Lecture No. 6 Soil erosion- types of soil erosion and factors affecting soil erosion

6.1 Definition

Soil erosion is the process of detachment of soil particles from the top soil and transportation of the detached soil particles by wind and/or water.

The agents causing erosion are wind and water. The detaching agents are falling raindrop, channel flow and wind. The transporting agents are flowing water, rain splash and wind.

6.2 Nature and extent of erosion

The problem of soil erosion exists all over the country. Out of the 329 m.ha of India’s geographical area about 175 m.ha (53.3%) is subjected to soil erosion and some kind of land degradation (Druvanarayana, 1993). About 150 m.ha is subjected to wind and water erosion. It is estimated that about 5333 Mt of soil is detached annually by soil erosion. Out of this 29% is carried away by rivers to seas and about 10% is deposited in reservoirs resulting in 1-2% of loss of storage capacity annually. The estimated annual soil loss is 16.35 tones/ha/year.

Physiographically India is divided into three regions as follows:

a) Himalayan region: Geologic immaturity made this region more vulnerable to erosion. High degree of seismicity of the area, very steep slopes, weak geological formation and improper land use practices accelerate erosion losses. Gullying, land slides and slips are most common.

b) Gangetic plains: Major problems in the region are riverine erosion, drainage, saline and alkali soil conditions.

c) Peninsular region: Main problems of this region are rill and gully erosion.

Arid regions have severe wind erosion. Semi arid regions are subjected to sheet and gully erosion and ravines are serious problem in Yamuna and Chambal region. Floods and stream bank cutting and sand deposition have degraded lands of north east region with heavy rainfall. South and south east are characterized by undulating terrain with severe erosion in black and red laterite soils.
6.3 Losses due to erosion:

i) Loss of fertile top soil  
ii) Loss of rain water  
iii) Loss of nutrients  
iv) Silting up of reservoirs  
v) Damage to forests  
vi) Reduction in soil depth  
vii) Floods  
viii) Adverse effect on public health  
ix) Loss of fertile land  
x) Economic losses

6.4 Types of erosion:

There are two major types of soil erosion

a) **Geological erosion** (Natural or normal erosion): is said to be in equilibrium with soil forming process. It takes place under natural vegetative cover completely undisturbed by biotic factors. This is very slow process.

b) **Accelerated erosion**: is due to disturbance in natural equilibrium by the activities of man and animals through land mismanagement, destructing of forests over grazing etc., Soil loss through erosion is more than the soil formed due to soil forming process.

Based on the agents causing erosion, erosion is divided into

a. Water erosion  
b. Wind erosion  
c. Wave erosion

6.4.1 Water erosion

Loss of soil from land surface by water including run off from melted snow and ice is usually referred to as water erosion.
Major erosive agents in water erosion are impacting/ falling raindrops and runoff water flowing over soil surface.

6.4.1.1 Process of water erosion

Detachment of soil particles is by either raindrop impact or flowing water. Individual raindrops strike the soil surface at velocities up to 9 m/s creating very intensive hydrodynamic force at the point of impact leading to soil particle detachment. Over land flow detaches soil particles when their erosive hydrodynamic force exceeds the resistance of soil to erosion. Detached soil particles are transported by raindrop splash and runoff. The amount of soil transported by runoff is more than due to raindrop splash. Thus the falling raindrops break the soil aggregates and detach soil particles from each other. The finer particles (silt and clay) block the soil pores and increase the rate of runoff and hence loss of water and soil.

6.4.1.2 Forms of water erosion

Water erosion occurs in stages identified as sheet erosion, rills, gullies, ravines, landslides and stream bank erosion.

a) Sheet erosion: It is the uniform removal of surface soil in thin layers by rainfall and runoff water. The breaking action of raindrop combined with surface flow is the major cause of sheet erosion. It is the first stage of erosion and is least conspicuous, but the most extensive.

b) Rill erosion: When runoff starts, channelisation begins and erosion is no longer uniform. Raindrop impact does not directly detach any particles below flow line in rills but increases the detachment and transportation capacity of the flow. Rill erosion starts when the runoff exceeds 0.3 to 0.7 mm/s. Incisions are formed on the ground due to runoff and erosion is more apparent than sheet erosion. This is the second stage of erosion. Rills are small channels, which can be removed by timely normal tillage operations.

c) Gully erosion: It is the advanced stage of water erosion. Size of the unchecked rills increase due to runoff. Gullies are formed when channelised runoff form vast sloping land is sufficient in volume and velocity to cut deep and wide channels. Gullies are
the spectacular symptoms of erosion. If unchecked in time no scope for arable crop production.

d) **Ravines:** They are the manifestations of a prolonged process of gully erosion. They are typically found in deep alluvial soils. They are deep and wide gullies indicating advanced stage of gully erosion.

e) **Landslides:** Landslides occur in mountain slopes, when the slope exceeds 20% and width is 6m. Generally land slides cause blockage of traffic in ghat roads.

f) **Stream bank erosion:** Small streams, rivulets, torrents (hill streams) are subjected to stream bank erosion due to obstruction of their flow. Vegetation sprouts when streams dry up and obstructs the flow causing cutting of bank or changing of flow course.

### 6.4.1.3 Factors affecting water erosion

a) **Climate:** Water erosion is directly a function of rainfall and runoff. Amount, duration and distribution of rainfall influences runoff and erosion. High intensity rains of longer duration causes severe erosion. Greater the intensity, larger the size of the raindrop. Rainfall intensity more than 5 cm/hr is considered as severe. Total energy of raindrops falling over a hectare land with rainfall intensity of 5 cm/hr is equal to 625 H.P. This energy can lift 89 times the surface 17.5 cm of soil from one ha to a height of 3 ft. Two-thirds of the above energy is used for sealing soil pores. Runoff may occur without erosion but there is no water erosion without runoff. The raindrop thus breaks down soil aggregates, detaches soil particles and leads the rainwater with the fine particles. These fine particles seal the pores of the surface soil and increases runoff causing erosion.

b) **Topography:** The degree, length and curvature of slope determine the amount of runoff and extent of erosion. Water flows slowly over a gentle slope where as at a faster rate over a steeper one. As water flows down the slope, it accelerates under the forces of gravity. When runoff attains a velocity of about 1 m/s it is capable of eroding the soil. If the percent of slope is increased by 4 times the velocity of water flowing down is doubled. Doubling the velocity quadruples the erosive power and increases the quantity of soil that can be transported by about 32 times and size of the particles that can be transported by about 64 times.
c) **Vegetation:** Vegetation intercepts the rainfall and reduces the impact of raindrops. It also decreases the velocity of runoff by obstructing the flow of water. The fibrous roots are also effective in forming stable soil aggregates, which increases infiltration and reduces erosion.

d) **Soil Properties:** Soil properties that influence soil erodability by water may be grouped into two types.

i. Those properties that influence the infiltration rate and permeability

ii. Those properties that resist the dispersion, splashing, abrasion and transporting forces of rainfall and runoff.

The structure, texture, organic matter and moisture content of upper layers determine the extent of erosion. Sandy soils are readily detachable but not readily transportable. Soils of medium to high clay content have low infiltration capacities and they are readily transported by water after they are dispersed, but their detachability is generally low.

e) **Man and beast**

Man and beast accelerates erosion by extensive farming and excessive grazing. Faulty practices like cultivation on steep slopes, cultivation up and down the slope, felling and burning of forests etc., leads to heavy erosion. Excessive grazing destroys all vegetation and increases the erosion.

**6.4.1.4 Estimation of soil loss by water erosion**

Based on the mechanism and factors influencing soil erosion, a universal soil loss equation (USLE) developed by Wischmeier (1959) is most useful for predicting soil loss due to water erosion. It is an empirical equation and estimates average annual soil loss per unit area as a function of major factors affecting sheet and rill erosion. It enables determination of land management erosion rate relationships for a wide range of rainfall, soil slope and crop and management conditions and to select alternative cropping and management combinations that limit erosion rates to acceptable limits.
A = R x K x L x S x C x P

where,
- A = predicted soil loss in t/ha/year
- R = rainfall erosivity factor or index
- K = soil erodibility factor
- L = length of slope factor
- S = slope steepness factor
- C = soil cover and management factor and
- P = erosion control factor

6.5 Wind erosion

Erosion of soil by the action of wind is known as wind erosion. It is a serious problem on lands devoid of vegetation. It is more common in arid and semi arid regions. It is essentially a dry weather phenomenon stimulated by the soil moisture deficiency. The process of wind erosion consists of three phases: initiation of movement, transportation and deposition. About 33 m.ha in India is affected by wind erosion. This includes 23.49 m.ha of desert and about 6.5 m.ha of coastal sands. The Thar Desert is formed mainly by blow in sand.

6.5 Mechanism of wind erosion

Lifting and abrasive action of wind results in detachment of tiny soil particles from the granules or clods. The impact of these rapidly moving particles dislodge other particles from clods and aggregates. These dislodged particles are ready for movement. Movement of soil particles in wind erosion is initiated when the pressure by the wind against the surface soil grains overcomes the force of gravity on the grains. Minimum wind velocity necessary for initiating the movement of most erodable soil particles (about 0.1 mm diameter) is about 16 km/hr at a height of 30.5 cm. Most practical limit under field conditions, where a mixture of sizes of single grained material present is about 21 km/hr at a height of 30.5 cm.

In general movement of soil particles by wind takes place in three stages: saltation, surface creep and suspension.
a. **Saltation:** It is the first stage of movement of soil particles in a short series of bounces or jumps along the ground surface. After being rolled by the wind, soil particles suddenly leap almost vertically to form the initial stage of movement in saltation. The size of soil particles moved by saltation is between 0.1 to 0.5 mm in diameter. This process may account for 50 to 70% of the total movement by wind erosion.

b. **Surface creep:** Rolling and sliding of soil particles along the ground surface due to impact of particles descending and hitting during saltation is called surface creep. Movement of particles by surface creep causes an abrasive action of soil surface leading to break down of non-erodible soil aggregates. Coarse particles longer than 0.5 to 2.0 mm diameter are moved by surface creep. This process may account for 5 to 25% of the total movement.

c. **Suspension:** Movement of fine dust particles smaller than 0.1 mm diameter by floating in the air is known as suspension. Soil particles carried in suspension are deposited when the sedimentation force is greater than the force holding the particles in suspension. This occurs with decrease in wind velocity. Suspension usually may not account for more than 15% of total movement.
Lecture No. 7  Soil conservation measures – agronomic measures of soil conservation

7.1 Definition of soil conservation

Soil conservation is using and managing the land based on the capabilities of the land itself involving application of the best management practices leading to profitable crop production without land degradation.

7.2 Control of water erosion

Water erosion occurs simultaneously in two steps: detachment of soil particles by falling raindrops and transportation of detached particles by flowing water. Hence preventing the detachment of soil particles and their transportation can minimize water erosion. Principles of water erosion control are

- Maintenance of soil infiltration capacity
- Soil protection from rainfall
- Control of surface runoff and
- Safe disposal of surface runoff

For a sound soil conservation programme every piece of land must be used in accordance with the land capability classification.

7.2.1 Measures of water erosion control

1. Agronomic measures

2. Mechanical measures (Engineering measures)

3. Forestry measures

4. Agrostological measures

7.2.2 Agronomic measures of soil conservation

In soil and water conservation programmes agronomic measures have to be considered in co-ordination with others for their effectiveness. These measures are effective in low rainfall areas particularly in fairly erosion resistant soils having gentle slope (< 2 %).

The different agronomic measures include
1. Land preparation
2. Contour cultivation
3. Choice of crops
4. Strip cropping
5. Crop rotation / cropping systems
6. Cover crops
7. Mulching
8. Application of manures and fertilizers
9. Application of chemicals

a) Land preparation: Land preparation including post harvest tillage influence intake of water, obstruction to surface flow and consequently the rate of erosion. Deep ploughing or chiseling has been found effective in reducing erosion. Rough cloddy surface is also effective in reducing erosion.

b) Contour cultivation (Contour farming): A line joining the points of equal elevation is called contour. All the cultural practices such as ploughing, sowing, intercultivation etc. done across the slope reduce soil and water loss. By ploughing and sowing across the slope, each ridge of plough furrow and each row of the crop act as obstruction to the runoff and provide more time for water to enter into the soil leading to reduced soil and water loss (Fig 7.1).

![Fig 7.1 Contour Cultivation](image-url)
c) **Choice of crops**: Row crops or tall growing crops such as sorghum, maize, pearl millet etc., are not effective in conserving soil as they expose majority of the soil and hence they are known as *erosion permitting crops*. Where as close growing crops such as cowpea, groundnut, green gram, black gram etc., which protect soil are known as *erosion resisting crops* as they are very effective in reducing soil loss by minimizing the impact of rain drop and acting as obstruction to runoff.

**d) Strip cropping**: It is a system of growing of few rows of erosion resisting crops and erosion permitting crops in alternate strips on contour (across the slope) with the objective of breaking long slopes to prevent soil loss and runoff. Close growing erosion resisting crops reduce the transporting and eroding power of water by obstructing runoff and filtering sediment from runoff to retain in the field. The width of the erosion permitting and erosion resisting crops vary as per the slope of the field. The strip cropping resembles the intercropping.

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<tr>
<th>Slope (%)</th>
<th>Width of crops (m)</th>
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<tr>
<td></td>
<td>Erosion resisting</td>
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<tr>
<td>Up to 1%</td>
<td>9.0</td>
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<tr>
<td>1 to 2%</td>
<td>6.0</td>
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<td>2 to 3%</td>
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With increase in per cent slope of the soil, the width of erosion permitting and erosion resisting crops decreases. The normal ratio between the erosion resisting crops and erosion permitting crops is 1: 3. Among the different crops the anti-erosion value of pillipesara is highest, where as cotton crop recorded the lowest value. The strip cropping is divided into four types as follows

**i) Contour strip cropping**: The erosion permitting crops and erosion resisting crops are grown in alternate strips along the contours.

**ii) Field strip cropping**: Alternate strips of erosion permitting crops and erosion resisting crops are raised across the general slope not necessarily on exact contour

**iii) Wind strip cropping**: Strip cropping of erosion permitting and erosion resisting crops across the direction of the most prevailing wind irrespective of the contour.
iv) **Buffer strip cropping:** this type of strip cropping is practiced in areas having steep slopes and badly eroded soils where strips of permanent cover crops or perennial legumes or grasses or shrubs are alternated with field crops.

The strip cropping is simple, cheap and effective soil conservation practice and can be adopted by the farmers.

e) **Crop rotation / cropping system:** Monocropping of erosion permitting crops accelerates soil and water loss year after year. Intercropping of erosion permitting crops and erosion resisting crops or their rotation has been found effective for reducing soil and water loss. Inclusion of legumes like lucerne in crop rotation reduces soil loss even in soils having 13% slope.

f) **Cover crops:** Good ground cover by canopy gives the protection to the land like an umbrella and minimize soil erosion. Besides conserving soil and moisture, the cover crops hold those soluble nutrients, which are lost by leaching. The third advantage of the cover crops is the addition of organic matter. The legumes provide better cover and better protection. Among the legumes cowpea has been found to produce maximum canopy followed by horsegram, green gram, black gram and dhaincha.

g) **Mulching:** Mulching of soil with available plant residues reduce soil loss considerably by protecting the soil from direct impact of raindrop and reducing the sediment carried with runoff. A minimum plant residue cover of 30 per cent is necessary to keep runoff and soil loss within the acceptable limits. Vertical mulching also reduce soil loss particularly in vertisols by increasing infiltration.

h) **Application of manures and fertilizers:** Organic manures besides supplying nutrients improve soil physical conditions thereby reduce soil loss. Fertilizers improve vegetative canopy, which aid in erosion control.

i) **Use of chemicals:** Breakdown of aggregates by the falling raindrops is the main cause of detachment of soil particles. Soils with stable aggregates resist breakdown and thus resist erosion. Aggregate stability can be increased by spraying chemicals like poly vinyl alcohol @ 480 kg/ha (rate will depend on the type of soil). Soils treated with bitumen increase water stable aggregates and infiltration capacity of the soil.