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Soil degradation and soil erosion Causes, extent and management in India

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Abstract
The debate over worldwide soil degradation, its scope, and agronomic impact can only be answered by understanding the processes and circumstances that contribute to the creation of cause–effect connections for important soils, ecosystems, and land uses. Soil deterioration may be quantified by assessing its influence on productivity for various land uses and management techniques. On a worldwide basis, the most common kind of soil deterioration is accelerated soil erosion. Soil erosion is a severe environmental issue that affects all terrestrial ecosystems across the world. Erosion produces a wide range of major problems in both controlled and natural ecosystems, including crops, pasture, and forests. Erosion, in particular, lowers soil organic matter and, as a result of fast water discharge, diminishes water-holding capacity. Soil erosion can be managed by a regional evaluation procedure for the establishment and recovery of plant cover, as well as conservation measures implemented in the most susceptible regions. As a result, the protection of these critical resources must be prioritized in order to ensure the successful conservation of developed and natural ecosystems.

Keywords: Degradation, soil, erosion, Causes, management

Introduction

Degradation of soil is described as the loss of existing or projected productivity or utility as a result of biological or mechanical activities (Lal, 1993, 1997) [1, 14]. Soil degradation is a worldwide concern with major ramifications for energy and food resources (Lal and Stewart, 1990). (Pimentel *et al*., 1976; Lal, 1988) [4-5] and the environment (La], 1997) [2], particularly in terms of water quality (Lal and Stewart, 1994) [7] and the greenhouse effect (Lal *et al*., 1995a,b, 1997a,b) [14-10-11, 7-8]. Soil deterioration, environmental quality, nutrition security, and energy consumption are all strongly linked.

Poverty contributes to soil deterioration (Lal *et al*., 1989) [8] and has a critical impact on all aspects of human society, including (1) farm yields and returns per unit input of essential resources; (2) environmental quality, including biodiversity loss; (3) income, calorie, nutritional characteristics, health, and living standards; and (4) political and social stability and equitable wealth distribution.

The overall environmental deterioration sets the stage for soil degradation. Environmental degradation is defined as any alteration or disturbance to the environment that is deemed detrimental or undesirable, while soil degradation (soil, water, vegetation) is a subtype of biodiversity loss (Johnson *et al*., 1997) [12]. (See Figure 1).

Due to negative changes in the pedosphere, soil degradation is a major component of land degradation. Among the three main forms of soil degradation (physical, chemical, and biological), rapid soil erosion is caused by the interaction of soil structure decrease and severe environment. In turn, soil erosion sets off a chain reaction. The reaction that aggravated all issues of natural degradation caused by extreme changes in the climate (emission of dust and a lot of greenhouse gases into the atmosphere), biome (decline in biodiversity and have the to habitat destruction), hydrologic cycle (due to agricultural runoff of surface and groundwater, contamination of underground water, and disruption in elements of the hydrological processes), and earth's crust (due to serious drainage channels, ravines, landslides, mass extinctions, and biodiversity loss).

On a worldwide basis, the most common kind of soil deterioration is accelerated soil erosion. The land area impacted by water erosion is projected to be 1094 million hectares. Wind erosion is the second most common kind of soil deterioration on all continents. Wind erosion is expected to damage 548 million hectares of land (Oldeman, 1994).

Climate Change and Erosion

Many communities across the United States have been experiencing first-hand the tragic consequences of climate change, including more frequent flooding, longer wildfire seasons, more intense droughts, and coastal erosion due to sea level rise. And climate change is already impacting farming practices, even some that farmers have used for millennia. Here's how climate changes worsen the impacts of erosion.

- **More frequent and intense rain events:** These increase soil erosion and result in greater amounts of sediment washing into rivers, lakes, and streams-just as we saw across the Midwest in 2019.
- **Hotter days:** Areas of the country where precipitation decreases-and soils dry out-are not only at risk for prolonged droughts but are also more vulnerable to wind erosion.
- **Larger wildfires:** A recent study by the U.S. Geological Survey found that soil erosion is expected to increase as more wildfires destroy landscapes; areas with less vegetation and groundcover are more prone to erosion by wind and water. In 2017, California experienced one of its worst wildfire seasons followed by heavy rains across parts of the state. The combination resulted in deadly mudslides.

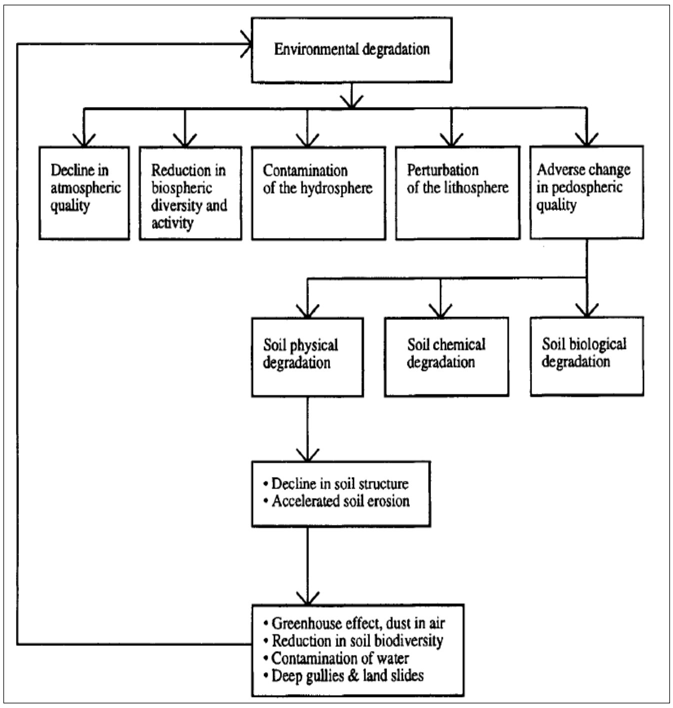

Fig 1: Soil degradation is linked to overall environmental degradation

Type of soil erosion

Water Erosion

Water erosion is described as the separation, movement, and depositing of soil particles caused by the action of water.

- **Mechanism of Water Erosion**

Hydraulic Action: It mostly occurs at high-velocity water rushes over the surface of the soil, compressing it, as a consequence of which the air mass existing in the voids of soil imposes high stress on the soil particles, contributing to soil detachment. The stresses imposed by air spaces are referred to as hydraulic pressure. The flowing water washes away soil particles that had become separated from their original positions.

1. Abrasion: In this scenario, dirt particles combined with rushing water provide a higher abrasive force.
2. Attrition: This situation causes mechanical degradation of soil particles.
3. Solution: This shape is related to the chemical activity of flowing water and soil.
4. Transportation: Under the specified forms, the activity of soil transport by moving or flowing water is completed.

Solution: The water-soluble substances existing in the water' are carried in solution form by the water.

Suspension: It relates to the transfer of finer or extremely minute soil particles that are suspended in flowing water.
Saltation and Surface Creep: It depicts the movement of mud through the stream bed with medium soil particles that are not suitable for suspension but are merged with water and stream. The coarse soil particles are transported by the surface creep process.

Deposition: When the gravitational force is higher than the forces keeping the particles in water, the particles detach.

- **Wind Erosion**

Wind erosion is a naturally occurring phenomenon that occurs when soil particles move from one site to another due to wind. It has the potential to inflict major economic and environmental harm.

- **Mechanism of Wind Erosion**

Surface creep, saltation, and suspension are the 3 phases of wind erosion. The three soil erosion mechanisms.

Suspension: It suggests that dirt with a diameter of less than 0.1 mm can be pushed into to the air through saltation, generating dust storms when carried further above by the turbulent effect of wind.

Saltation: Occurs amid middle-sized soil particles with diameters ranging from 0.05 mm to 0.5 mm. The soil particle travels across the surface in a collection of smaller bounces, causing abrasion & erosion on the soil surface.

Surface Creep: It refers to the movement of big particles ranging in diameter from 0.5 mm to 2 mm that are rolled all across the soil surface. As an outcome, they collide and displace other particles. Surface creep and wind erosion cause these bigger particles to move just a few metres.

What Causes Erosion?

Soil erosion occurs primarily when dirt is left exposed to strong winds, hard rains, and flowing water. In some cases, human activities, especially farming and land clearing, leave soil vulnerable to erosion. For example, when farmers till (plough) the soil before or after growing a season of crops, they may leave it exposed to the elements for weeks or months. The overgrazing of farm animals like cattle and sheep can also leave large areas of land devoid of ground-covering plants that would otherwise hold the soil in place. Another practice that has devastating consequences for soil health is deforestation, particularly clear cutting, a widespread practice of the industrial logging industry. When trees are cleared away, the land is left exposed to wind and rain without the

security of roots to prevent the soil from being swept away.
Climate is also a major driver of erosion. Changes in rainfall and water levels can shift soil, extreme fluctuations in temperature can make topsoil more vulnerable to erosion, and prolonged droughts can prevent plants from growing, leaving soil further exposed.

Soil Characteristics

Soils with a high proportion of sand and silt are often the most erodible. The erodibility of these soils diminishes as the clay and organic material concentration increases. Clay functions as a soil particle binder, lowering erodibility.
Organic material acts as the "glue" that holds soil particles together and helps to avoid soil erosion. Organic material is the primary energy source for both animals and plants and soil organisms. It also has an impact on the soil's infiltration ability. lower soil organic matter degrades soil structure and permeability.
The manner in which soil particles are kept together impacts the soil's friability, overall efficiency in which soil particles are removed by rains and runoff, and the soil's resistance to root and shoot development.
The capacity of the soil to convey air and water is referred to as permeability. High permeability soils are the least prone to eroding from precipitation and surface runoff.

Vegetation Cover

Controlling erosion is greatly aided by the vegetative cover. It protects the soil's surface from the effects of pouring rain. It keeps dirt particles in place. Keeps the soil's ability to absorb water. Stream flow velocity is reduced. Evapotranspiration is a mechanism that removes subterranean water between rainfalls.

Climate

The quantity of runoff generated in a particular region is determined by the frequency, intensity, and duration of rainfall. The capacity of runoff to separate and move soil particles rises as its volume and velocity increase. Erosion hazards are significant where floods are frequent, powerful, or last a long time. Temperature and rainfall variations throughout the year increase erosion risk.

Deforestation

The forest degradation deprives soils of their natural shelter from the sunrays and the direct effect of rains. The absorption of water into the soil is decreased, resulting in an increase in runoff water and a decrease in the amount of organic material. Because of these considerations, planting on slopes is required. The natural erodibility of particular soils, as well as the coincidence of field preparation with erosive rains, increase the erosion process and, as a result, worsen land degradation.

The extent of Soil Erosion in India

There has been a lot of research done on the large extend of soil erosion in India, but the final statistics differ from study to study (Table 1). As a preliminary estimation, Narayana and Ram Babu (1983) found that soil erodes at an average yearly rate of 16.35 tonnes per hectare throughout India, which equates to 5334 million tonnes per year for the nation as a whole. About 29 percent of water is lost forever to the sea, roughly 10 percent is stored in reservoirs (which reduces storage capacity by 1-2 percent yearly), and the leftover 61 percent is simply moved from one location to another.

Table 1: Estimates of Extent of Soil Erosion in India.

STUDIES	AREA (million hectares)
National Commission on Agriculture (1976)	150.0
Sehgal and Abrol (1994) [27]	162.4
Sehgal and Abrol (1997) [27]	167.0
The National Bureau of Soil Survey & Land Use Planning (NBSS & LUP, 2005)	119.19

According to Gurmel Singh, Ram Babu, Narain, and others (1990) [19], the average yearly soil loss is roughly 15.2 tonnes per hectare, with a national total of about 4978 million tonnes. The yearly erosion rates differ by area. Annual erosion rates under deep forest cover, frost cold deserts, and dry parts of western Rajasthan are below 5 tonnes per hectare. On the other hand, extremely to very severely eroded places, such as the Shiwalik hills (annual rate of much more over 80 tonnes/ha), the Western Ghats, black and red soil region, ravines and other gully eroded areas, and the north-eastern region, provide around 64 percent of the total soil. Using iso-erosion lines as a foundation for the first time, these academics created a map of soil degradation in India with lines connecting the locations of the same land subsidence (Figure 1).

Impacts of Erosion

Soil erosion reduces the quantity and the quality of soil ecosystems and arable land (land that can be used to grow crops). Scientists estimate that in the Midwest, home to some of America's most productive farmland, half of all topsoil loss has occurred in the last 50 years due to erosion intensified by human activity. According to the NRCS, cropland across Iowa has lost an average of 6.8 inches of topsoil since 1850. And soil erosion in the United States costs the country about $37.6 billion in productivity losses each year. Unmitigated, severe soil erosion can result in the loss of food crops, negatively impact community resiliency and livelihoods, and even alter ecosystems by reducing biodiversity above, within, and below the topsoil.

Consequences of Soil Erosio

Soil degradation concern. It has a direct negative impact on the primary industry and it has an indirect impact on the entire economy. The implications of soil degradation are serious both on and off the site. The loss of a top layer is a qualitative loss of the productive base as well as a quantitative loss. As a result, the soil resource is depleted and degraded. Soil quality and fertility decline, resulting in a drop in agricultural production. "Soil erosion is the biggest single harm to Indian agriculture activities," says Prof. S.P. Chatterjee. Excessive erosion degrades productive soils and turns them into the wasteland. Furthermore, nutrition loss is a significant economic burden. Because of differences in rooting systems and soil layer thickness, different crops respond differently to soil erosion. For example, the loss of production is greatest in the instance of groundnuts and least in the case of cotton crops, while shallow soils damage more than deep soils. Soil erosion reduces agricultural output by 5 to 50 percent, depending on the severe degree of soil erosion. According to Sehgal and Abrol (1994) [27], water-induced soil erosion affects soil production by 12 percent in deep soils to 73 percent in shallow soils, with red and black soils losing more than alluvial soils. The annual loss in output of major crops in India due to soil erosion has been estimated by UNDP, FAO, and UNEP (1993) to be 7.2 million tonnes, 13.5 million tonnes, or 3.1 percent of the overall major crop production by Bansil (1990) [16], and 4 to 6.3 percent of yearly crop yields in a World Bank report by Brandon, Hommann, and Kishor (1995). Even these estimations are understated since production losses are cumulative over time rather than isolated to a single crop year. Reddy (2003) [26] determined that the range of a net loss of replacement cost was from 1 to 1.7 percent of GDP based on a review of various data. Soil erosion also causes nutrient and/or organic matter loss. Approximately 3.7 million hectares of land suffer from nutrient loss and/or humus or organic matter depletion (Sehgal and Abrol, 1994) [27]. According to CSWCRTI, and ICAR, the loss caused by soil erosion in the nation is expected to be roughly 74 million tonnes of main nutrients per year. Because about 61 percent of eroded soil is simply transferred from one location to another, the topsoil loss is just 39 percent. Every year, 0.8 million tonnes of nitrogen, 1.8 million tonnes of phosphorus, and 26.3 million tonnes of potassium are lost. Soil erosion is therefore a threat that has a negative impact on agricultural production and productivity, resulting in not just food poverty but also economic insecurity. Siltation is a significant off-site effect of soil erosion. Siltation lowers the ability of streams, rivers, tanks, and reservoirs to store water. All studies have found substantially greater rates of siltation in reservoirs than were expected when river valley projects were designed. This has substantially decreased the life lifetime of many long-term projects to the medium-term, resulting in cost-benefit analysis reductions. For example, the Mayurakshi reservoir's siltation rate is 20.09 tonnes/ha/year, compared to pre-project projections of 3.61 tonnes/ha/year (Bali, 1994) [17]. Siltation lowers the ability of streams, rivers, tanks, and reservoirs to store water. It decreases reservoir power and irrigation potential. Soil erosion causes a reduction in soil moisture as well as a drop in the groundwater level. Soil erosion also affects the frequency and severity of landslide, floods, and droughts. The creation of braided streams occurs as a result of siltation in river beds, as seen in the mid and bottom course of the Brahmaputra, Ganga, and Kosi rivers. The deposition of silt in river beds, as well as the construction of sand barriers or river islands inside river beds, not only lowers the moisture retention of rivers, but also obstructs the free flow of water, resulting in overflow or the failure of banks or embankments, and subsequent floods.

Management of Soil Erosion

Soil is nature's most valuable treasure since it is necessary including all life on the earth. Only a fertile soil base can assure thriving agriculture, which in turn provides the foundation of a society's economic progress and improved level of living. Soil conservation and management are thus required to ensure that economic growth is a long-term process. Soil conservation encompasses any procedures that aid in the protection of soil from eroding and depletion. There are several strategies that may be used to conserve this crucial resource. Because the reasons for soil erosion change from one location to the next, different methods must be implemented to tackle the problem in each area. Contour tillage, contour bunding, check dam construction, terrace cultivation, trying to check the augmentation of gullies, strip cropping, and shelterbelts, afforestation, restriction on shifting cultivation, managed grazing, mixed cropping, mixed farming, crop rotation, and mulching are some of the important methods. Contour ploughing is the process of ploughing fields along contours rather than steep slopes. It causes the production of ridges and valleys in the opposite direction of flow, lowering the velocity of the water. It also improves water penetration into the soil and crop uptake. Contour bunding operates in a similar way. Check dams assist to reduce not just the velocity and also the total volume of water loss as runoff. As a result, it not only aids in soil and water conservation. Strip cropping refers to the cultivation of crops in parallel strips. While certain strips may be left barren for an extended period of time, others may be planted. Some of the plantation strips might also be utilized to grow tree crops. Windbreaks or shelterbelts are provided by the plantation of tall trees in a striped manner. Because various production is high at different periods, only a small area is left naked or vulnerable to soil degradation at any given moment. A network of Soil And water conservation, Analysis, Demonstration, and Training Centers was built under the First and Second Five Year Plans. These institutions were then transferred to ICAR in 1967, and in 1974, ICAR merged these research centers to become the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), with headquarters in Dehradun. The watershed management strategy is employed for the bulk of soil depletion prevention and control in India. Soil Management in the Catchment areas of River Valley Projects (RVP) was established in 1962. The initiative intends to manage reservoir siltation and increase catchment area production by integrated watershed planning and suitable techniques such as vegetative barriers, contour bunding, agroforestry, horticultural plantation, and Silvi-pastoral development, grassland development, afforestation, and so on. Only watersheds in the very high and high categories recognized by the All India Soil and Land Use Survey Organization (AISLUSO) are considered for treatment under the plan. The plan "Integrated Watershed Management in Flood Prone River Catchments" (FPR) was begun in 1982-83 and is presently being applied in 291 watersheds of 8 catchments situated in 8 states. The goal is to minimize flood occurrence and extent by limiting soil erosion in flood-prone river catchments. The Fifth Drought-Prone Area Programme (DPAP) and Desert Development Programme (DDP) were also conducted using a watershed concept with an emphasis on soil and water conservation. The National Watershed Development Programme for Rainfed Areas (NWDPRAs) and the Integrated Wasteland Development Project (IWDP, 1995) focused on the sustainable use of soil and other resources from 1990 to 1991. To properly address the issue of soil erosion and its management, the National Bureau of Soil Survey & Land Use Planning and the Central Soil and Water Conservation Research and Training Institute, the ICAR, the All-India Soil and Land Use Survey, and NRSA are preparing soil erosion maps at the watershed, state, and country levels.

Conclusion

Soil degradation in India is caused by a combination of natural and manmade processes. The rates of erosion are determined by changes in climate, hydrology, structure, terrain, land surface characteristics, land use, and land cover, as well as the interplay of all of these primary elements. Water erosion occurs across the country, while wind erosion is most prevalent in the west. The average yearly soil loss is around 16 tonnes per hectare, or approximately 5 billion tonnes per year. Soil erosion has major on-site and off-site consequences for the whole economy.

Siltation occurs as a result of soil erosion in reservoirs, lakes, and rivers. Declining agricultural average productivity is a result of soil depletion and degradation caused by erosion. A more regular and uniform database is necessary to estimate the amount of soil erosion throughout time and place. In India, the watershed management technique is the most often used method for controlling and preventing soil erosion. Soil conservation and management are required to attain the objective of sustainable development.

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