UNIT 1  WATER EROSION

Structure

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1.0 OBJECTIVES

After going through this unit, you should be able to:

- explain the causes and processes of erosion;
- classify soil erosion and water erosion;
- explain the sediment transportation processes and its deposition; and
- measure soil loss due to water erosion.
### 1.1 INTRODUCTION

Soil is the top layer of the earth's surface that is capable of sustaining life. Therefore, soil is very important to farmers, who depend on it to harvest abundant and healthy crops each year. One of the major problems in agriculture is the soil erosion. Soil erosion is the deterioration of soil by the physical movement of soil particles away from the original site. Wind, water, ice, animals and the use of tools by human beings are usually the main agents of soil erosion. Around 146.82 million ha land is affected by different kinds of land degradation in India. Out of this, around 64\% (93.68 million ha) is affected by water erosion, i.e. the highest among all categories of eroding as well as degrading agents of the land. If erosion occurs under natural process, it usually does not cause any major problem but it becomes a problem when human activities accelerate it to a rate faster than under normal conditions.

Much of the eroded soil is deposited either in low areas of the fields or it moves off the farm or eventually enters drainage ditches, streams or rivers. Soil that enters a water course reduces water quality, reduces the efficiency of drainage systems and the storage capacity of lakes and reservoirs. Sedimentation in rivers and reservoirs reduces their capacity to store water and is considered to be a major source of pollution. It can inhibit fish spawning and block the sunlight necessary to sustain plant life. The movement of chemical and nutrients flowing from farmers' fields must be checked in order to make the water safe for drinking.

Considering overall issues pertaining to hazards of water erosion causing loss of fertile top soils and its settlement in rivers and reservoirs, mechanisms of soil erosion by water and its consequences are discussed in the unit.

In the next unit, causes and processes of wind erosion are discussed. The factors affecting wind erosion and measurement of soil loss are also dealt with.

### 1.2 CAUSES OF SOIL EROSION

Processes of erosion and its transportation are difficult to understand without knowing the causes of erosion. It is possible to divide the causes of soil erosion into abiotic causes due to inert processes and biotic causes which relate to the activities of living beings. In any given situation, one or both causes may operate, but not necessarily simultaneously. Of the abiotic causes, water and wind are the main agents, while increased human activity dominates the biotic causes resulting into accelerated erosion. The main causes of soil erosion can be enumerated as:

- Indiscriminate cutting down of trees
- Overgrazing of the vegetative cover
- Forest fires
- Keeping the land barren and 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
- Faulty methods of irrigation
1.3 PROCESSES OF SOIL EROSION

When the raindrops strike the soil surface from a great height, they dislodge the fine soil particles from the soil mass. These dislodged soil particles are carried away in suspension with the overland flow. Further, the water flowing with a force over the surface of land dislodges a large number of soil particles of varying size, which slide, roll over the land surface and ultimately get transported to streams, channels, small rivulets and rivers. Erosion process involves three distinct steps as given below:

- loosening and dislodging of soil particles i.e. erosion;
- movement of soil particles by various agencies i.e. transportation; and
- deposition of soil particles i.e. deposition.

This can be described through a flowchart as:

Soil erosion ➔ Transportation ➔ Deposition

Check Your Progress 1

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) Enumerate causes and ill-effects of soil erosion.

2) Explain the processes of soil erosion.

1.4 TYPES OF EROSION

Soil erosion can be broadly categorized into two types, viz. geological erosion and accelerated erosion.

(a) Geological Erosion

Natural or geological soil erosion represents the erosion of soil in its natural state. Under natural undisturbed conditions, equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative cover like trees and forests retards the transportation of soil particles and acts as a barrier against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover conditions. Geological erosion, caused mainly by the action of water, wind and temperature, is responsible for soil formations and their distribution on the earth's surface. Its effects are not of much consequence so far as agricultural lands are concerned.
(b) Accelerated Erosion

When the natural balance between soil forming and depleting processes is disturbed by human activities, large-scale deforestation or conversion of forest land into agriculture, erosion intensity increases manifold. Under such conditions, the removal of surface soil due to natural agencies takes place at a faster rate than it can be built up by soil forming processes. Erosion occurring under these conditions is referred to as accelerated erosion and it occurs at a higher rate than the geological erosion. Accelerated erosion depletes the soil fertility in agricultural lands. The major agencies of erosion are water, wind and tides. On the basis of eroding agency, erosion can be further classified.

1.5 FORMS OF WATER EROSION

Water erosion is the loss of soil due to water movement. It is the major cause of soil loss from high and medium sloping lands. Water erosion occurs when excess rainfall generates runoff to transport the soil away. This may further be classified as:

i) Raindrop erosion
ii) Sheet erosion
iii) Rill erosion
iv) Gully erosion
v) Stream bank erosion
vi) Landslide or landslip erosion
vii) Ravine formation

1.5.1 Raindrop Erosion

The detachment and splash or transport of the soil particles occurring as a result of impact of falling raindrops is called raindrop erosion also known as splash erosion (Fig. 1.1). A considerable amount of soil is eroded by simple process of splashing and it is considered to be the first step in the erosion process.
This process can only move soil particles a few centimetres away at the most and its effects are solely local. Although large quantities of soil may be moved by rain splash, it is redistributed back over the surface of the soil except in steeply sloping lands.

1.5.2 Sheet Erosion

The removal of a more or less uniform thin layer or sheet of soil by running water from sloping land is known as sheet erosion (Fig. 1.2). Movement of the soil by raindrop splash is the main reason for sheet erosion. Raindrops cause the soil particles to be detached and increased sedimentation reduces the infiltration rate by sealing the soil pores.

![Fig. 1.2: Representation of both splash and sheet types of erosion](image)

1.5.3 Rill Erosion

It is an advanced form of sheet erosion which occurs due to concentration of flowing water (Fig. 1.3). Sheet flow occurs on the land surface mainly when the surface is smooth and has a uniform slope. However, it is rare in the cultivated fields. Normally, there are surface irregularities in most of the lands with high and low spots. These irregularities between soil clods and aggregates of different sizes are created during tillage operations.

1.5.4 Gully Erosion

It occurs when rills continue to extend in width, depth and length and become more serious (Fig. 1.4). It is more likely on steeper slopes and cannot be smoothened by normal tillage operations. Though the soil losses from gullies are
not as serious as the soil losses from sheet erosion but gullies are more evident than other types of erosion. Gullies can be classified on the basis of size, depth and drainage area as given in Tables 1.1 and 1.2.

![Formation of gully erosion](image)

**Fig. 1.4: Formation of gully erosion**

**Table 1.1: Gully Classes Based on Gully Depth and Drainage Area**

<table>
<thead>
<tr>
<th>Description</th>
<th>Drainage Area (ha)</th>
<th>Gully Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Less than 2 ha</td>
<td>Less than 1 m</td>
</tr>
<tr>
<td>Medium</td>
<td>2 to 20 ha</td>
<td>1 to 5 m</td>
</tr>
<tr>
<td>Large</td>
<td>More than 20 ha</td>
<td>More than 5 m</td>
</tr>
</tbody>
</table>

**Table 1.2: Gully Classes Based on Gully Depth, Width and Side Slopes**

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth</td>
</tr>
<tr>
<td>Very small gullies</td>
<td>&lt; 3 m</td>
</tr>
<tr>
<td>Small gullies</td>
<td>&lt; 3 m</td>
</tr>
<tr>
<td>Medium gullies</td>
<td>3-9 m</td>
</tr>
<tr>
<td>Deep and narrow gullies</td>
<td>a) 3-9 m</td>
</tr>
<tr>
<td></td>
<td>b) &gt; 9 m</td>
</tr>
</tbody>
</table>

Gullies can be further classified based on shape as:

- **U shaped gullies**: U shaped gullies are usually formed in alluvial valleys where both the surface and sub-surface soils are easily eroded.

- **V shaped gullies**: V shaped gullies are formed in those areas where sub-soils are more resistant than the top soil. This is the most common type of gully shape.

### 1.5.5 Stream Bank Erosion

Stream bank erosion is the scouring of soil material from the stream bed and cutting of stream bank by the force of flowing water. Stream erosion and gully erosion are distinguishable. Primarily, stream erosion applies to the lower end of head water tributaries and streams having a nearly continuous flow and relatively flat gradient, whereas gully erosion occurs generally in intermittent streams near the upper end of head water distributaries.

Stream bank gets eroded either by runoff flowing over the stream bank or scouring or undercutting (Fig. 1.5). Stream bank erosion is accelerated by the removal of
vegetation, overgrazing, or tillage near the banks. Scouring underneath the bank or on stream bed is affected by the velocity and direction of flow, depth and width of channel and soil texture.

1.5.6 Landslide or Landslip Erosion

Land slippage also known as mud slide or landslide or mass erosion occurs on wet sloping lands as saturated soil with water slips down the hillside or mountain slope (Fig. 1.6). Banks along highways, streams and ocean fronts are often prone to land slides. Landslide is the downward and outward movement of slope forming material composed of natural rocks, soil, artificial fills or combination of these materials. Landslips are the smaller masses moving all of a sudden while slides are bigger masses moving slowly though initiating as slips. Major causes of landslides are excavation or undercutting of the base of an existing slope, weak geology and lack of vegetative cover on the slope of slips. Landslides pose an immense threat to highways, villages and agriculture lands in the Himalayas, peninsular India and elsewhere.

1.5.7 Ravine Formation

Deep and narrow gullies with abrupt sides are usually called ravines (Fig. 1.7). Ravines (gullies) represent a severe erosion hazard resulting from enlargement of rills due to continuous non-judicious use of the land. The ravine system consists of almost a parallel set of gullies and is always associated with some river system. The major causes of ravine formation include abrupt change in elevation between
the river bed and the adjoining land, deep and porous soil strata with high erodibility, scanty vegetative cover and back flow of river water during recession period resulting in severe bank erosion.

In India, about 3.7 m ha area is affected by ravines, mostly covering the states of U.P., Madhya Pradesh, Rajasthan, Gujarat and Bihar. To tackle the problems of ravine formation effectively and suggest appropriate remedial measures for making these lands productive, Central Soil and Water Conservation Research and Training Institute has established three centers at Agra (U.P.), Kota (Rajasthan) and Vasad (Gujarat) for Yamuna, Chambal and Mahi river systems, respectively.

Fig. 1.7: Ravine formations in the Chambal river catchment

1.6 FACTORS INFLUENCING WATER EROSION

Removal of soil from land surface by running water is known as water erosion. Water erosion is caused by the dispersive and transporting power of water. Rainwater after meeting all requirements of abstraction such as infiltration, depression storage, detention storage etc. leaves the surface of land as runoff. There is a direct relationship between the volume of runoff and soil loss. For planning strategies for soil erosion control, it is, therefore, necessary to have a thorough knowledge of factors influencing erosion. The major factors influencing erosion are climate, topography, soil, vegetation and biotic activities. Hence, erosion can be expressed as a function of:

\[ E = f (C, T, S, V, B) \]  

Where, \( E \) represents the rate of erosion and \( C, T, S, V \) and \( B \) stand for climate, topography, soil, vegetation and biotic activities respectively. The vegetation and to some extent soil can be controlled. Climatic factors and topographic factors, except slope length are beyond the control of human being.

1.6.1 Climate

Rainfall characteristics namely temperature, wind, humidity and solar radiation are the climatic factors affecting erosion. Rainfall is one of the most powerful factors causing runoff and soil loss. Rainfall characteristics such as amount, duration, intensity and frequency greatly influence the runoff and erosion. Large amount of rainfall of low intensity may not produce any soil loss. Similarly, rainfall of high intensity and short duration may not produce sufficient runoff to cause erosion. When the large amount of rainfall with high intensity occurs for a long duration, there is large runoff and severe soil erosion. High intensity rain storms have bigger diameter of raindrops and when these drops strike the soil, large quantities of soil particles are detached and carried away by the runoff water from the field.
The influence of variability of mean annual rainfall on erosion indicates that in regions of low rainfall, there is very little erosion caused by rain. Further, whatever little rain occurs is used by vegetation and hence there is no runoff. On the other hand, even if rainfall of over 1000 mm occurs, dense vegetative cover protects the soil from raindrop impact and thus overcomes erosion problem. Erosion takes place in high rainfall areas without forest cover or where vegetation is disturbed.

1.6.2 Topography

Topographic features such as degree and length of slope, micro-topography, size and shape or configuration of a watershed influence erosion. On steep slopes, erosion is a very serious problem. As the land slope increases from mild to steep, the depression storage decreases and amount and rate of runoff increases. With increase in the land slope, velocity of flow increases. If land slope increases four times, the velocity of flow gets doubled and erosive or cutting power of water, expressed by kinetic energy \( KE = \frac{1}{2}mv^2 \); where \( m = \) mass; \( v = \) velocity) increases four times. The amount of soil material of a given size that can be transported by stream increases by 32 times while the size of particle that can be transported by flowing water increases 64 times. When the length of slope increases, the soil loss also increases. However, when length and degree of slope both increase simultaneously, there is an appreciable increase in soil loss.

1.6.3 Soils

Following soil characteristics influence erosion in an integrated manner.

a) **Soil texture:** It refers to the sizes and proportion of the particles making up a particular soil. Sand, silt and clay are three major fractions of soil particles. Soils which are high in sand content are considered as coarse textured. As water readily infiltrates into the sandy soils, the runoff and consequently erosion potential is relatively low. These soils are more easily detachable and less easily transportable than clay soils. Soils with high content of silt and clay are heavy with fine texture. Clay due to its stickiness binds soil particles together and is not easily detachable, but has low infiltration rate that leads to high runoff and increases erosion. Silty soils due to easy detachability and transportability are most erodible. Soil structure affects the soils ability to adsorb water. Compacted or crusted soil surfaces produce more runoff and less infiltration.

b) **Organic matter:** Organic matter comprising of plant and animal litter in various stages of decomposition improves soil structure and increases permeability, water holding capacity and soil fertility. Increase in permeability and water holding capacity of soil reduces runoff and consequently erosion potential.

c) **Soil structure:** It refers to the arrangement of soil particles in the aggregates. A granular structure is most desirable one. Erosion hazard increases with increased runoff. Loose granular soils retain water, reduce runoff and encourage plant growth.

d) **Soil permeability:** This indicates the ability of soil to allow air and water to move through the soil. Soil texture, structure and organic matter contribute to permeability. Soils with high permeability produce less runoff at a lower rate than soils with low permeability which minimizes erosion potential.
1.6.4 Vegetation

The following are the major benefits of a good vegetative cover:

- Reduces the effect of raindrops thereby preventing the detachment of soil particles. As a result of this, the pore spaces of the top soil surface are not blocked and the intake rates of water are not reduced. Higher intake rates decrease both the runoff and soil loss.

- Vegetation and vegetative residues increase the roughness of soil due to which the velocity of surface runoff is reduced resulting in reduced scouring of soil particles and their transportation.

- Roots of plant especially in a multi-layered forest hold the soil at different depths making it difficult for running water to detach and transport the soil.

- Vegetation especially grasses and herbs act as a fine sieve and reducing sediment load in surface runoff. Thus, a major portion of detached soil particles can be retained in the same area, provided a good soil cover exists.

Check Your Progress 2

Note: a) Use the space below for your answers.

   b) Compare your answers with those given at the end of unit.

1) Differentiate between geologic erosion and accelerated erosion.

2) List different forms of water erosion.

3) List the factors affecting water erosion.

1.7 ESTIMATION OF WATER EROSION LOSSES

Water erosion is caused by the action of rain or flowing water on the soil. The amount of erosion is, therefore, a function of energy of the flowing water or raindrops causing erosion and the ability of soil to withstand the impact of causative
factors. Thus, in mathematical terms, erosion is a function of erosivity of rain and erodibility of the soil.

Erosion = f (Erosivity, Erodibility)

**Erosivity:** It is defined as the potential ability of rain to cause erosion for a given soil condition. One storm can be compared quantitatively with another and numerical scale of values can be developed.

**Erodibility:** It is defined as the susceptibility of a soil to erosion and depends primarily on the physio-chemical characteristics of the soil to be determined in the laboratory. Secondly, it depends on land and crop management practices. Land management practices include contour farming, bunding and terracing etc., while crop management practices on arable lands include the kind of crop, the fertilizer treatment, harvesting and others.

### 1.7.1 Soil Erosion and Sediment Yield

Soil erosion is expressed as the gross amount of soil detached by the impact of raindrops, overland flow, wind or ice. Soil loss expressed as the net amount of soil loss in a specified period over an area of land in tones/ha or kg/m² for a single storm event or an average value for a number of years. Soil loss is of interest primarily in terms of on-site effects of erosion such as loss of crop productivity, while sediment yield refers to the amount of sediment which crosses a boundary, such as edge of a field or outlet of a watershed and is expressed in kg or kg/m or kg/m². Sediment yield is important in terms of off-site effects of erosion such as siltation of reservoirs, lakes, ditches and streams.

In most cases, not all the soil lost becomes sediment yield because some of the particles are deposited in the same field. The difference between net soil loss and net soil deposition is called as sediment yield. Relationship between soil loss and sediment yield is expressed as:

\[ \text{Sediment yield} = \text{sediment delivery ratio} \times \text{gross soil erosion} \]

Sediment delivery ratio is expressed as per cent of sediment yield to gross erosion. The delivery ratio is always less than 1 and has a specific value for each watershed.

### 1.7.2 Universal Soil Loss Equation (USLE)

The equation which is most commonly employed for the estimation of soil loss from agricultural lands under various agro-climatic and topographical situations is known as Universal Soil Loss Equation (USLE) and is expressed as:

\[ A = RKLSCP \]  

Where,

\[ A = \text{average annual soil loss; tones per ha per year;} \]

\[ R = \text{rainfall erosivity factor which is the number of rainfall erosion index units for a particular location;} \]

\[ K = \text{soil erodibility factor;} \]

\[ L = \text{slope length factor;} \]

\[ S = \text{slope steepness factor;} \]
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\[ C = \text{cropping and management factor; land} \]

\[ P = \text{supporting conservation practice factor for contouring, bunding, terracing and strip cropping etc.} \]

The equation predicts losses from sheet and rill erosion only and does not predict losses from gully erosion.

**Rainfall factor (R)**

R is the measure of erosivity of rainfall and runoff and refers to the number of rainfall erosion index units \( E_{I_{30}} \). It is the product of one hundredth of the kinetic energy of a rainstorm and the maximum 30 minutes intensity of the storm. The product is termed as \( E_{I_{30}} \) and can be expressed as:

\[ R = E_{I_{30}} = \text{Total energy} \times I_{30} / 10 \]

Total energy = \( KE \times P \)

\[ KE = 210.3 + 89 \log_{10} (I) \]  

\[ (1.3) \]

Where,

\[ E_{I_{30}} = \text{erosion index;} \]

\[ KE = \text{kinetic energy; m- tones/ha-cm;} \]

\[ I_{30} = \text{maximum 30 minutes rainfall intensity of the storm;} \]

\[ I = \text{rainfall intensity, cm/hr; and} \]

\[ P = \text{total rainfall depth during an event, cm.} \]

This index is a measure of rain’s ability to detach particles of soil from larger aggregates and to transport them.

**Soil erodibility factor (K)**

It is a measure of the erodibility of soil and expressed as soil loss in tones per ha per unit of rainfall erosion index for a particular soil on unit plot. The unit plot is defined as a plot of 22 m length with uniform slope of 9% maintained continuously in bare fallow condition and ploughed up and down the slope. When all these conditions are met, \( L, S, C, \) and \( P \) have values equal to 1.0 and \( K \) equals \( A/R \). A direct way to determine the \( K \) value is to establish a set of unit plots of above specifications and measure the soil loss for a sufficiently long time and calculate \( K \) value from the observed data. However, it is impractical. Therefore, from plots that usually do not have the prescribed slope, the \( K \) value is evaluated by equation 1.4 by adjusting the soil loss data to 9% slope by means of a slope as follows:

\[ A = A_o / S \]  

\[ (1.4) \]

Where,

\[ A = \text{soil loss expected from 22 m long and 9\% slope continuous fallow plot tilled up and down the slope;} \]

\[ A_o = \text{observed soil loss in s\% slope fallow plot of 22 m length, where s \% is the actual field slope; and} \]

\[ S = \text{slope gradient factor for s \% plot.} \]
\[ K = \frac{A}{EI(R)} \quad (1.5) \]

**Slope Length Factor (L)**

The slope length factor \( L \) is the ratio of the soil loss from field slope length and that of from 22 m length plot under identical conditions. This factor can be calculated by the following equation:

\[ L = (l/22)^m \quad (1.6) \]

Where,
- \( L \) = slope length factor;
- \( l \) = slope length m; and
- \( m \) = dimensionless exponent.

The value of exponent \( m \) varies with the slope. Wischmeir and Smith (1978) reported computed values of \( m \) for different slopes which are as follows:

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>( m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>0.2</td>
</tr>
<tr>
<td>1-3</td>
<td>0.3</td>
</tr>
<tr>
<td>3 - 5</td>
<td>0.4</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Slope Gradient Factor (S)**

The slope gradient factor \( S \) is the ratio of soil loss from field slope gradient to that from 9% slope gradient. Wischmeir and Smith (1978) suggested following relationship for computing \( S \):

\[ S = 65.41 \sin^2\theta + 4.56 \sin \theta + 0.065 \quad (1.7) \]

Where,
- \( S \) = slope gradient factor; and
- \( \theta \) = angle of slope.

\( L \) and \( S \) factors are generally combined in one term \( LS \) to define the topography of the area. The value of topographic factor \( LS \) can be computed by using the equation developed by Wischmeir and Smith (1978):

\[ LS = (l/22)^m (65.4 \sin^2\theta + 4.56 \sin \theta + 0.065) \quad (1.8) \]

The slope length is measured from the starting point of overland flow to the point where either the slope decreases to an extent that deposition of the sediment begins or where the runoff water enters a well defined channel.

**Crop Management Factor (C)**

The crop management factor \( C \) is the ratio of soil loss from land cropped under specified conditions to the soil loss from cultivated continuous fallow on identical soil and slope conditions and under similar rainfall. Table 1.3 presents the \( C \) values for various crops in different regions.
Soil Erosion

Table 1.3: Value of C for Different Regions

<table>
<thead>
<tr>
<th>Station</th>
<th>Crop</th>
<th>Soil loss (tones/ha)</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agra</td>
<td>Cultivated fallow</td>
<td>3.80</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Bajra</td>
<td>2.34</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Dichanthium annulatum</td>
<td>0.53</td>
<td>0.13</td>
</tr>
<tr>
<td>Dehradun</td>
<td>Cultivated fallow</td>
<td>33.42</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td><em>Cymbopogon grass</em></td>
<td>4.51</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Strawberry</td>
<td>8.89</td>
<td>0.27</td>
</tr>
<tr>
<td>Hyderabad</td>
<td>Cultivated fallow</td>
<td>5.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Average of 4 years</td>
<td>Grass</td>
<td>0.59</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Bajra followed by cowpea</td>
<td>1.91</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Bajra</td>
<td>2.00</td>
<td>0.40</td>
</tr>
<tr>
<td>Rehmankhera</td>
<td>Cultivated fallow</td>
<td>9.95</td>
<td>1.00</td>
</tr>
<tr>
<td>Average of 4 years</td>
<td>Jowar-Arhar</td>
<td>2.73</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Til-gram</td>
<td>4.50</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Conservation Practice Factor (P)

It is the ratio of soil loss with a given conservation practice to the corresponding soil loss under up and down cultivation. The most important conservation practices for arable lands are contour cultivation, strip cropping, terrace system and waterways for disposal of excess runoff. The value of P under different conservation practices and different locations is given in Table 1.4.

Table 1.4: Values of Conservation Practice Factor (P)

<table>
<thead>
<tr>
<th>Station</th>
<th>Practice</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehradun</td>
<td>Up-and-down cultivation</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Contour cultivation of maize</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>Contour farming</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Channel terraces with contour farming</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Channel terraces with graded furrows</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Strip cropping 3:1 (maize-cowpea)</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Terracing and bunding in agricultural watersheds</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Brushwood check dams in forest (Shorea robusta watersheds)</td>
<td>0.52</td>
</tr>
<tr>
<td>Udhagamandalam</td>
<td>Potato up-and-down</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Potato on contour</td>
<td>0.51</td>
</tr>
<tr>
<td>Hazaribagh</td>
<td>Up-and-down cultivation of maize</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Cultivation of maize along contour</td>
<td>0.31</td>
</tr>
<tr>
<td>Kanpur</td>
<td>Up-and-down cultivation of jowar</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Contour cultivation of jowar</td>
<td>0.39</td>
</tr>
<tr>
<td>Chandigarh</td>
<td>Contour bunding</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Limitations of USLE

The USLE is an empirically based equation that predicts sheet and rill erosion from relatively small areas, though it explicitly takes into account all the factors known to affect rainfall erosion. It predicts seasonal or annual soil loss and when applied on single storm basis, the results are highly erroneous. It is basically an erosion equation and does not estimate deposition and cannot be employed to estimate gully or stream bank erosion. In spite of its limitations, the USLE is the most widely used method of estimating soil loss, identifying critical areas and evaluating the effectiveness of soil conservation measures.

Example 1.1

Calculate the erosivity of rainfall storm having 5 cm/hr average rainfall intensity and 8 cm rainfall depth. The maximum 30 minutes rainfall intensity is 4.5 cm/hr.

Solution

\[ KE = 210.3 + 89 \log_{10} (I) \]

Putting the values of \( I \) in the above equation,

\[ KE = 210.3 + 89 \log_{10} (5) = 272.50 \]

\( P_r = 8 \text{ cm} \)

Total energy = \( KE \times P_r \)
\[ = 272.50 \times 8 = 2180.06 \]

Now, \( R = EI_{30} = \text{Total energy} \times I_{30}/10 \)
\[ = 2180.06 \times 4.5/10 \]
\[ = 981.02 \text{ m-tones/ha-cm} \]

Example 1.2

Work out the erodibility factor (\( K \)) for the field with the following data:

- a) Rainfall intensity = 5.0 cm/hr
- b) \( I_{30} = 6 \text{ cm/hr} \)
- c) Observed soil loss = 4.5 tones/ha
- d) Rainfall depth, \( P_r = 6 \text{ cm} \)
- e) \( LS \text{ factor} = 1 \)

Solution

\[ R = \text{Total energy} \times I_{30}/10 \]
\[ \text{Total energy} = [210.3 + 89 \log_{10} I] \times P_r \]
\[ = [210.3 + 89 \log_{10} (5)] \times 6 \]
\[ = 1635.04 \text{ m-tones/ha-cm} \]

Hence, \( R = 1635.04 \times 6 / 10 \)
\[ = 981.02 \text{ m-tones/ha} \]

2) Adjusted soil loss = Observed soil loss/\( LS \text{ Factor} \)
\[ = 4.5/1 = 4.5 \text{ tones/ha} \]
Example 1.3

A watershed has the following values of USLE parameters:

\[
R = 175, \quad K = 0.40, \\
LS = 0.70, \quad P = 0.55, \text{ and}
\]

Soil loss = 5 tones/ha/yr.

Compute the crop management practice factor under the specified conditions.

Solution

Universal soil loss equation is given as:

\[
A = RKLSCP
\]

Or, \( C = \frac{A}{RKLSP} \)

Substituting the values of various factors,

\[
= \frac{5}{(175 \times 0.40 \times 0.70 \times 0.55)} = 0.19
\]

Example 1.4

Suggest a suitable conservation practice to suit the soil loss tolerance of the watershed, i.e. 4 tones/ha/yr. The values of USLE factors are given below:

Erosivity \((R) = 240\); Erodibility \((K) = 0.25\);
Slope – length factor \((LS) = 1.5\); Crop Management Factor \((C) = 0.07\); and \(P = 1\) (under present situation); Assuming value of conservation practice factor \((P)\) for contour cultivation as 0.6

Solution

\[
A = RKLSCP
\]

\[
= 240 \times 0.25 \times 1.5 \times 0.07 \times 1
\]

\[
= 6.3 \text{ tones/ha/year}
\]

In the present condition, the rate of soil erosion is higher than that of given tolerance limit of the watershed. Therefore, another value of \(P\), i.e. 0.6 can be tested for the selection and application of conservation practice aiming to bring the rate within the tolerance limit.

\[
A = 240 \times 0.25 \times 1.5 \times 0.07 \times 0.6
\]

\[
= 3.78 \text{ tones/ha/year}
\]

Since the soil loss tolerance value of the watershed is 4 tones/ha/yr and the soil loss estimated as 3.78 by taking \(P = 0.6\), therefore the value of \(P\) is acceptable. By this, we can conclude that the values of \(P\) equal to or less than 0.6 is acceptable in the given watershed and contour cultivation is recommended.

Example 1.5

Using the USLE, calculate the annual soil loss in tonnes per ha from a field with the following details:

a) Rainfall erosivity factor \( = 800\)
b) Soil erodibility factor = 0.20
c) Crop management factor = 0.50
d) Conservation practice factor = 1.0
e) Topography factor = 0.2

What per cent of soil loss is reduced when the cultivation is done on the contours?
Assume value of conservation practice \( P \) for contouring as 0.5.

**Solution**

Annual soil loss from the field,

\[
A_1 = RKLSCP
\]

\[
= 800 \times 0.2 \times 0.2 \times 0.5 \times 1.0
\]

\[
= 16 \text{ tones/ha/year}
\]

When cultivation is done on contours, the value of \( P \) factor changes to 0.5, therefore, the soil loss will be:

\[
A_2 = 800 \times 0.2 \times 0.2 \times 0.5 \times 0.5 = 8 \text{ tones/ha/year}
\]

\[
\% \text{ reduction in soil loss} = \frac{16 - 8}{16} \times 100
\]

\[
= 50\%
\]

**Example 1.6**

Calculate the topographic factor using the following data

a) Slope length = 100 m
b) Slope angle = 12°
c) Exponent, \( m = 0.2 \)

**Solution**

Given, \( L = 100 \text{ m} \)

\[
\theta = 12°
\]

\[
LS = (L / 22)^m (65.4 \sin^2 \theta + 4.56 \sin \theta + 0.065)
\]

\[
= (100/22)^{0.2} (65.4 \sin^2 12 + 4.56 \sin 12 + 0.065)
\]

\[
= 5.19
\]

**1.7.3 Transportation Processes and Deposition**

**Transportation**

Precipitation is the chief agent, which initiates the process of transportation of soil particles (sediment) from the land surface. In water erosion, the process of soil transportation by running water may be of the following types:

- Suspension
- Saltation
- Surface creep or bed load
Suspension: Suspended sediment remains in the flowing water for a considerable period of time without any contact with the bed. Fine sediment particles are transported through this process. This process is associated with the chemical action between running water and soil or country rocks. The sediment concentration usually increases from a minimum at the water surface to a maximum near the bed.

Salination: This process is responsible for transport of medium size soil particles, which are not able to stand in suspension form, but are mixed in water and flow over the stream bed in the form of mud through hopping action. The saltation movement changes into suspension either when the velocity of flow is high or sediment size becomes finer. In comparison to the total amount of sediment transported, saltation is considered relatively of less importance.

Surface creep or bed load: It is the process in which relatively large size particles move, roll or slide along the stream bed by maintaining continuous contact with the bed. Particles are pushed or moved along the bed by the force of flowing water.

Deposition

The deposition of sediment load mixed with the running water occurs under the following conditions:

- When force by which the load is transported from one place to another is reduced considerably, the load present in the water tends to settle over the flow path.
- Surface obstructions in the flow path of running water tend to cause the deposition of load present in the water.
- The curves of meanders or winding courses of streams also cause deposition of the soil load running along with the flowing water.

1.7.4 Indicators of Water Erosion

There are many indicators, which show that a particular soil has been eroded by water in the field. Some of these indicators may be observed after a short period of occurrence of a storm.

- Mounds of relic soil around plants and under pebbles.
- Discoloured lines around stones where soil has been removed.
- Accumulation of transported sediment in the depressions and above obstacles.
- Occurrence of muddy water.
- Presence of rills or gullies in the upper slopes or on road sides.
- Exposure of plant roots.
- Change in colour and texture of bank near the base of the plant.
- Exposed parent material.
- Bare spots in the grasslands.
- Deposition of gravel, sand and silt over the gully bed.
- Accumulation of silt in the reservoirs.
Check Your Progress 3

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) Define soil loss and the terms of Universal Soil Loss Equation.

2) Using the USLE, calculate the annual soil loss in tones per ha from a field with the following details:
   (i) Rainfall erosivity factor = 600
   (ii) Soil erodibility factor = 0.30
   (iii) Crop management factor = 0.60
   (iv) Conservation practice factor = 1.0
   (v) Topography factor = 0.7

3) Describe in brief different forms of transportation.

1.8 LET US SUM UP

- Erosion is a two-phase process resulting from the detachment of individual soil particles from the soil mass, transporting them from one place to another (by the action of any one of the agents of erosion, viz. water, wind, ice or gravity; water and wind being the two major agents) and their deposition.

- When sufficient energy is not available to transport a particle, a third phase known as deposition occurs. In general, finer soil particles get eroded more easily than coarse particles (silt is more easily eroded than sand).

- Thus soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment).

- Sediment refers to any fragmented material transported or deposited by water, ice, air or any other natural agent.
• Climate, topography, soil characteristics (texture, soil structure, soil permeability, organic matter) and vegetation are the major factors influencing water erosion.

• Raindrop erosion, sheet erosion, rill erosion, gully erosion, stream bank erosion, landslide or landslip erosion and ravine formation are the major forms of water erosion.

• Soil loss expressed in tones/ha or kg/m² as the net amount of soil loss in a specified period over an area of land affects crop productivity, while sediment yield refers to the amount of sediment or siltation of reservoirs, lakes, ditches and streams.

1.9 KEYWORDS

Conservation : It is defined as the protection, improvement and use of natural resources in such a way so that maximum economic or social benefits are realized without deterioration of the resources.

Depression Storage : Amount of water needed to fill surface depressions.

Detention Storage : Amount of water involved in the head build-up.

Erodibility : It is vulnerability or susceptibility of the soil to erosion. It depends primarily on the physio-chemical characteristics of the soil.

Erosion : The detachment, transportation and deposition of soil particles from one place to another by water, wind or any other agent.

Erosivity : It is the potential ability of rain to cause erosion at a given location.

Rill Erosion : The erosion, resulting in the formation of smaller channels on the soil surface that can be removed or filled by performing tillage or agricultural operations, is called as rill erosion.

Saltation : Refers to transport process of medium size soil particles, which are not able to stand in suspension form but are mixed in water and flow over the stream bed in the form of mud through hopping action.

Surface Creep : The soil particles which are too heavy and move along the surface by the impact of flowing water.

Suspension : Refers to sediment particles remaining in the flowing water for a considerable period of time without any contact with the bed.
1.10 SUGGESTED READING


1.11 MODEL ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The main causes of soil erosion are as follows:

- Indiscriminate cutting down of trees;
- Overgrazing of the vegetative cover;
- Forest fires;
- Keeping the land barren and subjecting it to the action of rain and wind;
- Growing of crops that accelerate soil erosion;
Soil Erosion

- Removal of organic matter and plant nutrients by injudicious cropping patterns;
- Cultivation along the land slope; and
- Faulty methods of irrigation.

**Ill-effects of soil erosion**

- Poor return in agriculture, forest and grass lands
- High rate of erosion
- Denudation of land
- Siltation of reservoirs, lakes and rivers
- Poor water yield
- Poverty
- Anti-social activities
- Apathy to the development

2) Following processes are involved in erosion:

- loosening and dislodging of soil particles i.e. erosion;
- movement of soil particles by various agencies i.e. transportation;
- deposition of soil particles i.e. deposition.

This can be described through a flowchart as:

Soil removal → Transportation → Deposition

**Check Your Progress 2**

1) Geologic and accelerated soil erosion are distinct in the following ways:

- Natural or geological soil erosion represents the erosion of soil in its natural state but the accelerated soil erosion occurs under biotic and abiotic pressures.
- Under natural undisturbed conditions, equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer, while natural balance between soil forming and depleting processes is disturbed by human activities, large-scale deforestation or conversion of forest land into agriculture. Erosion intensity increases manifold under accelerated erosion.
- The rate of soil erosion is very slow and invisible under geological erosion but the rate is fast and visible in accelerated type of soil erosion.

2) Forms of water erosion can be enumerated as:

- Raindrop erosion,
- Sheet erosion,
- Rill erosion,
- Gully erosion,
Stream bank erosion,
Landslide or landslip erosion, and
Ravine formation

3) The major factors influencing erosion are climate, topography, soil characteristics such as soil texture, structure, permeability, organic matter and vegetation and biotic activities. The vegetation and to some extent soil can be controlled. Climatic factors and topographic factors, except slope length are beyond the control of human being.

Check Your Progress 3

1) The soil loss expressed in units of mass per unit area, such as tones per ha or kilogram per sq metre (kg/m²) is the net amount of soil lost in a specified period over a given piece of land. Universal Soil Loss Equation (USLE) is the most commonly used equation for the estimation of soil loss

\[ A = RKLSCP \]

The equation predicts soil losses from sheet and rill erosion only and does not predict losses from gully erosion.

Where,
- \( A \) = average annual soil loss; tones per ha per year;
- \( R \) = rainfall erosivity factor which is the number of rainfall erosion index units for a particular location;
- \( K \) = soil erodibility factor;
- \( L \) = slope length factor;
- \( S \) = slope steepness factor;
- \( C \) = cropping and management factor; and
- \( P \) = supporting conservation practice factor for contouring, bunding, terracing and strip cropping etc.

2) Annual soil loss from the field

\[ A = RKLSCP \]

\[ = 600 \times 0.3 \times 0.6 \times 0.7 \times 1.0 \]

\[ = 75.6 \text{ tones/ha/year} \]

3) In water erosion, the process of soil transportation by running water may be of the following types:

- **Suspension**: Suspended sediment is that which remains in the flowing water for a considerable period of time without any contact with the bed.

- **Saltation**: This process is responsible for transport of medium size soil particles, which are not able to stand in suspension form, but are mixed in water and flow over the stream bed in the form of mud through hopping action.

- **Surface creep or bed load**: It is the process in which relatively large size particles move, roll or slide along the stream bed by maintaining continuous contact with the bed.