International Journal of Multidisciplinary Research and Bulletin
ISSN 3108-1428
Volume 5 Issue 4 (July – Aug) 2026



# Soil Erosion: A Growing Threat to the Environment

**Mst. Shekha Nasrin[1], Joyenta Das[1], Sharmin Rahman[1], Md. Mostafijur Rahman[1], Md. Kayes Mahmud[1], Md. Jaber Chowdhury[1], Shaikh Motasim Billah[2], Mahmudul Hasan Chowdhury[1]***

*Correspondence: Mahmudul Hasan Chowdhury

[1]Soil Resource Development Institute, Ministry of Agriculture, Bangladesh

[2]Soil, Water and Environment Discipline, Khulna University, Bangladesh

***Article History***

Received: 10 July 2026 | Accepted: 31 July 2026 | Published: 09 Aug 2026

DOI: 10.5281/zenodo.21858784

## ABSTRACT

Soil erosion is a major form of land degradation that threatens agricultural productivity, ecosystem stability, and global food security. Accelerated by natural processes and human activities, it removes fertile topsoil, depletes nutrients, reduces soil organic matter, and degrades soil structure. This review summarizes the major drivers, impacts, and management strategies of soil erosion. It examines the key causes of soil loss, including rainfall, wind, topography, soil properties, vegetation cover, and human disturbances such as deforestation, intensive cultivation, overgrazing, and construction. The review highlights the effects of erosion on soil fertility, water availability, nutrient cycling, biodiversity, agricultural productivity, and ecosystem resilience, as well as off-site impacts such as sedimentation, water pollution, greenhouse gas emissions, and economic losses. It also outlines effective conservation measures, including conservation tillage, mulching, crop rotation, contour farming, vegetative barriers, and sustainable land management. Overall, protecting soil through integrated conservation practices, supportive policies, and climate-resilient management is essential for sustaining agricultural productivity, ecosystem services, and long-term global food security.

**Keywords:** Soil degradation; Environmental sustainability; Agricultural productivity; Soil conservation; Land degradation; Sustainable land management.

## Introduction

Accelerated soil erosion has emerged as one of the most serious environmental, agricultural, and socio-economic challenges worldwide. It is driven by multiple interacting factors, including water, wind, gravity, human activities, and animal disturbances, all of which contribute to the progressive removal of fertile topsoil. Since more than 95% of the global food supply relies on productive soils for crop and livestock production, maintaining soil quality is fundamental to ensuring food security and sustainable agricultural development (Food and Agriculture Organization of the United Nations [FAO], 2015). During the erosion process, the nutrient-rich surface layer is detached and transported away, exposing the less fertile subsoil beneath. As a consequence, soil fertility declines, crop growth is adversely affected, and the long-term productive capacity of agricultural land is significantly reduced (Gholizadeh et al., 2018). Beyond its direct effects on agricultural production, soil erosion also weakens the ability of soils to perform essential ecosystem functions. The loss of topsoil disrupts nutrient cycling, reduces soil water retention capacity, and degrades habitats for diverse soil organisms, thereby diminishing overall ecosystem resilience (Senanayake et al., 2020). Continued soil degradation further deteriorates the physical, chemical, and biological properties of soil, leading to lower land productivity, substantial economic losses, and increased environmental and social risks. Consequently, controlling soil erosion has become a critical priority for achieving sustainable land management, protecting ecosystem services, and ensuring global food security (Flanagan et al., 2011). Soil erosion is recognized as one of the most widespread forms of land degradation, affecting almost every terrestrial ecosystem, including agricultural lands, forests, grasslands, and rangelands. The continuous removal of fertile topsoil by natural agents such as water and wind has become increasingly severe due to intensive human activities, resulting in substantial environmental, ecological, and economic losses. Consequently, soil erosion has emerged as a major global concern because it threatens not only agricultural productivity but also the long-term sustainability of natural ecosystems (Pimentel and Kounang, 1998). The growing global population has intensified the demand for food, water, energy, and natural resources, placing unprecedented pressure on land resources. Under these circumstances, soil erosion has become one of the defining environmental challenges of the twenty-first century, alongside water scarcity, biodiversity loss, and climate-related environmental degradation. These interconnected challenges reduce ecosystem resilience and compromise the capacity of natural resources to sustain future generations (Lal and Stewart, 1990). Since terrestrial agriculture provides nearly all of the calories consumed by humans, the productivity, quality, and conservation of soil resources are fundamental to global food security. Healthy soils support plant growth by supplying essential nutrients, storing water, maintaining soil structure, and sustaining diverse biological communities. However, prolonged soil erosion has gradually depleted fertile topsoil in many regions of the world, resulting in declining soil fertility, reduced crop productivity, and, in severe cases, the abandonment of previously productive agricultural land (Pimentel et al., 1995; Young, 1998). The impacts of soil erosion extend far beyond reductions in crop yield. The removal of topsoil also destroys valuable soil organic matter and disrupts the habitats of countless microorganisms, earthworms, insects, and other soil organisms that regulate nutrient cycling, organic matter decomposition, and overall soil health. Consequently, erosion not only diminishes agricultural productivity but also weakens biodiversity and the ecological functions that are essential for maintaining healthy terrestrial ecosystems (Pimentel et al., 1995). In addition to its ecological consequences, soil erosion has significant environmental and socio-economic implications. The transport of eroded soil into rivers, lakes, and reservoirs contributes to sedimentation, deteriorates water quality, and damages aquatic habitats, while the loss of fertile land increases production costs and threatens the livelihoods of farming communities. These cumulative impacts highlight the importance of implementing sustainable land management practices to conserve soil resources and maintain ecosystem services for future generations (Pimentel et al., 1995; Young, 1998).

**What Drives Soil Erosion**

The physical characteristics of soil play a fundamental role in determining its susceptibility to erosion. Soils with fine- to medium-textured particles, low organic matter content, and weak structural stability are generally more vulnerable to erosive forces than well-structured soils. Poor soil aggregation reduces infiltration capacity and increases surface runoff during rainfall events, while weakly bound particles are more easily detached and transported by both flowing water and strong winds. As a result, soils with inadequate structural development are at a greater risk of losing fertile topsoil, highlighting the importance of maintaining soil organic matter and improving soil structure through appropriate land management practices to minimize erosion (Bajracharya and Lal, 1992).

Topography plays a crucial role in determining the intensity of water-induced soil erosion. As land slope increases, rainfall runoff travels more rapidly and gains greater erosive power, enabling it to detach and transport larger amounts of soil particles. The accelerated flow of water on sloping terrain removes nutrient-rich topsoil, reduces effective soil depth, and gradually impairs soil fertility and crop productivity. Consequently, cultivated fields located on steep slopes are considerably more susceptible to erosion than those on relatively flat landscapes. Evidence indicates that under severe runoff conditions, a large proportion of the surface soil may be lost from sloping areas, highlighting the importance of slope management and soil conservation practices in erosion control (Lal and Stewart, 1990).

Wind is another major natural force responsible for soil erosion, particularly in arid, semi-arid, and sparsely vegetated regions. Strong winds can detach loose soil particles from the land surface and transport them over both short and exceptionally long distances, resulting in substantial losses of fertile topsoil and degradation of agricultural land. A notable example occurred during the dry and windy winter of 1995–1996 in Kansas, USA, where croplands experienced soil losses of approximately 65 tonnes $ha^{-1}$, demonstrating the destructive potential of wind erosion under unfavorable climatic conditions. The influence of wind erosion is not confined to local landscapes. Satellite observations have shown that massive dust plumes generated in Africa can travel across the Atlantic Ocean and reach the Americas, illustrating the large-scale movement of eroded soil and the transboundary environmental impacts associated with wind-driven sediment transport (Pimentel, 2006).

Rainfall and surface runoff are among the primary natural forces responsible for initiating soil erosion. When soil remains uncovered by vegetation or crop residues, the direct impact of raindrops breaks down soil aggregates and detaches fine particles from the soil surface. These detached particles are subsequently transported by overland flow, resulting in the gradual removal of the nutrient-rich topsoil. This process, commonly referred to as sheet erosion, is regarded as one of the most widespread and destructive forms of soil degradation because it often occurs over extensive areas without being immediately noticeable (Troeh et al., 1991; Oldeman, 1997).

Vegetation plays a vital role in protecting soil from erosion by acting as a natural barrier against the erosive forces of rainfall and wind. Both living vegetation and dead plant residues intercept raindrops, reduce their impact on the soil surface, decrease wind velocity near the ground, and promote greater water infiltration. This protective layer minimizes soil particle detachment and reduces surface runoff, thereby lowering the overall risk of erosion. In contrast, the removal of vegetation leaves the soil directly exposed to erosive agents, resulting in rapid degradation of the fertile topsoil. The effectiveness of vegetative cover in controlling erosion has been demonstrated by field studies showing that erosion rates increase dramatically as ground cover declines. Research conducted in Utah and Montana revealed that reducing ground cover from complete protection to less than 1% increased soil erosion by approximately 200-fold, highlighting the critical importance of maintaining continuous vegetation on vulnerable land surfaces (Trimble and Mendel, 1995).

In forest ecosystems, adequate canopy cover is essential for stabilizing soil and reducing the risks of both erosion and landslides. Studies suggest that maintaining at least 60% forest canopy cover provides effective protection by intercepting rainfall, reinforcing soil with root systems, and slowing surface runoff (Singh and Kaur, 1989; Haigh et al., 1995; Forest Conservation Act, 2002). Consequently, deforestation for agricultural expansion, grazing, or other land-use changes often results in a substantial increase in soil erosion due to the loss of this natural protective cover.

The problem is particularly severe in many developing countries, where crop residues are commonly removed from fields and used as household fuel instead of being retained as mulch. This practice leaves agricultural soils exposed during critical periods of rainfall and wind, greatly increasing their susceptibility to erosion. It has been estimated that approximately 60% of crop residues in China and

90% in Bangladesh are utilized for cooking and heating rather than being returned to the soil, thereby reducing soil protection and accelerating land degradation (Wen, 1993).

Although agricultural activities are recognized as the dominant cause of global soil erosion, a variety of other human-induced and natural disturbances also contribute significantly to land degradation. Construction activities, including the development of roads, buildings, and parking areas, often require the removal of vegetation and disturbance of the soil surface. During active construction, these exposed areas become highly susceptible to erosion, with reported soil losses ranging from 20 to 500 tonnes $ha^{-1}$ $year^{-1}$. However, erosion rates generally decline once vegetation becomes re-established and the soil surface is stabilized (IECA, 1991).

River and stream banks are also vulnerable to erosion as a result of the continuous action of flowing water. This natural process can be intensified by livestock grazing along waterways, where trampling removes protective vegetation and weakens bank stability. A study from Wisconsin reported that cattle grazing contributed to annual soil losses of approximately 60 tonnes per kilometre of stream bank, illustrating the importance of proper grazing management in protecting riparian environments (Trimble, 1994; Trimble and Mendel, 1995).

Natural hazards such as earthquakes and landslides also accelerate soil movement and landscape degradation. Although these events can cause substantial localized soil loss, their contribution to global erosion is relatively limited because they occur less frequently than rainfall-, wind-, or land-use-induced erosion processes. Nevertheless, in regions prone to seismic activity or unstable slopes, these disturbances remain important considerations in soil conservation and land management planning.

**How Much Soil Is Being Lost**

Natural soil erosion is a continuous geomorphological process that has contributed to the formation and evolution of landscapes over geological time. Although the natural rate of soil loss is generally low, ranging from approximately 0.001 to 5 tonnes $ha^{-1}$ $year^{-1}$ depending on climate, vegetation, and topographic conditions, the cumulative effect over thousands of years has played a fundamental role in shaping valleys, floodplains, and river deltas (Patric, 2002). The gradual deposition of eroded sediments has led to the development of some of the world's most productive deltaic regions, including the Nile and Mississippi deltas, illustrating the constructive role of natural erosion under undisturbed environmental conditions (Solliday, 1997).

In contrast, human-induced soil erosion occurs at rates far exceeding natural background levels and has become a major driver of global land degradation. Unsustainable agricultural practices, deforestation, intensive land cultivation, and other anthropogenic disturbances have dramatically accelerated soil loss across many regions of the world. According to Myers (1993), approximately 75 billion tonnes of fertile soil are removed from the world's agricultural lands every year, and Pimentel (2006) suggested that this estimate may even underestimate the actual magnitude of the problem.

The severity of accelerated erosion is particularly evident in densely populated agricultural countries. Annual soil losses have been estimated at approximately 6.6 billion tonnes in India and 5.5 billion tonnes in China (Lal and Stewart, 1990; Wen, 1997). Similarly, the United States experience annual soil losses of nearly 3 billion tones reflecting the widespread impact of erosion even in countries with advanced agricultural systems (Carnell, 2001). These statistics emphasize that accelerated soil erosion is a global environmental issue requiring sustainable land management and effective soil conservation strategies to safeguard agricultural productivity and ecosystem health.

**Erosion across Land-Use Types**

Agricultural activities occupy nearly half of the Earth's terrestrial surface, with approximately one-third of this area used for crop cultivation and the remaining two-thirds managed as grazing land. In comparison, forests cover only about one-fifth of the global land area (USDA, 2001; WRI, 1997). Among these land-use systems, croplands are particularly susceptible to soil erosion because repeated tillage operations disturb soil structure and leave the surface exposed between growing seasons. Unlike natural forests, where continuous vegetation and litter protect the soil from rainfall and wind, cultivated fields frequently remain bare, greatly increasing their vulnerability to erosion. As a result, erosion rates on croplands have been estimated to be approximately 75 times higher than those occurring under undisturbed forest ecosystems (Myers, 1993).

Accelerated soil erosion has become a widespread problem across agricultural lands worldwide. Estimates indicate that nearly 80% of the world's croplands experience moderate to severe erosion, whereas only about 10% are affected by relatively low levels of soil loss (Lal, 1994). The average annual erosion rate on cultivated land is approximately 30 tonnes $ha^{-1}$, although reported values vary considerably depending on climate, topography, soil characteristics, and management practices, ranging from 0.5 to 400 tonnes $ha^{-1}$ $year^{-1}$ (Speth, 1994).

The long-term consequences of this continuous soil degradation are evident in the declining productivity of agricultural land. During the past four decades, approximately 30% of the world's arable land has become unsuitable for profitable crop production, and a substantial proportion of this degraded land has subsequently been abandoned (Kendall and Pimentel, 1994; WRI, 1994). The magnitude of this loss is particularly alarming because it approaches the total area currently under cultivation worldwide (Lal, 1990). Furthermore, an estimated 10 million hectares of cropland are abandoned each year due to erosion-induced declines in soil productivity, with the greatest impacts occurring in Asia, Africa, and South America (Faeth and Crosson, 1994).

Forest ecosystems provide one of the most effective natural defenses against soil erosion. Dense tree canopies intercept rainfall before it reaches the ground, while forest litter and well-developed root systems protect the soil surface, enhance water infiltration, and improve aggregate stability. As a result, erosion rates in undisturbed forests are extremely low, typically ranging from 0.004 to 0.05 tonnes $ha^{-1}$ $year^{-1}$, making forests among the most erosion-resistant terrestrial ecosystems (Roose, 1988; Lal, 1994). However, this natural protection is rapidly lost when forests are cleared for agricultural cultivation or livestock grazing. The removal of trees exposes previously protected soils to direct rainfall and runoff, substantially increasing erosion risk, especially on steep slopes. For example, an assessment conducted in northeastern Ecuador found that approximately 84% of the cleared hillside soils were unsuitable for conversion to pasture because of their high susceptibility to erosion, emphasizing the need for careful land-use planning and forest conservation in environmentally sensitive areas (Southgate and Whitaker, 1992).

Compared with intensively cultivated croplands, permanent pastures generally experience lower rates of soil erosion because continuous grass cover helps stabilize the soil surface and reduces the impact of rainfall and runoff. In the United States, the average annual soil loss from pastureland has been estimated at approximately 6 tonnes $ha^{-1}$, which is considerably lower than that observed in cultivated agricultural fields. Nevertheless, the protective function of pasture vegetation can be severely compromised by excessive grazing pressure. Overgrazing reduces plant biomass, exposes bare soil, weakens root systems, and increases surface runoff, thereby accelerating soil erosion and land degradation. At the global scale, more than half of the world's rangelands are reported to experience high levels of erosion. The problem is particularly severe in Africa, where nearly 80% of pasture and rangeland has undergone significant degradation, largely because of overgrazing and the widespread removal of crop residues and natural vegetation for household fuel (NAS, 2003).

**Effects of Soil Erosion on Ecosystem Productivity**

Soil erosion adversely affects ecosystem productivity through multiple interconnected mechanisms that collectively reduce soil quality and agricultural performance. The removal of fertile topsoil decreases water infiltration, accelerates surface runoff, depletes essential nutrients, reduces soil organic matter, and gradually diminishes effective soil depth. These processes are closely interrelated, creating a cycle of degradation in which nutrient depletion weakens soil biological activity, reduced biological activity limits organic matter accumulation, and declining organic matter further lowers soil water-holding capacity and structural stability (Troeh et al., 1991). Consequently, the combined effects of erosion are often far more damaging than any individual factor acting alone.

Soil organic matter is a key indicator of soil health because it improves nutrient availability, enhances soil aggregation, increases water-holding capacity, and supports diverse soil microorganisms. Under productive conditions, agricultural soils may contain approximately 100 tons of organic matter per hectare, storing nearly 95% of the soil nitrogen and 25–50% of the soil phosphorus (Allison, 1973). Since organic matter is concentrated near the soil surface, it is preferentially removed during erosion. Studies indicate that eroded sediments may contain 1.3–5 times more organic matter than the soil remaining in the field, accelerating the decline in soil fertility (Lal and Stewart, 1990). Even relatively small reductions in soil organic matter can substantially affect crop productivity. For instance, decreasing soil organic matter from 1.4% to 0.9% has been associated with nearly 50% reductions in grain yield potential (Libert, 1995). Similarly, field investigations conducted in the United States and the Philippines have reported maize yield losses ranging from modest reductions to as much as **80%** under severe erosion conditions (Dregne, 1992).

The loss of fertile topsoil during erosion is accompanied by the removal of substantial quantities of essential plant nutrients. Because nutrients are concentrated in the upper soil layers, the eroded sediment is generally much richer in nutrients than the soil that remains behind. It has been reported that eroded soil may contain approximately three times higher nutrient concentrations than the residual soil, resulting in rapid depletion of soil fertility (Young, 1989). Fertile topsoil typically contains 1–6 kg of nitrogen, 1–3 kg of phosphorus, and 2–30 kg of potassium per tonne, whereas severely eroded soils may retain only 0.1–0.5 kg of nitrogen per tonne (Troeh et al., 1991). Such nutrient depletion has been linked to 15–30% reductions in crop yield (Schertz et al., 1989).

The progressive reduction of effective soil depth is another major consequence of long-term erosion. Deep, well-developed soils provide sufficient rooting volume, moisture storage, and habitat for soil organisms that are essential for sustaining plant growth. Continuous erosion gradually removes the upper soil layers, restricting root penetration and reducing the availability of water and nutrients. Soil organisms such as earthworms and beneficial microorganisms also decline as soil depth decreases, further impairing soil biological functions. Studies have shown that when effective soil depth declines from approximately 30 cm to less than 1 cm, crop productivity decreases dramatically because the remaining soil can no longer adequately support healthy root development or normal ecosystem processes (Pimentel et al., 1995).

Adequate soil moisture is essential for maintaining plant growth and achieving optimum crop yields. Agricultural crops require enormous quantities of water throughout their growing season. For example, a single hectare of maize or wheat may transpire more than 5–7 million liters of water, while an additional 2 million liters may be lost through direct evaporation from the soil surface (Klocke et al., 1996). Soil erosion reduces the infiltration capacity of soils, causing a greater proportion of rainfall to be lost as surface runoff rather than stored within the root zone. Studies have shown that moderately eroded soils retain 10–300 mm less rainfall per hectare annually than non-eroded soils, representing a reduction of approximately 7–44% in plant-available water (Wendt et al., 1986). Reduced soil moisture subsequently limits plant growth, and a decline of 20–40% in available soil water has been associated with 10–25% reductions in biomass production (Evans et al., 1997).

The abundance and diversity of soil organisms are closely associated with the amount of soil organic matter and ecosystem biomass present in a given environment. Soils rich in organic materials generally support larger and more diverse biological communities because organic matter provides food, energy, and habitat for microorganisms and soil fauna (Heywood, 1995). A healthy soil ecosystem may contain approximately 200,000 arthropods and enchytraeids within a single square meter, in addition to billions of bacteria, fungi, and other microorganisms (Wood, 1989). On a hectare basis, the combined biomass of invertebrates and microorganisms can reach nearly 10,000 kg, highlighting the remarkable biological richness of fertile soils. Accelerated soil erosion poses a serious threat to this belowground biodiversity. When erosion rates exceed the natural rate of soil formation by 10–20 times, both the population size and species diversity of soil organisms decline significantly (Atlavinyte, 1965). The removal of topsoil reduces organic matter, destroys habitats, and disrupts nutrient cycling processes, ultimately weakening soil biological activity. In contrast, land management practices that effectively control erosion and maintain soil organic matter generally promote healthier and more diverse soil biota (FAO, 2001).

Soil organisms also play an active role in reducing erosion and maintaining soil stability. Earthworms are particularly important ecosystem engineers because they transport 10–500 tonnes of soil per hectare annually from deeper layers to the surface through their burrowing activities (Lee, 1985). Similarly, ants can move as much as 34 tonnes of soil per hectare each year, contributing to soil mixing and aggregate formation (Zacharias and Grube, 1984). The tunnels created by these organisms improve water infiltration, enhance soil aeration, and strengthen soil structure, thereby helping to reduce surface runoff and partially compensate for erosion-related losses. The ecological consequences of erosion become even more severe when it leads to the decline or disappearance of keystone species. The loss of dominant vegetation, pollinators, nitrogen-fixing organisms, or other functionally important species can trigger cascading effects throughout the ecosystem. Such disruptions may impair pollination, reduce plant reproduction, alter nutrient cycling, and ultimately decrease ecosystem resilience and productivity (Heywood, 1995). Therefore, conserving soil biodiversity is not only essential for maintaining soil health but also for sustaining the broader ecological processes that support agricultural production and environmental stability.

The effects of soil erosion extend far beyond the location where soil is detached. Once removed from agricultural fields or other land surfaces, eroded soil is transported and deposited in surrounding environments, creating numerous off-site environmental and economic problems. In the United States, approximately 60% of soil lost through water erosion is eventually transported into streams, while nearly two-thirds of the sediment eroded from croplands worldwide ultimately accumulates in rivers, lakes, and reservoirs (USDA, 1989). A notable example is China's Yellow River, which delivers approximately 2 billion tons of sediment each year into the Yellow Sea, illustrating the enormous scale of sediment transport associated with accelerated erosion (Lal and Stewart, 1990).

Sediment deposition in rivers and reservoirs reduces channel capacity, increases the likelihood of flooding, and disrupts aquatic ecosystems. Excessive sediment accumulation can elevate riverbeds and reduce water-storage capacity in reservoirs, thereby shortening the operational lifespan of dams and increasing maintenance costs. For example, sediment deposition contributed to severe flooding in parts of the Midwestern United States during 1993 by reducing the capacity of river channels to accommodate high water flows (Allen, 1994). In addition, eroded sediments often carry fertilizers, pesticides, and other agricultural contaminants into surface waters, degrading water quality and adversely affecting freshwater biodiversity and aquatic ecosystem health (Pimentel et al., 1995).

Soil erosion also contributes to global climate change by accelerating the loss of soil organic carbon. As organic matter is exposed and decomposes, carbon stored in the soil is released into the atmosphere in the form of carbon dioxide ($CO_2$), thereby increasing greenhouse gas concentrations. Conversely, climate change may intensify erosion by altering rainfall patterns, increasing the frequency of extreme precipitation events, and enhancing runoff. This interaction creates a positive feedback mechanism in which soil degradation and climate change reinforce one another, highlighting the need for integrated soil conservation and climate adaptation strategies (Lal, 2002; Lal, 2004).

**Soil Conservation and Future Perspectives**

The long-term consequences of uncontrolled soil erosion extend beyond environmental degradation and pose a serious threat to global food security. Estimates suggest that if land degradation continues at its current pace, global agricultural production could decline by approximately 30% in the coming decades, highlighting the urgent need for effective soil conservation and sustainable land management practices (Kendall and Pimentel, 1994). Protecting soil resources is therefore essential not only for maintaining agricultural productivity but also for ensuring ecosystem stability and the livelihoods of future generations. A wide range of soil conservation techniques has been developed to minimize erosion and improve soil health. Practices such as mulching, crop rotation, conservation tillage (including no-till and ridge-till systems), contour farming, grass buffer strips, and shelterbelts have proven effective in reducing soil loss under different environmental conditions. Although these techniques vary in their management approach, they all share a common objective: maintaining continuous soil cover to protect the soil surface from the erosive effects of rainfall and wind while improving soil structure, water infiltration, and long-term fertility (Troeh et al., 1991).

Although considerable advances have been made in understanding soil erosion, important scientific questions remain unresolved. The complex interactions among surface runoff, soil moisture dynamics, organic matter depletion, nutrient cycling, effective soil depth, and soil biodiversity are not yet fully understood. A better understanding of these interrelated processes is essential for designing more effective conservation strategies and predicting the long-term impacts of land degradation. Future research should therefore focus on integrated approaches that combine soil science, ecology, hydrology, and climate studies while promoting conservation technologies that are both environmentally sustainable and economically feasible. At the same time, stronger policy support, farmer education, and appropriate financial incentives are needed to encourage the widespread adoption of sustainable soil management practices capable of protecting soil resources and ensuring long-term agricultural and environmental sustainability (Troeh et al., 1991; NAS, 2003).

**Limitations**

This review provides a comprehensive synthesis of the current understanding of soil erosion, including its driving factors, global extent, environmental consequences, and conservation strategies. However, several limitations should be acknowledged. First, the review is primarily based on previously published literature and does not include new experimental data or field observations. Second, although studies from different regions of the world were considered, variations in climate, soil properties, land-use systems, and management practices may limit the universal applicability of some findings. Third, several statistics and estimates cited in this review originate from earlier studies, which remain scientifically important but may not fully reflect recent changes in land use, climate change, and advances in soil conservation technologies. Finally, this review mainly focuses on the environmental and agricultural impacts of soil erosion, whereas detailed analyses of socio-economic aspects, policy implementation, and advanced modeling approaches were beyond its scope. Future review studies should integrate updated global datasets, remote sensing techniques, and region-specific analyses to provide a more comprehensive understanding of soil erosion under changing climatic and land-use conditions.

**Conclusion**

Soil erosion is a gradual but persistent process that often progresses unnoticed until significant soil degradation has already occurred. Even the loss of a very thin layer of topsoil during a single erosion event represents a substantial reduction in fertile soil resources, while natural soil formation requires many years to replace what has been lost. Consequently, the imbalance between rapid soil loss and slow soil regeneration has become a major challenge for sustainable agriculture and environmental conservation. The long-term decline in soil quality has important implications for global food production. Although advances in agricultural technology have increased crop yields in many regions, population growth continues to place increasing pressure on limited land resources. Historical trends indicate that per capita cereal availability has declined over recent decades, despite improvements in agricultural productivity. Because cereal crops provide approximately 80% of the world's food supply, continued soil degradation represents a serious threat to global food security and the stability of food production systems. Without sustained efforts to conserve soil resources, the number of people experiencing food insecurity and malnutrition already estimated to exceed 3.7 billion worldwide is likely to increase, while the capacity of agricultural systems to meet future food demand will continue to decline (WHO, 2004). Therefore, protecting soil should be recognized as a global priority for achieving long-term agricultural productivity, environmental sustainability, and food security.

**Article Publication Details**

This article is published in the **International Journal of Multidisciplinary Research and Bulletin**, ISSN 3108-1428 (Online). In Volume 5 Issue 4 (July – Aug) 2026

The journal is published and managed by **IRPG**.



**Acknowledgements**

The authors gratefully acknowledge the use of artificial intelligence assisted writing tool during the preparation of this review manuscript. Those were used to improve language, sentence structure only.

We sincerely thank the editors and the reviewers for their valuable suggestions on this paper.

**Funding**

The authors declare that no funding was received for this work.

**Data availability**

No datasets were generated or analyzed during the current study.

**Declarations**

**Ethics approval and consent to participate**

The author(s) declare that it is not applicable.

**Consent for publication**

The author(s) declare that this is not applicable.

**Competing interests**

The author(s) declare that they have no competing interests.

## References


1. Allen, W. (1994). The flood of 1993 may rank as the worst weather disaster in U.S. history. *St. Louis Post-Dispatch*, p. 01B.
2. Allison, F. E. (1973). Soil organic matter and its role in crop production. *Elsevier*.
3. Atlavinyte, O. (1965). The effect of erosion on the population of earthworms (*Lumbricidae*) in soils under different crops. *Pedobiologia, 5*, 178–188.
4. Bajracharya, R. M., & Lal, R. (1992). Seasonal soil loss and erodibility variation on a Miamian silt loam soil. *Soil Science Society of America Journal, 56*(5), 1560–1565.
5. Carnell, B. (2001). *Soil erosion*. http://www.overpopulation.com/fag/natural_resources/food/soil_erosion.html
6. Dregne, H. E. (1992). Erosion and soil productivity in Asia. *Journal of Soil and Water Conservation, 47*, 8–13.
7. Eekhout, J. P., & de Vente, J. (2022). Global impact of climate change on soil erosion and potential for adaptation through soil conservation. *Earth-Science Reviews, 226*, 103921. https://doi.org/10.1016/j.earscirev.2022.103921
8. Evans, R., Cassel, D. K., & Sneed, R. E. (1997). *Soil, water, and crop characteristics important to irrigation scheduling*. http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html
9. Faeth, P., & Crosson, P. (1994). Building the case for sustainable agriculture. *Environment, 36*(1), 16–20.
10. Food and Agriculture Organization of the United Nations. (2015). *Healthy soils are the basis for healthy food production*. FAO.
11. Forest Conservation Act. (2002). *Riparian forest buffer panel (Bay Area Regulatory Programs)*. http://www.riparianbuffers.umd.edu/manuals/regulatory.html
12. Gholizadeh, M. H., Melesse, A. M., & Fuentes, H. R. (2018). Raindrop-induced erosion and sediment transport modelling in shallow waters: A review. *Journal of Soil and Water Science, 1*(1), 15–25.
13. Haigh, M. J., Rawat, J. S., Bartarya, S. K., & Rai, S. P. (1995). Interactions between forest and landslide activity along new highways in the Kumaun Himalaya. *Forest Ecology and Management, 78*(1–3), 173–189.
14. Heywood, V. H. (1995). *Global biodiversity assessment*. Cambridge University Press.
15. International Erosion Control Association. (1991). *Erosion control: A global perspective. Proceedings of Conference XXII*. International Erosion Control Association.

16. Kendall, H. W., & Pimentel, D. (1994). Constraints on the expansion of the global food supply. *Ambio*, *23*, 198–205.

17. Klocke, N. L., Hubbard, K. G., Kranz, W. L., & Watts, D. G. (1996). *Evapotranspiration (ET) or crop water use*. University of Nebraska Cooperative Extension. http://www.ianr.unl.edu/pubs/irrigation/g992.htm

18. Lal, R. (1990). Soil erosion and land degradation: The global risks. *Soil degradation* (pp. 129–172). Springer.

19. Lal, R. (1994). Water management in various crop production systems related to soil tillage. *Soil and Tillage Research*, *30*, 169–185.

20. Lal, R. (2002). *One answer for cleaner air, water: Better agricultural practices*. http://www.acs.ohio-state.edu/units/research/archive/sequest.htm

21. Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, *304*, 1623–1627.

22. Lal, R., & Stewart, B. A. (Eds.). (1990). *Soil degradation*. Springer.

23. Lee, K. E. (1985). *Earthworms: Their ecology and relationships with soils and land use*. Academic Press.

24. Libert, B. (1995). *The environmental heritage of Soviet agriculture*. CAB International.

25. Myers, N. (1993). *Gaia: An atlas of planet management*. Anchor/Doubleday.

26. National Academy of Sciences. (2003). *Frontiers in agricultural research: Food, health, environment and communities*. National Academies Press.

27. Oldeman, L. R. (1997). *Soil degradation: A threat to food security?* Paper presented at the International Conference on Time Ecology: Time for Soil Culture—Temporal Perspectives on Sustainable Use of Soil, Tutzing, Germany.

28. Patric, J. H. (2002). *Forest erosion rates*. http://syllabus.syr.edu/esf/rdbriggs/for345/erosion.htm

29. Pimentel, D. (1997). Soil erosion. *Environment*, *39*(10), 4–5.

30. Pimentel, D. (2006). *World soil erosion and conservation*. Cambridge University Press.

31. Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Sphpritz, L., Fitton, L., Saffouri, R., & Blair, R. (1995). Environmental and economic costs of soil erosion and conservation benefits. *Science*, *267*, 1117–1123.

32. Pimentel, D., & Kounang, N. (1998). Ecology of soil erosion in ecosystems. *Ecosystems*, *1*, 416–426.

33. Roose, E. (1988). Soil and water conservation lessons from steep-slope farming in French-speaking countries of Africa. In *Conservation farming on steep lands* (pp. 130–131). Soil and Water Conservation Society.

34. Schertz, D. L., Moldenhauer, W. C., Livingston, S. J., Weesies, G. A., & Hintz, E. A. (1989). Effect of past soil erosion on crop productivity in Indiana. *Journal of Soil and Water Conservation*, *44*(6), 604–608.
35. Senanayake, S., Pradhan, B., Huete, A., & Brennan, J. (2020). A review on assessing and mapping soil erosion hazard using geo-informatics technology for farming system management. *Remote Sensing*, *12*(20), 4063. https://doi.org/10.3390/rs12244063
36. Singh, T. V., & Kaur, J. (1989). *Studies in Himalayan ecology and development strategies*. Himalayan Books.
37. Solliday, L. (1997). *Sediment transport of an estuary*. http://bellnetweb.brc.tamus.edu/sediment.htm
38. Southgate, D., & Whitaker, M. (1992). Promoting resource degradation in Latin America: Tropical deforestation, soil erosion, and coastal ecosystem disturbance in Ecuador. *Economic Development and Cultural Change*, *40*(4), 787–807.
39. Speth, J. G. (1994). *Towards an effective and operational international convention on desertification*. United Nations.
40. Trimble, S. W. (1994). Erosional effects of cattle on streambanks in Tennessee, USA. *Earth Surface Processes and Landforms*, *19*, 451–464.
41. Trimble, S. W., & Mendel, A. C. (1995). The cow as a geomorphic agent: A critical review. *Geomorphology*, *13*, 233–253.
42. Troeh, F. R., Hobbs, J. A., & Donahue, R. L. (1991). *Soil and water conservation*. Prentice Hall.
43. U.S. Department of Agriculture. (1989). *The second RCA appraisal: Soil, water, and related resources on nonfederal land in the United States*. U.S. Department of Agriculture.
44. U.S. Department of Agriculture. (2001). *Agricultural statistics*. U.S. Department of Agriculture.
45. Wen, D. (1993). Soil erosion and conservation in China. In D. Pimentel (Ed.), *Soil erosion and conservation* (pp. 63–86). Cambridge University Press.
46. Wen, D. (1997). *Agriculture in China: Water and energy resources*. Institute of Applied Ecology, Chinese Academy of Sciences.
47. Wendt, R. C., Alberts, E. E., & Helmers, A. T. (1986). Variability of runoff and soil loss from fallow experimental plots. *Soil Science Society of America Journal*, *50*, 730–736.
48. World Health Organization. (2004). *World health report 2004*. http://www.who.int/whr/2004/annex/topic/en/annex_2_en.pdf
49. Wood, M. (1989). *Soil biology*. Chapman & Hall.
50. World Resources Institute. (1994). *World resources*. Oxford University Press.
51. World Resources Institute. (1997). *World resources*. Oxford University Press.

52. Young, A. (1989). *Agroforestry for soil conservation*. CAB International.
53. Young, A. (1998). *Land resources: Now and for the future*. Cambridge University Press.
54. Zacharias, T. P., & Grube, A. H. (1984). An economic evaluation of weed control methods used in combination with crop rotations: A stochastic dominance approach. *North Central Journal of Agricultural Economics, 6*, 113–120.