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General Article ________________________________ *Chapter –26*

SOIL AND WATER CONSERVATION

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Abstract

As we all know soil and water are two basic natural sources which need to be managed and conserved. Unfortunately now in our country we are losing almost 5000 million tons of soil, fertile soil to say every year due to improper management. This amounts to about 1 millimeter of top soil layer that are losing every year. What is soil and water? We know that soil and water are two basic natural resources that must be conserved and utilized judiciously and that is because for meeting the food, fiber and shelter needs for growing population and we too need the efficient utilization of these resources. In this chapter we will deal with the principles, concepts behind soil and water conservation, classification soil erosion process agronomical and engineering measures for controlling erosion and we will design bund terraces and gully control structure for water erosion and similarly in case of wind erosion we will see the design of wind break and shelterbelts.

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Introduction

As we all know soil and water are two basic natural sources which need to be managed and conserved. Unfortunately now in our country we are losing almost 5000 million tons of soil, fertile soil to say every year due to improper management. This amounts to about 1 millimeter of top soil layer that are losing every year. What is soil and water? We know that soil and water are two basic natural resources that must be conserved and utilized judiciously and that is because for meeting the food, fiber and shelter needs for growing population and we too need the efficient utilization of these resources. In this chapter we will deal with the principles, concepts behind soil and water conservation, classification soil erosion process agronomical and engineering measures for controlling erosion and we will design bund terraces and gully control structure for water erosion and similarly in case of wind erosion we will see the design of wind break and shelterbelts.

Soil

The term 'soil' has different meanings, depending upon the general professional field in which it is being considered. To an agriculturist soil does the substance exist on the earth's surface which grow and develop plant life, to the geologist soil is a material in the relatively thin surface zone within which root occur, to an engineer soil is a un aggregated or un cemented deposit mixture of mineral and organic components. It include widely different materials like bounders, sands, gravel, clay, and silts, and range of the particle size in the soil may extend from grains only a fraction of a micron (10^{-4}cm) in diameter up to large size bounders. To an engineer soil is considered as a complex material which produced by the weathering of the solid rock.

Three main components of soil are:

1. Minerals
2. organic matter
3. living organismsFunctions of soil
1. It serves as a media for production of food, fiber and fuel.
2. Soil regulates water flow
3. Soil regulates the atmosphere by emitting and absorbing gases.
4. Soil provide habitat for animals

Soil Erosion

Detachment and transport of soil particle by erosive agents most commonly water and wind is known as soil erosion. It consists of three basic stages: dislodgement, transportation and sedimentation. Erosion degrades soil quality and is a major reason for farmland loss in the world.

Soils generally take thousands of years to develop from their original parent material, and natural erosion is a part of this development process. Vegetation protects soil, and its roots hold and bind soil particles together, so that in long-term natural systems (e.g., forests and prairies) soil losses in upland areas may be relatively minimal. However, human activities, particularly agricultural production, soils generally take thousands of years to develop from their original parent material, and natural erosion is a part of this development process.

Causes of Soil Erosion

- Destruction of natural protective cover
- Indiscriminate cutting down of trees- loss of canopy cover, no interception, nodissipation of kinetic energy, highly vulnerable to erosion.
- Overgrazing of vegetative cover-exposed land surface, higher vulnerability toerosion
- Forest fire-loss of canopy cover as well as vegetative cover.
  Improper land use
- Barren land subject to the action of rain and wind- no protective cover on thesurface-higher vulnerability to erosion.
- Improper cultivation or cropping pattern- exposed land surface lead to highererosion
- Cultivation along the land slope- water flow along the land slope- higher erosivecapacity

Type of Soil Erosion

✓ **Geological erosion**
- also refer to "normal" or "natural" erosion
- it is a natural process responsible for formation of and the loss of soil simultaneously
- Relatively slow and continuous process that often gets unnoticed.
- Responsible for the formation of topographical features such as stream channel, valleyetc.

✓ **Accelerated erosion**
- Also refers as anthropogenic or man-induced erosion
- It is activated by human activities that bring changes in natural cover and soil condition
- Soil removal is much faster than the natural soil formation processAccelerated erosion is of two types based on the agent of erosion

1. Water erosion
2. Wind erosion
3. Water erosion – removal of soil from land surface by water including runoff from melted snowand ice is termed as water erosion.

Mechanics of Water Erosion

Erosion of soil occur in there different phases. They are (i) detachment of soil particle, (ii) transportation of detached soil particle and (iii) deposition of transported soil particles.

Water Erosion Occur in Five Stages

1. **Raindrop splash erosion**: The first stage of water erosion, when water drops strike the ground surface, the soil particle become loose and splashed due to its impact force. The soil splashed in air upto a height of 50-70 cm according to the size of rain drop. The loose particles clog the soil pores and result in reduced infiltration and increased runoff.

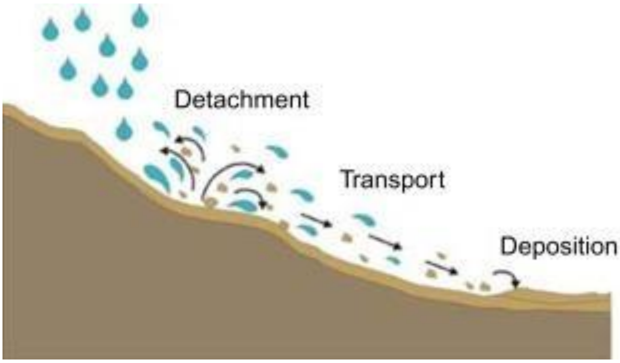

Fig 1. Raindrop/ Splash Erosion

2. **Sheet Erosion**: uniform removal of soil in thin layer during the overland flow process. Once the infiltration capacity is satisfied overland flow begins and this result in loss of the most fertile soil which contain most of the available nutrients and organic matter in the soil. In this soil is detached and then transported away from its origin. Overgrazed and cultivated soil are most vulnerable to sheet erosion

3. **Rill Erosion**: if the overland flow process continues, its erosive action results in the formation of shallow channels known as rills. The removal of soil by concentrated water running through rills is Rill erosion. It is common in bare agricultural land, overgrazed land and in freshly cultivated land. The rill can usually be removed with primary tillage implements.

4. **Gully Erosion**: if rills are not destroyed and the detachment continues, then these become wider and deeper and this results in formation of gullies. They cannot be smoothened out by normal cultivation. This is the advanced and last stage of erosion. The main problem of soil

erosion is gully erosion. In gully erosion large channel are formed in field and once they areformed it become difficult to destroy them through tillage.

Fig 2. Gully erosion (source from IISWC Dehradun)Two main process of gully erosion

1. Waterfall erosion: the overland flow falling into the gully at the head end undercuts it andresults in upslope extension of the gully.
2. Channel erosion: water falling through the gulley eroded the bed and side causing wallscollapse and slumping of the side wall

Development of Gully- there four stages of gully development

1. Formation stage: channel erosion by downward scour of the top soil.
2. Development stage; consist of upstream movement of gully head and enlargement of gully inwidth and depth.
3. Healing stage: vegetation growth begins in gully.
4. Stabilization stage: vegetation cover spread over the gully surface such that gully reachesstable gradient and walls reach a stable slope.

Classification of Gully
Based on Shape:
U Shape: formed where both the top soil and subsoil have the same resistance against erosion
V Shape: formed where the sub soil has more resistance than top soil against erosion

Table 1.1 Based on size

Size	Depth	Drainage area
Small	< 1 m	<2 ha
Medium	1-5 m	2-20 ha
Large	>5 m	>20 ha

Based on stage

Active Gully: when shape and size of gully changes with time.

Inactive Gully: when shape and size of gully changes with time.

5. **Stream Bank Erosion:** refers to the scouring and undercutting of the soil below the water surface in a stream. It is natural process but the rate at which it occurs may be influenced by human activities. It gets aggravated due to removal of vegetation, over grazing or cultivation of area close to steam banks.

Soil Loss Equation

Soil loss equation: the most widely accepted method for estimating the average annual soil lossis USLE (Universal Soil Loss Equation) the equation is originally proposed by Wischmeier and Smith (1958). And in (1978) they itself modified it as-"The USLE is an erosion prediction model for estimating long term averages of soil erosion from sheet and rill erosion from a specified landunder specific condition".

The equation is given by **A = RKLSCP**

Where A = average annual soil loss, metric ton/ha (t/ha) R = rainfall erosivity factor/index (MJ*mm/ha*h)

K = soil erodibility factor/index (t*ha*h/ha*MJ*mm)LS= topographic factor

C = crop management factor

P = conservation practice factor

Rainfall erosivity index (R): refers to the intrinsic capacity of rainfall to cause soil erosion.

It is a function of kinetic energy and the intensity of the rain storm. It is expressed as the productof kinetic energy of the storm and the maximum 30 min intensity.

$$R = EI_{30} = KE * I_{30}$$

Where EI_{30}= rainfall erosivity index (R) [E and I represent energy and intensity, KI kinetic energy of storm, I_{30} maximum 30 minute rainfall intensity during the storm.]

Soil erodibility factor (K): resistance of soil to both detachment and transportation. It can bedetermined through the measurement of soil loss from a standard runoff plot.

Topography (LS): steeper and longer the slope, the higher is the risk of erosion. Topographyfactor is given by $LS = (L/22.13)^m [65.41 \sin^2\theta + 4.58 \sin\theta + 0.065]$

Where L = slope length (m), θ = angle of slope, m depends on slope 0.5 for slope 5% or more;

for slope 3.5-4.5; 0.3 for 1-3% slope for 0.2 less than 1% slope so, if m is more than soil losswill be more.

Table 1.2. Source: htpp://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm

Slope length m(ft)	Slope%	LS factor
23.5	10	1.38
	8	1.00
	6	0.67
	5	0.54
	4	0.40
	3	0.30
	2	0.20
	1	0.13
	0	0.07

Crop management factor (C): it is the ratio of soil loss from a land cropped under specifiedconditions to the corresponding loss from clean tilled, continuous fallow land. It includes the effect of crop cover, crop sequence, tillage practices and residue management. The value of C is taken 1 if land is fallow.

Table 1.3. Source: Based on Reports from Different ICAR Research Centres

Crop	Kharagpur	Kota	Vasad
Moong		0.39	0.47
Paddy			0.28
Maize	0.35	0.50	
Groundnut		0.41	0.38
Cowpea	0.17	0.39	0.32
Grass	0.04	0.22	
Natural cover		0.14	

Conservation practices factor (P): it represent the ratio of soil loss from the land where conservation practices like contouring, strip cropping, terracing etc. are adopted. The value of Pis taken as 1 for no conservation practices.

Slope%	**contouring**	**Stripcropping + contouring**	**Terracing + contouring**
1.1-2.0	0.6	0.3	
2.1-7.0	0.5	0.25	0.1
7.1-12.0	0.6	0.3	0.12
12.1-18.0	0.8	0.4	0.16
18.1-24.0	0.9	0.45	

Table 1.4. Source: based on reports from different ICAR Research centres

Application of USLE

- To provide specific reliable guides for selecting appropriate erosion-control practices for farm land and construction areas.
- To determine upland erosion for reservoir sedimentation and stream loading, control of pollution from crop land and alternative land use treatment combination.

Limitation of USLE

- It is an empirical equation that uses empirical coefficient.
- Prediction of average annual soil loss: USLE was developed mainly on the basis of average annual soil loss data, hence its applicability is limited to average annual soil loss estimation.
- Non- consideration of gully erosion: the applicability of the equation is limited to sheet and rill erosion.
- Non-consideration of sediment deposition: the equation only calculates the soil loss

Modified Universal Soil Loss Equation

- USLE is unable to predict sediment yield from a single storm event
- To overcome this problem, Williams (1975) modified the USLE as modified universalsoil loss equation (MUSLE)
- Based on the fact that runoff is a superior indicator of sediment yield than rainfall, norunoff yields no sediment, though there can be rainfall with little or no runoff
- Modification was done by replacing rainfall erosivity factor/index by runoff factor/indexThe MUSLE (Williams, 1975) is given by the following equation;

$$A = 11.8(V_Q.Q_P)^{0.56}\ K.LS.C.P.$$

Where,

A= sediment yield for a single event, MgV_Q = volume of runoff, m^3
Q_P = peak flow rate, m^3/s
K,LS,C,P remains the same as in USLE

- Runoff volume is estimated using the SCS curve number method

SCS stands for soil conservation service was developed in 1969 and now it name changed as natural resources service (NRCS) but still the method is known as SCS method. This method is based on two fundamental hypotheses-

Runoff stars after an initial abstraction I_a (interception, surface storage, and infiltration) has been started.

1. The ratio of actual retention of rainfall to the potential maximum retention is equal to theratio of direct runoff to rainfall minus initial abstraction.

$$V_Q = (P-I_a)^2/(P-I_a)+S$$

Where,
V_Q= runoff volume uniformly distributed over the drainage basin$P$ = mean precipitation over drainage basin
S= retention of water by the drainage basin.

- Peak flow is estimated using the rational method

Rational method is proposed by Mulvaney, an Irish Engineer, in 1851Q = CiA/36
Where,
Q = Peak runoff rate (m^3/s)
C = runoff co-efficient (dimensionless)
i = average rainfall intensity for a duration equal to the time of concentration andat desired frequency at return period(cm/h)
A = catchment area (ha)

Assumption of Rational Method

- Rainfall is uniformly distributed over the catchment area.
- Rainfall is uniformly distributed over the storm duration.
- The runoff rate resulting from any rainfall event is the maximum when the rainfall lasts for duration equal to or greater than the time of concentration
- The return period of peak runoff is the same as that of the rainfall intensity
- The fraction of rainfall that becomes runoff is independent of the rainfall intensity or volume.

Time of Concentration (T_C): it is defined as the time required for water to flow from the hydraulically most remote point of the basin to the outlet.
This is estimated using kirpich formula (1940)

$$T_C = 0.0195\, L^{0.77}\, S^{-0.385}$$

Where, T_C = time of concentration of a basin, (min)
L = maximum flow length measured along the drainage line, (m)S = basin slope

Wind Erosion: it refers to the natural removal of soil from an area due to wind. It mostly occurs in low rainfall areas when soil moisture content is at wilting point or below. "**The process of detachment, transportation, and deposition of soil material by wind" (Troeh et al., 1991).** It may be caused by light wind erosion that roll soil particle along the surface through a strong wind that lift a large volume of soil particles into the air to create dust storms.
Windblown material move in three mode

1. **Suspension:** when particles less than 0.1mm size are lifted far above the surface and carried great distances this result in suspension. Movement of these fine particles is usually initiated by the impact of particles in saltation. About 3-40% of the soil weights are carried by suspension.

2. **Saltation:** when soil particle size is (0.1 – 0.5 mm) they move in a series of bounces and/or jump. This movement of particles depends upon the pressure of the wind and collision of a particle with other particles. The height of the jump depends upon size and density of the soil particle, roughness of soil surface and the velocity of wind. About 50- 75% of the soil weights are carried by saltation.

3. **Surface Creep:** rolling or sliding of large soil particles along with soil surface is known as surface creep. Soil particles having diameter between 0.5 – 2 mm come under this phase. About 5-25% of the total soil weight are carried in this.

Shelter Belts: Trees are arranged in rows along fence lines in shelter belts. They are mostly grown to provide shade in hot times and shield livestock or crops from cold winds. Shelter belts also lessen wind erosion in areas with a lot of cultivated land, like Canterbury.

Causes of Erosion:

- Deforestation
- Residential and commercial construction
- Traditional cultivation practice like ploughing or tillage

Factors Affecting Soil Erosion

Factors affection soil erosion can be summarized as follows-Soil erosion =f(C, T, V, S)
Where, C stands for climate

T stands for topographyV stands for vegetationS stands for soil
Climatic factors which affect soil erosion are

- Rainfall
- Wind
- Humidity
- Solar radiation
- Soil property
- Topography
- Vegetation

Ill- Effects of Soil Erosion

- Loss of top fertile soil impacts crop productivity and production
- Deposition of silts reduces the carrying capacity of rivers and streams
- Silting of reservoirs and other storage facilities reduces their capacity and useful
- Land degradation problem due to soil erosion are all over the country.
- Disease and public health hazards
- Loss of biodiversity

Erosion by Wind and Water

Out of 328 M ha area around 147 M ha area is affected by water and wind erosion and about 69 M ha is in critical stage and needs immediate attention. Wind erosion is mainly restricted to states of Rajasthan, Gujarat and Haryana. The severity of wind erosion is inversely related to the rainfall amount, lesser is the rainfall more would be the wind erosion. About 4 M ha of land in the country is affected by problem of gullies and ravines

Ravine (a valley with steep sides much larger than gully) is most located in Uttar Pradesh, Madhya Pradesh, Gujarat and Rajasthan.

Gullies on the other hand are seen in the plateau region of Eastern India, foot hill of Himalayas and areas of Deccan Plateau.

Water Logging: caused either by surface flooding or due to rise of water table. An area of 8.53 M ha is affected by water logging. Water logging due to surface flooding is predominant in states of west Bengal, Assam, Andhra Pradesh, Madhya Pradesh, Orissa, Kerala, Punjab and Haryana.

Soil Salinity saline soils are prevalent both in island as well as coastal areas. About 5.5 M ha areais affected by this problem in the country which include arid and semi arid areas of Rajasthan and Gujarat

Shifting Cultivation: also known as jhum cultivation is a traditional method of growing crops on hill slopes by slash and burn method. The method involves selection of appropriate site on the hill slope, cleaning of forest by cutting and burning, using the site for cultivation for few years and later on abandoning it and moving to the fresh site. The problem is much serious in north eastern region and in the state of Orissa and Andhra Pradesh

Erosion Control

Strategies for conservation must be based on

- Covering the soil to protect it from raindrop impact
- Increasing the infiltration capacity of soil to reduce runoff
- Improving the aggregate stability of soil
- Increasing surface roughness to reduce velocity of runoff

Erosion Control Measure

They are broadly classified into two groups: agronomical/biological measures and engineering measures.

Agronomical/Biological Measures: as the name itself suggest erosion is controlled through cropor vegetation that are basically used for controlling erosion. Cultivation should be done by adopting measures which shall minimize erosion. These measures include

Crop Rotation- defined as a more or less regular succession of different crops being grown on the same piece of land. Rotation of crop reduces erosion and increase the fertility of soil. Crop rotation varies with land, economic condition of the farmers and cropping system prevalent in an area.

Cover Cropping- grown as a conventional measures either during off season or in-between rows for ground protection under tree. Common crops are rye, oats, beans, pea, alfalfa and grass whichprovide good cover against erosion

Contour Farming- contour farming reduces soil loss up to 50% while enhancing the crop yield by 10%. Contour cultivation save power and its effectiveness depends upon length and steepnessof slope.

Strip Cropping- it is a practice of growing alternate strips of row crop across the slope of land. Strip cropping reduces runoff flowing through the crop rows and increase the infiltration rate of the soil under cover condition. It is of three types:

i. Buffer strip cropping: strips of grass or legumes crops are laid out between contour stripsof crop in regular rotation.
ii. Contour strip cropping: crops are arranged in strips or bands on contours at right angle tonatural slope of land.
iii. Field strip cropping: crops are laid out in strips across the slope but only approximately on slope.

Mulching: it is a crop and soil management practice that utilizes the residual mulches of preceding crop. Two major benefits of mulching are it dissipate the energy of raindrop and reduces the surface flow.

Engineering Measures: there are four type of engineering measures which are normally adopted

Bunds: are earthen embankments build across the slope of the land. Bunds are of two type (i) contour bund and (ii) graded bund

Terraces: terrace is a practice of cutting flat areas out of a hilly or mountainous landscape to grow crops terrace are of two type (i) bench terrace and (ii) broad based terrace

Vegetative Waterways: Vegetative waterways are natural and constructed waterways shaped to required dimensions and vegetated for safe disposal of runoff from a field, diversion, terrace or other structures.

Gully Control Structure: Gully control structures are adopted to control gully erosion. We have seen gully erosion already over this is most severe type of erosion. Measure adopted to control gully erosion are vegetative measure, temporary gully control structure, permanent gully control structure

Conclusion

Soil erosion is the loss of the top most fertile soil from the earth crust. The two main factors that cause soil erosion are water and wind. Soil loss due to runoff is a serious and ongoing ecological issue. Soil erosion has been accelerated as a result of deforestation, bad farming practices, and unrestrained grazing. We will classify soil erosion processes, discuss agronomical and engineering measures for controlling erosion, and design bund terraces and gully control structures for water erosion and shelter belts for wind erosion, respectively. In this chapter, we will also discuss the principles and concepts behind soil and water conservation. We will utilize the universal soil loss equation and the modified universal soil loss equation to determine the annual soil loss.

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