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Water Erosion Causes, Effects and Remediation

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Introduction

Land is an important natural resource, as it is not only a medium for plant growth but also act as a store house of water and nutrients. Soil is the top layer of the earth's surface that is capable of sustaining life. Soil erosion is the process of displacement of the upper layer of the soil. Soil erosion by water and wind together accounts for 87% of the total area affected by various forms of land degradation and desertification in the country. Erosion by water is the most serious process of land degradation and desertification in country. Erosion by water is the chief contributor (45.3%), followed by chemical deterioration (4.2%), wind erosion (4.1%) and physical deterioration (3.5%). On an average, about 5334 million tonnes of soil lost annually through water erosion of which 29% is lost permanently into sea, 10% gets deposited in reservoir reducing their capacity by 1-2% every year, and the remaining 61% displaced from one place to another. The nutrient losses estimated 5.33 million tonnes of N, P and K. Therefore, an agronomical as well as mechanical measure to control erosion of soil by water not only reduces the losses of soil and water but will sustain soil productivity and ultimately increased the crop productivity.

What is erosion?

Soil erosion is defined as a natural process that involves detachment, transport and subsequent deposition of soil particles and small aggregates from land surface by different agency like; wind, water ice or gravity.

Mechanism of water erosion

Detachment needs energy which is mainly supplied by the falling rain drops. Transport of detached soil particles is carried out by flowing water which is caused by the slop of the soil. Soil particles are deposited at new sites.

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Types of water erosion

Rain Splash erosion

This occurs due to the bombardment of raindrops on soil surface. The intensity of the splash erosion depends on the kinetic energy of falling raindrops. As precipitation fills the pore spaces, loosening & driving soil particles apart. Impact of subsequent rain drops hitting the surface.

Sheet erosion

It is uniform removal of soil in thin layers from slopping land resulting from rain splash erosion. The breaking action of raindrop combined with surface flow is the major cause of sheet erosion. Surface runoff forms when the intensity of rainfall exceeds than infiltration capacity of soil.

Rill erosion

When runoff starts, channelization begins and erosion is no longer uniform. Rill erosion caused by runoff water when it creates small, linear depressions in the soil surface and more apparent than sheet erosion. These are easily removed during land tillage.

Gully erosion

They are formed from small depressions, which concentrate water and enlarge until several join to form a channel. It is advance stage of rill erosion in which channels are widens due to force of runoff water. Gullies are the most spectacular symptoms of erosion. Gullies are deep and not removed during normal cultivation with ordinary farm implements. If unchecked, cultivation becomes difficult.

Ravines

Large gullies and their networks are called ravines. These are manifestation of a prolonged process of gully erosion, typically found in the large expanses (area) of deep alluvial soils. They are deep and wide gullies and their formation indicates very advanced stage of gully erosion.

Sea or shore erosion

Tidal waves of sea cause considerable damage to the soil along the sea coast. Broken material is then removed by the retreating sea waves. This type of erosion is seen throughout the eastern and western coast of India.

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Stream-bank erosion

Small streams, rivulets, torrents (hill streams) are subjected to stream-bank erosion due to obstruction to their flow. Vegetation sprouts when the streams dry up and obstructs the flow causing cutting of bank or changing of the flow course. Torrents with flashy flows and swift currents bring uprooted plants and are deposited in the downstream side causing overflowing and stream-bank erosion.

Land slides

Sliding down of large chunk of soil due to steep slopes is called landslides. The fundamental causes of land slides are topography of the region and geological structure, the kind of rocks and their physical characteristics. In this type of erosion when the running water percolates through the crevices of rocks great masses of soils and loose rocks lying on the steep slops slip downwards. The immediate cause of a slide may be an earthquake or a heavy rainfall, which unduly structures the ground or part of road.

Factors influencing erosion

Rainfall

Rainfall influences both the process of detachment and transportation. Amount, intensity, duration and distribution of rainfall influence runoff and erosion. Generally, intensity depends upon size of raindrop. Majority of raindrop (1-4 mm dia.), when raindrop size (7-9 mm dia.) it called Higher intensity of rainfall while Higher intensity with longer duration of rainfall Causes severe soil erosion. Subsequently, water present on the soil receives the beating action of rain drops, the over land flow act as a powerful detaching and transporting agent.

Vegetation

Among the different factors that influence erosion, vegetative cover is more important. The impact of raindrops is absorbed by vegetation present on the soil surface, and therefore, there is no break-down of soil aggregate and thus reducing surface sealing and runoff. Retardation of erosion by decreased surface velocity. Physical restraint of soil movement. The plant roots bind the soil particles. Due to addition of organic matter by vegetation, stable aggregate is formed and porosity of the soil by roots and plant residue which are resistant to break-down.

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Increased biological activity in the soil, and Transpiration, which decreases soil water, resulting in increased storage capacity and less runoff.

Soil characteristic

Erosivity is the capacity of agents causing erosion while Erodibility is the susceptibility of the soil to erosion. Soil Erodibility influence by:

a) Topography

Among them topography is the most important character that influences runoff and sediment transport. Topographic features that influence erosion are degree, shape and length of slope, size and shape of the watershed determine the amount and extent of erosion. On steep slopes, runoff water is more erosive and can more easily transport detached sediment down the slope. On longer slopes, an increased accumulation of overland flow tends to increase rill erosion. Concave slopes, with lower slopes at the foot of the hill, are less erosive than convex slopes.

b) Physical property

The soil physical properties like soil structure and texture influence both detach and transport of soil particles. Soil with stable aggregates are resistant to detachment. Light soil like sandy soil and sandy loams are easy to detach, but difficult to transport as the particles are heavy. In addition, the infiltration rate is high in light soil and runoff is less. With higher clay content of heavy soils, detachment is difficult, but transportation is easy because most of the particles are light in weight. The infiltration rate is also less unless these soils have deep cracks. Erosion results in an increased sand content and decreased colloidal fraction of organic matter content of soils as organic matter and colloidal particles are light and susceptible to transport. In general, runoff and soil loss increases with increasing fineness of soil texture. Soil compaction by agricultural machinery increases bulk density, soil erodibility as it decreases infiltration. Compacted sub soils or hard pans impede infiltration, and so contribute to surface runoff and soil erosion. The quantity of soil lost by erosion is proportional to the volume of water flow in runoff. Moist soils are most susceptible to water erosion than dry soils because of higher runoff.

c) Chemical and biological property

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The chemical and biological properties of soils influence soil erosion through their effect on soil aggregation and dispersal. Soil with higher cation exchange capacity, calcium and magnesium content on the exchange complex, have favorable influence on the soil structure and are, therefore, less susceptible to erosion. Soils with high salt and sodium content are susceptible as they cause soil dispersion. Organic matter plays important role in soil erosion prevention by act as a cementing agent that binds soil particles together. It protect the Soil against compaction and erosion by improving soil structure, increase water and nutrient holding capacity and healthy communities of soil organisms.

Man and beast

Man and beast accelerated erosion by extensive farming and excessive grazing. Practices like cultivation on steep slops, cultivation along the slop, cutting and burning of forests lead to heavy erosion. Excessive grazing destroys all vegetation, leaving the land bar for ravages of erosion.

Some of the adverse impacts of soil erosion by water are

1) On site effect

Loss of rain water: rain water is the only source of crop production in dry land agriculture. Runoff water leaving the cultivated fields is loss of an important natural resource. It removes fertile top soil rendering the eroded area poorly productive. Crop emergence, growth and yield are directly affected through the loss of natural nutrient and applied fertilizers with soil. Seeds and plants can be disturbed or completely removed from the eroded site. Largest part of organic matter can be found in the fertile top soil, its content highly reduced when top soil is eroded. Soil quality, structure, stability and texture affected by loss of soil. Long-term soil erosion results in exposure of light coloured subsoil at the surface.

2) Off site effect

Eroded soil deposited down slop can inhibit or delay the emergence of seeds, bury small seedling and necessitate replanting in the affected area. Pesticide and fertilizers frequently transported along with the eroding soil can contaminate or pollute downstream water resources and recreational area. Sediment can be deposited on down slope properties and contribute to road damage. It causes sedimentation of the downstream river reaches that in turn changes flow section, slows down the flow rate and increases pollution hazard. Gradual deposition of silt at

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the downstream river reaches raises the river bed elevation and causes flood hazard. Sediments which reach streams can accelerated bank erosion, clog drainage ditches and stream channels and cover fish spawning ground. Sedimentation of the reservoirs built across rivers reduces their live storage capacity, which adversely affects drinking water supply projects, irrigation projects and hydro-electric projects depending on the reservoir water. High rate of siltation in dams and reservoir leads to high maintenance cost and shortens the life of the construction. High level of chemical in ground water and water bodies can seriously decline the quality of drinking water.

Management strategies that minimize water erosion

A) Agronomical measures

Choice of crop

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. Whereas 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.

Cropping system

Mono cropping by erosion permitting crops accelerates soil and water loss year after year. Therefore, cropping system is better to reduce water erosion and restore soil fertility. Intercropping by erosion resistant crops which have been found effective for soil conservation. Cover crops reducing soil erosion it is used as intercrops with widely space crops can gave protection against water erosion. In multiple cropping systems, where the soil is covered with crops all through the year, there may be runoff but soil loss is minimum as the falling rain drops are intercepted by the crops.

Cover crops

The practice of growing crops to cover the soil surface to reduce wind and water erosion is called cover cropping. Good ground cover by canopy gives the protection to the land like an umbrella and minimizes 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

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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 horse gram, green gram, black gram and dhaincha.

Strip cropping

Strip cropping is a system of crop production in which long and narrow strips of erosion resistant crops (close growing crops) are alternated with strips of erosion permitting crops (erect growing crops). The strips are laid across the slope. Strips of close growing crops reduce the transporting and eroding power of water by forming obstruction to runoff and filter out the soil from the runoff and retain it in the field. This method becomes more effective for erosion control, in the area where terraces are not practically feasible and length of slope is not too longer.

Mulching

Mulching of soil with available plant residues reduce soil loss considerably by protecting the soil from direct impact of raindrop and reducing sediment carried with runoff. Spreading on the bare soil surface or placement of plant materials such as dry grass, straw, dry leaves, banana leaves, sugar cane trash, and other crop residues around the stem of the plants is helpful in controlling soil erosion by check runoff on soil surface and increase the infiltration rate.

Tillage practice

Tillage Improve soil structure, increase infiltration rate of soil, obstruction to surface flow and consequently reduced the rate of erosion and runoff. Increase depth of soil for moisture storage. Soil leveling can be maintained by tillage practice. Create furrow dikes across the slope of field. Deep ploughing or chiselling has been found effective in reducing erosion by rough cloddy soil surface. Preventing or reducing soil compaction and increasing the residue cover by reducing intensity and frequency of soil management operations and introducing conservation, contour, strip, mulch or minimum tillage.

Ridge and furrows and Tied ridging

Furrows of 30-45 cm width and 15-20 cm height are formed across the slope. The furrows guide runoff water safely when rainfall intensity is high and avoid water stagnation. They

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collect and store water when rainfall intensity is less. It is suitable for medium deep to deep black soils and deep red soils. It is not suitable for shallow red, black soils and sandy/ gravelly soils. It can be practiced in wide row spaced crops like cotton, maize, chilies, tomato etc.

Tied ridging:

It is a modification of the system of ridges and furrows wherein the ridges are connected or tied by a small bund at 2-3 m interval along the furrows to allow the rain water collection in the furrows which slowly percolated in to the soil profile.

Broad bed furrows (BBF)

This practice has been recommended by ICRISAT. It is mainly for vertisols or black soils in high rainfall areas (>750 mm). Beds of 90-120 cm width, 15 cm height and convenient length are formed, separated by furrows of 60 cm width and 15 cm depth. When runoff occurs, its velocity will be reduced by beds and infiltration opportunity time is increased. It can be formed by bullock drawn or tractor drawn implements. It help in moisture storage. Safely dispose off surplus surface runoff without causing erosion. Provide better drainage facilities. Facilitate dry seedling. It can accommodate a wide range of crop geometry i.e., close as well as wide row spacing. It is suitable for both sole cropping and inter-cropping systems.

Compartmental bunding

Small bunds of 15 cm width and 15 cm height are formed in both directions to divide the field into small basins or compartments of square or rectangular shape of 6×6 m to 10×10 m size using bund former. They are useful for temporary impounding of rain water which facilitates high infiltration resulting high moisture storage in the soil. Recommended for black soils with a slope 0.5 to 1%. Maize, sunflower, sorghum performs well in this type of bunding.

Contour Cultivation

Contour cultivation includes contour ploughing, sowing and other intercultural operations, by ploughing and sowing across the slope. Each ridge of plough furrow and each row of the crop act as an obstruction to runoff, providing more opportune time for water to enter into the soil and reduce soil loss. Contour cultivation is a very simple practice and can easily be practiced. In unbunded areas, cultural operations can be done across the general slope.

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Application of Chemicals

Soils with stable aggregates resist break down and thus resist erosion. Aggregate stability can be increased by spraying chemicals like polyvinyl alcohol however, the rate depending on the type of soil. Soils treated with bitumen increase water stable aggregates and infiltration capacity of the soil.

Application of manure and fertilizers

However, practical method of increasing stability of aggregates is by application of organic matter, farmyard manure, crop residues, green manure etc. Applying organic matter as a way of achieving and maintaining soil fertility which effects an improved the cohesiveness of the soil, an increased water retention capacity and a stable aggregate structure. The crumb and granular structure increases the infiltration and permeability in the soil and conserve the soil water. Consequently soil erosion decreases. Soil stabilizers: Improving soil structure by applying soil conditioners which may take the form of polyvalent salts such as gypsum, which bring about flocculation of clay particles, organic by-products or synthetic polymers, which both bind the soil particles into aggregates.

B) Agrostological measures

Cultivation of grasses (ley farming) is the method consists in growing grasses in rotation with agricultural crops. Grasses prevent soil erosion by intercepting rainfall, by binding the soil particles and by improving soil structure. This practice is recommended for Nilgiris and similar places which are subjected to very severe soil erosion.

C) Agroforestry measures

Planting of trees or shrubs or protecting the naturally sustaining trees along with the crops called agro forestry. Trees decrease the magnitude of splash erosion by reducing the raindrops impacts on the soil. They regulate soil temperature by shading the soil thus reducing the water evaporation. They also minimize the wind erosion by acting as wind breaks. They also play important role in nutrient recycling in the deep soil, leguminous trees fix nitrogen that benefits food crops. Incorporating trees within a farming system by planting them on land that is not suitable for crop production where trees help to preserve the fertility of the soil through the

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return of organic matter and the fixation of nitrogen, improve the soil's structure, and help to maintain high infiltration rates and greater water-holding capacity.

D) Mechanical measures

Contour Bunding

Building earth banks of 1.5-2 m width, thrown across the slope to act as a barrier to runoff, to form a water storage area on their upslope side and to break up a slope into segments shorter in length than is required to generate overland flow. It is most popular in the hilly area of the country. Contour bunding consists of narrow based trapezoidal bunds on contours to impound runoff water behind them so that it can gradually infiltrate into the soil for crop use. Contour bunding is generally recommended for areas receiving low rainfall areas (<600 mm) and for permeable (light textured) soils up to slopes of about 6%.

Graded Bunding

Graded bunds or channel terraces are constructed in high rainfall areas of >600 mm and for poor permeable (heavy textured) soil where excess water has to be removed safely from the field to avoid water stagnation. In case of highly impermeable soils like deep black soils graded bunds are recommended even in lesser rainfall area (500 mm).

Bench Terracing

It is practiced in steep hill slopes, where only reduction of slope length is not adequate for reducing the intensity of scouring action of runoff flowing down. In addition to slope length reduction, the degree of slope is also reduced. Bench terracing consists of transforming relatively steep land into a series of level strips or platforms across the slope to reduce the slope length and consequently erosion. The field is made into a series of benches by excavating soil from upper part and filling in the lower part of the terrace. It is normally practiced on slopes from 16 to 33%. Depending on soil, climate and crop requirements bench terraces may be table top or level, sloping outwards or sloping inwards.

Grassed Waterways

Grassed waterways are drainage channels either developed by shaping the existing drainage ways or constricted separately to agricultural lands. They are used to handle runoff discharge from graded bunds, broad base terraces and bench terraces etc. Provide drainage to agricultural

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fields. To convert gullies or unstable channels into stable channels by providing grass cover for leading water at non-erosive velocity into farm pond. Grassed waterways are generally dug to a shallow depth of 0.15 to 0.5 m with flat sides slope of 4:1 and gradient depend on the existing slope of the land. Suitable perennial grasses for waterways are *cynodon dactylon, cynodon plactostachium* and *panicum repens.*

Conclusion

Soil and water can be efficiently conserved by agronomic and mechanical measures viz., choice of crop, cropping system, land configuration, contour cultivation, strip cropping, mulching, use of organic manures, fertilizers, bunding, terracing, contour trenching, vegetative barrier, agrostological and agro forestry with integrated approaches of available resources can be advantageous for reducing a large amount of runoff, soil losses, increase infiltration rate and also improve soil fertility. Thus, it enhances the crop yield in a sustainable basis for longer period of time.