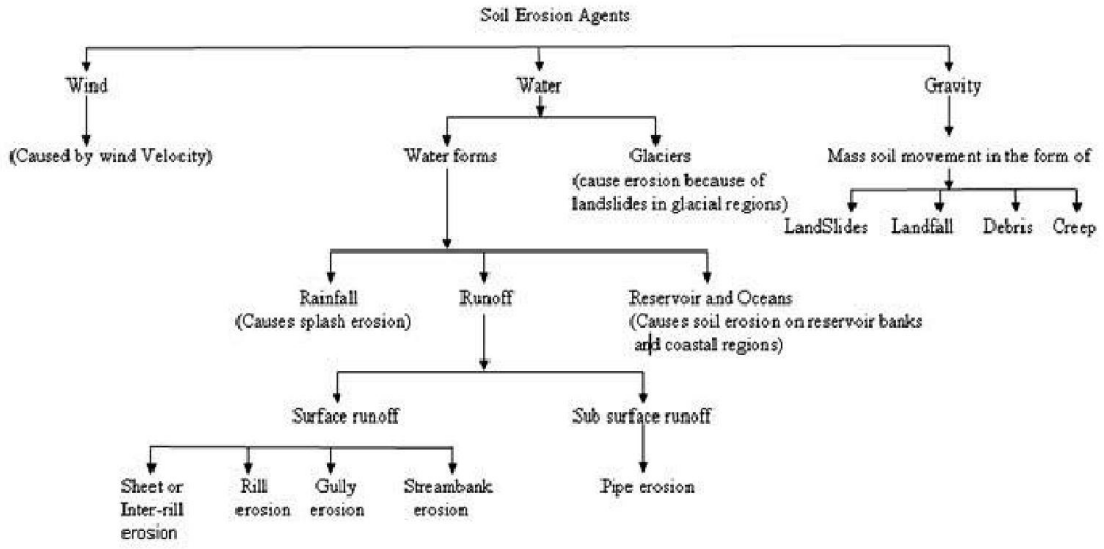
(3) Glacial Erosion: Glacial erosion, also referred to as ice erosion, is common in cold regions at high altitudes. When soil comes in contact with large moving glaciers, it sticks to the base of these glaciers. This is eventually transported with the glaciers, and as they start melting it is deposited in the course of the moving chunks of ice.

(4) Gravitational Erosion: Although gravitational erosion is not as common a phenomenon as water erosion, it can cause huge damage to natural, as well as man-made structures. It is basically the mass movement of soil due to gravitational force. The best examples of this are

Agents of Soil Erosion

Soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion. Water in the form of rain, flood and runoff badly affects the soil. Soil is in fact a composite of sand, silt and clay. When the rain falls along the mountains and bare soil, the water detaches the soil particles, and takes away the silt and clay particles along with the flowing water. Similarly, when wind blows in the form of storms, its speed becomes too high to lift off the entire soil upper layer and causes soil erosion.

Other factors responsible for soil erosion are human and animal activities. Vegetation is the natural cover of soil. When the animals continuously graze in the pastures, the vegetation is removed due to their walking and grazing. Bare lands left behind are easily affected by soil erosion. Activities of human like forest cutting, increased agriculture, and clearing of land for different purposes are the other agents that cause erosion of the soil. The soil erosion agent can be classified and summarized as shown in Fig.



Broadly, soil erosion can be divided into three categories depending on the eroding agents namely water erosion, wind erosion and chemical or geological erosion. Soil erosion due to the agents like water and wind is mostly prevalent and tangible. The erosion caused through chemical and geological agents is a slow process and continues to years and often it is non-tangible. Water erosion is further subdivided into classes depending on the effect of water

erosion. These include sheet erosion, rill erosion, gully erosion, land slide or slip erosion and stream bank erosion.

Geologic Erosion

Geologic erosion sometimes referred to as natural or normal erosion; represent erosion under the cover of vegetation. It includes soil as well as soil eroding processes that maintain the soil in favourable balance, suitable for the growth of most plants. The rate of erosion is so slow that the loss of soil is compensated by the formation of new soil under natural weathering processes. The various topographical features such as existing of streams, valleys, etc. are the results of geologic erosion.

Wind Erosion

Wind erosion is the detachment, transportation and redeposition of soil particles by wind. A sparse or absent vegetative cover, a loose, dry and smooth soil surface, large fields and strong winds all increase the risk of wind erosion. Air movement must attain a certain velocity (with enough speed to generate visible movement of particles at the soil level) before it can generate deflation and transport of particles. Winds with velocities of less than 12-19 km/hr seldom impart sufficient energy at the soil surface to dislodge and put into motion sand-sized particles. Drifting of highly erosive soil usually starts when the wind attains a forward velocity of 25-30 km/hr. Wind erosion tends to occur mostly in low rainfall areas when soil moisture content is at wilting point or below, but all drought-stricken soils are at risk. Often the only evidence of wind erosion is an atmospheric haze of dust comprising fine mineral and organic soil particles that contain most of the soil nutrients. Actions to minimize wind erosion include improving soil structure so wind cannot lift the heavier soil aggregates; retaining vegetative cover to reduce wind speed at the ground surface; and planting windbreaks to reduce wind speed. Also, be ready for severe wind erosion seasons which tend to be the summers following dry autumns and winters. The most familiar result of wind erosion is the loss of topsoil and nutrients, which reduces the soil's ability to produce crops. Topsoil loss can be seen as rocky or gravelly knolls, thin soils mixed with lighter coloured subsoil, or the presence of calcium carbonate in surface soils.

Soil productivity is affected by wind erosion in various ways. Areas of erosion and deposition within a field increase the variation in soil characteristics, requiring more costly and less efficient soil management practices. Wind removes the smaller clay particles and organic matter from the soil while coarser materials are left behind. The continued loss of fine particles reduces soil quality. In shallow soils and soils with a hardpan layer, wind erosion also results in decreased root zone depth and water-holding capacity. Such changes may occur slowly and go unnoticed for many years especially if mixing by tillage masks the effects of wind erosion.

Process of Wind Erosion

The process of wind erosion comprises of three basic stages namely saltation, suspension and surface creep. Fig. 2

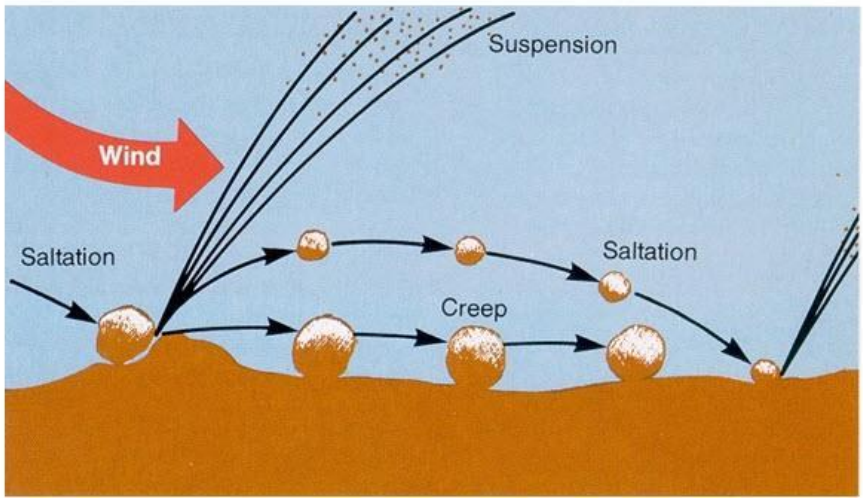


Fig.2 Process of wind erosion

- **Saltation**: Saltation occurs when the wind lifts larger particles off the ground for short distances, leading to sand drifts. Fine and medium sand-sized particles are lifted a short distance into the air, dislodging more soil as they fall back to the ground.
- **Suspension**: Suspension occurs when the wind lifts finer particles into the air leading to dust storms. Very fine soil particles are lifted from the surface by the impact of saltation and carried high into the air, remaining suspended in air for long distances.
- **Surface Creep**: The movement of large soil particles along the surface of the soil after being loosened by the impact of saltating particles.

✓ **Extent of Wind Erosion**

Several factors, other than the wind velocity itself, contribute to wind erosion. These fall into two main groups of closely interrelated elements: those inherent in the properties of the soil per se and those associated with soil cover. A rough soil structure, especially at the surface, effectively reduces the movement of soil particles. Arid regions, however, are dominated by smooth, pulverized and structure less top soils. Soil texture also influences soil erodibility; soils of fine texture are, for example, particularly susceptible to wind erosion.

Measurements of dust in the air up to three metres above the soil surface at Jodhpur, India, showed that on a stormy day the amount of dust blowing varied between 50 and 420 kg/ha. In the Jaisalmer region of India, where wind speeds generally are higher, average soil loss of 511 kg/ha was recorded.

Water Erosion

The soil erosion caused by water as an agent is called water erosion. In water erosion, the water acts as an agent to dislodge and transport the eroded soil particle from one location to another.

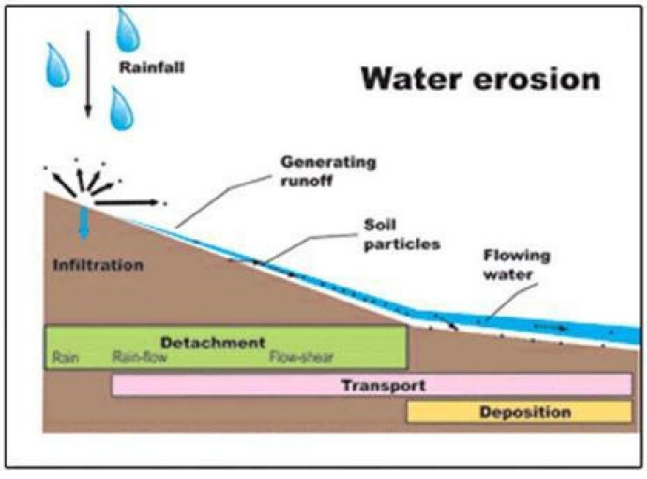


Fig. 4 Process of water erosion

- **Extent of Water Erosion**

The extent of water erosion in Indian subcontinent are presented in Table 1.2. In India, 32.8 Mha area in India is affected by water erosion which accounts for 18% of the land. However, the water erosion extent estimated by different sources varies from 87 to 111 Mha in India.

Table 6 Extent of erosion in India unit- (1000 ha)

S. No.	Name of the States	Water Erosion	Wind Erosion
1	Andhra Pradesh	11518	0
2	Arunachal Pradesh	2372	0
3	Assam	688	0
4	Bihar+ Jharkhand	3024	0
5	Goa	60	0
6	Gujarat	5207	443
7	Haryana	315	536
8	Himachal Pradesh	2718	0
9	Jammu & Kashmir	5460	1360
10	Karnataka	5810	0
11	Kerala	76	0
12	Madhya Pradesh + Chhattisgarh	17883	0
13	Maharastra	11179	0
14	Manipur	133	0
15	Mizoram	137	0
16	Meghalaya	137	0
17	Nagaland	390	0
18	Orissa	5028	0
19	Punjab	372	282
20	Rajasthan	3137	6650
21	Sikkim	158	0
22	Tamil Nadu	4926	0
23	Tripura	121	0
24	Uttar Pradesh + Uttarakhand	11392	212
25	West Bengal	1197	0
26	Delhi	55	0
27	Union Territories	187	0
	Grand Total	**93680**	**9483**
	Grand Total(Million ha)	**93.68**	**9.48**

Forms of Water Erosion:

The impact of rainfall causes splash erosion. Runoff water causes scraping and transport of soil particles leading to sheet, rill and gully erosion. Water waves cause erosion of bank sides of reservoirs, lakes and oceans. The subsurface runoff causes soil erosion in the form of pipe erosion, which is also called tunnel erosion. The glacial erosion causes heavy landsides. In

India, glacial erosions are mainly confined to Himalayan regions. The various forms of water erosion are given below.

Hydraulic Action: The hydraulic action takes place when water runs over the soil surface compressing the soil, as a result of which the air present in the voids exerts a pressure on the soil particles and this leads to the soil detachment. The pressure exerted by the air voids is called hydraulic pressure. The soil particles so detached from their places, are scoured by the running water. The hydraulic action is more effective when the soil is in loose condition.

Abrasion: Soil particles mixed with the running water create an abrasive power in the water which increases the capacity of flowing water to scour more soil particles. Due to this effect, larger soil particles are eroded by the flowing water.

Attrition: This form includes mechanical breakdown of loads running along the moving water due to collision of particles with each other. The broken particles are moved along with the flow velocity, which generate abrasion effect on the bottom and banks of the water course. This effect pronounces the water erosion.

Solution: This form is associated with the chemical action between running water and soil or country rocks. This type condition is observed in areas where existing rocks or soils are easily dissolved in the running water.

Transportation: The process of soil transportation by running water is completed under the following forms:

Saltation: the water soluble contents present in the water are transported by the water in solution form.

Suspension: it involves the transportation of finer soil particles, which are present in suspension form in the flowing water.

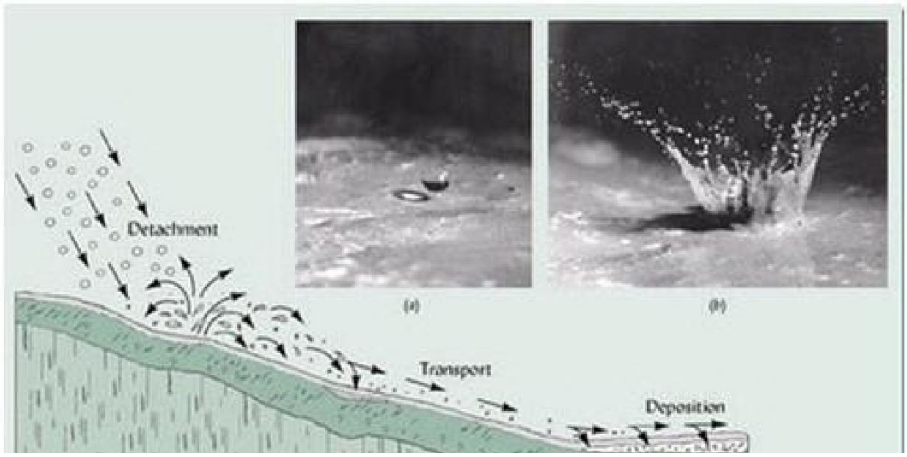
Surface Creep: it involves transportation of medium size soil particles that are not able to stand in suspension form, but are mixed in water and flow over the stream bed in the form of mud. The surface creep action is responsible for transporting the coarser soil particles.

Types of Water Erosion

The different types of water erosion are described in the following section.

- **Splash Erosion**

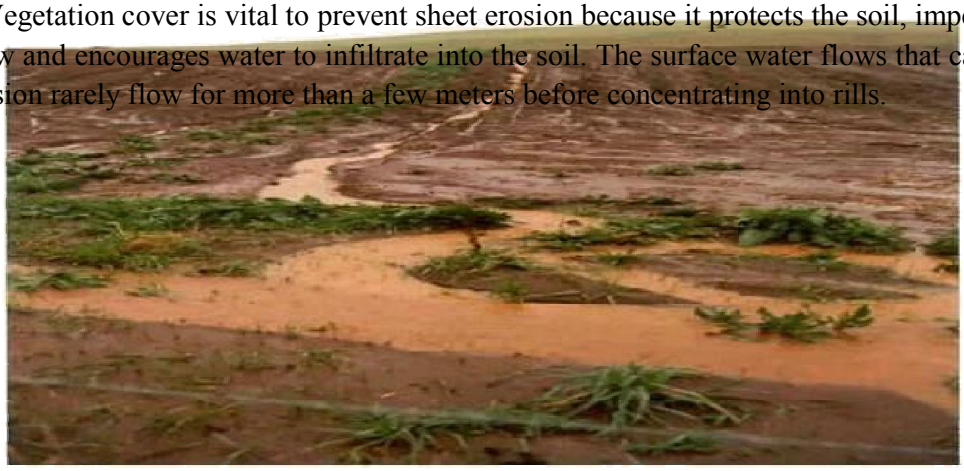
This type of soil erosion is because of the action of raindrop. The kinetic energy of falling raindrop dislodges the soil particle and the resultant runoff transports soil particles. Splash erosion is the first stage of soil erosion by water. It occurs when raindrops hit bare soil. The explosive impact breaks up soil aggregates so that individual soil particles are 'splashed' onto the soil surface. The splashed particles can rise as high 0.60 meter above the ground and move up to 1.5 meter from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms a crust that reduces infiltration and increases runoff.



- **Sheet Erosion**

Sheet erosion is the removal of soil in thin layers by raindrop impact and shallow surface flow. This action called skimming and is prevalent in the agricultural land. It results in loss of the finest soil particles that contain most of the available nutrients and organic matter in the soil. Soil loss is so gradual that the erosion usually goes unnoticed, but the cumulative impact accounts for large soil losses. This type of soil erosion is mainly responsible for loss of soil productivities. Soils most vulnerable to sheet erosion are overgrazed and cultivated soils where there is little vegetation to protect and hold the soil. Early signs of sheet erosion include bare areas, water puddling as soon as rain falls, visible grass roots, exposed tree roots, and exposed subsoil or stony soils. Soil deposits on the high side of obstructions such as fences may indicate active sheet erosion.

Vegetation cover is vital to prevent sheet erosion because it protects the soil, impedes water flow and encourages water to infiltrate into the soil. The surface water flows that cause sheet erosion rarely flow for more than a few meters before concentrating into rills.



- **Rill Erosion**

Rills formation is the intermittent process of transforming to gully erosion. The advance form of the rill is initial stage of gully formation. The rills are shallow drainage lines less than 30cm deep and 50 cm wide. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is common in bare agricultural land, particularly overgrazed land, and in freshly tilled soil where the soil structure has been loosened. The rills can usually be removed with farm machinery. Rill erosion is mostly occurs in alluvial soil and is quite frequent in Chambal river valley in India.

Fig.7. Rill Erosion

- **Gully Erosion**

The advance stage of rills is transformed into initial stage of gully. Gully formation are initiated when the depth and width of the rill is more than 50 cm. Gullies (Fig. 1.6) are deeper channels that cannot be removed by normal cultivation. Hillsides are more prone to gullying when they cleared of vegetation, through deforestation, over-grazing or other means. The eroded soil is easily carried by the flowing water after being dislodged from the ground, normally when rainfall falls during short, intense storms. Depending upon the depth and width, the gullies further divided into 4 classes namely G1, G2, G3 and G4. Gullies reduce the productivity of farmland where they incise into the land, and produce sediment that may clog downstream water bodies. Because of this, much effort are required to invested into the study of gullies within the scope of geomorphology, in the prevention of gully erosion, and in restoration of gullied landscapes. The total soil loss from gully formation and subsequent downstream river sedimentation can be sizable.

Fig. 8 Gully Erosion

Table: Classification of Gully

Particulars	Description of symbols of Gully			
	G1	**G2**	**G3**	**G4**
Depth (m)	Up to 1.0	1.0-3.0	3.0-9.0	>9.0
Width (m)	<18.0	<18.0	18	>18.0
Side slope (%)	<6.0	<6.0	6.0-12.0	>12.0

- **Tunnel Erosion**

Tunnel erosion occurs when surface water moves into and through dispersive sub soils. Dispersive soils are poorly structured so they erode easily when wet. The tunnel starts when surface water moves into the soil along cracks or channels or through rabbit burrows and old tree root cavities. Dispersive clays are the first to be removed by the water flow. As the space enlarges, more water can pour in and further erode the soil. As the tunnel expands, parts of the tunnel roof collapse leading to potholes and gullies. Indications of tunnel erosion include water seepage at the foot of a slope and fine sediment fans downhill of a tunnel outlet. This type of erosion is more frequent in foothills where elevation is between 500-750 meter.

Fig.9. Tunnel Erosion

- **Stream Bank Erosion**

Stream bank erosion occurs where streams begin cutting deeper and wider channels as a consequence of increased peak flows or the removal of local protective vegetation. Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. This is quite prevalent in alluvial river and streams. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

(a) (b)

Fig10. Stream Bank Erosion

- **Coastal erosion**

The waves, geology and geomorphology are the three major factors that affect the coastal erosion. Waves are the cause of coastal erosion. Wave energy is the result the speed of the wind blowing over the surface of the sea, the length of fetch and the wind blowing time. The geology of the coastline also affects the rate of erosion. If the coast is made of a more resistant type of rock (say, granite), the erosion rate will be lower than if the coast is made of a less resistant type of rock (say, boulder clay). The geomorphology (or shape) of the coastline further affects the rate of erosion. Headlands cause wave refraction, making waves converge and combining their energy. Wider, shallower bays, meanwhile, allow waves to diverge, losing energy due to friction with the sea bed. A wider beach cause more wave energy to be lost due to friction before the waves can break. A narrower beach will mean that the breaking point of the waves is closer to the coastline, and less energy will have been lost due to friction before they break. Similarly, shingle and pebbles will allow more water to infiltrate and cause more wave energy to be lost due to friction, while sandy beaches allow less infiltration and cause less friction and so allow for a higher rate of erosion. If the beach gradient is steep, this will encourage steeper, higher-energy waves. Paradoxically, though, because shingle and pebble beaches leave less energy for backwash, material tends to be moved upwards, making the beach steeper. The coastal erosion is a major concern for India

as about 40% of the Indian coasts are subjected to severe erosion that has the potential to change the coast line.

Mechanics of Soil Erosion

Soil erosion is initiated by detachment of soil particles due to action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process. Different soil erosion processes are shown in Fig.

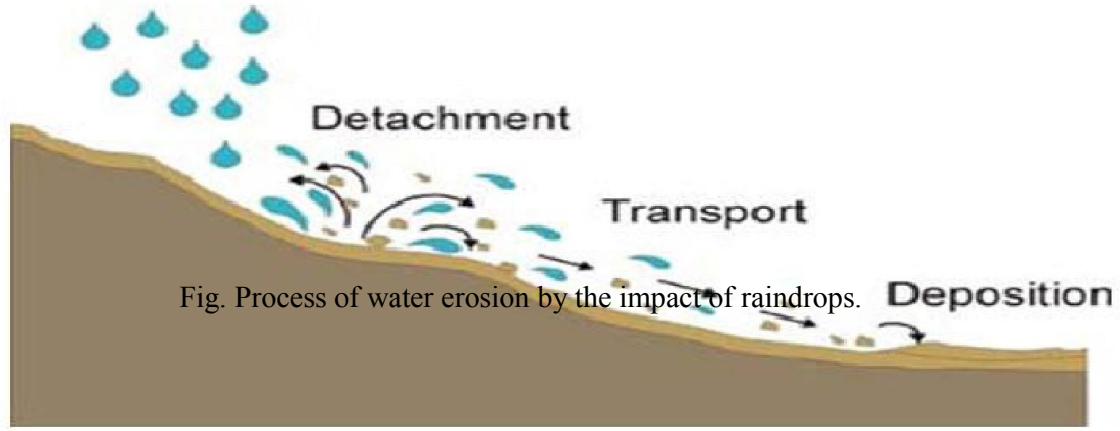


Fig. Process of water erosion by the impact of raindrops.

Mechanics of soil erosion due to water and wind is discussed below.

Mechanics of Water Erosion

There are three steps for accelerated erosion by water:

- ✓ Detachment or loosening of soil particles caused by flowing water, freezing and thawing of the top soil, and/or the impact of falling raindrops,
- ✓ Transportation of soil particles by floating, rolling, dragging, and/or splashing and
- ✓ Deposition of transported particles at some places of lower elevation.

Rain enhances the translocation of soil through the process of splashing as shown in Fig.2.2. Individual raindrops detach soil aggregates and redeposit them as particles. The dispersed particles may then plug soil pores, reducing water intake (infiltration). Once the soil dries, these particles develop into a crust at the soil surface and runoff is further increased.\

Mechanics of Wind Erosion:

Wind erosion occurs where soil is exposed to the dislodging force of wind. The intensity of wind erosion varies with surface roughness, slope and types of cover on the soil surface and wind velocity, duration and angle of incidence. Fine soil particles can be carried to great heights and for (may be) hundreds of kilometers. The overall occurrence of wind erosion could be described in three different phases. These are initiation of movement, transportation and deposition.

Initiation of Movement: The initiation of the movement of soil particles is caused by several factors acting separately in combination. In the course of collision of grains rolling and

bumping on the surface, some particles may be bounced up. It occurs when the wind force or the impact of moving particles is strong enough to dislodge stationary soil particles.

Transportation: The transportation of the particles once they are dislodged take place in three ways:

- ✓ Saltation – In saltation soil particles of medium size (0.10-0.15 mm diameter) are carried by wind in a series of short bounces. These bounces are caused by the direct pressure of the wind on soil particles.
- ✓ Surface Creep – Saltation also encourages surface creep (rolling or sliding) along the surface of the particles (0.5-1.0 mm diameter). The bouncing particles carried by saltation strike the large aggregates and speed up their movement along the surface.
- ✓ Suspension – When the particles of soil are very small (less than 0.1 mm) they are carried over long distances. Finer suspended particles are moved parallel to the ground surface and upward.

Deposition: Deposition of the particles occurs when the gravitational force is greater than the forces holding the particles in air. Deposition could occur when the wind velocity is decreased due to surface obstructions or other natural causes.

❖ Effects of Soil Erosion

The soil erosion adversely affects the livelihood of the people in one way or other. The major losses and problem occurs due to the soil erosion from various agents are listed below.

- Siltation of rivers.
- Siltation of irrigation channels and reservoirs.
- Problems in crop irrigation and consequent need of conserving the water.
- Damage to sea coast and formation of sand dunes.
- Disease and public health hazards.
- Soils eroded by water get deposited on river beds, thus increasing their level and causing floods. These floods sometime have various extreme effects, such as killing human and animals and damaging various buildings.
- Soil erosion decreases the moisture supply by soil to the plants for their growth. It also affects the activity of soil micro-organisms thus deteriorating the crop yield.
- Top layer of soil contains most of the organic matter and nutrients, loss of this soil reducing soil fertility and affecting its structure badly.
- Wind erosion is very selective, carrying the finest particles - particularly organic matter, clay and loam for many kilometres. There the wind erosion causes losses of fertile soils from highly productive farming areas.
- The most spectacular forms are dunes - mounds of more or less sterile sand - which move as the wind takes them, even burying oases and ancient cities.
- Sheets of sand travelling close to the ground (30 to 50 metres) can degrade crops.
- Wind erosion reduces the capacity of the soil to store nutrients and water, thus making the environment drier.

Reference Books		
1.	Soil and water conservation Engineering.	Suresh, R.
2.	Principles of Agricultural Engineering	Ojha, T.P. and A.M.Michae
3.	Agricultural Engineering	Singhal, O.P.