Soil and water Conservation Engineering

Introduction

In India about 81 million hectare lands are affected by erosion problem out of total geographical area of 326.8 m.ha. In other term " out of net cultivated area of 185.8 m.ha., 56.7 m.ha lands are Suffering from erosion either due to water or wind. Out of these about 40m.ha lands are badly affected and needed immediate Control measures.

The dominating factors which are responsible for Producing the problems of Soil erosion in India, are the excessive deforestation, overgrazing, faulty agricultural practices and occurence of flood.

In order to maximize the net cultivable area, importance is now given to the Soil Conservation work in our Country. In the first five year plan, the urgency has been given for making the nationwide policy, dealing with various existing problems, which resulted into the reorganization of Soil and water Conservation work plan. In the first five year plan (i.e. 1954 to 1956) the Soil Conservation Schemes were approved in three heads; these are the immobilizing of deserts, bunding and terracing on hilly land and afforestation of ravines and Severely eroded areas. In which, about 2.8 lakh hectares land were used for bunding and terracing Practices in the first five year plan.

In addition, eight regional training cum research centres are also established to study the soil conservation problems of the country. During this Central Arid Zone Research Institute, Jodhpur was established to undertake the studies on the desert problems existing in the state of Rajasthan. The Central Soil and water Conservation Research and Training Institute, Dehradun as one of the ICAR institute was also established in 1954 as a central body to conduct different activities regarding the soil conservation and subsequently was recognized into a central institute in the year of 1974. This institute has 8 regional research centres all over country, located at Chandigarh to tackle the Siwalik foot hill problems, ~~Agra~~, Kota, Vasad, Bellary, Oota Chamund, Koraput and Datia.

Similarly, in the second five year plan the soil conservation works such as contour bunding and terracing were made on rapid progress and an area of about 8 lakh hectares was completed. Soil conservation and land use survey was also initiated on about 5 lakh ha land. In addition, soil conservation measures works were also conducted on different catchment areas of major river valleys of the country as a very urgent, due to increasing rate of silt deposition in the reservoirs.

Soil Conservation Research and Training Centres

In India, the research on soil and water Conservation was started around in the thirties of the 20th Century. For the purpose, in 1953 the Government of India set up a Soil Conservation Board, which chairman is Union Agriculture Minister and other members are appointed from different departments and organizations. The main function of this board is to coordinate the soil conservation research Programmes running throughout the country. This board also set up different regional research centres, demonstration & training centres for pursuance of different objectives related to soil conservation. The different research centres and their research problems being dealt, are given as under

Research Centres	Region	Problems to deal
Dehradun (U.P.) Uttarakand	North Western Himalayan Region	Erosion Problems in the Himalayan mountain gullies and torrents control, Stabilization of landslides; development of technology for better crop Production based on conservation Practices; trials grown on severely degraded lands falling in Himalayan regions.
Kota (Rajasthan)	Ravine Problem on the Banks of Chambal river	Survey, Classification and reclamation of ravines of the catchment of Chambal river, establishment of pasture & forest in the areas which have been reclaimed.
Vasad (Gujarat)	Ravine Problem on the banks of Mahi rives (Gujarat)	Control of ravines associated with the Catchment of Mahi rives; Production of crops, forage and forestry in the ravines
Agra (U.P.)	Ravine Problem on the banks of Yamuna river	Survey classification and implementation of control measures in the ravine of Yamuna river, measures for the Production of cereals and fodder. afforestation of the reclaimed land.
Chandigarh	Sub mountain tracts in North western	Erosion control in Siwalik hills; Survey of streams having stream bank erosion

	regions of India with special reference to Siwalik hills.	and measures to Prevent them from overlogging.
Ootachamund (TamilNadu)	Southern hilly high rainfall region	Conservation of soil and water of Nelegiris and Western ghat regions; development of models for Construction of bench terraces Suitable for Potato cultivation, evolution of Suitable techniques, Study of hydrological Conditions under different vegetative covers; development of pastures and tree plantation.
Bellary (Karnataka)	Black soil region (semi-arid)	Soil and water conservation in the tract of black cotton soils of Peninsular India. Development of suitable bunding techniques; Evolution of Suitable methods of cotton cultivation together with soil & water conservation measures.
Ibrahimpatnam (A.P.)	Red soil region (Semi arid)	Problem related to soil & water conservation in Red soil regions; Dry land farming Systems;

Apart from above soil & water conservation Research centres, the Central Arid Zone Research Institute, Jodhpur (Rajasthan) is also conducting several valuable research Programs in the field of soil and water conservation especially for arid zones, the soil conservation centre, Hazaribagh is also dealing the soil conservation problem of Damodar valley area.

Erosion

The word erosion has been derived from the latin word 'erodere' which means eating away or to excavate. The word erosion was first used in geology for describing the term hollow created by water.

Erosion actually is a two phase process involving the detachment of individual soil particle from the soil mass, transporting it from one place to another (by the action of any one of the agents of erosion, viz: water, wind) and its 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).

Soil erosion

Soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment). It is evident that sediment is the end product of soil erosion process. Sediment is, therefore, defined as any fragmented material, which is transported or deposited by water, air or any other natural agent.

The natural sequence of the sediment cycle is as follows:

Soil erosion ⟶ Transportation ⟶ Deposition.

Detachment is the dislodging of the soil particle from the soil mass by erosive agents. In case of water erosion, major erosive agents are impacting raindrops and runoff water flowing over the soil surface. Transportation is the entertainment and movement of detached soil particles (sediment) from their original location.

Types of Erosion

Soil erosion can broadly classified into two groups i.e. geological erosion and accelerated erosion.

Geological Erosion

Natural geological soil erosion represents the erosion of soil in its natural state. Semi-arid and arid soils, which lack protective plant cover, may erode naturally at rates averaging 10-50 times greater than those for humid climate soils. Natural erosion takes place at such a slow pace that a balance is always maintained between soil lost by erosion and soil formed from parent material. Geological erosion is caused mainly by the action of water, wind, temperature and is responsible for soil formations and their distribution on the earth's surface.

Accelerated Erosion

When the natural balance is distributed by human activities, large scale deforestation or leveling of field for cultivation, the process of erosion is increased manifolds. This rapid erosion as a result of human interference is referred to as accelerated erosion or abnormal erosion. Since the erosion on cultivated land is of accelerated type, it can be referred to as soil erosion or simply erosion. Accelerated erosion depletes the soil fertility in agricultural lands. The various forces involved in accelerated erosion are i) attacking forces- which detach and transport the soil particles, and ii) resisting forces- which resist erosion.

Causes and agents of erosion

It is possible to divide the causes of soil erosion into abiotic causes due to inanimate processes & biotic causes which relate to activity of living things. Of the abiotic causes, water & wind are the main agents, while increased human activity has come to dominate the biotic causes resulting into accelerated erosion.

Some of the harmful effects of the soil erosion are

1) Loss of soil fertility and thus effecting the crop productio
2) Rising the beds of streams & rivers thus reducing their capacity and consequently spilling of the flood water into adjoining areas.
3) Silting of the reservoirs & other storage facilities reducing their capacity and useful life.
4) Damage to agricultural land, Railways & roads due to soil deposition.

Causes of Soil erosion

The main causes of soil erosion can be enumerated as 1) Destruction of natural protective cover by

a) Indiscriminate cutting down of trees (deforestation)
b) Overgrazing of vegetative cover
c) Forest fires

2) Improper use of land such as

a) Keeping the land barren subjecting it the action of rain & wind.
b) Growing of crops the accelerate soil erosion.
c) Cultivation along the land slope.
d) Faulty method of irrigation.

Factors influencing water erosion

Removal of soil from land surface by running water is known as water erosion.

The major factors influencing erosion are climate, topography, soil, vegetation and biotic activities. Hence, erosion can be expressed as a function of:

$$\boxed{E = f(C, T, S, V, B)}$$

where E represents the rate of erosion & C, T, S, V & B stand for climate, topography, soil, vegetations & biotic activities respectively.

Climate (C)

Climatic factors affecting erosion are rainfall characteristics, temperature, wind, humidity & solar radiation. Of these, rainfall is one of the most powerful factor causing runoff and soil loss. Rainfall characteristics such as amount, duration, intensity and frequency greatly influence the runoff and erosion.

Topography (T)

Topographical features that influence erosion are degree of slope, length of slope, micro-topography, aspect of slope, size and shape or configuration of a watershed. On flat slopes, erosion is usually not a problem. On steep slopes, erosion is a very serious problem. With increase in the land slope, velocity of flow increases. When the land slope increases 4 times, the velocity of flow gets doubled. If velocity is doubled the erosive or cutting power of water, expressed by kinetic energy as $KE = \frac{1}{2}mv^2$, increases 4 times.

Soils (S)

The response of soil erosion process is complex and is greatly influenced by four soil characteristics, viz. soil texture, organic matter, soil structure & permeability.

a) Soil texture

It refers to the sizes and proportion of the particles making up a particular soil. Sand, silt and clay are the three major fractions of soil particles. The related percentage of these particles in soil determines the soil type.

Soils which are high in sand content are considered as coarse textured. Because water readily infiltrates into the sandy soils, the runoff and consequently erosion potential is relatively low.

Soils with high content of silt and clay are fine textured or heavy clay because of its stickiness. But has low infiltration rate that leads to high runoff and increase erosion.

b) Organic matter:

It consists of plant and animal litter in various stages of decomposition. Organic matter improves soil structure & 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 particles into the aggregates. A granular structure is most desirable one. Soil structure affects the soils ability to adsorb water.

d) Soil Permeability:

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

Vegetation (V)

All types of vegetation ranging from grass to forests, even crop stubble and residue in agricultural fields acts as a cover over the soil surface and provides it a much needed protection against the impact of falling rain drops.

Biological factors (B)

Biological factors that influence the soil erosion are the activities like faulty cultivation practices, overgrazing by cattle etc. These factors influencing the soil erosion have been broadly classified into following 3 groups by Morgan (1986) 1. Energy factors 2. Resistance factors & 3. Protection factors.

1. Energy factors:

They include such factors which influence the potential ability of rainfall, runoff and wind to cause erosion. This ability is termed as erosivity.

2. Resistance factors:

They are also called erodibility factors which depend upon the mechanical and chemical properties of soil.

3. Protection factors:

This primarily focuses on factors related to plant cover. plant cover protects the soil from erosion by intercepting the rainfall & reducing the velocity of runoff & wind.

Forms of erosion / Different Stages of erosion ⓒ

Depending upon the agency causing erosion, it is also ~~calle~~ classified as follows:

1. Water erosion
   a. Raindrop erosion / Splash erosion
   b. Sheet erosion
   c. Rill erosion
   d. Gully erosion
   e. Stream bank erosion
   f. Slip erosion
2. Wind erosion
3. Sea Side or Coastal erosion
4. Landslide erosion.

~~Rain~~ 1. Water Erosion

Removal of soil from land surface by running water is known as "water erosion".

(a) Raindrop erosion

The detachment and splash or transport of the soil particles occuring as a result of impact of falling rain drops is called rain drop erosion. It is also called as splash erosion.

When a rain drop strikes the land surface, it breaks down the clods and detaches the soil particles from soil mass. After this, the fine particles move into suspension & the splash becomes muddy. As the muddy water moves over the soil;

factors affecting the raindrop erosion

1. vegetating cover & mulches
2. Rainfall
3. wind velocity
4. Soil texture & structure
5. Topography &
6. High wind velocity

(b) 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".

(c) Rill erosion

Sheet flow occurs on the land surface mainly when the surface is smooth and ~~the~~ has a uniform slope. Water moves over the land surface and small finger like channels, called "rills" are formed. These rills ~~are~~ can be smoothened by the ~~natural~~ normal cultivation operations.

(d) Gully erosion

This is an advanced form of rill erosion. Gullies are formed due to removal of soil by running water with the formation of channels which cannot be obliterated by normal cultivation or tillage operations because of their depth.

The advanced stage of gully erosion leads to formation of "ravines" near the river systems.

Gully erosion is the removal of soil by excessive concentration of running water resulting in the formations of channels ranging from 30 cm to 10 cm or more size.

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Stage-1: Formation Stage

Channel erosion takes place by downwards scour of the top soil. If the top soil can provide resistance, this stage proceeds slowly.

Stage-2: Development stage

Upstream moment of the gully head and simultaneous enlargement width and depth takes place. The weak parent material in rapidly removed by cutting "C"- horizon.

Stage-3: Healing stage

Vegetation begins to grow in a channel and further erosion ceases.

Stage-4: Stabilization stage

The gully bed and sides reaches a stable slope and sufficient vegetation grows to anchor the soil and to top soil flowing from upstream. New top soil develops and vegetative cover grows.

Classification of Gullies

Gullies are classified as per their cross-sections depending upon the soil, climatic conditions, age of the gully and types of erosion it may be either 'U' shaped or 'V' shaped.

The following classification of gullies based on the drainage areas and gully sizes:

S.No.	Symbol	Description	Specification
1.	G1	Very small gullies	Up-to 3m deep bed width not greater than 18m Side slope vary.
2.	G2	Small gullies	Upto 3m deep bed width greater than 18m, sides uniformly sloping between 8-15%.
3.	G3	Medium gullies	Depth between 3 to 9m bed width not less than 18m Sides uniformly sloping between 8-15%.
4.	G4	Deep & Narrow gullies	a) 3-9m deep bed width less than 18m side slopes vary. b) Depth >9m, bed widths varies, side slopes vary mostly.

Sediment yield

The net difference between net soil loss and net soil deposition is called the sediment yield. The 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 percent of sediment yield to gross erosion. The sediment delivery ratio is always less than 1.

Soil loss Estimation

The Universal Soil Loss Equation (USLE) Wischmeier and Smith, 1965 was developed to predict the soil loss from field-size small areas. This equation does not compute the sediment yield from the watershed, directly.

Annual soil loss from the field, tonnes/ha/year.

$$A = RKLSCP$$

Where R = Rainfall erosivity factor

K = Soil erodibility factor

L = Length

S = Slope

LS = Slope length factor

C = Crop management factor

P = Conservation Practice factor

Erosion is a function of erosivity of rain and erodibility of the soil.

$$\text{Erosion} = f(\text{Erosivity}, \text{Erodibility})$$

Erosivity of rainfall

It is defined as the potential ability of rain to cause erosion and for a given soil condition.

Erodibility

It is defined as the vulnerability or susceptibility of soil to erosion. It depends primarily on the physio-chemical characteristics of the soil. Secondly, it depends on what treatment is given to soil i.e. how soil is being managed.

Slope-length factor (LS)

$$LS = \left(\frac{L}{22}\right)^m (65.4 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

where L = slope length, m

θ = slope angle, degrees (°)

m = exponent

Crop management (C) & Conservation Practice (P) factors

The factors C and P are also the ratio of soil loss under given cover, management and supporting practices to that from a field in contineous fallow with periodic tillage to control weeds and break the crusts, keeping all other conditions unchanged. These two factors (C & P) are dimensionless, and require no use of conversion.

Modified Universal Soil Loss Equation (MUSLE)

To overcome above demerits of USLE regarding Prediction of Sediment yield, williams in 1975 made an effort to modify the USLE fit for Computation of Sediment yield either monthly or Seasonal. He modified the USLE by replacing the rainfall energy factor (R) with another factor called as 'runoff factor'. To make this modification, he used the data of 18. Small watersheds at Riesel, Texes Hastings and Nebraska, which explained about 92 percent variation in sediment yield for 778 individual storms on these watersheds.

The modified Universal Soil Loss Equation is given as:

$$Y = 95\,(Q \cdot q_p)^{0.56} \cdot KLSCP$$

where, Y = Sediment yield for an individual storm (tonnes)

Q = Volume of runoff (acre-feet)

q_p = Peak flow rate (CFS)

K, L, S, C, P are the factors of USLE, which are already defined.