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SOIL EROSION - CAUSES, EFFECTS, AND PREVENTION

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ABSTRACT

Soil erosion is agriculture's enemy: a major environmental threat to sustainability and productivity with knock-on effects on the climate crisis and food security. Protection against soil erosion through sustainable land management can solve a multitude of problems.

Soil erosion is a continuous process that occurs either slowly or at an alarming rate. It results in a continuous loss of topsoil, ecological degradation, soil collapse, among other things. The purpose of this paper is to discuss the causes, effects, and preventive measures of soil erosion. Responsible soil management techniques are critical to protecting land from soil erosion.

Keywords: Soil Erosion, Soil, Farm Management.

1. INTRODUCTION

Soil erosion is the process of wearing away of the surface layer, or topsoil, by the transportation of the surface particles under the mechanical actions of agents/physical sources such as wind and water. [1] It can cause a great many problems for homeowners and farmers by threatening the viability of their gardens and agricultural land. Simply put, soil erosion strips a piece of land of its valuable natural resources. [2] Soil erosion is agriculture's enemy: a major environmental threat to sustainability and productivity with knock-on effects on the climate crisis and food security. Protecting against soil erosion through sustainable land management can solve a multitude of problems. [3] Soil erosion is a continuous process that occurs either slowly or at an alarming rate. It results in a continuous loss of topsoil, ecological degradation, soil collapse, etc. [4]

2. CAUSES OF SOIL EROSION

Soil erosion involves a gradual wearing away of the soil surface, rocks, and pebbles. This movement in turn removes most of the organic matter and key nutrients from the soil. Consequently, the soil quality is degraded, crop yields are reduced, and the rooting depth of plants and crops is decreased. [2] Agents responsible for soil erosion are the same as agents of all types of erosion: water, wind, ice, or gravity. Running water is the leading cause of soil erosion because water is abundant and has tremendous power. The wind is also a leading cause of soil erosion as it can pick up soil and blow it far away. Activities that remove vegetation, disturb the ground or allow the ground to dry increase erosion. [5]

Both water and wind can erode soils, carrying valuable topsoil downstream or downwind. Water erosion happens most often on sloping ground that is bare and exposed to the elements. Erosion

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by wind occurs primarily in areas with high prevailing winds, such as on hilltops, over flat prairies, and along the ocean. [1] The following are the important causes of soil erosion:

Wind

Wind erosion is the result of material movement by the wind. There are two main effects. First, wind causes small particles to be lifted and therefore moved to another region, a phenomenon known as deflation. Second, these suspended particles may impact solid objects causing erosion by abrasion (ecological succession). Wind erosion occurs in areas with little or no vegetation, often in areas where there is insufficient rainfall to support vegetation. An example is the formation of sand dunes, on a beach or in a desert. Windbreaks (such as big trees and bushes) are often planted by farmers to reduce wind erosion. [1] Soil drifting or wind erosion is when high air velocity, close to the ground, causes the removal, transportation, and deposition of topsoil. Too much wind is often a problem on flat land with drier climates. [2]

Water

Water erodes soil in two ways: one is by the action of raindrops breaking the soil surface into tiny crumbs that are splashed and set in motion by the force of the raindrops. Although not seriously damaging in itself, this acts as the beginning of more serious erosion. The other way water erodes soil is by its cutting and carrying power as it courses downhill. The more concentrated the water is, the faster and more damaging the erosion. This type of erosion can dig up slopes overnight and create huge gullies in days. Because of the power of large amounts of water, it is difficult to stop erosion in steep gullies. The only ways to do it are to construct retaining walls to slow the flow of water or fill the gully with large rocks or other objects too large to be moved by water.

However, it is easy to stop erosion where the water has not had an opportunity to build up force. It can be done by placing a protective cover over the soil or by shaping the land to eliminate the slope. [1] Sometimes, the soil gets carried away by heavy rain or irrigation water. Water erosion could be either sheet erosion (caused by direct rainfall) whereby the soil materials get removed uniformly from the top layer or rill erosion (caused by poor surface drainage) whereby little streamlets of water cause rills and gullies. [2]

Tillage

Usually, tillage erosion occurs when any tilling activity drags the soil downhill. The extent of damage depends on the grade of the slope and the depth of the tillage. [2]

Agriculture/Farming

Agriculture is the most significant activity that accelerates soil erosion because of the amount of land that is farmed and the extent to which farming practices disturb the ground. Farmers remove native vegetation and then plow the land to plant new seeds. Because most crops grow only in spring and summer, the land lies fallow during the winter. Of course, winter is also the stormy season in many locations, so wind and rain are present to wash soil away. Tractor tires make deep grooves, which are natural pathways for water. Fine soil is blown away by wind. The soil that is most likely to erode is the nutrient-rich topsoil, which degrades the farmland. [5]

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Farming practices are the major cause of soil erosion. Agricultural activities disturb the ground. Trees are cleared, and the land is ploughed to sow new seeds. Since most of the crops are grown during the spring season, the land lies fallow during winters. Most of the soil is eroded during winters. Moreover, the types of tractors make grooves on the land, making a natural pathway for water. Fine soil particles are eroded by wind. [4]

Grazing

Grazing animals wander over large areas of pasture or natural grasslands eating grasses and shrubs. Grazers expose soil by removing the plant cover for an area. Animals also churn up the ground with their hooves. If too many animals graze the same land area, the animals' hooves pull plants out by their roots. A land is overgrazed if too many animals are living there. [5]

Logging and Mining

Logging removes trees that protect the ground from soil erosion. The tree roots hold the soil together and the tree canopy protects the soil from hard falling rain. Logging results in the loss of leaf litter, or dead leaves, bark, and branches on the forest floor. Leaf litter plays an important role in protecting forest soils from erosion. Much of the world's original forests have been logged. Many of the tropical forests that remain are currently the site of logging because North America and Europe have already harvested many of their trees. Soils eroded from logged forests clog rivers and lakes, fill estuaries, and bury coral reefs. Surface mining disturbs the land and leaves the soil vulnerable to erosion. [5]

A large number of trees are cut down to carry out the logging process. Trees hold the soil firmly. The canopy of the trees protects the soil from heavy rainfall. The leaf litter that protects the soil from erosion is also lost during logging. Mining activities also disturb the land and leave the soil more prone to erosion. [4]

Construction

Constructing buildings and roads churns up the ground and exposes soil to erosion. In some locations, native landscapes, such as forest and grasslands, are cleared for construction purposes, which exposes the soil, making it vulnerable to erosion. Near construction sites, dirt, picked up by the wind, is often in the air. Completed construction can also contribute to erosion. [5]

Recreational Activities

Recreational activities may accelerate soil erosion. Road vehicles disturb the landscape, and the area eventually develops bare spots where no plants can grow. In some delicate habitats, even hikers' boots can disturb the ground, so it is important to stay on the trail. Other examples are ATVs churning up the soil, accelerating erosion, and hiking trails becoming eroded. Soil erosion is as natural as any other type of erosion, but human activities have accelerated soil erosion. In some locations, soil erosion may occur about 10 times faster than its natural rate. Since Europeans settled in North America, about one-third of the topsoil in the area that is now the United States has eroded away. [5]

Rainfall and Flooding

Higher intensity of rainstorms is the primary cause of soil erosion. Four types of soil erosion are caused by rainfall:

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- Rill erosion
- Gully erosion
- Sheet erosion
- Splash erosion.

Raindrops disperse the soil, which is then washed away into the nearby streams and rivers. Regions with very heavy and frequent rainfall face a large amount of soil loss. The flowing water during floods also erodes a lot of soil by creating potholes, rock-cut basins, and so on. [4]

Rivers and Streams

The flowing rivers and streams carry away the soil particles leading to V-shaped erosion activity. [4]

Types of Erosion [6]

The word erosion is derived from the Latin *rodere* meaning to 'gnaw,' the same root that gives us the word 'rodent.' The main agents of erosion are water, wind, and gravity. Erosion is a natural process but is often intensified by human land-use practices. Listed below are the different types of erosion.

Water erosion

The north coast's high rainfall makes the region's soils vulnerable to water erosion. High-intensity destructive storms are responsible for a significant proportion of the erosion.

Splash erosion

Splash erosion is the first stage of the erosion process. It occurs when raindrops hit bare soil. The explosive impact breaks up soil aggregates so that individual soil particles are 'splashed' onto the soil surface. The splashed particles can rise as high as 60 cm above the ground and move up to 1.5 meters from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms a crust that reduces infiltration and increases runoff.

Sheet erosion

Sheet erosion is the removal of soil in thin layers by raindrop impact and shallow surface flow. It results in the loss of the finest soil particles that contain most of the available nutrients and organic matter in the soil. Soil loss is such a gradual process that the erosion usually goes unnoticed, but the cumulative impact accounts for large soil losses. Soils most vulnerable to sheet erosion are overgrazed and cultivated soils where there is little vegetation to protect and hold the soil. Early signs of sheet erosion include bare areas, water puddling as soon as rain falls, visible grassroots, exposed tree roots, and exposed subsoil or stony soils. Soil deposits on the high side of obstructions such as fences may indicate active sheet erosion. Vegetation cover is vital to prevent sheet erosion because it protects the soil, impedes waterflow, and encourages water to infiltrate into the soil. The surface water flows that cause sheet erosion rarely continues for more than a few meters before concentrating into rills.

Rill erosion

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Rills are shallow drainage lines less than 30 cm deep. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is common in bare agricultural land, particularly overgrazed land, and in freshly cultivated soil where the soil structure has been loosened. The rills can usually be removed with farm machinery. Rill erosion can be reduced by decreasing the volume and speed of surface water with grassed waterways and filter strips, ripped mulch lines, and contour drains. Rill erosion is often described as the intermediate stage between sheet erosion and gully erosion.

Gully erosion

Gullies are channels deeper than 30 cm that cannot be removed by normal cultivation. They can be spectacular to look at but over time, actually lose less soil than sheet and rill erosion. Gullies form when smaller water flows concentrate and cut a channel through the soil. Most gullies extend to reduce soil erosion upslope as a result of the head of the gully being continually undercut and collapsing. However, the collapse and slumping of sidewalls usually contribute to a greater proportion of soil loss.

Tunnel erosion

Tunnel erosion occurs when surface water moves into and through dispersive subsoils. Dispersive soils are poorly structured, so they erode easily when wet. The tunnel starts when surface water moves into the soil along cracks or channels or through rabbit burrows and old tree root cavities. Dispersive clays are the first to be removed by the water flow. As the space enlarges, more water can pour in and further erode the soil. As the tunnel expands, parts of the tunnel roof collapse leading to potholes and gullies. Indications of tunnel erosion include water seepage at the foot of a slope and fine sediment fans downhill of a tunnel outlet. Remediation actions include breaking open existing tunnels, revegetation, and increasing soil organic matter. Extensive earthworks may be required.

Wind erosion

Wind erosion refers to the detachment and movement of soil particles by air moving at least 20 km per hour. Wind moves the soil in two ways, suspension and saltation. Suspension occurs when the wind lifts finer particles into the air leading to dust storms. Saltation occurs when the wind lifts larger particles off the ground for short distances, leading to sand drifts. Wind erosion tends to occur most in low rainfall areas when the soil's moisture content is at the wilting point or below, but all drought-stricken soils are at risk. Often the only evidence of wind erosion is an atmospheric haze of dust comprising fine mineral and organic soil particles that contain most of the soil nutrients. Actions to minimize wind erosion include improving soil structure so the wind cannot lift the heavier soil aggregates, retaining vegetative cover to reduce wind speed at the ground surface, and planting windbreaks to reduce wind speed. Also, one should be prepared for severe wind erosion seasons which tend to be the summers following dry autumns and winters.

Mass movement

Mass movement is the downward movement of soil and rock under the influence of gravity. It is most frequent on slopes above 25 degrees with little vegetation and annual rainfall over 900 mm and often occurs after heavy storms when soil becomes waterlogged and heavy. A mass

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movement is a major form of natural land degradation in some regions, including the NSW north coast due to its intense rainfall events. Types of mass movement include soil creep, earth flow, slumps, landslips, landslides, and avalanches. Factors increasing mass movement include erosion or excavation undermining the foot of a slope, weight loads of buildings or embankments, and loss of stabilizing roots through the removal of vegetation. Vegetation removal may also increase soil water levels and soil water pressure, reducing the cohesive strength of the soil. In clay soils with high shrink-swell capacity, water enters the soil through cracks and then swells the subsoil, increasing its weight on the slope. Early signs of mass movement include previous movement, bare soil 'scars' across slopes, and stock tracks causing cracks or minor terracing. Old or dormant landslips are characterized by long, uneven hummocky slopes and bent tree trunks on steep slopes. Because gravity is the principal force in mass movement, expert advice is needed to remedy the affected land. Remediation actions include diverting water away from slip-prone areas, fencing off suspect areas, and revegetating with trees and perennial pastures.

Effects of soil erosion

Soil erosion results in a gradual loss of soil to natural elements such as wind and water—degrading it over time. Unfortunately, soil erosion affects not just one's immediate property but the entire area too. If one does not protect one's soil from erosion, its effects can soon resound throughout their neighborhood. [2]

3. THE MAJOR EFFECTS OF SOIL EROSION INCLUDE:[4]

Loss of Arable Land

Soil erosion removes the top fertile layer of the soil. This layer is rich in the essential nutrients required by plants and the soil. The degraded soil does not support crop production and leads to low crop productivity.

Clogging of Waterways

The agricultural soil contains pesticides, insecticides, fertilizers, and several other chemicals. This pollutes the water bodies where the soil flows. The sediments accumulate in the water and raise the water levels resulting in flooding.

Air Pollution

The dust particles merge in the air, resulting in air pollution. Some of the toxic substances such as pesticides and petroleum can be extremely hazardous when inhaled. The dust plumes from the arid and semi-arid regions cause widespread pollution when the winds move.

Desertification

Soil erosion is a major factor for desertification. It transforms the habitable regions into deserts. Deforestation and the destructive use of land worsen the situation. This also leads to loss of biodiversity, degradation of the soil, and alteration in the ecosystem.

Destruction of Infrastructure

The accumulation of soil sediments in dams and along the banks can reduce their efficiency. Thus, it affects infrastructural projects such as dams, embankments, and drainage.

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Other effects include the following: [2]

- Silt build-up at the bottom of driveways
- Clogging of drainage and storm drains
- interference with swimming pool maintenance and driveway stability.

4. HERE IS A DEEPER LOOK AT THE CAUSES AND SOLUTIONS TO PREVENT SOIL EROSION:

Why Is Soil Erosion Such a Big Problem?

Soil is a natural resource that may look robust and endless but is in fact the fragile product of thousands of years of formation. Topsoil, which lies closest to the surface of the land, contains essential nutrients for crops. It is this layer of soil that is endangered by wind and water erosion. Soil erosion decreases soil fertility, which can negatively affect crop yields. It also sends soil-laden water downstream, which can create heavy layers of sediment that prevent streams and rivers from flowing smoothly and can eventually lead to flooding. Once soil erosion occurs, it is more likely to happen again.

This is a global problem. Soil is eroding more quickly than it is being formed, causing land to become unsuitable for agriculture, a particularly serious concern in a world where the population is expected to top 9 billion by midcentury. Smarter land management is a necessity. [3]

How Does Soil Erosion Affect Climate Change?

Erosion degrades the land, which means it can support fewer plants that can take in climate-warming carbon dioxide. Soils themselves could potentially sequester enough greenhouse gases in a year to equal about 5% of all annual human-made GHG emissions. Better land management can help keep soils intact so they can grow more carbon-sucking vegetation. This is already happening in China, where the Grain-for-Green project in the Yellow River basin has conserved soil and water and reduced carbon emissions.

On the other side, unchecked climate change can worsen erosion. A report from the Intergovernmental Panel on Climate Change (IPCC) found that when cultivated without conservation practices, the soil is currently eroding up to 100 times quicker than it is forming. The risk of erosion will become even higher in the future due to emissions-driven temperature changes, with resulting decreases in agricultural production, land value, and human health. [3]

What Are the Impacts of Soil Erosion?

We are already seeing the risks of soil erosion play out around the world. Jakarta's deadly floods earlier this year are a prime example. Eroded sediments from further upstream clogged Jakarta's rivers and canals, causing them to overflow. Similar erosion-related floods have occurred in many other countries, such as Colombia, India, the Philippines, and the Democratic Republic of the Congo.

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Soil erosion is not only an environmental issue; it also causes huge losses to the economy. One study estimated global economic losses from soil erosion to be around $8 billion, due to reduced soil fertility, decreased crop yields, and increased water usage. In Java, Indonesia, soil erosion is responsible for a 2% loss in total agricultural GDP, taking into account the losses farmers face directly and the losses others face downstream. Another study revealed that soil erosion in Sleman, a district located in Java, costs 17% of an average farmer's net income per hectare of agricultural land.

The U.S. agricultural sector loses about $44 billion per year from erosion. This value includes lost productivity, along with sedimentation and water pollution. Lost farm income is estimated at $100 million per year. Soil erosion also costs European countries $1.38 billion in annual agricultural productivity losses and $171 million in lost GDP (about 1% of total GDP). South Asia loses $10 billion annually thanks to soil erosion. [3]

What Solutions Exist to Prevent Soil Erosion?

1. Use Soil-friendly Agricultural Practices

Terraced farming needs to be implemented to make hillside agriculture manageable. Terraces prevent erosion and allow more water to flow to crops. Additionally, hillside farm fields need full crop cover to help keep the soil in place. This can be accomplished by intercropping, which means growing two crops together in the same field, such as planting rows of maize or soybean between rows of oil palm trees. For smallholders, agroforestry systems where a diverse set of crops, including trees, are grown together can be effective. Access to manure improves the organic matter of the soil, which inhibits erosion. Finally, alternating deep-rooted and shallow-rooted crops improves soil structure and reduces erosion at the same time. [3]

2. Offer Incentives for Land Management

Although the science of sustainable land management has been gaining support, the socio-economic context often makes implementation difficult. Sustainable land practices need to be financially viable for farmers. Anti-erosion measures have a median cost of $500 per hectare, a considerable investment for a farmer. Governments and banks must help farmers gain access to credit and support in implementing erosion prevention. This would not only be a profitable deal for the farmer but for the whole community. The cost of erosion prevention is far lower than the price of land restoration and rehabilitation, which one source estimated to be around $1,500–$2,000 per hectare. Another source found it could reach $15,221 per hectare. [3]

3. Prevention and Rehabilitation

The key to managing and reducing soil erosion is to rehabilitate already damaged land, stop further degradation, and put erosion-preventative measures at the core of land management policy. In this manner, we can help prevent hunger and mitigate the climate crisis. [3]

5. METHODS TO PREVENT SOIL EROSION

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Soil erosion is a serious environmental issue. Steps should be taken to curb this problem. The beginning of preventing erosion is to break the force of raindrops on bare soil by covering the soil with something. Following are some of the methods of soil erosion prevention:

While it is impossible to control wind and rain and stop erosion completely, there are some techniques to prevent soil erosion. It should be remembered that these land management measures depend on the type of soil one has, the area's topography, climatic conditions, along with other factors. [1]

Plant vegetation

Plant vegetation as ground cover: trees and grass help bind the soil through their roots, preventing soil movement. Plants such as herbs, wildflowers, small trees, and creepers prevent wind, soil, and water erosion by covering the soil to a large extent. [4]

Mulches

Mulches are quick and easy to apply, inexpensive, and quite effective. Raindrops that hit a mulch are reduced to a gentle trickle when they reach the soil and sink into the soil rather than running over its surface. However, most mulches must be reapplied at regular intervals. If erosion is a serious problem, such as on steep hillsides or regions that receive torrential downpours, select a coarse or fibrous mulch, such as bark chunks, straw, or pine needles. The mulch can be held in place with erosion control netting on steep hillsides. [1]

Ground covers

Ground covers take longer to establish than a mulch but are longer lasting. Lawns make ideal ground covers to prevent erosion. Their closely spaced blades keep water from picking up enough speed to cut into the soil regardless of the steepness of the slope. Ground covers that root where branches touch the ground or that spread from runners or roots eventually form dense mats that effectively prevent erosion. [1]

Erosion control netting

Erosion control netting is designed to keep water from picking up speed as it flows down a slope. Due to the open space, these nettings do not protect the soil from raindrop erosion. Because they can be pegged to even the steepest slopes, they can be used in almost any situation. Erosion control netting may be made of jute or polyethylene. Both degrade but under different conditions. Jute rots when it is damp and will disappear after 2 or 3 years in all but the driest areas. Polyethylene degrades when exposed to sunlight. It also disappears in a few years, but only if exposed to sunlight. Buried in the soil or under a mulch, it can persist for years. Netting is pegged in place with wooden pegs made for the purpose, which also rot in a few years. An erosion control project might utilize any or all three of these methods. For example, you might hold a steep bank in place with jute netting spread over a couple of inches of straw mulch and plant a ground cover in the holes of the netting. By the time the netting rots, the ground cover will be established. [1]

Breaking the Slope

Another way to handle erosion is by shaping the land into terraces. This is a time-consuming and expensive solution but allows land to be used for gardening that might otherwise be unavailable.

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Low retaining walls—those under 2 or 3 feet high—are simple to build. Higher walls bear more weight and should be designed by an engineer. To keep the job simple, it should be designed with a greater number of but lower walls. [1]

Control Wind Erosion

Although a serious region-wide problem in some areas, few gardens outside of these areas experience wind erosion. The most common troubling situations are presented by seaside and hilltop gardens. Soil can be protected from wind erosion by two of the same three methods used to protect the soil from water erosion: mulch and a plant cover. Selecting a mulch with particles heavy enough to stay in place in the wind helps. Almost any ground cover will keep soil from being shifted by the wind, but not all ground covers will thrive in windy locations. One can check with their local nursery for ground covers suited to one's area. [1]

6. CONCLUSION

Although soil erosion is a natural process, human activities have accelerated it. The agents of soil erosion are the same as other types of erosion: water, ice, wind, and gravity. Soil erosion is more likely where the ground has been disturbed by agriculture, grazing animals, logging, mining, construction, and recreational activities. It is impossible to completely prevent erosion from taking its course. However, there are many ways to keep the process under control. Plans suited to a particular site are required. Working out practical methods of control and preventive measures can reduce soil erosion in the best possible way. When soil is bare, it has the highest chance of serious soil erosion.

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