Soil Erosion- Causes and Effects

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Soil Erosion – Causes and Effects

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Objectives:

Soil is the most fundamental and basic natural resource for all life to survive. Water and wind erosion are two main agents that degrade soils. Runoff washes away the soil particles from sloping and bare lands while wind blows away loose and detached soil particles from flat and unprotected lands. *Geologic erosion* is a normal process of weathering that generally occurs at low rates in all soils as part of the natural soil-forming processes. Magnitude and the impacts of soil erosion on productivity depend on soil profile and horizonation, terrain, soil management, and climate characteristics. There are so many factors and processes are responsible for soil erosion. The major objective of studying this lesson is to understand the causative factors of soil erosion and their effects.

1. Introduction:

Soil erosion is an important social and economic problem and an essential factor in assessing ecosystem health and function. Soil erosion is one of the naturally occurring problems in soils. It will affect all landforms. Soil erosion may also happen through forces associated with farming activities such as tillage. Topsoil, which is rich in organic matter, high fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried "off-site" where it fills in drainage channels. Soil erosion reduces cropland productivity.
Soil erosion contributes to the pollution of adjacent watercourses, wetlands and lakes.

2. Definition:

Soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind.
It can be a slow process. It is relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil.
Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinisation and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process.
Soil Erosion, whether it is by water, wind or tillage, involves three distinct actions – soil detachment, movement and deposition.
Accelerated erosion is largely the consequence of human activity. The primary causes are tillage, grazing, and cutting of timber. The rate of erosion can be increased by activities other than those of humans. Fire that destroys vegetation and triggers erosion has the same effect.

3. Gobal Problem:

Erosion is a major problem affecting soils all over the world.
The rapid growth of the world's population has resulted in increased cultivation of land. This puts more pressure on land and leads to soil losing its structure and cohesion, which means that it can be eroded more easily.
Heavy farming machinery can also 'compact' soil, which causes water to run straight off the surface after rain, taking soil particles with it, instead of infiltrating into the soil.
The total land area subjected to human-induced soil degradation is estimated at about 2 billion ha. Of this, the land area affected by soil degradation due to erosion is estimated at 1100 Mha by water erosion and 550 Mha by wind erosion.

4. Gravity Erosion

Mass-Wasting is the down-slope movement of rock and sediments, mainly due to the force of gravity. Mass-wasting is an important part of the erosional process, as it moves material from higher elevations to lower elevations where transporting agents like streams and glaciers can then pick up the material and move it to even lower elevations. Mass-wasting processes are occurring continuously on all slopes; some mass-wasting processes act very slowly.
Slumping happens on steep hillsides, occurring along distinct fracture zones, often within materials like clay, that, once released, may move quite rapidly downhill.
Surface creep is the slow movement of soil and rock debris by gravity which is usually not perceptible except through extended observation.

5. Water-borne Soil Erosion
The rate and magnitude of soil erosion by water is controlled by the following factors:

a) Rainfall and Runoff
b) Soil Erodibility
c) Slope Gradient and Length
d) Cropping and Vegetation
e) Tillage Practices

6. Rainfall and Runoff
The greater the intensity and duration of a rainstorm, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water. Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil. Reduced infiltration due to soil compaction, crusting or freezing increases the surface runoff and soil erosion. Runoff from agricultural land is greatest when compared with other land areas.

7. Soil Erodibility
Soil erodibility – susceptibility of soil to agent of erosion - is determined by inherent soil properties e.g., texture, structure, soil organic matter content, clay minerals, exchangeable cations and water retention and transmission
properties. Climatic erosivity includes drop size distribution and intensity of rain, amount and frequency of rainfall, run-off amount and velocity, and wind velocity. Important terrain characteristics for studying soil erosion are slope gradient, length, aspect and shape. Ground cover exerts a strong moderating impact on dissipating the energy supplied by agents of soil erosion. Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil.

Texture is the principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion.
Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils.
Tillage and cropping practices that reduce soil organic matter levels, cause poor soil structure, or result in soil compaction, contribute to increases in soil erodibility.
The formation of a soil crust, which tends to "seal" the surface, also decreases infiltration.

8. Slope Gradient and Length
The steeper and longer the slope of a field, the higher the risk for erosion.
Soil erosion by water increases as the slope length increases due to the greater accumulation of runoff.

Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).

9. Cropping and Vegetation

The potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues.

Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate.

The erosion-reducing effectiveness of plant and/or crop residues depends on the type, extent and quantity of cover.

The effectiveness of any protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods.

Crops that provide a full protective cover for a major portion of the year (e.g., alfalfa or winter cover crops) can reduce erosion much more than can crops that leave the soil bare for a longer period of time (e.g., row crops), particularly during periods of highly erosive rainfall such as spring and summer.

10. Tillage Practices

The potential for soil erosion by water is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes.

Minimum till or no-till practices are effective in reducing soil erosion by water. Tillage and other practices performed up and down field slopes creates pathways for surface water runoff and can accelerate the soil erosion process.

11. Forms of Water Erosion

The major forms of water-borne soil erosion are:

a) Sheet Erosion
b) Rill Erosion
c) Gully Erosion
d) Bank Erosion

12. Sheet Erosion

Sheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope or in low areas.

Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.

13. Rill Erosion

Rill erosion is the removal of soil by concentrated water running through little streamlets, or headcuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. As detachment continues or flow increases, rills will become wider and deeper. Rill erosion mainly occurs as a result of concentrated overland flow of water leading to the development of small well-defined channels. These channels act as sediment sources and transport passages, leading to soil loss.

14. Gully Erosion

Gully erosion is "the removal of soil or soft rock material by water, forming distinct narrow channels, larger than rills, which usually carry water only during and immediately after rains". Gully erosion is an advanced stage of rill erosion.

A gully is a distinct channel, carved into a hillslope or valley bottom by intermittent or ephemeral runoff. Such channels are carved where the force exerted by flowing water – a function of its mass

and velocity – exceeds the subsoil's resistance. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery.

15. Bank Erosion

Bank erosion is the wearing away of the banks of a stream or river. This is distinguished from erosion of the bed of the watercourse, which is referred to as *scour*. Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways.

There are three main processes that cause bank erosion (scour, mass failure and slumping), and it is essential to determine which are operating at any particular site because the management required to slow or prevent them may differ. Bank scour is the direct removal of bank materials by the physical action of flowing water and is often dominant in smaller streams and the upper reaches of larger streams and rivers. Mass failure, which includes bank collapse and slumping, is where large chunks of bank material become unstable and topple into the stream or river in single events. Mass failure is often dominant in the lower reaches of large streams and often occurs in association with scouring of the lower banks.

16. Effects of Water Erosion on site

The main on-site impact is the reduction in soil quality which results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of many eroded soils. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture.
Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such as drought. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by the erosion. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field, particularly during spring thaw conditions. Pesticides may also be carried off the site with the eroded soil. Soil quality, structure, stability and texture can be affected by the loss of soil.

17. Effects of Water Erosion Off-Site

In addition to its on-site effects, the soil that is detached by accelerated water or wind erosion may be transported considerable distances. This gives rise to 'off-site problems'. Water erosion's main off-site effect is the movement of sediment and agricultural pollutants into watercourses. This can lead to the silting-up of dams, disruption of the ecosystems of lakes, and contamination of drinking water. In some cases, increased downstream flooding may also occur due to the reduced capacity of eroded soil to absorb water. Sediment can accumulate on down-slope and contribute to road damage. Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality.

Pesticides and fertilizers, frequently transported along with the eroding soil, contaminate or pollute downstream water sources, wetlands and lakes. Rapid bank erosion leads to loss of valuable land, reduced water quality as sediment and nutrients enter the stream, as well as threatening infrastructure such as roads, bridges and buildings. Stream bank erosion is the dominant source of sediment in many river systems.

18. Wind-borne soil Erosion

Wind erosion is the detachment and transportation of soil particles by wind when the airstream passing over a surface generates sufficient lift and drag to overcome the forces of gravity, friction and cohesion. Once a particle has been dislodged from the surface, it may be transported in suspension or

by saltation or by surface creep. Loss of topsoil by wind erosion over a relatively short time period can significantly decrease soil fertility and crop yield.
The rate and magnitude of soil erosion by wind is controlled by the following factors:

1. Soil Erodibility
2. Soil Surface Roughness
3. Climate(wind patterns, precipitation, frost action)
4. Unsheltered Distance
5. Vegetative Cover
6. Topography (exposure, elevation, terrain roughness, localised funnelling of wind)
7. Cultural practices (cultivation,vegetation depletion).

19. Soil Erodibility

Very fine soil particles are carried high into the air by the wind and transported great distances (suspension).
Fine-to-medium size soil particles are lifted a short distance into the air and drop back to the soil surface, damaging crops and dislodging more soil (saltation).
Larger-sized soil particles that are too large to be lifted off the ground are dislodged by the wind and roll along the soil surface (surface creep).
The abrasion that results from windblown particles breaks down stable surface aggregates and further increases the soil erodibility.

20. Soil Surface Roughness

Soil surfaces that are not rough offer little resistance to the wind. However, ridges left from tillage can dry out more quickly in a wind event, resulting in more loose, dry soil available to blow. Over time, soil surfaces become filled in, and the roughness is broken down by abrasion.
This results in a smoother surface susceptible to the wind.

21. Climate

The speed and duration of the wind have a direct relationship to the extent of soil erosion.
Soil moisture levels are very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind.

22. Unsheltered Distance

A lack of windbreaks (trees, shrubs, crop residue, etc.) allows the wind to put soil particles into motion for greater distances, thus increasing abrasion and soil erosion.
Knolls and hilltops are usually exposed and suffer the most.

23. Vegetative Cover

The lack of permanent vegetative cover in certain locations results in extensive wind erosion.
Loose, dry, bare soil is the most susceptible; however, crops that produce low levels of residue (e.g., soybeans and many vegetable crops) may not provide enough resistance.
In severe cases, even crops that produce a lot of residue may not protect the soil.

24. Effects of Wind Erosion

Wind erosion damages crops through sandblasting of young seedlings or transplants, burial of plants or seed, and exposure of seed. Crops are ruined, resulting in costly delays and making reseeding necessary. Plants damaged by sandblasting are vulnerable to the entry of disease with a resulting decrease in yield, loss of quality and market value. Soil drifting is a fertility-depleting process that can lead to poor crop growth and yield reductions in areas of fields where wind erosion is a recurring problem.
Continual drifting of an area gradually causes a textural change in the soil. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture-holding capacity of the soil. Also, soil nutrients and surface-applied chemicals can be carried along with the soil particles,

contributing to off-site impacts. In addition, blowing dust can affect human health and create public safety hazards.

25. Tillage Erosion

Tillage erosion is the redistribution of soil through the action of tillage and gravity. It results in the progressive down-slope movement of soil, causing severe soil loss on upper-slope positions and accumulation in lower-slope positions. This form of erosion is a major delivery mechanism for water erosion. Tillage action moves soil to convergent areas of a field where surface water runoff concentrates. Also, exposed subsoil is highly erodible to the forces of water and wind. Tillage erosion has the greatest potential for the "on-site" movement of soil and in many cases can cause more erosion than water or wind.

The rate and magnitude of soil erosion by tillage is controlled by the following factors:

1. Type of Tillage Equipment
2. Direction
3. Speed and Depth
4. Number of Passes

26. Type of Tillage Equipment

Tillage equipment that lifts and carries will tend to move more soil. As an example, a chisel plow leaves far more crop residue on the soil surface than the conventional mold board plow but it can move as much soil as the mold board plow and move it to a greater distance. Using implements that do not move very much soil will help minimize the effects of tillage erosion.

Direction : Tillage implements like a plow or disc throw soil either up or down slope, depending on the direction of tillage. Typically, more soil is moved while tilling in the down-slope direction than while tilling in the up-slope direction.

Speed and Depth : The speed and depth of tillage operations will influence the amount of soil moved. Deep tillage disturbs more soil, while increased speed moves soil further.

Number of Passes: Reducing the number of passes of tillage equipment reduces the movement of soil. It also leaves more crop residue on the soil surface and reduces pulverization of the soil aggregates, both of which can help resist water and wind erosion.

27. Effects of Tillage Erosion

Tillage erosion impacts crop development and yield.

Crop growth on shoulder slopes and knolls is slow and stunted due to poor soil structure and loss of organic matter and is more susceptible to stress under adverse conditions. Changes in soil structure and texture can increase the erodibility of the soil and expose the soil to further erosion by the forces of water and wind.

28. Conservation Measures

Soil conservation is the preventing of soil loss from erosion or reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination.

Soil conservation is about solving the problems of land degradation, particularly soil erosion.

Soil conservation is fundamentally a matter of determining a correct form of land use and management.

Soil conservation can be defined as the combination of the appropriate land use and management practices that promotes the productive and sustainable use of soils and, in the process, minimizes soil erosion and other forms of land degradation. Slash-and-burn and other unsustainable methods of subsistence farming are practiced in some lesser developed areas. A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification. Techniques for improved soil conservation include crop rotation, cover crops, conservation tillage and planted windbreaks and affect both erosion and fertility.

29. Notable methods of soil erosion control:

- Contour ploughing.

- Terracing or terrace farming.
- Keyline design.
- Perimeter runoff control.
- Windbreaks.
- Cover crops/crop rotation.
- Soil-conservation farming.
- Salinity management.

30. Conclusion

Soil erosion remains a key challenge for agriculture in several countries. Proper management of this valuable resource is vital to sustain long-term agricultural productivity. Soil conservation practices are tools the farmer can use to prevent soil degradation and build organic matter. These practices include: crop rotation, reduced tillage, mulching, cover cropping and cross-slope farming.